Physics 2011 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. **Define electric dipole moment. Write its S.I. unit.** **[1]**

Answer : Electric dipole moment : Dipole moment is a measure of strength of electric dipole. It is vector quantity whose magnitude is equal to product of magnitude of charge and the distance between them.

$$p = q \times 2d$$

SI unit of dipole moment is coulomb-metre (Cm).

2. **Where on the surface of Earth is the angle of dip 90° ?** **[1]**

Answer : Magnetic dip is the angle made by a compass needle with the horizontal point on earth's surface. The angle of dip is 90° at the poles.

3. **A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. What is potential at the centre of the sphere ? [1]**

Answer : Potential inside the charged sphere is constant and equal to potential on the surface of the conductor. So, potential at the centre of sphere is 10 V.

4. **How are radiowaves produced ?** **[1]**

Answer : Radiowaves are produced by :

(i) Rapid acceleration and deceleration of electrons.

(ii) Using tuning circuits like LCR, LC and RC.

(iii) Accelereted motion of charges in conducting wires.

(iv) They are also given off by stars, sparks and lightning.

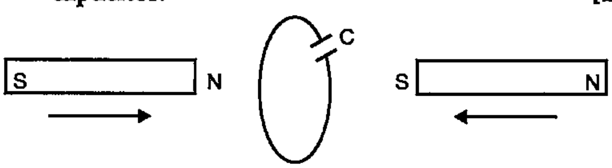
5. **Write any two characteristic properties of nuclear force.** **[1]**

Answer : Characteristic properties of nuclear forces are :

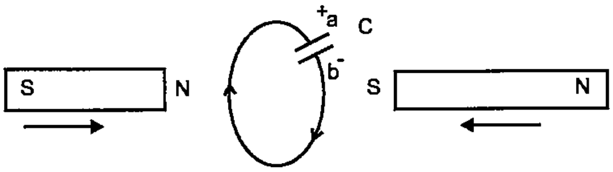
(i) Nuclear forces are strongest forces in nature.

(ii) Nuclear forces are charge independent.

6. **Two bar magnets are quickly moved towards a metallic loop connected across a capacitor 'C' as shown in the figure. Predict the polarity of the capacitor.** **[1]**



Answer : In this situation, *a* will become positive with respect to *b*, as current induced is in clockwise direction.



7. **What happens to the width of depletion layer of a *p-n* junction when it is (i) forward biased, (ii) reverse biased ?** **[1]**

Answer : (i) Forward biased : Potential drop across the junction decreases and diffusion of holes and electrons across the junction increases. It makes the width of the depletion layer smaller.

(ii) Reverse biased : Potential drop across the junction increases and diffusion of holes and electrons across the junction decreases. It makes the width of the depletion layer larger.

8. **Define the term 'stopping potential' in relation to photoelectric effect.** **[1]**

Answer : Stopping potential is the minimum negative (retarding) potential of anode for which photocurrent stops or becomes zero. It is denoted by V_s. The value of stopping potential is different for different metals but it is independent of the intensity of incident light and depends on the frequency of the incident light.

9. **A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius *r* and length *l*, its axis coinciding with the length of the wire. Find the expression for the electric flux through the surface of the cylinder.** **[2]**

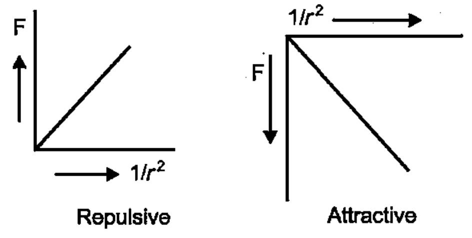
Answer : Charge enclosed by the cylindrical surface $q = \lambda l$

$$\text{Flux, } \phi = \frac{q}{\varepsilon_0}$$

$$\phi = \frac{\lambda l}{\varepsilon_0}$$

10. **Plot a graph showing the variation of Coulomb force (F) versus $\left(\frac{1}{r^2}\right)$, where *r* is the distance between the two charges of each pair of charges : (1 μC, 2 μC) and (2 μC, –3 μC). Interpret the graphs obtained.** **[2]**

Answer : The following graph shows the variation of Coulomb force (F) versus *r*.



According to Coulomb's law,

$$F \propto q_1 q_2$$

$$F \propto \frac{1}{r^2}$$

∴ For both pair of charges, graph between F and $\frac{1}{r^2}$ is a straight line.

Between (1 μC, 2 μC), force is positive/repulsive.

Value of slope, $m = \frac{2}{4\pi\varepsilon_0}$

Between (2μC, – 3μC), force is negative/attractive.

Value of slope, $m = \frac{-6}{4\pi\varepsilon_0}$.

11. Write the expression for Lorentz magnetic force on a particle of charge 'q' moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Show that no work is done by this force on the charged particle. [2]

Answer : Magnetic Lorentz force is given by

$$\vec{f_m} = q(\vec{v} \times \vec{B})$$

$$\text{Work done} = \vec{f_m} \cdot \vec{S} = f_m S \cos\theta$$

$\vec{f_m}$ is always perpendicular to $\vec{v}$ *i.e.,* perpendicular to the direction of motion of the charge.

∴ Work done $= f_m S\cos\theta = f_m S\cos 90° = 0$

12. What are eddy currents ? Write any two applications of eddy currents. [2]

Answer : When a bulk piece of conductor is subjected to changing magnetic flux, the induced current developed in it is called eddy current.

Applications of eddy currents :

(i) Magnetic brakes in trains.

(ii) Electromagnetic damping.

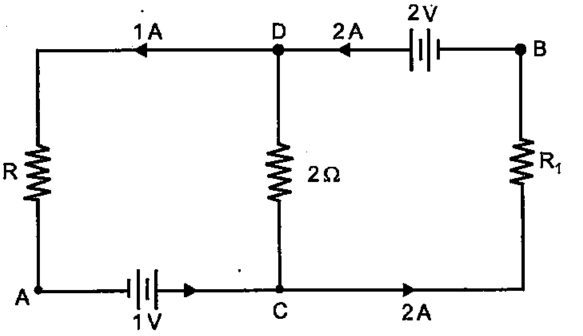
(iii) Induction furnaces.

(iv) Electric power meter.

13. What is sky wave communication ? Why is this mode of propagation restricted to the frequencies only upto few MHz ? [2]**

**Answer is not given due to the change in present syllabus.

14. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. [2]



Answer : $V_D - V_C = 2 \times 1 = 2\text{ V}$ ...(i)

∵ $V_A = 0$

∴ $V_C - V_A = 1\text{ V}$

⇒ $V_C = 1\text{ V}$ ...(ii)

From (i) and (ii),

$V_D = 2 + V_C = 3\text{ V}$ ...(iii)

Now $V_D - V_B = 2\text{ V}$

⇒ $3 - V_B = 2\text{ V}$

⇒ $V_B = 1\text{ V}$

15. A parallel plate capacitor is being charged by a time varying current. Explain briefly how Ampere's circuital law is generalized to incorporate the effect due to the displacement current. [2]

Answer : Gauss' law states that the electric flux ϕ_E of a parallel plate capacitor having an area A, and a total charge Q is given by

$$\phi_E = EA = \frac{1\,Q}{A\varepsilon_0} \times A \qquad \left[\because E = \frac{Q}{A\varepsilon_0}\right]$$

$$= \frac{Q}{\varepsilon_0}$$

As the charge Q on the capacitor plates change with time, so current is given by

$$i = \frac{dQ}{dt}$$

$$\therefore \quad \frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{Q}{\varepsilon_0}\right) = \frac{1}{\varepsilon_0}\frac{dQ}{dt}$$

$$\Rightarrow \quad \varepsilon_0 \frac{d\phi_E}{dt} = \frac{dQ}{dt} = i$$

This is the missing term in Ampere's Circuital law.

So, the total current through the conductor is

i = Conduction current (i_c) + Displacement current (i_d)

$$i = i_c + \varepsilon_0 \frac{d\phi_E}{dt} \quad \text{...(i)}$$

Ampere's circuital law states that

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i \quad \text{...(ii)}$$

Putting equation (i) in (ii), we get

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i_c + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$$

This is the required generalized form of Ampere's circuital law.

16. Net capacitance of three identical capacitors in series is 1 μF. What will be their net capacitance if connected in parallel ?

Find the ratio of energy stored in the two configurations if they are both connected to the same source. [2]

Answer : Net capacitance in series = 1 μF

If $C_1 = C_2 = C_3 = C$

Let C be the capacitance of each of three capacitors and C_S and C_P be the capacitance of series and parallel combination respectively.

Then,
$$\frac{1}{C_S} = \frac{1}{C}+\frac{1}{C}+\frac{1}{C} = \frac{3}{C}$$

$$C_S = \frac{C}{3}$$

$$1\ \mu F = \frac{C}{3}$$

$$\therefore \quad C = 3\ \mu F$$

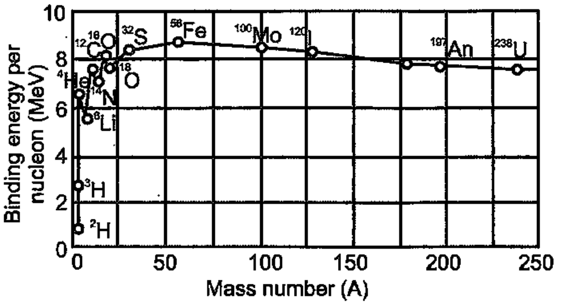
Also
$$C_P = C + C + C$$
$$= 3 + 3 + 3 = 9\ \mu F$$

Energy stored in capacitor

$$E = \frac{1}{2}CV^2$$

$$\therefore \quad \frac{E_S}{E_P} = \frac{\frac{1}{2}C_S V^2}{\frac{1}{2}C_P V^2} = \frac{C_S}{C_P} = \frac{1}{9}$$

17. Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release in energy in the processes of nuclear fission and nuclear fusion can be explained. [2]



Answer : The above curve shows that :

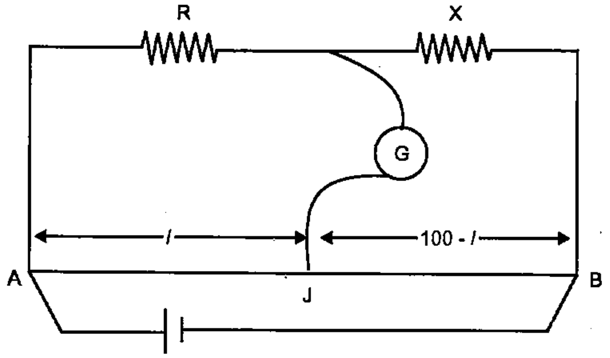
(i) When a heavy nucleus breaks into two medium sized nuclei (in nuclear fission), the BE/nucleon increases resulting in the release of energy.

(ii) When two small nuclei combine to form a relatively bigger nucleus in nuclear fusion, BE/nucleon increases, resulting in the release of energy.

18. In the meter bridge experiment, balance point was observed at J with AJ = l. [2]

(i) The values of R and X were doubled and then interchanged. What would be the new position of balance point ?

(ii) If the galvanometer and battery are interchanged at the balance position, how will the balance point get affected ?



Answer : (i) Initially, balanced condition will be given as

$$\frac{R}{X} = \frac{l}{100-l} \quad \text{...(i)}$$

By doubling and interchanging R and X. Let the new balance point be obtained at l'.

Then,

$$\frac{2X}{2R} = \frac{l'}{100-l'}$$

$$\Rightarrow \quad \frac{X}{R} = \frac{l'}{100-l'} \quad \text{...(ii)}$$

From equations (i) and (ii),

$$l' = 100 - l$$

(ii) By interchanging galvanometer and battery, there will be no change in the balance point position.

19. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33. [3]

(a) Will it behave as a converging or a diverging lens in the two cases ?

(b) How will its focal length change in the two media ?

Answer : (a) Here ${}^a\mu_g = 1.5$

Let f_{air} be the focal length of lens in air, then

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}\,(1.5-1)}$$

$$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{f_{air}} \quad \text{...(i)}$$

(i) When lens is dipped in medium A.

Here $${}^a\mu_A = 1.65$$

Let f_A be focal length of lens, when dipped in medium A, then

$$\frac{1}{f_A} = ({}^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\frac{1}{f_A} = \left(\frac{{}^a\mu_g}{{}^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i), we have

$$\frac{1}{f_A} = \left(\frac{1.5}{1.65} - 1\right) \times \frac{2}{f_{air}}$$

$$= -\frac{0.15}{1.65} \times \frac{2}{f_{air}}$$

or $$f_A = -5.5 f_{air} \quad \text{...(ii)}$$

As sign of f_A is opposite to that of f_{air}, the lens will behave as a diverging lens.

(ii) When lens is dipped in medium B.

Here, $${}^a\mu_B = 1.33.$$

Let f_B be the focal length, when dipped in medium B, then

$$\frac{1}{f_B} = ({}^B\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i), we have

$$\frac{1}{f_B} = \left(\frac{1.5}{1.33} - 1\right) \times \frac{2}{f_{air}}$$

$$\therefore \quad f_B = 3.9 f_{air} \quad \text{...(iii)}$$

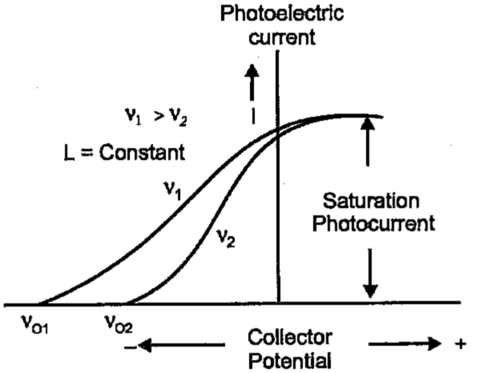
As sign of f_B is same as that of f_{air}, the lens will behave as converging lens.

(b) (i) As seen from equation (ii), focal length becomes negative and increases in magnitude.

(ii) As seen from equation (ii), focal length remains positive and increases in magnitude.

20. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_1 > \nu_2$, of incident radiation having the same intensity. In which case will be stopping potential be higher ? Justify your answer. [3]

Answer :



Stopping potential is more for the curve corresponding to the frequency ν_2. ($\because \nu_1 > \nu_2$)

This is due to the fact that with increase in the frequency, the kinetic energy of emitted photoelectrons also increases. Therefore, we need more negative potential to stop these electrons.

21. Write briefly any two factors which demonstrate the need for modulating a signal. Draw a suitable diagram to show amplitude modulation using a sinusoidal signal as a modulating signal. [3]**

22. Use the mirror equation to show that [3]

(a) an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$.

(b) a convex mirror always produces a virtual image independent of the location of the object.

****Answer is not given due to the change in present syllabus.**

(c) an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

Answer : Mirror equation is given as,

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

For concave mirror, $f < 0$ or $f = -$ve

For convex mirror, $f > 0$ or $f = +$ ve

Concave Mirror

Let $f = -c$

Also, let $u = nf = -nc$

$$\frac{1}{v} = \frac{1}{f}-\frac{1}{u}$$

$$\frac{1}{v} = \frac{1}{-c}-\frac{1}{-nc}$$

$$v = \frac{nc}{(1-n)}$$

(a) When object is between f and $2f$: We have $1 < n < 2$.

In this case, v is $-ve$ *i.e.* real image.

(For $n = 1$ and $n = 2$), magnitude of v becomes ∞ and $-2c$, respectively.

Therefore, real image is formed beyond $2f$.

(b) Convex Mirror : As we know $f = +d$

Let $u = -pd$ (p can have any value)

$$\frac{1}{v} = \frac{1}{d}+\frac{1}{pd}=\frac{(1+p)}{pd}$$

$$v = \frac{pd}{(p+1)}$$

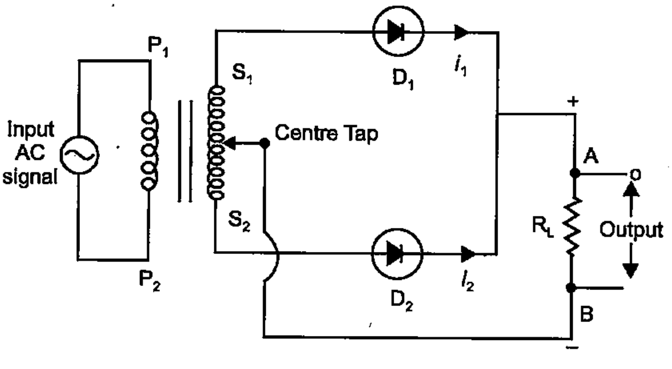
Therefore, v is always $+ve$ and always less than d, so we can say that convex mirror always produces a virtual image between pole and focus.

(c) Object between pole and F : We have $0 < n < 1$. In this case, v is +ve (virtual image) and $|v| > c$.

Therefore, we get a virtual and enlarge image.

23. Draw a labelled diagram of a full wave rectifier circuit. State its working principle. Show the input-output waveforms. [3]

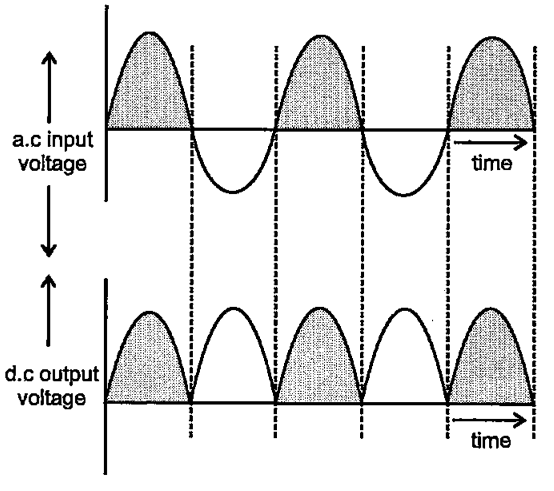
Answer :



Rectification : Rectification means conversion of ac into dc. A p-n diode acts as a rectifier because an ac changes polarity periodically and a p-n diode conducts only when it is forward biased; it does not conduct when it is reverse biased.

Working : The ac input voltage across secondary S_1 and S_2 changes polarity after each half cycle. Suppose during the first cycle of input ac signal, the terminal S_1 is positive relative to centre tap and S_2 is negative relative to it. Then diode D_1 is forward biased and D_2 is reverse biased. Therefore, diode D_1 conducts while D_2 does not. Thus, the current in load resistance R_L is in the same direction for both half cycles of input ac signal and the output current is a continuous series of unidirectional pulses.

In a full wave rectifier, if input frequency is f Hertz, then output frequency will be $2f$ Hertz because for each cycle of input, two positive half cycles of output are obtained.



24. (a) Using de-Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.

(b) The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of the electron in this state ? [3]

Answer : (a) The second postulate of Bohr atom model says that angular momentum of electron orbiting around the nucleus is quantized, *i.e.*, $mvr = \frac{nh}{2\pi}$, where $n = 1, 2, 3,......$

According to de-Broglie, a stationary orbit is that which contains an integral number of de-Broglie waves associated with the revolving electron.

For an electron revolving in the n^{th} circular orbit of radius r_n, total distance covered = circumference of the orbit = $2\pi r_n$

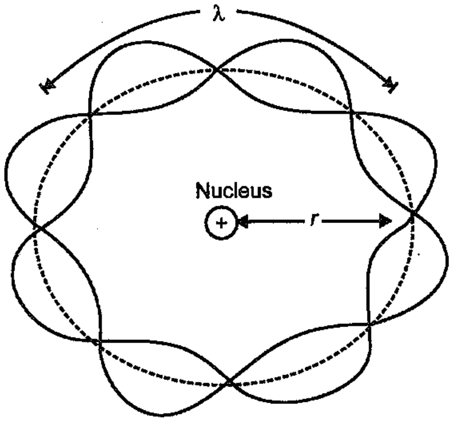
$$2\pi r_n = n\lambda$$

According to de-Broglie, $\lambda = \frac{h}{mv_n}$

Where v_n is speed of electron revolving in n^{th} orbit.

$$2\pi r_n = \frac{nh}{mv_n} \text{ or } mv_n r_n = \frac{nh}{2\pi}$$

i.e., angular momentum of electron revolving in n^{th} orbit must be an integral multiple of $\frac{h}{2\pi}$, which is the quantum condition proposed by Bohr in second postulate.



(b) The kinetic and the potential energies of electron in the hydrogen atom (Z = 1) are given by

$$K = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r} \text{ and } U = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r},$$

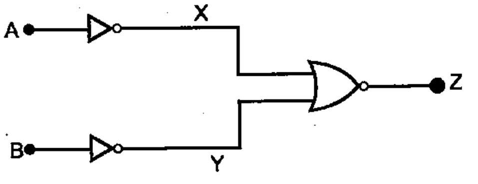
where r is the radius of the orbit in the given energy state. The total energy is

$$E = K + U = \frac{1}{4\pi\varepsilon_0}\left(\frac{e^2}{2r} - \frac{e^2}{r}\right) = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r}$$

Thus, $K = -E = -(-13.6 \text{ eV}) = +13.6 \text{ eV}$

$U = 2E = 2 \times (-13.6 \text{ eV}) = -27.2 \text{ eV}$

25. You are given a circuit below. Write its truth table. Hence, identify the logic operation carried out by this circuit. Draw the logic symbol of the gate it corresponds to.** **[3]**



****Answer is not given due to the change in present syllabus.**

26. A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of the microscope. **[3]**

OR

A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 cm is used, find the angular magnification of the telescope.

If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens ? The diameter of the moon is 3.42×10^6 m and the radius of the lunar orbit is 3.8×10^8 m.

Answer : Focal length of objective, $f_o = 4$ cm

Focal length of eyepiece, $f_e = 10$ cm

Object distance, $u_o = 6$ cm

By lens formula, for objective lens,

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o}$$

$$\frac{1}{v_o} = \frac{1}{4} - \frac{1}{6} = \frac{1}{12}$$

$$\Rightarrow \quad v_0 = 12 \text{ cm}$$

Magnification by objective,

$$m_0 = \frac{v_o}{|u_o|}$$

$$= \frac{12}{6} = 2$$

Magnification by eyepiece,

$$m_e = \left(1 + \frac{D}{f_e}\right) \text{ or } \frac{D}{f_e}$$

[$\therefore$ D = 25 cm for compound microscope]

$$= \left(1 + \frac{25}{10}\right) \text{ or } \frac{25}{10}$$

$$= 3.5 \text{ or } 2.5$$

Magnification power of the microscope,

$$m = m_0 \times m_e$$

$$= 2 \times 3.5 \text{ or } 2 \times 2.5$$

$$= 7 \text{ or } 5$$

For eyepiece, by lens formula

$$\frac{1}{v_e}-\frac{1}{u_e} = \frac{1}{f_e}$$

For image to be formed at least distance of distinct vision, $v_e = 25$ cm.

$$\therefore \quad -\frac{1}{25}-\frac{1}{u_e} = \frac{1}{10}$$

$$\Rightarrow \quad \frac{1}{u_e} = -\frac{1}{25}-\frac{1}{10}=\frac{-7}{50}$$

$$\Rightarrow \quad u_e = \frac{-50}{7}\text{ cm} = -7.14\text{ cm.}$$

Length of the microscope,

$L = v_o + |u_e|$ or $L = v_o + |f_e|$

$L = 12 + 7.14$ or $L = 12 + 10$

$L = 19.14$ cm or $L = 22$ cm

OR

(a) Angular magnification, $m = \frac{f_o}{f_e} = \frac{15}{1\times10^{-2}}$
$= 1500$

(b) Diameter of moon $= 3.42 \times 10^6$ m

And radius of lunar orbit $= 3.8 \times 10^8$ m

Let d be diameter of the image.

We know,

$$d = \alpha f_o$$

Where $\alpha = \frac{\text{Diameter of moon}}{\text{Radius of lunar orbit}}$

$$\therefore \quad d = \frac{3.42\times10^6}{3.8\times10^8}\times15$$

$= 0.135$ m or 13.5 cm

27. Two heating elements of resistances R_1 and R_2 when operated at a constant supply of voltage V, consume powers P_1 and P_2 respectively. Deduce the expressions for the power of their combination when they are, in turn, connected in (i) series and (ii) parallel across the same voltage supply. [3]

Answer : (i) In series,

Net resistance, $R = R_1 + R_2$ ...(i)

The heating elements are operated at same voltage.

$$\therefore \quad P = \frac{V^2}{R}; P_1 = \frac{V^2}{R_1}; P_2 = \frac{V^2}{R_2}$$

From equation (i)

$$\frac{V^2}{P} = \frac{V^2}{P_1}+\frac{V^2}{P_2}$$

$$\Rightarrow \quad \frac{1}{P} = \frac{1}{P_1}+\frac{1}{P_2}$$

(ii) In parallel combination,

Net resistance can be calculated as,

$$\frac{1}{R} = \frac{1}{R_1}+\frac{1}{R_2}$$

$$\Rightarrow \quad \frac{1}{\frac{V^2}{P}} = \frac{1}{\frac{V^2}{P_1}}+\frac{1}{\frac{V^2}{P_2}}$$

$$\Rightarrow \quad P = P_1 + P_2$$

28. (a) Using Ampere's circuital law, obtain the expression for the magnetic field due to a long solenoid at a point inside the solenoid on its axis.

(b) In what respect is a toroid different from a solenoid ? Draw and compare the pattern of the magnetic field lines in the two cases.

(c) How is the magnetic field inside a given solenoid made strong ? [5]

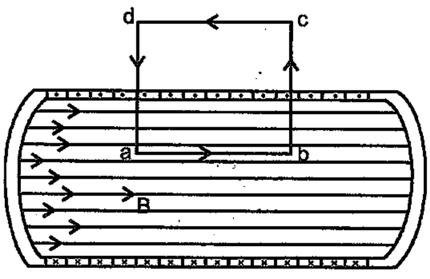
OR

(a) State the principle of the working of a moving coil galvanometer, giving its labelled diagram.

(b) "Increasing the current sensitivity of a galvonometer may not necessarily increase its voltage sensitivity." Justify this statement.

(c) Outline the necessary steps to convert a galvanometer of resistance R_G into an ammeter of a given range.

Answer : (a) Magnetic field inside a long solenoid is uniform every where and approximately zero outside it. Fig. shows a sectional view of long solenoid current coming out of the plane of the papers at points marked ⊙ and current entering the plane of the paper at points marked ⊗. To find the magnetic field $\vec{B}$ at any point inside the solenoid, consider a rectangular loop *abcd* as Amperian loop. According to Ampere's circuital law,



$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \times \text{Total current through the loop}$$

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \Sigma I$$

$$\oint \vec{B}\cdot\vec{dl} = \int_a^b \vec{B}\cdot\vec{dl} + \int_b^c \vec{B}\cdot\vec{dl} + \int_c^d \vec{B}\cdot\vec{dl} + \int_d^a \vec{B}\cdot\vec{dl}$$

$$= \int_a^b B\cdot dl\cos 0° + \int_b^c B\cdot dl\cos 90° + \int_c^d B\cdot dl\cos 180° + \int_d^a B\cdot dl\cos 90°$$

$$= B\int_a^b dl + 0 + 0 + 0 \quad \left[\because \int B\,dl\cos 180° = 0\right.$$

$$= B\times l + 0 + 0 + 0 \quad \left.\because B = 0 \text{ outside the solenoid}\right]$$

$$\oint \vec{B}\cdot\vec{dl} = Bl$$

Where, l = length of the loop $abcd$

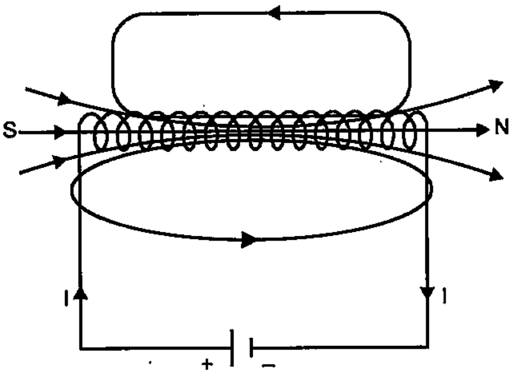
$\Sigma I = nlI$ [where I is the current passing through the solenoid]

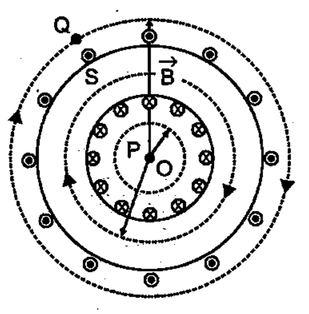
$\therefore \quad Bl = \mu_0 nlI$

$\Rightarrow \quad B = \mu_0 nI$

(b) Difference : In a toroid, magnetic lines do not exist outside the body. Toroid is closed whereas the solenoid is open on both sides.

Magnetic field is uniform inside a toroid whereas for solenoid, it is different at the two ends and centre.





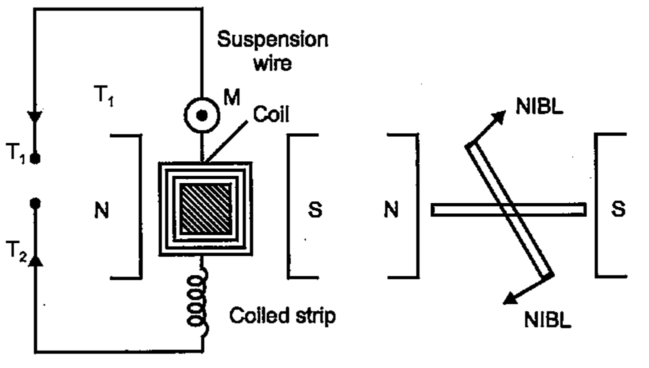
(c) Strength of magnetic field :

(1) By inserting the ferromagnetic substance inside the solenoid.

(2) By increasing the current through the solenoid.

OR

(a)



Principle : Its working is based on the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque.

Working : When current (I) is passed in the coil, torque τ acts on the coil, given by

$$\tau = NIAB\sin\theta$$

where, θ = Angle between normal to plane of coil

B = Magnetic field of strength

N = No. of turns in a coil.

For equilibrium,

deflecting torque = restoring torque

$$NIAB = C\theta$$

$$\Rightarrow \quad \theta = \frac{NAB}{C} I$$

where, C = Torsional rigidity of the wire

$\Rightarrow \quad \theta \propto I$

The deflection of coil is directly proportional to the current flowing in the coil.

(b) Due to deflecting torque, the coil rotates and suspension wire gets twisted. A restoring torque is set up in the suspension wire.

$$NIBA = C\theta \qquad (\because \text{In equilibrium})$$

$$I = \frac{C}{NBA}\theta$$

$$I = G\theta$$

where, $G = \dfrac{C}{NBA}$

It is known as galvanometer constant.

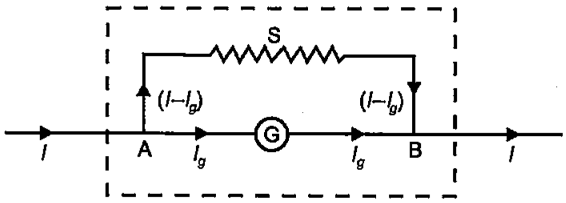
Current sensitivity, $S_C = \dfrac{\theta}{I} = \dfrac{NAB}{C}$

and voltage sensitivity, $S_V = \frac{\phi}{V} = \left(\frac{NAB}{C}\right)\frac{1}{R}$

$$= \frac{S_C}{R}$$

It means voltage sensitivity is dependent on current sensitivity and resistance of galvanometer, R. If we increase current sensitivity and galvanometer resistance is high, then it is not certain that voltage sensitivity will be increased. Thus, the increase of current sensitivity does not imply the increase of voltage sensitivity.

(c) Conversion of a galvanometer to ammeter :



A galvanometer can be converted into ammeter by connecting a shunt (low resistance) in parallel with the galvanometer and its value is given by

$$S = \left[\frac{I_g}{I - I_g}\right]G$$

29. State the working of a.c. generator with the help of a labelled diagram.

The coil of an a.c. generator having N turns, each of area A, is rotated with a constant angular velocity ω. Deduce the expression for the alternating e.m.f. generated in the coil. What is the source of energy generation in this device ? [5]

OR

(a) Show that in an a.c. circuit containing a pure inductor, the voltage is ahead of current by π/2 in phase.

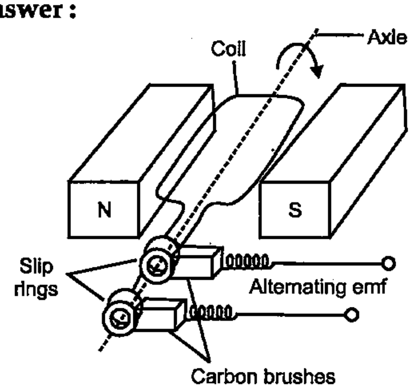
(b) A horizontal straight wire of length L extending from east to west is falling with speed *v* at right angles to the horizontal component of Earth's magnetic field B.

(i) Write the expression for the instantaneous value of the e.m.f. induced in the wire.

(ii) What is the direction of the e.m.f. ?

(iii) Which end of the wire is at the higher potential ?

Answer :



Working : When a coil (armature) rotates inside a uniform magnetic field, magnetic flux linked with the coil changes w.r.t. time. This produces an e.m.f. according to Faraday's law.

For first half of the rotation, the current will be from one end (first ring) to the other end (second ring). For second half of the rotation, it is in opposite sense.

To calculate the magnitude of e.m.f. induced,

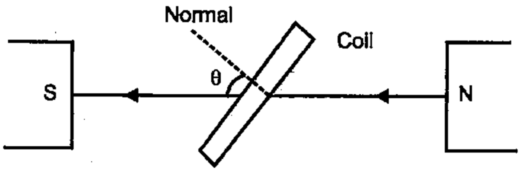
Suppose

N = number of turns in the coil.

A = area enclosed by each turn of coil.

$\vec{B}$ = strength of magnetic field.

θ = angle which normal to the coil makes with $\vec{B}$ at any instant *t*,



∴ Magnetic flux linked with the coil in this position

$$\phi = N(\vec{B} \cdot A) = NBA \cos\theta$$

$$= NBA \cos\omega t \quad ...(i)$$

where is the angular velocity of the coil. At this instant *t*, if *e* is the e.m.f. induced in the coil, then

$$e = \frac{-d\phi}{dt} = \frac{-d}{dt}(NAB \cos\omega t)$$

$$= -NAB\frac{d}{dt}(\cos\omega t)$$

$$= -NAB\,\omega\,(-\sin\omega t)$$

∴ $$e = NAB\,\omega \sin\omega t \quad ...(ii)$$

The induced e.m.f. will be maximum, when $\sin\omega t$ is maximum *i.e.*, 1

∴ $$e_{max} = NAB\,\omega \times 1 \quad ...(iii)$$

Put in (ii), if we denote NABω as e_0, then

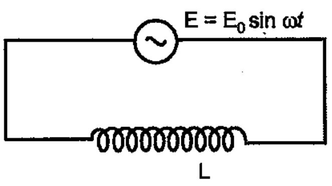
$$e = e_0 \sin \omega t$$

Source of energy : Mechanical energy.

The word generator is a misnomer, because nothing is generated by the machine, it is an alternator converting one form of energy to another.

OR

(a) Circuit containing inductance only : Let an alternating emf given by $E = E_0 \sin \omega t$, ...(i)



be applied across a pure (zero resistance) coil of inductance L. As the current i in the coil grow continuously, an opposing emf is induced in the coil whose magnitude is $L\frac{di}{dt}$, where $\frac{di}{dt}$ is the rate of change of current. But this should be zero because there is no resistance in the current. Thus,

$$E_0 \sin \omega t - L\frac{di}{dt} = 0$$

$$\Rightarrow \quad \frac{di}{dt} = \frac{E_0}{L} \sin \omega t$$

$$\Rightarrow \quad di = \frac{E_0}{L} \sin \omega t \, dt$$

Integrating both sides, we have

$$\int di = \frac{E_0}{L} \int \sin \omega t \, dt$$

$$i = \frac{E_0}{L}\left(-\frac{\cos \omega t}{\omega}\right) = \frac{E_0}{\omega L}(-\cos \omega t \, dt)$$

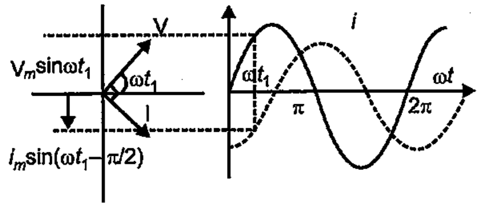
$$\Rightarrow \quad i = \frac{E_0}{\omega L} \sin(\omega t - \pi/2)$$

The maximum value of $\sin(\omega t - \pi/2)$ is 1.

Therefore, $\frac{E_0}{\omega L}$ is the maximum current in the circuit. Thus,

$$i = i_0 \sin(\omega t - \pi/2) \qquad \text{...(ii)}$$

From equations (i) and (ii), it is proved that voltage is ahead of current by $\frac{\pi}{2}$.



(b) **(i)** $e = BLv$

(ii) Direction of e.m.f is from west to east.

(iii) Wire 1 is at greater potential than wire 2.

30. State the importance of coherent sources in the phenomenon of interference.

In Young's double slit experiment to produce interference pattern, obtain the conditions for constructive and destructive interference. Hence deduce the expression for the fringe width.

How does the fringe width get affected, if the entire experimental apparatus of Young is immersed in water ? **[5]**

Answer : Two sources of light which continuously emit light waves of same frequency with a zero or constant phase difference between them are called coherent sources. They are necessary to produce sustained interference pattern.

A thin film of oil spread over water shows beautiful colours due to interference of light.

If coherent sources are not taken, the phase difference between the two interfering waves will change continuously and a sustained interference pattern will not be obtained.

$$y_1 = a \cos \omega t$$

$$y_2 = a[\cos(\omega t + \phi)]$$

According to principle of superposition, the resultant wave is given by

$$y = y_1 + y_2$$

$$\Rightarrow \quad y = a[\cos \omega t + \cos(\omega t + \phi)]$$

$$\Rightarrow \quad y = 2a \cos \phi/2 \cos(\omega t + \phi/2)$$

Resultant amplitude $= 2a \cos(\phi/2)$

The intensity is directly proportional to the square of the amplitude. $I \propto a^2$

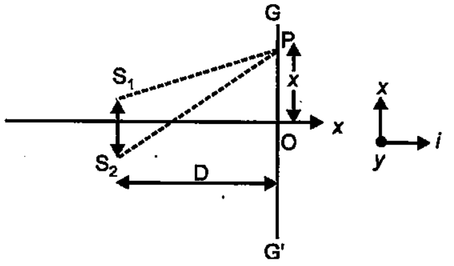
$$\therefore \quad I = 4I_0 \cos^2(\phi/2)$$

Condition for constructive interference

$\phi = 0, 2\pi, 4\pi, ...$ or $= \pm 2n\pi$ $(n = 0, 1, 2, ...)$

Condition for destructive interference

$\phi = \pm \pi, \pm 3\pi, \pm 5\pi, ...$ or $= \pm (2n + 1)\pi$ $(n = 0, 1, 2, ...)$



We have, $(S_2P)^2 - (S_1P)^2$

$$= \left[D^2 + \left(x + \frac{d}{2}\right)^2\right] - D^2\left[x - \frac{d}{2}\right]^2 = 2xd$$

$$\therefore \quad S_2P - S_1P = \frac{2xd}{S_2P + S_1P} \approx \frac{2xd}{2D} = \frac{xd}{D}$$

Constructive interference : The intensity of light will be maximum at those places where the path difference between the interfering light waves is zero or an integral multiple of λ, *i.e.*, $\lambda, 2\lambda, ...$

Hence for maximum intensity, we have

$$\frac{xd}{D} = n\lambda$$

$$\Rightarrow \quad x = \frac{nD\lambda}{d}$$

Destructive interference : The intensity of light will be minimum at those places where the path difference between the interfering light-waves is an old integral multiple of $\frac{\lambda}{2}$ $\left(\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, ...\right)$.

Hence for minimum intensity, we have

$$\frac{D\lambda}{d} = (2n-1)\frac{\lambda}{2} = (n - \frac{1}{2})\lambda$$

$$x = (n - \frac{1}{2})\frac{D\lambda}{d}$$

Fringe width, $\beta = x_{n+1} - x_n = (n+1)\frac{D\lambda}{d} - \frac{nD\lambda}{d}$

$\beta = \frac{D\lambda}{d}$, which will be same for constructive and destructive interference.

So fringe width is directly proportional to λ. On immersing the apparatus in water, the wavelength of light decreases $(\lambda_\omega = \lambda/n)$.

Therefore, fringe width will decrease in water.

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Physics 2011 (Outside Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

1. **A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 5 V. What is the potential at the centre of the sphere ? [1]**

Answer : Potential inside the charged sphere is constant and equal to potential on the surface of conductor.

Therefore, potential at the centre of sphere is 5 V.

2. **How are X-rays produced ? [1]**

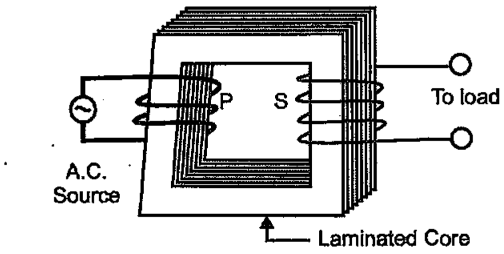
Answer : X-rays are produced when electron strike a metal target. The electrons are liberated from the heated filament and accelerated from the high voltage towards the metal target. X-rays are also produced when electrons collide with the atom and nuclei of metal target.

4. **Where on the surface of Earth is the angle of dip zero ? [1]**

Answer : At magnetic equator angle of dip is zero.

12. **State the principle of working of a transformer. Can a transformer be used to step up or step down a d.c. voltage ? Justify your answer. [2]**

Answer : Transformer principle : It is a device which converts high voltage a.c. into low voltage a.c. and *vice-versa*.



It is based upon the principle of mutual induction. When alternating current is passed through a coil, an induced e.m.f. is set up in the neighbouring coil.

Working : When an alternating current is passed through the primary, the magnetic flux through the iron core changes which does two things. It produces e.m.f. in the primary and an induced e.m.f. is also set up in the secondary. If we assume that the resistance of primary is negligible, the back e.m.f. will be equal to the voltage applied to the primary.

$$\therefore \quad V_P = -N_P\frac{d\phi}{dt}$$

and $$V_S = -N_S\frac{d\phi}{dt}$$

where N_P and N_S are number of turns in the primary and secondary respectively. V_P and V_S are their respective voltages.

$$\therefore \quad \frac{V_S}{V_P} = \frac{N_S}{N_P}$$

The ratio $\frac{N_S}{N_P}$ is called the turns ratio.

In a step-up transformer : $N_S > N_P$

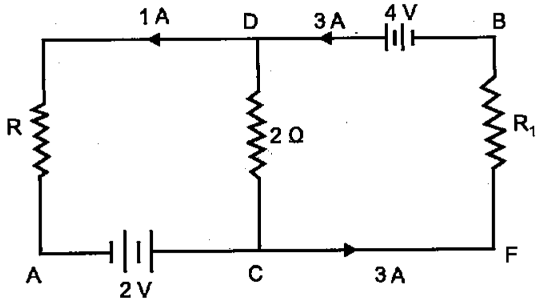
So $V_S > V_P$

In a step-down transformer : $N_S < N_P$

So $V_S < V_P$

A transformer can not be used to step up or step down a d.c. voltage because d.c. can not produce a changing magnetic flux in the core of the transformer and no emf will be induced.

14. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. **[2]**



Answer : $V_D - V_C = 2 \times 2 = 4$ V ...(i)

$$V_C - V_A = 2 \text{ V}$$

$\because$ $V_A = 0 \Rightarrow V_C = 2$ V ...(ii)

Now, from equations (i) and (ii),

$$V_D = 6 \text{ V} \quad ...(iii)$$

Thus, $V_D - V_B = 4 \text{ V} \Rightarrow V_B = 2$ V

17. What is ground wave communication ? On what factors does the maximum range of propagation in this mode depend ?** **[2]**

22. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.6, (ii) a medium of refractive index 1.3. **[3]**

(a) Will it behave as a converging or a diverging lens in two cases ?

(b) How will its focal length change in the two media ?

Answer : (a) Here ${}^a\mu_g = 1.5$

Let f_{air} be the focal length of lens in air, then

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}\,(1.5-1)}$$

$$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{f_{air}} \quad ...(i)$$

(i) When lens is dipped in medium A.

Here ${}^a\mu_A = 1.6$

Let f_A be focal length of lens, when dipped in medium A, then $\frac{1}{f_A} = ({}^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

or $$\frac{1}{f_A} = \left(\frac{{}^a\mu_g}{{}^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i), we have

$$\frac{1}{f_A} = \left(\frac{1.5}{1.6} - 1\right)\frac{2}{f_{air}} = \frac{-0.1}{1.6}\ \frac{2}{f_{air}}$$

or $$f_A = -8 f_{air} \quad ...(ii)$$

As sign of f_A is opposite to that of f_{air}, the lens will behave as a diverging lens.

****Answer is not given due to the change in present syllabus.**

(ii) When lens is dipped in medium B:

Here, $^a\mu_B = 1.3$

Let f_B be the focal lens, when dipped in medium B, then

$$\frac{1}{f_B} = \left({}^B\mu_g - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$= \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i) we have,

$$\frac{1}{f_B} = \left(\frac{1.5}{1.3} - 1\right) \times \frac{2}{f_{air}}$$

or $\qquad f_B = 3.25 f_{air} \qquad$ (iii)

As sign of f_B is same as that of f_{air}, the lens will behave as converging lens.

(b) (i) As seen from equation (ii),

$$f_A = -f_{air},$$

$\therefore$ Focal length increases in magnitude and becomes negative.

(ii) As seen from equation (iii),

$$f_B = 3.25 f_{air}$$

$\therefore$ Focal length increases in magnitude and remains positive.

Physics 2011 (Outside Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

1. A hollow metal sphere of radius 6 cm is charged such that the potential on its surface is 12 V. What is the potential at the centre of sphere ? [1]

Answer : Potential inside the charged sphere is constant and equal to potential on the surface of conductor. So therefore, potential at the centre of sphere is 12 V.

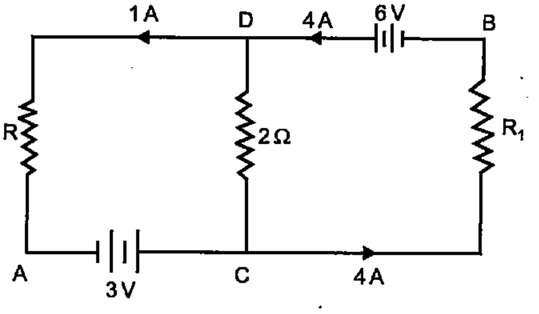
3. How are microwaves produced ? [1]

Answer : Microwaves are electromagnetic waves with wavelength ranging from as long as metre to as short as one millimetre, or equivalently with frequencies between 300 MHz and 300 GHz. Microwaves are produced by vacuum tubes devices that operate on the ballistic motion of electron controlled by magnetic or electric fields. Some different kinds of microwaves emitters are the cavity magnetron, the klystron, the travelling wave tube (TWT), the gyrotron and all stars.

12. Mention various energy losses in transformer. [2]

Answer : Magnetic core losses are exaggerated with higher frequencies, eddy currents in the iron core, resistance of windings or copper loss, hysteresis loss and flux leakage are energy losses in transformers. Transformers energy losses tend to worsen with increasing frequency.

14. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. [2]



Answer : $V_D - V_C = 2 \times 3 = 6$ V ...(i)

then, $\quad V_C - V_A = 3$ V

$\because \quad V_A = 0$

$\Rightarrow \quad V_C = 3$ V ...(ii)

From equations (i) and (ii),

$$V_D - 3 = 6 \text{ V}$$

$\Rightarrow \quad V_D = 9$ V ...(iii)

Now, $\quad V_D - V_B = 6$ V

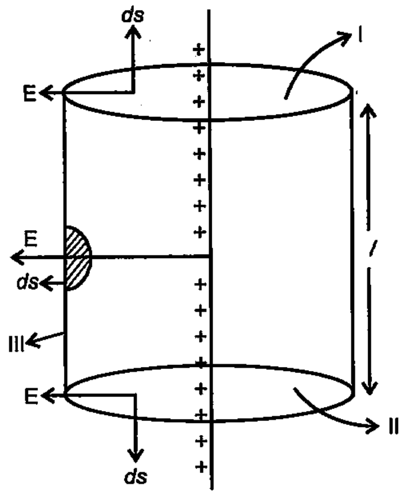
$\Rightarrow \quad 9 - V_B = 6$ V

$\Rightarrow \quad V_B = 3$ V

18. A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its

axis coinciding with the length of the wire. Find the expression for the electric flux through the surface of the cylinder. **[2]**

Answer :



There will be no electric flux through the circular ends of the cylinder.

So, according to Gauss's law,

Flux, $\phi = \frac{q}{\varepsilon_0}$

Since, charge enclosed by gaussian surface

i.e. $q = \lambda \times l,$

$\therefore \quad \phi = \frac{\lambda l}{\varepsilon_0}$

20. A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. It is immersed in a liquid of refractive index 1.3. Calculate its new focal length. **[3]**

Answer : If f_a be the focal length of glass lens in air, then.

$$\frac{1}{f_a} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{... (i)}$$

If f_l be the focal length of glass lens in liquid. Then

$$\frac{1}{f_l} = ({}^l\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(ii)}$$

Dividing equation (i) by (ii),

$$\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1}$$

$$\frac{f_l}{20} = \frac{1.6 - 1}{\frac{1.6}{1.3} - 1}$$

or $\quad f_l = 52$ cm.

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Physics 2011 (Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. **A point charge is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative ?** **[1]**

Answer : If Q is positively charged, $V_A - V_B$ = positive.

If Q is negatively charged, $V_A - V_B$ = negative.

2. **A plane electromagnetic wave travels in vacuum along Z-direction. What can you say about the direction of electric and magnetic field vector ?** **[1]**

Answer : In electromagnetic wave, the electric field vector $\vec{E}$ and magnetic field vector $\vec{B}$ show their variations perpendicular to the direction of propagation of wave as well as perpendicular to each other. As the electromagnetic wave is travelling along Z-direction, hence $\vec{E}$ and $\vec{B}$ show their variation in XY-plane.

3. **A resistance R is connected across a cell of emf ε and internal resistance *r*. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for '*r*' in terms of ε, V and R.** **[1]**

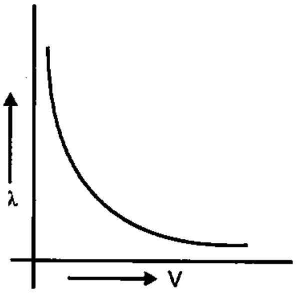
Answer : $r = \left(\frac{\varepsilon}{V} - 1\right) \times R$

4. **The permeability of magnetic material is 0.9983. Name the type of magnetic materials it represents.** **[1]**

Answer : Diamagnetic material.

5. Show graphically, the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest. [1]

Answer :



6. In a transistor, doping level in base is increased slightly. How will it affect (i) collector current and (ii) base current ? [1]**

7. Define the term 'wattless current'. [1]

Answer : Current flowing in a circuit without any net dissipation of power is called wattless current.

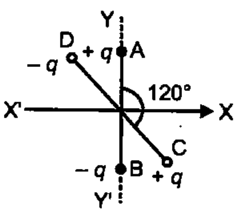
8. When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain. [1]

Answer : Atoms (of the second medium) oscillate with the same (incident light) frequency and in turn, emit light of the same frequency.

9. Two Uniformly large parallel thin plates having charge densities +σ and –σ are kept in the X-Z plane at a distance '*d*' apart. Sketch an equipotential surface due to electric field between the plates. If a particle of mass *m* and charge '–*q*' remains stationary between the plates, what is the magnitude and direction of this field ? [2]

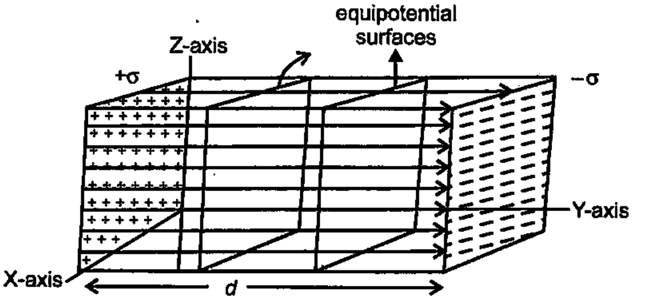
OR

Two small identical electrical dipoles AB and CD, each of dipole moment '*p*' are kept at an angle of 120° as shown in the figure. What is the resultant dipole moment of this combination ? If this system is subjected to electric field $\vec{E}$ directed along +X direction, what will be the magnitude and direction of the torque acting on this ?

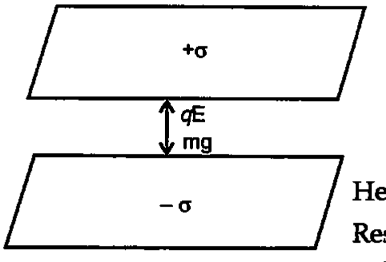


**Answer is not given due to the change in present syllabus.

Answer :



Downward force due to gravity is balanced by upward force due to electric field



i.e., $mg = qE$

$\therefore \quad E = \dfrac{mg}{g}$

OR

Here $p_{AB} = p_{CD} = p$

Resultant dipole moment

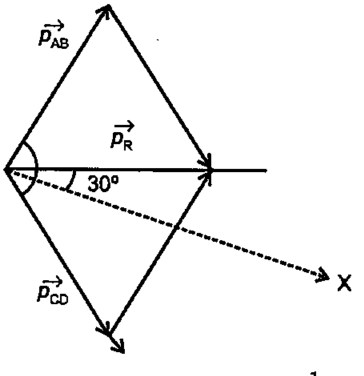
$$p_R = \sqrt{p^2 + p^2 + 2p^2 \cos 120°}$$

$$= \sqrt{2p^2 + 2p^2\left(-\frac{1}{2}\right)}$$

$$= \sqrt{2p^2 - p^2} = \sqrt{p^2}$$

$$= p$$

When this dipole is placed in an electric field along + X-axis, it will experience a torque.



$$\tau = pE \sin 30° = pE \times \frac{1}{2} = \frac{1}{2}pE$$

$$= \frac{pE}{2}$$

According to right hand thumb rule, torque will be into the plane of the paper *i.e.,* along Z-axis.

10. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place. [2]

Answer : Given, angle of dip, $\delta = 60°$

$$H = 0.4\,G$$
$$R = ?$$

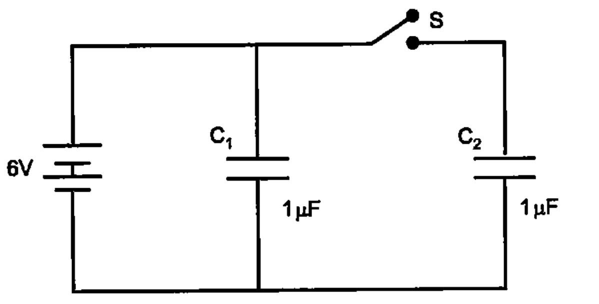
We know, $H = R\cos\delta$

or $R = \frac{H}{\cos\delta} = \frac{0.4}{\cos 60°}$

$= \frac{0.4}{1/2} = 0.4 \times 2$

$\therefore$ $R = 0.8\,G$

11. Figure shows two identical capacitors, C_1 and C_2, each of 1μF capacitance connected to a battery of 6 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ? [2]



Answer : When S is closed :

P.d. across C_1 = P.d. across C_2 = 6 V

$V_1 = V_2 = 6\,V$ $[\because q = CV]$

$\therefore q_1 = q_2 = 1\,\mu F \times 6\,V = 6\,\mu C$

When S is open :

When dielectric slab (K = 3) are inserted,

$$C_1 = 3 \times 1\,\mu F = 3\,\mu F$$
$$C_2 = 3 \times 1\,\mu F = 3\,\mu F$$

P.d. across C_1,

$$V_1' = 6\,V$$

$\therefore$ $q_1' = 3\,\mu F \times 6\,V = 18\,\mu C$

P.d. across C_2,

$$V_2' = \frac{q_2}{C_2} = \frac{6\,\mu C}{3\,\mu F} = 2\,V$$

$\therefore$ $V_2' = 2\,V$

12. Two convex lenses of same focal length but of aperture A_1 and A_2 ($A_2 < A_1$), are used as the objective lenses in two astronomical telescopes having identical eyepieces. What is the ratio of their resolving power ? Which telescope will you prefer and why ? Give reason. [2]

Answer : Resolving power of a telescope is proportional to its aperture, and is given by a relation,

$$R.P. = \frac{A}{1.22\,\lambda}$$

Where, A is aperture and λ is wavelength for a given light.

or $\frac{(R.P.)_1}{(R.P.)_2} = \frac{A_1}{A_2}$

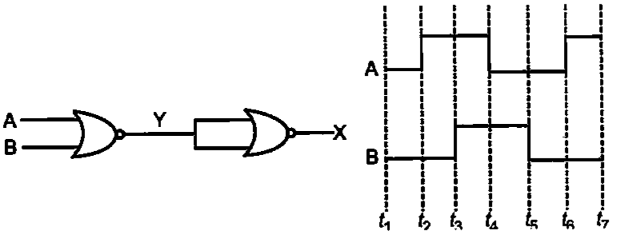
Since, $A_1 > A_2$ (Given),

Therefore, the telescope with objective of aperture A_1 should be preferred for viewing as this would :

(i) give a better resolution.

(ii) have a higher light gathering power of telescope.

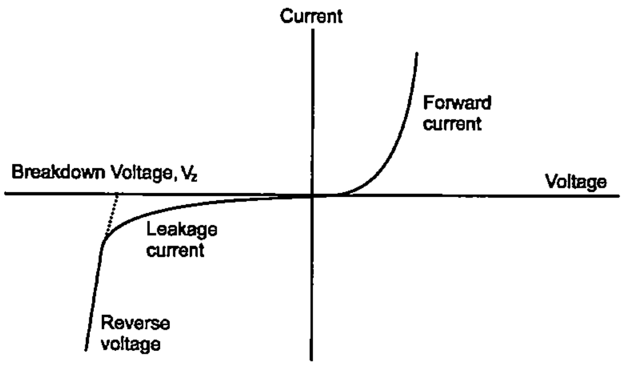
13. Draw the output waveform at X, using the given inputs A and B for the logic circuit shown below. Also, identify the logic operation performed by this circuit. [2]**



14. Name the semiconductor device that can be used to regulate an unregulated dc power supply. With the help of I-V characteristics of this device, explain its working principle. [2]

Answer : Zener diode is a specially designed diode which is operated in reverse breakdown region continuously without any damage. When zener diode is operated in the reverse break down region, the voltage across it remains practically constant (V_z) for a large change in reverse current. Therefore, for any increase/decrease of the input voltage, there is a increase/decrease of the voltage drop across series resistance (R_s) without any change in the voltage across zener diode.

**Answer is not given due to the change in present syllabus.



I-V characteristic curve of zener diode

15. How are infrared waves produced ? Why are these referred to as 'heat wave' ? Write their one important use. [2]

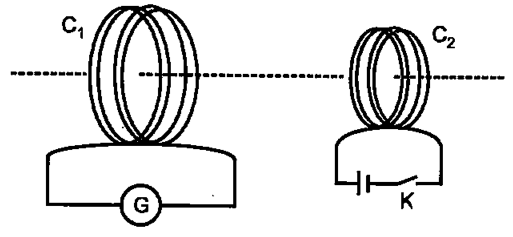
Answer : Infrared rays are produced by hot bodies or due to vibration of atoms and molecules of the bodies. Infrared waves are called heat waves as they cause heating effect. Infrared waves are used to maintain earth's warmth, in physical therapy, remote switches etc.

16. Draw the transfer characteristic curve of a base biased transistor in CE configuration. Explain clearly how the active region of the V_o versus V_i curve in a transistor is used as an amplifier.[2]**

17. (a) Define modulation index.

(b) Why is the amplitude of modulating signal kept less than the amplitude of carrier wave ? [2]**

18. A current is induced in coil C_1 due to the motion of current carrying coil C_2. (a) Write any two ways by which a large deflection can be obtained in the galvanometer G. (b) Suggest an alternative device to demonstrate the induced current in place of a galvanometer. [2]



Answer : (a) Any two ways to obtain large deflection in G :

(i) Moving C_2 faster towards C_1.

(ii) Insertion of soft iron core in C_1.

(b) Alternative device that can be used in place of galvanometer is LED.

**Answer is not given due to the change in present syllabus.

19. Define the terms (i) drift velocity, (ii) relaxation time.

A conductor of length L is connected to a dc source of emf ε. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3 L, how will the drift velocity change ? [3]

Answer : (i) Drift velocity : The average velocity with which the free electrons drift towards positive terminal under the influence of an external electric field is called drift velocity.

(ii) Relaxation time : Average time interval between two successive collisions of an electron with the positive ions / atoms of the conductor.

Drift velocity is given by,

$$v_d = \frac{e\tau}{m}\frac{E}{L}$$

or
$$v_d \propto \frac{1}{L}$$

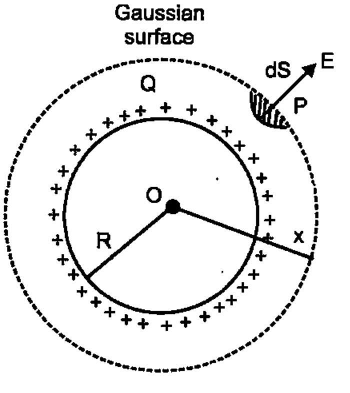
The drift velocity is inversely proportional to L.
If length L of conductor is made 3 times, drift velocity will become one-third of its initial value.

$$v'_d = \frac{v_d}{3}$$

20. Using Gauss's law obtain the expression for the electric field due to a uniformly charged thin spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for $r > R$ and $r < R$. [3]

Answer : Electric field at point P at a distance 'r' outside the spherical shell.

According to Gauss' law,



$$\phi = \oint \vec{E}\cdot\vec{dS}$$
$$= \oint E \cdot dS$$
$$= E\oint dS$$
$$\phi = E \times 4\pi r^2 \qquad ...(i)$$

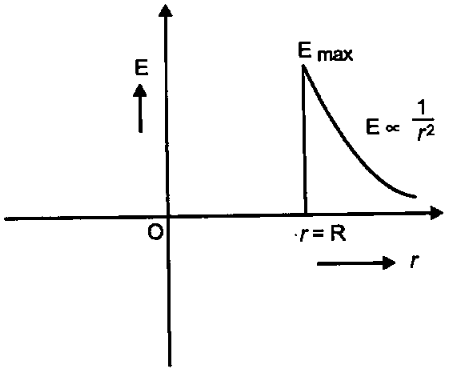
According to gauss' law, the electric flux through a surface is $\frac{1}{\varepsilon_0}$ times the net charge enclosed by it.

$\therefore \qquad \phi = \frac{Q}{\varepsilon_0} \qquad$ ...(ii)

From equations (i) and (ii),

$$E \times 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$



Variation of E with r (distance)

For $r < R$, there is no strength of electric field inside a charged spherical shell.

For $r > R$, electric field outside a spherical shell is same as if the whole charge Q is concentrated at the centre.

21. An electron and a photon each have a wavelength 1.00 nm. Find
(a) their momenta,
(b) the energy of the photon, and
(c) the kinetic energy of electron. **[3]**

Answer : $\lambda_e = \lambda_p = 1.00 \text{ nm} = 10^{-9}$m

(a) For electron or photon, momentum

$$p = p_e = p_p = \frac{h}{\lambda}$$

$$\Rightarrow \quad p = \frac{6.63\times10^{-34}}{10^{-9}}$$

$$= 6.63 \times 10^{-25}\ kg\ m/s$$

(b) Energy of photon,

$$E = \frac{hc}{\lambda}$$

$$= (6.63 \times 10^{-34}) \times \frac{3\times10^8}{10^{-9}} \approx 19.89 \times 10^{-17}\text{ J}$$

(c) Kinetic energy of electron,

$$= \frac{p^2}{2m}$$

$$= \frac{1}{2} \times \frac{(6.63\times10^{-25})^2}{9.1\times10^{-31}}\text{ J} \approx 2.42 \times 10^{-19}\text{ J}$$

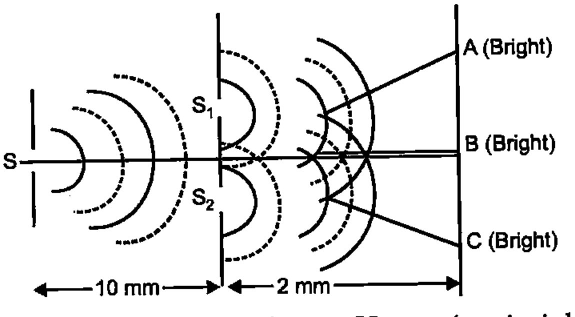
22. Draw a schematic diagram showing the (i) ground wave (ii) sky wave and (iii) space wave propagation modes for em waves.
Write the frequency range for each of the following : **[3]**
(i) Standard AM broadcast
(ii) Television
(iii) Satellite communication.**

23. Describe Young's double slit experiment to produce interference pattern due to a monochromatic source of light. Deduce the expression for the fringe width. **[3]**

OR

Use Huygen's principle to verify the laws of refraction.

Answer : S is a narrow slit (of width about 1 mm) illuminated by a monochromatic source of light. At a suitable distance (= 10 mm) from S, two slits S_1 and S_2 are placed parallel to S. When a screen is placed at a large distance (about 2 m) from the slit S_1 and S_2, alternate dark and bright bands appear on the screen. These are the interference bands or fringes. The band disappear when either slit is covered.



Explanation : According to Huygen's principle, the monochromatic source of light illuminating the slit S sends out spherical wavefront.

The two waves of same amplitude and same frequency superimpose on each other. Dark fringes appear on the screen when the crest of one wall falls on the trough of other and they neutralize the effect of each other. Bright fringes appear on the screen when the crest of one

****Answer is not given due to the change in present syllabus.**

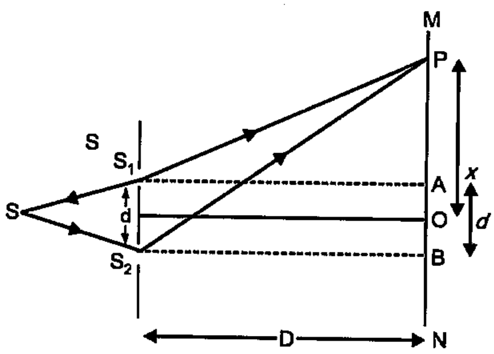
wave coincides with the crest of other and they reinforce each other.

Expression for the fringe width :

Let d = distance between slits S_1 and S_2,

D = distance of screen from two slits, and

x = distance between the central maxima 'O' and observation point P.



Light waves spread out from S and fall on both S_1 and S_2. The spherical waves emanating from S_1 and S_2 will produce interference fringes on the screen MN.

$$S_1P = \sqrt{(S_1A)^2 + (AP)^2}$$

$$\Rightarrow \quad \sqrt{D^2 + \left(x - \frac{d}{2}\right)^2} = \sqrt{D^2\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]}$$

$$\Rightarrow \quad S_1P = D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]^{\frac{1}{2}}$$

By binomial theorem and neglecting higher terms, we have

$$S_1P = D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{2D^2}\right] = D + \frac{\left(x - \frac{d}{2}\right)^2}{2D}$$

$$\text{Similarly } S_2P = D + \frac{\left(x + \frac{d}{2}\right)^2}{2D}$$

Hence, path difference $= S_2P - S_1P$

$$= D + \frac{\left(x + \frac{d}{2}\right)^2}{2D} - D - \frac{\left(x - \frac{d}{2}\right)^2}{2D}$$

$$= \frac{1}{2D}\left[x^2 + \frac{d^2}{4} + xd - x^2 - \frac{d^2}{4} + xd\right]$$

$$= \frac{1}{2D}.2xd = \frac{xd}{D}$$

For bright fringe,

Path difference $= n\lambda$, where $n = 0, 1, 2, \ldots\ldots\ldots$

$$\Rightarrow \quad \frac{xd}{D} = n\lambda$$

$$\therefore \quad x_n = \frac{n\lambda D}{d}$$

For dark fringe,

Path difference $= (2n - 1)\frac{\lambda}{2}$, where $n = 1, 2, 3, \ldots\ldots$

$$\Rightarrow \quad \frac{xd}{D} = (2n-1)\frac{\lambda}{2}$$

$$\therefore \quad x_n = \left(n - \frac{1}{2}\right)\frac{\lambda D}{d}$$

So, fringe width

$$x_{n+1} - x_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d}$$

[Considering bright fringes]

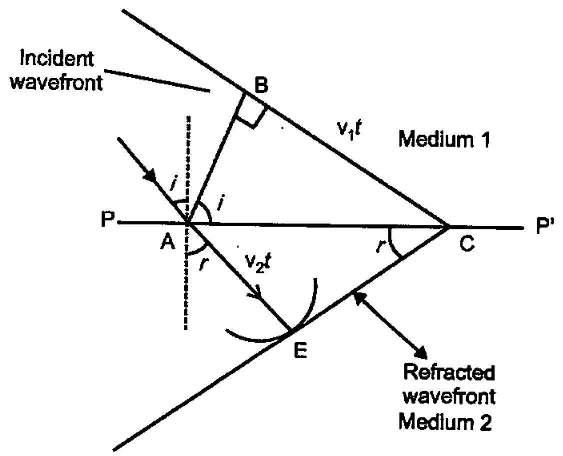
$$= \frac{\lambda D}{d}$$

Fringe width is same for both dark and bright fringe.

OR

Wavefront : The continuous locus of all the particles of a medium, which are vibrating in the same phase is called wavefront.

Laws of refraction : Let PP' represent the surface separating medium 1 and medium 2 as shown in fig.



From ΔABC,

$$\sin i = \frac{BC}{AC} = \frac{v_1t}{AC}$$

From ΔAEC,

$$\sin r = \frac{AE}{AC} = \frac{v_2t}{AC}$$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \times \frac{AC}{v_2 t} = \frac{v_1}{v_2} = \mu$$

$$\therefore \quad \frac{\sin i}{\sin r} = \mu$$

which is Snell's law of refraction of light (first law).

Second law : Incident wavefront, refracted wavefront, normals all lie in the same plane.

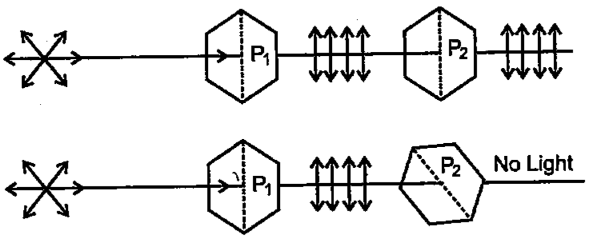
24. (a) Describe briefly, with the help of suitable diagram, how the transverse nature of light can be demonstrated by the phenomenon of polarization.

(b) When unpolarized light passes from air to a transparent medium, under what condition does the reflected light get polarized ? [3]

Answer :

(a) When a polaroid P_1 is rotated in the path of an unpolarized light, there is no change in transmitted intensity.

The light transmitted through polaroid P_1 is made to pass through polaroid P_2. On rotating polaroid P_2 in path of light transmitted from P_1 we notice a change in intensity of transmitted light. This shows the light transmitted from P_1 is polarized. Since light can be polarized, it has transverse nature.



(b) Whenever unpolarized light is incident from air to a transparent medium at an angle of incidence equal to polarizing angle, the reflected light gets fully polarized.

According to Brewster's law,

$$n = \tan i_p \quad \text{...(i)}$$

where i_p in the polarizing angle and n is refractive index of the transparent material.

By Snell's law, we have

$$n = \frac{\sin i_p}{\sin r}$$

or $$\tan i_p = \frac{\sin i_p}{\sin r} \quad \text{[From (i)]}$$

$$\therefore \quad \cos i_p = \sin r$$

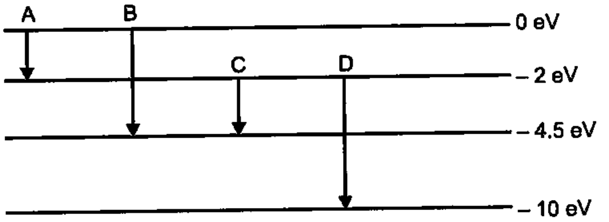
$$\cos i_p = \cos (90° - r)$$

$$\therefore \quad i_p + r = 90°$$

Thus, when the sum of polarizing angle and reflected angle is 90°, the reflected light is fully polarized.

25. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm ?

Which of these transitions correspond to emission of radiation of (i) maximum and (ii) minimum wavelength ? [3]



Answer : If a photon of wavelength $\lambda = 275$ nm is to be emitted, then energy of photon is given by

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{275 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{ eV} = 4.5 \text{ eV}$$

Hence transition B would result in the emission of a photon of wavelength 275 nm.

(i) Transition A corresponds to maximum wavelength.

(ii) Transition D corresponds to minimum wavelength.

26. State the law of radioactive decay.

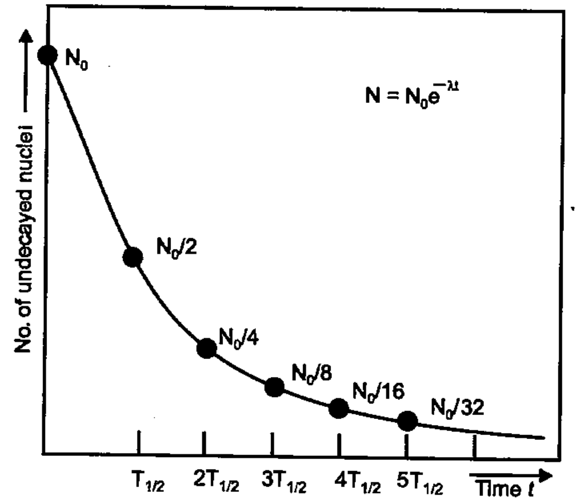
Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half life $T_{1/2}$.

Depict in the plot the number of undecayed nuclei at (i) $t = 3\, T_{1/2}$ and (ii) $t = 5\, T_{1/2}$. [3]

Answer : The number of nuclei undergoing decay per unit time, at any instant t, is proportional to the total number of nuclei in the sample at that instant.

$$-\frac{dN}{dt} \propto N$$

$$\Rightarrow \quad \frac{dN}{dt} = -\lambda N$$

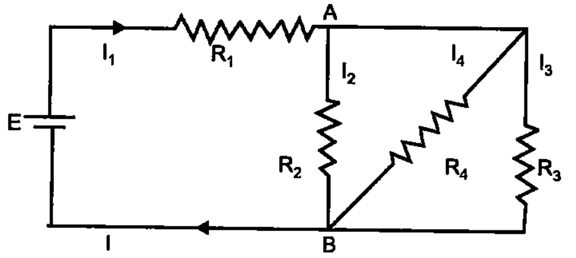


From graph, number of undecayed nuclei at

(i) $3\ T_{1/2}$ is $N_0/8$.

(ii) $5\ T_{1/2}$ is $N_0/32$.

27. In the circuit shown, $R_1 = 4\ \Omega$, $R_2 = R_3 = 15\ \Omega$, $R_4 = 30\ \Omega$ and E = 10 V. Calculate the equivalent resistance of the circuit and the current in each resistor. [3]



Answer : R_2, R_3, R_4 are in parallel combination.

$$\therefore \quad \frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{15} + \frac{1}{15} + \frac{1}{30}$$

$$= \frac{2+2+1}{30} = \frac{5}{30}$$

$$\Rightarrow \quad R_{234} = 6\ \Omega$$

Now R_{234} is in series with R_1, so,

$$R_{eq} = 4\ \Omega + 6\ \Omega = 10\ \Omega$$

$$\therefore \quad I = \frac{E}{R_{eq}} = \frac{10}{10}\ A = 1\ A$$

$\therefore$ Current through $R_1 = 1$ A

P.D. across R_1, $V = IR_1 = 1 \times 4 = 4$ V

So, P.D. across $R_{234} = 6$ V

$$\because \quad I_2R_2 = I_3R_3 = I_4R_4 = 6\ V$$

[Voltage in parallel combination is equal]

$$I_2 = \frac{6}{15}\ A = 0.4\ A$$

$$I_3 = \frac{6}{15}\ A = 0.4\ A$$

$$I_4 = \frac{6}{30}\ A = 0.2\ A$$

28. State Biot-Savart's law, giving the mathematical expression for it.

Use this law to derive the expression for the magnetic field due to a circular coil carrying current at a point along its axis.

How does a circular loop carrying current behave as a magnet ? [5]

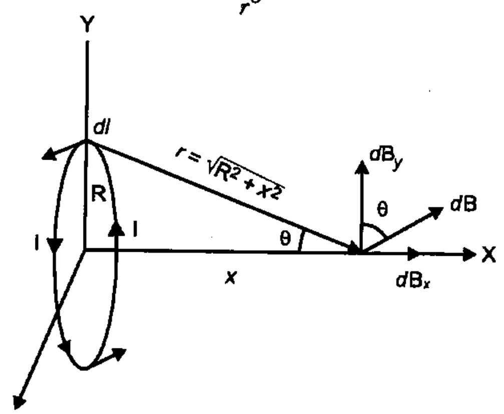
OR

With the help of a labelled diagram, state the underlying principle of a cyclotron. Explain clearly how it works to accelerate the charged particles.

Show that cyclotron frequency is independent of energy of the particle. Is there an upper limit on the energy acquired by the particle ? Give reason.

Answer : Biot-Savart's law states that the magnitude of magnetic field $\vec{dB}$ due to current element is directly proportional to the current I, the element length $|dl|$ and inversely proportional to the square of the distance r of the field point. Its direction is perpendicular to the plane containing $\vec{dl}$ and $\vec{r}$.

$$d\vec{B} \propto \frac{I \cdot d\vec{l} \times \vec{r}}{r^3}$$



According to Biot-Savart's law

$$dB = \frac{\mu_0}{4\pi}\frac{I\,\vec{dl}\times\vec{r}}{r^3}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}\sin 90^\circ \qquad \left[\because \vec{dl}\perp\hat{r}\right]$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$$

dB has two components dB_x and dB_y. dB_y cancel out and only dB_x component remains.

$$\therefore \quad dB_x = dB\sin\theta$$

$$= \frac{\mu_0 Idl}{4\pi r^2}\times\frac{R}{(x^2+R^2)^{1/2}}$$

$$\text{or} \quad dB_x = \frac{\mu_0 Idl}{4\pi}\times\frac{R}{(x^2+R^2)^{3/2}}$$

$$[\because r^2 = x^2+R^2]$$

Total magnetic field at P,

$$B = \int dB_x$$

$$= \int\frac{\mu_0 IRdl}{4\pi(x^2+R^2)^{3/2}}$$

$$\int dl = 2\pi R$$

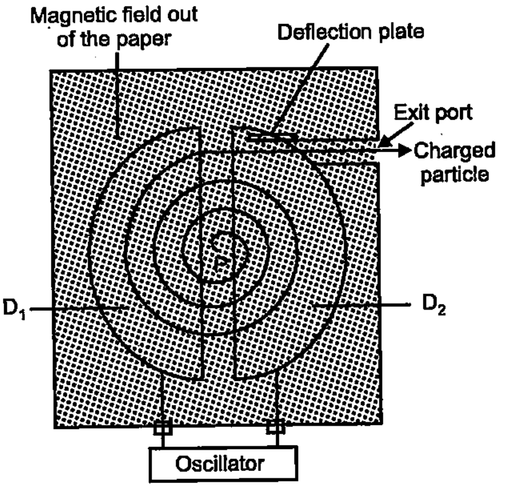
$$\therefore \quad B = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}$$

$$\vec{B} = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}\hat{i}$$

Explanation : A magnetic needle placed at the centre or axis of a circular coil shows deflection. This implies that a circular coil behaves as a magnet.

OR

Principle : Cyclotron works on the principle that a charged particle moving normal to a magnetic field experiences Lorentz magnetic force due to which the particle moves in a circular path.



Working : High frequency oscillator maintains moderate alternating potential difference between the dees. This potential difference establishes an electric field that reverse its direction periodically. Suppose a positive ion of moderate mass produced at the centre of the dees finds D_2 at negative potential. It gets accelerated towards it. A uniform magnetic field, normal to the plane of the dees, makes it move in a circular track. Particle traces a semicircular track and returns back to the region between the dees. The moment it arrives in the region electric field reverses its direction and accelerate the charge towards D_1. This way charge keeps on getting accelerated until it is removed out of the dees.

Centripetal force, needed by the charged particle to move in circular track, is provided by the magnetic field.

$$\frac{mv^2}{r} = qvB$$

$$\Rightarrow \quad v = \frac{qBr}{m}$$

$$\text{Period of revolution, } T = \frac{2\pi r}{v}$$

$$= \frac{2\pi rm}{qBr}$$

$$\Rightarrow \quad T = \frac{2\pi m}{qB}$$

$$\Rightarrow \quad \nu = \frac{1}{T} = \frac{qB}{2\pi m}$$

Thus, frequency of revolution is independent of the energy of the particle.

Yes, there is an upper limit on the energy acquired by the charged particle. The charged particle gains maximum speed when it moves in a path of radius equal to the radius of the dees.

i.e., $v_{max} = \dfrac{qBR}{m}$

where, R = radius of the dees.

So, maximum kinetic energy

$$K.E. = \frac{1}{2}mv^2_{max} = \frac{1}{2}m\left(\frac{qBR}{m}\right)^2 = \frac{q^2B^2R^2}{2m}$$

29. (a) Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism.

Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.

(b) Explain briefly how the phenomenon of total internal reflection is used in fibre optics. **[5]**

OR

(a) Obtain Lens Maker's formula using the expression

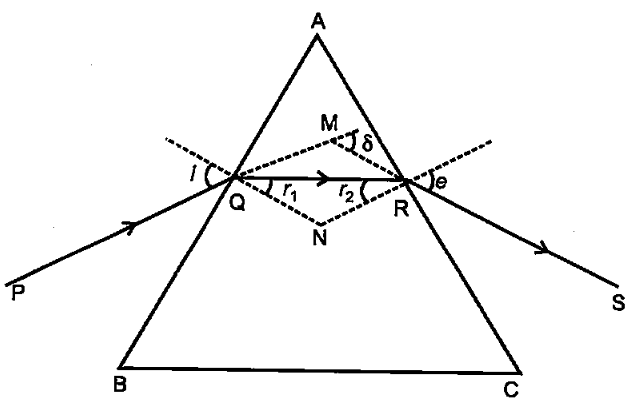
$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

Here the ray of light propagated from a rarer medium of refractive index (n_1) to a denser medium of refractive index (n_2) is incident on the convex side of spherical refracting surface of radius of curvature R.

(b) Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the pole. Using this diagram, derive the magnification formula for the image formed.

Answer :

(a)



From ΔMQR, $(i - r_1) + (e - r_2) = \delta$

So, $(i + e) - (r_1 + r_2) = \delta$

From ΔRQN, $r_1 + r_2 + \angle QNR = 180°$

Also, $A + \angle QNR = 180°$

Thus, $A = r_1 + r_2$

So, $i + e - A = \delta$

At minimum deviation,

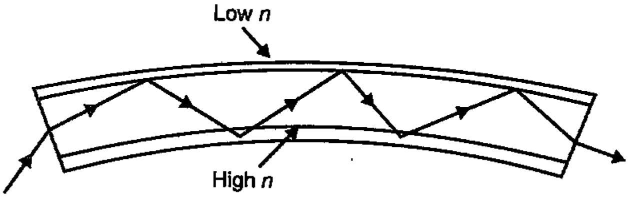
$$i = e, r_1 = r_2 = r \text{ and } \delta = \delta_m$$

$\Rightarrow$ $$i = \frac{A + \delta_m}{2} \text{ and } r = \frac{A}{2}$$

Also $$\mu = \frac{\sin i}{\sin r}$$

Hence $$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

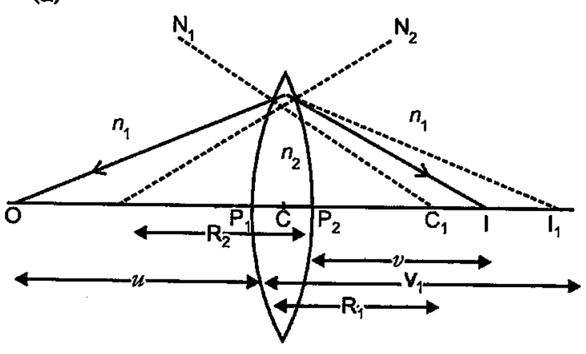
(b)



Each optical fibre consists of a core and cladding, refractive index of the material of the core is higher than that of cladding. When a signal, in the form of light, is directed into the optical fibre, at an angle greater than the critical angle, it undergoes repeated total internal reflections along the length of the fibre and comes out of it at the other end with almost negligible loss of intensity.

OR

(a)



For refraction at the first surface

$$\frac{n_2}{v_1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad ...(i)$$

For the second surface, I_1 acts as a virtual object (located in the denser medium). So, for refraction at this surface, we have

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2} \quad ...(ii)$$

Adding (i) and (ii),

$$\frac{n_1}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} + \frac{n_1 - n_2}{R_2}$$

$$\Rightarrow \quad \frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \quad \frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

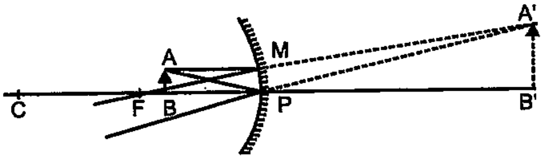
The point where image of an object, located at infinity, is formed is called the focus F of the lens and the distance f gives its focal length.

So for $u = \infty$,

$v = +f$

$$\Rightarrow \quad \frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

(b)



ΔABP is similar to ΔA'B'P

So, $\frac{A'B'}{AB} = \frac{B'P}{BP}$

Now, A'B' = I

AB = O

B'P = v

BP = $-u$

$\therefore$ Magnification,

$$m = \frac{I}{O} = -\frac{v}{u}$$

30. (a) With the help of a labelled diagram, describe briefly the underlying principle and working of a step up transformer.

(b) Write any two sources of energy loss in a transformer.

(c) A step up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy ? Explain. [5]

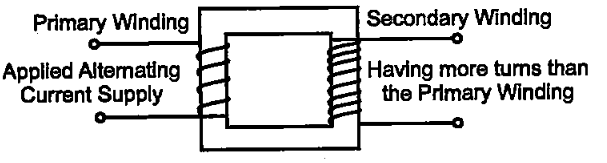
OR

Derive an expression for the impedance of a series LCR circuit connected to an AC supply of variable frequency.

Plot a graph showing variation of current with the frequency of the applied voltage.

Explain briefly how the phenomenon of resonance in the circuit can be used in the tuning mechanism of a radio or a TV set.

Answer : (a) Step-up transformer :



Principle : It works on the principle of mutual induction. When alternating current is passed through a coil, an induced emf is set up in the neighbouring coil.

Working : When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it. We consider an ideal transformer in which the primary has negligible resistance and all the flux in the core links with both primary and secondary windings. Let ϕ be the flux in each turn in the core at any time t due to current in the primary when a voltage V_p is applied to it.

Then the induced emf or voltage E_s in the secondary with N_s turns is

$$E_s = N_s \frac{d\phi}{dt}$$

The alternating flux also induces an emf, called back emf in the primary given by

$$E_p = -N_p \frac{d\phi}{dt}$$

But $E_p = V_p$ (since resistance of primary is small) and $E_s = V_s$ (since secondary current is small)

So, $V_S = -N_p \frac{d\phi}{dt}$

And $V_S = -N_p \frac{d\phi}{dt}$

Thus, $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

For a step up transformer,

$$\frac{V_s}{V_p} > 1$$

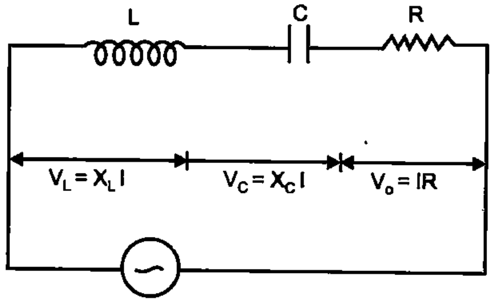
$\Rightarrow \quad V_s > V_p$

(b) Sources of energy loss in transformer are : Joule's loss in the resistance of windings, loss due to eddy currents.

(c) No. A step up transformer steps up the voltage while it steps down the current. So the input and output power remain same (provided there is no loss). Hence, there is no violation of the principle of energy conservation.

OR

Impedance (Z) in LCR circuit : The effective resistance offered by a series LCR circuit to the flow of current is called its impedance. It is denoted by Z.



Suppose an inductance L, capacitance C and resistance R are connected in series to a source of alternating emf given by,

$$V = V_0 \sin \omega t$$

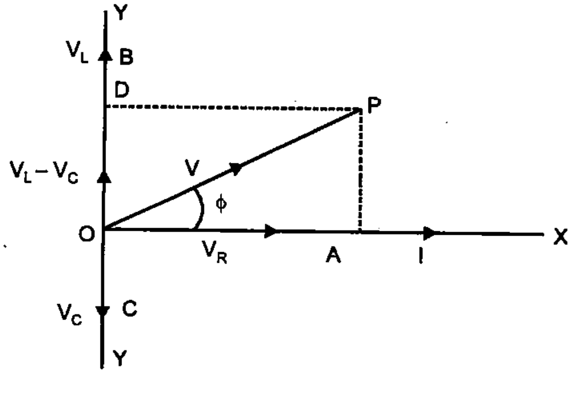
Let I be the instantaneous value of current in series circuit. Then voltages across the three components are :

(i) $V_L = X_L I$. It is ahead of current I in phase by 90°.

(ii) $V_C = X_C I$. It lags behind the current I in phase by 90°.

(iii) $V_R = RI$. It is in phase with current I.

These voltages are shown in the phasor diagram given below.



As V_L and V_C are in opposite direction, their resultant is OD = $V_L - V_C$, in the positive Y-direction.

By parallelogram law, the resultant voltage (V) is represented by $\vec{OP}$.

$$V = \sqrt{OA^2 + OD^2}$$

$$= \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{R^2 I^2 + (X_L I - X_C I)^2}$$

$$= I\sqrt{R^2 + (X_L - X_C)^2}$$

$$\therefore \quad \frac{V}{I} = \sqrt{R^2 + (X_L - X_C)^2}$$

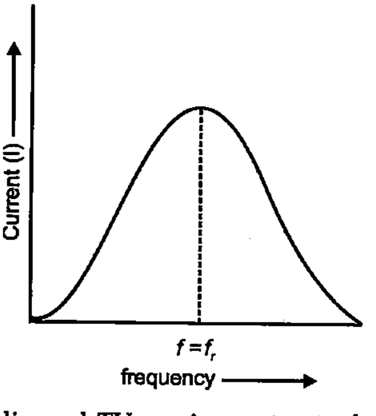
Here, V/I is the effective resistance of the series LCR circuit and is called impedance (Z).

$$\therefore \quad Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\left[\because \begin{array}{l} X_L = \omega L \\ X_C = 1/\omega C \end{array}\right]$$

The given graph shows the variation of current with the frequency of the applied voltage.



The radio and TV receiver sets are the practical applications of series resonant circuits. Signals of several different frequencies are available in air. By turning the tuning knob of the radio set, we vary the frequency of the LC circuit till it matches the frequency of the desired signal.

●●

Physics 2011 (Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

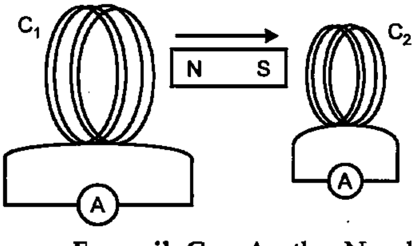
2. The susceptibility of magnetic material is 1.9×10^{-5}. Name the type of magnetic materials it represents. [1]

Answer : Paramagnetic substance because susceptibility of para-magnetic material is positive.

4. A plane electromagnetic wave travels in vacuum along X-direction. What can you say about the direction of electric and magnetic field vectors ? [1]

Answer : The electric and magnetic field vectors are in YZ-plane.

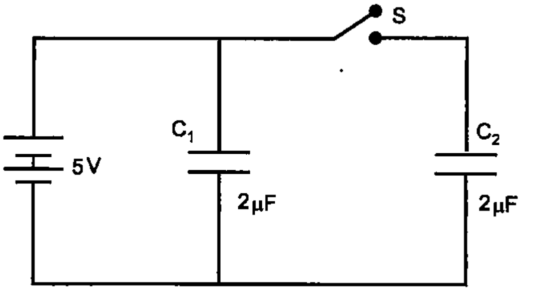
10. A magnet is quickly moved in the direction indicated by an arrow between coils C_1 and C_2 as shown in figure. What will be the direction of induced current in each coil as seen from the magnet ? Justify your answer. [2]



Answer : For coil C_1 : As the N-pole of the magnet is moving away from the coil C_1, the end of the coil will behave as S-pole so as to oppose the motion of the magnet. Therefore, looking from the end, the current in the coil C_1 will be in clockwise direction.

For coil C_2 : The end of the coil should behave as S-pole so as to repel the approaching magnet. Looking from the end, the direction of current in the coil of C_2 will be in clockwise direction.

11. Figure shows two identical capacitors C_1 and C_2 each of 2 μF capacitance, connected to a battery of 5 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant k = 5 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ? [2]



Answer : When switch S is closed :

p.d. across C_1 = p.d. across C_2

i.e. $V_1 = V_2 = 5\text{ V}$

Charge on each capacitor is same

i.e., $Q = CV$

$= 2\ \mu F \times 5\text{ V} = 10\ \mu C$

When dielectric slab is inserted between plates of capacitors,

$C_1 = C_2 = C' = KC = 5 \times 2\ \mu F = 10\ \mu F$

When switch S is open :

For C_1, battery is still connected

$\therefore$ $Q_1 = C'V_1 = 10\ \mu F \times 5\text{ V} = 50\ \mu C$

For C_2, charge remains the same

$Q_2 = C'V_2$

$10\ \mu C = 10\ \mu F \times V_2$

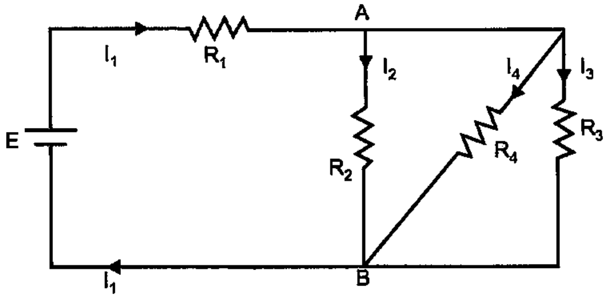
$\therefore$ $V_2 = 1$ volt

16. How is forward biasing different from reverse biasing in a *p-n* junction diode ? [2]

Answer : Forward Biasing : The positive terminal of the external battery is connected to *p*-side and negative terminal of battery to *n*-side of *p-n* junction. The forward bias voltage oppose the potential barrier. Due to this, the potential barrier is reduced and hence the depletion becomes thin. The resistance of *p-n* region junction decreases.

Reverse biasing : The negative terminal of the external battery is connected to *p*-side and positive terminal of battery to *n*-side of *p-n* junction. The reverse bias voltage supports the potential barrier. Due to this, the potential barrier is increased. The resistance of *p-n* junction becomes high.

20. In the circuit shown, $R_1 = 4\Omega$, $R_2 = R_3 = 5\Omega$, $R_4 = 10\Omega$, and E = 6 V. Work out the equivalent resistance of the circuit and the current in each resistor. [3]



Answer : R_2, R_3, R_4 are in parallel.

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{5} + \frac{1}{5} + \frac{1}{10} = \frac{2+2+1}{10}$$

$$= \frac{5}{10} = \frac{1}{2}$$

$\therefore$ $R_{234} = 2\ \Omega$

R_{234} and R_1 are in series.

$\therefore$ $R_{1234} = 2 + 4 = 6\ \Omega$

$\therefore$ $I = \frac{V}{R} = \frac{6}{6}$

$I = 1$ A

23. An electron and a photon each have a wavelength of 1.50 nm. Find :
(i) their momenta
(ii) the energy of the photon
(iii) the kinetic energy of the electron [3]

Answer :

(i) For each electron or photon, momenta,

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{1.5 \times 10^{-9}}$$

$$= 4.42 \times 10^{-25} \text{ kg m/sec}$$

(ii) $$E = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})\text{eV}}{(1.5 \times 10^{-9})(1.6 \times 10^{-19})}$$

$$= 828.75 \text{ eV}$$

(iii) $$E_k = \frac{1}{2}\frac{p^2}{m}$$

$$= \frac{1(4.42 \times 10^{-25})^2}{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19}} \text{eV}$$

$$= 0.671 \text{ eV}$$

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Physics 2011 (Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

2. A plane electromagnetic wave travels in vacuum along Y-direction. What can you say about the direction of electric and magnetic field vectors ? [1]

Answer : For an electromagnetic wave propagating along Y-direction, the electric and magnetic field vectors vary sinusoidally along X-direction and Z-direction respectively.

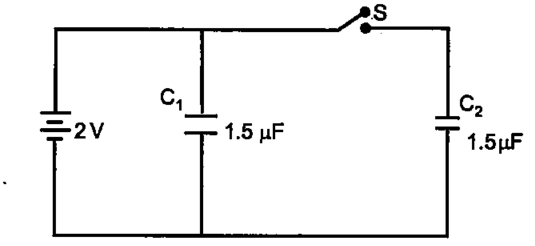
7. The susceptibility of a magnetic material is -4.2×10^{-6}. Name the type of magnetic materials it represents. [1]

Answer : Diamagnetic substance.

9. Explain how a depletion region is formed in a junction diode. [2]

Answer : With the formation of *p-n* junction, the holes from *p*-region diffuse into the *n*-region and electrons from *n*-region diffuse into the *p*-region and electron-hole pair combine and get annihilated. This in turn, produces potential barrier across the junction which opposes the further diffusion through the junction. Thus, a small region is formed which is depleted of free charge carriers and has only immobile ions. This region is called depletion region.

14. Figure shows two identical capacitors C_1 and C_2 each of 1.5 μF capacitance, connected to a battery of 2 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant K=2 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ? [2]



Answer : When switch S is closed :

p.d. across C_1 = p.d. across C_2

i.e., $V_1 = V_2 = 2\text{ V}$

Charge on each capacitor

$$= C \times V$$

$$= 1.5\ \mu F \times 2\ V = 3\ \mu C$$

When dielectric slab is inserted between plates of capacitor,

$$C_1' = C_2' = C' = KC = 1.5\ \mu F \times 2 = 3\ \mu F$$

When switch S is open :

Battery is still connected to C_1

$\therefore$ $Q_1 = C'V_1 = 3\ \mu F \times 2 = 6\ \mu C$

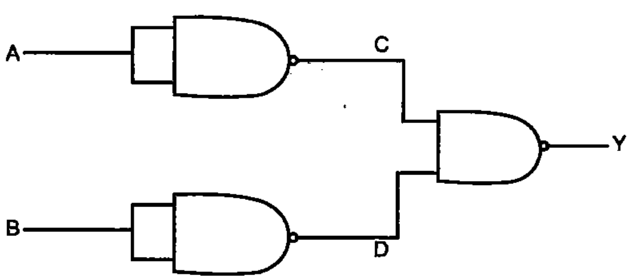
For C_2, charge remain constant

$$Q_2 = C'V_2$$

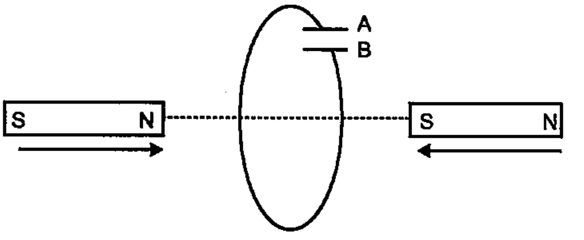
$$3\ \mu C = 3\ \mu F \times V_2$$

$$V_2 = 1\text{ volt}$$

16. Write the truth table for the logic circuit shown below and identify the logic operation by this circuit.**

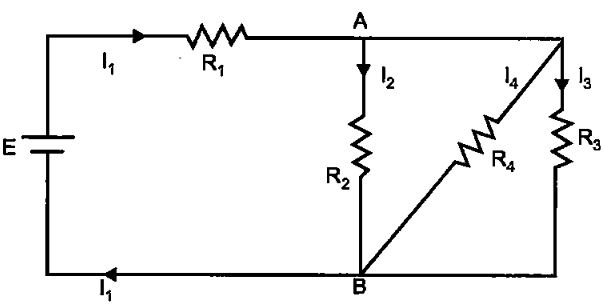


17. Predict the polarity of the capacitor when the two magnets are quickly moved in the directions marked by arrows. [2]



Answer : In the situation shown, A will become positive with respect to B, as current induced is in clockwise direction.

23. In the circuit shown, $R_1 = 2\ \Omega$, $R_2 = R_3 = 10\ \Omega$, $R_4 = 20\ \Omega$, and E = 6 V. Work out the equivalent resistance of the circuit and the current in each resistor. [3]



Answer :

R_2, R_3 and R_4 are in parallel combination

$$\therefore \quad \frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{10} + \frac{1}{10} + \frac{1}{20}$$

$$= \frac{2+2+1}{20} = \frac{5}{20}$$

$$R_{234} = 4\ \Omega$$

R_{234} and R_1 are in series combination

$$R = R_{1234} = R_{234} + R_1$$

$$R = 4 + 2 = 6\ \Omega$$

$$I = \frac{V}{R} = \frac{6}{6}$$

$$\therefore \quad I = 1\text{ A}$$

**Answer is not given due to the change in present syllabus.

25. An electron and a photon each have a wavelength of 2 nm. Find :

(i) their momenta

(ii) the energy of photon

(iii) the kinetic energy of the electron **[3]**

Answer.

(i) For each electron or photon, momenta,

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{2 \times 10^{-9}}$$

$$= 3.315 \times 10^{-25}\, kg\ \text{m/sec}$$

(ii)

$$E = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})\ \text{eV}}{(2 \times 10^{-9})(1.6 \times 10^{-19})}$$

$$= 621.6\ \text{eV}$$

(iii)

$$E_k = \frac{1}{2}\frac{p^2}{m}$$

$$= \frac{1(3.315 \times 10^{-25})^2\ \text{eV}}{2(9 \times 10^{-31})(1.6 \times 10^{-19})}$$

$$= 0.3816\ \text{eV}.$$

●●

Physics 2012 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. **Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker ?** **[1]**

Answer : Since the resistivity of alloy is greater than the resistivity of its constituents. We have resistivity of manganin greater than resistivity of copper metal.

So, resistance, $R = \rho \frac{l}{A}$

Where l is length and A is area of cross-section of material. Also ρ is the resistivity of the material.

For copper, $R_{Cu} = \rho_{cu} \frac{l_{Cu}}{A_{Cu}}$

and for magnanin, $R_M = \rho_M \frac{l_M}{A_M}$

We have $\rho_M > \rho_{Cu}$

or $\frac{\rho_M}{\rho_{Cu}} > 1$

As $l_{Cu} = l_M$

On Dividing $\frac{R_{Cu}}{R_M} = \frac{\rho_{Cu} A_M}{\rho_M A_{Cu}}$

Again $R_{Cu} = R_M$

$\therefore$ $\rho_{Cu} A_M = \rho_M A_{Cu}$

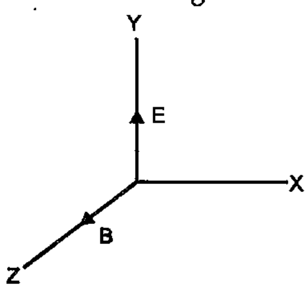
$\frac{\rho_M}{\rho_{Cu}} = \frac{A_M}{A_{Cu}} > 1$

Hence, $A_M > A_{Cu}$.

$\Rightarrow$ Manganin wire is thicker.

2. **What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves ?** **[1]**

Answer : Since electromagnetic waves are transverse in nature. We have electric and magnetic fields associated with an electromagnetic wave perpendicular to each other and perpendicular to the direction of propagation of electromagnetic waves.



Let the direction of electric field and magnetic field is along Y and Z-axis then the direction of propagation of EM waves will be along positive X-axis.

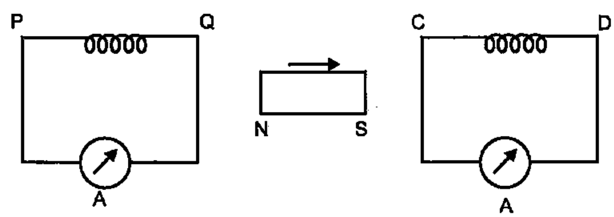
3. **How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled ?** **[1]**

Answer : We know angular separation is given as

$$\theta = \frac{\beta}{D} = \frac{\frac{D\lambda}{d}}{D} = \frac{\lambda}{d}$$

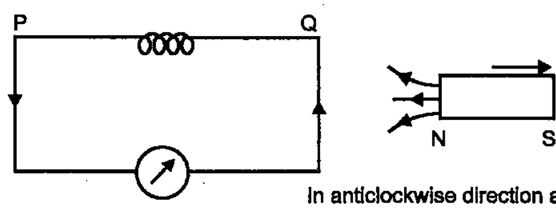
Since θ is independent of D *i.e.*, the distance of separation between the screen and the slit, so when D is doubled, angular separation would remain same.

4. **A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the directions of induced current in each coil.** **[1]**



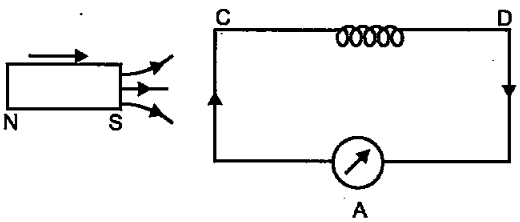
Answer : According to Lenz's, law the polarity of the induced emf is such that it opposes the change in magnetic flux responsible for its production.

Since, North pole of bar magnet is receding away from the coil so the right end of the coil will develop South pole *i.e.*, induced current as seen from the left end will be anticlockwise.



In anticlockwise direction as seen from left

Again, since South pole is pushing towards the second coil so the left end of the coil will develop South pole in order to repel it and decrease the flux *i.e.*, induced current as seen from the left end will be clockwise.



In clockwise direction as seen from left

5. For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum ? [1]

Answer : As light travels from a rarer to denser medium it bends towards the normal as its speed decreases. So, if the bending is more, the speed of the light would be less in that medium, compared to other media. As the angle of refraction is measured with respect to the normal, the ray making the least angle of refraction would bend more and the speed of light would be minimum in that case. So, the correct option is medium A where refracting angle is 15°.

6. A proton and an electron have same kinetic energy. Which one has greater de-Broglie wavelength and why ? [1]

Answer : Since de-Broglie wavelength λ in terms of kinetic energy is given as

$$\lambda = \frac{h}{\sqrt{2mE_k}}$$

Where, E_k is kinetic energy, m is mass of electron and h is the Planck's constant.

Thus, for electron and proton with same kinetic energy, de-Broglie wavelength would depend on mass.

Since $\qquad \lambda \propto \frac{1}{\sqrt{m}}$

As $\qquad m_p > m_e$

$\Rightarrow \qquad \lambda_e > \lambda_p.$

Hence, wavelength of electron is greater than wavelength of proton.

7. Mention the two characteristic properties of the material suitable for making core of a transformer. [1]

Answer : Two characteristic properties of material :

(i) Low hysteresis loss.

(ii) Low coercivity.

8. A charge 'q' is placed at the centre of a cube of side l. What is the electric flux passing through each face of the cube ? [1]

Answer : By using Gauss's law,

$$\phi = \oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$$

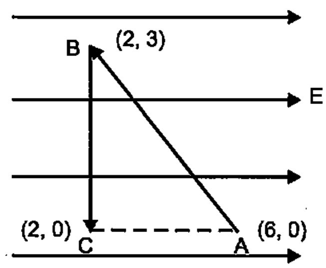
Now, the flux passing through all the six faces would be

$$\phi = 6\phi = \frac{q}{\varepsilon_0}$$

And the flux passing through each face would be

$$\phi = \frac{q}{6\varepsilon_0}$$

9. A test charge 'q' is moved without acceleration from A to C along the path from A to B and then from B to C in electric field E as shown in the figure. (i) Calculate the potential difference between A and C. (ii) At which point (of the two) is the electric potential more and why ? [2]



Answer : (i) Since work done is independent of the path therefore, we may directly move from A to C.

Potential difference between A and C is given by,

$$V_C - V_A = -\int_A^C \vec{E} \cdot \vec{dl}$$

negative sign is due to the work done against electric field

$$= -\int_A^C E \cdot dl \cos 180°$$

$$= -E(-1)\int_A^C dl$$

$$= E \times 4$$

$$= 4\,E$$

So, $\qquad V_C - V_A = 4\,E$

(ii) Electric potential will be more at point C as direction of electric field is in decreasing potential.

Hence,

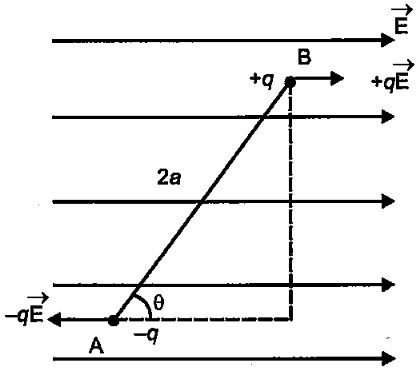
$$V_C > V_A.$$

10. An electric dipole is held in a uniform electric field. [2]

(i) Show that the net force acting on it is zero.

(ii) The dipole is aligned parallel to the field. Find the work done in rotating it through the angle of 180°.

Answer : (i) Consider an electric dipole consisting of two equal and opposite point charges, $-q$ at A and $+q$ at B, separated by a small distance $2a$.



Dipole moment of a dipole is given by,

$$|\vec{p}| = q(2a)$$

Let this dipole be held in a uniform external electric field $\vec{E}$ at an angle θ with the direction of $\vec{E}$.

Force on charge $-q$ at A = $-q\vec{E}$, in a direction opposite to $\vec{E}$. Force on charge $+q$ at B = $+q\vec{E}$, along the direction to $\vec{E}$.

Net force on the dipole $= q\vec{E} - q\vec{E} = 0$

(ii) Work done on dipole, $W = \Delta U = pE(\cos\theta_1 - \cos\theta_2)$

$$W = pE(\cos 0^\circ - \cos 180^\circ)$$

$$W = 2pE.$$

11. State the underlying principle of a transformer. How is the large scale transmission of electric energy over long distances done with the use of transformers ? [2]

Answer : Transformer is a device which converts high voltage AC into low voltage AC and vice-versa. It is based on the principle of mutual induction. When alternating current is passed through a coil, an induced emf is set up in the neighbouring coil.

Transformers are used for transmission of electrical energy over long distances.

It step up the output voltage of power plant using step up transformer which reduces the current and inereases the Voltage and hence reduces resistive power loss. Then a step down transformer is used at consumer end to step down the voltage and to increases the current.

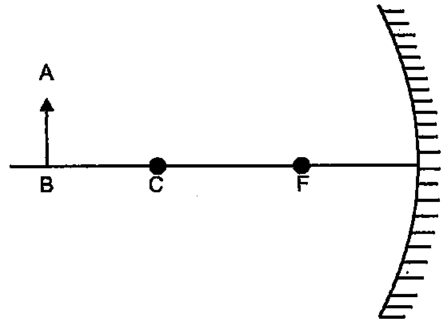
12. A capacitor of capacitance 'C' is being charged by connecting it across a dc source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging ? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit ? Write the expression for the current inside the capacitor. [2]

Answer : Yes, the ammeter shows a momentary deflection during the process of charging because during charging, conduction current flows through the wires which leads to deposition of charges on the plates of capacitor. This produce an electric field of increasing magnitude, which in turn, produces a displacement currents between the plates and this displacement current maintains the continuity of current in the circuit.

Current inside the capacitor,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

13. An object AB is kept in front of a concave mirror as shown in the figure. [2]



(i) Complete the ray diagram showing the image formation of the object.

(ii) How will the position and intensity of the image be affected if the lower half of the mirror's reflecting surface is painted black ?

Answer : (i)

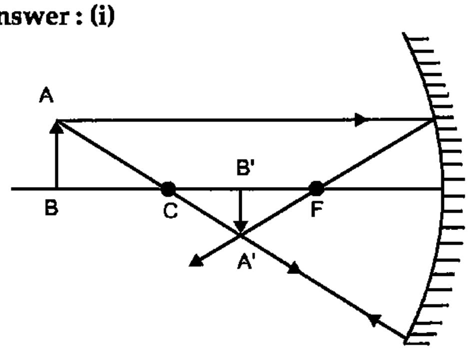
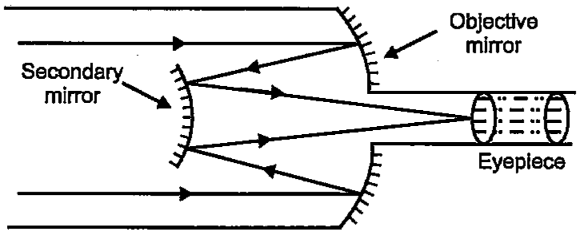


Image formed will real and inverted, between focus and center of curvature and small in size.

(ii) If the lower half of the mirror's reflecting surface is painted black, the position of image will be same but its intensity gets reduced.

14. Draw a labelled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope. [2]

Answer : Reflecting Telescope :



Advantages over refracting telescope :

1. There is no chromatic aberration in reflecting telescope.
2. The resolving power of a large aperture mirror is high and hence minute details of distant stars can be obtained.

15. Describe briefly with the help of a circuit diagram, how the flow of current carriers in a *p-n-p* transistor is regulated with emitter-base junction forward biased and base-collector junction reverse biased. [2]**

16. In the given block diagram of a receiver, identify the boxes labelled as X and Y and write their functions. [2]**

17. A light bulb is rated 100 W for 220 V ac supply of 50 Hz. Calculate : [2]

(i) The resistance of the bulb;

(ii) The rms current through the bulb.

OR

An alternative voltage given by V = 140 sin 314*t* is connected across a pure resistor of 50 Ω. Find

(i) the frequency of the source.

(ii) the rms current through the resistor.

Answer : $P = 100$ W and $V_{rms} = 220$ V, $f = 50$ Hz

(i) Resistance, $R = \frac{V_{rms}^2}{P} = \frac{220 \times 220}{100} = 848\ \Omega$

(ii) $P = I_{rms} \times V_{rms}$

$$I_{rms} = \frac{P}{V_{rms}} = \frac{100}{220} = 0.45 \text{ A}$$

OR

Given, $V = 140 \sin 314t$, $R = 50\ \Omega$

(i) Comparing with $V = V_0 \sin \omega t$

Thus, $V_0 = 140$ V

And, $\omega = 314$

$$2\pi v = 314$$

$$v = \frac{314}{2 \times 3.14} = 50 \text{ Hz}$$

(ii) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{140}{\sqrt{2}} = 98.99$ V

$$I_{rms} = \frac{V_{rms}}{R} = \frac{98.99}{50} = 1.97 \text{ A}$$

****Answers is not given due to change in the present syllabus.**

18. A circular coil of 'N' turns and radius 'R' carries a current 'I'. It is unwound and rewound to make another coil of radius 'R/2', current 'I' remaining the same. Calculate the ratio of the magnetic moments of the new coil and original coil. [2]

Answer : The magnetic moment m of a current, carrying loop,

$$m = NIA$$

Where, N = number of turns.

Let m_1 and m_2 be the magnetic moments of circular original coil of radius 'R' and new coil of radius 'R/2'.

Length of wire remains same. Thus,

$$N(2\pi r) = N'\left(2\pi\left(\frac{R}{2}\right)\right)$$

$$N' = 2N$$

Now, $m_1 = NIA_1 = NI\pi R^2$

$$m_2 = N'IA_2 = 2NI\left[\pi\left(\frac{R}{2}\right)^2\right]$$

$$= \frac{1}{2} NI\pi R^2$$

$$\frac{m_2}{m_1} = \frac{\frac{1}{2}}{1} = \frac{1}{2}$$

19. Deduce the expression for the electrostatic energy stored in a capacitor of capacitance 'C' and having charge 'Q'.

How will the (i) energy stored and (ii) the electric field inside the capacitor be affected when it is completely filled with a dielectric material of dielectric constant 'K' ? [3]

Answer : Energy stored in a charged capacitor :

The energy of a charged capacitor is measured by the total work done in charging the capacitor to a given potential. We know that, Capacitance,

$$C = \frac{q}{V}.$$

Where q is the charge on the plates and V is potential difference.

When an additional amount of charge dq is transferred from negative to positive plate, the small work done is given by

$$dW = V dq = \frac{q}{C} dq$$

The total work done in transferring total charge Q is given by

$$W = \int_0^Q \frac{q}{C} dq = \frac{1}{C}\int_0^Q q\,dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{C}\left[\frac{Q^2}{2} - 0\right]$$

$$\frac{Q^2}{2C}$$

This work is stored as electrostatic potential energy U in the capacitor.

$\therefore \quad U = \frac{Q^2}{2C}$

or $\quad U = \frac{(CV)^2}{2C} \quad [\because Q = CV]$

or $\quad U = \frac{1}{2}CV^2$

or $\quad U = \frac{1}{2}QV$

When dielectric material of dielectric constant 'K' is introduced inside the capacitor :

(i) $\quad V_0 = E_0 d \quad$ ...(i)

Where V_0 is the potential when there is vacuum between the plates of the capacitor and d is the separation between the plates of the capacitor.

When dielectric is introduced, potential difference is given by

$V = Ed \quad$ ...(2)

Dividing equations (i) and (ii)

$$\frac{V_0}{V} = \frac{E_0}{E} = K$$

But $\quad K > 1$

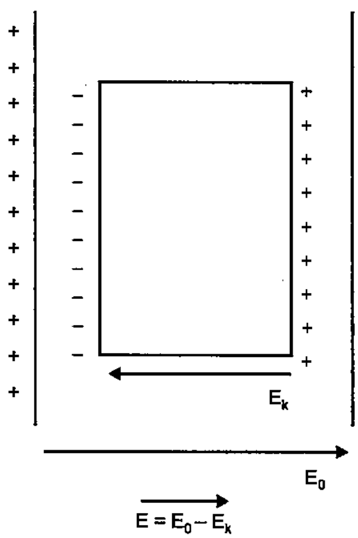
$\therefore \quad V_0 > V$

Thus, potential difference also decreases.

We have energy stored as $U = \frac{1}{2}QV$

Since V decreases, U also decreases.

(ii)

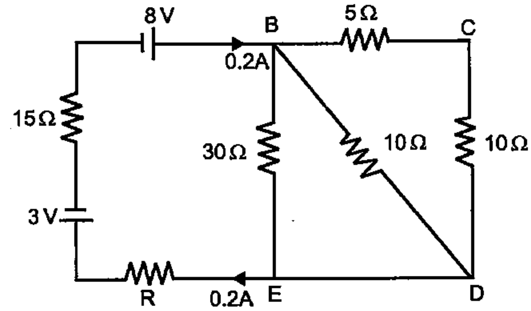


But $\quad K > 1 \; \frac{E_0}{E} = K$

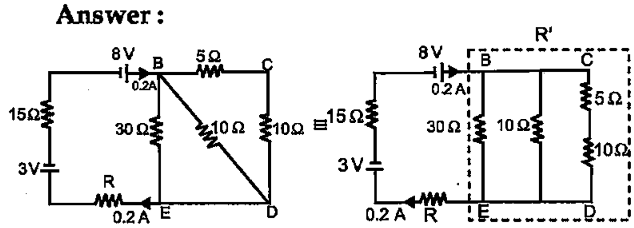
So, $\quad \frac{E_0}{E} > 1$ or $E_0 > E$

Thus, electric field is reduced.

20. Calculate the value of the resistance R in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points B and E ? [3]



Answer :

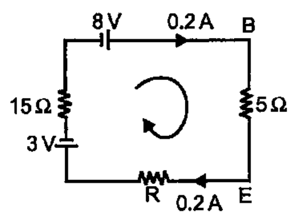


Equivalent resistance R' is given by

$$\frac{1}{R'} = \frac{1}{30} + \frac{1}{10} + \frac{1}{10+5}$$

$$= \frac{1}{30} + \frac{1}{10} + \frac{1}{15} = \frac{6}{30}$$

$\Rightarrow \quad R' = 5\,\Omega$



On applying Kirchhoff's second law, we get

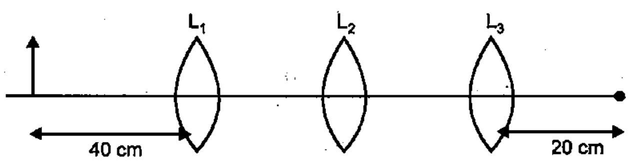
$\Rightarrow 5(0.2) + R(0.2) + 15(0.2) = 8 - 3$

$\Rightarrow$ and $\quad R = 5\,\Omega$

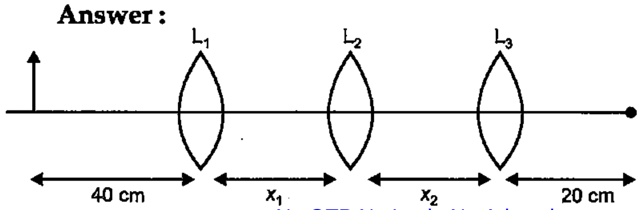
$V_{BE} = 5(0.2) = 1$ V

$[\because R_{BE} = R' = 5\,\Omega]$

21. You are given three lenses L_1, L_2 and L_3 each of focal length 20 cm. An object is kept at 40 cm in front of L_1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separations between L_1, L_2 and L_3. [3]



Answer :



Here, $f_1 = f_2 = f_3 = 20$ cm

Now, $u_1 = -40$ cm

For lens L_1, from Lens Makers formula,

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$

$$\frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1}$$

$$= \frac{1}{20} + \frac{1}{40}$$

$$= \frac{2-1}{40} = \frac{1}{40}$$

$$v_1 = 40 \text{ cm}$$

For lens L_3

$f_3 = 20$ cm, $v_3 = 20$ cm, $u_3 = ?$

By lens formula,

$$\frac{1}{v_3} - \frac{1}{u_3} = \frac{1}{f_3}$$

$$\Rightarrow \quad \frac{1}{20} - \frac{1}{u_3} = \frac{1}{20}$$

$$\Rightarrow \quad \frac{1}{u_3} = 0 \Rightarrow u_3 = \infty$$

Thus lens L_2 should produce image at infinity. Hence, for L_2, its object should be at focus.

But we have seen above that image by L_1 is formed at 40 cm on the right of L_1 which is at 20 cm left of L_2 (focus of L_2).

So, X_1 = distance between L_1 and L_2 = (40 + 20) cm = 60 cm

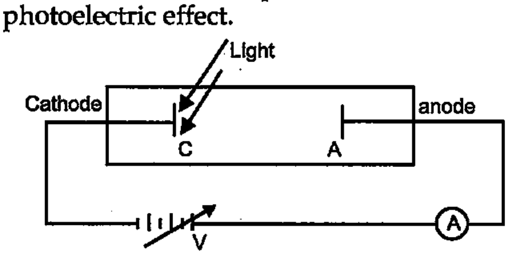
Again distance between L_2 and L_3 does not matter as the image by L_2 is formed at infinity.

Hence, the distance between L_2 and L_3 can have any value.

22. Define the terms (i) 'cut-off voltage' and (ii) 'threshold frequency' in relation to the phenomenon of photoelectric effect.

Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of a suitable plot/graph. **[3]**

Answer : When light of suitable frequency is incident on a metal surface, electrons are ejected from the metal. This phenomenon is called the photoelectric effect.



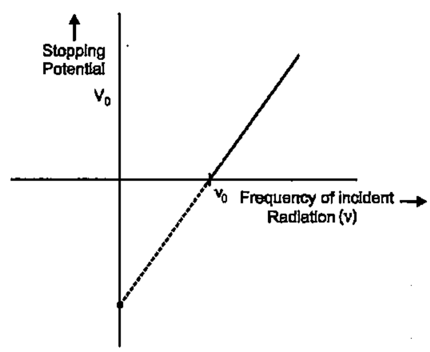
(i) The cathode is illuminated with light of some fixed frequency v and fixed intensity I_1. A small photoelectric current is observed due to few electrons that reach anode just because they have sufficiently large velocity of emission. If we make the potential of the anode negative with respect to cathode then the electrons emitted by cathode are repelled. Some electrons even go back to the cathode so that the current decreases. At a certain value of this negative potential, the current is completely stopped. The least value of this anode potential which just stops the photocurrent is called cut off potential or stopping potential.

(ii) For a given material, there is a certain minimum frequency that if the incident radiation has a frequency below this threshold, no photoelectric emission will take place, howsoever intense the radiation may be falling. This minimum frequency is called threshold frequency.

According to Einstein's photoelectric equation, maximum K.E. is given as

$$K.E_{max} = \frac{hc}{\lambda} - \phi = hv - \phi$$

Where λ is wavelength of light and ν is corresponding frequency and ϕ is work function. We expose a material to lights of various frequencies and thus photoelectric current is observed and cut off potential needed to reduce this current to zero is noted. A graph is plotted and that is straight line.



According to Einstein's photoelectric equation

$$K.E_{max} = \frac{hc}{\lambda} - \phi = h\nu - \phi$$

$$K.E_{max} = eV_0$$

$$\therefore \quad eV_0 = h\nu - \phi$$

$$V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi}{e} \quad \text{...(i)}$$

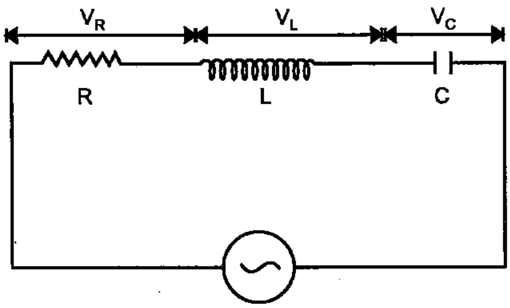
We can read the value of threshold frequency from graph.

From equation (i), we can find the value of stopping potential (V_0).

23. A series LCR circuit is connected to an ac source. Using the phasor diagram, derive the expression

for the impedance of the circuit. Plot a graph to show the variation of current with frequency of the source, explaining the nature of its variation. **[3]**

Answer : Let an alternating emf $E = E_0 \sin \omega t$ is applied to a series combination of inductor L, capacitor C and resistance R. Since all three of them are connected in series the current through them is same. But the voltage across each element has a different phase relation with current.



LCR Circuit

The potential difference V_L, V_C and V_R across L, C and R at any instant is given by

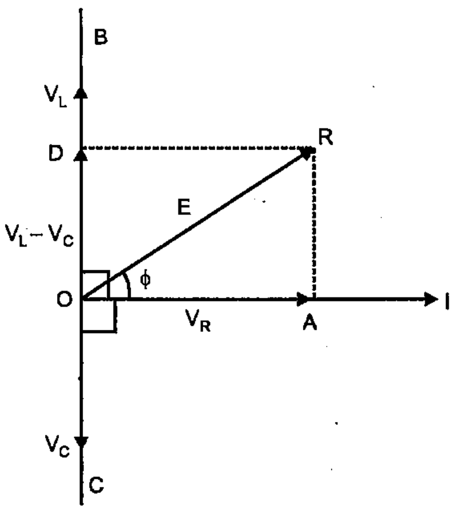
$$V_L = IX_L,\ V_C = IX_C \text{ and } V_R = IR$$

Where I is the current at that instant.

X_L is inductive reactance and

X_C is capacitive reactance.

V_R is in phase with I, V_L leads I by 90° and V_C lags behind I by 90°.



In the phasor diagram,

V_L and V_C are opposite to each other. If $V_L > V_C$ then resultant $(V_L - V_C)$ is represented by OD. OR represent the resultant of V_R and $(V_L - V_C)$. It is equal to the applied emf E.

$$E^2 = V_R^2 + (V_L - V_C)^2$$

$$E^2 = I^2\left[R^2 + (X_L - X_C)^2\right]$$

or
$$I = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}}$$

The term $\sqrt{R^2 + (X_L - X_C)^2}$ is called impedance Z of the LCR circuit.

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$$

Emf leads current by a phase angle ϕ, which is given by

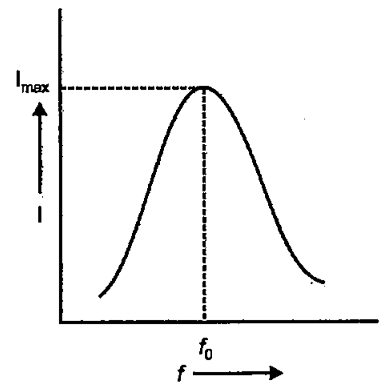
$$\tan \phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} = \frac{L\omega - \frac{1}{C\omega}}{R}$$

When resonance takes place, $X_L = X_C$

or
$$\omega L = \frac{1}{\omega C}$$

At resonance, impedance of circuit becomes equal to R. Current becomes maximum and is equal to $\frac{E}{R}$

The graph of variation of peak current I_{max} with frequency is shown below :



$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

With increase in frequency, current first increases and then decreases. At resonant frequency, the current amplitude is maximum.

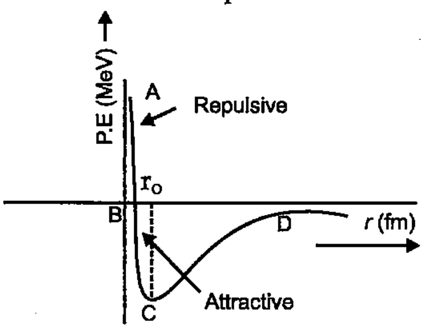
24. Mention three different modes of propagation used in communication system. Explain with the help of a diagram how long distance communication can be achieved by ionospheric reflection of radiowaves.** **[3]**

25. Draw a plot of potential energy of a pair of nucleons as a functions of their separations. Mark the regions where the nuclear force is

**Answers is not given due to change in the present syllabus.

(i) attractive and (ii) repulsive. Write any two characteristic features of nuclear forces. [3]

Answer : Potential energy of a pair of nucleons as a function of their separation :



Here, Part AB represents repulsive force and part BCD represents attractive force.

r_0 is the distance at which potential energy is minimum.

Characteristic features of nuclear forces are :

(i) Nuclear forces are much stronger then Coulomb forces acting between charges or the gravitational forces between masses.

(ii) The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

26. In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of Z = 80, when α-particle of 8 MeV energy impinges on it before it comes momentarily to rest and reverses its direction.

How will the distance of closest approach be affected when the kinetic energy of the α-particle is doubled ? [3]

OR

The ground state energy of hydrogen atom is –13.6 eV. If an electron makes a transition from an energy level –0.85 eV to –3.4 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does the wavelength belong ?

Answer : Let r_0 be the centre to centre distance between the alpha-particle and nucleus.

Given, $Z = 80, E_k = 8$ MeV

Now, $$E_k = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r_0}$$

or $$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{E_k}$$

$$= \frac{9\times10^9\times80\times2(1.6\times10^{-19})^2}{8\times10^6\times1.6\times10^{-19}}$$

$$= \frac{18\times10\times10^9\times1.6\times10^{-19}}{8\times10^6}$$

$$= 2.88\times10^{-14}\text{ m}$$

$$= 28.8\text{ fm}$$

Since, $r_0 \propto \frac{1}{E_k}$

So when kinetic energy is doubled the distance of closest approach r_0 is halved.

OR

We know that, $E_n = -\frac{13.6}{n^2}$eV

Here, ground state energy for $n = 1$,

$$E_1 = -13.6\text{ eV}$$

Now, electron transist from $Ep = -0.85$ eV to $Eq = -3.4$ eV

$$-0.85 = \frac{-13.6}{n_p^2}$$

$$n_p^2 = \frac{13.6}{0.85} = 16$$

Thus, $n_p = 4$

Again, $$-3.4 = \frac{-13.6}{n_q^2}$$

$$n_q^2 = \frac{13.6}{3.4} = 4$$

$\Rightarrow$ $n_q = 2$

Thus, electron makes transition from $n = 4$ to $n = 2$. Hence, it is Balmer series. Now, $R = 1.0974\times10^7\text{m}^{-1}$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_q^2}-\frac{1}{n_p^2}\right)$$

$$\frac{1}{\lambda} = 1.0974\times10^7\left(\frac{1}{2^2}-\frac{1}{4^2}\right) = \frac{1.0974\times10^7\times12}{4\times16}$$

$$\frac{1}{\lambda} = 0.2057\times10^7$$

$$\lambda = 4.861\times10^{-7}\text{ m}$$

$$\lambda = 4861\text{ Å}.$$

27. Define relaxation time of the free electrons drifting in a conductor. How is it related to the drift velocity of free electrons ? Use this relation to deduce the expression for the electrical resistivity of the material. [3]

Answer : Relaxation time (τ) is the time for which a free electron accelerates before it undergoes a collision with the positive ion in the conductor.

Or, we can say it is the average time elapsed between two successive collisions. It is of the order 10^{-14} seconds. It decreases with increase of temperature and is given as

$$\vec{v}_d = \vec{a}\tau$$

or $$\vec{v}_d = -\frac{eE}{m}\tau$$

$$\left[\because \vec{a} = \frac{-e\vec{E}}{m}\right]$$

Where $\vec{v}_d$ is the drift velocity, E is the applied electric field. e and m are the charge and mass of electron respectively.

Again consider a conductor with length l and A as area of cross-section. Let n be the number of electrons per unit volume in the conductor.

We know, $$v_d = -\frac{eE}{m}\tau$$

Magnitude of drift velocity

And, the current flowing through the conductor due to drift of electron is given by,

$$I = neAv_d$$

Substituting value of v_d

$$I = nA\left(\frac{eE\tau}{m}\right)e$$

$$I = \frac{nAe^2E\tau}{m}$$

If V is potential difference applied across the two ends then

$$E = \frac{V}{l}$$

So, $$I = \frac{nAe^2V\tau}{ml}$$

$$\frac{V}{I} = \frac{m}{ne^2\tau}\cdot\frac{l}{A}$$

Now, according to Ohm's law $\frac{V}{I}$ = R(Resistance of conductor)

Thus,

$$R = \frac{ml}{ne^2\tau A} = \frac{m}{me^2\tau}\frac{l}{A}$$

Comparing this with formula of resistance,

$$R = \rho\cdot\frac{l}{A}$$

Where ρ is the resistivity of the material.

We get, $$\rho = \frac{m}{ne^2\tau}$$

28. (a) In Young's double slit experiment, derive the condition for

(i) constructive interference and

(ii) destructive interference at a point on the screen.

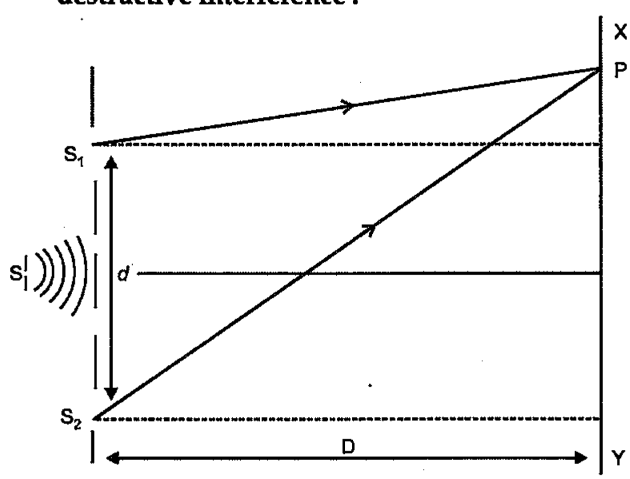
(b) A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide. [5]

OR

(a) How does an unpolarized light incident on a polaroid get polarized ? Describe briefly, with the help of a necessary diagram, the polarization of light by reflection from a transparent medium.

(b) Two polaroids 'A' and 'B' are kept in crossed position. How should a third polaroid 'C' be placed between them so that the intensity of polarized light transmitted by polaroid B reduces to 1/8th of the intensity of unpolarized light incident on A ?

Answer : (a) Condition of constructive and destructive interference :



In the given figure, S is a monochromatic source of light. S_1 and S_2 are two narrow pin holes equidistant from S and they act as coherent sources. Consider a point P on the screen XY placed parallel to S_1 and S_2.

Let a_1 be the amplitude of the waves from S_1 and a_2 is from S_2. Let ϕ be the phase difference between the two waves reaching the point P. Let y_1 and y_2 be the displacements of the two waves, arriving at P.

$$y_1 = a_1 \sin \omega t \quad ...(1)$$

$$y_2 = a_2 \sin (\omega t + \phi) \quad ...(2)$$

By the principle of superposition, the resultant displacement of the two waves at P is

$$y = y_1 + y_2 = a_1 \sin\omega t + a_2 \sin (\omega t + \phi)$$

$$y = a_1 \sin \omega t + a_2 \sin \omega t \cos \phi + a \cos \omega t \sin \phi$$

$$= \sin \omega t (a_1 + a_2 \cos \phi) + \cos \omega t (a_2 \sin \phi) \quad ...(3)$$

$$a_1 + a_2 \cos \phi = A \cos \theta \quad ...(4)$$

$$a_2 \sin \phi = A \sin \theta \quad ...(5)$$

Substituting in equation (3),

$$y = \sin \omega t\, A \cos \theta + \cos \omega t\, A \sin \theta$$

$$= A \sin (\omega t + \theta) \quad ...(6)$$

Thus, the resultant vibration is S.H.M. and the resultant amplitude is A.

Squaring and adding equation (4) and equation (5),

$$A^2 \cos^2 \theta + A^2 \sin^2 \theta = (a_1 + a_2 \cos \phi)^2 + a_2^2 \sin^2 \phi$$

$$A^2 = a_1^2 + 2a_1a_2 \cos \phi + a_2^2 \cos^2 \phi + a_2^2 \sin^2 \phi$$

$$= a_1^2 + a_2^2 + 2a_1a_2 \cos \phi$$

The amplitude of the resultant wave is A

$$A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos \phi}$$

The resultant intensity at P is given by the square of the amplitude

Intensity, $I = A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos \phi$

Clearly, the intensity of resultant wave at any point depends on the amplitude of individual waves and the phase difference between the waves at the point.

Constructive interference : For maximum intensity at any point, $\cos \phi = +1$

For phase difference ϕ

$$= 0, 2\pi, 4\pi, 6\pi \ ....$$

$$= 2n\pi \ (n = 0, 1, 2, ...)$$

The maximum intensity,

$$I_{max} = a_1^2 + a_2^2 + 2a_1a_2 = (a_1 + a_2)^2$$

Path difference, $\Delta = \dfrac{\lambda}{2\pi} \times$ Phase difference

$$= \frac{\lambda}{2\pi} \times 2n\pi$$

$$= n\lambda$$

Clearly, the maximum intensity is obtained in the region of superposition at those points where waves meet in the same phase or the phase difference between the waves is even multiple of π or path difference between them is the integral multiple of λ and maximum intensity is $(a_1 + a_2)^2$ which is greater than the sum intensities of individual waves by an amount $2a_1a_2$.

Destructive interference : For minimum intensity at any point, $\cos \phi = -1$.

for phase difference $\phi = \pi, 3\pi, 5\pi, 7\pi......$

$$= (2n - 1)\pi, n = 1, 2, 3......$$

In this case the minimum intensity,

$$I_{min} = a_1^2 + a_2^2 - 2a_1a_2 = (a_1 - a_2)^2$$

Path difference, $\Delta = \dfrac{\lambda}{2\pi} \times$ Phase difference

$$= \frac{\lambda}{2\pi} \times (2n - 1)\pi = (2n - 1)\frac{\lambda}{2}$$

Clearly, the minimum intensity is obtained in the region of superposition at those points where waves meet in opposite phase or the phase difference between the waves is odd multiple of π or path difference between the waves is odd multiple of $\dfrac{\lambda}{2}$ and minimum intensity = $(a_1 - a_2)^2$ which is less than the sum of intensities of the individual waves by an amount $2a_1a_2$.

(b) Given : $\lambda_1 = 800$ nm $= 800 \times 10^{-9}$m

$\lambda_2 = 600$ nm $= 600 \times 10^{-9}$m

$D = 1.4$ m

$d = 0.28$ mm $= 0.28 \times 10^{-3}$m

Suppose n_1^{th}, maximum corresponds to wavelength λ_1 and it coincides with n_2^{th} maximum corresponding to wavelength λ_2.

$$\therefore \quad n_1 \frac{\lambda_1 D}{d} = n_2 \frac{\lambda_2 D}{d}$$

or

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{600}{800} = \frac{3}{4}$$

Thus, 3rd maximum corresponding to wavelength 800 nm coincides with 4th maximum corresponding to wavelength 600 nm.

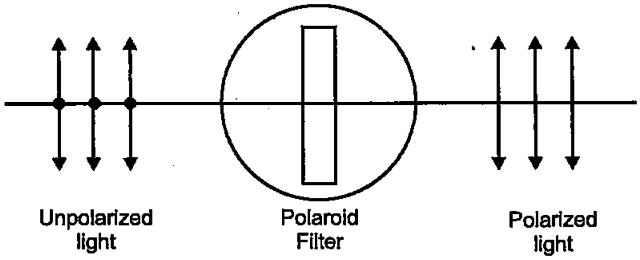
And the minimum distance is given by,

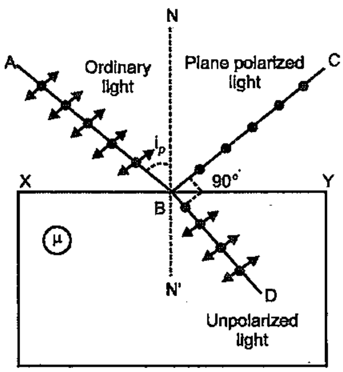
$$x_{min} = n_1 \frac{\lambda_1 D}{d} = \frac{3 \times 800 \times 10^{-9} \times 1.4}{0.28 \times 10^{-3}}$$

$$x_{min} = 12 \text{ mm}$$

OR

(a) Polaroid is made up of a special material which blocks one of the two planes of vibration of an electromagnetic wave. Because of its chemical composition, it allows only those vibrations of the electromagnetic wave which are parallel to its crystallographic axis.





An ordinary beam of light on reflection from a transparent medium becomes partially polarized. The degree of polarization increases as the angle of incidence is increased. At a particular value of angle of incidence, the reflected beam becomes completely polarized. This angle of incidence is called the polarizing angle (i_p).

(b) By Malus law, the intensity of light emerging from the middle polaroid 'C' is given by

$$I_1 = I_0 \cos^2 \theta$$

This light (intensity I_1) falls on the polaroid 'B' whose polarization axis makes an angle of (90° – θ) with the polarization axis of the polaroid 'C'. Therefore, the intensity of light emerging from 'B' is given by

$$I_2 = I_1 \cos^2 (90° - \theta) = I_0 \cos^2 \theta \cos^2 (90° - \theta)$$

$$= I_0 \cos^2\theta \sin^2\theta = \frac{2I_0}{8}$$

Where $2I_0$ is intensity of unpolarized light incident on A

$$4 \cos^2 \theta \sin^2 \theta = 1$$

$$(2 \sin \theta \cos \theta)^2 = 1$$

$$(\sin 2\theta)^2 = 1$$

$$\sin 2\theta = 1 = \sin 90°$$

$$\theta = \frac{90°}{2} = 45°$$

Thus, polaroid 'C' must be placed at an angle 45° with polaroid 'B'.

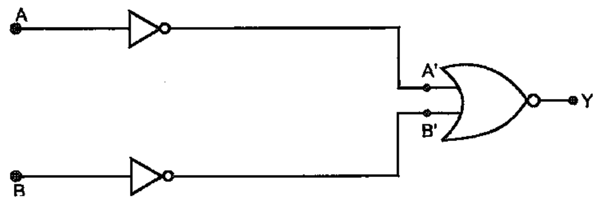
29. (a) Describe briefly, with the help of a diagram, the role of the two important processes involved in the formation of a *p-n* junction.

(b) Name the device which is used as a voltage regulator. Draw the necessary circuit diagram and explain its working. [5]

OR

(a) Explain briefly the principle on which a transistor-amplifier works as an oscillator. Draw the necessary circuit diagram and explain its working.**

(b) Identify the equivalent gate for the following circuit and write its truth table.**



Answer : (a) Two important process involved in the formation of a *p-n* junction are (i) diffusion and (ii) drift.

In *n*-type semiconductor, electrons are the majority carriers and holes are minority carriers. In the same way, in *p*-type semiconductor holes are majority and electrons are minority carriers. During the formation of *p-n* junction, due to concentration gradient, the holes diffuse from *p* side to *n* side and electrons diffuse from *n* side to *p* side. This motion gives rise to **diffusion current** across the junction.

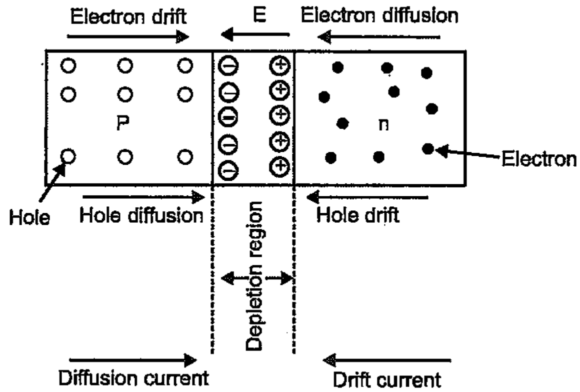
When an electron diffuses from *n* to *p* side, it leaves behind a positive charge. In such a manner a positively charged layer forms on *n*-side of the junction.

Similarly, when a hole diffuses from *p* to *n* side, it leaves behind a negative charge and a negatively charged layer forms on *p* side of the junction.

This space charge region is known as **depletion region**. An electric field directed from *n*-region to *p*-region develops across the junction. Due to this field, electrons on *p* side of the junction move to *n*-side and holes on *n* side of the junction move to *p* side. This motion of charge carriers due to the electric field is called **drift**.

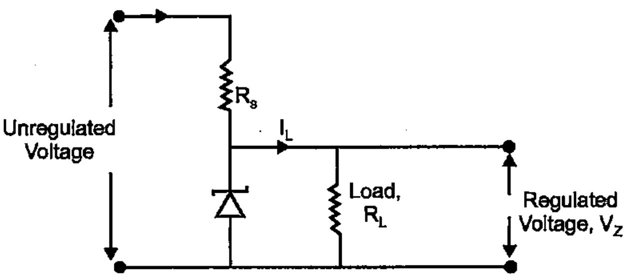
Drift current is opposite in direction to the diffusion current.

****Answers is not given due to change in the present syllabus.**



Initially, diffusion current is large and drift current is small. Space-charge region on either side increases as the diffusion process continues. This increases the electric field and hence the drift current. This process continues until the diffusion current equals the drift current.

(b) Zener diode is used as a voltage regulator.



Voltage regulator converts an unregulated dc voltage into a constant regulated dc voltage using zener diode. The unregulated voltage is connected to the zener diode through a series resistance R_S such that the zener diode is reverse biased. If the input voltage increases, the current through R_S and zener diode also increases. This increases the voltage drop across R_S without any change in voltage drop across zener diode. This is because in the breakdown region, zener voltage remain constant even though the current through zener diode changes.

Similarly, if the input voltage decreases, the current through R_S and zener diode decrease. The voltage drop across R_S decrease without any change in the voltage across the zener diode. Thus any change in input voltage results the change in voltage drop across R_S without any change in voltage across the zener diode.

30. (a) Write the expression for the force $\vec{F}$, acting on a charged particle of charge 'q', moving with a velocity $\vec{v}$ in the presence of both electric field $\vec{E}$ and magnetic field $\vec{B}$. Obtain the condition under which the particle moves undeflected through the fields.

(b) A rectangular loop of size l × b carrying a steady current I is placed in a uniform magnetic field $\vec{B}$. Prove that the torque $\vec{\tau}$ acting on the loop is given by, $\vec{\tau} = \vec{m} \times \vec{B}$ where $\vec{m}$ is the magnetic moment of the loop. [5]

OR

(a) Explain giving reasons, the basic difference in converting a galvanometer into (i) a voltmeter and (ii) an ammeter.

(b) Two long straight parallel conductors carrying steady currents I_1 and I_2 are separated by a distance 'd'. Explain briefly, with the help of a suitable diagram, how the magnetic field due to one conductor acts on the other. Hence deduce the expression for the force acting between the two conductors. Mention the nature of this force.

Answer : (a) Force acting on a charge 'q' moving with velocity $\vec{v}$ in the presence of both electric field $\vec{E}$ and magnetic field $\vec{B}$ is given by,

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

Consider a region in which magnetic field, electric field and velocity of charge particle are perpendicular to each other.

To move charge particle undeflected, the net force acting on the particle must be zero *i.e.*, the electric force must be equal and opposite to the magnetic force.

$$q\vec{E} = -q(\vec{v} \times \vec{B})$$

$$\vec{E} = -(\vec{v} \times \vec{B})$$

$$\vec{E} = \vec{B} \times \vec{v}$$

$$\vec{E} = Bv\sin\theta = Bv \quad (\because \theta = 90°)$$

$$v = \frac{E}{B}$$

The direction of electric and magnetic forces are in opposite direction. Their magnitudes are in such a way that they cancel out each other to give net force zero and so the charge particle does not deflect.

(b) When an electric current flows in closed loop of wire, placed in a uniform magnetic field, the magnetic forces produce a torque which

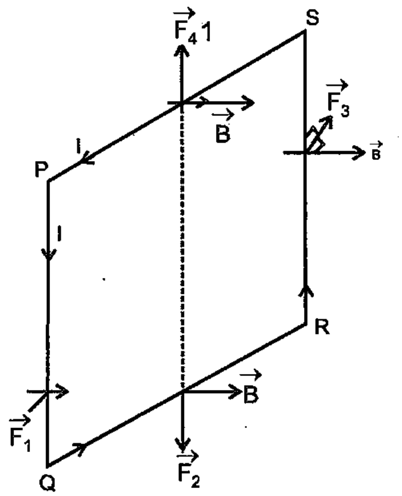


Fig. (a)

tends to rotate the loop so that area of the loop is perpendicular to the direction of the magnetic field.

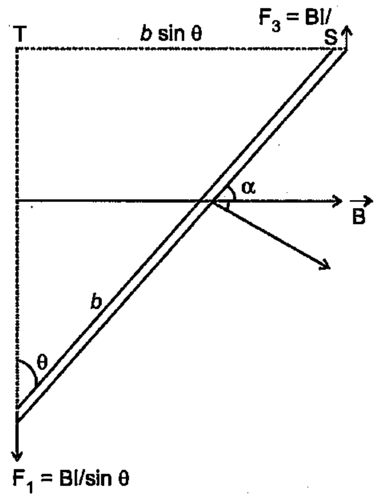


Fig. (b)

Consider a rectangular coil PQRS placed in an external magnetic field as shown in Fig (a). Let 'I' be the current flowing through the coil. Each part of the coil experiences a Lorentz force. Forces of each part is $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$ and $\vec{F}_4$ as shown. The $\vec{F}_4$ and $\vec{F}_2$ are equal in magnitude but act in opposite directions along the same straight line. Hence, they cancel out each other.

The force $\vec{F}_1 = I(\vec{PQ} \times \vec{B})$

$F_1 = IlB \quad (\because \theta = 90°)$

($\vec{F}_1$ acts in direction perpendicular to the plane of paper)

Similarly, $\vec{F}_3 = I(\vec{RS} \times \vec{B})$

$F_3 = IlB$

These two forces constitute a couple and so rotates the coil in the anticlockwise direction. The torque

$$\tau = \text{force} \times \text{arm of couple}$$

$$\tau = Fb \cos\theta$$

$$\tau = IlB\, b \cos\theta$$

$$\tau = IAB \cos\theta \quad [\because l \times b = A]$$

If the coil has N turns then

$$\tau = NIAB \cos\theta$$

The area vector A makes an angle α with $\vec{B}$ so

$$\theta + \alpha = 90°$$

$$\cos\theta = \cos(90 - \alpha) = \sin\alpha$$

$$\therefore \quad \tau = NIAB \sin\alpha$$

$$\tau = m B \sin\alpha$$

or $$\vec{\tau} = \vec{m} \times \vec{B}$$

where $m = NIA$ is called the magnetic dipole moment of the loop.

OR

(a) **(i)** In converting a galvanometer into a voltmeter, a very high suitable resistance is connected in series to its coil, so, that galvanometer gives full scale deflection.

(ii) In converting a galvanometer into an ammeter, a very small suitable resistance is connected in parallel to its coil. The remaining pair of the current *i.e.*, $(I - I_g)$ flows through the resistance.

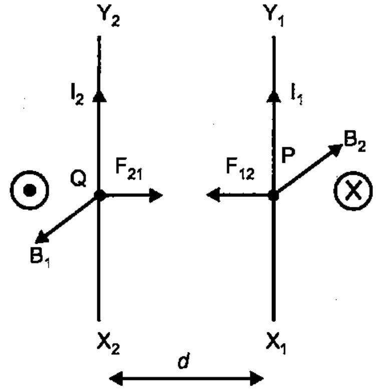
(b) **Assumption** : Current flowing in the conductors are in the same direction.

Using right hand thumb rule, the direction of the magnetic field at point P due to current I_2 is perpendicular to the plane of paper and inwards.

Similarly, at point Q on X_2Y_2, the direction of magnetic field due to current I_1 is perpendicularly outward.

Using Fleming's left hand rule we can find the direction of forces F_{12} and F_{21} which are in opposite directions,

Thus, by Ampere's circuital law, we have,



$$B_2 = \frac{\mu_0}{4\pi}\frac{2I_2}{d}$$

Now, $F_{12} = I_1 L B_2$ (Where L = length of the conductors)

$$F_{12} = \frac{\mu_0}{4\pi}\frac{2I_1I_2L}{d} = \frac{\mu_0}{2\pi}\frac{I_1I_2L}{d}$$

In similar manner, we get

$$F_{21} = \frac{\mu_0}{2\pi}\frac{I_1I_2L}{d} \quad ...(i)$$

From above we get the magnitude of forces F_{12} and F_{21} are equal but in opposite direction. So, $F_{12} = -F_{21}$

Therefore, two parallel straight conducting carrying current in the same direction attract each other. Similarly, we can prove if two parallel straight conductors carry currents in opposite direction, they repel each other with the same magnitude as equation (i).

●●

Physics 2012 (Outside Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

8. In a single-slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ? [1]

Answer : In single-slit diffraction experiment, fringe width is given as

$$\beta = \frac{2\pi D}{d}$$

Where, β = fringe width

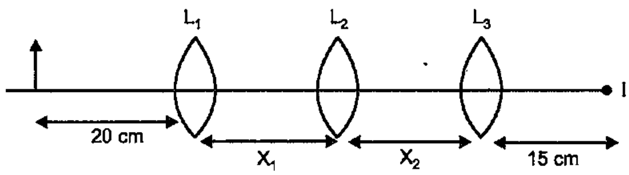
λ = wavelength of light used

D = the distance between screen and slit

d = the width of the slit.

If d is doubled, the width of the central maximum is halved. Thus there is a reduction in the size of the central diffraction band. Intensity of central band of the diffraction pattern varies square of the slit width so as the slit gets double, intensity will get four times.

19. You are given three lens L_1, L_2, L_3 each of focal length 15 cm. An object is kept at 20 cm in front of L_1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separations between L_1, L_2 and L_3. [3]



Answer : We have, $f_1 = f_2 = f_3 = 15$ cm

By lens formula for lens L_1,

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$

$$\frac{1}{v_1} - \frac{1}{-20} = \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{1}{-20} + \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{1}{60}$$

$\Rightarrow \quad v_1 = 60$ cm

For lens L_3, $v_3 = f_3 = 15$ cm, it means image by L_3 is formed at focus. By using lens formula we find that the object lie at infinity of L_3. Hence, L_2 will produce image at infinity. So, we can conclude that object for L_2 should be at its focus.

But, we have seen above the image by L_1 is formed at 60 cm right of L_1 which is at 15 cm left of L_2 (focus of L_2).

So, X_1 = distance between L_1 and L_2 = (60 + 15) cm = 75 cm

Again distance between L_2 and L_3 does not matter as the image by L_2 is formed at infinity so X_2 can take any value.

27. In a Geiger Marsden experiment, calculate the distance of closest approach to the nucleus of Z = 75, when an particle of 5 MeV energy impinges on it before it comes momentarily to rest and reverse its direction.

How will the distance of closest approach be affected when the kinetic energy of the-particle is doubled ? [3]

OR

The ground state energy of hydrogen atom is –13.6 eV. If an electron make a transition from an energy level –0.85 eV to –1.51 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong ?

Answer : Let r_0 be the centre to centre distance between the alpha-particle and nucleus when the α-particle is at its stopping point.

Now, $$E_k = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r_0}$$

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{E_K}$$

Given, $$E_K = 5 \times 10^6 \text{ eV}$$
$$= 5 \times 10^6 \times 1.6 \times 10^{-19} \text{ V}$$
$$Z = 75$$
$$r_0 = \frac{9\times10^9 \times 75\times 2\times(1.6\times10^{-19})^2}{5\times10^6\times1.6\times10^{-19}}$$
$$= \frac{3456\times10^9\times10^{-38}}{8\times10^{-13}}$$
$$= 432 \times 10^{-16}\text{m}$$
$$= 43.2 \times 10^{-15}\text{m}$$
$$= 43.2 \text{ fm}$$

Since distance of closest approach (r_0) is given as

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{E_K}$$

$$\Rightarrow \quad r_0 \propto \frac{1}{E_K}$$

So, when kinetic energy of the α-particle is doubled the distance between closest approach r_0 is halved.

OR

Since energy of hydrogen atom is given as

$$E_n = \frac{-13.6}{n^2} eV$$

Ground state energy, $E_1 = -13.6\ eV$

Now electron makes a transition from an energy level

$E_p = -0.85$ eV to $E_q = -1.51$ eV

Now,

$$E_p = \frac{-13.6}{n_p^2} eV$$
$$n_p^2 = \frac{-13.6}{-0.85} = 16$$
$$n_p = 4$$

Again,

$$E_q = \frac{-13.6}{n_p^2} eV$$
$$n_p^2 = \frac{-13.6}{-1.51}$$
$$n_q = 3$$

Thus, we have transition from $n = 4$ to $n = 3$.

Since transition corresponds to the transition of an electron from $n = 4$ to an orbit having $n = 3$. It is Paschen series of the hydrogen spectrum.

Wavelength is given as

$$\frac{1}{\lambda} = R\left(\frac{1}{n_q^2} - \frac{1}{n_p^2}\right)$$

Where R is Rydberg's constant

$$\Rightarrow \frac{1}{\lambda} = 1.0974 \times 10^7 \left(\frac{1}{9} - \frac{1}{16}\right)$$

$$\Rightarrow \frac{1}{\lambda} = 1.0974 \times 10^7 \times \frac{7}{9\times16}$$

$$\Rightarrow \lambda = \frac{9\times16}{1.097\times10^7\times7}$$

$$= 18.752 \times 10^{-7}\text{m}$$

$$= 1875 \text{ mm.}$$

Physics 2012 (Outside Delhi)

SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Sets.

1. How does the fringe width, in Young's double-slit experiment change when the distance of separation between the slits and screen is doubled ? **[1]**

Answer : We have, frings width

$$\beta = \frac{\lambda D}{d}$$

$$\Rightarrow \quad \beta \propto D$$

The fringe width becomes double when the distance of separation between the slits and screen is doubled.

4. The speed of an electromagnetic wave in a material medium is given by $v = \frac{1}{\sqrt{\mu\varepsilon}}$, μ being the permeability of the medium and ε is its permittivity. How does its frequency change ? **[1]**

Answer : The frequencies of electromagnetic waves have its inherent characteristics. When an electromagnetic wave travels from one medium to another, its wavelength changes but frequency remains unchanged.

7. A proton and an electron have same kinetic energy. Which one has smaller de-Broglie wavelength and why ? **[1]**

Answer : In terms of kinetic energy, wavelength is given by

$$\lambda = \frac{h}{\sqrt{2mE_k}}$$

$$\Rightarrow \quad \lambda \propto \frac{1}{\sqrt{m}}$$

So wavelength is inversely proportional to $\sqrt{m}$, *i.e.*, more the mass, less the wavelength and vice-versa.

So, for same kinetic energy, as a proton has a larger mass than an electron, thus a proton has smaller de-Broglie wavelength than a electron.

9. A circular coil of closely wound N turns and radius *r* carries a current I. Write the expression for the following : **[2]**

(i) the magnetic field at its centre

(ii) the magnetic moment of this coil

Answer : (i) Magnetic field at its centre is given by,

$$B = \frac{\mu_0 NI}{2r}$$

(ii) Magnetic moment of this coil is

$$m = NIA = NI\pi r^2$$

12. A light bulb is rated 150 W for 220 V a.c supply of 60 Hz. Calculate **[2]**

(i) the resistance of the bulb

(ii) the rms current through the bulb

OR

An alternating voltage given by $V = 70 \sin 100\pi t$ is connected across a pure resistor of 25 Ω. Find

(i) the frequency of the source.

(ii) the rms current through the resistor.

Answer : (i) Resistance of the bulb,

$$R = \frac{V^2}{P} = \frac{(220)^2}{150} = \frac{48400}{150}$$

$$R = 322.6\ \Omega$$

(ii) The rms current through the bulb

$$I = \frac{P}{V}$$

$$\therefore \quad I = \frac{150}{220}$$

$$I = 0.68\ A$$

OR

An ac voltage is given by

$$V = V_0 \sin \omega t$$

Given, $V = 70 \sin 100\,\pi t$

$$\therefore \quad \omega = 100\pi \text{ and } V_0 = 70\ V$$

(i) Frequency of the source,

$$f = \frac{\omega}{2\pi} = \frac{100\pi}{2\pi} = 50\ Hz$$

(ii) $$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{70}{\sqrt{2}} = 49.5\ V$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{49.5}{25} = 1.98\ A$$

20. Explain briefly the following terms used in communication system :**** **[3]**

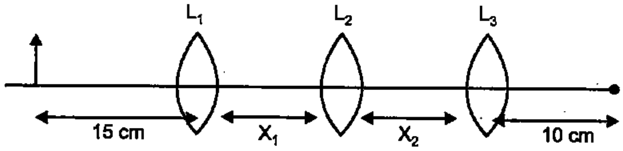
(i) Transducer

(ii) Repeater

(iii) Amplification

**Answers is not given due to change in the present syllabus.

22. You are given three lens L_1, L_2 and L_3 each of focal length 10 cm. An object is kept at 15 cm in front of L_1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separations between L_1, L_2 and L_3. **[3]**



Answer : We have,

$$f_1 = f_2 = f_3 = 10 \text{ cm}$$

For lens L_1, from lens makers formula,

$$u_1 = -15 \text{ cm}$$

$$f_1 = 10 \text{ cm}$$

By lens formula,

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$

$$\frac{1}{v_1} - \frac{1}{-15} = \frac{1}{10}$$

$$\frac{1}{v_1} = \frac{1}{10} - \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{3-2}{30} = \frac{1}{30}$$

$$\frac{1}{v_1} = \frac{1}{30}$$

$$\Rightarrow \quad v_1 = 30 \text{ cm}$$

For lens L_3, $v_3 = f_3 = 10$ cm, it means image by L_3 is formed at focus. So by using lens formula, we get that object should lie at infinity for L_3. Hence, L_2 will produce image at infinity. So, we can conclude that object for L_2 should be at its focus.

But, we have seen above that image by L_1 is formed at 30 cm right of L_1 which is at 10 cm left of L_2 (focus of L_2).

So, X_1 = distance between L_1 and L_2 = (30 + 10) cm = 40 cm

Again distance between L_2 and L_3 does not matter as the image by L_2 is formed at infinity so X_2 can take any value.

Physics 2012 (Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. When electrons drift in a metal from lower to higher potential, does it mean that all the free electrons of the metal are moving in the same direction ? **[1]**

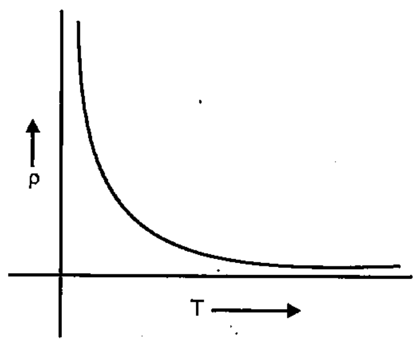
Answer : No, when electric field is applied, the electrons will have net drift from lower to higher field but locally electrons may collide with ions and may change their direction of motion.

2. The horizontal component of the earth's magnetic field at a place is B and angle of dip is 60°. What is the value of vertical component of earth's magnetic field at equator ? **[1]**

Answer : On the equator, the value of both angle of dip (δ) and vertical component of earth's magnetic field is zero. So, in this case, $B_v = 0$.

3. Show on a graph, the variation of resistivity with temperature for a typical semiconductor. **[1]**

Answer : The following curve shows the variation of resistivity with temperature for a typical semiconductor.



This is because, for a semiconductor, resistivity decreases rapidly with increasing temperature.

4. Why should electrostatic field be zero inside a conductor ? **[1]**

Answer : Charge on conductor resides on its surface. So if we consider a Gaussian surface inside the conductor to find the electrostatic field,

$$\phi = \frac{q}{\varepsilon_0}$$

Where, q = charge enclosed in Gaussian surface.

$q = 0$, inside the conductor, Hence the electrostatic field inside the conductor is zero.

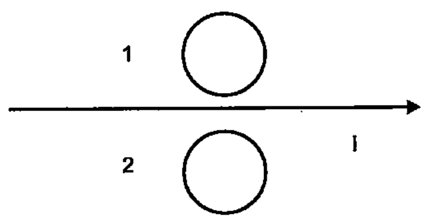
5. Name the physical quantity which remains same for microwaves of wavelength 1 mm and UV radiations of 1600 Å in vacuum. [1]

Answer : Both microwaves and UV rays are a part of the electromagnetic spectrum. Thus, the physical quantity that remains same for both types of radiation will be their speeds which is equal to c (3×10^8 m/s).

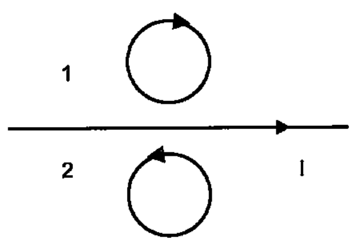
6. Under what condition does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid ? [1]

Answer : A biconvex lens will act like a plane sheet of glass if it is immersed in a liquid having the same index of refraction as itself.

7. Predict the directions of induced currents in metal rings 1 and 2 lying in the same plane where current I in the wire is increasing steadily. [1]



Answer : Using Lenz's law we can predict the direction of induced current in both the rings. Induced current oppose the cause of increase of magnetic flux. So,



It will be clockwise in ring 1 and anticlockwise in ring 2.

8. State de-Broglie hypothesis. [1]

Answer : de Broglie postulated that the material particles may exhibit wave aspect. Accordingly a moving material particle behaves as wave and the wavelength associated with material particle is

$$\lambda = \frac{h}{mv}$$

where h = Planck's constant

m = mass of the object

v = velocity of the object

9. A ray of light incident on an equilateral prism ($\mu_g = \sqrt{3}$) moves parallel to the base line of the prism inside it. Find the angle of incidence for this ray. [2]

Answer : It is given that the prism is equilateral in shape. So, all the angles are equal to 60°. Thus, the angle of prism, $A = 60^\circ$.

The angle of refraction in case of a prism,

$$r = \frac{A}{2} = 30^\circ$$

We can now apply Snell's law

$$\mu_a \sin i = \mu_g \sin r$$

Here, μ_a = refractive index of air = 1

μ_g = refractive index of glass = $\sqrt{3}$

i = angle of incidence

$$\sin i = \left(\frac{\mu_g}{\mu_a}\right)\sin r = \left(\frac{\mu_g}{\mu_a}\right)\sin 30^\circ$$

$$\sin i = \frac{\sqrt{3}}{2}$$

So, the angle of incidence is $i = 60^\circ$.

10. Distinguish between 'Analog and Digital signals'. [2]**

OR

Mention the functions of any two of the following used in communication system : **

(i) Transducer

(ii) Repeater

(iii) Transmitter

(iv) Bandpass Filter

11. A cell of emf E and internal resistance r is connected to two external resistance R_1 and R_2 and a perfect ammeter. The current in the circuit is measured in four different situations

(i) without any external resistance in the circuit

(ii) with resistance R_1 only

(iii) with R_1 and R_2 in series combination

(iv) with R_1 and R_2 in parallel combination

The currents measured in the four cases are 0.42 A, 1.05 A, 1.4 A and 4.2 A, but not necessarily in the order. Identify the currents corresponding to the four cases mentioned above. [2]

Answer : The current relating to corresponding situations is as follows :

(i) Without any external resistance in the circuit :

$$I_1 = \frac{E}{r}$$

The current in this case would be maximum.

**Answers is not given due to change in the present syllabus.

So, $\quad I_1 = 4.2\ A$

(ii) With resistance R_1 only :

$$I_2 = \frac{E}{r + R_1}$$

The current in this case will be second smallest value,

So, $\quad I_2 = 1.05\ A$

(iii) With R_1 and R_2 in series combination

$$I_3 = \frac{E}{r + (R_1 + R_2)}$$

The current in this case will be minimum as the resistance will be maximum.

So, $\quad I_3 = 0.42\ A.$

(iv) With R_1 and R_2 in parallel combination

$$I_4 = \frac{E}{r + \left(\frac{R_1 R_2}{R_1 + R_2}\right)}$$

The current in this case would be the second largest value.

So, $\quad I_4 = 1.4\ A.$

12. The susceptibility of a magnetic material is –2.6 × 10^{-5}. Identify the type of magnetic material and state its two properties. [2]

Answer : Diamagnetic materials have negative susceptibility. So the given magnetic material is diamagnetic.

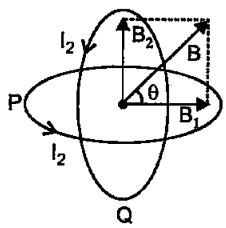
Two properties of diamagnetic material :

(i) They do not obey Curie's law.

(ii) They are feebly repelled by a magnet.

13. Two identical circular wires P and Q each of radius R and carrying current 'I' are kept in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils. [2]

Answer : Magnetic field produced by the two coils at their common centre having currents I_1 and I_2, radius a_1 and a_2, number of turns N_1 and N_2 respectively are given by :



$$B_1 = \frac{\mu_0 N_1 I_1}{2a_1}$$

$$B_2 = \frac{\mu_0 N_2 I_2}{2a_2}$$

The resultant field at the common centre is :

$$B = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{\left(\frac{\mu_0 N_1 I_1}{2a_1}\right)^2 + \left(\frac{\mu_0 N_2 I_2}{2a_2}\right)^2}$$

Here $N_1 = N_2 = 1, \quad I_1 = I_2 = I, \quad a_1 = a_2 = R$

$$B = \sqrt{\left(\frac{\mu_0 \times 1 \times I}{2R}\right)^2 + \left(\frac{\mu_0 \times 1 \times I}{2R}\right)^2}$$

$$= \frac{\mu_0 I}{2R}\sqrt{1+1} = \sqrt{2}\left(\frac{\mu_0 I}{2R}\right)$$

Direction of B, $\tan\theta = \frac{B_2}{B_1} = 1$

$\therefore \quad \theta = 45°$

Hence, the net magnetic field is directed at an angle of 45° with either of the fields.

14. When an ideal capacitor is charged by a d.c. battery, no current flows. However, when an a.c. source is used, the current flows continuously. How does one explain this based on the concept of displacement current ? [2]

Answer : When an ideal capacitor is charged by d.c. battery, charge flows till the capacitor gets fully charged.

When an a.c. source is connected then conduction current $i_c = \frac{dq}{dt}$ flows in the connecting wire. Due to changing current, charge deposited on the plates of the capacitor changes with time. Changing charge causes electric field between the plates of capacitor to be varying, giving rise to displacement current $i_d = \varepsilon_0 \frac{d\phi_c}{dt}$ [As displacement current is proportional to the rate of flux variation].

Between the plates, electric field

$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0}$$

Electric flux, $\phi_c = EA = \frac{q}{A\varepsilon_0}A$

$$\text{So, } i_d = \frac{\varepsilon_0 d\phi_c}{dt} = \frac{\varepsilon_0 d}{dt}\left(\frac{qA}{A\varepsilon_0}\right) = \frac{\varepsilon_0 \times A}{\varepsilon_0 \times A}\frac{dq}{dt} = \frac{dq}{dt} = i_c$$

Displacement current brings continuity in the flow of current between the plates of the capacitor.

15. Draw a plot showing the variation of (i) electric field (E) and (ii) electric potential (V) with distance r due to a point charge Q. [2]

Answer : We know that for a point charge Q.

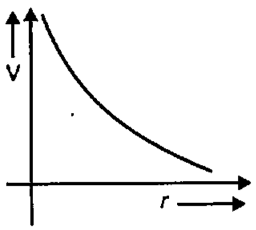
Electric potential, $V = \dfrac{Q}{4\pi\varepsilon_0 r}$

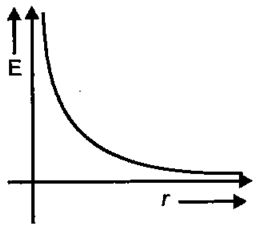
or $V \propto \dfrac{1}{r}$

Electric field, $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$

or $E \propto \dfrac{1}{r^2}$

Thus, electric potential shows an inverse relationship with distance r while electric field shows a inverse square relationship with r. So, their corresponding plots would be





16. Define self-inductance of a coil. Show that magnetic energy required to build up the current I in a coil of self inductance L is given by $\frac{1}{2}LI^2$. [2]

Answer : Self inductance is the inherent inductance of a circuit, given by the ratio of the electromotive force produced in the circuit by self-induction to the rate of change of current producing it. It is also called coefficient of self-induction.

Suppose I = Current flowing in the coil at any time.

ϕ = Amount of magnetic flux linked.

It is found that $\phi \propto I$

$$\phi = LI$$

where, L is the constant of proportionality and is called coefficient of self induction.

SI unit of self-inductance is henry.

Let at $t = 0$, the current in the inductor is zero. So at any instant t, the current in the inductor is I and rate of growth of I is dI/dt.

Then, the induced emf is $E = L \times dI / dt$

If the source is sending a constant current I through the inductor for a small time dt, then small amount of work done by the source is given by

$$dW = EI\,dt = (L dI/dt)I\,dt = LI dI$$

The total amount of work done by the source of emf, till the current increases from its initial value I = 0 to its final value I is given by

$$W = \int_0^1 LI dI = L\int_0^1 I dI = L\left[\frac{I^2}{2}\right]$$

$$= \frac{1}{2}LI^2$$

This work done by the source of emf used in building up current from zero to I is stored in the inductor in energy form. Therefore, energy stored in the inductor is

$$U = \frac{1}{2}LI^2$$

17. The current in the forward bias is known to be more (~ mA) than the current in the reverse bias (~ μA). What is the reason, then, to operate the photodiode in reverse bias ? [2]

Answer : The current in the forward bias is due to majority carriers whereas current in the reverse bias is due to minority carriers. So current in forward bias is more (~mA) than current in reverse bias (~μA).

On illumination of photodiodes with light, the fractional change in the majority carriers would be much less than that in minority carriers. It implies that fractional change due to light on minority carriers dominated reverse bias current is more easily measurable than fractional change in forward bias current. So, photodiodes are operated in reverse bias condition.

18. A metallic rod of 'L' length is rotated with angular frequency of 'ω' with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius L about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. Deduce the expression for the emf between the centre and the metallic ring. [2]

Answer : The induced emf,

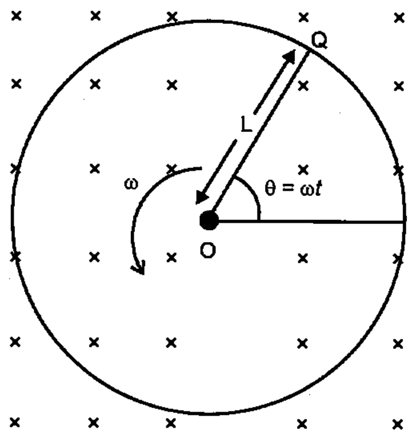
$$e = \frac{d\phi_B}{dt}$$

$$e = \frac{d}{dt}(BA\cos\phi)$$

$$[\because \phi_B = BA\cos\phi]$$

$$= B\frac{dA}{dt} \qquad [\because \phi = 0°]$$

where $\frac{dA}{dt}$ = Rate of change of area of loop formed by the sector OPQ. Let θ be the angle between the rod and the radius of the circle at P at time t.



The area of the sector OPQ $= \pi L^2 \times \frac{\theta}{2\pi} = \frac{1}{2}L^2\theta$

where L = Radius of the circle.

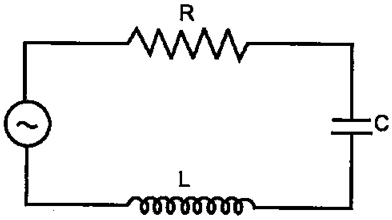
$$\text{Hence } e = B \times \frac{d}{dt}\left(\frac{1}{2}L^2\theta\right) = \frac{1}{2}BL^2\frac{d\theta}{dt} = \frac{B\omega L^2}{2}$$

19. The figure shows a series LCR circuit with L = 5.0 H, C = 80 μF, R = 40 Ω connected to a variable frequency 240 V source, calculate [3]

(i) the angular frequency of the source which drives the circuit at resonance,

(ii) the current at the resonating frequency,

(iii) the rms potential drop across the inductor at resonance.



Answer : Given, L = 5.0 H, C = 80 μF, R = 40 Ω, V = 240 V

(i) Resonant angular frequency

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5\times 80\times 10^{-6}}}$$

$$= \frac{1}{\sqrt{400\times 10^{-6}}}$$

$$= \frac{1}{20\times 10^{-3}}$$

$$= \frac{1000}{20}$$

$$\omega = 50 \text{ rad s}^{-1}$$

(ii) At resonant frequency, we know that the inductive reactance cancels out the capacitive reactance. i.e, $X_L = X_\omega$

∴ Impedance, Z = R = 40 Ω

The current at resonant frequency

$$I_{rms} = \frac{V_{rms}}{R} = \frac{240}{40} = 6 \text{ A}$$

(iii) rms potential drop across inductor

$$V_L = I_{rms} \times X_L$$

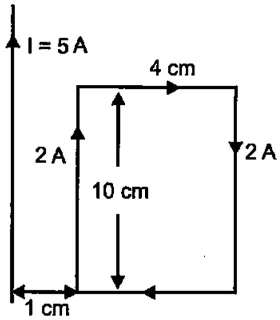
$$= I_{rms} \times \omega L$$

$$= 6 \times 50 \times 5 = 1500 \text{ V}$$

20. A rectangular loop of wire of size 4 cm × 10 cm carries a steady current of 2 A. A straight long wire carrying 5 A current is kept near the loop as shown. If the loop and the wire are coplanar, find [3]

(i) the torque acting on the loop and

(ii) the magnitude and direction of the force on the loop due to the current carrying wire.



Answer :

(i) $\vec{\tau} = \vec{m} \times \vec{B} = \vec{m}\,B \sin\theta$

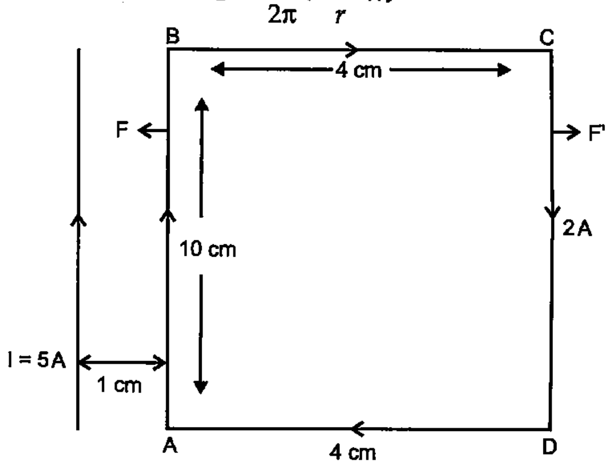
Here, m and B have the same direction

∴ θ = 0°

$|\vec{\tau}| = mB\sin\theta = 0$

(ii) Force between two current carrying wires is given by,

$$F = \frac{\mu_0}{2\pi}\cdot\frac{I_1 I_2}{r}\times l$$



Force on wires BC and AD being equal and opposite will cancel out each other. Now, force on wire AB

$$F = \frac{\mu_0}{2\pi} \times \frac{5\times 2}{1\times 10^{-2}} \times (0.10)$$

$$F = \frac{\mu_0}{2\pi} \times 100$$

force will be attractive as current is flowing in same direction

And force on wire CD

$$F' = \frac{\mu_0}{2\pi} \times \frac{5\times 2}{5\times 10^{-2}} \times (0.10)$$

$$F' = \frac{\mu_0}{2\pi} \times 20$$

force will be repulsive as current is in opposit direction

Now, resultant force on loop,

$$F_{net} = F - F'$$

$$= \frac{\mu_0}{2\pi}[100-20]$$

$$= 2\times 10^{-7} \times 80 = 16\times 10^{-6}\text{ N}$$

The direction of net force is towards the straight wire *i.e.*, attractive.

21. (a) Using Bohr's second postulate of quantization of orbital angular momentum show that the circumference of the electron in the n^{th} orbital state in hydrogen atom is n times the de Broglie wavelength associated with it.

(b) The electron in hydrogen atom is initially in the third excited state. What is the maximum number of spectral lines which can be emitted when it finally moves to the ground state? [3]

Answer: (a) According to Bohr's second postulate of quantization, the electron can revolve around the nucleus only in those circular orbits in which the angular momentum of the electron is integral multiple of $\frac{h}{2\pi}$ where h is Planck's constant ($= 6.62\times 10^{-34}$ Js).

So, if m is the mass of electron and v is the velocity of electron in permitted quantized orbit with radius r then

$$mvr = n\frac{h}{2\pi} \qquad ...(1)$$

Where n is the principal quantum number and can take integral values like

$$n = 1, 2, 3, ...$$

This is the Bohr's quantization condition.

Now, de-Broglie wavelength is given as

$$\lambda = \frac{h}{mv}$$

Where λ = Wavelength of wave associated with electron

m = Mass of the electron

h = Planck's constant

$$mv = \frac{h}{\lambda}$$

or $$mvr = \frac{hr}{\lambda} \qquad ...(2)$$

From equations (i) and (ii)

$$\therefore \quad \frac{h}{\lambda}r = \frac{nh}{2\pi}$$

$$\frac{r}{\lambda} = \frac{n}{2\pi}$$

$$2\pi r = n\lambda$$

Now, circumference of the electron in the n^{th} orbital state of Hydrogen atom with radius r is $n\lambda$.

(b) If n is quantum number of the highest energy level involved in the transitions, then the total number of possible spectral lines emitted is

$$N = \frac{n(n-1)}{2}$$

Third excited state means fourth energy level *i.e.* $n = 4$. Here, electron makes transition from $n = 4$ to $n = 1$. So, highest n is $n = 4$.

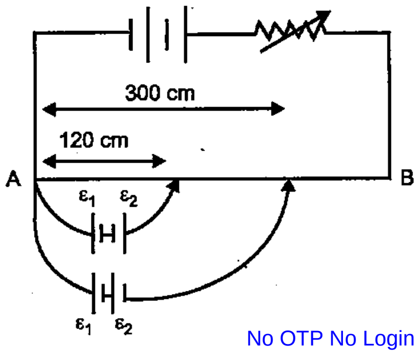
Thus, possible spectral lines

$$N = \frac{4(4-1)}{2}$$

$$= \frac{4\times 3}{2} = 6$$

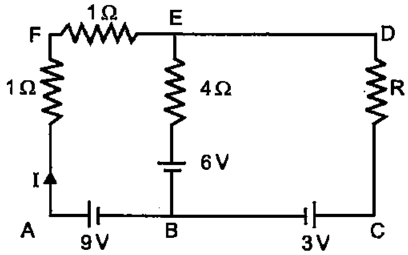
The maximum possible number of spectral lines is 6.

22. In the figure a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end A. Find (i) $\varepsilon_1/\varepsilon_2$ and (ii) position of null point for the cell ε_1. [3]
How is the sensitivity of a potentiometer increased?

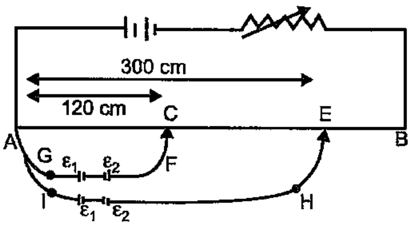


OR

Using Kirchhoff's rules determine the value of unknown resistance R in the circuit so that no current flows through 4 Ω resistance. Also find the potential between A and D.



Answer :



(i) Apply Kirchhoff's law in loop ACFGA :

$$k(120) = \varepsilon_1 - \varepsilon_2$$

k = potential drop per unit length

or $\varepsilon_1 = \varepsilon_2 + k(120)$ ...(1)

For loop AEHIA :

$$k(300) = \varepsilon_2 + \varepsilon_1$$

By substituting value of ε_1 from equation (i),

$$\varepsilon_2 + [\varepsilon_2 + k(120)] = k(300)$$

$$2\varepsilon_2 = k(300 - 120)$$

or, $\varepsilon_2 = 90k$ ...(ii)

Thus, $\varepsilon_1 = 90k + 120k$

$\varepsilon_1 = 210k$ ...(iii)

Hence, $\frac{\varepsilon_1}{\varepsilon_2} = \frac{210}{90} = \frac{7}{3}$

(ii) As we know, $\varepsilon = kl$

Thus, from equations (ii) and (iii),

Null point for cell ε_2 is 90 cm

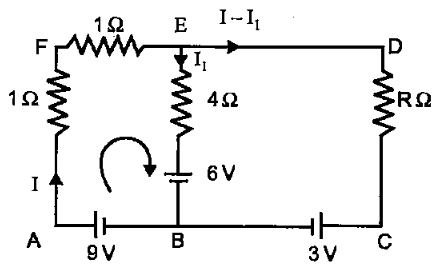
And for cell ε_1, it is 210 cm.

Sensitivity of the potentiometer can be increased by :

(a) Increasing the length of the potentiometer wire.

(b) Decreasing the resistance in the primary circuit.

OR



Apply Kirchhoff's law in loop AFEBA :

$$I + I + 4I_1 = 9 - 6$$

$$2I + 4I_1 = 3 \quad ...(i)$$

As there is no current flowing through the 4 Ω resistance,

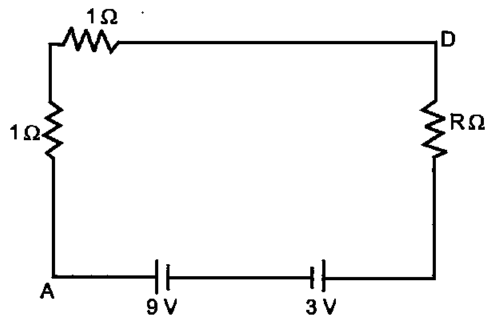
$\therefore \quad I_1 = 0$

or $\quad 2I = 3$

or $\quad I = 1.5$ A

Thus, the current through resistance R is 1.5 A.

As there is no current through branch EB, thus equivalent circuit will be,



By applying Kirchhoff's loop law, we get

$$1.5 + 1.5 + R(1.5) = 9 - 3$$

$$R = 2\ \Omega$$

Potential difference between A and D = 2 × 1.5 = 3 V.

23. (i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number 'A' lying 30 < A < 170 ?

(ii) Show that the density of nucleus over a wide range of nuclei is constant and independent of mass number A. [3]

Answer : (i) The constancy of BE/A over most of the range is due to saturation property of nuclear force.

In heavy nuclei : nuclear size > range of nuclear force.

So, nucleons experiences nearly constant interaction.

(ii) To find the density of nucleus of an atom, we have an atom with mass number let say A and let mass of the nucleus of the atom of the mass number A be m A.

Where, m is mass of one nucleon.

Let radius of nucleus be R.

Then, volume of nucleus $= \frac{4}{3}\pi R^3$

$$= \frac{4}{3}\pi(R_0 A^{1/3})^3$$

$[\because R = R_0 A^{1/3}]$

**Answers is not given due to change in the present syllabus.

$$= \frac{4}{3}\pi R_0^3 A$$

Density of the nucleus,

$$\rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$$

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} = \frac{3m}{4\pi R_0^3}$$

This expression is independent of mass number A and since m, π and R_0 have same values for any atom, therefore, density is constant also.

24. Write any two factors which justify the need for modulating a signal.
Draw a diagram showing an amplitude modulated wave by superposing a modulating signal over a sinusoidal carrier wave. [3]**

25. Write Einstein's photoelectric equation. State clearly how this equation is obtained using the photon picture of electromagnetic radiation.
Write the three salient features observed in photoelectric effect which can be explained using this equation. [3]

Answer : Einstein's photoelectric equation,

$$h\nu = K_{max} + \phi$$

Where, h = Planck's constant

ν = frequency of radiation

ϕ = Work function

According to Planck's quantum theory, light radiations consist of small packets of energy.

Einstein postulated that a photon of energy $h\nu$ is absorbed by the electron of the metal surface, then the energy equal to ϕ is used to liberate electron from the surface and rest of the energy $h\nu - \phi$ becomes the kinetic energy of the electron.

∴ Energy of photon is,

$$E = h\nu$$

The minimum energy required by the electron of a material to escape out of its work function 'ϕ'.

The additional energy acquired by the electron appears as the maximum kinetic energy 'K_{max}' of the electron.

i.e., $K_{max} = h\nu - \phi$

or $h\nu = K_{max} + \phi$

where $\phi = eV_0$.

Sailent features observed in photoelectric effect :

1. The stopping potential and hence the maximum kinetic energy of emitted electrons varies linearly with the frequency of incident radiation.
2. There exists a minimum cut-off frequency ν_0, for which the stopping potential is zero.
3. Photoelectric emission is instantaneous.

26. (a) Why are coherent sources necessary to produce a sustained interference pattern ?
(b) In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$. [3]

Answer : (a) Coherent sources have constant phase difference between them *i.e.,* phase difference does not change with time. Hence, the intensity distribution on the screen remains constant and sustained.

(b) We know

$$\text{Phase difference} = \left(\frac{2\pi}{\lambda}\right) \times \text{Path difference}$$

At path difference λ

$$\text{Phase difference, } \phi = \frac{2\pi}{\lambda} \times \lambda = 2\pi$$

$$\text{Intensity, } I = 4I_0 = \cos^2 \frac{\phi}{2}$$

But I = K at path difference λ

$$\therefore \quad K = 4I_0 \cos^2 \frac{2\pi}{2}$$

$$\text{or} \quad K = 4I_0$$

$$\text{or} \quad I_0 = \frac{K}{4}$$

Now, at path difference $= \frac{\lambda}{3}$

$$\phi' = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

$$\text{Intensity, } I' = 4I_0 \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right)$$

$$I' = 4 \times \frac{K}{4} \cos^2 \frac{\pi}{3}$$

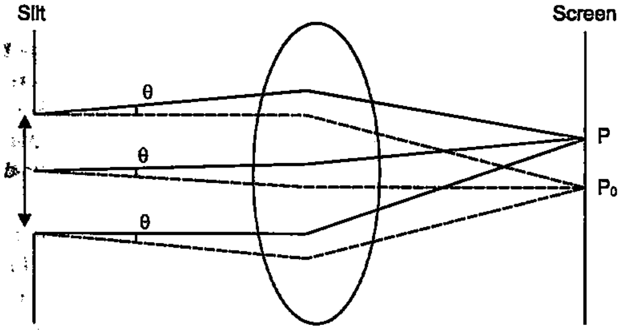
$$= K \times \left(\frac{1}{2}\right)^2$$

$$= \frac{1}{4}K$$

27. Use Huygen's principle to explain the formation of diffraction pattern due to a single slit illuminated by a monochromatic source of light.
When the width of the slit is made double the original width, how would this affect the size and intensity of the central diffraction band ? [3]

Answer : Consider a parallel beam of monochromatic light is incident normally on a slit of width b as shown in figure. According to Huygen's principle, every point of slit acts as a source of secondary wavelets spreading in all directions. Screen is placed at a larger distance.

Consider a particular point P on the screen that receives waves from all the secondary sources. All these waves start from different point of the slit and interfere at point P to give resultant intensity.



Point P_0 is a bisector plane of the slit. At P_0, all waves are travelling equal optical path. So all wavelets are in phase thus interfere constructively with each other and maximum intensity is observed. As we move from P_0, the wave arrives with different phases and intensity is changed. Intensity at point P is given by

$$I = I_0 \frac{\sin^2 \alpha}{\alpha}$$

Where $\alpha = \frac{\pi}{\lambda} b \sin\theta$

For central maxima, $\alpha = 0$ thus,

$$I = I_0$$

When the width of slit is made double the original width intensity will get four times of its original value.

Width of central maximum is given by,

$$\beta = \frac{2D\lambda}{b}$$

Where, D = Distance between screen and slit,

λ = Wavelength of the light,

b = size of slit

So with the increase in size of slit the width of central maxima decrease. Hence, double the size of the slit would result in half the width of the central maxima.

28. Explain the principle of a device that can build up high voltage of the order of a few million volts.

Draw a schematic diagram and explain the working of this device.

Is there any restriction on the upper limit of the high voltage set up in this machine ? Explain. [5]

OR

(a) Define electric flux. Write its S.I. units.

(b) Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it.

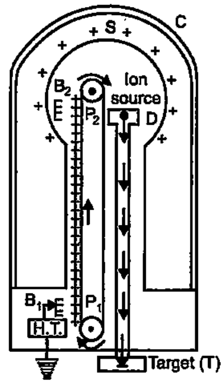
(c) How is the field directed if (i) the sheet is positively charged, (ii) negatively charged ?

Answer : Van de Graaff generator is the device used for building up high voltages of the order of a few million volts.

Such high voltages are used to accelerate charged particles such as electrons, protons, ions, etc.

It is based on the principle that charge given to a hollow conductor is transferred to outer surface and is distributed uniformly over it.

Construction :



It consists of large spherical conducting shell (S) supported over the insulating pillars. A long narrow belt of insulating material is wound around two pulleys P_1 and P_2, B_1 and B_2 are two sharply pointed metal combs. B_1 is called the spray comb and B_2 is called the collecting comb.

Working : The spray comb is given a positive potential by high tension source. The positive charge gets sprayed on the belt.

As the belt moves and reaches the sphere, a negative charge is induced on the sharp ends of collecting comb B_2 and an equal positive charge is induced on the farther end of B_2.

This positive charge shifts immediately to the outer surface of S. Due to discharging action of sharp points of B_2, the positive charge on the belt is neutralized. The uncharged belt returns down and collects the positive charge from B_1, which in turn is collected by B_2. This is repeated. Thus, the positive charge of S goes on accumulating. In this way, potential differences of as much as 6 or 8 million volts (with respect to the ground) can be built up.

The main limiting factor on the value of high potential is the radii of sphere.

If the electric field just outside the sphere is sufficient for dielectric breakdown of air, no more charge can be transferred to it.

For a conducting sphere,

Electric field just outside sphere

$$E = \frac{Q}{4\pi\varepsilon_0 R^2}$$

and electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 R}$$

Thus, $E = V/R$

Now, for $E = 3 \times 10^6$ V/m (dielectric breakdown)

Radius of sphere should be 1 m.

Thus, the maximum potential of a sphere of radius 1 m would be 3×10^6 V.

OR

(a) Electric Flux : It is the number of electric field lines passing through a surface normally.

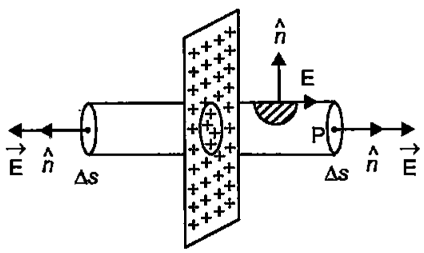
$$\phi = \vec{E} \cdot \vec{A}$$

where E = Electric field, A = Area

S.I. unit of flux is Nm^2C^{-1}

(b) Consider a uniformly charged infinite plane sheet of charge density σ.

We have to find electric field E at point P as shown in figure.



Now, we construct a Gaussian surface as shown in figure in the form of cylinder.

Applying Gauss's law,

$$\phi = \oint \vec{E} \cdot \vec{ds} = \frac{\sigma \Delta s}{\varepsilon_0}$$

$$\Rightarrow \quad E\Delta s + E\Delta s + 0 = \frac{\sigma \Delta s}{\varepsilon_0}$$

$$= 2E\Delta s = \frac{\sigma \Delta s}{\varepsilon_0}$$

$$\Rightarrow \quad E = \frac{\sigma}{2\varepsilon_0}$$

It shows that electric field is uniform due to charged infinite plane sheet. Also, we can say that E is independent from distance from the sheet.

(c) $$E = \frac{\sigma}{2\varepsilon_0}$$

(i) Direction of field will be away from the sheet if sheet is positively charged.

(ii) $$E = \frac{-\sigma}{2\varepsilon_0}$$

Direction of field will be towards the sheet if sheet is negatively charged.

29. Define magnifying power of a telescope. Write its expression.

A small telescope has an objective lens of focal length 150 cm and an eye-piece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, find the height of the final image when it is formed 25 cm away from the eye-piece. [5]

OR

How is the working of a telescope different from that of a microscope ?

The focal lengths of the objective and eyepiece of a microscope are 1.25 cm and 5 cm respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment.

Answer : Magnifying power of a telescope is defined as the ratio of the angle subtended at the eye by the image formed at the least distance of distinct vision to the angle subtended at the eye by the object lying at infinity, when seen directly.

The formula for magnifying power is,

$$\text{Magnifying power, } M = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Where, f_o = Focal length of the objective = 150 cm

f_e = Focal length of the eye-piece = 5 cm

D = Least distance of distinct vision = 25 cm

$$M = \frac{-150}{5} \times \left(1 + \frac{5}{25}\right) = -36$$

Also, by definition, $M = \frac{\beta}{\alpha}$

or $$M = \frac{\tan\beta}{\tan\alpha}$$

(As angles *a* and *b* are small)

$$\tan\alpha = \frac{\text{Height of object}}{\text{Distance of object from objective}}$$

$$= \frac{H}{u} = \frac{100}{300} = \frac{1}{30}$$

$$M = \frac{\tan\beta}{\left(\frac{1}{30}\right)}$$

$$\tan\beta = \frac{-36}{30}$$

$$\tan\beta = \frac{\text{Height of image}}{\text{Distance of image from eye-piece}} = \frac{H'}{D}$$

Thus,

$$H = \frac{-36 \times 25}{30} = -30 \text{ cm}$$

Negative sign indicates that we get an inverted image.

OR

A microscope is used to look into smaller objects like structure of cells etc. On the other hand, a telescope is used to see larger objects that are very far away like stars, planets etc.

Telescope mainly focuses on collecting the light into the objective lens, which should thus be large, where the microscope already has a focus and the rest is blurred around it.

There is a big difference in their magnification factors.

For telescope, the angular magnification is given by

$$M = \frac{f_o}{f_e}$$

Where f_o is the focal length of the objective lens and f_e is the focal length of the eyepiece.

For microscope, the angular magnification is given by

$M = 1 + \frac{D}{f_o}$ when image is formed at distance of least distinct vision.

$M = \frac{D}{f_o}$ when image is formed infinity.

Where D is the distance of least distinct vision.

Given : $f_o = 1.25$ cm

$f_e = 5$ cm

M = –30 (Magnifying power is negative)

We know,

$$M = \frac{v_0}{u_0}\left(1 + \frac{D}{f_o}\right)$$

Where, v_0 = Distance of image from objective

u_0 = Distance of object from objective

$$-30 = \frac{v_0}{u_0}\left(1 + \frac{25}{5}\right)$$

$$v_0 = -5\mu_0$$

Using Lens formula,

$$\frac{1}{f_o} = \frac{1}{u_0} + \frac{1}{v_0}$$

$$\frac{1}{1.25} = -\frac{1}{u_0} - \frac{1}{5u_0}$$

$$u_0 = -1.5 \text{ cm}$$

Thus the distance of object from objective is 1.5 cm.

30. Draw a simple circuit of a CE transistor amplifier. Explain its working. Show that the voltage gain, A_V, of the amplifier is given by

$A_V = \frac{-\beta_{ac} RL}{r_i}$, where β_{ac} is the current gain; R_L is the load resistance and r_i is the input resistance of the transistor. What is the significance of the negative sign in the expression for the voltage gain ?** **[5]**

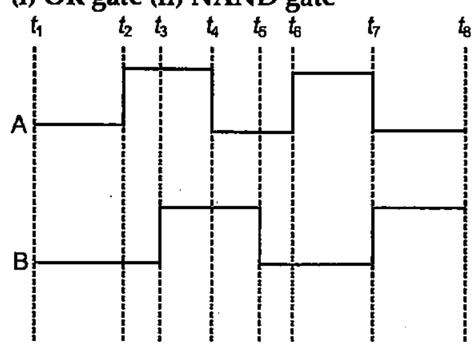
OR

(a) Draw the circuit diagram of a full wave rectifier using *p-n* junction diode.

Explain its working and show the output, input waveforms.**

(b) Show the output waveforms (Y) for the following inputs A and B of

(i) OR gate (ii) NAND gate**



Physics 2012 (Delhi) SET II

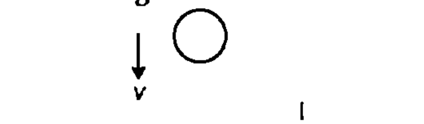
Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

1. Why must electrostatic field be normal to the surface at every point of a charged conductor ? **[1]**

Answer : The electrostatic field must be normal to the surface of the conductor at every point because if the electric field is not normal to the surface of the charged conductor, there will be a component of the electric field along the surface of the conductor, which would exert a force on the charges at the surface. Due to this, charge starts flowing which is not possible.

6. Predict the direction of induced current in a metal ring when the ring is moved towards a straight conductor with constant speed v. The conductor is carrying current I in the direction shown in the figure. [1]



Answer : Clockwise

10. Derive the expression for the self inductance of a long solenoid of cross-sectional area A and length l, having n turns per unit length. [2]

Answer : Self-inductance of a long Solenoid :

The magnetic field B at any point inside a solenoid is constant and given by,

$$B = \frac{\mu_0 NI}{l} \qquad ...(i)$$

Where, μ_0 = Absolute magnetic permeability of free space

N =Total number of turns in the solenoid

∴ Magnetic flux through each turn of the solenoid coil = B × Area of each turn

$$B = \frac{\mu_0 NI}{l}.A$$

Where, A = Area of each turn of the solenoid.

Total magnetic flux linked with the solenoid

$$\phi = \frac{\mu_0 NIA}{l} \times N \qquad ...(ii)$$

If L is coefficient of self-inductance of the solenoid, then

$$\phi = LI \qquad ...(iii)$$

Equating (ii) and (iii),

$$LI = \frac{\mu_0 NIA}{l} \times N$$

$$L = \frac{\mu_0 N^2 A}{l}$$

If core is of any other magnetic material, μ_0 is replaced by $\mu = \mu_0\mu_r$ then,

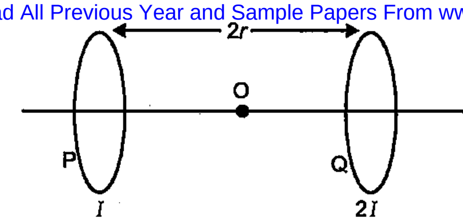
$$L = \mu_r\mu_0 N^2 A/l.$$

If n is the number of turns per unit length then

$$L = \mu_r \mu_0 n^2 A l$$

This is self inductance of a long solenoid.

16. Two identical circular loops, P and Q, each of radius r and carrying currents I and 2I respectively are lying in parallel planes such that they have a common axis. The direction of current in both the loops is clockwise as seen from O which is equidistance from the both loops. Find the magnitude of the net magnetic field at point O. [2]



Answer : Field due to loop P,

$$\vec{B}_P = \frac{\mu_0 r^2 I}{2(r^2+r^2)^{3/2}} = \frac{\mu_0 I}{4\sqrt{2}r} \text{ towards P.}$$

Field due to loop Q,

$$\vec{B}_Q = \frac{\mu_0 r^2 (2I)}{2(r^2+r^2)^{3/2}} = \frac{\mu_0 (2I)}{4\sqrt{2}r} \text{ towards Q.}$$

So, net field at O

$$\vec{B} = \vec{B}_Q - \vec{B}_P$$

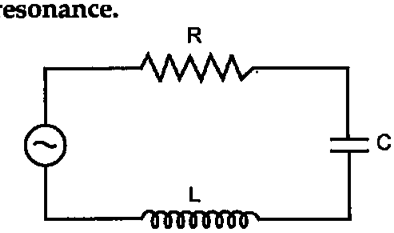
$$= \frac{\mu_0 (2I)}{4\sqrt{2}r} - \frac{\mu_0 I}{4\sqrt{2}r} = \frac{\mu_0 I}{4\sqrt{2}r} \text{ towards Q.}$$

20. A series LCR circuit with L = 4.0 H, C = 100 μF, R = 60 Ω connected to a variable frequency 240 V source as shown in figure calculate : [3]

(i) the angular frequency of the source which drives the circuit at resonance,

(ii) the current at the resonating frequency,

(iii) the rms potential drop across the inductor at resonance.



Answer :

(i) Angular frequency at resonance

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4 \times 100 \times 10^{-6}}} = \frac{1}{2 \times 10^{-2}}$$

$$= 50 \text{ rad s}^{-1}$$

(ii) At Resonance, we know the inductive reactance cancels out the capacitive reactance.

$$Z = R = 60\ \Omega$$

∴ The current at resonant frequency

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{240}{60}$$

$$= 4\ A$$

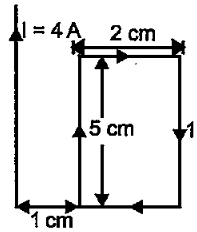
(iii) rms potential drop across inductor at resonance

$$V_L = I_{rms} \cdot X_L = I_{rms} \cdot \omega L$$

$$= 4 \times 50 \times 4 = 800\ V$$

**Answers is not given due to change in the present syllabus.

22. A rectangular loop of wire of size 2 cm × 5 cm carries a steady current of 1 A. A straight long wire carrying 4 A current is kept near the loop as shown in the figure. If the loop and the wire are coplanar, find (i) the torque acting on the loop and (ii) the magnitude and direction of the force on the loop due to the current carrying wire. [3]



Answer : (i) $|\vec{\tau}| = \vec{m} \times \vec{B} = mB \sin\theta$

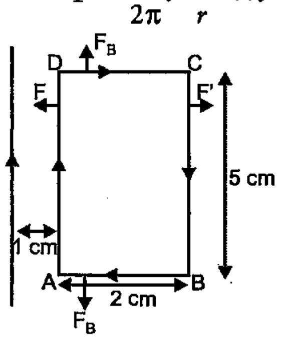
Here m and B have the same direction

$$\theta = 0$$

$$\Rightarrow \quad |\vec{\tau}| = mB\sin\theta = 0$$

(ii) Force between two current carrying wires is given by,

$$F = \frac{\mu_0}{2\pi} \cdot \frac{I_1 I_2}{r} \times l$$



On wire AB and CD, the magnetic forces are equal and opposite, hence they cancel out each other.

Magnetic force on wire AD,

$$F = \frac{\mu_0}{2\pi} \frac{4 \times 1}{(0.01)} (0.05)$$

(Attractive)

$$F = \frac{\mu_0}{2\pi} \times 20$$

Magnetic force on line CB,

$$F' = \frac{\mu_0}{2\pi} \frac{4 \times 1}{0.03} (0.05)$$

(Repulsive)

$$= \frac{\mu_0}{2\pi} \times \frac{20}{3}$$

Now, resultant force on loop

$$F_{net} = F - F'$$

$$= \frac{\mu_0}{2\pi} 20 \left(1 - \frac{1}{3}\right)$$

$$= 2 \times 10^{-7} \times 20 \left(\frac{2}{3}\right)$$

$$= 26.67 \times 10^{-7}\ \text{N}$$

The direction of net force is towards the wire *i.e.*, attractive.

27. Name the three different modes of propagation of electromagnetic waves. Explain, using a proper diagram the mode of propagation used in the frequency range above 40 MHz. [3]**

Physics 2012 (Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

6. Why is electrostatic potential constant throughout the volume of the conductor and has the same value (as inside) on its surface ? [1]

Answer : We know that the electric field inside a conductor is zero. This is the reason why electrostatic potential is constant, as

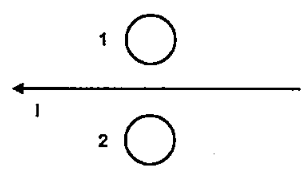
$$E = -\frac{dV}{dr}.$$

So, if $E = 0$

$$\frac{dV}{dr} = 0$$

Thus, V = constant.

8. Predict the direction of induced current in metal rings 1 and 2 when current I in the wire is steadily decreasing ? [1]



****Answers is not given due to change in the present syllabus.**

Answer : Using Lenz's law, we can predict the direction of induced current in the ring. Induced current oppose the cause of change of magnetic flux in moving towards the conductor.

In metal Ring 1, induced current will be in is clockwise.

In metal Ring 2, induced current will be in is anticlockwise.

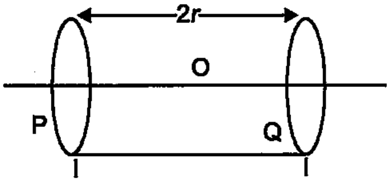
9. The relative magnetic permeability of a magnetic material is 800. Identify the nature of magnetic material and state its two properties. [2]

Answer : A magnetic material having relative permeability of 800 would be classified as a ferromagnet. A few examples of such materials include iron and nickel.
Its two properties are :

(i) All ferromagnetic materials become paramagnetic when heated to a temperature above the Curie temperatue (T_C).

(ii) These materials show a strong attraction towards magnetic fields and have a tendency to become magnets themselves.

16. Two identical circular loops, P and Q, each of radius r and carrying equal currents are kept in the parallel planes having a common axis passing through O. The direction of current in P is clockwise and in Q is anti-clockwise as seen from O which is equidistant from the loops P and Q. Find the magnitude of the net magnetic field at O. [2]



Answer : The standard formula for field at an axial point is given as

$$\frac{\mu_0 Ia^2}{2(a^2+x^2)^{3/2}}$$

Field at O due to loop P

$$B_p = \frac{\mu_0 I(r)^2}{2\left[r^2+\left(\frac{2r}{2}\right)^2\right]^{3/2}} = \frac{\mu_0 I}{2\pi}$$

And, field at O due to loop Q

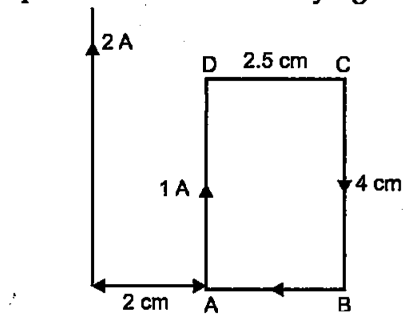
$$B_Q = \frac{\mu_0 I(r)^2}{2\left[r^2+\left(\frac{2r}{2}\right)^2\right]^{3/2}} = \frac{\mu_0 I}{2\pi}$$

Now, as the current flowing in loop P is clockwise, by using right hand thumb's rule, the direction of the magnetic field will be towards left and as the current in loop Q is clockwise then the direction of magnetic field is towards left. So the net magnetic field at point O will be the sum of the magnetic fields due to loops P and Q.

So, net field

$$B = B_P + B_Q = \frac{2\mu_0 I}{2r} = \frac{\mu_0 I}{r}$$

23. A rectangular loop of wire of size 2.5 cm × 4 cm carries a steady current of 1 A. A straight wire carrying 2 A current is kept near the loop as shown. If the loop and the wire are co-planar, find the (i) torque acting on the loop and (ii) the magnitude and direction of the force on the loop due to the current carrying wire. [3]



Answer : (i) $|\vec{\tau}| = \vec{m} \times \vec{B} = mB\sin\theta$

Here m and B have the same direction

$\therefore \quad \theta = 0°$

$\Rightarrow \quad \vec{\tau} = mB\sin\theta = 0$

(ii) We know that force between two current carrying wires is given by,

$$F = \frac{\mu_0}{2\pi}\cdot\frac{I_1 I_2}{r} l$$

On line AB and CD, the magnetic forces are equal and opposite. So they cancel out each other.

Magnetic force on line AD,

$$F = \frac{\mu_0}{2\pi}\cdot\frac{2\times1\times0.04}{0.02} \quad \text{(Attractive)}$$

$$= \frac{\mu_0}{2\pi}\times 4$$

Magnetic force on line CB,

$$F' = \frac{\mu_0}{2\pi}\cdot\frac{2\times1\times0.04}{0.045}$$

$$= \frac{\mu_0}{2\pi}\times\frac{16}{9}$$

So, net force

$$F_{net} = F - F'$$

$$= \frac{\mu_0}{2\pi}\left[4-\frac{16}{9}\right]$$

$$= 2\times10^{-7}\times\frac{20}{9}$$

$$= 4.44\times10^{-7}\text{ N}$$

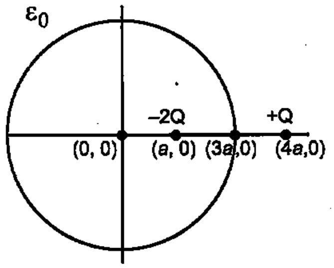
The direction of the force on the loop will be towards the wire *i.e.*, attractive.

Physics 2013 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. **Two charges of magnitudes −2Q and +Q are located at point (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '3a' with its centre at the origin ?** **[1]**

Answer : Gauss's theorem states that the electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed. The sphere encloses a charge of −2Q thus, $\phi = \frac{2Q}{\varepsilon_0}$



2. **How does the mutual inductance of a pairs of coils change when**
(i) distance between the coils is increased and
(ii) number of turns in the coils is increased ? **[1]**

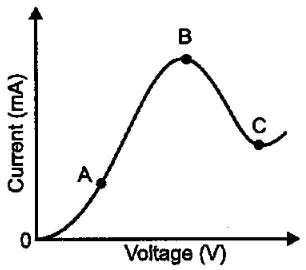
Answer : (i) As $\phi = MI$, with the increase in the distance between the coils, the magnetic flux linked with the stationary coil decreases and hence the mutual inductance of the two coils will decrease.

(ii) Mutual inductance of two coils can be found out by

$$M = \mu_0 n_1 n_2 AI$$

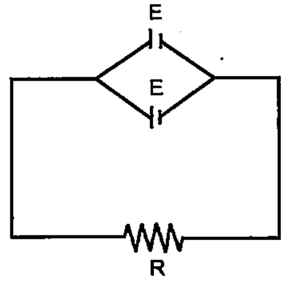
i.e., $M \propto n_1 n_2$ so with the increase in number of turns, mutual inductance increases.

3. **The graph shown in the figure represents a plot of current versus voltage for given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance.** **[1]**



Answer : Resistance of a material can be found out by the slope of the V-I curve. Part BC of the curve shows the negative resistance as with the increase in voltage, current decreases.

4. **Two identical cells, each of emf E , having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through this resistance ?** **[1]**



Answer : The cells are arranged as shown in the circuit diagram. As the internal resistance is negligible, so total resistance of the circuit = R.

So, current through the resistance, $I = \frac{E}{R}$.

5. **The motion of copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping ? [1]**

Answer : As the copper plates oscillate in the magnetic field between the two poles of the magnet, there is a continuous change of magnetic flux linked with the copper plate. Due to this, eddy currents are set up in the copper plate which try to oppose the motion of the plate according to the Lenz's law and finally bring it to rest.

6. **Define the activity of a given radioactive substance. Write its S.I. unit. [1]**

Answer : Activity of a radioactive substance is defined as number of radioactive disintegrations taking place in one second in the sample.

S. I. unit of activity is Becquerel (Bq).

1 Becquerel = 1 Bq = 1 decay per second.

7. **Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency. [1]**

Answer : Welders wear special goggles with glass windows to protect the eyes from ultraviolet rays (UV rays). The range of frequency of UV rays is 8×10^{14}Hz to 3×10^{16}Hz.

8. **Write the expression for the de-Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V. [1]**

Answer : Let v be the velocity gained by the given charge particle when it is accelerated through a potential difference of 'V' volts.

Kinetic energy of the particle = $\frac{1}{2}mv^2$.

Kinetic energy of the particle = Work done on the particle by electric field.

$$\therefore \quad \frac{1}{2}mv^2 = qV$$

$$\text{or} \quad \frac{p^2}{2m} = qV$$

$$p = \sqrt{2mqV}$$

de-Broglie wavelength (λ) associated with the particle,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

9. **Draw a typical output characteristics of an *n-p-n* transistor in CE configuration. Show how these characteristics can be used to determine output resistance.** [1]**

10. **A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit. [1]**

Answer : The distance of the n^{th} minimum from the centre of the screen is, $x_n = \frac{nD\lambda}{a}$

Where, D = distance of slit from screen = 1 m

λ = wavelength of the light = 500×10^{-9}m

a = width of the slit

For first minimum, $n = 1$

$$\text{Thus,} \quad 2.5 \times 10^{-3} = \frac{1(1)(500 \times 10^{-9})}{a},$$

$$a = 2 \times 10^{-4} \text{ m}$$

$$a = 0.2 \text{ mm}$$

11. **A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness *d*/2, where *d* is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor. [2]**

Answer : Initially when there is vacuum between the two plates, the capacitance of the two parallel plate is

$$C_0 = \frac{\varepsilon_0 A}{d}$$

Where, A is the area of parallel plates.

Suppose that the capacitor is connected to a battery, an electric field E_0 is produced.

Now, if we insert the dielectric slab of thickness $t = \frac{d}{2}$, the electric field reduces to E.

Now, the gap between plates is divided in two parts, for distance t there is electric field E and for the remaining distance $(d - t)$ the electric field is E_0.

If V is the potential difference between the plates of the capacitor, then $V = Et + E_0 (d-t)$.

**Answers is not given due to change in the present syllabus.

$$V = \frac{Ed}{2} + \frac{E_0 d}{2} = \frac{d}{2}(E + E_0) \quad \left[\because t = \frac{d}{2}\right]$$

$$V = \frac{d}{2}E_0\left(\frac{E}{E_0} + 1\right) \quad \left[\because \frac{E_0}{E} = K\right]$$

$$= \frac{dE_0}{2K}(K+1)$$

Now $E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A}$

$$\Rightarrow \quad V = \frac{d}{2K}\frac{q}{\varepsilon_0 A}(K+1)$$

We know,

$$C = \frac{q}{V} = \frac{2K\varepsilon_0 A}{d(K+1)}$$

12. A capacitor, made of two parallel plates each of plate area A and separation d, being charged by an external ac source. Show that the displacement current inside the capacitor is same as the current charging the capacitor. [2]

Answer : Let the alternating emf charging the plates of capacitor be $E = E_0 \sin \omega t$.

Charge on the capacitor,

$$q = CE = CE_0 \sin \omega t$$

Instantaneous current is I.

$$I = \frac{dq}{dt} = \frac{d}{dt}(CE_0 \sin\omega t)$$

$$= \omega CE_0 \cos \omega t$$

$$= I_0 \cos \omega t \quad \text{...(i)}$$

where, $I_0 = \omega CE_0$

Displacement current,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

$$= \varepsilon_0 A \frac{d(E)}{dt} \quad [\phi = E \cdot A]$$

$$= \varepsilon_0 A \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A}\right) \quad \left[\because E = \frac{q}{\varepsilon_0 A}\right]$$

$$= \varepsilon_0 A \frac{d}{dt}\left(\frac{CE_0 \sin \omega t}{\varepsilon_0 A}\right)$$

$$= \frac{d}{dt}(CE_0 \sin \omega t)$$

$$= \omega CE_0 \cos \omega t$$

$$= I_0 \cos \omega t \quad \text{...(ii)}$$

From equations (i) and (ii), the displacement current inside the capacitor is same as the current charging the capacitor.

13. Explain the term 'drift velocity' of electrons in a conductor. Hence obtain the expression for the current through a conductor in terms of 'drift velocity'. [3]

OR

Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a cell.

Answer : Drift velocity of electrons in a conductor : Metals contain a large number of free electrons. These electrons are in continuous random motion. Due to the random motion, the free electrons collide with positive metal ions with high frequency and undergo change in direction at each collision. So the average velocity for the electrons in a conductor is zero.

Now, when this conductor is connected to a source of emf, an electric field is established in the conductor, such that

$$E = \frac{V}{L}$$

Where, V = potential difference across the conductor and,

L = length of the conductor.

The electric field exerts an electrostatic force '$-Ee$' on each free electron in the conductor.

The acceleration of each electron is given by

$$\vec{a} = -\frac{e\vec{E}}{m}$$

Where, e = electric charge on the electron and m = mass of electron.

The negative sign indicates the force and hence the acceleration is in a direction opposite to the direction of the electric field. Due to this acceleration, the electrons attain a velocity in addition to thermal velocity in the direction opposite to that of electric field. The average velocity of all the free electrons in the conductor is called the drift velocity of free electrons of the conductor.

Thus, the expression for the drift velocity in electric field (E)

$$\vec{v} = \frac{e\vec{E}}{m}\tau \quad \text{...(i)}$$

Where τ = relaxation time between two successive collision,

Let n = number density of electrons in the conductor.

No. of free electrons in the conductor = nAL

Total charge on the conductor, $q = nALe$

Time taken by this charge to cover the length L of the conductor,

$$t = \frac{L}{v_d}$$

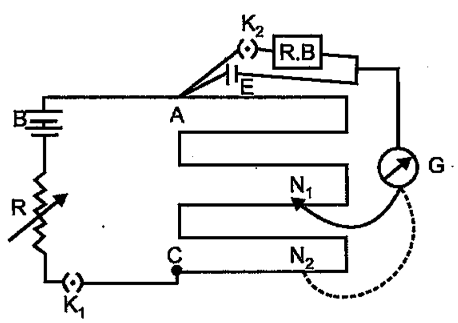
Current $$I = \frac{q}{t}$$

$$= \frac{n\,ALe}{L} \times v_d$$

$$= nAev_d$$

OR

Measurement of internal resistance of a cell using potentiometer is shown in figure. The cell of emf, E is connected across a resistance box (R) through key K_2.



When K_2 is open, balance length is obtained at length $AN_1 = l_1$

$$E \propto l_1$$

$$E = \phi\, l_1 \quad \text{...(i)}$$

When K_2 is closed :

Let V be the terminal potential difference of cell and the balance is obtained at $AN_2 = l_2$

$$V \propto l_2$$

$$V = \phi\, l_2 \quad \text{...(ii)}$$

From equations (i) and (ii), we get

$$\frac{E}{V} = \frac{l_1}{l_2} \quad \text{...(iii)}$$

But $$E = I\,(r + R)$$

$$V = IR$$

$$\frac{E}{V} = \frac{r+R}{R} \quad \text{...(iv)}$$

From equations (iii) and (iv), we get

$$\frac{R+r}{R} = \frac{l_1}{l_2}$$

$$\therefore \quad r = R\left(\frac{l_1}{l_2} - 1\right)$$

We know l_1, l_2 and R, so we can calculate r.

14. A convex lens of focal length f_1 is kept in contact with a concave lens of focal length f_2. Find the focal length of the combination. [2]

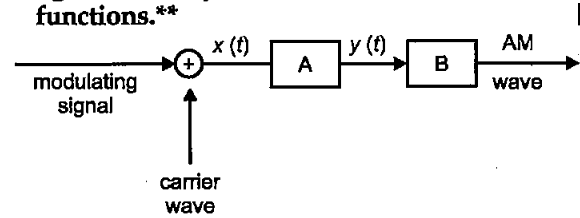
Answer : For convex lens, focal length, $f = f_1$ and for concave lens, the focal length, $f = -f_2$

The equivalent focal length of a combination of convex lens and concave lens is given as :

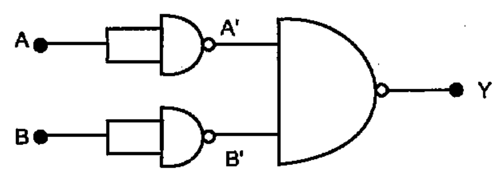
$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{-f_2}$$

$$F = \frac{f_1 f_2}{f_1 - f_2}$$

15. In the block diagram of a simple modulator for obtaining an AM signal, shown in the figure, identify the boxes A and B. Write their functions. [2]**



16. In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table. [2]**



17. (a) For a given a.c., $i = i_m \sin \omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_m^2 R$.

(b) A light bulb is rated at 100 W for a 220 V a.c. supply. Calculate the resistance of the bulb. [2]

Answer : (a) The average power dissipated

$$P = \left|i^2 R\right| = \left|i_m^2 R \sin^2 \omega t\right|$$

$$= i_m^2 R \left|\sin^2 \omega t\right|$$

$$\sin^2 \omega t = \frac{1}{2}(1 - \cos 2\,\omega t)$$

$$\Rightarrow \quad \left|\sin^2 \omega t\right| = \frac{1}{2}(1 - |\cos 2\,\omega t\,|) = \frac{1}{2}$$

$$[\because \ (|\cos 2\omega t\,|) = 0]$$

$$\therefore \quad \overline{P} = \frac{1}{2} i_m^2 R$$

(b) Power of the bulb, P = 100 W and voltage, V= 220 V.

**Answers is not given due to change in the present syllabus.

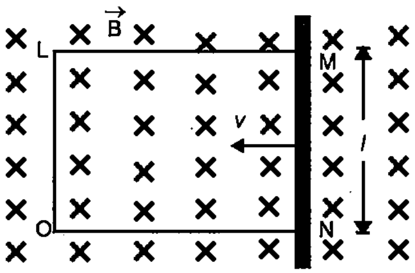
The resistance of the bulb is given as

$$R = \frac{V^2}{P}$$

$$= \frac{(220)^2}{100}$$

$$= 484\ \Omega$$

18. A rectangular conductor LMNO is placed in a uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm. [2]



OR

A wheel with 8 metallic spokes each 50 cm long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. The Earth's magnetic field at the place is 0.4 G and the angle of dip is 60°. Calculate the emf induced between the axle and the rim of the wheel. How will the value of emf be affected if the number of spokes were increased ?

Answer : Let ON be x at some instant.

The emf induced in the loop = e.

$$e = \frac{d\phi}{dt} = \frac{-d(Blx)}{dt}$$

$$e = Bl\left(\frac{-dx}{dt}\right)$$

$$= Blv = 0.5 \times 0.2 \times 10 \qquad \left[\because v = \frac{-dx}{dt}\right]$$

$$= 1\ V$$

Current in the arm,

$$I = \frac{e}{R} = \frac{1}{5} = 0.2\ A$$

OR

$H = B \cos \theta = 0.4 \cos 60° = 0.2\ G = 0.2 \times 10^{-4} T.$

This component is parallel to the plane of the wheel. Thus, the emf induced is given as,

$$E = \frac{1}{2} Bl^2\omega$$

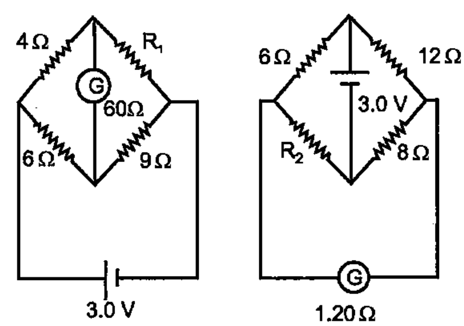
$$\text{Where, } \omega = \frac{2\pi N}{t}$$

$$E = \frac{1}{2} \times 0.2 \times 10^{-4} \times (0.5)^2 \times \frac{2 \times 3.14 \times 120}{60}$$

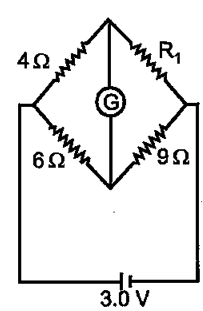
$$= 3.14 \times 10^{-5} V$$

The value of emf induced is independent of the number of spokes as the emf across the spokes are in parallel. So, the emf will be unaffected with the increase in spokes.

19. Define the current sensitivity of a galvanometer. Write S.I. unit. Figure shows two circuits each having a galvanometer and a battery of 3 V. When the galvanometers in each arrangement do not show any deflection, obtain the ratio R_1/R_2. [2]



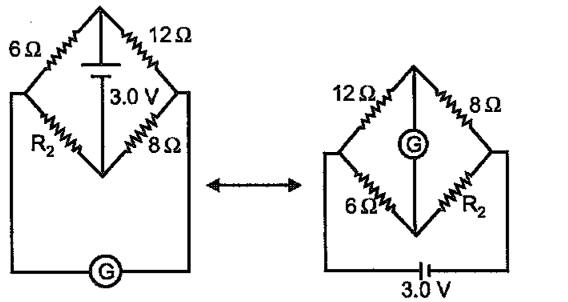
Answer : Current sensitivity of a galvanometer is defined as the deflection in galvanometer per unit current. Its SI unit is radians/ampere.



For balanced Wheatstone bridge, there will no deflection in the galvanometer.

$$\frac{4}{R_1} = \frac{6}{9}$$

$$R_1 = \frac{4 \times 9}{6} = 6\ \Omega$$



For the equivalent circuit, when the Wheatstone bridge is balanced, there will be no deflection in the galvanometer.

$$\frac{12}{8} = \frac{6}{R_2}$$

$$R_2 = \frac{6 \times 8}{12}$$

$$= 4\,\Omega$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$$

20. A wire AB is carrying a steady current 12 A and is lying on the table. Another wire CD carrying 5 A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. [Take the value of $g = 10\ \text{ms}^{-2}$] **[2]**

Answer : Force per unit length between the current carrying wires is given as :

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$

Let m be the mass per unit length of wire CD. As the force balances the weight of the wire,

$$\therefore \quad \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} = mg$$

Here, m is mass per unit length.

$$10^{-7} \times \frac{2 \times 12 \times 5}{1 \times 10^{-3}} = m \times 10$$

$$m = 10^{-7} \times \frac{2 \times 12 \times 5}{1 \times 10^{-3}} \times \frac{1}{10}$$

$$= 1.2 \times 10^{-3}\ \text{kg m}^{-1}$$

The direction of current in CD is opposite to the direction of current AB. because in this they will repel each other and CD will remain suspended.

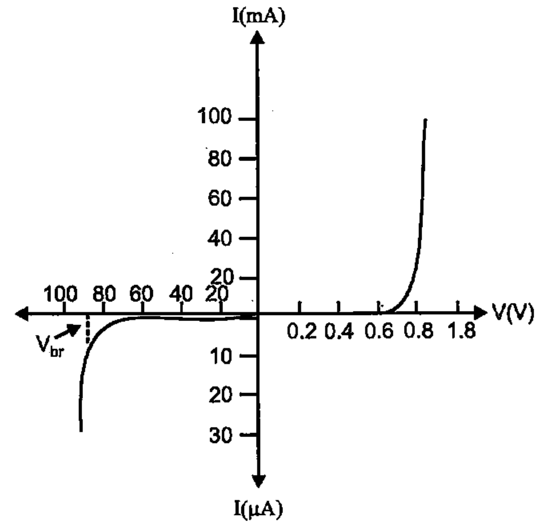
21. Draw V-I characteristics of a *p-n* junction diode. Answer the following questions, giving reasons :

(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage ?

(ii) Why does the reverse current show a sudden increase at the critical voltage ?

Name any semiconductor device which operates under the reverse bias in the breakdown region. **[3]**

Answer : V-I characteristics of *p-n* junction diode :



(i) Under the reverse bias condition, the holes of *p*-side are attracted towards the negative terminal of the battery and the electrons of the *n*-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However the minority charge carriers are drifted across the junction producing a small current. At any temperature the number of minority carriers is constant and very small so there is the small current at any applied potential. This is the reason for the current under reverse bias to be almost independent of applied potential. At the critical voltage, avalanche break down takes place which results in a sudden flow of large current.

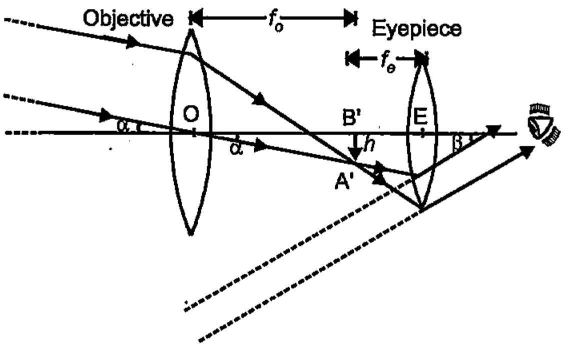
(ii) At the critical voltage, the holes in the *n*-side and conduction electrons in the *p*-side are accelerated due to the reverse-bias voltage. These minority carriers acquire sufficient kinetic energy from the electric field and collide with valence electrons. Thus, the bond is finally broken and the valence electrons move into the conduction band resulting in enormous flow of electrons and thus result in formation of hole-electron pairs. Thus, there is a sudden increase in the current at the critical voltage.

Zener diode is a semiconductor device which operates under the reverse bias condition in the breakdown region.

22. Draw a labelled ray diagram of a refracting telescope. Define its magnifying power and write the expression for it.

Write two important limitations of a refracting telescope over a reflecting type telescope. [3]

Answer : Refracting telescope :



Magnifying power : The magnifying power is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye.

$$m = -\frac{\beta}{\alpha} = -\frac{h}{f_e} \cdot \frac{f_o}{h} = -\frac{f_o}{f_e}$$

Limitations of refracting telescope over reflecting type telescope :

(i) Refracting telescope suffers from chromatic aberration as it uses large sized lenses.

(ii) The requirement of big lenses tend to be very heavy and therefore, difficult to make and support by their edges.

23. Write Einstein's photoelectric equation and point out any two characteristic properties of photons on which this equation is based.

Briefly explain the three observed features which can be explained by this equation. [4]

Answer : Einstein's photoelectric effect equation :

$$K_{max} = \frac{1}{2} m v_{max}^2 = (h\nu - \phi_0)$$

or $$K_{max} = h(\nu - \nu_0)$$

The two characteristics properties of the photon on which this equation is based :

(i) The light travel in the form of photons *i.e.* small packet of enery and each photon has energy $h\nu$.

(ii) Each photon interact with one electron.

Three observed features that can be explained by this equation.

(i) When $\nu < \nu_0$, K_{max} becomes negative. The negative value of K./E. has no physical significance. Hence, no photoelectric effect is possible below there shold frequency.

(ii) When $\nu > \nu_0$, $K_{max} \propto \nu$, *i.e.* max. K.E. of the emitted photo electrons depends linearly on the frequency of incident radiations.

(iii) It is clear from the photoelectric equation that the maximum K.E. of photoelectrons is independent of intensity of incident reactions.

24. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies ?

A transmitting antenna at the top of a tower has a height of 20 m and the height of the receiving antenna is 45 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4×10^6 m)**

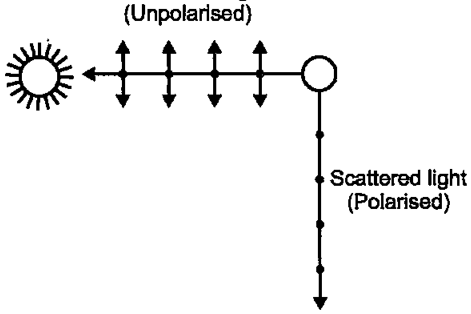
[5]

25. (a) What is linearly polarised light. Describe briefly using a diagram how sunlight is polarised.

(b) Unpolarised light is incident on a Polaroid. How would the intensity of transmitted light change when the Polaroid is rotated ? [5]

Answer : (a) The light in which the vibrations of electric vector are restricted to a particular plane, is called plane polarised light.

The incident sunlight is unpolarised. The dot and double arrows show the polarisation in the perpendicular and in the plane of the figure respectively. Under the influence of the electric field of the incident wave, the electrons in the molecules of the atmosphere acquire components of motion in both these directions. For an observer looking at 90° to the direction of the sun, the charges accelerating parallel to the double arrows do not radiate energy towards this observer since their acceleration has no transverse component. The radiation scattered by the molecule is therefore, represented by dots. It is linearly polarised light perpendicular to the plane of the figure.



(b) If the unpolarised light is incident on a polaroid, the intensity is reduced by half. Even if the polaroid is rotated by angle θ the average

****Answers is not given due to change in the present syllabus.**

over $\cos^2\theta = \frac{1}{2}$. Thus, from Malus' law : $I = I_0 \cos^2\theta$

$$|I| = |I_0 \cos^2\theta|$$
$$= I_0 |\cos^2\theta| = \frac{I_0}{2}$$

Thus, the intensity of the transmitted light remains unchanged when the polaroid is rotated.

26. One day Chetan's mother developed a severe stomach ache all of a sudden. She rushed to the doctor who suggested for an immediate endoscopy test and gave an estimate of expenditure for the same. Chetan immediately contacted his class teacher and shared the information with her. The class teacher arranged for the money and rushed to the hospital. On realizing that Chetan belonged to a below average income group family, even the doctor offered concession for the test fee. The test was conducted successfully.

Answer the following questions based on the above information : [5]

(a) Which principle in optics is made use of in endoscopy ?

(b) Briefly explain the values reflected in the action taken by the teacher.**

(c) In what way do you appreciate the response of the doctor on the given situation ?

Answer : (a) Endoscopy is based on total internal reflection principle. It has tubes which are made up of optical fibres and are used for transmitting and receiving electrical signals, which are converted into light by suitable transducer.

(c) Doctor gave monetary help to Chetan by understanding his poor financial condition

27. (a) Using Biot-Savart's law, derive the expression for the magnetic field in the vector form at a point on the axis of a circular current loop.

(b) What does a toroid consist of ? Find out the expression for the magnetic field inside a toroid for N turns of the coil having the average radius r and carrying a current I. Show that the magnetic field in the open space inside and exterior to the toroid is zero. [5]

OR

(a) Draw a schematic sketch of a cyclotron. Explain clearly the role of crossed electric and magnetic field in accelerating the charge. Hence derive the expression for the kinetic energy acquired by the particles.

(b) An α-particle and a photon are released from the centre of the cyclotron and made to accelerate.

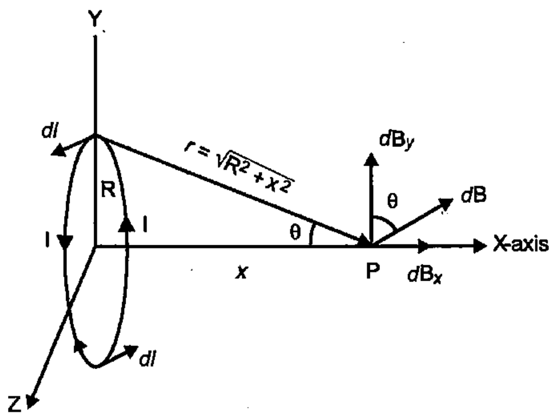
(i) Can both be accelerated at the same cyclotron frequency ? Give reason to justify your answer.

(ii) When they are accelerated in turn, which of the two will have higher velocity at the exit slit of the dees ?

Answer : (a) Magnetic field on the axis of a circular loop

$I \rightarrow$ Current
$R \rightarrow$ Radii
$X \rightarrow$ Axis
$x \rightarrow$ Distance of OP
$dl \rightarrow$ Conducting element of the loop

According to Biot-Savart's law, the magnetic field at P is



$$dB = \frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\vec{r}}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \quad \left[\because \vec{dl} \perp \hat{r}\right]$$

dB has two components dB_x and dB_y. dB_y components being in opposite direction cancel out each other and dB_x component being in same direction added up.

$$\therefore \quad dB_x = dB\sin\theta$$

$$= \frac{\mu_0 Idl}{4\pi r^2}\times\frac{R}{(x^2+R^2)^{1/2}}$$

$$dB_x = \frac{\mu_0 Idl}{4\pi}\times\frac{R}{(x^2+R^2)^{\frac{3}{2}}}$$

$[\because r^2 = x^2 + R^2]$

Total magnetic field at P

$$B = \int dB_x$$

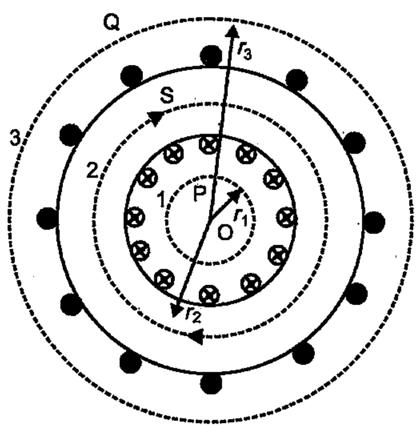
$$= \int \frac{\mu_0 IR\,dl}{4\pi (x^2 + R^2)^{3/2}}$$

$$\frac{\mu_0 IR}{4\pi (x^2 + R^2)^{3/2}} \int dl = \frac{\mu_0 IR}{4\pi \left(x^2 + R^2\right)^{3/2}} \times 2\pi R$$

$$B = \frac{\mu_0 IR^2}{2\left(x^2 + R^2\right)^{3/2}}$$

$$\vec{B} = \frac{\mu_0 IR^2}{2\left(x^2 + R^2\right)^{3/2}} \hat{i}$$

(b) Toroid is a hollow circular ring on which a large number of turns of a wire are closely wound. Figure shows a sectional view of the toroid. The direction of the magnetic field inside is clockwise as per the right-hand thumb rule for circular loops. Three circular Amperian loops 1, 2 and 3 are shown by dashed lines.



By symmetry, the magnetic field should be tangential to each of them and constant in magnitude for a given loop.

Let the magnetic field inside the toroid be B. Then by Ampere's circuital law,

$$\int \vec{B} \cdot \vec{dl} = \mu_0 I \Rightarrow BL = \mu_0 NI$$

Where, L is the length of the loop for which B is tangential, I is the current enclosed by one loop and N is the number of turns.

We find, $L = 2\pi r$

The current threads the ring as many times are there are turns in the solenoid, therefore total current in the solenoid is NI.

$$B(2\pi r) = \mu_0 NI$$

or $$B = \frac{\mu_0 NI}{2\pi r}$$

Open space inside the toroid encloses no current thus, I = 0.

Hence, B = 0

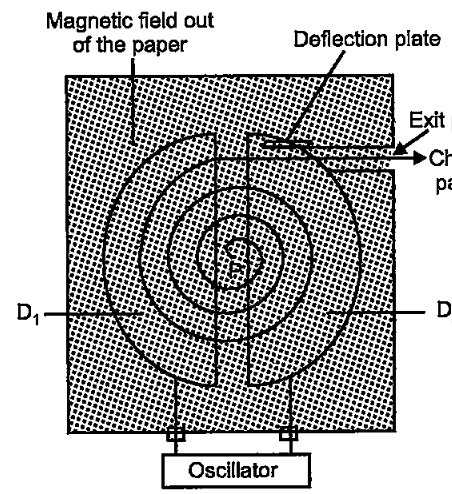
Open space exterior to the toroid :

Each turn of current carrying wire is cut twice by the loop 3. Thus, the current coming out of the plane of the paper is cancelled exactly by the current going into it. Thus,

I= 0, and B = 0

OR

(a) Schematic sketch of cyclotron : The combination of crossed electric and magnetic field is used to increase the energy of the charged particle. Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy. Inside the dees particle is shielded from the electric field and magnetic field acts on the particle and makes it to go round in a circular path. Every time the particle moves from one dee to the other it comes under the influence of electric field which ensures to increase the energy of the particles as the sign of the electric field changed alternately. The increase in energy increases the radius of the circular path so the accelerated particle moves in a spiral path.



Since, magnetic force provides required centripetal force

$$\therefore \quad qvB = \frac{mv^2}{r}$$

or $$r = \frac{mv}{qB}$$

Here, r is the radius of semi-circular path which a particle covers inside a dee.

Hence, the kinetic energy of ions,

$$\text{K.E.} = \frac{1}{2}mv^2$$

$$\text{K.E.} = \frac{1}{2}m\frac{r^2q^2B^2}{m^2} \quad \left[\because v = \frac{rqB}{m}\right]$$

$$\text{K.E.} = \frac{1}{2}\frac{r^2q^2B^2}{m^2}$$

(b) (i) Let us consider :

$m \rightarrow$ mass of proton

$q \rightarrow$ charge of proton

$\therefore$ Mass of alpha particle = 4 m

Charge of alpha particle = 2 q

Cyclotron frequency is given by,

$$\nu = \frac{Bq}{2\pi m}$$

or $$\nu \propto \frac{q}{m}$$

For proton :

Frequency, $$\nu_p \propto \frac{q}{m}$$

For alpha particle,

Frequency, $$\nu_\alpha \propto \frac{2q}{4m}$$

or $$\nu_\alpha \propto \frac{q}{2m}$$

Thus, particles will not accelerate with same cyclotron frequency. The frequency of proton is twice than the frequency of alpha particle.

(ii) Velocity, $$v = \frac{Bqr}{m}$$

or $$v \propto \frac{q}{m}$$

For proton :

Velocity, $$v \propto \frac{q}{m}$$

For alpha particle :

Velocity, $$v_\alpha \propto \frac{2q}{4m} \text{ or } v_\alpha \propto \frac{q}{2m}$$

Thus, particles will not exit the dees with same velocity. The velocity of proton is twice the velocity of alpha particle.

28. (a) Define electric dipole moment. Is it a scalar or a vector ? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.

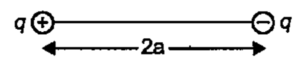
(b) Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero. [5]

OR

Using Gauss' law deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point (i) outside and (ii) inside the shell.

Plot a graph showing variation of electric field as a function of r > R and r < R. (r being the distance from the centre of the shell)

Answer : (a) Electric dipole moment : Electric dipole moment is defined as the product of magnitude of either charges and the distance between the positive and negative charge of the electric dipole. The strength of any electric dipole is measured by the magnitude of its electric dipole moment.

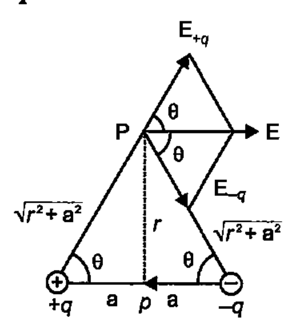


Electric dipole moment, $p = q \times 2a$

It is a vector quantity.

In vector form it is written as $\vec{p} = q \times 2\vec{a}$ where the direction of $\vec{a}$ is from negative charge to positive charge.

Electric Field of dipole at points on the equatorial plane :



Let P be the point on the equatorial plane of the dipole where electric field is to be calculated. Let its distance from either charge be 'r'. The magnitude of the electric field due to the two charges $+q$ and $-q$ at P is given by

$$E_{+q} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r^2 + a^2} \quad \text{...(i)}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r^2 + a^2} \quad \text{...(ii)}$$

From equations (i) and (ii),

$$E_{+q} = E_{-q} = E(\text{say})$$

The direction of E_{+q} and E_{-q} are shown in figure.

Total electric field at P,

$$\vec{E}_p = \vec{E}_{+q} + \vec{E}_{-q}$$

Magnitude of E (using || gm law of vector addition),

$$E_p = \sqrt{E_{+q}^2 + E_{-q}^2 + 2E_{+q}E_{-q}\cos 2\theta}$$

$$= \sqrt{E^2 + E^2 + 2E^2\cos 2\theta}$$

$$= \sqrt{2E^2 + 2E^2\cos 2\theta}$$

$$= \sqrt{2E^2(1+\cos 2\theta)}$$

$$= \sqrt{2E^2\, 2\cos^2\theta}$$

$$= \sqrt{4E^2\cos^2\theta}$$

$$E_p = 2E\cos\theta$$

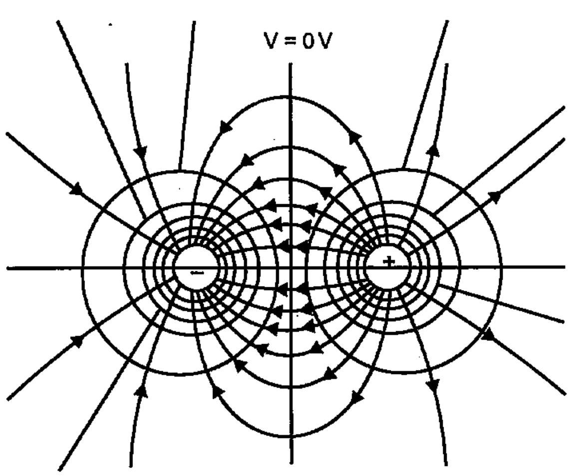
$$= 2\times\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\times\frac{a}{(r^2+a^2)^{1/2}}$$

$$E_p = \frac{2aq}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}$$

$$E_p = \frac{p}{4\pi\varepsilon_0(r^2+a^2)^{3/2}} \quad [\because p = 2aq]$$

$$\vec{E}_p = \frac{\vec{p}}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}$$

(b) Equipotential surface due to electric dipole :

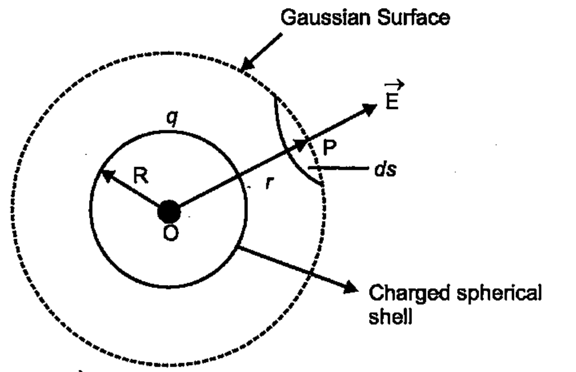


The potential due to the dipole is zero at the line bisecting the dipole length.

OR

Electric field due to a uniformly charged thin spherical shell :

(i) When point P lies outside the spherical shell : Consider a spherical shell of radius R and centre O. Let q be the charge on the spherical shell. Suppose that we have to calculate electric field at the point P at a distance r (r > R) from its centre. Draw the Gaussian surface through point P so as to enclose the charged spherical shell. The Gaussian surface is a spherical shell of radius r and centre O.



Let $\vec{E}$ be the electric field at point P. Then, the electric flux through area element $\vec{ds}$ is given by

$$d\phi = \vec{E}\cdot\vec{ds}$$

Since $\vec{ds}$ is also along normal to the surface,

$$\therefore \quad d\phi = E\,ds$$

∴ Total electric flux through the Gaussian surface is given by

$$\phi = \oint_S E.ds$$

$$= E\oint_S ds$$

Now,

$$\oint ds = 4\pi r^2$$

$$\therefore \quad \phi = E\times 4\pi r^2 \quad \text{...(i)}$$

Since the charge enclosed by the Gaussian surface is q, according to Gauss theorem,

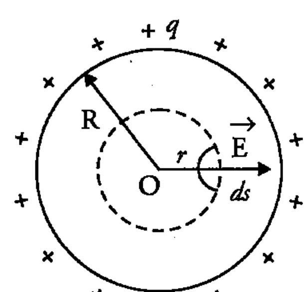
$$\phi = \frac{q}{\varepsilon_0} \quad \text{...(ii)}$$

From equations (i) and (ii), we get,

$$E\times 4\pi r^2 = \frac{q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2} \quad (\text{for } r > R)$$

(ii) When point P lies inside the spherical shell : In such a case the Gaussian surface encloses no charge,

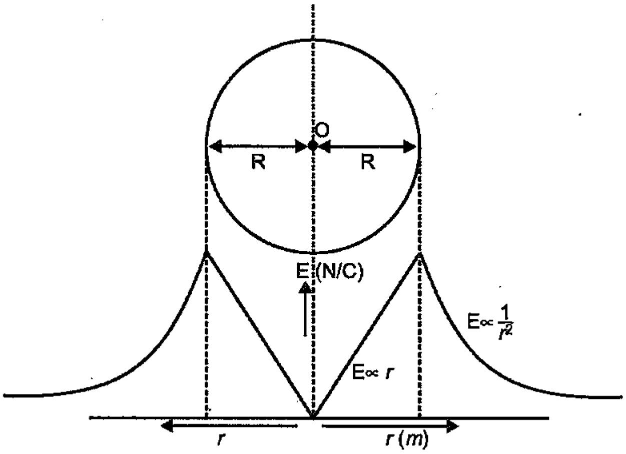


According to Gauss law,

$$E \times 4\pi r^2 = 0$$

i.e., $E = 0 \ (r < R)$

Graph showing the variation of electric field as a function of r.



29. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f).

When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$, identify the spectral series to which the emission lines belong. [5]

OR

(a) Draw the plot of binding energy per nucleon (BE/A) as a function of mass number. Write two important conclusions that can be drawn regarding the nature of nuclear source.

(b) Use this graph to explain the release of energy in both the processes of nuclear fusion and fission.

(c) Write the basic nuclear process of neutron undergoing β-decay. Why is the detection of neutrinos found very difficult ?

Answer : In the hydrogen atom,

Radius of electron orbit,

$$r = \frac{n^2h^2}{4\pi^2kme^2} \quad ...(i)$$

Kinetic energy of electron,

$$E_k = \frac{1}{2}mv^2 = \frac{ke^2}{2r}$$

Using equation (i), we get

$$E_k = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$$

Potential energy,

$$E_p = \frac{-k(e)\times(e)}{r} = \frac{-ke^2}{r}$$

Using equation (i), we get

$$E_p = -ke^2 \times \frac{4\pi^2k\,kme^2}{n^2h^2}$$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2}$$

Total energy of electron,

$$E = \frac{2\pi^2k^2me^4}{n^2h^2} - \frac{4\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{h^2} \times \left(\frac{1}{n^2}\right)$$

Now, according to Bohr's frequency condition when electron in hydrogen atom undergoes transition from higher energy state to the lower energy state (n_f) is,

$$h\nu = E_{n_i} - E_{n_f}$$

$$\text{or} \quad h\nu = -\frac{2\pi^2k^2me^4}{h^2} \times \frac{1}{n_i^2} - \left(\frac{-2\pi^2k^2me^4}{h^2} \times \frac{1}{n_f^2}\right)$$

$$\text{or} \quad h\nu = \frac{2\pi^2k^2me^4}{h^2} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\nu = \frac{2\pi^2k^2me^4}{h^3} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\nu = \frac{c2\pi^2k^2me^4}{ch^3} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{2\pi^2k^2me^4}{ch^3} = R \text{ (Rydberg constant)}$$

$$R = 1.097 \times 10^7 m^{-1}$$

Thus,

$$\nu = Rc \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Now, higher state,

$$n_i = 4$$

Lower state,

$$n_f = 3, 2, 1$$

For the transition

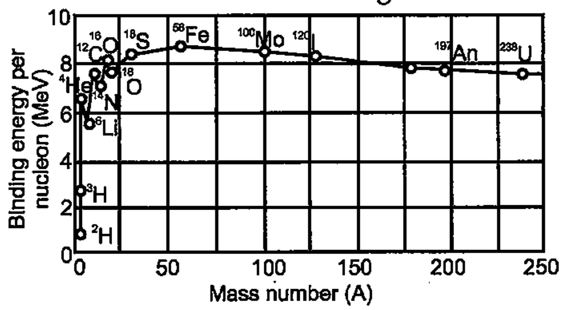
$n_i = 4$ to $n_f = 3 \rightarrow$ Paschen series

$n_i = 4$ to $n_f = 2 \rightarrow$ Balmer series

$n_i = 4$ to $n_f = 1 \rightarrow$ Lyman series

OR

(a) Plot of binding energy per nucleon as the function of mass number A is given as below :



Following are the two conclusion that can be drawn regarding the nature of the nuclear force :

(i) The force is attractive and strong enough to produce a binding energy of few MeV per nucleon.

(ii) The constancy of the binding energy in the range 30 <A<170 is a consequence of the fact that the nuclear force is short range force.

(b) Nuclear fission : A very heavy nucleus (say, A = 240) has lower binding energy per nucleon as compared to the nucleus with A = 120. Thus, if the heavier nucleus breaks to the lighter nucleus with high binding energy per nucleon, nucleons are tightly bound.

This implies that energy will be released in the process which justifies the energy release in fission reaction.

Nuclear fusion : When two light nuclei (A<10) are combined to form a heavier nuclei, the binding energy of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. Thus the final system is more tightly bound than the initial system. Again the energy will be released in fusion reaction.

(c) The basic nuclear process of neutron undergoing β-decay is given as :

$$n \rightarrow p + e^- + \bar{\nu}$$

Neutrinos are massless and chargeless particles. Neutrinos interact very weakly with matter that it becomes very difficult to detect them. That's why the detection of neutrinos is found very difficult.

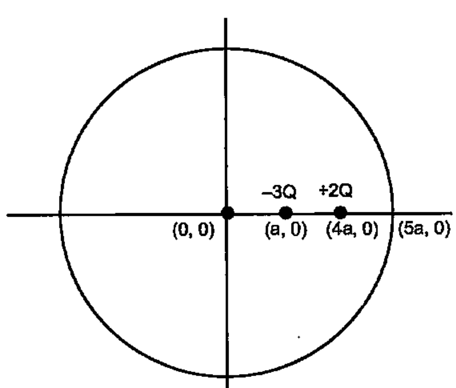
Physics 2013 (Outside Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

4. Two charges of magnitudes –3Q and +2Q are located at points (*a*, 0) and (4*a*, 0) respectively. What is the electric flux due to these charges through a sphere of radius '5*a*' with its centre at the origin ?[1] **[1]**

Answer : According to Gauss' theorem, the electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.



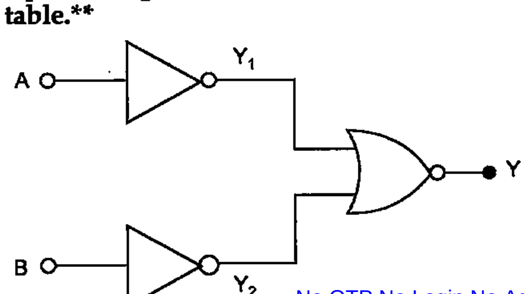
The sphere enclose charge = –3Q + 2Q = –Q

$\therefore$ Total electric flux, $\phi = \frac{Q}{\varepsilon_0}$

7. A light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why ? Give reason. **[2]**

Answer : A light metal disc on the top of an electromagnet is thrown up as the current is switched on because when the current flows through the electromagnet, the magnetic flux through the disc increases which leads in setting up an eddy current in the disc in the same direction of the electromagnetic current. So the upper surface of electromagnet and the lower surface of the disc acquire same polarity. Since body with same polarity repels, therefore, the disc is thrown up.

9. In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table.** **[2]**



**Answer is not given due to change in the present syllabus.

13. A parallel beam of light of 600 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.2 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit. [3]

Answer : The distance of the n^{th} minimum from the centre of the screen is, $x_n = \frac{nD\lambda}{a}$

where, D= distance of slit from screen

λ = wavelength of the light

a = width of the slit

For first minimum, $n = 1$

$x_n = 3 \times 10^{-3}$ m

$\lambda = 600 \times 10^{-9}$ m

D = 1.2 m

$$3 \times 10^{-3} = \frac{1 \times 1.2 \times 600 \times 10^{-9}}{a}$$

$$a = \frac{1 \times 1.2 \times 600 \times 10^{-9}}{3 \times 10^{-3}}$$

$$= \frac{1.2 \times 6 \times 10^{-4}}{3}$$

$$= 2.4 \times 10^{-4} \text{ m}$$

$$= 0.24 \times 10^{-3} \text{ m}$$

$$a = 0.24 \text{ mm}$$

19. A wire AB is carrying a steady current of 10 A and is lying on the table. Another wire CD carrying 6 A is held directly above AB at a height of 2 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. [Take the value of $g = 10 \text{ ms}^{-2}$] [3]

Answer : Force per unit length between the current carrying wires is given as :

$$F = \frac{\mu_0}{4\pi} \frac{2I_1I_2}{r}$$

where

The current in wire AB, $I_1 = 10$ A

The current in wire CD, $I_2 = 6$ A

The distance between wires, $r = 2 \text{ mm} = 2 \times 10^{-3}$m

Let m be the mass per unit length of wire CD.

As this force balances the weight of the wire CD.

$$\therefore \quad \frac{\mu_0}{4\pi} \frac{2I_1I_2}{r} = mg$$

$$\Rightarrow \quad 10^{-7} \times \frac{2 \times 10 \times 6}{2 \times 10^{-3}} = m \times 10$$

$$\therefore m = 10^{-7} \times \frac{2 \times 10 \times 6}{2 \times 10^{-3}} \times \frac{1}{10} = 6 \times 10^{-4} \text{ kg/m}$$

The direction of current in CD w.r.t. AB is opposite (antiparallel) because in this condition both the wires will repel each other.

23. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies ?

A transmitting antenna at the top of a tower has a height of 45 m and the height of the receiving antenna is 80 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4×10^6 m) [4]**

24. (a) For a given a.c., $i = i_m \sin\omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_m^2$RR

(b) A light bulb is rated at 120 W for a 240 V a.c. supply. Calculate the resistance of the bulb. [5]

Answer : (a) The average power dissipated

$$P_{av} = \langle i^2R \rangle = \langle i_m^2 R \sin^2\omega t \rangle$$
$$= i_m^2 R \langle \sin^2\omega t \rangle$$

since, $\sin^2 \omega t = \frac{1}{2}(1 - \cos 2\omega t)$

$$\therefore \quad \langle \sin^2 \omega t \rangle = \frac{1}{2}[1 - \langle \cos 2\omega t \rangle] = \frac{1}{2}$$

$[\because \langle\cos 2\omega t\rangle = 0]$

$$\therefore \quad P_{av} = \frac{1}{2} i_m^2 R$$

(b) Power of the bulb, P = 120 W

Voltage, V = 240 V

The resistance of the bulb is given as

$$R = \frac{V^2}{P} = \frac{240^2}{120} = 480\ \Omega.$$

**Answers is not given due to change in the present syllabus.

Physics 2013 (Outside Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions all the remaining question have been asked in previous Sets.

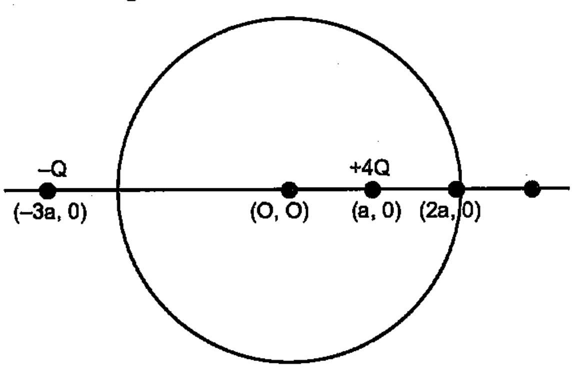
1. **Write the expression for the de-Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V.** **[1]**

Answer : de-Broglie wavelength associated with the particle,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

3. **Two charges of magnitudes + 4Q and –Q are located at points $(a, 0)$ and $(-3a, 0)$ respectively. What is the electric flux due to these charges through a sphere of radius '$2a$' with its centre at the origin ?** **[1]**

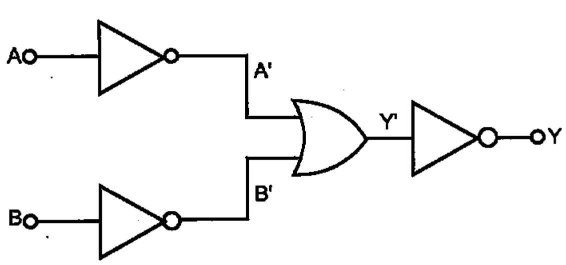
Answer : Gauss's theorem states that the electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.



The sphere enclose charge = + 4Q

Thus, total electric flux $\phi = \frac{4Q}{\varepsilon_0}$

9. **In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table.**** **[1]**



**Answers is not given due to change in the present syllabus.

11. **A parallel beam of light of 450 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.5 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit.** **[2]**

Answer : The distance of the n^{th} minimum from the centre of the screen,

$$x_n = \frac{nD\lambda}{a}$$

Where, D → distance of slit from screen.

λ → wavelength of the light.

a → width of the slit

For first minimum, $n = 1$,

$$x_n = 3 \times 10^{-3} \text{ m}$$
$$D = 1.5 \text{ m}$$
$$\lambda = 450 \times 10^{-9} \text{ m}$$

$$3\times10^{-3} = \frac{1\times(1.5)\times(450\times10^{-9})}{a} \frac{nD\lambda}{a}$$

$$a = \frac{1\times(1.5)\times(450\times10^{-9})}{3\times10^{-3}}$$

$$a = 0.255\text{mm}$$

17. **A wire AB is carrying a steady current of 6 A and is lying on the table. Another wire CD carrying 4 A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. [Take the value of $g = 10 \text{ ms}^{-2}$]** **[3]**

Answer : Force per unit length between the current carrying wire is given as :

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$

Let m be the mass per unit length of wire CD. As the force balance the weight of the wire

$$\therefore \quad \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} = mg$$

Here m → Mass per unit length

$$\frac{10^{-7}\times2\times6\times4}{1\times10^{-3}} = m\times10$$

$$m = 4.8 \times 10^{-4} \text{ kg m}^{-1}$$

The current in CD is in opposite direction to that in AB than they will repel each other and CD wire remain suspended in air.

18. (b) A light bulb is rated at 125 W for a 250 V a.c. supply. Calculate the resistance of the bulb. [3]

Answer : (b) Power of the bulb, P = 125 W

Voltage, V = 250 V

The resistance of the bulb is given as

$$R = \frac{V^2}{P} = \frac{(250)^2}{125}$$

$$= 500\ \Omega$$

25. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies ?

A transmitting antenna at the top of a power has a height of 45 m and the receiving antenna is on the ground. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4 × 10^{6}m) [5]**

●●

Physics 2013 (Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

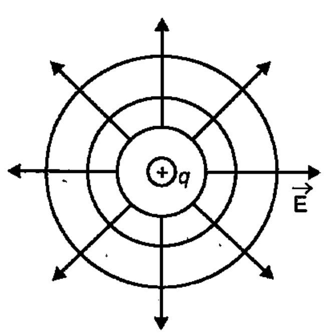
1. What are permanent magnets ? Give one example. [1]

Answer : The magnets which have high retentivity and high coercivity are known as permanent magnets.

For example : Steel, cobalt

2. What is the geometrical shape of equipotential surface due to a single isolated charge ? [1]

Answer : The equipotential surfaces of an isolated charge are concentric spherical shells and the distance between the shells increase with the decrease in electric field and vice-versa.



3. Which of the following waves can be polarized (i) Heat waves (ii) Sound waves ? Give reason to support your answer. [1]

Answer : Heat waves can be polarized as they are transverse waves whereas sound waves cannot be polarized as they are longitudinal waves.

Transverse waves can oscillate in the direction perpendicular to the direction of its transmission but longitudinal waves oscillate only along the direction of its transmission. So, longitudinal waves cannot be polarized.

4. A capacitor has been charged by a dc source. What are the magnitude of conduction and displacement current, when it is fully charged ? [1]

Answer : Electric flux through plates of capacitor,

$$\phi = \frac{q}{\varepsilon_0}$$

Here charge q is constant as the capacitor is fully charged.

Displacement current,

$$I_D = \varepsilon_0 \frac{d\phi}{dt} = \varepsilon_0 \frac{d\left(\frac{q}{\varepsilon_0}\right)}{dt} = 0$$

[since q is constant]

Conduction current,

$$I = C\frac{dV}{dt} = 0$$

As voltage also becomes constant when capacitor is fully charged.

Therefore, magnitude of di splacement to and induction current is zero.

5. Write the relationship between angle of incidence 'i', angle of prism 'A' and angle of minimum deviations δ_m for a triangular prism. [1]

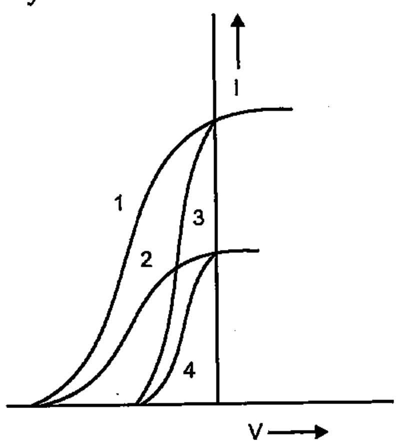
Answer : The relation between the angle of incidence i, angle of prism A, and the angle of minimum deviation δ_m, for a triangular prism is given by

$$i = \frac{A + \delta_m}{2}$$

6. The given graph shows the variation of photoelectric current (I) versus applied voltage (V) for two different photosensitive materials

**Answers is not given due to change in the present syllabus.

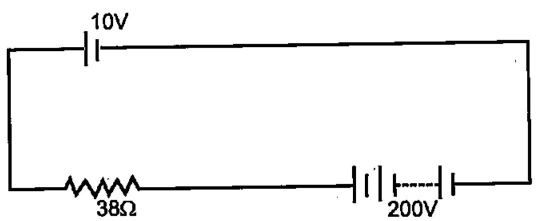
and for two different intensities of the incident radiations. Identify the pairs of curves that correspond to different materials but same intensity of incident radiation. **[2]**



Answer : Curves 1 and 2 correspond to similar materials while curves 3 and 4 represent different materials, since the value of stopping potential for 1, 2 and 3, 4 are the same. For the given frequency of the incident radiation, the stopping potential is independent of its intensity.

So, the pairs of curves (1 and 3) and (2 and 4) correspond to different materials but same intensity of incident radiation.

7. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current in circuit. **[2]**



Answer : Since, the positive terminal of the batteries are connected together (So they oppose each other), so the equivalent emf of the batteries is given by

$$E = 200 - 10 = 190 \text{ V}$$

Hence, the current in the circuit is given by

$$I = \frac{E}{R} = \frac{190}{38} = 5A$$

8. The emf of a cell is always greater than its terminal voltage. Why ? Give reason. **[2]**

Answer : The emf of a cell is greater than its terminal voltage because there is some potential drop across the cell due to its small internal resistance.

9. (a) Write the necessary conditions for the phenomenon of total internal reflection to occur.

(b) Write the relation between the refractive index and critical angle for a given pair of optical media. **[2]**

Answer : (a) Necessary conditions for total internal reflection to occur are :

1. The incident ray on the interface should travel in optically denser medium.
2. The angle of incidence should be greater than the critical angle for the given pair of optical media.

(b) $$^a\mu_b = \frac{1}{\sin C}$$

Where a and b are the rarer and denser media respectively. C is the critical angle for the given pair of optical media.

10. State Lenz's law.

A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends ? Justify your answer. **[2]**

Answer : Lenz's law states that the polarity of induced emf is such that it produces a current which opposes the change in magnetic flux that produces it.

Yes, emf will be induced in the rod as there is change in magnetic flux.

When a metallic rod held horizontally along east-west direction, is allowed to fall freely under gravity *i.e.*, fall from north to south, the magnetic flux changes due to vertical component of Earth's magnetic field, which keeps on changing and the emf is induced in it.

11. A convex lens of focal length 25 m is placed coaxially in contact with a concave lens of focal length 20 cm. Determine the power of the combination. Will the system be converging or diverging in nature ? **[2]**

Answer : We have, focal length of convex lens,

$$f_1 = +25 \text{ cm} = +0.25 \text{ m}$$

Focal length of the concave lens,

$$f_2 = -20 \text{ cm} = -0.20 \text{ m}$$

Equivalent focal length,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} + \frac{1}{-20} = -\frac{1}{100}$$

$\therefore$ $F = -100$ cm

Power of convex lens,

$$P_1 = \frac{1}{f_1} = \frac{1}{0.25}$$

Power of concave lens,

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.20}$$

Power of the combination,

$$P = P_1 + P_2$$

$$P = \frac{1}{0.25} + \frac{1}{-0.20} = \frac{100}{25} - \frac{100}{20} = \frac{400-500}{100}$$

$$= -\frac{100}{100} = -1$$

$\therefore$ $P = -1\,D$

The focal length of the combination

$= -1m = -100$ cm.

As the focal length is negative, the system will be diverging in nature.

12. An ammeter of resistance 0.80 Ω can measure current up to 1.0 A. [3]

(i) What must be the value of shunt resistance to enable the ammeter to measure current up to 5.0 A ?

(ii) What is the combined resistance of the ammeter and the shunt ?

Answer : We have, resistance of ammeter, $R_A = 0.80\,\Omega$

Maximum current through ammeter, $I_A = 1.0$ A

So, voltage across ammeter, $V = IR = 1 \times 0.80 = 0.8V$

Let the value of shunt be x.

(i) Resistance of ammeter with shunt,

$$R = \frac{R_A x}{R_A + x} = \frac{0.8x}{0.8+x}$$

Current through ammeter, I = 5 A

$$\therefore \left(\frac{0.8x}{0.8+x}\right) \times 5 = 0.8$$

$$\Rightarrow \quad 0.8x \times 5 = 0.8(0.8+x)$$

$$4x = 0.64 + 0.8x$$

$$x = \frac{0.64}{3.2}$$

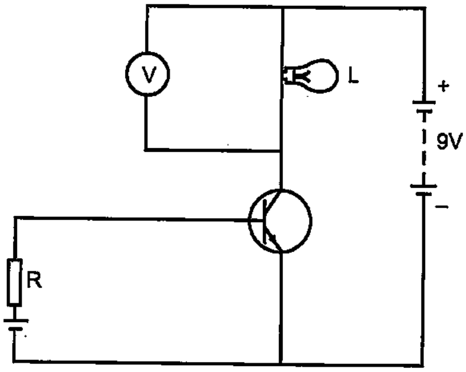
$$x = 0.2$$

Thus, the shunt resistance is 0.2 Ω

(ii) Combined resistance of the ammeter and the shunt,

$$R = \frac{0.8x}{0.8+x} = \frac{0.8 \times 0.2}{0.8+0.2} = \frac{0.16}{1} = 0.16\,\Omega$$

13. In the given circuit diagram a voltmeter 'V' is connected across a lamp 'L'. How would (i) the brightness of the lamp and (ii) voltmeter reading 'V' be affected, if the value of resistance 'R' is decreased ? Justify your answer. [3]



Answer : The given figure is Common Emitter (CE) configuration of an *n-p-n* transistor. The input circuit is forward biased and collector circuit is reverse biased.

If resistance R decreases, forward biased in the input circuit will increase, thus the base current (I_B) will decrease and the emitter current (I_E) will increase. This will increase the collector current (I_C) as $I_E = I_B + I_C$.

When I_C increases which flows through the lamp, the voltage across the bulb will also increase making the lamp brighter and since the voltmeter is connected in parallel with the lamp, the reading in the voltmeter will also increase.

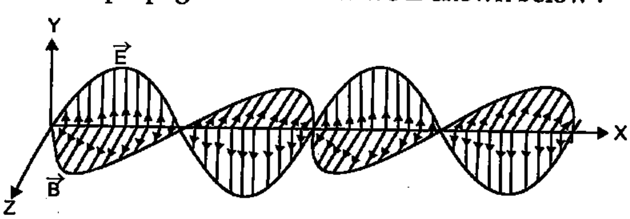
14. (a) An EM wave is travelling in a medium with a velocity $v = v\hat{i}$. Draw a sketch showing the propagation of the EM wave, indicating the direction of the oscillating electric and magnetic fields.

(b) How are the magnitudes of the electric and magnetic fields related to velocity of the EM wave ? [3]

Answer : (a) Given.

Velocity, $v = v\hat{i}$ and electric field, E along Y-axis and magnetic field, B along Z-axis.

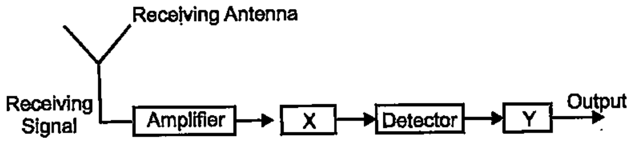
The propagation of EM wave is shown below :



(b) Speed of EM wave can be given as the ratio of magnitude of electric field (E_0) to the magnitude of magnetic field (B_0),

$$c = \frac{E_0}{B_0}$$

15. Block diagram of a receiver is shown in the figure :**



(a) Identify 'X' and 'Y'.

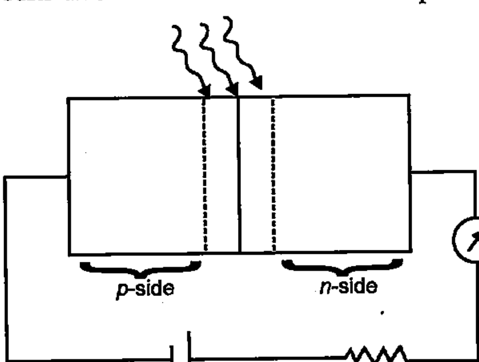
(b) Write their functions.

16. Explain, with the help of a circuit diagram, the working of a photodiode. Write briefly how it is used to detect the optical signals. [3]

OR

Mention the important consideration required while fabricating a *p-n* junction diode to be used as a Light Emitting Diode (LED). What should be the order of band gap of an LED if it is required to emit light in the visible range ?

Answer : A junction diode made from light sensitive semiconductor is called a photodiode.



An electrical device that is used to detect and convert light into an energy signal with the use of a photo detector is known as a photodiode. The light that falls on it controls the function of *pn*-junction. Suppose, the wavelength is such that the energy of a photon $\frac{hc}{\lambda}$ is enough to break a valence bond. There is an increase in number of charge carriers and hence the conductivity of the junction also increases. New hole-electron pairs are created when such light falls on the junction. If the junction is connected in a circuit, the intensity of the incident light controls the current in the circuit.

OR

(i) The reverse breakdown voltage of LEDs are very low, which is around 5V. So enough care is to be taken while fabricating a *pn*-junction diode such that the high reverse voltages do not occur across them.

(ii) There exist very small resistance to limit the current in LED. So, a resistor must be placed in series with the LED such that no damage is occurred to the LED.

The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV.

17. Write three important factors which justify the need of modulating a message signal. Show diagrammatically how an amplitude modulated wave is obtained when a modulating signal is superimposed on a carrier wave. [3]**

18. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 360 μC. When potential across the capacitor is reduced by 120 V, the charge stored in it becomes 120 μC.

Calculate :

(i) The potential V and the unknown capacitance C.

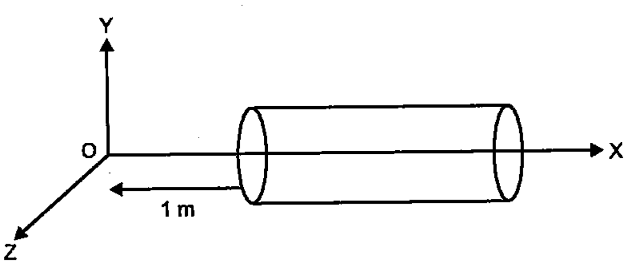
(ii) What will be the charge stored in the capacitor, if the voltage applied had increased by 120 V ? [3]

OR

A hollow cylindrical box of length 1 m and area of cross-section 25 cm^2 is placed in a three-dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50x\,\hat{i}$ where E is NC^{-1} and x is in metres. Find :

(i) Net flux through the cylinder.

(ii) Charge enclosed by the cylinder.



Answer :

(i) Initial voltage, $V_1 = V$ volts and charge stored,

$$Q_1 = 360\ \mu C$$

$$Q_1 = CV_1 \quad ...(i)$$

Changed potential, $V_2 = V - 120$

$$Q_2 = 120\ \mu C$$

$$Q_2 = CV_2 \quad ...(ii)$$

By dividing (ii) from (i), we get

$$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2}$$

**Answers is not given due to change in the present syllabus.

$$\Rightarrow \quad \frac{360}{120} = \frac{V}{V-120}$$

$$V = 180 \text{ volts}$$

$$\therefore \quad C = \frac{Q_1}{V_1} = \frac{360 \times 10^{-6}}{180}$$

$$= 2 \times 10^{-6} \text{ F} = 2 \mu\text{F}$$

(ii) If the voltage applied had increased by 120 V, then

$$V_3 = 180 + 120 = 300 \text{ V}.$$

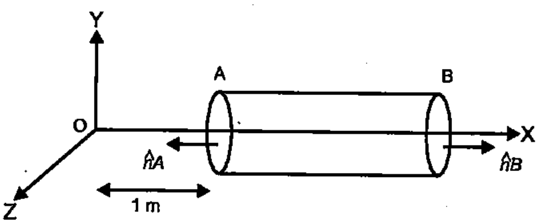
Hence, charge stored in the capacitor,

$$Q_3 = CV_3 = 2 \times 10^{-6} \times 300 = 600 \mu\text{C}$$

OR

(i) Given,

$$\vec{E} = 50x\hat{i}, \text{ and } \Delta s = 25 \text{ cm}^2 = 25 \times 10^{-4} \text{ m}^2$$



As the electric field is only along the X-axis, so, flux will pass only through the cross-section of cylinder.

Magnitude of electric field at cross-section A,

$$E_A = 50 \times 1 = 50 \text{ NC}^{-1}$$

Magnitude of electric field at cross-section B,

$$E_B = 50 \times 2 = 100 \text{ NC}^{-1}$$

The corresponding electric fluxes are :

$$\phi_A = \vec{E} \cdot \vec{\Delta s} = 50 \times 25 \times 10^{-4} \times \cos 180° = -0.125 \text{ Nm}^2/\text{C}$$

$$\phi_B = \vec{E} \cdot \vec{\Delta s} = 100 \times 25 \times 10^{-4} \times \cos 0° = 0.25 \text{ Nm}^2/\text{C}$$

So, the net flux through the cylinder,

$$\phi = \phi_A + \phi_B = -0.125 + 0.25 = 1.25 \text{Nm}^2/\text{C}$$

(ii) Using Gauss's Law :

$$\oint E.ds = \frac{q}{\varepsilon_0}$$

$$\Rightarrow \quad 0.125 = \frac{q}{8.85 \times 10^{-12}}$$

$$q = 8.85 \times 0.125 \times 10^{-12} = 1.1 \times 10^{-12} \text{C}$$

19. (a) In a typical nuclear reaction, *e.g.*

$$^2_1\text{H} + ^2_1\text{H} \rightarrow ^3_2\text{He} + ^1_0n + 3.27 \text{ MeV},$$

although number of nucleons is conserved, yet energy is released. How ? Explain.

(b) Show that nuclear density in a given nucleus is independent of mass number A. **[3]**

Answer :

(a) In a nuclear reaction, the aggregate of the masses of the target nucleus ($^2_1$H) and the bombarding particle may be greater or less than the aggregate of the masses of the product nucleus ($^3_2$He) and the outgoing particle (^1_0n). So from the law of conservation of mass-energy some energy (3.27 MeV) is evolved or involved in a nuclear reaction. This energy is called Q-value of the nuclear reaction.

(b) Density of the nucleus = $\frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

Mass of the nucleus = A amu = A × 1.666 × 10^{-27} kg

Volume of the nucleus

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3$$

Where, $\quad R = R_0 A^{1/3}$

$$V = \frac{4}{3}\pi R_0^3 A$$

$$\text{Thus, density} = \frac{A \times 1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)A}$$

$$= \frac{1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)} \qquad \left[\because f = \frac{M}{V}\right]$$

which shows that the density is independent of mass number A.

20. (a) Why photoelectric effect cannot be explained on the basis of wave nature of light ? Give reasons.

(b) Write the basic features of photon picture of electro-magnetic radiation on which Einstein's photoelectric equation is based. **[3]**

Answer : (a) Wave nature of radiation cannot explain the following :

1. The immediate ejection of photoelectrons.

2. The presence of threshold frequency for a metal surface.

3. The fact that kinetic energy of the emitted electrons is independent of the intensity of light and depends upon its frequency.

Thus, the photoelectric effect cannot be explained on the basis of wave nature of light.

(b) Photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based on particle nature of light.

Its basic features are :

1. In interaction with matter, radiation behaves as if it is made up of particles called photons.

2. Each photon has energy ($E = h\nu$), momentum $\left(p = \frac{h\nu}{c}\right)$, where c is the speed of light

3. All photons of light of a particular frequency ν, or wavelength λ, have the same energy $\left(E = h\nu = \frac{hc}{\lambda}\right)$ and momentum $\left(p = \frac{h\nu}{c}\right)$

4. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons emitted per second crossing a given area, with each photon having the same energy. Thus, photon energy is independent of intensity of radiation.

5. Photons are electrically neutral and are not deflected by electric and magnetic fields.

6. In a photon–particle collision (such as photon-electron collision), the total energy and total momentum are conserved. However, number of photons may not be observed.

21. A metallic rod of length 'l' is rotated with a frequency ν with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius r, about an axis passing through the centre and perpendicular to the plane of the ring. A constant uniform magnetic field B parallel to the axis is present everywhere. Using Lorentz force, explain how emf is induced between the centre and the metallic ring and hence obtained the expression for it. [3]

Answer : Suppose the length of the rod is greater than the radius of the circle and rod rotates anticlockwise and suppose the direction of electrons in the rod at any instant be along $+y$ direction.

Suppose the direction of the magnetic field is along +z direction.

Then, using Lorentz law, we get the following :

$$\vec{F} = e(\vec{v} \times \vec{B})$$

$$\vec{F} = -(n\hat{j} \times B\hat{k})$$

$$\vec{F} = -eB\hat{i}$$

Thus, the direction of force on the electrons is along $-x$ axis.

So, the electrons will move towards the centre *i.e.*, the fixed end of the rod. This movement of electrons will effect in current and thus it will generate an emf in the rod between the fixed end and the point touching the ring.

Let θ be the angle between the rod and radius of the circle at any time t.

Then, area swept by the rod inside the circle = $\frac{1}{2}\pi r^2\theta$

Induced emf

$$= B \times \frac{d}{dt}\left(\frac{1}{2}\pi r^2\theta\right) = \frac{1}{2}\pi r^2 B\frac{d\theta}{dt} = \frac{1}{2}\pi r^2 B\omega$$

$$= \frac{1}{2}\pi r^2 B(2\pi v) = \pi^2 r^2 Bv$$

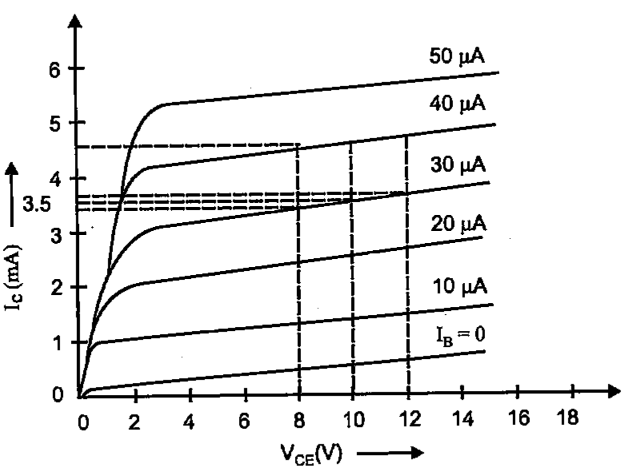
22. Output characteristics of an n-p-n transistor in CE configuration is shown in the figure. [3]

Determine :

(i) dynamic output resistance

(ii) dc current gain and

(iii) ac current gain at an operating point V_{CE} = 10 V, when I_B = 30 µA.**



23. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels. [4]

Answer : In a hydrogen atom,

Radius of electron orbit,

$$r = \frac{n^2h^2}{4\pi^2 k\, me^2} \quad ...(i)$$

and, angular momentum

$$mvr = \frac{nh}{2\pi}$$

**Answers is not given due to change in the present syllabus.

or
$$v = \frac{nh}{2\pi mr}$$
$$v = \frac{nh}{2\pi m\left(\frac{n^2h^2}{4\pi^2 k ne^2}\right)}$$
$$= \frac{2\pi ke^2}{nh}$$

So, kinetic energy,
$$E_k = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{2\pi ke^2}{nh}\right)^2$$
$$= \frac{4\pi^2k^2e^4m}{2n^2h^2} = \frac{2\pi^2k^2e^4m}{n^2h^2}$$

Potential energy
$$E_p = \frac{-k(e)\times(e)}{r} = -\frac{ke^2}{r}$$
Using equation (i), we get
$$E_p = -ke^2 \times \frac{4\pi^2kme^2}{n^2h^2}$$
$$= -\frac{4\pi^2k^2me^4}{n^2h^2}$$

Hence, total energy of the electron in the n^{th} orbit
$$E = E_p + E_k$$
$$= -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2}$$
$$= -\frac{2\pi^2k^2me^4}{n^2h^2}$$

We know $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ Nm^2C^{-2}$

h (Planck's constant) $= 6.6 \times 10^{-34}$ Js

m for H-atom $= 1.67 \times 10^{-27}$ kg

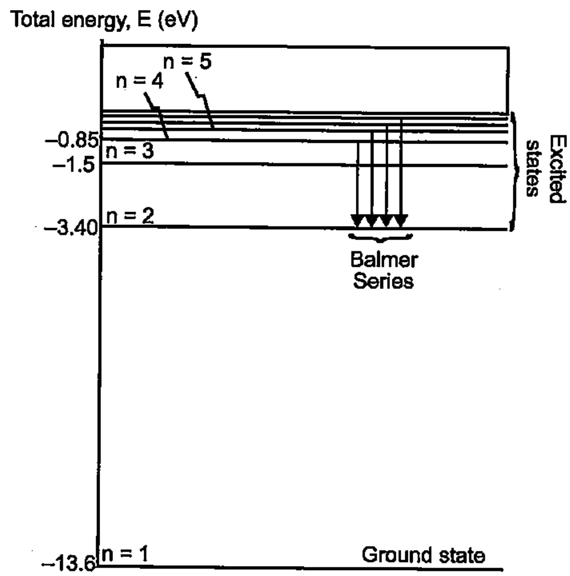
$e = 1.6 \times 10^{-19}$ C

Substituting these values, we get
$$E = \frac{-13.6}{n^2}\ eV$$

When the electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a spectral line.

In H-atom, when an electron jumps from the orbit n_i to orbit n_f, the wavelength of the emitted radiation is given by,
$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$
Where,
R → Rydberg's constant = $1.09678 \times 10^7\ m^{-1}$
For Balmer series, $n_f = 2$ and $n_i = 3, 4, 5, \ldots$
$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_i^2}\right)$$
Where, $n_i = 3, 4, 5, \ldots$

These spectral lines lie in the visible region.



24. (a) In what way is diffraction from each slit related to the interference pattern in a double slit experiment.

(b) Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases. [5]

Answer : (a) If the width of each slit is comparable to the wavelength of light used, the interference pattern thus obtained in the double-slit experiment is modified by diffraction from each of the two slits.

(b) Given that : Wavelength of the light beam,
$$\lambda_1 = 590\ nm = 5.9 \times 10^{-7} m$$
Wavelength of another light beam,
$$\lambda_2 = 596\ nm = 5.96 \times 10^{-7} m$$
Distance of the slits from the screen = D = 1.5 m
Distance between the two slits, $a = 2 \times 10^{-4}$m

For the first secondary maxima, $\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$

$$x_1 = \frac{3\lambda_1 D}{2a} \text{ and } x_2 = \frac{3\lambda_2 D}{2a}$$

$$x_1 = \frac{3\times 590\times 10^{-9}\times 15}{2\times 2\times 10^{-4}}, \quad x_2 = \frac{3\times 596\times 10^{-9}\times 1.5}{2\times 2\times 10^{-4}}$$

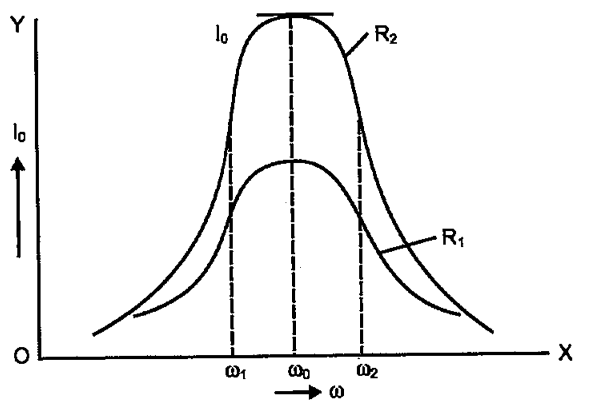
$$x_1 = 663.75 \times 10^{-5}, \qquad x_2 = 670.50 \times 10^{-5}$$

∴ Spacing between the positions of first secondary maxima of two sodium lines

$x_2 - x_1 = 6.75 \times 10^{-5}$ m = 0.0675 mm.

25. In a series LCR circuit connected to an ac source of variable frequency and voltage $v = v_m \sin \omega t$, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and R_2 ($R_1 > R_2$). Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced ? Define Q-factor of the circuit and give its significance. [5]

Answer : Figure shows the variation of i_m with ω in a LCR series circuit for two values of Resistance R_1 and R_2 ($R_1 > R_2$),



The condition for resonance in the LCR circuit is,

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

We can observe that the current amplitude is maximum at the resonant frequency ω_0. Since $i_m = V_m/R$ at resonance, the current amplitude for case R_2 is sharper to that for case R_1.

Quality factor or simply the Q-factor of a resonant LCR circuit is defined as the ratio of voltage drop across the capacitor (or inductor) to that of applied voltage.

It is given by $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

The Q factor determines the sharpness of the resonance curve and if the resonance is less sharp, the maximum current decreases and also the circuit is close to the resonance for a larger range $\Delta\omega$ of frequencies and the regulation of the circuit will not be good. So, less sharp the resonance, less is the selectivity of the circuit while higher is the Q, sharper is the resonance curve and lesser will be the loss in energy of the circuit and circuit will be more selective.

26. While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for thunderstorm to stop. Suddenly he noticed a child walking alone on the road. He asked the boy to come inside the car till the thunderstorm stopped. Dr. Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child.

Answer the following questions based on the above information : [5]

(a) Why is it safer to sit inside a car during a thunderstorm ?

(b) Which two values are displayed by Dr. Pathak in his action ?**

(c) Which values are reflected in parents' response to Dr. Pathak ?**

(d) Give an example of similar action on your part in the part from everyday life.

Answer : (a) It is safer to be inside a car during thunderstorm because the car acts like a Faraday cage.

(d) Once I came across to a situation where a puppy was struck in the middle of a busy road during rain and was not able to cross due to heavy flow, So I quickly rushed and helped him.

27. (a) Draw a ray diagram showing the image formation by a compound microscope. Hence obtain expression for total magnification when the image is formed at infinity.

(b) Distinguish between myopia and hypermetropia. Show diagrammatically how these defects can be corrected. [5]

OR

(a) State Huygen's principle. Using this principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence verify Snell's law of refraction.

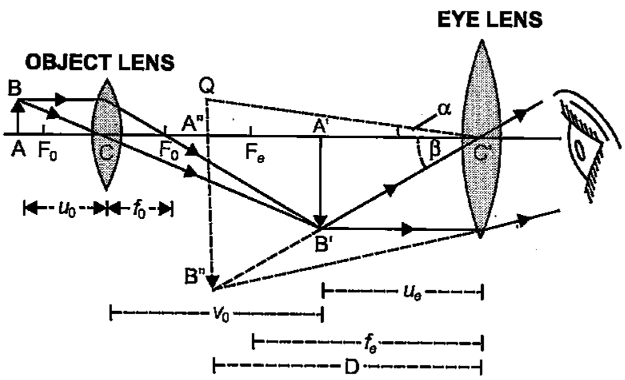
(b) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons :

****Answers is not given due to change in the present syllabus.**

(i) **Is the frequency of reflected and refracted light same as the frequency of incident light ?**

(ii) **Does the decrease in speed imply a reduction in the energy carried by light wave ?**

Answer : (a) A compound microscope consists of two convex lenses parallel separated by some distance. The lens nearer to the object is called the objective. The lens through which the final image is viewed is called the eyepiece.



Magnifying power when final image is at infinity : The magnification produced by the compound microscope is the product of the magnifications produced by the eyepiece and objective.

$\therefore$ $$M = M_e \times M_o \quad ...(i)$$

Where, M_e and M_o are the magnifying powers of the eyepiece and objective respectively.

If u_0 is the distance of the object from the objective and v_0 is the distance of the image from the objective, then the magnifying power of the objective is

$$M_o = \frac{h'}{h} = \frac{L}{f_o}$$

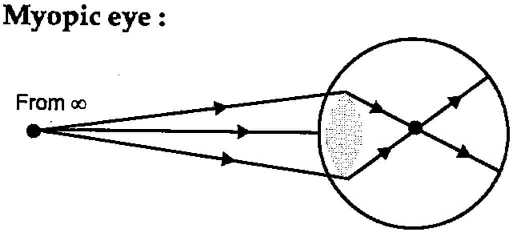
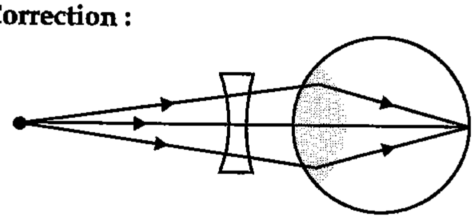
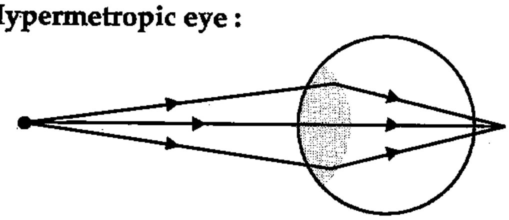
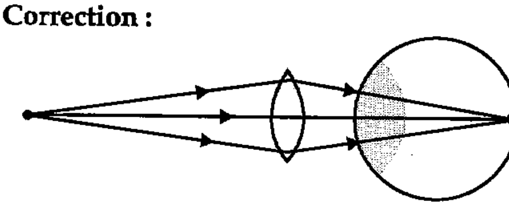
Where, h, h' are object and image heights respectively and f_o is the focal length of the objective and L is the tube length *i.e.*, the distance between the second focal point of the objective and the first focal point of the eyepiece.

When the final image is at infinity,

$$M_e = \frac{D}{f_e}$$

Magnifying power of compound microscope,

$$M = M_o \times M_e = \frac{L}{f_o} \times \frac{D}{f_e}$$

	Myopia		Hypermetropia
1.	Also known as nearsightedness.	**1.**	Also known as farsightedness.
2.	Person is not able to see far objects clearly.	**2.**	Person is not able to see near objects clearly.
3.	For myopic eye, far point is less than infinity.	**3.**	For hypermetropic eye, near point is greater than D *i.e.*, 25 cm (least distance of distinct vision).
4.	To correct myopia, concave lens of appropriate focal length is used. **Myopic eye :**  **Correction :** 	**4.**	To correct hypermetropia convex lens of appropriate focal length is used. **Hypermetropic eye :**  **Correction :** 

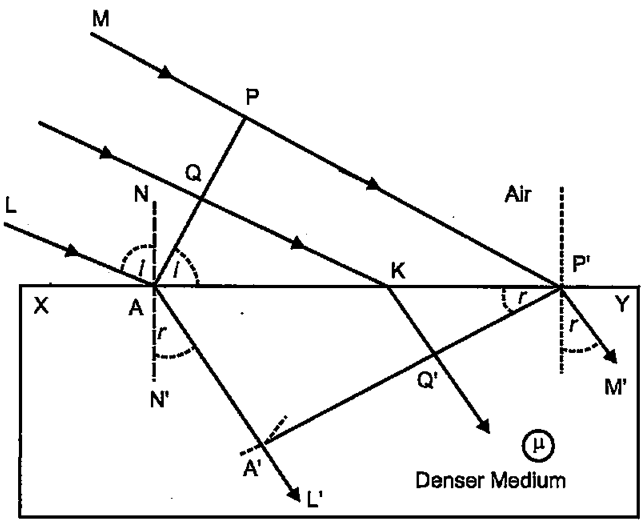
OR

(a) **Huygen's Principle :**

1. Each point on the primary wave front acts as a source of secondary wavelets, transferring out disturbance in all directions in the same way as the original source of light does.
2. The new position of the wave front at any instant is the envelope of the secondary wavelets at that instant.

Refraction on the basis of wave theory

1. Consider any point Q on the incident wave front.
2. Suppose when disturbance from point P on incident wave front reaches point P' on the refracted wave front, the disturbance from point Q reaches Q' on the refracting surface XY.



3. Since P'A' represents the refracted wave front, the time taken by light to travel from a point on incident wave front to the corresponding point on refracted wave front should always be the same. Now, time taken by light to go from Q to Q′ will be

$$t = \frac{QK}{c} + \frac{QK}{v} \qquad ...(i)$$

In right-angled ΔAQK, $\angle QAK = i$

$$\therefore \qquad QK = AK \sin i \qquad ...(ii)$$

In right-angled $\Delta P'Q'K$, $\angle Q'P'K = r$ and $Q'K = KP' \sin r$ ...(iii)

Substituting (ii) and (iii) in equation (i),

$$t = \frac{AK \sin i}{c} + \frac{KP' \sin r}{v}$$

$$t = \frac{AK \sin i}{c} + \frac{(AP' - AK \sin r)}{v}$$

[$\because$ KP' = AP' – AK]

$$t = \frac{AP'}{v} \sin r + AK\left(\frac{\sin i}{c} - \frac{\sin r}{v}\right) \qquad ...(iv)$$

The rays from different points on the incident wave front will take the same time to reach the corresponding points on the refracted wave front *i.e.*, given equation (iv) is independent of AK. It will happen so, if

$$\frac{\sin i}{c} - \frac{\sin r}{v} = 0$$

$$\Rightarrow \qquad \frac{\sin i}{\sin r} = \frac{c}{v}$$

$$\Rightarrow \qquad n = \frac{\sin i}{\sin r}$$

This is the Snell's law for refraction of light.

(b) (i) The frequency of reflected and refracted light remains constant as the frequency of incident light because frequency only depends on the source of light.

(ii) Since the frequency remains same, hence there is no reduction in energy.

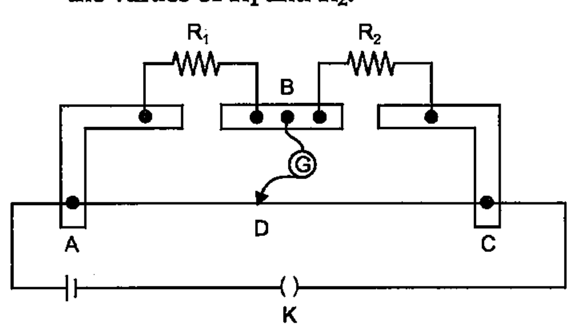
28. (a) State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs.

(b) Write two possible causes for one sided deflection in a potentiometer experiment. **[5]**

OR

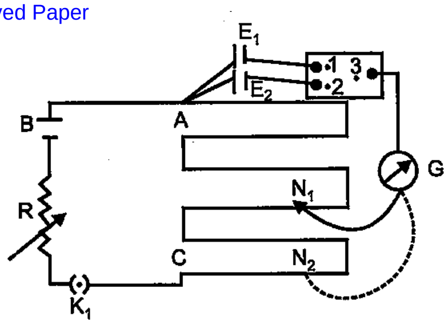
(a) State Kirchhoff's rules for an electric network. Using Kirchhoff's rules, obtain the balance condition in terms of the resistance of four arms of Wheatstone bridge.

(b) In the meter bridge experimental set-up, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of the meter bridge wire. If a resistance of 10 Ω is connected in series with R_1, null point is obtained at AD = 60 cm. Calculate the values of R_1 and R_2.



Answer : (a) Working principle of Potentiometer : When a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.

Applications of Potentiometer for comparing emf's of two cells : The following figure shows an application of the potentiometer to compare the emf of two cells of emf E_1 and E_2.



E_1, E_2 are the emf of the two cells.
1, 2, 3 form a two way key.
When 1 and 3 are connected, E_1 is connected to the galvanometer (G).
Jockey is moved to N_1, which is at a distance L_1 from A, of cell E the balancing length.
By the potentiometer principle

$E_1 = kl_1$ where k is the potential gradient

Similarly for E_2 is balanced at l_2 (AN_2)

$E_2 = kl_2$

By (i) and (ii)

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} \quad \text{...(iii)}$$

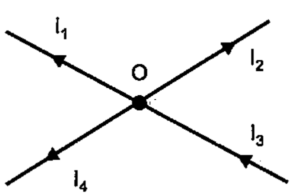
Thus, we can compare the emf's of any two sources. Generally, one of the cells is chosen as a standard cell whose emf is known to a high degree of accuracy. The emf of the other cell is then calculated from equation (iii).

(b) (i) The emf of the cell connected in main circuit may not be more than the emf of the primary cells whose emfs are to be compared.

(ii) The positive ends of all cells are not connected to the same end of the wire.

OR

(a) Kirchhoff's first law – Junction rule : The algebraic sum of the currents meeting at a point in an electrical circuit is always zero.



Let the currents be I_1, I_2, I_3, and I_4.

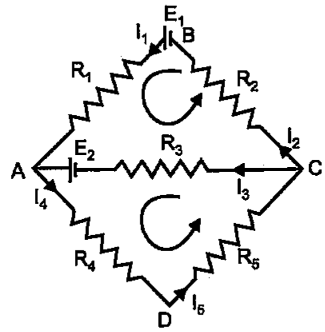
Convention : Current towards the junction positive

Current away from the junction negative

$$I_3 + (-I_1) + (-I_2) + (-I_4) = 0$$

This law is in accordance with conservation of charge

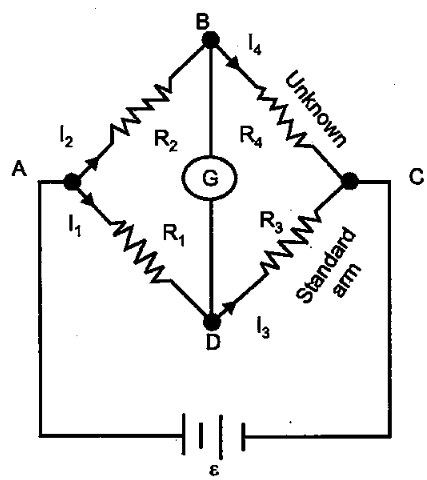
Kirchhoff's second law–Loop rule : In a closed loop, the algebraic sum of the emfs is equal to the algebraic sum of the products of the resistance and current flowing through them.



For closed part BACB, $E_1 - E_2 = I_1R_1 + I_1R_2 - I_3R_3$

For closed part CADC, $E_2 = I_3R_3 + I_4R_4 + I_5R_5$

Wheatstone bridge : The Wheatstone bridge is an arrangement of four resistances as shown in the following figure.



R_1, R_2, R_3, and R_4 are the four resistances.

Galvanometer (G) has a current I_g flowing through it.

At balanced condition, $I_g = 0$

Applying junction rule at B,

$\therefore \quad I_2 = I_4$

Applying loop rule to closed loop ADBA,

$$-I_1R_1 + 0 + I_2R_2 = 0$$

$$\therefore \quad \frac{I_1}{I_2} = \frac{R_2}{R_1} \quad \text{...(i)}$$

Applying loop rule to closed loop CBDC,

$$I_2R_4 + 0 - I_1R_3 = 0$$

$(\because I_3 = I_1, I_4 = I_2)$

$$\therefore \quad \frac{I_1}{I_2} = \frac{R_4}{R_3} \quad \text{...(ii)}$$

From equations (i) and (ii),

$$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$

This is the required balanced condition of Wheatstone bridge.

(b) Considering both the situations and writing them in the form of equations Let R′ be the resistance per unit length of the potentiometer wire,

$$\frac{R_1}{R_2} = \frac{l_1 R'}{(100 - l_1)R'}$$

$$\Rightarrow \quad \frac{R_1}{R_2} = \frac{R' \times 40}{R'(100-40)} = \frac{40}{60} = \frac{2}{3} \quad \text{...(i)}$$

$$\Rightarrow \quad \frac{R_1 + 10}{R_2} = \frac{R' \times 60}{R'(100-60)} = \frac{60}{40} = \frac{3}{2} \quad \text{....(ii)}$$

Putting the value of R_1 from equation (i) and substituting in equation (ii)

$$\frac{2}{3} + \frac{10}{R_2} = \frac{3}{2}$$

$$R_2 = 12\ \Omega$$

Recalling equation (i) again

$$\frac{R_1}{12} = \frac{2}{3}$$

$$R_1 = 8\ \Omega$$

29. (a) Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

(b) A proton and a deuteron having equal momenta enter in a region of a uniform magnetic field at right angle to the direction of the field. Depict their trajectories in the field. [5]

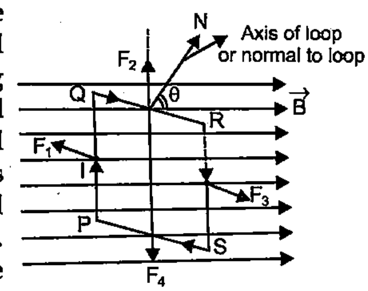
OR

(a) A small compass needle of magnetic moment '*m*' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period.

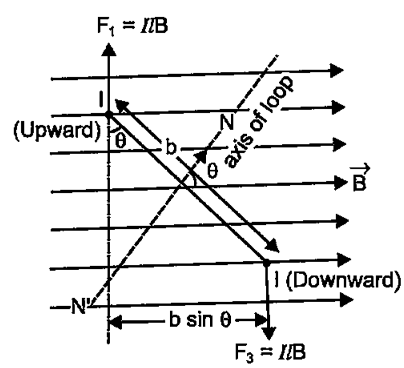
(b) A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.

Answer :

(a) Consider a rectangular loop PQRS of length *l*, breadth *b* suspended in a uniform magnetic field $\vec{B}$. The length of loop = PQ = RS = *l* and breadth = QR = SP = *b*. Let at any instant the normal to the plane of loop make an angle θ with the direction of magnetic field $\vec{B}$ and *I* be the current in the loop. We know that a force acts on a current carrying wire placed in a magnetic field. Therefore, each side of the loop will experience a force. The net force and torque acting on the loop will be determined by the forces acting on all sides of the loop. Suppose that the forces on sides PQ, QR, RS and SP are $\vec{F}_1, \vec{F}_2, \vec{F}_3$ and $\vec{F}_4$ respectively. The sides QR and SP make angle (90° − θ) with the direction of magnetic field.



Therefore each of the forces $\vec{F}_2$ and $\vec{F}_4$ acting on these sides has same magnitude F = B*Ilb* sin (90° − θ) = B*Ib* cos θ. According to Fleming's left hand rule the forces $\vec{F}_2$ and $\vec{F}_4$ are equal and opposite but their line of action is same. Therefore, these forces cancel each other *i.e.,* the resultant of $\vec{F}_2$ and $\vec{F}_4$ is zero.



The sides PQ and RS of current loop are perpendicular to the magnetic field, therefore, the magnitude of each of forces $\vec{F}_1$ and $\vec{F}_3$ is zero.

$$F = IlB \sin 90° = IlB.$$

According to Fleming's left hand rule the forces $\vec{F}_1$ and $\vec{F}_3$ acting on side PQ and RS are equal and opposite, but their lines of action are different; therefore, the resultant force of $\vec{F}_1$ and $\vec{F}_3$ is zero, but they form a couple called the deflecting couple. When the normal to plane of loop makes and angle θ with the direction of magnetic field B, the perpendicular distance between F_1 and F_3 is *b* sin θ.

∴ Moment of couple or Torque,

τ = (Magnitude of one force F) × Perpendicular distance

$= (BIl).(b \sin\theta) = I(lb) B \sin\theta$

But lb = area of loop = A (say)

∴ Torque, $\tau = IAB \sin\theta$

If the loop contains N-turns, then $\tau = NI AB \sin\theta$

In vector form $\vec{\tau} = NI \vec{A} \times \vec{B}$.

The magnetic dipole moment of rectangular current loop

$= M = NIA$

∴ $$\vec{\tau} = \vec{M} \times \vec{B}$$

Direction of torque is perpendicular to direction of area of loop as well as the direction of magnetic field *i.e.*, along $(\vec{A} \times \vec{B})$

(b) We know, Lorentz force, $F = Bqv \sin\theta$

Where θ = angle between velocity of particle and magnetic field = 90°

So, Lorentz force, $F = Bqv$

Thus, the particles will move in circular path and required centripetal force is provided by this Lorentz force.

$$Bqv = \frac{mv}{r} \Rightarrow r = \frac{mv}{Bq}$$

Let m_p = mass of proton, m_d = mass of deuteron, v_p = velocity of proton and v_d = velocity of deuteron.

$$r_p = \frac{m_p v_p}{Bq} \quad ...(i)$$

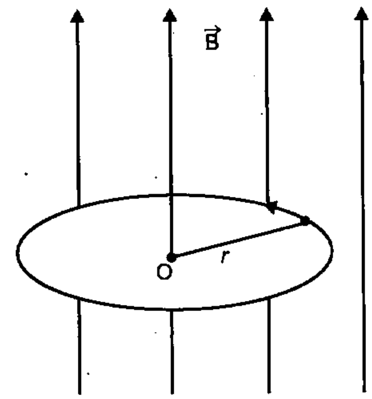
$$r_d = \frac{m_d v_d}{Bq} \quad ...(ii)$$

The charge of proton and deuteron are equal.

Given that, $m_p v_p = m_d v_d$

Since, RHS of equation (i) and (ii) are equal, so $r_p = r_d = r$.

Thus, the trajectory of both the particles will be same.



OR

(a) The torque on the needle is $\tau = m \times B$

In magnitude $\tau = mB \sin\theta$

Here τ is restoring torque and θ is the angle between m and B.

Therefore, in equilibrium $I\frac{d^2\theta}{dt^2} = mB \sin\theta$

Negative sign with $mB \sin\theta$ implies that restoring torque is in a position to deflecting torque. For small values of θ in radians, we approximate $\sin\theta \approx \theta$ and get

$$I\frac{d^2\theta}{dt^2} = -mB \sin\theta$$

or $$\frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta$$

This represents a simple harmonic motion.

The square of the angular frequency $\omega^2 = mB/I$ and the time period is,

$$T = 2\pi\sqrt{\frac{1}{mB}} \quad [\because = \frac{2\pi}{T}]$$

(b) Since the needle rotates in vertical plane, so the place here is magnetic pole of earth.

Therefore, $B_H = 0$

and, angle of dip at magnetic pole, $\delta = 90°$

●●

Physics 2013 (Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

> **Note : Except for the following questions, all the remaining questions have been asked in previous Set.**

1. A cell of emf 'E' and internal distance 'r' draws a current 'I'. Write the relation between terminal voltage 'V' in terms of E, I, r. **[1]**

Answer : When the current I draws from a cell of emf E and internal resistance r, then the terminal voltage is $V = E - Ir$

2. Which of the following substances are diamagnetic ? **[1]**

Bi, Al, Na, Cu, Ca and Ni

Answer : B and Cu are diamagnetic substances.

3. A heating element is marked 210 V, 630 W. What is the value of current drawn by the element when connected to a 210 V dc source ? [1]

Answer : In dc source, P = VI

Given that P = 630 W and V = 210 V.

So,

$$I = \frac{P}{V} = \frac{630}{210} = 3A$$

10. An ammeter of resistance 1 Ω can measure current upto 1.0 A. (i) What must be the value of the shunt resistance to enable the ammeter to measure upto 5.0 A ? (ii) What is the combination resistance of the ammeter and the shunt ? [1]

Answer : We have, Resistance of ammeter, $R_A = 1\ \Omega$

Maximum current across ammeter, $I_A = 1.0$ A

So, Voltage drop across ammeter, V = IR = 1.0 × 1.0 = 1V

(i) Resistance of ammeter with shunt,

$$R = \frac{R_A x}{R_A + x} = \frac{x}{1+x}$$

Current through ammeter,

$$I = 5A$$

Now, V = IR

$$\left(\frac{x}{1+x}\right) \times 5 = 1.0$$

$$x \times 5 = 1 + x$$

$$4x = 1$$

$$x = 0.25$$

Thus the shunt resistance is 0.25 Ω

(ii) Combined resistance of the ammeter and the shunt

$$R = \frac{x}{1+x}$$

$$R = \frac{0.25}{1+0.25}$$

$$R = \frac{0.25}{1.25}$$

$$R = 0.2\ \Omega$$

14. A convex lens of focal length 20 cm is placed coaxially in contact with a concave lens of focal length 25 cm. Determine the power of the combination. Will the system be converging or diverging in nature ? [2]

Answer : We have, Focal length of concave lens, $f_1 = +20$ cm = +0.20 m

Focal length of concave lens, $f_2 = -25$ cm = −0.25 m

Power of convex lens,

$$P_1 = \frac{1}{f_1} = \frac{1}{0.20}$$

Power of concave lens,

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.25}$$

Power of the combination lens,

$$P = P_1 + P_2$$

$$= \frac{1}{0.20} + \frac{1}{-0.25}$$

$$= \frac{100}{20} + \frac{100}{-25}$$

$$= \frac{500-400}{100}$$

$$= \frac{100}{100}$$

$$= 1D$$

As the power is positive, the system will be converging in nature.

15. Using Bohr's postulates, obtain the expressions for (i) kinetic energy and (ii) potential energy of the electron in stationary state of hydrogen atom.

Draw the energy level diagram showing how the transitions between energy levels result in the appearance of Lyman series. [2]

Answer : According to Bohr's postulates, in a hydrogen atom, a single electron revolves around a nucleus of charge + *e*.

And the radius of orbit in which the electron revolves, is given by

$$r = \frac{n^2h^2}{4\pi^2kme^2} \quad ...(i)$$

(i) Kinetic energy of electron,

$$E_K = \frac{1}{2}mv^2 = \frac{ke^2}{2r}$$

Using equation (i), we get

$$E_K = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2}$$

(ii) Potential energy

$$E_P = \frac{-k(e)\times(e)}{r} = \frac{-ke^2}{r}$$

Using equation (i), we get

$$E_P = -ke^2 \times \frac{4\pi^2 kme^2}{n^2h^2}$$

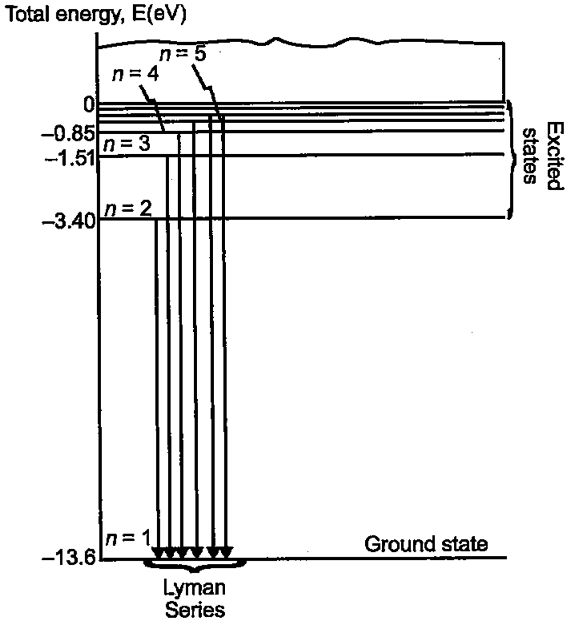
$$= -\frac{4\pi^2 k^2 me^4}{n^2h^2}$$

Energy level diagram showing the transitions between energy levels result in the appearance of Lyman series :

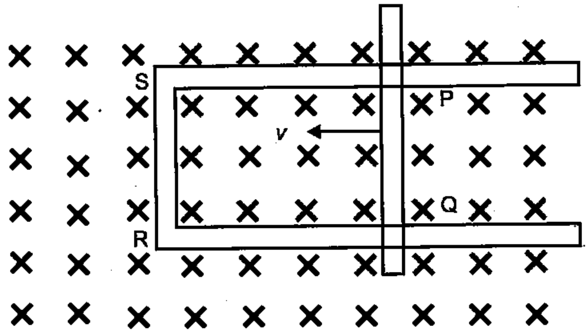
For Lyman series, $n_f = 1$ and $n_i = 2, 3, 4, 5, \ldots$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

Where, $n_i = 2, 3, 4, 5, \ldots\ldots$



22. Figure shows a rectangular loop conducting PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity *v* towards the arm RS Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance *r*, obtain the expression for (i) the current in the loop (ii) the force and (iii) the power required to move the arm PQ.



[3]

Answer : Let the length RQ = x and RS = l.

Let the magnitude of the uniform magnetic field be B.

(i) The magnetic flux ϕ enclosed by the loop PQRS is given by, $\phi = Blx$

As, x is changing with time, the rate of change of flux $\frac{d\phi}{dt}$ will induce an emf given by :

$$E = -\frac{d\phi}{dt} = -\frac{d(Blx)}{dt} = -Bl\frac{dx}{dt} = Blv$$

$$\left[as, \frac{dx}{dt} = -v\right]$$

Current in the loop is given by,

$$I = \frac{E}{r} = \frac{Blv}{r}$$

(ii) The magnetic force on the PQ is,

$$F = BIl = B\left(\frac{Blv}{r}\right) \times l = \frac{B^2l^2v}{r}$$

(iii) Power required to move the arm PQ is,

$$P = F \times v = \frac{B^2l^2v}{r} \times v = \frac{B^2l^2v^2}{r}$$

23. Distinguish between 'sky waves' and 'space waves' modes of propagation in communication system.** **[4]**

(a) Why is sky wave mode propagation restricted to frequencies upto 40 MHz ?

(b) Give two examples where space wave mode of propagation is used.

****Answers is not given due to change in the present syllabus.**

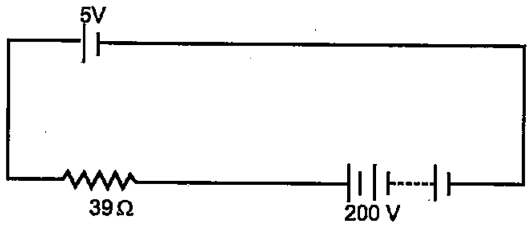
Physics 2013 (Delhi)

SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Sets.

6. A 5 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 39 Ω as shown in the figure. Find the value of the current. [2]



Answer : Let I be the current flowing in the circuit.

Using Kirchhoff's law,

$$39\,I = 200 - 5$$

$$I = \frac{195}{39}$$

$$I = 5\text{ A}.$$

7. Which of the following substances are paramagnetic ? [2]

Bi, Al, Cu, Ca, Pb, Ni

Answer : Paramagnetic substances are Aluminium (Al) and Calcium (Ca).

9. An ammeter of resistance 0.6 Ω can measure current upto 1.0 A. Calculate (i) The shunt resistance required to enable the ammeter to measure current upto 5.0 A. (ii) The combined resistance of the ammeter and the shunt. [2]

Answer : We have, resistance of ammeter, R_A = 0.60 ohm.

Maximum current across ammeter, I_A = 1.0 A

So, voltage across ammeter,

$$V = IR$$

$$= 1.0 \times 0.60$$

$$V = 0.6\text{ V}$$

Let the value of shunt be x.

(i) Resistance of ammeter with shunt

$$R = \frac{R_A x}{R_A + x}$$

$$= \frac{0.6x}{0.6 + x}$$

Current through ammeter I = 5A

$\because$ V = IR

Now, $$\left(\frac{0.6x}{0.6+x}\right)\times 5 = 0.6$$

$$0.6x \times 5 = 0.6(0.6 + x)$$

$$3x = 0.36 + 0.6x$$

$$3x - 0.6x = 0.36$$

$$x = \frac{0.36}{2.4}$$

$$x = 0.15\,\Omega$$

Therefore, the shunt resistance is 0.15 ohm.

(ii) Combined resistance of the ammeter and the shunt is given by

$$R = \frac{0.6x}{0.6 + x}$$

$$R = \frac{0.6 \times 0.15}{0.6 + 0.15}$$

$$R = 0.12\,\Omega$$

15. A convex lens of focal length 30 cm is placed coaxially in contact with a concave lens of focal length 40 cm. Determine the power of the combination. Will the system be converging or diverging in nature ? [3]

Answer : We have, focal length of convex lens,

$$f_1 = +30\text{ cm}$$

$$= 0.30\text{ m}$$

Focal length of concave lens

$$f_2 = -40\text{ cm}$$

$$= -0.40\text{ m}$$

Equivalent focal length

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$= \frac{1}{30} + \frac{1}{-40}$$

$$= \frac{40 - 30}{1200} = \frac{1}{120}$$

$\therefore$ $$F = 120\text{ cm}$$

$$= 1.2\text{ m}$$

$\therefore$ Power of the combination,

$$P = \frac{1}{F} = \frac{1}{1.2} = 0.83\,\text{D}$$

The focal length of combination = 1.2 m = 120 cm.

As the focal length is positive the system will be converging in nature.

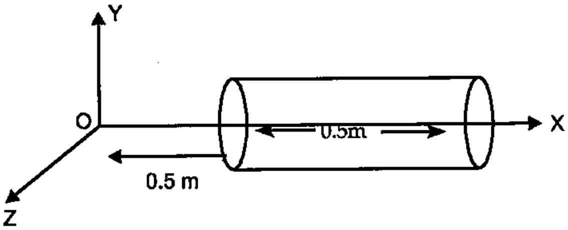
18. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 300 μC. When potential across the capacitor is reduced by 100 V, the charge stored in it becomes 100 μC. Calculate the potential V and the unknown capacitance. What will be the charge stored in the capacitor if the voltage applied had increased by 100 V ? **[3]**

OR

A hollow cylindrical box of length 0.5 m and area of cross-section 20 cm is placed in a three-dimensional coordinate system as shown in the figure. The electric field in the region is given by $E = 20x\hat{i}$, where E is NC^{-1} and x is in meters. Find

(i) Net flux through the cylinder

(ii) Charge enclosed in the cylinder.



Answer : (i) Initial voltage

$$V_1 = V \text{ volts}$$

Charge stored,

$$Q_1 = 300\ \mu C$$

$$Q_1 = CV_1 \quad ...(i)$$

Changed potential, $V_2 = V - 100$ V

$$Q_2 = 100\ \mu C$$

$$Q_2 = CV_2 \quad ...(ii)$$

By dividing (ii) from (i), we get

$$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2}$$

$$\frac{Q_1}{Q_2} = \frac{V_1}{V_2}$$

$$\frac{300}{100} = \frac{V}{V-100}$$

$$V = 150 \text{ volts}$$

$$C = \frac{Q_1}{V_1} = \frac{300 \times 10^{-6}}{150}$$

$$= 2 \times 10^{-6} F$$

$$C = 2\mu F$$

If the voltage applied had increased by 100 V, then

$$V_3 = 150 + 100$$

$$= 250 \text{ V}$$

Hence, charge stored in the capacitor,

$$Q_3 = CV_3 = 2 \times 10^{-6} \times 250$$

$$= 500\ \mu C$$

OR

(i) Given, $\vec{E} = 20x\,\hat{i}$

and $\Delta s = 20 \text{ cm}^2$

$$= 20 \times 10^{-4} m^2$$

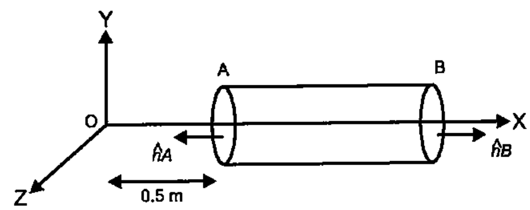
As the electric field is only along the X-axis, so flux will pass only through the cross-section of cylinder.

Magnitude of electric field at A,

$$E_A = 20 \times 0.5 = 10 \text{ N/C}$$

Magnitude of electric field at cross-section B.

$$E_B = 20 \times 1 = 20 \text{ N/C}$$



The corresponding electric fluxes are :

$$\phi_A = \vec{E} \cdot \Delta \vec{s}$$

$$= 10 \times 20 \times 10^{-4} \times \cos 180°$$

$$= -0.02 \text{ Nm}^2\text{C}^{-1}$$

$$\phi_A = \vec{E} \cdot \Delta \vec{s}$$

$$= 20 \times 20 \times 10^{-4} \times \cos 0°$$

$$= 0.04 \text{ Nm}^2\text{C}^{-1}$$

So, the net flux through the cylinder,

$$\phi = \phi_A + \phi_B$$

$$= -0.02 + 0.04$$

$$= 0.02 \text{ Nm}^2\text{C}^{-1}$$

(ii) Using Gauss's law :

$$\int \vec{E} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$$

$$0.02 = \frac{q}{8.85 \times 10^{-12}}$$

$$q = 8.85 \times 0.02 \times 10^{-12}$$

$$q = 0.177 \times 10^{-12} C$$

19. (a) Write two characteristic features distinguishing the diffraction pattern from the interference fringes obtained in Young's double slit experiment.

(b) Two wavelength of sodium light 590 nm and 596 nm are used, in turn, to study the

diffraction taking place due to a single slit of aperture 1×10^{-4} m. The distance between the slit and the screen is 1.8 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases. **[3]**

Answer : (a) Two characteristic features distinguishing the diffraction pattern from the interference fringes obtained in Young's double slit experiment are :

(i) The interference fringes may or may not be of the same width whereas the fringes of diffraction pattern are always of varying width.

(ii) In interference the bright fringes are of same intensity whereas in diffraction pattern the intensity falls as we go to successive maxima away from the centre, on either side.

(b) Wavelength of the light beam, $\lambda_1 = 590$ nm $= 5.9 \times 10^{-7}$ m

Wavelength of another light beam, $\lambda_2 = 596$ nm $= 5.96 \times 10^{-7}$ m

Distance of the slits from the screen = D = 1.8 m

Distance between the two slits = 1×10^{-4} m

For the first secondary maxima,

$$\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$$

$$x_1 = \frac{3\lambda_1 D}{2a}$$

and $$x_2 = \frac{3\lambda_2 D}{2a}$$

$\therefore$ Spacing between the positions of first secondary maxima of two sodium lines

$$= x_2 - x_1$$

$$= \frac{3D}{2a}(\lambda_2 - \lambda_1)$$

$$= \frac{3 \times 1.8 \times 6 \times 10^{-9}}{2 \times 10^{-4}} = 1.62 \times 10^{-4} \text{m}$$

21. (a) In a nuclear reaction

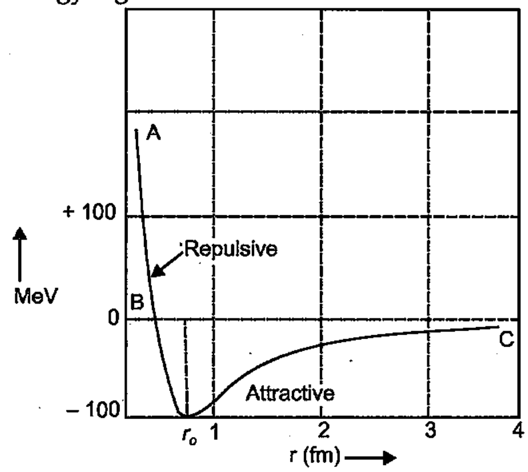
$${}^3_2\text{He} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + {}^1_1\text{H} + {}^1_1\text{H} + 12.86\,\text{MeV},$$

though the number of nucleons is conserved on both sides of the reaction, yet the energy is released. How ? Explain.

(b) Draw a plot of potential energy between a pair of nucleons as a function of their separation. Mark the regions where potential energy is (i) positive and (ii) negative. **[3]**

Answer : (a) In a nuclear reaction, the sum of the masses of the target nucleus ${}^3_2$He may be greater or less the sum of the masses of the product nucleus ${}^4_2$He and the ${}^1_1$H . So from the law of conservation of mass energy, some energy, (12.86 MeV) is evolved in nuclear reaction. This energy is called Q-value of the nuclear reaction. The binding energy of the nucleus on the left side is not equal to the right side. The difference in the binding energies on two sides appears as energy released or absorbed in the nuclear reaction.

(b) The potential energy is minimum at r_0. For distance larger than r_0 the negative potential energy goes on decreasing and for the distances less than r_0 the negative potential energy decrease to zero and then becomes positive and increases abruptly. Thus, A to B is the positive potential energy region and B to C is the negative potential energy region.



25. (b) What is the significance of negative sign in the expression for the energy ?

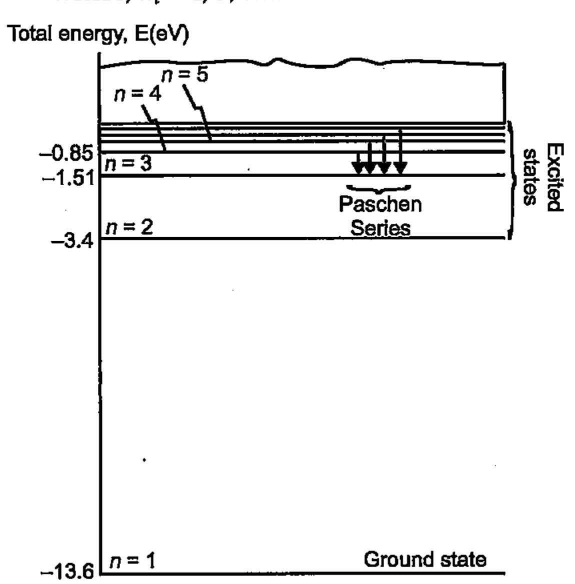
(c) Draw the energy level diagram showing how the line spectra corresponding to Paschen series occur due to transition between energy levels. **[5]**

Answer : (b) Negative sign indicates that revolving electron is bound to the positive nucleus.

(c) For Paschen series, $n = 3$ and $n_i = 4, 5, \ldots$

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n_i^2}\right)$$

where, $n_i = 4, 5, \ldots..$



Physics 2014 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. **Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.** **[1]**

Answer : One ampere is the current which when flowing through each of the two parallel uniform long linear conductors placed in free space at a distance of one metre from each other will attract or repel each other with a force of 2×10^{-7} N per metre of their length.

2. **To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong ?** **[1]**

Answer : The frequency 5×10^{19} Hz lies in the gamma region of the electromagnetic spectrum.

3. **What is the force between two small charges of 2×10^{-7}C and 3×10^{-7}C placed 30 cm apart in air?** **[1]**

Answer :

We know that, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

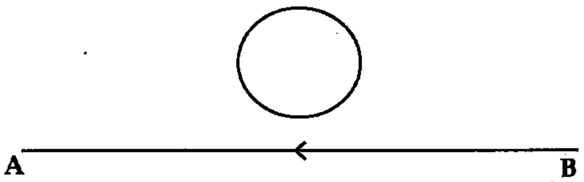
$$= 9 \times 10^9 \times \frac{(2\times10^{-7})(3\times10^{-7})}{(0.30)^2}$$

$$= 6 \times 10^{-3}\ \text{N}$$

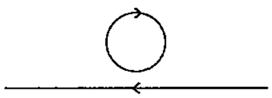
4. **Define intensity of radiation on the basis of photon picture of light. Write its S.I. unit. [1]**

Answer : The intensity of radiation can be defined as the energy associated with photons emitted from a unit surface area in unit time. Its S.I. unit is joule/metre^{2}second (J/m^{2}s).

5. **The electric current flowing in a wire in the direction from B to A is decreasing. Find out the direction of the induced current in the metallic loop kept above the wire as shown. [1]**



Answer : The direction of the current in the loop will be such as to oppose the decrease of this field (Lenz's Law).



6. **Why is it found experimentally difficult to detect neutrinos in nuclear β-decay ? [1]**

Answer : Neutrinos are difficult to detect experimentally in β-decay because these are uncharged particles with almost zero mass and also they interact weakly with matter.

7. **Why is the use of A.C. voltage preferred over D.C. voltage ? Give two reasons. [1]**

Answer : The use of A.C. voltage is preferred over the use of D.C. voltage because of the following reasons :

(i) The energy losses while transmission of A.C. voltage are very less as compared to D.C. voltage.

(ii) A.C. voltage can be controlled as required by using a transformer (*i.e.*, stepped up or stepped down).

8. **A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens ? Give reason.[1]**

Answer : In this case the biconvex lens will behave as a diverging lens because the refractive index of water (1.33) is more than that of the material (1.25) of the lens.

9. **Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron ? [2]**

OR

Using Bohr's postulates of the atomic model, derive the expression for radius of n^{th} electron orbit. Hence obtain the expression for Bohr's radius.

Answer :

In a hydrogen atom, an electron having charge $-e$ revolves around the nucleus having charge $+e$ in a circular orbit of radius r.

Let,

F_c = Centripetal force required by the electron to move in circular orbit of radius r.

F_e = Electrostatic force of attraction between revolving electron and nucleus.

The electrostatic force of attraction (F_e) provides the necessary centripetal force,

$$F_c = F_e$$

$$\frac{mv^2}{r} = \frac{(e)(e)}{4\pi\varepsilon_0 r^2} \quad ...(i)$$

K.E. of electron in the orbit,

$$\text{K.E.} = \frac{1}{2}mv^2$$

From equation (i),

$$\text{K.E.} = \frac{e^2}{8\pi\varepsilon_0 r}$$

Potential energy of electron in orbit,

$$\text{P.E.} = \frac{(e)(-e)}{4\pi\varepsilon_0 r} = \frac{-e^2}{4\pi\varepsilon_0 r}$$

∴ Total energy of electron in hydrogen atom

$$E = \text{E.K.} + \text{P.E.} = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r}$$

$$\text{E.K.} = -\frac{e^2}{8\pi\varepsilon_0 r}$$

Here, negative sign indicates that the revolving electron is bound to the positive nucleus.

OR

Suppose m be the mass of an electron and v_n be its speed in n^{th} orbit of radius r_n. From Rutherford model, the centripetal force for revolution is produced by electrostatic attraction between electron and nucleus.

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2} \quad ...(i)$$

From Bohr's postulate for quantization of angular momentum of n^{th} orbit.

$$mv_n r_n = \frac{nh}{2\pi} \Rightarrow v_n = \frac{nh}{2\pi m r_n}$$

Substituting this value in equation (i), we get

$$\frac{m}{r_n}\left[\frac{nh}{4\pi m r_n}\right]^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2}$$

or $$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}$$

For Bohr's radius $n = 1$,

$$r_1 = \frac{\varepsilon_0 h^2}{\pi m Z e^2}$$

This is the expression for Bohr's radius.

10. A parallel plate capacitor of capacitance C is charged to a potential V. It is then connected to another uncharged capacitor having the same capacitance. Find out the ratio of the energy stored in the combined system to that stored initially in the single capacitor. [2]

Answer : Let 'q' be the charge on the charged capacitor.

Energy stored in it is,

$$U = \frac{q^2}{2C}$$

When another similar uncharged capacitor is connected, the net capacitance of the system is,

$$C' = 2C$$

The charge on the system is constant. So, the energy stored in the system now is,

$$U' = \frac{q^2}{2(C')^2}$$

$$\Rightarrow \quad U' = \frac{q^2}{2(2C)}$$

$$\Rightarrow \quad U' = \frac{q^2}{4C}$$

Thus, the required ratio is,

$$\frac{U'}{U} = \frac{\frac{q^2}{4C}}{\frac{q^2}{2C}}$$

$$\Rightarrow \quad \frac{U'}{U} = \frac{1}{2}$$

11. Considering the case of a parallel plate capacitor being charged, show how one is required to generalize Ampere's circuital law to include the term due to displacement current. [2]

Answer : Gauss' law states that the electric flux ϕ_E of a parallel plate capacitor having an area A, and a total charge Q is given by

$$\phi_E = EA = \frac{Q}{\varepsilon_0 A} \times A \qquad \left[\because E = \frac{Q}{A\varepsilon_0}\right]$$

$$= \frac{Q}{\varepsilon_0}$$

As the charge Q on the capacitor plates change with time, so current is given by

$$i = \frac{dQ}{dt}$$

$$\therefore \quad \frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{Q}{\varepsilon_0}\right) = \frac{1}{\varepsilon_0}\frac{dQ}{dt}$$

$$\Rightarrow \quad \varepsilon_0 \frac{d\phi_E}{dt} = \frac{dQ}{dt} = i$$

This is the missing term in Ampere's Circuital law.

So, the total current through the conductor is

i = Conduction current (i_c) + Displacement current (i_d)

$$i = i_c + \varepsilon_0 \frac{d\phi_E}{dt} \qquad ...(i)$$

Ampere's circuital law states that,

$$\oint \vec{B}.\vec{dl} = \mu_0 i \qquad ...(ii)$$

Putting equation (i) in (ii), we get

$$\oint \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$$

This is the required generalized form of Ampere's circuital law.

12. A cell of emf 'E' and internal resistance 'r' is connected across a variable resistor 'R'. Plot a graph showing variation of terminal voltage 'V' of the cell versus the current 'I'. Using the plot, show how the emf of the cell and its internal resistance can be determined. [2]

Answer : The terminal voltage 'V' of the cell is given by

$$V = E - Ir$$

where E is the emf of the cell,

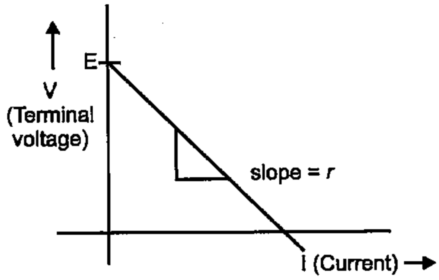
r is the internal resistance of the cell

and, I is the current through the circuit.

Comparing with the equation of a straight line $y = mx + c$, we get

$$y = V; x = I; m = -r; c = E$$

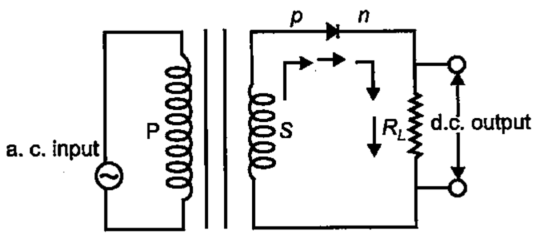
Graph showing variation of terminal voltage 'V' of the cell versus the current 'I'.



Emf of the cell = Intercept on V axis.
Internal resistance = slope of the line.

13. Explain, with the help of a circuit diagram, the working of a *p-n* junction diode as a half-wave rectifier. [2]

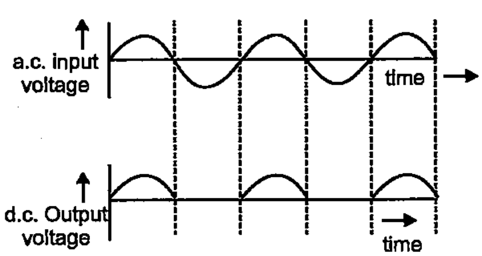
Answer : The circuit diagram for a *p-n* junction diode as a half wave rectifier is shown below :



Working : During the positive half cycle of the input a.c., the *p-n* junction is forward biased *i.e.*, the forward current flows from *p* to *n*. In the forward biasing, the diode provides a very low resistance and allows the current to flow. Thus, we get output across load.

During the negative half cycle of the input a.c., the *p-n* junction is reversed biased. In the reverse biasing, the diode provides a high resistance and hence a very small amount of current will flow through the diode which is of negligible amount. Thus no output is obtained across the load. During the next half cycle, output is again obtained as the junction diode gets forward biased. Thus, a half wave rectifier gives discontinuous and pulsating d.c. output across the load resistance.

The waveform of input and output is shown below :



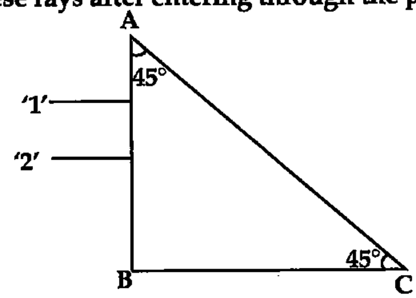
14. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area $1.0 \times 10^{-7} m^2$ carrying a current of 1.5 A. Assume the density of conduction electrons to be $9 \times 10^{28} m^{-3}$. [2]

Answer : Since, drift velocity, $v_d = \frac{I}{nAq}$
where,
I is the current,
n is the charge density,
q is charge of the electron, and
A is cross-sectional area.

$$v_d = \frac{1.5}{9 \times 10^{28} \times 1.0 \times 10^{-7} \times 1.6 \times 10^{-19}}$$

$$v_d = 10.4 \times 10^{-4} \text{ m/s}$$

15. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism. [2]



Answer : Critical angle of ray '1':

$$\sin(c_1) = \frac{1}{\mu_1} = \frac{1}{1.35}$$

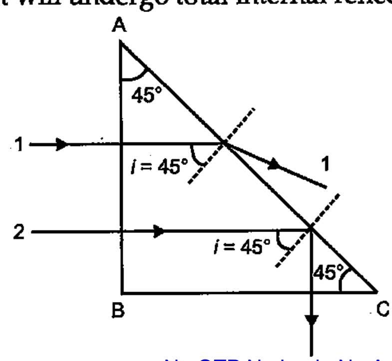
$$\Rightarrow \quad c_1 = \sin^{-1}\left(\frac{1}{1.35}\right) = 47.79°$$

Similarly, critical angle of ray '2':

$$\sin(c_2) = \frac{1}{\mu_2} = \frac{1}{1.45}$$

$$\Rightarrow \quad c_1 = \sin^{-1}\left(\frac{1}{1.45}\right) = 43.6°$$

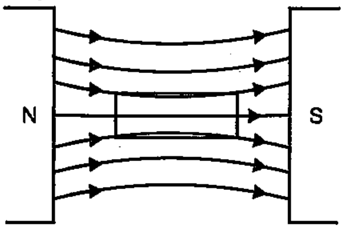
Ray '1' and '2' will fall on the side AC at an angle of incidence (*i*) of 45°. Critical angle of ray '1' is greater than *i*, so it will get refracted from the prism. Critical angle of ray '2' is less than that of *i*, so it will undergo total internal reflection.



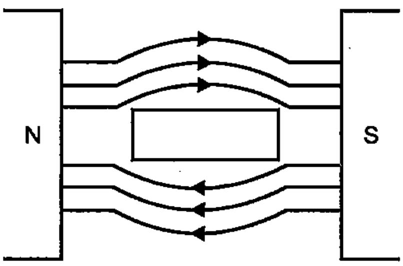
16. Write the functions of the following in communication systems :** **[2]**
(i) Transducer
(ii) Repeater

17. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature ? **[2]**

Answer : (i) The behaviour of magnetic field lines in the presence of a paramagnetic substance is shown below :



(ii) The behaviour of magnetic field lines in the presence of a diamagnetic substance is shown below :



This distinguishing feature is because of the difference in their relative permeability. The relative permeability of diamagnetic substance is less than 1, so the magnetic lines of force do not prefer passing through the substance whereas the relative permeability of a paramagnetic substance is greater than 1, so the magnetic lines of force prefer passing through the substance.

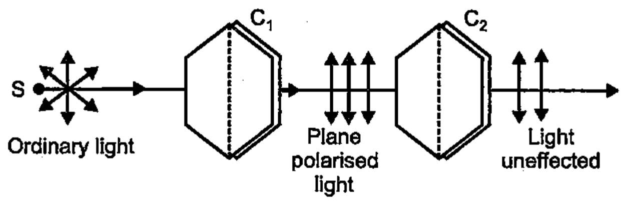
18. Draw a circuit diagram of *n-p-n* transistor amplifier in CE configuration. Under what condition does the transistor act as an amplifier ?** **[2]**

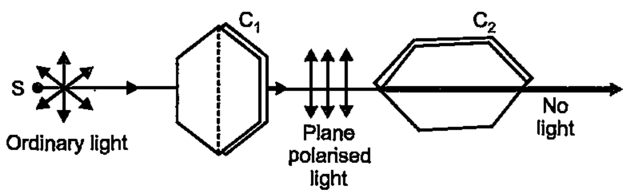
19. (a) Using the phenomenon of polarization, show how transverse nature of light can be demonstrated.

(b) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 30° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. **[3]**

**Answers is not given due to change in the present syllabus.

Answer : (a) Suppose that an ordinary light is incident normally on a pair of crystals C_1 and C_2. When the incident ray of light passes through crystal C_1, it gets plane polarised in the direction perpendicular to the length of crystal. Now, we see that when the axis of two crystals are parallel, the intensity of the emerging light will be maximum. When the second crystal is placed perpendicular with respect to the first crystal, the intensity of light observed is zero. This is due to the electric field of the plane polarised light obtained from C_1 can vibrate only in one direction. Hence, when the axis of the crystal C_2 is perpendicular to its direction of vibration of electric field, it gets blocked. This shows the transverse nature of light.





(b) Intensity of light after falling on P_1,

$$I = \frac{I_0}{2}$$

Intensity of light after falling on P_3,

$$I' = I\cos^2(\theta) = \frac{I_0}{2}\cos^2(30°) = \frac{3I_0}{8}$$

$$\left[\because \cos 30° = \frac{\sqrt{3}}{2}\right]$$

Therefore, a light of intensity $\frac{3I_0}{8}$ will pass through the P_2, and the angle between P_3 and P_2 will be 60° because of the condition given in the question. Intensity of light after falling on P_2,

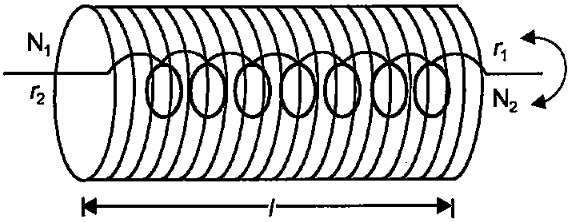
$$I'' = I'\cos^2 60°$$

$$I'' = \frac{3I_0}{8}\cos^2(60°) = \frac{3I_0}{32} \quad \left[\because \cos 60° = \frac{1}{2}\right]$$

20. Define the term 'mutual inductance' between the two coils.

Obtain the expression for mutual inductance of a pair of long coaxial solenoids each of length l and radii r_1 and r_2 ($r_2 >> r_1$). Total number of turns in the two solenoids are N_1 and N_2 respectively. **[3]**

Answer : Mutual inductance of two coils is equal to the e.m.f. induced in one coil when rate of change of current through the other coil is unity.



Mutual inductance of two co-axial solenoids :

Consider two long co-axial solenoid each of length l with number of turns N_1 and N_2 wound one over the other. Number of turns per unit length in solenoid, $n = \frac{N_1}{l}$. If I_1 is the current flowing in primary solenoid, the magnetic field produced within this solenoid.

$$B_1 = \frac{\mu_0 N_1 I_1}{l}$$

The flux linked with each turn of inner solenoid coil is $\phi_2 = B_1 A_2$, where A_2 is the cross-sectional area of inner solenoid. The total flux linkage with inner coil of N_2 turns.

$$\phi_2 = N_2 \phi_2$$

$$= N_2 B_1 A_2$$

$$= N_2 \left(\frac{\mu_0 N_1 I_1}{l}\right) A_2$$

$$= \frac{\mu_0 N_1 N_2 A_2 I_1}{l}$$

Mutual Inductance, $M_{21} = \frac{\phi_2}{I_1} = \frac{\mu_0 N_1 N_2 A_2}{l}$

If n_1 is number of turns per unit length of outer solenoid and r_2 is radius of inner solenoid, then

$$M = \mu_0 n_1 N_2 \pi r_2^2.$$

21. Answer the following : **[3]**

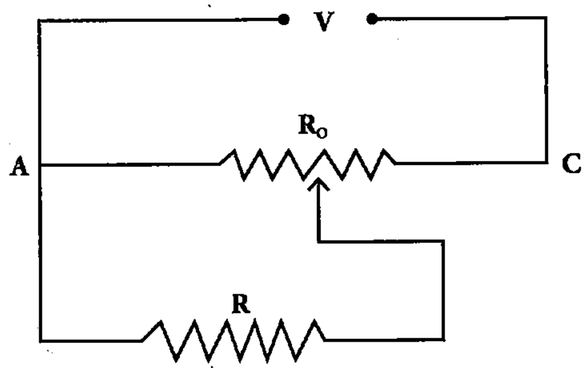
(a) Why are the connections between the resistors in a meter bridge made of thick copper strips ?

(b) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire ?

(c) Which material is used for the meter bridge wire and why ?

OR

A resistance of R Ω draws current from a potentiometer as shown in the figure. The potentio meter has a total resistance R_0 Ω. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of the potentiometer.



Answer : (a) The connection between the resistors in a meter bridge is made of thick copper strips because the resistivity of a copper wire is very low. As, the connections are thick, so the area becomes large and the resistance of the wires becomes almost negligible.

(b) It is preferred to obtain the balance point in the middle of the meter bridge wire because it improves the sensitivity of the meter bridge.

(c) Constantan is used for meter bridge wire because its temperature coefficient of resistance is almost negligible due to which the resistance of the wire does not get affected on increasing temperature of the wire due to flow of current.

OR

As the slide is in the middle of the potentiometer so, only half of its resistance $(R_0/2)$ will be in parallel with the resistance R. Hence, the total resistance (R_1) will be given by the following expression :

$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{(R_0/2)}$$

$$R_1 = \frac{R_0 R}{R_0 + 2R}$$

The total resistance between A and C is $R_1 + R_0/2$.

$\therefore$ The current flowing through the potentiometer will be

$$I = \frac{V}{R_1 + R_0/2} = \frac{2V}{2R_1 + R_0}$$

The voltage V_1 taken from the potentiometer will be the product of current I and resistance R_1.

$$V_1 = IR_1 = \left(\frac{2V}{2R_1 + R_0}\right) \times R_1$$

Substituting for R_1, we have

$$V_1 = \frac{2V}{2\left(\frac{R_0 \times R}{R_0 + 2R}\right) + R_0} \times \frac{R_0 R}{(R_0 + 2R)}$$

$$V_1 = \frac{2VR}{2R + R_0 + 2R}$$

or $$V_1 = \frac{2VR}{R_0 + 4R}$$

22. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm apart from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed. **[3]**

Answer : Let us first locate the image of the point object O formed by the convex lens.

Here : $u = -60$ cm and $f = 20$ cm

From the lens formula, we have :

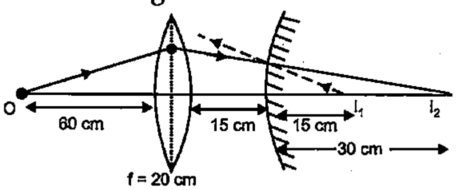
$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$= \frac{1}{20} + \frac{1}{-60} = \frac{3-1}{60} = \frac{2}{60} = \frac{1}{30}$$

$$v = +30 \text{ cm}$$

The positive sign indicates that the image is formed at the right of the lens.



The image I_1 is formed behind the mirror and acts as a virtual oject for the mirror. The convex mirror forms the image I_2, whose distance from the mirror can be determined as :

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Here,

$$u = 15 \text{ cm}$$

and, $$f = \frac{R}{2} = 10 \text{ cm}$$

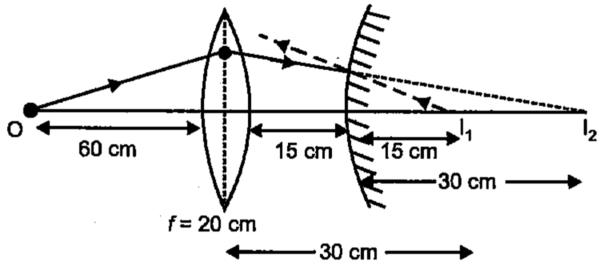
$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{10} - \frac{1}{15}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{3-2}{30} = \frac{1}{30}$$

$$\Rightarrow \quad v = 30 \text{ cm}$$

Hence, the final virtual image is formed at a distance of 30 cm from the convex mirror.



23. A voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for the average power dissipated over a cycle. Under what condition is (i) no power dissipated even though the current flows through the circuit, (ii) maximum power dissipated in the circuit ? **[3]**

Answer : Voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit.

Current is $\quad I = I_0 \sin(\omega t + \phi)$

$$I_0 = \frac{V_0}{Z}$$

$$\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$$

Instantaneous power supplied by the source is

$$P = VI = (V_0 \sin \omega t) \times (I_0 \sin(\omega t + \phi))$$

$$= \frac{V_0 I_0}{2}[\cos\phi - \cos(2\omega t + \phi)]$$

The average power over a cycle is average of the two terms on the R.H.S. of the above equation.

The second term is time dependent, so, its average is zero.

So, $$P = \frac{V_0 I_0}{2}\cos\phi$$

$$= \frac{V_0 I_0}{\sqrt{2}\sqrt{2}}\cos\phi$$

$$= VI\cos\phi$$

$$P = I^2 Z \cos\phi$$

where, $\cos\phi$ is called the power factor.

Case 1.

For pure inductive circuit or pure capacitive circuit, the phase difference between current and voltage *i.e.*, ϕ is $\frac{\pi}{2}$.

$$\therefore \quad \phi = \frac{\pi}{2}$$

So $$\cos\phi = 0$$

Therefore, no power is dissipated.

Case 2.

For power dissipated at resonance in an LCR circuit,

$$X_C - X_L = 0, \quad \phi = 0$$

$$\therefore \quad \cos\phi = 1$$

So, maximum power is dissipated.

24. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. [3]

Answer : Conductors :

(i) In case of conductors, the valence band is completely filled and the conduction band can have two cases-either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with the two bands overlapping each other as shown below :

Case 1	Case 2
Conduction Band	Conduction Band
Valence Band	Valence Band

(ii) Even when a small current is applied, conductors can conduct electricity.

Insulators :

(i) In case of insulators, the energy gap between the conduction and valence bands is very large and the conduction band is practically empty.

Conduction Band

↑
Forbidden Energy Gap
↓

Valence Band

(ii) When an electric field is applied to such kind of material, the electrons find hard to receive such a large amount of energy to reach the conduction band. Thus, the conduction band remains empty. That is why no current flows through insulators.

Semiconductors :

(i) In case of semiconductor, the energy band structure of semiconductors is similar to insulators, But in this case, the size of forbidden energy gap is quite smaller than that of the insulators.

Conduction Band

↑
Forbidden Energy Gap
↓

Valence Band

(ii) When an electric field is applied to a semiconductor, the electrons in the valence band find it relatively easier to jump to the conduction band. So, the conductivity of semiconductors lies between the conductivity of conductors and insulators.

25. For the past some time, Aarti had been observing some erratic body movement, unsteadiness and lack of coordination in the activities of her sister Radha, who also used to complain of severe headache occasionally. Aarti suggested to her parents to get a medical check-up of Radha. The doctor thoroughly examined Radha and diagnosed that she has a brain tumour. [3]

(a) What, according to you, are the values displayed by Aarti?**

(b) How can radioisotopes help a doctor to diagnose brain tumour ?

Answer :

(b) A little amount of radioisotope like radioiodine is inserted into the body along with organic dyes which are absorbed strongly by the tumour tissue than the normal tissues. By detecting the emitted radiation, the radiologist get information about the size and location of the tumour.

26. Write two basic modes of communication. Explain the process of amplitude modulation. Draw a schematic sketch showing how amplitude modulated signal is obtained by superposing a modulating signal over a sinusoidal carrier wave. [3]**

27. An electron microscope uses electrons accelerated by a voltage of 50 kV. Determine the de-Broglie wavelength associated with the electrons. Taking other factors, such as numerical aperture etc., to be same, how does the resolving power of an electron microscope compare with that of an optical microscope which used yellow light ? [3]

Answer : The de-Broglie wavelength of the electrons is given by :

$$\lambda = \frac{h}{\sqrt{2meV}}$$

Here,

m = mass of the electron $= 9.1 \times 10^{-31}$ kg

e = charge on the electron $= 1.6 \times 10^{-19}$ C

V = accelerating potential = 50 kV

h = Planck's constant $= 6.626 \times 10^{-34}$ Js

$$\Rightarrow \quad \lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2(9.1 \times 10^{-31})(1.6 \times 10^{-19})(50 \times 10^{3})}}$$

$$\Rightarrow \quad \lambda = 0.0549 \text{Å}$$

**Answers is not given due to change in the present syllabus.

Resolving power of a microscope, $R = \frac{2\mu \sin \theta}{\lambda}$

This formula shows that to enhance resolution, we have to use shorter wavelength and media with large indices of refraction.

For an electron microscope, μ is equal to 1 (vacuum).

For an electron microscope, the electrons are accelerated through a 60,000 V potential difference.

Thus, the wavelength of electrons is given by,

$$\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{60000}} = 0.05 \text{ Å}$$

As, λ is very little (roughly 10^{-5} times smaller) for electron microscope than an optical microscope which uses yellow light of wavelength (5700 Å to 5900 Å). So, the resolving power of electron microscope is about 10^5 greater than that of optical microscope.

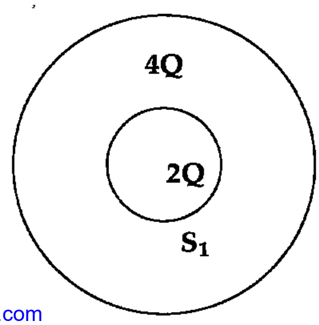
28. Draw a labelled diagram of Van de Graaff generator. State its working principle to show how by introducing a small charged sphere into a larger sphere, a large amount of charge can be transferred to the outer sphere. State the use of this machine and also point out its limitations. [5]

OR

(a) Deduce the expression for the torque acting on a dipole of dipole moment $\vec{p}$ in the presence of a uniform electric field $\vec{E}$.

(b) Consider two hollow concentric spheres, S_1 and S_2, enclosing charges 2Q and 4Q respectively as shown in the figure. (i) Find out the ratio of the electric flux through them. (ii) How will the electric flux through the sphere S_1 change if a medium of dielectric constant 'ε_r', 'ε_r' is introduced in the space inside S_1 in place of air?

Deduce the necessary expression.



Answer : Van de Graaff generator is a device used for building up high potential differences of the order of a few million volts.

Principle : The working of Van de Graaff generator is based on the following two electrostatic phenomena.

(i) Discharging action at sharp points (corona discharge) *i.e.*, electric discharge takes place in air or gases readily at the pointed ends of conductors.

(ii) If a charged conductor is brought into internal contact with a hollow conductor, all of its charge transfers to the hollow conductor, howsoever high the potential of the latter may be.

Construction : It has a big spherical conducting shell (S) kept over insulating pillars. A long narrow insulating belt is wound around two pulleys P_1 and P_2. B_1 and B_2 are two metal combs with sharp points. B_1 is known as spray comb and B_2 collecting comb.

Working : The spray comb provides positive potential by high tension source. The positive charge is sprayed on belt.

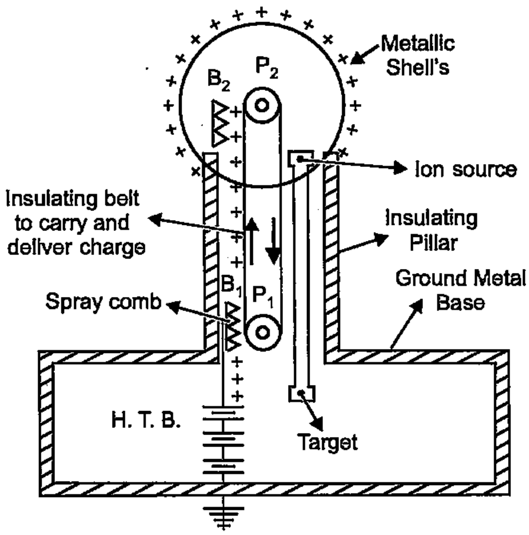
As belt moves and touches the sphere, a negative charge is induced on the sharp ends of collecting comb B_2 and similar positive charge is induced on the further end of B_2. This positive charge moves immediately to the outer surface of S, because of discharging action of sharp points of B_2, the positive charge on the belt is neutralized. The uncharged belt moves downwards and collects the positive charge from B_1, which is then collected by B_2. This process is repeated and the positive charge on S goes on accumulating. In this way, voltage differences of as much as 6 or 8 million volts (with respect to the ground) can be created.

Use : Van de Graaff generator is used to create high potential differences that are used to accelerate charged particles such as electrons, protons, ions, etc., used for nuclear reactions.

Limitations :

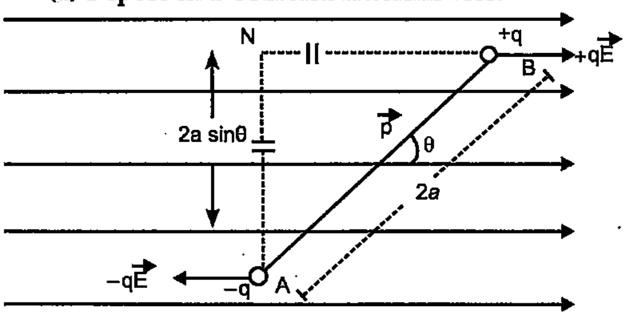
1. It is a series of combination that allows only one way for moving charge.

2. It can accelerate only the charged particles and not the uncharged particles.



OR

(a) Dipole in a Uniform External Field



Consider an electric dipole consisting of charges $-q$ and $+q$ and of length $2a$ placed in a uniform electric field $\vec{E}$ making an angle θ with electric field.

Force on charge $-q$ at A $= -q\vec{E}$ (opposite to $\vec{E}$)

Force on charge $+q$ at B $= +q\vec{E}$ (along $\vec{E}$)

Electric dipole is under the action of two equal and unlike parallel force, which give rise to a torque on the dipole.

τ = Force × Perpendicular distance between the two forces

$$\tau = qE(AN) = qE\,(2a\sin\theta)$$

$$\tau = pE\sin\theta \qquad [\because 2qa = P]$$

$$\vec{\tau} = \vec{p} \times \vec{E}$$

(b) (i) Charge enclosed by sphere $S_1 = 2Q$

By Gauss' law, electric flux through sphere S_1 is

$$\phi_1 = \frac{2Q}{\varepsilon_0}$$

Charge enclosed by sphere S_2 is

$$Q' = 2Q + 4Q = 6Q$$

Electric flux through sphere S_2 is

$$\therefore \quad \phi_2 = \frac{6Q}{\varepsilon_0}$$

The ratio of the electric flux is

$$\frac{\phi_1}{\phi_2} = \frac{\frac{2Q}{\varepsilon_0}}{\frac{6Q}{\varepsilon_0}} = \frac{2}{6} = \frac{1}{3}$$

(ii) For sphere S_1, the electric flux is

$$\phi' = \frac{2Q}{\varepsilon_r}$$

$$\therefore \quad \frac{\phi'}{\phi_1} = \frac{\varepsilon_0}{\varepsilon_r}$$

$$\Rightarrow \quad \phi' = \phi_1 \times \frac{\varepsilon_0}{\varepsilon_r}$$

$$\because \quad \varepsilon_r > \varepsilon_0$$

$$\therefore \quad \phi' < \phi_1$$

Therefore, the electric flux through the sphere S_1 decreases with the introduction of the dielectric inside it.

29. (a) In Young's double slit experiment, describe briefly how bright and dark fringes are obtained on the screen kept in front of a double slit. Hence obtain the expression for the fringe width.

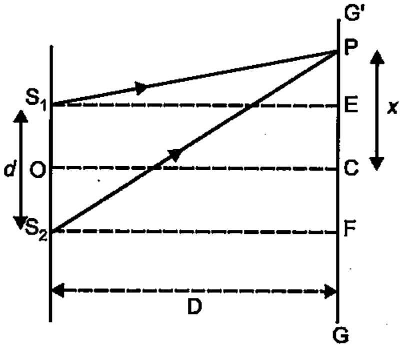
(b) The ratio of the intensities at minima to the maxima in the Young's double slit experiment is 9 : 25. Find the ratio of the widths of the two slits. **[5]**

OR

(a) Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

(b) Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^{-6} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of first maxima of the diffraction pattern obtained in the two cases.

Answer : (a) In Young's double slit experiment, the wave fronts from the two illuminated slits supere mpose on the screen. This results in formation of alternate bright and dark fringes because of constructive and destructive interference, respectively. The intensity of light is maximum at the centre C of the screen and it is called central maxima.



Let S_1 and S_2 be two slits separated by a distance d. GG' is the screen at a distance D from the slits S_1 and S_2. Both the slits are equidistant from point C. The intensity of light will be maximum at this point due to the path difference of the waves reaching this point will be zero.

At point P, the path difference between the rays coming from the slits S_1 and S_2 is $S_2P - S_1P$.

Now, $S_1S_2 = d$, $EF = d$, and $S_2F = D$

$\therefore$ In ΔS_2PF,

$$S_2P = [S_2F^2 + PF^2]^{\frac{1}{2}}$$

$$S_2P = \left[D^2 + \left(x + \frac{d}{2}\right)^2\right]^{\frac{1}{2}}$$

$$= D\left[1 + \frac{\left(x + \frac{d}{2}\right)^2}{D^2}\right]^{\frac{1}{2}}$$

Similarly, in ΔS_1PE

$$S_1P = D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]^{\frac{1}{2}}$$

$$S_2P - S_1P = D\left[1 + \frac{\left(x + \frac{d}{2}\right)^2}{D^2}\right]^{\frac{1}{2}} - D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]^{\frac{1}{2}}$$

On expanding it binomially,

$$S_2P - S_1P = \frac{1}{2D}\left[4x \times \frac{d}{2}\right] = \frac{xd}{D}$$

For bright fringes (constructive interference), the path difference is an integral multiple of wavelengths, *i.e.*, path difference is $n\lambda$.

$$\therefore \quad n\lambda = \frac{xd}{D}$$

$$x = \frac{n\lambda D}{d}, \text{ where } n = 0, 1, 2, 3, 4, \ldots\ldots$$

For $n = 0$, $x_0 = 0$

$n = 1$, $x_1 = \frac{\lambda D}{d}$

$n = 2$, $x_2 = \frac{2\lambda D}{d}$

$n = 3$, $x_3 = \frac{3\lambda D}{d}$

$\vdots$

$n = n$, $x_n = \frac{n\lambda D}{d}$

The separation between the centres of two consecutive bright interference fringes is the width of a dark fringe.

$$\therefore \quad \boxed{\beta_1 = x_n - x_{n-1} = \frac{\lambda D}{d}}$$

Similarly, for dark fringes,

$$x_n = (2n-1)\frac{\lambda D}{2d}$$

For $n = 1$, $x_1 = \frac{\lambda D}{2d}$

For $n = 2$, $x_2 = \frac{3\lambda D}{2d}$

The separation between the centres of two consecutive dark interference fringes is the width of a bright fringe.

$$\therefore \quad \boxed{\beta_2 = x_n - x_{n-1} = \frac{\lambda D}{d}}$$

$$\therefore \quad \beta_1 = \beta_2$$

All the bright and dark fringes are of equal width as $\beta_1 = \beta_2$

(b) Let w, a and I represent the slit width, amplitude and intensity respectively.

$$\frac{I_{min}}{I_{max}} = \frac{(a_1 - a_2)^2}{(a_1 + a_2)^2} = \frac{9}{25}$$

$$\frac{(a_1 - a_2)}{(a_1 + a_2)} = \frac{3}{5}$$

$$\frac{(a_1 - a_2) + (a_1 + a_2)}{(a_1 + a_2) - (a_1 - a_2)} = \frac{3+5}{5-3}$$

(By Componendo and dividendo)

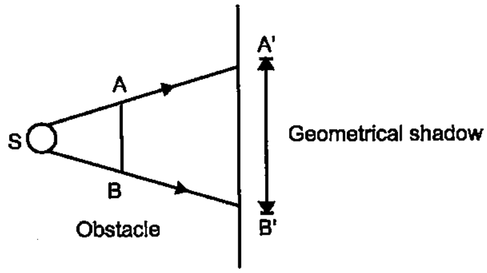
$$\frac{2a_1}{2a_2} = \frac{8}{2}$$

or $$\frac{a_1}{a_2} = \frac{4}{1}$$

and $$\frac{w_1}{w_2} = \frac{(a_1)^2}{(a_2)^2} = \frac{16}{1}$$

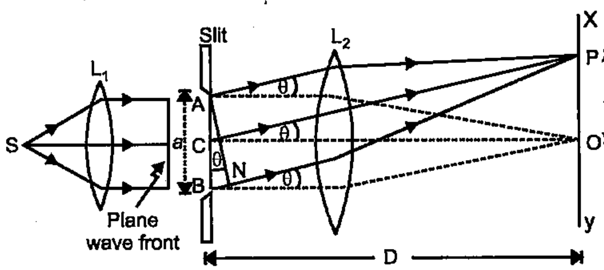
OR

(a) The phenomenon of bending of light round the sharp corners of an obstacle and spreading into the regions of the geometrical shadow is called diffraction.



Screen

Expression for Fringe width



Consider a parallel light beam from a lens is incident on slit AB. As diffraction happens, the pattern is focussed on screen XY with the help of lens L_2. We will get a diffraction pattern that is a central maximum at the centre O flanked by a number of dark and bright fringes known as secondary maxima and minima.

Central Maximum : Each point on the plane wave front AB sends secondary wavelets in all directions. The waves from points equidistant from the centre C kept on the upper and lower half reach point O with zero path difference and so, reinforce each other, making maximum intensity at point O.

Positions and Widths of Secondary Maxima and Minima

Consider a point P on screen at which wavelets moving in a direction making angle θ with CO are brought to focus by the lens. The wavelets from points A and B will have a path difference similar to BN :

From the right-angled ΔANB, we have :

$$BN = AB \sin\theta$$

$$BN = a \sin\theta \qquad ...(i)$$

Suppose $BN = \lambda$ and $\theta = \theta_1$

Then, the above equation becomes

$$\lambda = a \sin\theta_1,$$

$$\sin\theta_1 = \frac{\lambda}{a} \qquad ...(ii)$$

Such a point on the screen will be the position of first secondary minimum,

If $BN = 2\lambda$ and $\theta = \theta_2$, then

$$\sin\theta_2 = \frac{2\lambda}{a} \qquad ...(iii)$$

Such a point on the screen will be the position of second secondary minimum.

In general, for n^{th} minimum at point P,

$$\sin\theta_n = \frac{n\lambda}{a} \qquad ...(iv)$$

If y_n is the distance of the n^{th} minimum from the centre of the screen, from right-angled ΔCOP, we have :

$$\tan\theta_n = \frac{OP}{CO}$$

$$\tan\theta_n = \frac{y_n}{D} \qquad ...(v)$$

In case θ_n is small, $\tan\theta_n \approx \sin\theta_n$

∴ Equations (iv) and (v) give

$$\frac{y_n}{D} = \frac{n\lambda}{a}$$

$$y_n = \frac{nD\lambda}{a}$$

Width of the secondary maximum,

$$\beta = y_n - y_{n-1} = \frac{nD\lambda}{a} - \frac{(n-1)D\lambda}{a}$$

$$\beta = \frac{D\lambda}{a} \qquad ...(vi)$$

∴ β is independent of n, all the secondary maxima are of the same width β.

If $BN = \frac{3\lambda}{2}$ and $\theta = \theta'$, from equation (i), we have :

$$\frac{3\lambda}{2} = a \sin\theta'_1$$

$$\sin\theta'_1 = \frac{3\lambda}{2}$$

In general, for the n^{th} maximum at point P,

$$\sin\theta'_n = \frac{(2n+1)\lambda}{2a} \qquad ...(vii)$$

If y'_n is the distance of n^{th} maximum from the centre of the screen, then the angular position of the maximum is given by

$$\tan\theta'_n = \frac{y'_n}{D} \qquad ...(viii)$$

In case θ'_n is small,

$\sin\theta'_n \approx \tan\theta'_n$

$$\therefore \quad y'_n = \frac{(2n+1)D\lambda}{2a} \qquad ..(viii)$$

Width of the secondary minimum,

$$\beta' = y'_n - y'_{n-1} = \frac{(2n+1)D\lambda}{2a} - \frac{(2n-1)D\lambda}{2a}$$

$$\beta' = \frac{D\lambda}{a} \quad ...(ix)$$

Since β' is independent of *n*, all the secondary minima are of the same width β'.

(b) For first maxima of the diffraction pattern we know

$$\sin\theta = \frac{3\lambda}{2a}$$

where *a* is aperture of slit.

For small value of θ, $\sin\theta \approx \tan\theta = \frac{y}{D}$

Where *y* is the distance of first minima from central line and D is the distance between the slit and the screen.

So, $$y = \frac{3\lambda}{2a}D$$

When λ = 590 nm, a = 2 × 10^{-6}m, D = 1.5m

$$y_1 = \frac{3\times590\times10^{-9}}{2\times2\times10^{-6}}\times1.5$$

$$y_1 = 0.66375 \text{ m}$$

When λ = 596 nm, a = 2 × 10^{-6}, D = 1.5m

$$y_2 = \frac{3\times596\times10^{-9}}{2\times2\times10^{-6}}\times1.5$$

$$y_2 = 0.6705 \text{ m}$$

Separation between the positions of first maxima $= y_2 - y_1 = 0.00675$ m or 6.75 mm

30. (a) Deduce an expression for the frequency of revolution of a charged particle in a magnetic field and show that it is independent of velocity or energy of the particle.

(b) Draw a schematic sketch of a cyclotron. Explain, giving the essential details of its construction, how it is used to accelerate the charged particles. [5]

OR

(a) Draw a labelled diagram of a moving coil galvanometer. Describe briefly its principle and working.

(b) Answer the following :

(i) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer.

(ii) Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason.

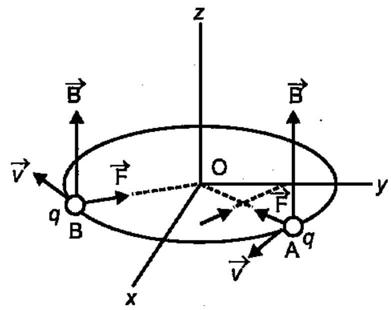
Answer : (a) When a charged particle having charge *q* moves inside a magnetic field $\vec{B}$ having velocity *v*, it experiences a force, which is given by :

$$\vec{F} = q(\vec{v}\times\vec{B})$$

Here,

$\vec{v}$ is perpendicular to $\vec{B}$,

$\vec{F}$ is the force on the charged particle which behaves as the centripetal force and make it to move in a circular path.



Let *m* be the mass of the charged particle and *r* be the radius of the circular path.

$$\therefore \quad q(\vec{v}\times\vec{B}) = \frac{mv^2}{r}$$

v and B are at right angles :

$$\therefore \quad qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{Bq}$$

Time period of circular motion of the charged particle can be calculated by,

$$T = \frac{2\pi r}{v} = \frac{2\pi}{v}\frac{mv}{Bq}$$

$$T = \frac{2\pi m}{Bq}$$

∴ Angular frequency is

$$\omega = \frac{2\pi}{T}$$

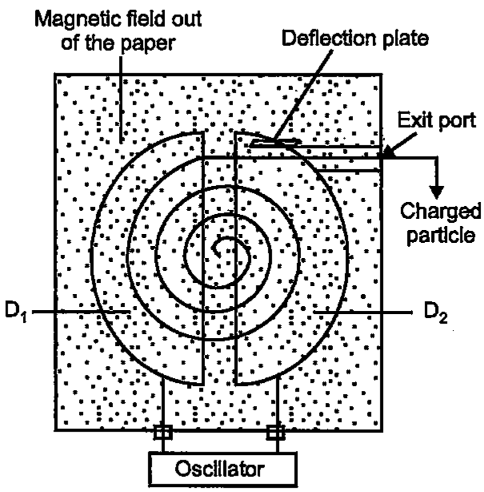
$$\therefore \quad \omega = \frac{Bq}{m}$$

Therefore, the frequency of the revolution of the charged particle is independent of the velocity or the energy of the particle.

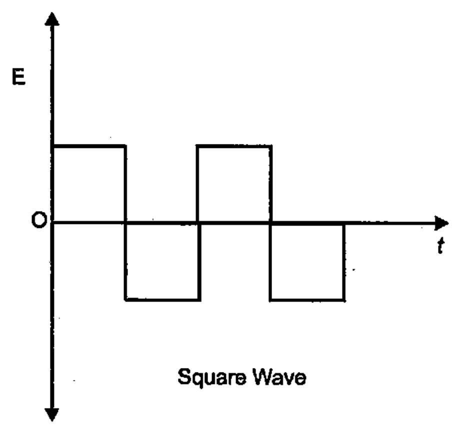
(b) The working principle of a cyclotron is that a charge particle can be accelerated to high energy by an oscillating electric field.

A cyclotron uses an electric field to accelerate charge particles across the gap between the two

D-shaped magnetic field regions. The magnetic field is perpendicular to the paths of the charged particles that makes them follow in circular paths within the two Ds. Each time the charged particles cross the Ds, it is accelerated by an alternating voltage. As its speed increases the radius of path of each particle also increases. So, the accelerated particles move in a spiral path to the other wall of the cyclotron.



Square wave electric fields are used to accelerate the charged particles in a cyclotron.

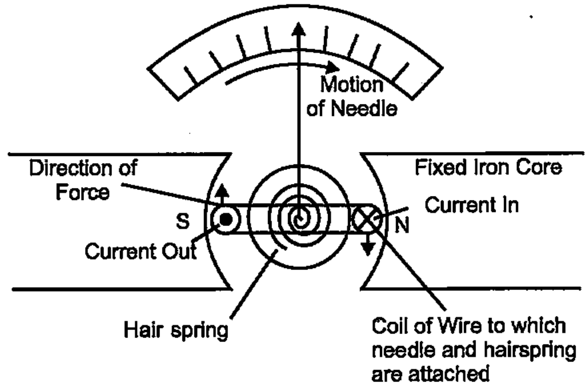


At the time the charge particle finishes its half circle, the accelerating electric field reverse so that it gets accelerated across the gap between the Ds.

The particle gets accelerated again and again, and its velocity increases. Therefore, a high kinetic energy is achieved.

OR

(a) Moving coil galvanometer : It is a device used for detecting and measuring small electric current.



Principle : The working is based upon the principle, when a current carrying coil suspended in a magnetic field experiences a torque.

Construction : It consists of a coil with a large number of turns of insulated copper wire wounded on a metallic frame. The coil is suspended by means of a phosphor bronze strip and a horse shoe magnet's NS surrounds it. The lower end of the coil is attached with a hair spring. The scale of the pointer is attached to the other end of the spring.

Working : When current is passed, the couple acts on it. Since the plane remains parallel to the magnetic field in all position of the coil, the force on the vertical arms always remains perpendicular to the place of the coil.

Let I = the current flowing through coil,

B = magnetic field supposed to be uniformed and always parallel to the coil, and

A = area of the coil.

Deflection acting on the coil is

$\tau = NIBA \sin 90° = NIBA$ $[\because \sin 90° = 1]$

Due to the deflection torque, the coil rotates and suspended wire gets twisted. The suspension fiber experiences a restoring torque. If ϕ is angle through the coil rotates and k is the restoring torque per unit angular twist, then

Restoring torque, $\tau = k\phi$

In equilibrium, Deflection torque = Restoring torque

$$NIBA = k\phi$$

$$\phi = \left(\frac{NBA}{k}\right)I$$

$$\Rightarrow \quad \phi = \left(\frac{I}{G}\right)\cdot I$$

$$I = G\phi$$

where $G = \frac{k}{NBA}$ known as galvanometer constant.

$\therefore \quad \phi \propto I$

This provides a linear scale for the galvanometer.

(b) (i) When a soft iron core is used the magnetic field lines tend to crowd through the core. It is because, soft iron core is ferromagnetic in nature. As a result, the strength of the magnetic field due to the field magnet increases, which in turn increases the sensitivity of the galvanometer.

(ii) Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit current flows through it.

$$I_s = \frac{\theta}{I} = \frac{nBA}{K} \quad \text{...(i)}$$

Voltage sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit voltage is applied across two terminals.

$$V_s = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{nBA}{KR} = \frac{I_s}{R} \quad \text{...(ii)}$$

Where n = number of turns in the coil of galvanometer

B = Magnetic field around coil

A = Area of coil

K = restoring torque per unit twist

From equation (i) we can say that current sensitivity increases by increasing n, B, A and decreases by decreasing K.

From equation (ii) we can say that voltage sensitivity increases by increasing n, B, A and decreases by de reasing K, R.

In case of current sensitivity if we increases the no. of turns n its current sensitivity increases. Since resistance of galvanometer R also increases, voltage sensitivity remains same or unchanged.

Therefore increase in current sensitivity of galvanometer may not necessarily increase the voltage.

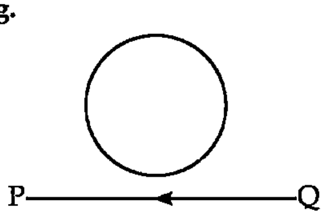
●●

Physics 2014 (Outside Delhi) SET II

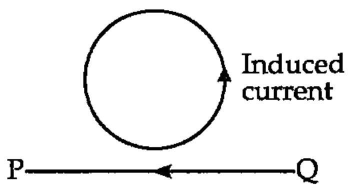
Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

1. A conducting loop is held above a current carrying wire 'PQ' as shown in the figure. Depict the direction of the current induced in the loop when the current in the wire PQ is constantly increasing. **[1]**



Answer : Anticlockwise



4. Why do the electrostatic field lines not form closed loops ? **[1]**

Answer : The electrostatic field lines originate from positive charge and end at the negative charge. As the isolated positive and negative charge do exist, the electrostatic field lines do not form closed loops.

5. A biconvex lens made of a transparent material of refractive index 1.5 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens ? Give reason. **[1]**

Answer : The refractive index of material of lens (1.5) is greater than the refractive index of water (1.33). So, it will behave as a converging lens.

7. To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13} Hz belong ? **[2]**

Answer : The frequency 3×10^{13} Hz belongs to infrared region of electromagnetic spectrum.

9. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area $2.5 \times 10^{-7} m^2$ carrying a current of 1.8 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. **[2]**

Answer : Given : Current (I) = 1.8 A

Charge density (n) = 9×10^{28} m^{-3}

Cross-section area (A) = 2.5×10^{-7} m^2

Charge of electron (q) = 1.6×10^{-19} C

$$v_d = \frac{I}{nAq}.$$

$$= \frac{1.8}{9 \times 10^{28} \times 2.5 \times 10^{-7} \times 1.6 \times 10^{-19}}$$

$$= 0.0005 \text{ m/s} = 0.5 \text{ mm s}^{-1}$$

13. Write the functions of the following in communication systems :** **[3]**

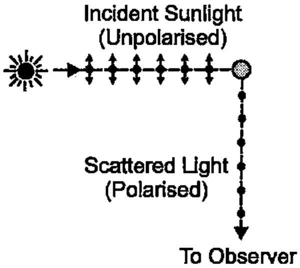
(i) Transmitter

(ii) Modulator

21. (a) Show with the help of a diagram, how unpolarised sunlight gets polarised due to scattering.

(b) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 45° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. **[3]**

Answer : (a) The given figure shows, the incident sunlight is unpolarised. The dots stand for polarisation perpendicular to



the plane of the figure. The double arrows show polarisation in the plane of the figure. Under the influence of the electric field of the incident wave the electrons in the molecules acquire components of motion in both these directions. We have drawn an observer looking at 90° to the direction of the sun. Clearly, charges accelerating parallel to the double arrows do not radiate energy towards this observer since their acceleration has no transverse component. The radiation scattered by the molecule is therefore represented by dots. It is polarised perpendicular to the plane of the figure. This explains the polarisation of scattered light from the sky.

(b) As given in the question, the polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Also, P_3 is placed at an angle of 45° with respect to P_1.

Now, we have :

Intensity of light after falling on P_1, $I = I_0/2$

Intensity of light after falling on P_3,

$$I' = I\cos^2\theta = \frac{I_0}{2}\cos^2 45° = \frac{I_0}{4}$$

Therefore, a light of intensity $I_0/4$ will pass through P_3 and the angle between P_3 and P_2 will be 45° because of the condition given in the question.

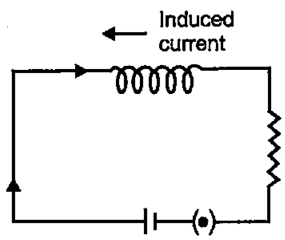
Intensity of light after falling on P_2,

$$I'' = I'\cos^2(\theta) = \frac{I_0}{4}\cos^2 45° = \frac{I_0}{8}$$

22. Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it. **[3]**

Answer : The ratio of magnetic flux through the solenoid to the current passing through it is called self-inductance of a solenoid. It is given by

$$L = \frac{\phi}{I}$$



Energy stored in an inductor : When a current grows through an inductor, a back e.m.f. is set up which opposes the growth of current. So work needs to be done against back e.m.f. (e) in building up the current. This work done is stored as magnetic potential energy.

Let I be the current through the inductor L at any instant t. The current rises at the rate dI/dt.

So the induced e.m.f. is

$$e = \frac{-L\,dI}{dt}$$

The work done against induced e.m.f. in dt is

$$dW = P\,dt$$
$$= -e\,I\,dt \qquad [P = VI]$$
$$= \frac{L\,dI}{dt}I\,dt$$
$$= LI\,dI$$

For total work from 0 to I_0 current

$$W = \int dW$$
$$= \int_0^{I_0} LI\,dI$$

**Answers is not given due to change in the present syllabus.

$$= L\left[\frac{I^2}{2}\right]_0^{I_0}$$

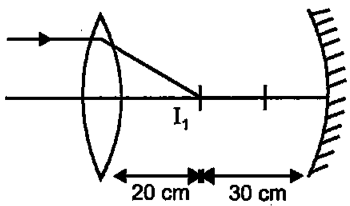
$$= \frac{1}{2}LI_0^2$$

Hence, this work done is stored as the magnetic potential energy U in the inductor

$$U = \frac{1}{2}LI^2$$

24. A convex lens of focal length 20 cm is placed coaxially with a concave mirror of focal length 10 cm at a distance of 50 cm apart from each other. A beam of light coming parallel to the principal axis is incident on the convex lens. Find the position of the final image formed by this combination. Draw the ray diagram showing the formation of the image. [5]

Answer : The beam incident on lens L is parallel to principal axis. Hence the lens forms an image I_1 at its focus. *i.e.*, at a distance OI_1 (= 20 cm) from the lens.



The image I_1 is formed in front of the mirror and hence, acts as a real source for the mirror. The concave mirror forms the image I_2, whose distance from the mirror can be calculated as;

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Here : $u = -30$ cm, and $f = -10$ cm

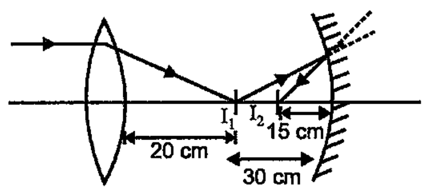
$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\Rightarrow \quad \frac{1}{v} = -\frac{1}{10} + \frac{1}{30}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1-3}{30} = -\frac{2}{30}$$

$$\Rightarrow \quad v = -15 \text{ cm}$$

Hence, the final image is formed at a distance of 15 cm from the concave mirror, as shown in the following figure.

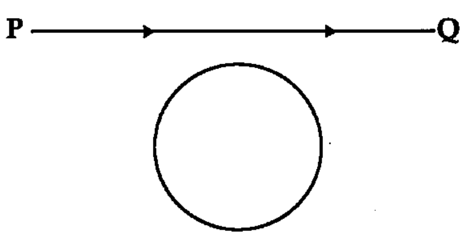


Physics 2014 (Outside Delhi) SET III

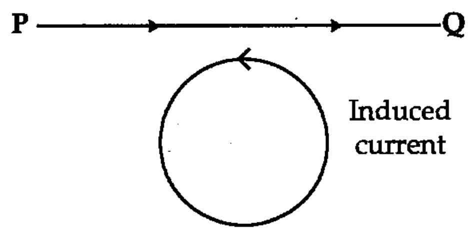
Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Sets.

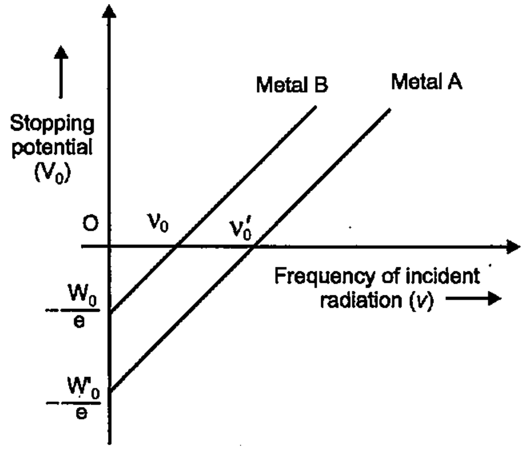
1. A conducting loop is held below a current carrying wire PQ as shown. Predict the direction of the induced current in the loop when the current in the wire is constantly increasing. [1]



Answer : Anticlockwise direction



2. The graph shows variation of stopping potential V_0 versus frequency of incident radiation ν for two photosensitive metals A and B. Which of the two metals has higher threshold frequency and why ? [1]



Answer : Metal A has higher threshold frequency because from the graph it is clear that the minimum frequency required to start photoemission is more in A than that of B.

5. **Why do the electric field lines never cross each other ? [1]**

Answer : At any point, if electric field lines cross each other than two tangents can be drawn, it means at that point there are two directions of electric field, which is impossible.

6. **To which part of the electromagnetic spectrum does a wave of frequency 5×10^{11} Hz belong ? [2]**

Answer : A wave of frequency 5×10^{11} Hz will belong to the microwaves of electromagnetic spectrum.

10. **Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area $2.5\times10^{-7}m^2$ carrying a current of 2.7 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. [2]**

Answer : We know that drift velocity, $v_d = \frac{I}{nAq}$

Where I is the current, n is charge density, q is charge of electron and A is cross-sectional area.

$$v_d = \frac{2.7}{9\times10^{28}\times2.5\times10^{-7}\times1.6\times10^{-19}}$$

$$v_d = 7.5\times10^{-4}\ \text{m/s}$$

or $$v_d = 0.75\ \text{mm s}^{-1}$$

This is the required average drift velocity.

18. **Write the functions of the following in communication systems :** [3]**

(i) Receiver

(ii) Demodulator

19. **A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm from each other. A point object placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw a ray diagram to show the formation. [3]**

Answer : Given, 4 = –40 cm and, f = 20 cm

From the lens formula, we have :

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

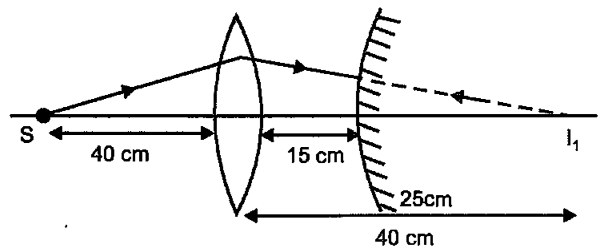
$$\Rightarrow \quad \frac{1}{v}=\frac{1}{f}+\frac{1}{u}$$

$$\Rightarrow \quad \frac{1}{v}=\frac{1}{20}+\frac{1}{(-40)}$$

$$\Rightarrow \quad \frac{1}{v}=\frac{2-1}{40}=\frac{1}{40}$$

$$\Rightarrow \quad v = 40\ \text{cm}$$

The positive sign describes that the image is formed to the right of the lens.



The image I_1 is formed behind the mirror and thus acts as a virtual source for the mirror. The convex mirror forms the image I_2, whose distance from the mirror is given by :

$$\frac{1}{v}+\frac{1}{v} = \frac{1}{f}$$

Here : $u = 25$ cm

$$f = \frac{R}{2} = 10\ \text{cm}$$

$$\frac{1}{v}+\frac{1}{v} = \frac{1}{f}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f}-\frac{1}{u}$$

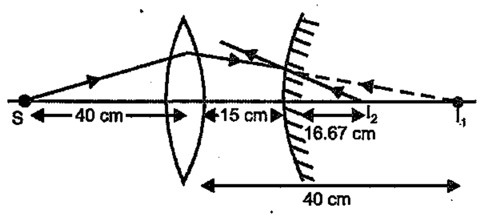
$$\Rightarrow \quad \frac{1}{v} = \frac{1}{10}-\frac{1}{25}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{5-2}{50}=\frac{3}{50}$$

$$\Rightarrow \quad v = +16.67\ \text{cm}$$

Hence, the final image is formed at a distance of 16.67 cm behind the convex mirror.

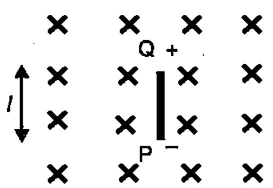
**Answers is not given due to change in the present syllabus.



25. (a) A rod of length 'l' is moved horizontally with a uniform velocity 'v' in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod.

(b) How does one understand this motional emf by involving the Lorentz force acting on the free charge carriers of the conductor? Explain. [5]

Answer : (a) Consider a rod PQ of length l, moving in a magnetic field $\vec{B}$ with a constant velocity $\vec{v}$. The length of the rod is perpendicular to the magnetic field and also the velocity is perpendicular to both the rod and field. The free electrons of the rod also move at this velocity $\vec{v}$ because of which it experiences a magnetic force.



$$\vec{F}_b = q\vec{v} \times \vec{B}$$

This force is towards Q to P.

Thus, the free electrons will move towards P and positive charge will appears at Q. An electrostatic field E is developed within the wire from Q to P. This field exerts a force.

$$\vec{F}_e = q\vec{E}$$

on each free electron. The charge keeps on gathering until

$$\vec{F}_b = \vec{F}_e$$

$$\Rightarrow \qquad |q\vec{v} \times \vec{B}| = |q\vec{E}|$$

$$vB = E$$

After this, resultant force on the free electrons of the wire PQ becomes zero. The potential difference between the ends Q and P is given by,

$$V = El = vBl$$

Thus, the potential difference is maintained by the magnetic force on the moving free electron and hence, produces an emf, $e = Bvl$

(b) Lorentz force acting on a charge q which is moving with a speed v in a (normal) uniform magnetic field B, is Bqv.

All the charges will experience the same force.

Work done to move the charge from P to Q,

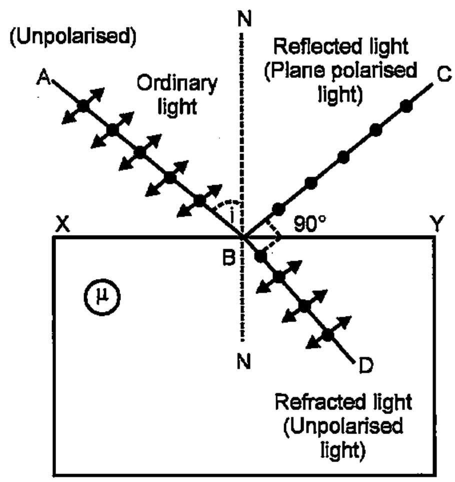
$$W = Bqv \times l$$

$$\therefore \qquad e = \frac{W}{q} = \frac{Bqvl}{q} = Blv$$

26. (a) Show, giving via suitable diagram, how unpolarized light can be polarised by reflection.

(b) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 60° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. [5]

Answer : (a) On reflection from a transparent medium a normal light beam becomes partially polarised. As the angle of incidence gets higher, the degree of polarization gets higher.



The reflected light beam becomes fully polarised at a certain angle. This angle of incidence is known as polarizing angle (p).

At the interface of a refracting medium when light is incident at polarizing angle, the refractive index of the medium is similar to the tangent of the polarizing angle.

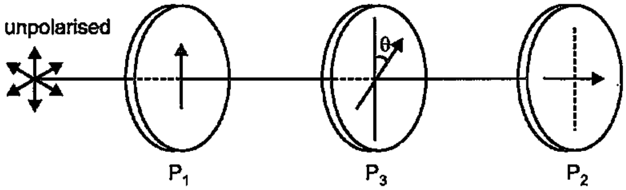
$$\mu = \tan p$$

where

$\mu \rightarrow$ Refractive index of the refracting medium

$p \rightarrow$ Polarising angle

(b) As given, the polaroid P_1 and P_2 are placed with their axes perpendicular to each other and polaroid P_3 placed at 60° with respect to P_1.



Therefore,

Intensity of light after falling on first polaroid P_1,

$$I = \frac{I_0}{2}$$

Intensity of light after falling on third polaroid P_3,

$$I' = I\cos^2(\theta) = \frac{I_0}{2}\cos^2(60°) = \frac{I_0}{8}$$

Therefore, the intensity $\frac{I_0}{8}$ will pass through the P_3 and angle between P_3 and P_2 is 30°. Because of the condition given in the question,

Intensity of light after falling on second polaroid P_2,

$$I'' = I'\cos^2\theta$$

$$= I''\cos^2 30° = \frac{3I_0}{32}$$

●●

Physics 2014 (Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. **Define the term 'mobility' of charge carriers in a conductor. write its S.I. unit. [1]**

Answer : Mobility of charge carriers in a conductor is defined as the magnitude of their drift velocity per unit applied electric field.

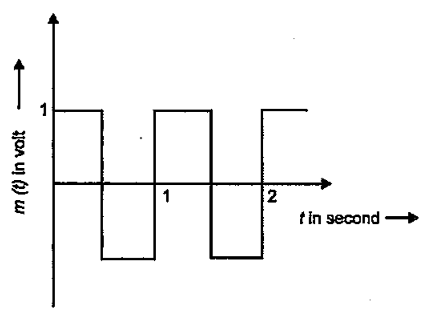
Mobility, μ = Drift of electric field

$$\mu = \frac{v_d}{E}$$

S.I. unit of mobility is $m^2V^{-1}s^{-1}$.

2. **The carrier wave is given by C(*t*) = 2 sin (8π*t*) volt.**

The modulating signal is a square wave as shown. Find modulation index. [1]**



3. **For any charge configuration, equipotential surface through a point is normal to the electric field. Justify. [1]**

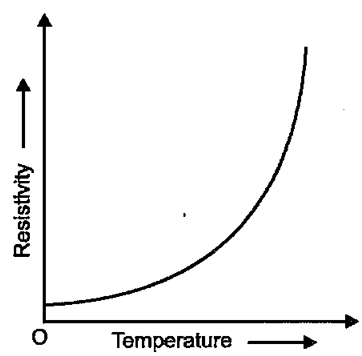
Answer : If the electric field were not normal to equipotential surface, it would have non-zero component along the surface. To move a charge against this component, work would have to be done. But no work is needed to move a test charge on an equipotential surface. Hence electric field must be normal to the equipotential surface at every point.

4. **Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why ? [1]**

Answer : Glass bob will reach the ground earlier than the metallic bob. As the metallic bob falls, it intercepts earth's magnetic field and induced currents are set up in it which oppose its downward motion. But no such currents are induced in the glass bob.

5. **Show variation of resistivity of copper as a function of temperature in a graph. [1]**

Answer : The variation of resistivity of copper with temperature is parabolic in nature. This is shown in the following graph :

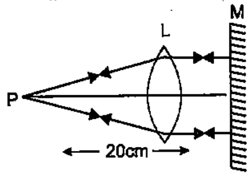


6. **A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image**

****Answers is not given due to change in the present syllabus.**

coinciding with itself. What is the focal length of the lens ? **[2]**

Answer : The figure shows a convex lens L placed in contact with a plane mirror M. P is the point object, kept in front of



this combination at a distance of 20 cm, from it. As the image coincides with itself, the rays from the object, after refraction from lens, should fall normally on the mirror M, so that they retrace their path. For this, the rays from P, after refraction from the lens must form a parallel beam perpendicular to M. For clarity, M has been shown at a small distance from L (in diagram). As the rays from P, form a parallel beam after refraction, P must be at the focus of the lens. Hence, the focal length of the lens is 20 cm.

7. Write the expression, in a vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force ? **[2]**

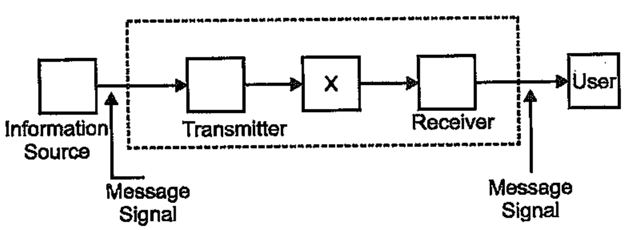
Answer : The Lorentz magnetic force is given by the following relation :

$$\vec{F} = q(\vec{v} \times \vec{B})$$

Here q, is the magnitude of the moving charge.

The direction of the magnetic force is perpendicular to the plane containing the velocity vector $\vec{v}$ and the magnetic field vector $\vec{B}$.

8. The figure given below shows the block diagram of a generalized communication system. Identify the element labelled 'X' and write its function.** **[2]**



9. Out of the two magnetic materials, 'A' has relative permeability slightly greater than unity while 'B' has less than unity. Identify the nature of the materials 'A' and 'B'. Will their susceptibilities be positive or negative? **[2]**

Answer : For a paramagnetic material, the relative permeability lies between $1 < \mu r < 1 + \varepsilon$ and its susceptibility lies between $0 < \chi < \varepsilon$.

Hence, 'A' is a paramagnetic material and its susceptibility is positive. This is because its relative permeability is slightly greater than unity. For a diamagnetic material, the relative permeability lies between $0 \leq \mu_r < 1$ and its susceptibility lies between $-1 < \chi < 0$. Hence, 'B' is a diamagnetic material and its susceptibility is negative. This is because its relative permeability is less than unity.

Here μ_r and χ refer to the relative permeability and susceptibility.

10. Given a uniform electric field $\vec{E} = 5 \times 10^3 \hat{i}$ N/C find the flux of this field through a square of 10 cm on a side whose plane is parallel to the YZ plane. What would be the flux through the same square if the plane makes a 30° angle with the X-axis ? **[2]**

Answer : When the plane is parallel to the Y-Z plane :

Electric flux, $\phi = EA$

Here, $E = 5 \times 10^3 \hat{i}$ N/C

$A = 10 \text{ cm}^2 \hat{i} = 10^{-2} \hat{i} \text{ m}^2 = 10^{-2} \hat{i} \text{ m}^2$

$\phi = 5 \times 10^3 \hat{i} \cdot 10^{-2} \hat{i}$

$\Rightarrow \quad \phi = 50$ weber or Nm^2C^{-1}

When the plane makes a 30° angle with the X-axis, the area vector makes 60° with the X-axis.

$\phi = \vec{E} \cdot \vec{A}$

$\Rightarrow \quad \phi = EA \cos \theta$

$\Rightarrow \quad \phi = 5 \times 10^3 \cdot 10^{-2} \cos 60°$

$\Rightarrow \quad \phi = \frac{50}{2}$

$\Rightarrow \quad \phi = 25$ weber or Nm^2C^{-1}

11. For a single slit of width a, the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance a. Explain. **[3]**

**Answers is not given due to change in the present syllabus.

Answer : When a single slit is used, the interference pattern is due to the diffraction phenomenon. In case of diffraction from a single slit of width a using monochromatic light of wavelength λ, the first minimum of the interference pattern occurs at an angle θ_1, which is given by

$$\sin\theta_1 = \frac{\lambda}{a}$$

Since λ is very small, θ_1 will also be very small.

$$\therefore \quad \theta_1 \approx \sin\theta_1 = \frac{\lambda}{a} \quad ...(i)$$

In case of interference from two narrow slits separated by a distance a using monochromatic light of wavelength λ, the first maximum occurs at a distance y_1 from the centre of the screen, which is given by.

$$y_1 = \frac{D\lambda}{a}$$

Here, D is the distance of the screen from the centre of the slits.

If the first maximum occurs at an angle θ_1', then

$$\tan\theta_1' = \frac{y_1}{D} = \frac{\lambda}{a}$$

Again as λ is very small, θ_1' will also be very small.

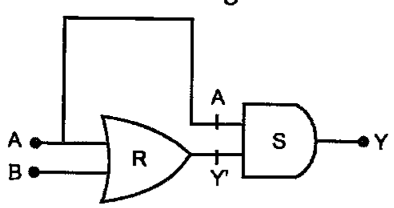
$$\therefore \quad \tan\theta_1' \approx = \theta_1' = \frac{\lambda}{a} \quad ...(ii)$$

From the equations (i) and (ii), we have

$$\theta_1 = \theta_1' = \frac{\lambda}{a}$$

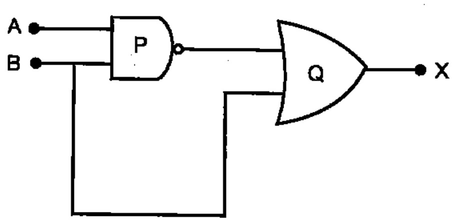
Hence, it proves the result.

12. Write the truth table for the combination of the gates shown. Name the gates used.** **[3]**



OR

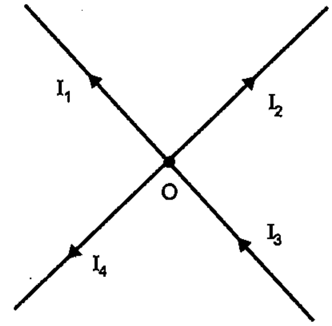
Identify the logic gates marked 'P' and 'Q' in the given circuit. Write the truth table for the combination.**



13. State Kirchhoff's rules. Explain briefly how these rules are justified. **[3]**

Answer : Kirchhoff's first Law–Junction Rule

In an electrical circuit, the algebraic sum of the currents meeting at a junction is always zero.



I_1, I_2, I_3 and I_4 are the currents flowing through the respective wires.

Convention : The current flowing towards the junction is taken as positive.

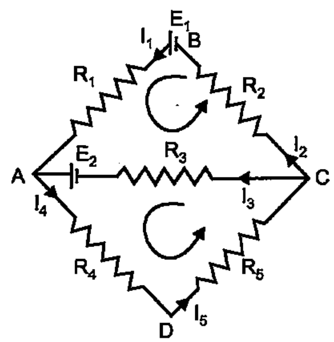
The current flowing away from the junction is taken as negative.

$$I_3 + (-I_1) + (-I_2) + (-I_4) = 0$$

This law is based on the law of conservation of charge.

Kirchhoff's Second Law – Loop rule

In a closed loop, the algebraic sum of the emf's is equal to the algebraic sum of the products of the resistances and the currents flowing through them.



For the closed loop BACB :

$$E_1 - E_2 = I_1R_1 + I_2R_2 - I_3R_3$$

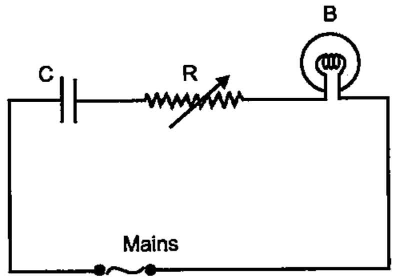
For the closed loop CADC :

$$E_2 = I_3R_3 + I_4R_4 + I_5R_5$$

This law is based on the law of conservation of energy.

14. A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance ? **[3]**

**Answers is not given due to change in the present syllabus.



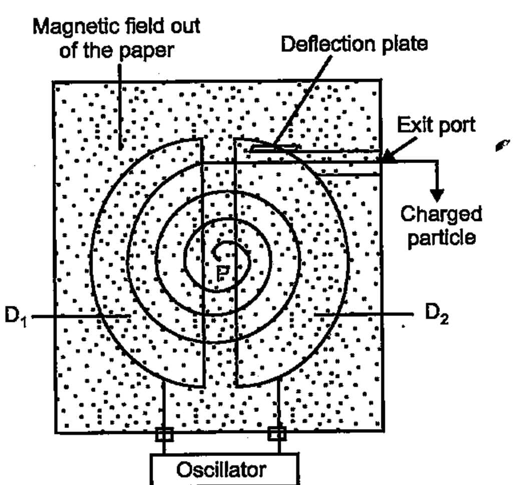
Answer : (i) As the dielectric slab is introduced between the plates of the capacitor, its capacitance will increase. Hence, the potential drop across the capacitor will decrease ($V = Q/C$). As a result, the potential drop across the bulb will increase (since both are connected in series). So, its brightness will increase.

(ii) As the resistance (R) is increased, the potential drop across the resistor will increase. As a result, the potential drop across the bulb will decrease (since both are connected in series). So, its brightness will decrease.

15. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies. **[3]**

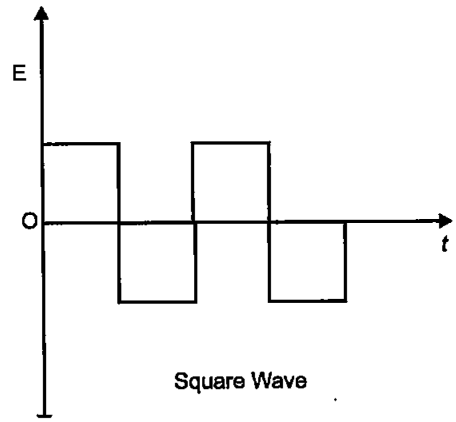
Answer : The underlying principle of a cyclotron is that an oscillating electric field can be used to accelerate a charged particle to high energy.

A cyclotron involves the use of an electric field to accelerate charge particles across the gap between the two D-shaped magnetic field regions. The magnetic field is perpendicular to the paths of the charged particles that makes them follow in circular paths within the two Ds. An alternating voltage accelerates the charged particles each time they cross the Ds. The radius of each particle's path increases with its speed. So, the accelerated particles spiral toward the outer wall of the cyclotron.



The Ds are the semi-circular structures (D_1 and D_2) between which the charges move. The accelerating voltage is maintained across the opposite halves of the Ds.

Square wave electric fields are used to accelerate the charged particles in a cyclotron.



The accelerating electric field reverses just at the time the change particle finishes its half circle. So that it gets accelerated across the gap between the Ds.

The particle gets accelerated again and again, and its velocity increases. Therefore, it attains high kinetic energy.

The positively charged ion adopts a circular path with a constant speed v, under the action of magnetic field B, which is perpendicular to the planes of D's of radius r.

$$r = \frac{mv}{qB}$$

16. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has charge ± 8 nC. **[3]**

Answer : As $\tau = pE \sin\theta$

$\therefore \quad 4\sqrt{3} = pE \sin\theta$

$\Rightarrow \quad pE \times \frac{\sqrt{3}}{2} = 4\sqrt{3}$

$\Rightarrow \quad pE = 8$

Potential energy of dipole,

$$U = -pE\cos\theta$$
$$= -pE\cos 60°$$
$$= -8 \cdot \frac{1}{2}$$
$$= -4 \text{ J.}$$

17. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has

(a) greater value of de-Broglie wavelength associated with it, and

(b) less momentum ?

Give reasons to justify your Answer. [3]

Answer : (a) de-Broglie wavelength,

$\lambda \propto 1/\text{mass}$ (for same accelerating potential)

Mass of a proton is less as compared to a deuteron. So, proton will have greater value of de-Broglie wavelength associated with it.

(b) Momentum, $p \propto$ mass (for same accelerating potential)

Mass of deuteron is more as compared to a proton. So, it will have a greater value of momentum.

18. (i) Monochromatic light of frequency 6.0 × 10^{14} Hz is produced by a laser. The power emitted is 2.0 × 10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface. [3]

Answer: (i) The energy of a photon of frequency ν is $E = h\nu = (6.63 \times 10^{-34}\,\text{Js}) \times (6 \times 10^{14}\,\text{s}^{-1}) = 3.98 \times 10^{-19}\,\text{J} \approx 4\ 10^{-19}\,\text{J}$

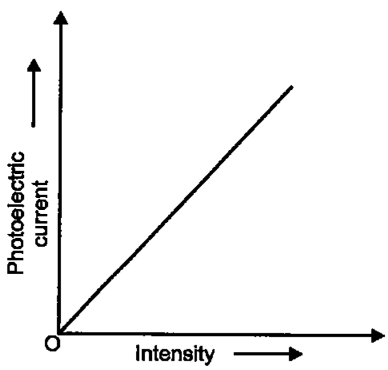
If n be the number of photons emitted by the source per second, then the power P transmitted in the beam is given by

$$P = nE$$

$$\therefore \quad n = \frac{P}{E}$$

$$\Rightarrow \quad n = \frac{2\times10^{-3}}{4\times10^{-19}} = 5 \times 10^{15}\ \text{photons/sec.}$$

(ii)



19. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited ? Calculate the wavelength of the first member of Lyman and first member of Balmer series. [3]

Answer : Energy of the electron in the n^{th} state of an atom

$$= \frac{-13.6}{n^2} \times Z^2 eV$$

Here, Z is the atomic number of the atom. For hydrogen atom, Z is equal to 1. Energy required to excite an atom from the initial state (n_i) to the final state (n_f).

$$E_f = \frac{-13.6}{n_f^2} + \frac{13.6}{n_i^2}\ \text{eV}$$

This energy must be equal to or less than the energy of the incident electron beam.

$$\Rightarrow \quad -\frac{-13.6}{n_f^2} + \frac{13.6}{n_i^2} = 12.5$$

Energy of the electron in the ground state = 13.612 = −13.6 eV

$$\Rightarrow \quad \frac{-13.6}{n_f^2} + 13.6 = 12.5 \qquad [\because n_i = 1]$$

$$\Rightarrow \quad 13.6 - 12.5 = \frac{13.6}{n_f^2}$$

$$\Rightarrow \quad n_f^2 = \frac{13.6}{1.1}$$

$$\Rightarrow \quad n_f^2 = 12.36$$

$$\Rightarrow \quad n_f = 3.5$$

State cannot be a fraction number $n_f = 3$

Hence, hydrogen atom would be excited up to 3^{rd} energy level.

Rydberg formula for the spectrum of the hydrogen atom is given below.

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Here, λ is the wavelength and R is the Rydberg constant.

$$R = 1.097 \times 10^7\,\text{m}^{-1}$$

For the first member of the Lyman series : $n_f = 1$ and $n_i = 2$

$$\frac{1}{\lambda} = 1.097\times10^7\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\lambda = 1215\ (\text{Å})$$

For the first member of Balmer series : $n_f = 2$ and $n_i = 3$

$$\frac{1}{\lambda} = 1.097\times10^7\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\Rightarrow \quad \lambda = 6563\ \text{Å}$$

20. When Sunita, a class XII student, came to know that her parents are planning to rent out the top floor of their house to a mobile company she protested. She tried hard to convince her parents

that this move would be a health hazard.

Ultimately her parents agreed : [3]

(1) In what way can the setting up of transmission tower by a mobile company in a residential colony prove to be injurious to health ?

(2) By objecting to this move of her parents, what value did Sunita display ?**

(3) Estimate the range of e.m. waves which can be transmitted by an antenna of height 20 m. (Given radius of the earth = 6400 km) [3]

Answer : (1) A transmitting tower makes use of electromagnetic waves such as microwaves, exposure to which can cause severe health hazards like, giddiness, headache, tumour and cancer. Also, the transmitting antenna operates on a very high power, so the risk of someone getting severely burnt in a residential area increases.

(3) Range of the transmitting antenna.

$$d = \sqrt{2hR}$$

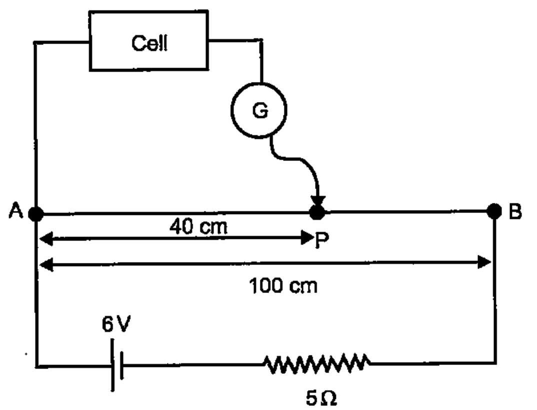
Here, h is the height of the transmitting antenna and R is the radius of the earth.

$$R = 6400 \text{ km} = 64 \times 10^5 \text{ m}$$

$$d = \sqrt{2 \times 20 \times 64 \times 10^5} = 16000 \text{ m}$$

21. A potentiometer wire of length 1 m has a resistance of 10 Ω. It is connected to a 6 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 40 cm. [3]

Answer : From the figure below :



Total resistance of the circuit,

$$R = (R_{AB} + 5) = (10 + 5)\ \Omega = 15\ \Omega$$

Current in the circuit, $I = \frac{V}{R} = \frac{6}{15}$ A

$$V_{AB} = 6 - \frac{6}{15} \times 5 = 6 - 2 = 4 \text{ V}$$

∴ Voltage across AB,

Emf of the cell, $e = \left(\frac{l}{L}\right) V_{AB}$

Here : l = 40 m (balance point)

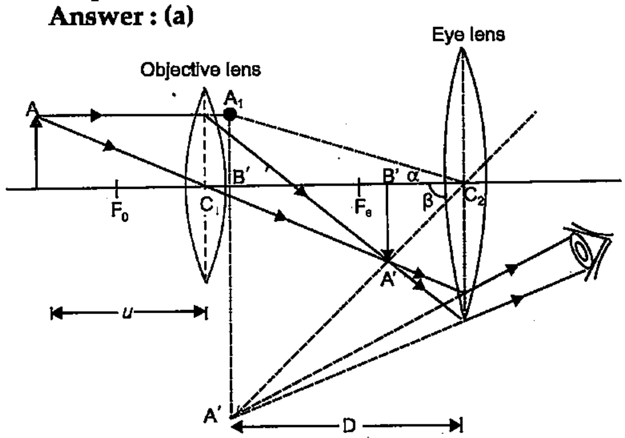
AB = L = 1 m = 100 cm (total length of the wire)

$$\therefore \quad e = \left(\frac{40}{100}\right) 4 = 1.6 \text{V}$$

22. (a) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.

(b) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eye-piece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye-piece. [3]

Answer : (a)



(b) For the least distance of clear vision, the total magnification is given by :

$$m = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) = m_o m_e \qquad \text{...(i)}$$

where,

L is the separation between the eyepiece and the objective

f_o is the focal length of the objective

f_e is the focal length of the eyepiece.

D is the least distance for clear vision.

Also, the given magnification for the eyepiece :

$$m_e = 5 \; m_e = 1 + \frac{D}{f_e}$$

**Answers is not given due to change in the present syllabus.

$$\Rightarrow \quad 5 = 1 + \frac{20}{f_e}$$

$$\Rightarrow \quad f_e = 5 \text{ cm}$$

Substituting the value of m and m_e in equation (i), we get :

$$m = m_o m_e$$
$$20 = m_o \times 5$$
$$m_o = 4$$

For the eyepiece $v_e = -20$cm, fe = 5cm

$$\therefore u_e = \frac{v_e f_e}{f_e - v_e} = \frac{20 \times 5}{5+20} = -4\text{cm}$$

Now, we have

$$|u_e| + |v_o| = 14$$

(*i. e.*, distance between objective and eye piece)

$$u_e + v_o = 14$$
$$v_o = (14-4) \text{ cm}$$
$$\Rightarrow \quad v_o = 10 \text{ cm}$$

Now, $$m_o = 1 - \frac{v_o}{f_o}$$

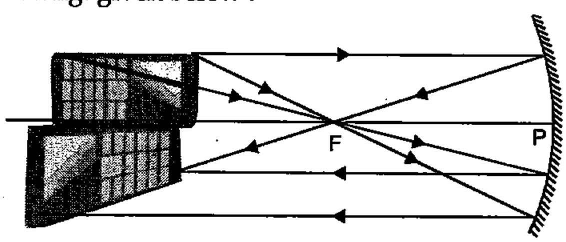
$$\Rightarrow \quad -4 = 1 - \frac{10}{f_o}$$

$$f_o = 2 \text{ cm}$$

23. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.

(b) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object ? Explain. [4]

Answer : (a) The image of the mobile phone formed by the convave mirror will be as shown in fig. given below :



The magnification produced by a concave mirror,

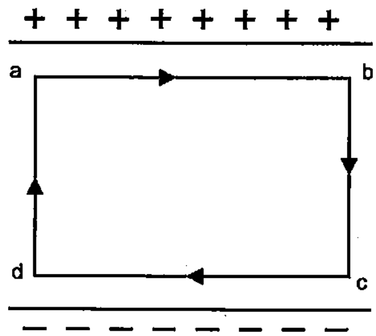
$$m = \frac{I}{O} = \frac{f}{f-u}$$

Since the object distance for the different parts of the mobile phone along its length are different, the different parts will be magnified differently. Hence, the magnification is not uniform.

(b) As the laws of reflection are true for all points of the mirror, the height of the whole image will be produced. However, as the area of the reflecting surface has been reduced, the image intensity will be reduced. In other words, the image produced will be less bright.

24. (a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.

(b) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop *abcda*. [5]



OR

(a) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation *d*.

(b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charge q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.

Answer : (a) Let us consider a parallel-plate capacitor of plate area A. If separation between plates is d metre, capacitance C is given by

$$C = \frac{\varepsilon_0 A}{d}$$

We know that, the magnitude of the electric field between the charged plates of the capacitor is

$$E = \frac{\sigma}{\varepsilon_0}$$

Where σ in surface density of either plate. Therefore, the plate charge is

$$Q = \sigma A = \varepsilon_0 EA$$

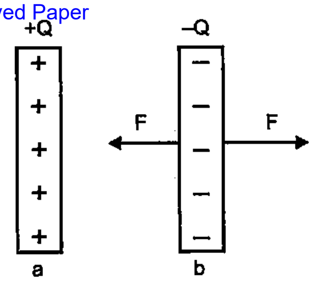
Now, the energy stored in the capacitor is

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(\varepsilon_0 EA)^2}{\varepsilon_0 A/d}$$

$$U = \frac{1}{2}\varepsilon_0 E^2 (Ad) \text{ J}$$

The volume between the plates is Ad metre^3. Therefore, the energy per unit volume is given by

$$U' = \frac{U}{Ad} = \frac{1}{2}\varepsilon_0 E^2 \text{ J/m}^3$$



(b) Work done, $W = F.d$

Here, F is the force exerted on the charge (q) due to electric field (E) and is given by,

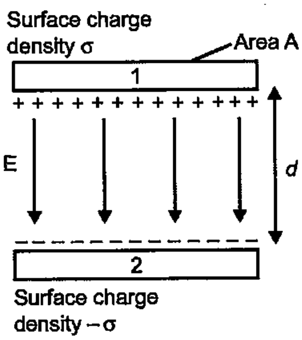
$$F = qE$$

Net displacement, $d = 0$

$$\therefore \quad W = 0$$

OR

(a) Derivation for the capacitance of parallel plate capacitor:



A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance. The two plates have charges q and $-q$ and distance between them is d.

Plate 1 has charge density, $\sigma = \dfrac{q}{A}$

Plate 2 has charge density, $\sigma = -\dfrac{q}{A}$

In the inner region between the plates 1 and 2, the electric fields due to the two charged plates add up.

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0}$$

The direction of electric field is from the positive to the negative plate.

For this electric field, potential difference between the plates is given by,

$$V = Ed = \frac{1}{\varepsilon_0}\frac{qd}{A}$$

The capacitance C of the parallel plate capacitor is then

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$$

(b) The surface charge density for a spherical conductor of radius R_1 is given by :

$$\sigma_1 = \frac{q_1}{4\pi R_1^2}$$

Similarly, for spherical conductor R_2, the surface charge density is given by :

$$\sigma_2 = \frac{q_2}{4\pi R_2^2}$$

$$\therefore \quad \frac{\sigma_1}{\sigma_2} = \frac{q_1 R_2^2}{q_2 R_1^2} \quad \text{...(i)}$$

As the spheres are connected so the charges will flow between the spherical conductors till their potential become equal.

$$i.e., \quad \frac{kq_1}{R_1} = \frac{kq_2}{R_2}$$

$$\Rightarrow \quad \frac{q_1}{q_2} = \frac{R_1}{R_2} \quad \text{...(ii)}$$

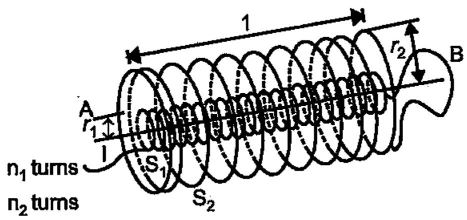
Using (ii) in (i)

We have, $\dfrac{\sigma_1}{\sigma_2} = \dfrac{R_1}{R_2} \cdot \dfrac{R_2^2}{R_1^2} = \dfrac{R_2}{R_1}$

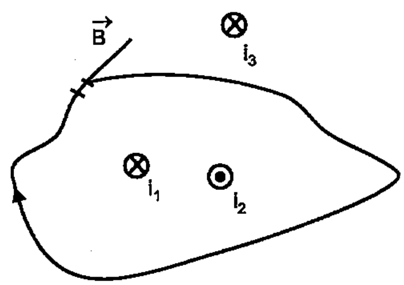
$$\Rightarrow \quad \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

25. (a) State Ampere's circuital law, expressing it in the integral form.

(b) Two long coaxial insulated solenoids, S_1 and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current "I" flow through the inner solenoid S_1 to the other end B, which is connected to the outer solenoid S_2 through which the same current "I" flows in the opposite direction so as to come out at end A. If n_1 and n_2 are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system. **[5]**



Answer : (a) Ampere's circuital law states that the circulation of the resultant magnetic field along a closed, plane curve is equal to μ_0 times the total current crossing the area bounded by the closed curve, provided the electric field inside the loop remains constant.



In the above illustration, the Ampere's circuital law can be written as follows :

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 i$$

where $i = i_1 - i_2$

(b) (i) The magnetic field due to a current carrying solenoid :

$$B = \mu_0 n i$$

where, n = number of turns per unit length, i = current through the solenoid.

Now, the magnetic field due to solenoid S_1 will be in the upward direction and the magnetic field due to S_2 will be in the downward direction (by right-hand screw rule).

$$B_{net} = B_1 - B_2$$
$$B_{net} = \mu_0 n_1 I - \mu_0 n_2 I$$
$$= \mu_0 I(n_1 - n_2)$$

(ii) The magnetic field is zero outside a solenoid.

26. Answer the following : **[5]**

(a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.

(b) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now ? Explain.

(c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.

Answer : (a) Microwaves are suitable for radar systems used in aircrafts navigation. The range of frequency for these waves is 10^9 Hz to 10^{12} Hz.

(b) In the absence of atmosphere, there would be no greenhouse effect on the surface of the Earth. As a result, the temperature of the Earth would decrease rapidly, making it difficult for human survival.

(c) The momentum transported by electromagnetic waves is given by

$$p = \frac{U}{c}$$

where U is the energy transported by electromagnetic waves in a given time and c is speed of electromagnetic waves in free space. As a result, when these waves strike a surface, pressure and hence force is exerted by them on the surface.

27. (a) Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay.

(b) (i) Write symbolically the process expressing the β+ decay of $^{22}_{11}Na$. Also write the basic nuclear process underlying this decay.

(ii) Is the nucleus formed in the decay of the nucleus $^{22}_{11}Na$, an isotope or isobar? **[5]**

Answer : (a) Suppose initially the number of atoms in radioactive element is N_0 and N the number of atoms after time t. After time t, let dN be the number of atoms which disintegrate in a short interval dt, then rate of disintegration will be, $\frac{dN}{dt}$, this is also called the activity of the element.

According to Rutherford-Soddy law,

$$\frac{dN}{dt} \propto N$$

or

$$\frac{dN}{dt} = -\lambda N \quad \text{...(i)}$$

where λ is a constant, called decay constant or disintegration constant of the element. Its unit is s^{-1}. Negative sign shows that the rate of disintegration decreases with increase of time. For a given element λ is a constant and is different for different elements. Equation (i) may be rewritten as

$$\frac{dN}{N} = -\lambda dt$$

Integrating $\log_e N = -\lambda t + C$ ...(ii)

where C is a constant of integration.

At $t = 0, N = N_0$

$\therefore$ $\log_e N_0 = 0 + C \Rightarrow C = \log_e N_0$

$\therefore$ Equation (ii) gives $\log_e N = -\lambda t + \log_e N_0$

or $\log_e N - \log_e N_0 = -\lambda t$

or

$$\log_e \frac{N}{N_0} = -\lambda t$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$N = N_0 e^{-\lambda t}$$

(b) (i) The β^+ decay of $_{11}N^{22}$ is expressed as below :

$$_{11}N^{22} \rightarrow {}_{10}Ne^{22} + 1e^0 + \nu$$

The neutron-proton ratio is also an important factor that determines the stability of a nucleus. A proton-rich nucleus undergoes positron emission (β^+ decay), so as to improve the neutron-proton ratio. The positron emission decreases proton number relative to neutron number and the product nucleus becomes relatively more stable. In β^+ decay, neutrino (ν) is emitted so as to conserve spin.

(ii) The nucleus so formed is an isobar of $11N^{22}_a$ because the mass number is same, but the atomic numbers are different.

28. (a) (i) 'Two independent mono-chromatic sources of light cannot produce a sustained interference pattern'. Give reason.

(ii) Light wave each of amplitude 'a' and

frequency 'ω', emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.

(b) In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is λ/3. [5]

OR

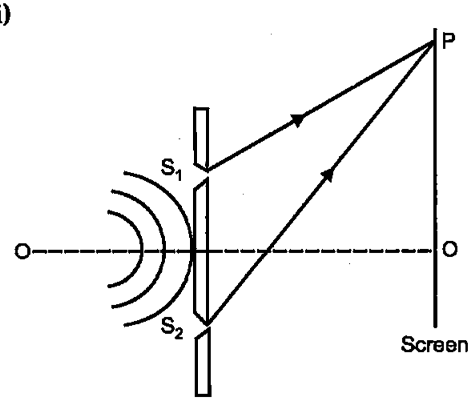
(a) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a polaroid gets polarized ?

(b) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when $\mu = \tan i_B$, where μ is the refractive index of glass with respect to air and i_B is the Brewster's angle.

Answer : (a) (i) The condition for the sustained interference is that both the sources must be coherent (*i.e.*, they must have the same wavelength and the same frequency, and they must have the same phase or constant phase difference).

Two sources are monochromatic if they have the same frequency and wavelength. Since they are independent, *i.e.*, they have different phases with irregular difference, they are not coherent sources.

(ii)



Let the displacement of the waves from the sources S_1 and S_2 at point P on the screen at any time t be given by :

$$y_1 = a\cos\omega t$$

and $$y_2 = a\cos(\omega t + \phi)$$

Where, ϕ is the constant phase difference between the two waves.

By the superposition principle, the resultant displacement at point P is given by :

$$y = y_1 + y_2$$

$$y = a\cos\omega t + a\cos(\omega t + \phi)$$

$$y = 2a\left[\cos\left(\frac{\omega t + \omega t + \phi}{2}\right)\cos\left(\frac{\omega t - \omega t - \phi}{2}\right)\right]$$

$$y = 2a\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \quad ...(i)$$

Let $2a\cos(\phi/2) = A$ ...(ii)

Then, equation (i) becomes

$$y = A\cos(\omega t + \phi/2)$$

Now, we have :

$$A^2 = 4a^2\cos^2(\phi/2) \quad ...(iii)$$

The intensity of light is directly proportional to the square of the amplitude of the wave. The intensity of light at point on the screen is given by

$$I = 4a^2\cos^2\frac{\phi}{2}$$

(b) Intensity $I = 4I_0\cos^2\frac{\phi}{2}$

When path difference is λ, phase difference is 2π

$$I = 4I_0\cos^2\pi$$
$$= 4I_0 = k \text{ (given)}$$

When path difference, $\Delta = \frac{\lambda}{3}$, the phase difference

$$\phi_1 = \frac{2\pi}{\lambda}\Delta$$

$$= \frac{2\pi}{\lambda}\times\frac{\lambda}{3} = \frac{2\pi}{3}$$

$$I_1 = 4I_0.\cos^2\frac{2\pi}{3} \quad (\text{since } k = 4I_0)$$

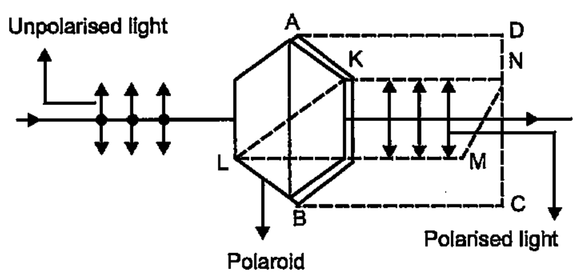
$$= k\cos^2\frac{2\pi}{3}$$

$$= k\times\left(-\frac{1}{2}\right)^2$$

$$= \frac{1}{4}k$$

OR

(a)



The phenomenon of restricting the vibration of light (electric vector) in a particular direction perpendicular to the direction of the wave propagation is called polarization of light.

When unpolarised light is passed through a polaroid, only those vibrations of light pass through the crystal, which are parallel to the axis of the crystal (AB). All other vibrations are absorbed and that is why intensity of the emerging light is reduced.

The plane ABCD in which the vibrations of the polarised light are confined is called the plane of vibration. The plane KLMN that is perpendicular to the plane of vibration is defined as the plane of polarization.

(b) When unpolarised light is incident on the glass-air interference at Brewster angle i_B, then reflected light is totally polarised. This is called Brewster's Law.

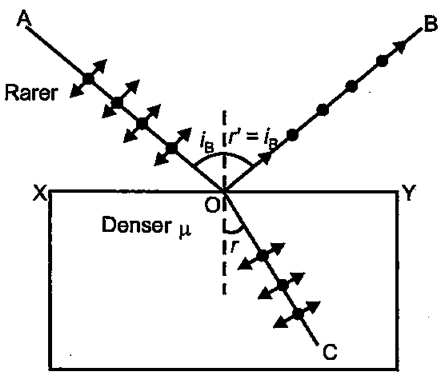
When light is incident at Brewster angle, the reflected component OB and the refracted component OC are mutually perpendicular to each other.

From the figure,

We have : $\angle BOY + \angle YOC = 90°$

$$(90° - i_B) + (90° - r) = 90°$$

$$i_B + \mu = 90°$$



Where, r is angle of refraction

According to the Snell's law :

$$\mu = \frac{\sin i_B}{\sin r} = \frac{\sin i_B}{\sin(90° - i_B)}$$

$$\mu = \frac{\sin i_B}{\cos i_B}$$

$\mu = \tan i_B$ **Hence proved.**

29. (a) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it.

(b) The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation.

(i) Magnetic flux versus the current

(ii) Induced emf versus dI/dt

(iii) Magnetic potential energy stored versus the current. [5]

OR

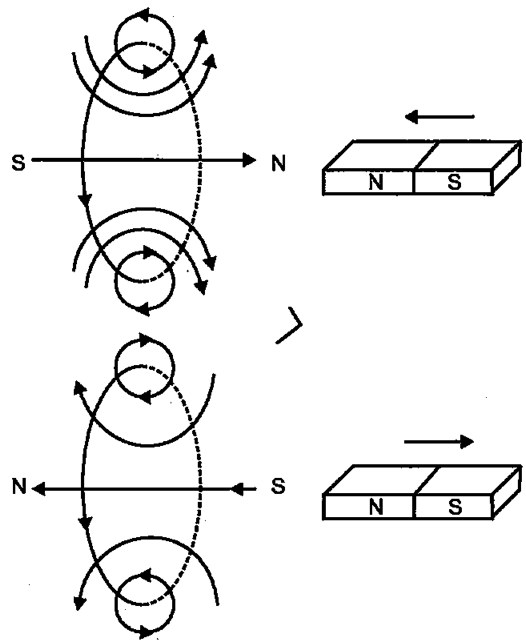
(a) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of

(i) Magnetic flux and

(ii) Alternating emf versus time generated by a loop of wire rotating in a magnetic field.

(b) Why is choke coil needed in the use of fluorescent tubes with ac mains ?

Answer : (a) Lenz's law : According to Lenz's law, the polarity of the induced emf is such that it opposes a change in magnetic flux responsible for its production.



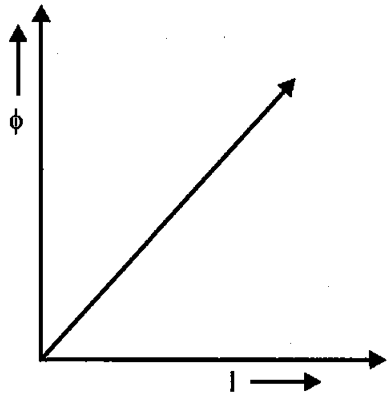
When the north pole of a bar magnet is pushed towards the coil, the amount of magnetic flux linked with the coil increase. Current is reduced in the coil from a direction such that it opposes the increase in magnetic flux. This is possible only when the current induced in the coil is in anti-clockwise direction, with respect to an observer. The magnetic moment M associated with this induced emf has north polarity, towards the north pole of the approaching bar magnet. Similarly, when the north pole of the bar magnet is moved away from the coil, the magnetic flux linked with the coil decreases. To counter this decrease in magnetic flux, current is induced in the coil in clockwise direction so that its south pole faces the receding north pole of the bar magnet. This would result in an attractive force which opposes the motion of the magnet and the corresponding decrease in magnetic flux.

(b) (i) Since $\phi = LI$

where, I = strength of current through the coil at any time

ϕ = Amount of magnetic flux linked with all turns of the coil at that time and,

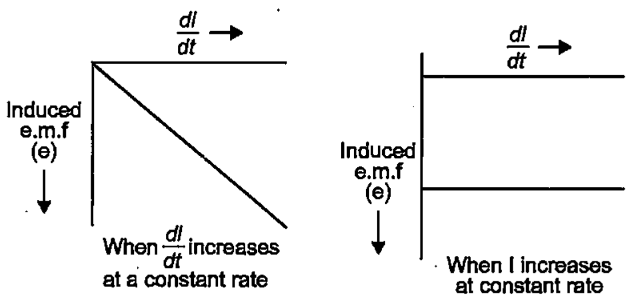
L = Constant of proportionally called coefficient of self induction.



(ii) Induced emf,

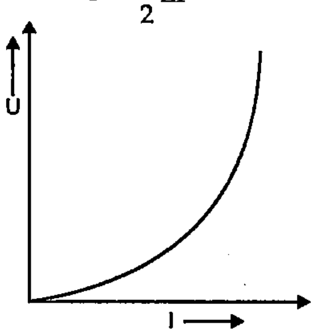
$$e = \frac{-d\phi}{dt} = -\frac{d\,(LI)}{dt}$$

i.e. $$e = -L\left(\frac{dI}{dt}\right)$$



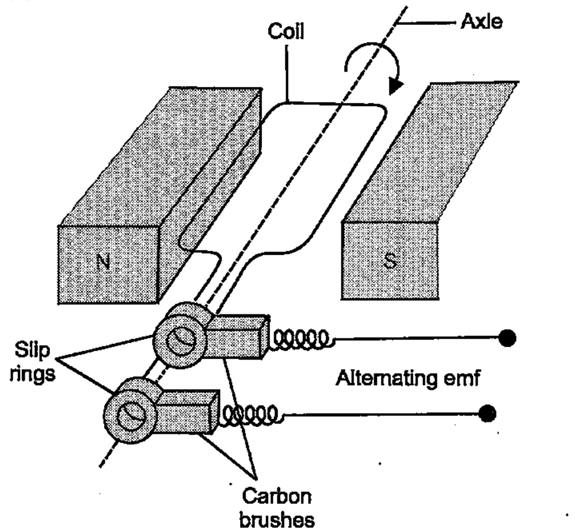
(iii) Since magnetic potential energy is given by

$$U = \frac{1}{2}LI^2$$



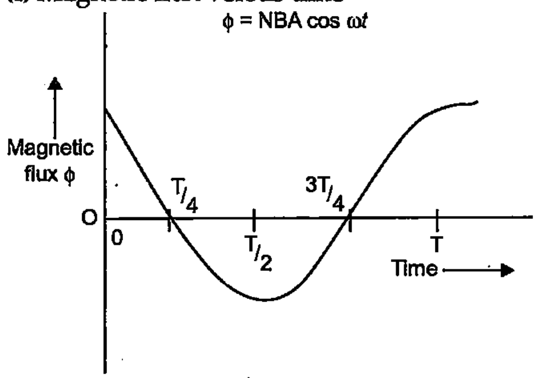
OR

(a)



It works on the process of electromagnetic induction, *i.e.*, when a coil rotates continuously in a magnetic field, the effective area of the coil, linked (normally) with the magnetic field lines, changes continuously with time. This variation of magnetic flux with time results in the production of a (alternating) emf in the coil.

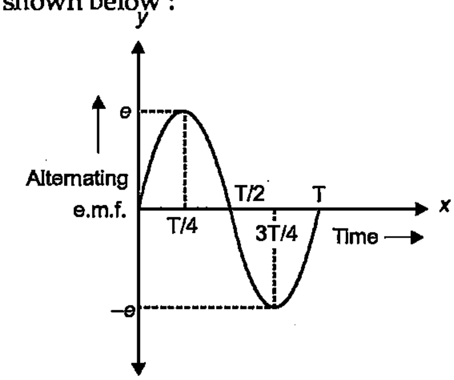
(i) Magnetic flux versus time



(ii) Alternating emf versus time

$e = NAB\omega \sin \omega t = e_0 \sin \omega t$

The graph between alternating emf versus time is shown below :



(b) A choke coil is an electrical appliance used for controlling current in an a.c. circuit. Therefore, if we use a resistance R for the same purpose, a lot of energy would be wasted in the form of heat etc.

30. (a) State briefly the processes involved in the formation of *p-n* junction explaining clearly how the depletion region is formed.

(b) Using the necessary circuit diagram, show how the V-I characteristics of a *p-n* junction are obtained in

(i) Forward biasing

(ii) Reverse biasing

How are these characteristics made use of in rectification ? [5]

OR

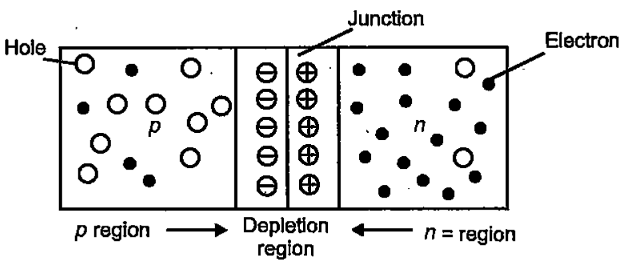
(a) Differentiate between three segments of a transistor on the basis of their size and level of doping.**

(b) How is a transistor biased to be in active state ?**

(c) With the help of necessary circuit diagram, describe briefly how *n-p-n* transistor in CE configuration amplifies a small sinusoidal input voltage. Write the expression for the ac current gain.**

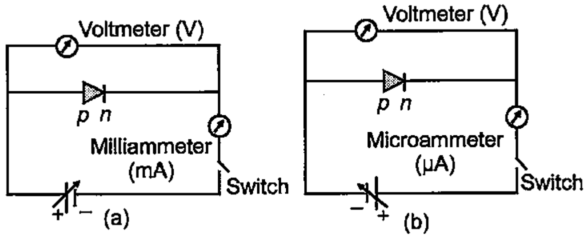
Answer : (a) As we know that *n*-type semi-conductor has more concentration of electrons than that of a hole and *p*-type semi-conductor has more concentration of holes than an electron. Due to the difference in concentration of charge carriers in the two regions of *p-n* junction, the holes diffuse from *p*-side to *n*-side and electrons diffuse from *n*-side to *p*-side.

When an electron diffuses from *n* to *p*, it leaves behind an ionized donor on *n*-side. The ionised donor (+*ve* charge) is immobile as it is bounded by the surrounding atoms. Therefore, a layer of positive charge is developed on the *n*-side of the junction. Similarly, a layer of negative charge is developed on the *p*-side.

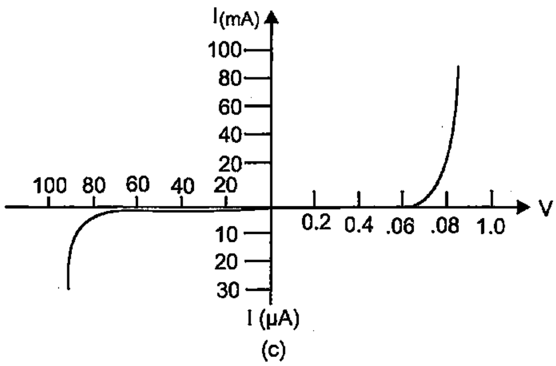


Hence, a space-charge region is formed on both side of the junction, which has immobile ions and is devoid of any charge carrier, called as depletion layer or depletion region.

(b)



Using the circuit arrangements shown in fig (a) and fig (b), we study the variation of current with applied voltage to obtain the V-I characteristics shown below.



From the V-I characteristics of a junction diode, it is clear that it allows the current to pass only when it is forward biased. So when an alternating voltage is applied across the diode, current flows only during that part of the cycle when it is forward biased.

Physics 2014 (Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

> **Note : Except for the following questions, all the remaining questions have been asked in previous Set.**

1. Define the term 'electrical conductivity' of a metallic wire. Write its S.I. unit. [1]

Answer : The electrical conductivity of a metallic wire is defined as the ratio of the current density to the electric field it creates.

Electrical conductivity, $\sigma = \frac{J}{E}$

**Answers is not given due to change in the present syllabus.

S.I. unit = $(\text{ohm m})^{-1}$

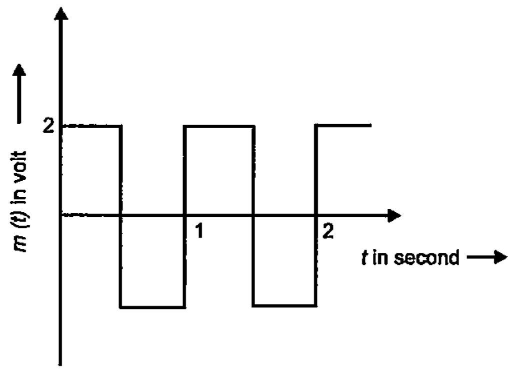
OR

The reciprocal of resistivity of a material is called its electrical conductivity.

$$\text{Conductivity} = \frac{1}{\text{Resistivity}}$$

or $$\sigma = \frac{1}{\rho}$$

2. The carrier wave is represented by C (*t*) = 5 sin (10 π*t*) volt A modulating signal is a square wave as shown. Determine modulation index. [1]**



10. An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of ±4 nC. [2]

Answer : As $\tau = pE \sin\theta$

$\therefore$ $$8\sqrt{3} = pE\sin\theta$$
$$= pE\sin 60^\circ$$
$$= \frac{pE\sqrt{3}}{2}$$

$\Rightarrow$ $$pE = 16$$

Also potential energy of the dipole,

$\Rightarrow$ $$U = -pE\cos\theta$$
$$= -pE\cos 60^\circ$$
$$= \frac{-16\cdot 1}{2} = -8 \text{ J}.$$

15. A proton and an alpha particle are accelerated through the same potential ? Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less kinetic energy. Give reasons to justify your answer. [3]

Answer : (i) de-Broglie wavelength of a particle depends upon its mass and charge for same accelerating potential such that

$$\lambda \propto \frac{1}{\sqrt{(\text{Mass})(\text{Charge})}}$$

If mass and charge of a proton are m_p and e respectively, then, mass and charge of an alpha particle are $4m_p$ and $2e$ respectively. Where, e is the charge of an electron

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p\, q_p}}$$
$$= \sqrt{\frac{(4m_p)(2e)}{(m_p)(e)}} = 2\sqrt{2}$$

Thus, de-Broglie wavelength associated with proton is $2\sqrt{2}$ times of the de-Broglie wavelength of alpha particle.

(ii) K.E. $\propto q$ (for same accelerating potential).

Charge of an alpha particle is more as compared to a proton. So, it will have a greater value of K.E. Hence, proton will have lesser kinetic energy.

16. Given a uniform electric field $\vec{E} = 2\times 10^3\,\hat{i}$ N/C. Find the flux of this field through a square of side 20 cm, whose plane is parallel to the Y-Z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the X-axis ? [3]

Answer : When the plane is parallel to the Y-Z plane

$$\phi = \vec{E}\cdot\vec{A}$$

Here,

$$\vec{E} = 2\times 10^3\,\hat{i}$$
$$A = (20 \text{ cm})^2 i = 0.04 \text{ m}^2 i.$$

$\therefore$ $$\phi = (2\times 10^3 i).(0.04 i).$$

$\Rightarrow$ $$\phi = 80 \text{ weber or Nm}^2\text{C}^{-1}.$$

When the plane makes a 30° angle with the X-axis, the area vector makes a 60° angle with the X-axis.

$$\phi = \vec{E}\cdot\vec{A}$$

$\Rightarrow$ $$\phi = EA\cos\theta$$

$\Rightarrow$ $$\phi = 2\times 10^3 \times 0.04\times\cos 60^\circ$$

$\Rightarrow$ $$\phi = 2\times 10^3\times 0.04\times\frac{1}{2}$$

$\Rightarrow$ $$\phi = 40 \text{ weber or Nm}^2\text{C}^{-1}.$$

20. A 12.9 eV beam of electronic is used to bombard gaseous hydrogen at room temperature.

Upto which energy level the hydrogen atoms would be excited ? Calculate the wavelength

**Answers is not given due to change in the present syllabus.

of the first member of Paschen series and first member of Balmer series. [3]

Answer : Energy of the electron in the n^{th} state of an atom

$$= \frac{-13.6Z^2}{n^2}$$

Here, Z is the atomic number of the atom.

For hydrogen atom, Z = 1

Energy required to excite an atom from initial state (n_i) to final state (n_f),

$$E = -13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) eV$$

$$\Rightarrow \quad \frac{-13.6}{n_f^2} + \frac{13.6}{n_i^2} = 12.9$$

This energy must be equal to or less than the energy of the incident electron beam.

$$\Rightarrow 13.6 - 12.9 = \frac{13.6}{n_f^2}. \qquad [\because n' = 1]$$

$$n_f^2 = \frac{13.60}{0.7} = 19.43.$$

$$\Rightarrow \quad n_f = 4.4.$$

State cannot be a fraction number.

$$\Rightarrow \quad n_f = 4.$$

Hence, the hydrogen atom would be excited up to 4^{th} energy level.

Rydberg's formula for the spectrum of the hydrogen atom is given by :

$$\frac{1}{\lambda} = R\left(\frac{1}{n_2^1} - \frac{1}{n_2^2}\right)$$

Here, λ is the wavelength.

Rydberg's constant, R = 1.097×10^7 m^{-1}

For the first member of the Paschen series

$$n_1 = 3, n_2 = 4$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$

$$\lambda = 18752.4 \text{ Å}$$

For the first member of Balmer series

$$n_1 = 2, n_2 = 3$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\lambda = 6563.3 \text{ Å}$$

22. Answer the following : [3]

(a) Name the e.m. waves which are used for the treatment of certain forms of cancer. Write their frequency range.

(b) Thin ozone layer on top of stratosphere is crucial for human survival. Why ?

(c) Why is the amount of the momentum transferred by the e.m. waves incident on the surface so small ?

Answer : (a) Gamma rays are used for the treatment of certain forms of cancer. Their frequency range is 3×10^{19} H_3 to 5×10^{20} Hz.

(b) The thin ozone layer on top of stratosphere absorb most of the harmful ultraviolet rays coming from the Sun towards the Earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the Earth. Hence, this layer is crucial for human survival.

(c) The momentum transported by electromagnetic waves is given by

$$p = \frac{U}{c} = \frac{h\nu}{c}$$

where U is the energy transported by electromagnetic waves in a given time and c is speed of electromagnetic waves in free space.

Now, $h = 6.62 \times 10^{-34}$ J s, $c = 3 \times 10^8$ m s^{-1}

Therefore, even for γ-rays ($\nu \approx 10^{20}$ Hz),

$$p = \frac{6.62 \times 10^{-34} \times 10^{20}}{3 \times 10^8}$$

$$= 2.2 \times 10^{-22} \text{ kg m s}^{-1}$$

Thus, the amount of the momentum transferred by the e.m. waves incident on a surface is very small.

24. A potentiometer wire of length 1.0 m has a resistance of 15 Ω. It is connected to a 5 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm. [5]

Answer : Current through potentiometer wire,

$$I = \frac{V}{R_{AB} + R}$$

$$= \frac{5}{15 + 5} 0.25 \text{ A}$$

P.D. across the potentiometer wire,

$$V = IR_{AB}$$

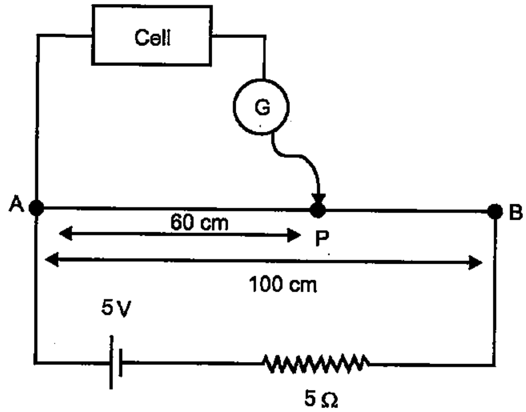
$$= 0.25 \times 15 = 3.75 \text{ V}$$

Potential gradient,

$$k = V/l$$
$$= 3.75/100$$
$$= 0.0375 \text{ V/cm}$$

So, unknown e.m.f. balanced against 60 cm of the wire,

$$e = kl' = 0.0375 \times 60$$
$$= 2.25 \text{ V}$$



Physics 2014 (Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

> **Note : Except for the following questions, all the remaining questions have been asked in previous Sets.**

1. **Define the term 'drift velocity' of charge carriers in a conductor and write its relationship with the current flowing through it.** **[1]**

Answer : The net speed achieved by an electron in a current carrying conductor is called as drift velocity.

The average velocity acquired by the free electrons along the length of a metallic conductor under a potential difference applied across the conductor is called drift velocity of the electrons.

$$v_d = \frac{I}{neA}$$

Here :

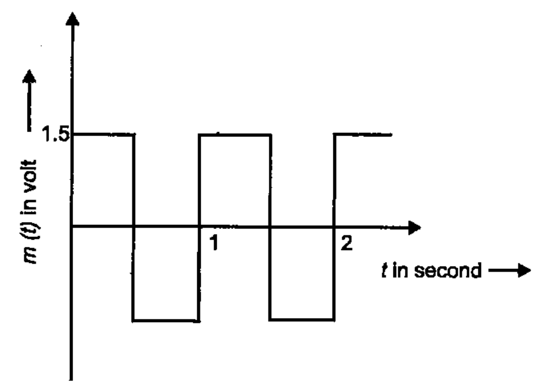
I is the current flowing through the conductor.

n is the number density of an electron.

A is the area of the conductor,

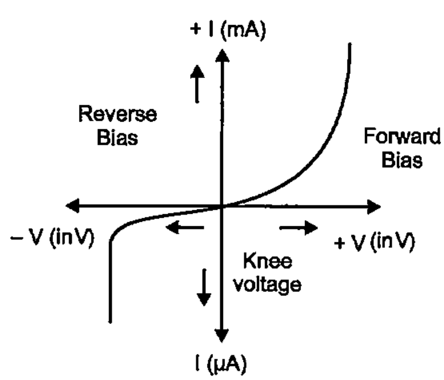
e is the charge of the electron.

2. **The carrier wave of a signal is given by C(t) = 3 sin (8πt) volt. The modulating signal is a square wave as shown. Find its modulation index.**** **[1]**



4. **Plot a graph showing variation of current versus voltage for the material Ga.** **[1]**

Answer : Current–Voltage characteristics graph for Ga :



9. **An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $6\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of ±2 nC.** **[1]**

Answer : As $\tau = pE \sin\theta$

**Answer is not given due to change in the present syllabus.

$$6\sqrt{3} = pE\sin 60°$$
$$= pE\times\frac{\sqrt{3}}{2}$$

or $$pE = 12$$

Potential energy of a dipole,

$$U = -pE\cos\theta$$
$$= -12\times\cos 60°$$
$$= -12\times\frac{1}{2} = -6\text{ J}$$

12. A deuteron and an alpha particle are accelerated with the same accelerating potential. [3]
Which one of the two has
(1) greater value of de-Broglie wavelength, associated with it, and
(2) less kinetic energy ? Explain.

Answer : (1) de-Broglie wavelength of a particle is dependent on its mass and charge for same accelerating potential, such that

$$\lambda \propto \frac{1}{\sqrt{(\text{Mass})(\text{Charge})}}$$

Mass and charge of a deuteron are $2m_p$ and e respectively and, mass and charge of an alpha particle are $4m_p$ and $2e$ respectively.
Where,

m_p = the mass of a proton.
and e = the charge of an electron.

$$\frac{\lambda_D}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_D q_D}} = \sqrt{\frac{(4m_p)(2e)}{(2m_p)(e)}} = \frac{2}{1}.$$

Thus, de-Broglie wavelength related with deuteron is twice of the de-Broglie wavelength of alpha particle.

(2) $\quad$ K.E. $\propto q$

(for same accelerating potential)

Charge of a deuteron is less as compared to an alpha particle. So, deuteron will have less kinetic energy.

15. Given a uniform electric field $\vec{E} = 4\times10^3\,\hat{i}$ N/C. Find the flux of this field through a square of 5 cm on a side whose plane is parallel to the Y-Z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the X-axis ? [3]

Answer : When the plane is parallel to the Y-Z plane :

Electric flux, $\quad \phi = \vec{E}\cdot\vec{A}$

Here,

$$\vec{E} = 4\times10^3\,\hat{i}\text{ N/C}$$

$$\vec{A} = (5\text{ cm})^2\,\hat{i} = 0.25\times10^{-2}\,\hat{i}\,m^2$$

$\therefore \quad \phi = (4\times10^3\,\hat{i})\cdot(25\times10^{-4}\,\hat{i})$

$\Rightarrow \quad \phi = 10$ weber or Nm^2C^{-1}

When the plane makes a 30° angle with X-axis, the area vector makes a 60° angle with the X-axis.

$$\phi = \vec{E}\cdot\vec{A}$$

$\Rightarrow \quad \phi = EA\cos\theta$

$\Rightarrow \quad \phi = (4\times10^3)(25\times10^{-4})\cos 60°$

$\Rightarrow \quad \phi = 10/2$

$\Rightarrow \quad \phi = 5$ weber or Nm^2C^{-1}

20. A 12.3 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited ? Calculate the wavelength of the second member of Lyman series and second member of Balmer series. [3]

Answer : Let the hydrogen atoms be excited to n^{th} energy level.

$$E = -13.6\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)\quad[\because n_i = 1]$$

$\Rightarrow \quad 12.3 = \left(\frac{1}{1^2}-\frac{1}{n^2}\right)$

$\Rightarrow \quad 12.3 = 13.6-\frac{13.6}{n^2}$

$\Rightarrow \quad \frac{13.6}{n^2} = 13.6-12.3 = 1.3$

$\Rightarrow \quad n^2 = \frac{13.6}{1.3}$

$\Rightarrow \quad n \approx 3$

The formula for calculating the wavelength of Lyman series is given below :

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$$

For second member of Lyman series, $n = 3$

$\therefore \quad \frac{1}{\lambda} = R\left(1-\frac{1}{3^2}\right)$

$\Rightarrow \quad \frac{1}{\lambda} = (1.09737\times10^7)\left(\frac{8}{9}\right)$

$\Rightarrow \quad \lambda = 1025.1$ Å

The formula for calculating the wavelength of Balmer series is given below :

$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{4}-\frac{1}{n^2}\right)$

For second member of Balmer series :

$$n = 4$$

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{4^2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda} = (1.09737 \times 10^7)\left(\frac{3}{16}\right)$$

$$\Rightarrow \quad \lambda = 4861 \text{ Å}$$

24. Answer the following : **[5]**

(a) Name the em waves which are used for the treatment of certain forms of cancer. Write their frequency range.

(b) Welders wear special glass goggles while working. Why ? Explain.

(c) Why are infrared waves often called as heat waves ? Give their one application.

Answer :

(a) Gamma rays are used for the treatment of certain forms of cancer. The frequency range of Gamma rays is 3×10^{19} to 5×10^{20} Hz.

(b) Welders wear special glass goggles while working so that they can protect their eyes from harmful electromagnetic radiation.

(c) Infrared waves are often called as heat waves because they induce resonance in molecules and increase internal energy in a substance.

Infrared waves are used in burglar alarms, security lights and remote controls for television and DVD players.

●●

Physics 2015 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

SECTION–A

1. Define the term 'self-inductance' of a coil. Write its S.I. unit. [1]

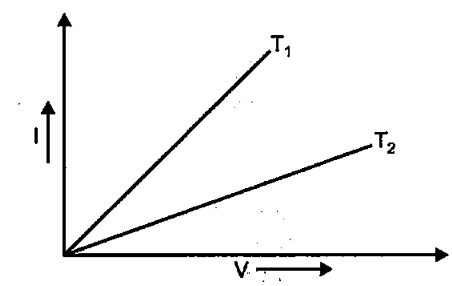
Answer : Self-inductance of a coil is numerically equal to the amount of magnetic flux linked with the coil when unit current flows through the coil. The S.I. unit of self inductance is henry (H) or weber per ampere.

$$1\ \text{H} = 1\ \text{Wb/A}$$

2. Why does bluish colour predominate in a clear sky ? [1]

Answer : While light from the sun reaches the atmosphere that is comprised of the tiny particles of the atmosphere. These act as a prism and cause the different components to scatter. As blue light travels in shorter and smaller waves in comparison to the other colours of the spectrum, it is scattered the most, causing the sky to appear bluish.

3. I-V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in the figure. Which of the two temperature is lower and why ? [1]



Answer : The slope of a V-I graph is given by the formula $\frac{I}{V} = \frac{1}{R}$. Thus, the smaller the slope larger is the resistance. As the resistance of a metal increases with the increase in temperature, so resistance at T_2 is higher and T_1 is lower.

4. Which basic mode of communication is used for telephonic communication ? [1]**

5. Why do the electrostatic field lines not form closed loops ? [1]

Answer : Electrostatic field lines never form loops because they do not converge at only one point as in the case with magnetic field lines. They depend on +ve and –ve charges that can extend to infinity in any particular direction.

SECTION–B

6. When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de-Broglie wavelength associated with the electron change ? Justify your answer. [2]

Answer : de-Broglie wavelength associated with a moving charge particle having a K.E. 'K' can be given as

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} \quad \left[K = \frac{1}{2}mv^2 = \frac{p^2}{2m}\right] \quad \text{... (i)}$$

The kinetic energy of the electron in any orbit of hydrogen atom can be given as

$$K = -E = -\left(\frac{13.6}{n^2}\,eV\right) = \frac{13.6}{n^2}\,eV \quad \text{... (ii)}$$

**Answers is not given due to change in the present syllabus.

Let K_1 and K_4 be the K.E. of the electron in ground state and third excited state, where $n_1 = 1$ shows ground state and $n_2 = 4$ shows third excited state. Using the concept of equations (i) and (ii), we have

$$\frac{\lambda_1}{\lambda_4} = \sqrt{\frac{K_4}{K_1}} = \sqrt{\frac{n_1^2}{n_2^2}}$$

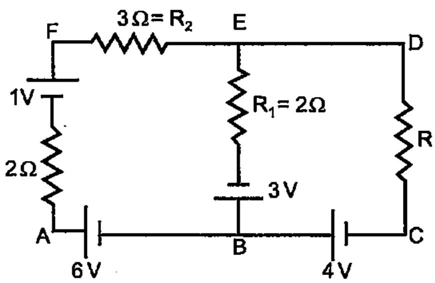
$$\frac{\lambda_1}{\lambda_4} = \sqrt{\frac{1^2}{4^2}} = \frac{1}{4}$$

$$\Rightarrow \qquad \lambda_1 = \frac{\lambda_4}{4}$$

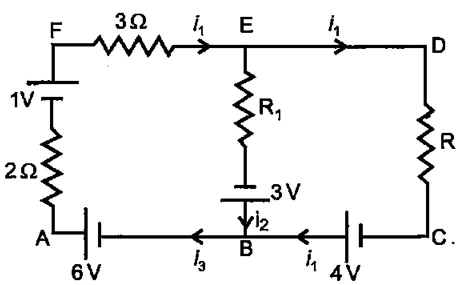
i.e., the wavelength in the ground state will decrease.

7. Write two factors which justify the need of modulating a low frequency signal into high frequencies before transmission. [2]**

8. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the arm BE of the electric network shown in the figure. [2]



Answer :



According Kirchhoff's junction law at B,

$$i_3 = i_1 + i_2$$

As $\quad i_2 = 0$ (given)

$\therefore \quad i_3 = i_1$

Applying kirchhoff's second law to loop AFEB,

$$\therefore \quad i_3 \times 2 + i_1 \times 3 + i_2 R_1 = 1 + 3 + 6$$

$$2i_3 + 3i_3 = 10$$

$$5i_3 = 10$$

$$i_3 = i_1 = 2 \text{ A}$$

The potential difference between A to D along the branch AFD,

$$\therefore \quad V_{AD} = 2i_3 - 1 + 3 \times i,$$

$$= (4 - 1 + 6)\text{V}$$

$$= 9 \text{ V}$$

9. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece. [2]

OR

A small telescope has an objective lens of focal length 150 cm and eye-piece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment ?

If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens ?

Answer : Given, $f_e = 5$ cm; $f_o = 1.25$ cm and $M = -30$.

Let L be the tube length (distance between the objective and the eyepiece)

$$\therefore \quad M = \frac{-L}{f_o}\left(1 + \frac{d}{f_e}\right)$$

[d is a constant and equals to the normal distance of clear vision of the human eye]

$$\text{Hence,} \quad -30 = -\frac{L}{1.25}\left(1 + \frac{25}{5}\right)$$

$$\therefore \quad L = \frac{30 \times 1.25}{6}$$

$$= 6.25 \text{ cm}$$

Hence, the tube length = 6.25 cm.

OR

If the telescope is in normal adjustment, *i.e.*, the final image is at infinity.

$$M = \frac{f_o}{f_e}$$

Since $f_o = 150$ cm, $f_e = 5$ cm

$$M = \frac{150}{5} = 30$$

If tall tower is at distance 3 km from the objective lens of focal length 150 cm. It will form its image at distance v_0. So,

$$\frac{1}{f_o} = \frac{1}{v_o} \quad \frac{1}{u_o}$$

$$\frac{1}{150 \text{ cm}} = \frac{1}{v_o} - \frac{1}{(-3 \text{ km})}$$

$$\frac{1}{v_o} = \frac{1}{1.5\text{ m}} - \frac{1}{3000\text{ m}}$$

$$v_o = \frac{3000 \times 1.5}{3000 - 1.5} = \frac{4500}{2998.5} = 1.5\text{ m}$$

$$\text{Magnification, } m_o = \frac{I}{O} = \frac{h_i}{h_o} = \frac{v_o}{u_o}$$

$$\frac{h_i}{100\text{ m}} = \frac{1.5\text{ m}}{3\text{ km}} = \frac{1.5\text{ m}}{3000\text{m}}$$

$$h_i = \frac{1.5 \times 100}{3000} = \frac{1}{20}\text{ m}$$

$$h_i = 0.05\text{ m}$$

10. Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region (infrared, visible, ultraviolet) of hydrogen spectrum does this wavelength lie ? [2]

Answer : The formula for wavelength (λ) in Balmer series is :

$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ where $n = 3, 4, 5$ and

$R = 1.097 \times 10^7 m^{-1}$ is the Rydberg constant.

Now, the shortest wavelength in Balmer series when $n = \infty$ is

$$\frac{1}{\lambda} = 1.097 \times 10^7\text{ m}^{-1} \times \left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times (0.25 - 0)$$

$$\frac{1}{\lambda} = 0.2743 \times 10^7$$

$$\lambda = 3.6456 \times 10^{-7}$$

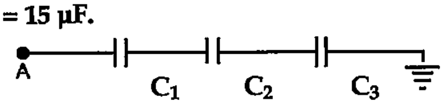
$$= 364.56 \times 10^{-9}\text{ m}$$

$$= 364.56\text{ nm.}$$

This wavelength lies in the visible region of the hydrogen spectrum.

SECTION – C

11. Calculate the potential difference and the energy stored in the capacitor C_2 in the circuit shown in the figure. Given potential at A is 90 V, C_1 = 20 μF, C_2 = 30 μF and C_3 = 15 μF. [3]



Answer : The given capacitors are connected in series,

$$\therefore \quad \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$= \frac{1}{20} + \frac{1}{30} + \frac{1}{15}$$

$$= \frac{3+2+4}{60} = \frac{9}{60} = \frac{3}{20}$$

$$C = \frac{20}{3}\ \mu\text{F},$$

As the capacitors are connected in series, so the charge remains same.

$$\therefore \quad Q = CV = \frac{20}{3} \times 90 = 600\ \mu\text{C}$$

Potential difference across C_2,

$$V_2 = \frac{Q}{C_2}$$

$$= \frac{600}{30} = 20\text{ V}$$

Energy stored in capacitor C_2,

$$U = \frac{1}{2}C_2(V_2)$$

$$= \frac{1}{2} \times 30 \times 10^{-6} \times (20)^2$$

$$= \frac{1}{2} \times 30 \times 10^{-6} \times 400$$

$$= 6 \times 10^{-3}\text{ J}$$

12. Find the relation between drift velocity and relaxation time of charge carriers in a conductor. A conductor of length L is connected to a d.c. source of emf 'E'. If the length of the conductor is tripled by stretching it, keeping 'E' constant, explain how its drift velocity would be affected. [3]

Answer : All free electrons suffer collisions with the heavy fixed ions inside the conductor. After collisions, these electrons again emerge with the same speed, but in random directions. So, at given time, net velocity of the electrons is zero *i.e.,*

$$\vec{u}_{avg} = \frac{\vec{u}_1 + \vec{u}_2 + ... + \vec{u}_n}{n} = 0$$

If the electric field established inside the conductor, electrons get accelerated, so

$$a = -\frac{eE}{m}$$

Now, the average velocity of all electrons is given by

$$\vec{v}_d = \vec{u}_{avg} - \frac{eE}{m}\tau$$

$$\vec{v}_d = 0 - \frac{eE}{m}\tau$$

where τ is the average relaxation time.

But $$E = \frac{V}{l}$$

$$\vec{v}_d = -\frac{eV\tau}{ml}$$

$$v_d \propto \frac{1}{l}$$

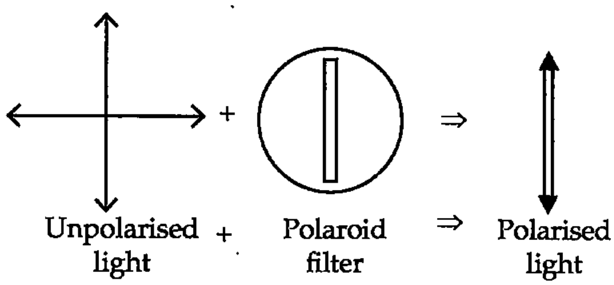
As the drift velocity is inversely proportional to length of conductor, so the drift velocity would be reduced by one third if the length of the conductor is tripled.

13. State clearly how an unpolarised light gets linearly polarised when passed through a polaroid. [3]

(i) Unpolarised light of intensity I_0 is incident on a polaroid P_1 which is kept near another polaroid P_2 whose pass axis is parallel to that of P_1. How will the intensities of light, I_1 and I_2, transmitted by the polaroids P_1 and P_2 respectively, change on rotating P_1 without disturbing P_2 ?

(ii) Write the relation between the intensities I_1 and I_2.

Answer : Polaroid filters are made of a special material that is capable of blocking of the two planes of vibration of an electromagnetic wave. In this sense, a polaroid acts as a device that filter out half of the vibrations on transmission of the light through the filter. When unpolarised light is transmitted through a polaroid filter, it emerge with one-half the intensity and with vibrations in a single plane; it emerges as polarised light.



(i) When an unpolarised light of intensity I_0 is incident on a polaroid P_1 of the light intensity I_1 will become half of the incident intensity.

$$I_1 = \frac{I_0}{2}$$

and when it will pass through P_2 polaroid kept near P. whose pass axis is parallel to that of P, then, there is no change in the intensity but the angle will change by $\cos^2\theta$

$$I_2 = I_1\cos^2\theta = \frac{I_0}{2}\cos^2\theta$$

(ii) The relation between I_1 and I_2 is given by

$$\frac{I_2}{I_1} = \cos^2\theta$$

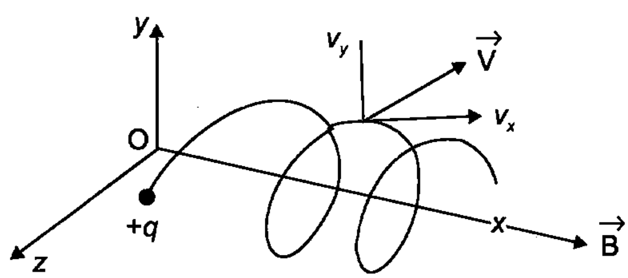
14. Define modulation index. Why is its value kept, in practice, less than one ?

A carrier wave of frequency 1.5 MHz and amplitude 50 V is modulated by a sinusoidal wave of frequency 10 kHz producing 50% amplitude modulation. Calculate the amplitude of the AM wave and frequencies of the side bands produced. [3]**

15. A uniform magnetic field B is set up along the positive X-axis. A particle of charge 'q' and mass 'm' moving with a velocity v enters the field at the origin in X-Y plane such that it has velocity components both along and perpendicular to the magnetic field B. Trace, giving reason, the trajectory followed by the particle. Find out the expression for the distance moved by the particle along the magnetic field in one rotation. [3]

Answer : If component v_x of the velocity vector is along the magnetic field, and remain constant, the charge particle will follow a helical trajectory; as shown in figur.

If the velocity component v_y is perpendicular to the magnetic field B, the magnetic force acts like a centripetal force qv_y B.



So $$qv_y B = \frac{mv_y^2}{r}$$

$$v_y = \frac{qBr}{m}$$

Since tangent velocity $v_y = r\omega$

$$\Rightarrow \quad r\omega = \frac{qBr}{m}$$

$$\Rightarrow \quad \omega = \frac{qB}{m}$$

**Answers is not given due to change in the present syllabus.

Time taken for one revolution,

$$T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$

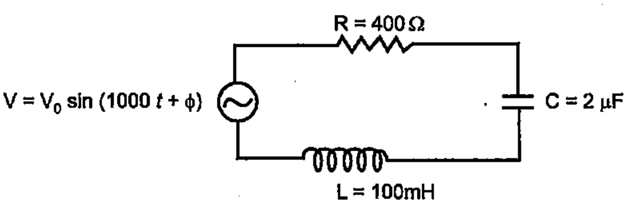
$$[\because W = 2\pi f]$$

and the distance moved along the magnetic field in the helical path is

$$x = v_x . T$$

$$= v_x . \frac{2\pi m}{qB}$$

16. (a) Determine the value of phase difference between the current and the voltage in the given series LCR circuit.



(b) Calculate the value of the additional capacitor which may be joined suitably to the capacitor C that would make the power factor of the circuit unity. [3]

Answer : (a) $V = V_0 \sin(1000t + \phi)$

Comparing this with $V = V_0 \sin(\omega t + \phi)$

we have,

$$\omega = 1000$$

Given : $L = 100 \times 10^{-3}$ H, $R = 400\ \Omega$, $C = 2\ \mu F$

$$X_L = \omega L$$

$$X_L = 1000 \times 100 \times 10^{-3} = 100\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} =$$

$$= \frac{1}{2} \times 10^3$$

$$= 500\ \Omega$$

Phase difference,

$$\tan\phi = \frac{X_L - X_C}{R}$$

$$\tan\phi = \frac{X_C - X_L}{R}, X_C > X_L$$

we have, $R = 400\ \Omega$

$$\tan\phi = \frac{500 - 100}{400} = \frac{400}{400} = 1$$

$$\tan\phi = 1$$

$$\therefore \quad \tan\phi = \tan 45°$$

$$\phi = 45°$$

(b) The power factor of the circuit is unity. It means that the given circuit is in resonance. It is possible, if another capacitor C′ is used in the circuit.

$$X_C' = X_L$$

$$\frac{1}{\omega C'} = \omega L$$

$$C' = \frac{1}{\omega^2 L} = \frac{1}{(1000)^2 \times 100 \times 10^{-3}}$$

$$C' = 10\ \mu F$$

Since C′ > C, so an additional capacitor of 8 μF would be connected in parallel to the capacitor of C = 2μF.

17. Write the expression for the generalized form of Ampere's circuital law. Discuss its significance and describe briefly how the concept of displacement current is explained through charging/discharging of a capacitor in an electric circuit. [3]

Answer : Generalized form of Ampere circuital law :

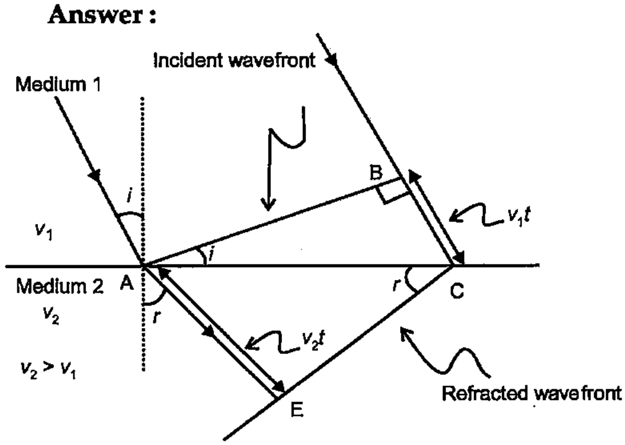
$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \left(I_c + \varepsilon_0 \frac{d\phi}{dt} \right)$$

It signifies that the source of magnetic field is not just due to the conduction electric current due to flow of charge but also due to the time rate of change of electric field called displacement current.

During charging and discharging of a capacitor the electric field between the plates will change, because of which there will be a change of electric flux (displacement current) between the plates.

18. Use Huygen's principle to show how a plane wavelength propagates from a denser to rarer medium. Hence verify Snell's law of refraction. [3]

Answer :



In Δ ABC,

$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC} \qquad \text{(i)}$$

In Δ CEA,

$$\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC} \qquad \text{(i)}$$

From equetion (i) and (ii)

$\therefore \quad \dfrac{\sin i}{\sin r} = \dfrac{BC}{AE} = \dfrac{v_1 t}{v_2 t} = \dfrac{v_1}{v_2}$ (iii)

$\therefore$ But $\mu_1 = \dfrac{c}{v_1}$

$\mu_2 = \dfrac{c}{v_2}$

$\therefore \quad \dfrac{\mu_2}{\mu_1} = \dfrac{v_1}{v_2}$ (iv)

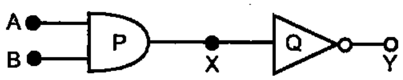
on comparing equation (iii) and (iv)

$\therefore \quad \dfrac{\sin i}{\sin r} = \dfrac{\mu_2}{\mu_1}$

or $\mu_2 \sin r = \mu_1 \sin i.$

It is Snell's law.

19. Identify the gates P and Q shown in the figure. Write the truth table for the combination of the gates shown.



Name the equivalent gate representing this circuit and write its logic symbol. [3]**

20. Draw a circuit diagram of a C.E. transistor amplifier. Briefly explain its working and write the expression for (i) current gain, (ii) voltage gain of the amplifier. [3]**

21. (a) Write three characteristic properties of nuclear force.

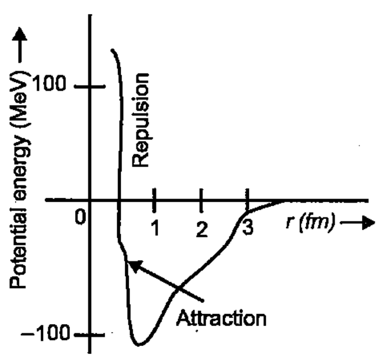
(b) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the graph. [3]

Answer : (a) 1. Nuclear forces are short range forces ;

2. Nuclear forces are primarily attractive and extremly strong;

3. Nuclear forces are charge independent.

(b)



22. (a) Describe briefly three experimentally observed features in the phenomenon of photoelectric effect.

(b) Discuss briefly how wave theory of light cannot explain these features. [3]

OR

(a) Write the important properties of photons which are used to establish Einstein's photoelectric equation.

(b) Use this equation to explain the concept of (i) threshold frequency and (ii) stopping potential.

Answer : (a) 1. The photoelectric effect will not occur when the frequency of the incident light is less than the threshold frequency. Different materials have different threshold frequencies and most elements have threshold frequencies in the ultraviolet region of the electromagnetic spectrum.

2. The maximum KE of a stream of photoelectrons increases linearly with the frequency of the incident light above the threshold frequency.

3. The rate at which photoelectrons are emitted from a photosensitive surface is directly proportional to the intensity of incident light when the frequency is constant.

(b) Classical wave theory cannot explain :

1. The existence of threshold frequency because it predicts that electrons would absorb enough energy to escape and there would not be any threshold frequency.

2. The almost immediate emission of photoelectrons as, according to this theory, electrons require a period of time before sufficient energy is absorbed by it to escape from the metal; however, such a thing does not happen practically.

3. It cannot explain why maximum KE is dependent on the frequency and independent of intensity.

OR

(a) The important property of photons that is useful in establishing Einstein's photoelectric equation is their ability to hold on to the electrons of an atom by their forces of attraction.

(b) Einstein's photoelectric equation states that :

$$E_{max} = h\nu - \phi$$

If $E_{max} > 0$ then $h\nu - \phi > 0$

or $h\nu - h\nu_0 > 0$

Here, ν_0 do is the threshold frequency.

Again, loss in KE = gain in electromagnetic PE.

or $E_{max} = eV_s$

where V_s represents the stopping potential.

**Answers is not given due to change in the present syllabus.

SECTION–D

23. One morning an old man walked bare-foot to replace the fuse wire in kit kat fitted with power supply mains for his house. Suddenly he screamed and collapsed on the floor. His wife cried loudly for help. His neighbour's son Anil heard the cries and rushed to the place with shoes on. He took a wooden baton and used it to switch off the main supply. [4]

Answer the following questions :

(i) What is the voltage and frequency of mains supply in India ?

(ii) These days most of the electrical devices we use require a.c. voltage. Why ?

(iii) Can a transformer be used to step up d.c. voltage ?

(iv) Write two qualities displayed by Anil by his action.**

Answer : (i) The voltage and frequency of mains supply in India are 240 V and frequency is 50 Hz.

(ii) Most electrical devices require a.c. voltage because a.c. is available by default through the mains supply and also because d.c., is actually a one-way current and is available only through batteries.

(iii) No, a transformer cannot be used to step-up d.c. voltage because induced emf in the secondary coil of the transformer is only due to of change of magnetic flux in primary coil.

SECTION – E

24. (a) Define electric flux. Write its S.I. unit.

"Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is". Justify this statement with the help of a suitable example.

(b) Use Gauss's law to prove that electric field inside a uniformly charged spherical shell is zero. [5]

OR

(a) Derive the expression for the energy stored in a parallel plate capacitor. Hence obtain the expression for the energy density of the electric field.

(b) A fully charged parallel plate capacitor is connected across an uncharged identical capacitor. Show that the energy stored in the combination is less than that stored initially in the single capacitor.

Answer : (a) The electric flux through an area is defined as the electric field multiplied by the area of the surface projected on a plane, perpendicular to the field. Its S.I. unit is voltmeter (Vm) or Newton metre square per coulomb ($Nm^2 C^{-1}$).

The given statement is justified because while measuring the flux, the surface area is more important than its volume or its size.

(b) To prove that the electric field inside a uniformly charged spherical shell is zero, we place a single positive point charge 'q' at the centre of an imaginary spherical surface with radius R. The field lines of this point radiate outside equally in all directions. The magnitude E of the electric field at every point on the surface

is given by $E = \dfrac{1}{4\pi\varepsilon_0} \times \dfrac{q}{R^2}$.

At each point on the surface, $\vec{E}$ is $\perp$ to the surface and its magnitude is the same.

Thus, the total electric flux (ϕ_E) is the product of their field magnitude E and the A.

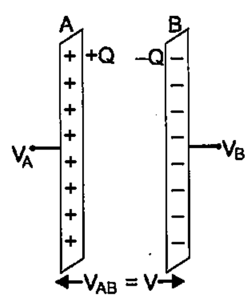
Hence,
$$\phi_E = EA$$
$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^2}(4\pi\varepsilon R^2)$$
$$= \frac{q}{\varepsilon_0}$$

If the sphere is uniformly charged, then there is zero charge inside the sphere, according to Gauss's law

When $q = 0$, $\phi_E = \dfrac{0}{\varepsilon_0} = 0$

OR

(a) Consider a capacitor of capacitance C. Initial charge on capacitor is zero. Initial potential difference between capacitor plates is zero. Let a charge Q be given to it in small steps. When charge is given to capacitor, the potential difference between its plates increases. Let at any instant when charge on capacitor be q, the



potential difference between its plates $V = \dfrac{q}{C}$.

Now work done in giving an additional infinitesimal charge dq to capacitor

**Answers is not given due to change in the present syllabus.

$$dW = V\,dq = \frac{q}{C}\,dq$$

The total work done in giving charge from 0 to Q will be equal to the sum of all such infinitesimal works, which may be obtained by integration. Therefore, total work done.

$$W = \int_0^Q V\,dq = \int_0^Q \frac{q}{C}\,dq$$

$$= \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{C}\left(\frac{Q^2}{2} - \frac{0}{2}\right) = \frac{Q^2}{2C}$$

If V is the final potential difference between capacitor plates, then Q = CV

$$\therefore \quad W = \frac{(CV)^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

This work is stored as electrostatic potential energy of capacitor *i.e.*,

Electrostatic potential energy,

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Energy density : Consider a parallel plate capacitor consisting of plates, each of area A, separated by a distance d. If space between the plates is filled with a medium of dielectric constant K, then

Capacitance of capacitor, $C = \dfrac{K\varepsilon_0 A}{d}$

If σ is the surface charge density of plates, then electric field strength between the plates

$$E = \frac{\sigma}{K\varepsilon_0} \Rightarrow \sigma = K\,\varepsilon_0\,E$$

Charge on each plate of capacitor, $Q = \sigma A = K\,\varepsilon_0\,E\,A$

$\therefore$ Energy stored by capacitor,

$$U = \frac{Q^2}{2C} = \frac{(K\,\varepsilon_0 EA)^2}{2\,(K\varepsilon_0\,A/d)}$$

$$= \frac{1}{2}K\,\varepsilon_0\,E^2\,A\,d$$

But Ad = Volume of space between capacitor plates

$\therefore$ Energy stored, $U = \frac{1}{2}K\,\varepsilon_0\,E^2\,Ad$

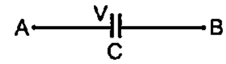
Electrostatic energy stored per unit volume,

$$u_e = \frac{U}{Ad} = \frac{1}{2}K\varepsilon_0\,E^2$$

This is expression for electrostatic energy density in medium of dielectric constant K.

(b) Initially, if we consider a charged capacitor, then its charge would be

$$Q = CV$$

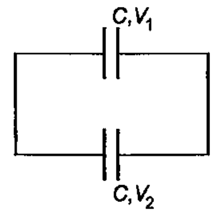


and energy stored is

$$U_1 = \frac{1}{2}CV^2 \quad \text{...(i)}$$

Then, this charged capacitor is connected to uncharged capacitor.

Let the common potential be V. The charge flows from first capacitor to the other capacitor unless both the capacitors attain common potential.



$$\Rightarrow \quad Q_1 = CV_1 \text{ and } Q_2 = CV_2$$

Applying conservation of charge,

$$Q = Q_1 + Q_2 \Rightarrow CV = CV_1 + CV_2$$

$$\Rightarrow \quad V = V_1 + V_2 \Rightarrow V_1 = \frac{V}{2} \; [\because V_1 = V_2]$$

Total energy stored,

$$U_2 = \frac{1}{2}CV_1^2 + \frac{1}{2}CV_2^2$$

$$U_2 = \frac{1}{2}C\left(\frac{V}{2}\right)^2 + \frac{1}{2}C\left(\frac{V}{2}\right)^2$$

$$\Rightarrow \quad U_2 = \frac{1}{4}CV^2 \quad \text{...(ii)}$$

From Equations (i) and (ii), we get

$$U_2 < U_1$$

$\Rightarrow$ Energy stored in the combination is less than that stored initially in single capacitor.

25. Explain, using a labelled diagram, the principle and working of a moving coil galvanometer. What is the function of (i) uniform radial magnetic field, (ii) soft iron core ?

Define the terms (i) current sensitivity and (ii) voltage sensitivity of a galvanometer. Why does increasing the current sensitivity not necessarily increase voltage sensitivity ? [5]

OR

(a) Write using Biot-Savart law, the expression for the magnetic field $\vec{B}$ due to an element $\vec{dl}$ carrying current I at a distance $\vec{r}$ from it in a vector form.

Hence derive the expression for the magnetic field due to a current carrying loop of radius R at a point P distant X from its centre along the axis of the loop.

(b) Explain how Biot-Savart law enables one to express the Ampere's circuital law in the integral form, viz.,

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

Where I is the total current passing through the surface.

Answer : The basic principle of a moving coil galvanometer is that when a current carrying coil is placed in a magnetic field, it experiences a torque.

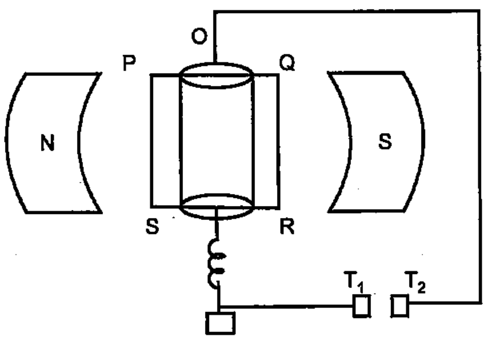
When the current I is passed through the coil, the torque experienced is given by $\tau = NIAB \sin\theta$

Where N = No. of turns of the coil,

A = Area of the coil

B = Magnetic field and

θ = Angle between normal of coil and magnetic field



(i) The uniform radial magnetic field is used to make the scale linear.

(ii) The soft iron core increases the strength of the magnetic field.

The current sensitivity is defined as the deflection produced in the galvanometer, while passing a current of 1 ampere. (1 amp). through it

Thus, current sensitivity $\left(\frac{\alpha}{I}\right) = \frac{NBA}{K}$.

The voltage sensitivity is defined as the deflection produced in the galvanometer when a potential difference of 1V is applied to the coil.

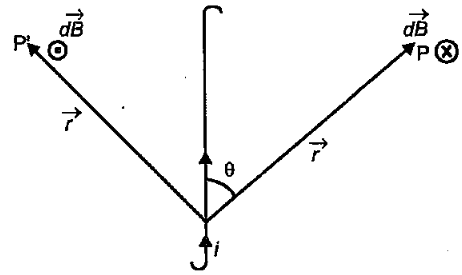
Thus, voltage sensitivity $\left(\frac{\alpha}{V}\right) = \frac{NBA}{KR}$.

Where R is the resistance.

Increasing the current sensitivity does not necessarily increase the voltage sensitivity as there is an increase in the resistance as well.

OR

(a) Suppose we have a conductor of length l in which current i is flowing. We need to calculate the magnetic field at a point P in vacuum. If $i\vec{dl}$ is one of the infinitely small current element, the magnetic field $d\vec{B}$ at point P is given by

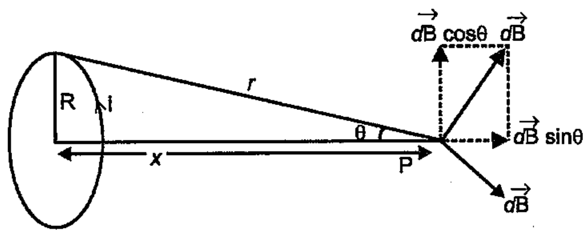


$$d\vec{B} \propto \frac{i\vec{dl} \times \vec{r}}{r^3}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\vec{dl} \times \vec{r}}{r^3}$$

Where $\frac{\mu_0}{4\pi}$ is a proportionality constant.

Suppose there is a circular coil of radius R, carrying a current i. Let P be a point at the axis of the coil at a distance x from the centre, at which the field in required.



Consider a conducting element dl of the loop. The magnetic field due to dl is given by the Biot-Savart law,

$$dB = \frac{\mu_0}{4\pi}\frac{i|\vec{dl} \times \vec{r}|}{r^3}$$

$$dB = \frac{\mu_0}{4\pi}\frac{idl}{(R^2 + x^2)}$$

The direction of dB is perpendicular to the plane formed by dl and r. It has an X-component dB_x and a component perpendicular to X-axis, $dB_{\perp y}$. When the components perpendicular to the X-axis are summed over, they cancel out and we obtain null result. Thus, only the X-component survives.

So the resultant field $\vec{B}$ at P in given by

$$B = \int dB \sin\theta$$

$$B = \frac{\mu_0}{4\pi}\frac{i}{r^2}\int dl \sin\theta$$

$$B = \frac{\mu_0}{4\pi}\frac{iR}{r^3}\int dl \qquad \left[\because \sin\theta = \frac{R}{r}\right]$$

But $\int dl = 2\pi R$ and $r = (R^2 + x^2)^{1/2}$

$$\therefore \qquad B = \frac{\mu_0}{4\pi}\frac{2\pi i R^2}{(R^2+r^2)^{3/2}}$$

If the coil has N turns, then each turn will contribute equally to B. Then,

$$B = \frac{\mu_0 N i R^2}{2(x^2+R^2)^{3/2}}$$

(b) According to Biot-Savart law the line integral of the magnetic field $\vec{B}$ around any 'closed' path is equal to μ_0 times the net current I passing through the area enclosed by the path.

$$\therefore \qquad i.e. \oint \vec{B}\cdot\vec{dl} = \mu_0 I$$

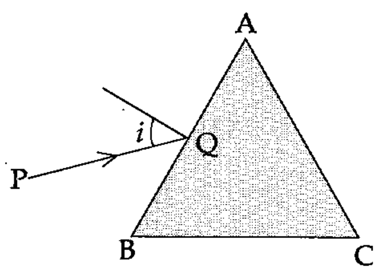
Where μ_0 in the permeability of free space. Ampere's circuital law in electromagnetism is analogous to Gauss' law in electrostatics.

26. (a) Consider two coherent sources S_1 and S_2 producing monochromatic waves to produce interference pattern. Let the displacement of the wave produced by S_1 be given by Y_1 = a cos ωt and the displacement by S_2 be Y_2 = a cos (ωt + φ). Find out the expression for the amplitude of the resultant displacement at a point and show that the intensity at that point will be $I = 4a^2 \cos^2 \phi/2$. Hence establish the conditions for constructive and destructive interference.

(b) What is the effect on the interference fringes in Young's double slit experiment when (i) the width of the source slit is increased; (ii) the monochromatic source is replaced by a source of white light. [5]

OR

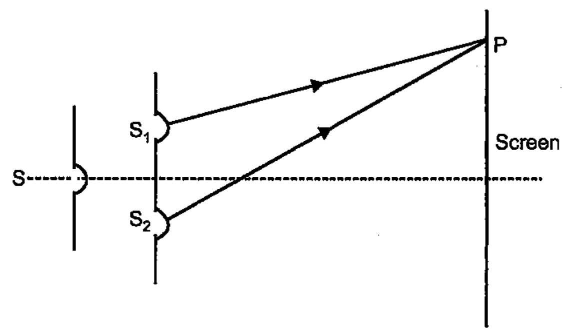
(a) A ray 'PQ' of light is incident on the face AB of a glass prism ABC (as shown in the figure) and emerges out of the face AC. Trace the path of the ray. Show that $\angle i + \angle e = \angle A + \angle\delta$. When δ and *e* denote the angle of deviation and angle of emergence respectively.



Plot a graph showing the variation of the angle of deviation as a function of angle of incidence. State the condition under which ∠δ is minimum.

(b) Find out the relation between the refractive index (μ) of the glass prism and ∠A for the case when the angle of prism (A) is equal to the angle of minimum deviation (δ_m). Hence obtain the value of the refractive index for angle of prism A = 60°.

Answer : (a) Let S be a narrow slit illuminated by a monochromatic source of light and S_1 and S_2 two similar parallel slits very close together and equidistant from S.



Displacement of the wave produced by S_1 is given by

$$y_1 = a \cos \omega t$$

and the displacement of the wave produced by S_2 is given by

$$y_2 = a \cos(\omega t + \phi)$$

The resultant displacement is given by

$$y = y_1 + y_2$$
$$y = a \cos\omega t + a \cos(\omega t + \phi)$$
$$y = 2a \cos\phi/2 \cos(\omega t + \phi/2)$$

The amplitude of the resultant displacement is $2a \cos\phi/2$. The intensity of light is directly proportional to the square of amplitude of the wave.

The resultant intensity is given by

$$I = 4a^2\cos^2 \phi/2$$

For constructive interference the intensity of light at point P is maximum, if

$$\cos\phi = \max = +1 : \phi = 0, 2\pi, 4\pi.....$$

i.e., $\phi = 2n\pi$ where $n = 0, 1, 2, ...$

$$\text{Path difference} = \frac{\lambda}{2\pi} \times 2n\pi$$
$$= n\lambda$$

For destructive interference the intensity of light at point P is minimum, if

$$\cos\phi = -1$$

$\therefore \quad \phi = \pi, 3\pi, 5\pi, \ldots\ldots$

or $\quad \phi = (2n-1)\pi$ where $n = 1, 2, 3\ldots\ldots$

The corresponding path difference between the two waves

$$x = \frac{\lambda}{2\pi}\phi = \frac{\lambda}{2\pi}(2n-1)\pi = (2n-1)\frac{\lambda}{2}$$

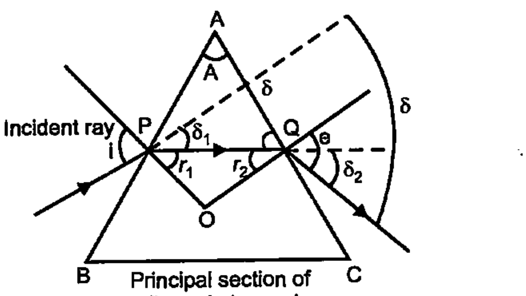
(b) (i) As the width of the slits is increased, the fringe width decreases. because,

$$\beta \propto \frac{1}{d}$$

(ii) The different colours of white light will produce different interference patterns but the central bright fringes due to all colours are at the same positions. Therefore, the central bright fringe is white in colour. Since the wavelength of the blue light is smallest, the fringe closed on the either side of the central white fringe is blue and farthest is red. Beyond a few fringes, no clear fringe pattern is visible.

OR

(a) Let the incident ray meet refracting face AB of the prism at point P. Ray PQ is the refracted ray inside the prism and δ_2 and r_1 are the angle of the deviation and refraction at interface AB. At interface AC the ray goes out of the prism. Let e be the angle of emergence. The angle of deviation at point Q is δ_2 as shown in figure.



Principal section of equilateral glass prism

Using geometry, we see that at point P,

$i = \delta_1 + r_1 \quad \therefore \ \delta_1 = i - r_1$

and at point Q, $\ e = \delta_2 + r_2$

$\delta_2 = e - r_2$

The total deviation δ, suffered by the incident ray is equal to $\delta_1 + \delta_2$.

or
$$\delta = \delta_1 + \delta_2$$
$$= (i - r_1) + (e - r_2)$$
$$= (i + e) - (r_1 + r_2) \quad \ldots\text{(i)}$$

In quadrilateral POQA, the sum of all four angle is 360°.

$$P + O + Q + A = 360°$$

as P and Q both are right angles

$$P + Q = 180°$$
$$O + A = 180° \quad \ldots\text{(ii)}$$

In triangle POQ

$$O + r_1 + r_2 = 180° \quad \ldots\text{(iii)}$$

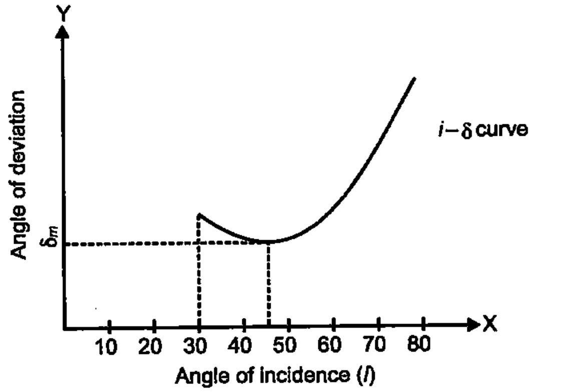
Comparing equations (ii) and (iii), we have

$$A = r_1 + r_2$$

Substituting this value in equation (i)

$$\delta = i + e - A$$
$$\delta + A = i + e \quad \ldots\text{(iv)}$$

So angle of deviation produced by a prism depends upon the angle of incidence, refracting angle of prism, and the material of the prism.



When prism is in the position of minimum deviation,

then $i = e$ and $r_1 = r_2$

From equation (iv),

$$\delta_m + A = i + i$$
$$i = \frac{(\delta_m + A)}{2}$$

(b) by Snell's law, $\mu = \dfrac{\sin i}{\sin r}$ putting the value of i and r

$$\mu = \frac{\sin\left(\frac{A + \delta_{min}}{2}\right)}{\sin\frac{A}{2}}$$

But $\quad A = \delta_m$

$$\therefore \quad \mu = \frac{\sin\left(\frac{A + A}{2}\right)}{\sin\frac{A}{2}}$$

$$= \frac{\sin A}{\sin\frac{A}{2}} = \frac{2\sin\frac{A}{2}.\cos\frac{A}{2}}{\sin\frac{A}{2}} = 2\cos\frac{A}{2}$$

If $\quad A = 60°$,

$$\mu = 2\cos\frac{60°}{2} = 2\cos 30°$$

$$= 2 \times \frac{\sqrt{3}}{2} = \sqrt{3}$$

Note : All questions of Outside Delhi Set II are from Outside Delhi Set I and Outside Delhi Set III are from Set I and Set II.

Physics 2015 (Delhi)

SET I

Time allowed : 3 hours **Maximum marks : 70**

SECTION–A

1. Define capacitor reactance. Write its S.I. units. [1]

Answer : Capacitor reactance is the resistance offered by a capacitor to the flow of a.c. It is given by

$$X_C = \frac{1}{\omega C}$$

Where $\omega = 2\pi f$, f = frequency of the source

$$X_C = \frac{1}{2\pi f C}$$

ω = Angular frequency of the source

C = Capacitance of the capacitor.

The SI unit of capacitor reactance is ohm (Ω).

2. What is the electric flux through a cube of side 1 cm which encloses an electric dipole ? [1]

Answer : The electric flux through a cube of side 1 cm which encloses an electric dipole will be zero, as net charge enclosed by a cube is zero.

3. A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens ? [1]

Answer : Since μ_g lens < μ_m surroundings.

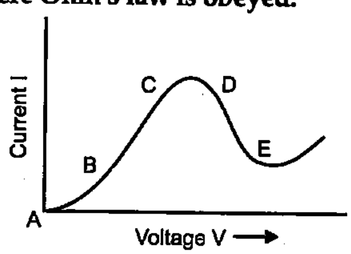
It behaves like a converging lens.

4. How are side bands produced ? [1]**

5. Graph showing the variation of current versus voltage for a material Ga As is shown in the figure. Identify the region of : [1]

(i) negative resistance

(ii) where Ohm's law is obeyed.



Answer : (i) DE is the region of negative resistance because the slope of curve in this part is negative.
(ii) BC is the region where Ohm's law is obeyed because in this part, the current varies linearly with the voltage.

SECTION–B

6. A proton and an α-particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds. [2]

Answer : (i) The de-Broglie wavelength of a particle is given by

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

where, V is the accelerating potential of the particle.

It is given that

$$\lambda_{\text{proton}} = \lambda_{\text{alpha}}$$

$$\Rightarrow \frac{h}{\sqrt{2m_p q_p V_p}} = \frac{h}{\sqrt{2m_\alpha q_\alpha V_\alpha}}$$

$$\sqrt{2m_\alpha q_\alpha V_\alpha} = \sqrt{2m_p q_p V_p}$$

On squaring both sides, we get

$$2m_\alpha\, q_\alpha\, V_\alpha = 2\, m_p\, q_p\, V_p$$

$$\Rightarrow \frac{V_p}{V_\alpha} = \frac{m_\alpha\, q_\alpha}{m_p q_p} = \frac{4m_p \times 2q_p}{m_p q_p} \quad \left[\because m_a = 4m_p \text{ and } q_\alpha = 2q_p\right]$$

$$= \frac{8}{1}$$

(ii) We can also write de-Broglie wavelength as

$$\lambda = \frac{1}{2\pi f C}$$

where h is Planck's constant, m is mass of the particle and v is speed of the particle.

It is given that

$$\lambda_{\text{proton}} = \lambda_{\text{alpha}}$$

We know

$$m_{\text{alpha}} = 4m_{\text{proton}}$$

$$\therefore \quad \lambda_{\text{alpha}} = \frac{h}{4m_{\text{proton}}\, v_{\text{alpha}}}$$

$$\Rightarrow \text{Now L,} \quad \frac{h}{m_{\text{proton}}\, v_{\text{proton}}} = \frac{h}{4m_{\text{proton}}\, v_{\text{alpha}}}$$

$$\frac{v_{\text{proton}}}{v_{\text{alpha}}} = 4$$

7. Show that the radius of the orbit in hydrogen atom varies as n^2. Where n is the principal quantum number of the atom. [2]

Answer : According to the Bohr's theory of hydrogen atom, the angular momentum of a revolving electron is given by

$$mvr = \frac{nh}{2\pi} \quad \text{...(i)}$$

**Answers is not given due to change in the present syllabus.

Here, m = Mass of the electron
v = Velocity of the electron
r = Radius of the orbit
h = Planck's constant
n = Principal quantum number of the atom

If an electron of mass m and velocity v is moving in a circular orbit of radius r, then the centripetal force required is given by

$$F = \frac{mv^2}{r}$$

Also, if the charge on the nucleus is Ze, then the force of electrostatic attraction between the nucleus and the electron will provide the necessary centripetal force.

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2} = \frac{KZe^2}{r^2}$$

where $$K = \frac{1}{4\pi\varepsilon_0}$$

$$\therefore \quad \frac{mv^2}{r} = \frac{KZe^2}{r^2} \quad \text{...(ii)}$$

From (i), we get $$v = \frac{nh}{2\pi mr}$$

Putting this value in (ii), we get

$$\frac{m}{r}\frac{n^2h^2}{4\pi^2m^2r^2} = \frac{KZe^2}{r^2}$$

$$\Rightarrow \quad r = \frac{n^2h^2}{4\pi^2 mKZe^2}$$

$$\Rightarrow \quad r \propto n^2.$$

8. Distinguish between 'intrinsic' and 'extrinsic' semiconductors. [2]

Answer :

Intrinsic semiconductor	Extrinsic semiconductor
1. It is pure semiconducting material with no impurity atoms added to it.	It is prepared by doping a small quantity of impurity atoms to the pure semiconductor.
2. The number of free electrons in the conduction band and the number of holes in valence band is exactly equal.	The number of free electrons and holes is never equal. There is an excess of electrons in n-type semiconductors and an excess of holes p-type semiconductors.

3. Its electrical conductivity is a function of temperature alone.	Its electrical conductivity depends upon the temperature and the amount of impurity added in them. to it.

9. Use the mirror equation to show that an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$. [2]

OR

Find an expression for intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum ?

Answer :

Mirror equation is

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Where u is the distance of object from the mirror, v is the distance of image from the mirror and f is the focal length of the mirror.

For a concave mirror f is negative *i.e.* $f < 0$, $u < 0$

For a real object (on the left of mirror)

$$\therefore \quad 2f < u < f$$

$$\Rightarrow \quad \frac{1}{2f} > \frac{1}{u} > \frac{1}{f}$$

$$\frac{1}{2f} - \frac{1}{f} > \frac{1}{u} - \frac{1}{f} > \frac{1}{f} - \frac{1}{f}$$

$$\frac{1}{f} - \frac{1}{2f} < \frac{1}{f} - \frac{1}{u} < \frac{1}{f} - \frac{1}{f}$$

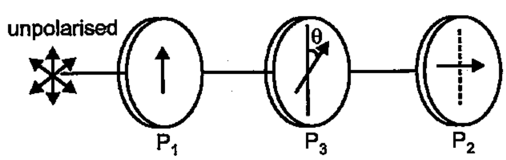
$$\Rightarrow \quad \frac{1}{2f} < \frac{1}{v} < 0$$

$\Rightarrow \quad v < 0$. Also $v > 2f$

$\therefore$ Image is real.

This implies that v is negative and greater than $2f$. This means that the image lies beyond $2f$.

OR



Let us consider two crossed polarisers P_1 and P_2 with a polaroid sheet P_3 placed between them.

Let I_0 be the intensity of polarised light after passing through the first polarizer P_1. If θ is the angle between the axes of P_1 and P_3, then the intensity of the polarized light after passing through P_3 will be $I = I_0 \cos^2 \theta$.

As P_1 and P_2 are crossed. The angle between the axes of P_1 and $P_2 = 90°$.

$\therefore$ Angle between the axes of P_2 and $P_3 = (90° - \theta)$

The intensity of light emerging from P_2 will be given by

$$I' = I \cos^2 (90 - \theta)$$

$$I' = [I_0 \cos^2 \theta] \cos^2 (90° - \theta)$$

$$\Rightarrow \quad I' = [I_0 \cos^2 \theta] \sin^2 \theta$$

$$\Rightarrow \quad I' = \frac{I_0}{4}(4 \cos^2 \theta \sin^2 \theta)$$

$$\Rightarrow \quad I' = \frac{I_0}{4}(2 \sin \theta \cos \theta)^2$$

$$\Rightarrow \quad I' = \frac{I_0}{4}(\sin^2 2\theta)$$

The intensity of polarized light transmitted from P_2 will be maximum when

$$\sin 2\theta = \text{maximum} = 1$$

$$\Rightarrow \quad \sin 2\theta = \sin 90°$$

$$\Rightarrow \quad 2\theta = 90°$$

$$\Rightarrow \quad \theta = 45°$$

The maximum transmitted intensity of polarised light is

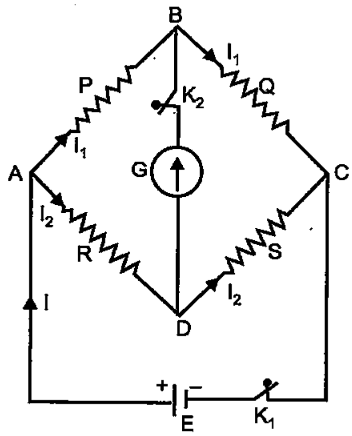
$$I' = \frac{I_0}{4}$$

10. Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge. [2]

Answer : Let us consider a Wheatstone bridge arrangement as shown below :

Wheatstone bridge is a special bridge type circuit which consists of four resistances, a galvanometer and a battery. It is used to determine unknown resistance.

In figure four resistance P, Q, R and S are connected in the form of four arms of a quadrilateral. Let the current given by battery in the balanced position be I. This current on reaching point A is divided into two parts I_1 and I_2. As there is no current in galvanometer in balanced state, therefore, current in resistances P and Q is I_1 and in resistances R and S it is I_2.



Applying Kirchhoff's first law i.e. junction law at point A

$$I - I_1 - I_2 = 0 \text{ or } I = I_1 + I_2 \qquad ...(i)$$

Applying Kirchhoff's second law to closed mesh ABDA

$$-I_1P + I_2R = 0 \text{ or } I_1P = I_2R \qquad ...(ii)$$

Applying Kirchhoff's second law to mesh BCDB

$$-I_1Q + I_2S = 0 \text{ or } I_1Q = I_2S \qquad ...(iii)$$

Dividing equation (ii) by (iii), we get

$$\frac{I_1P}{I_1Q} = \frac{I_2R}{I_2S} \quad \text{or} \quad \frac{P}{Q} = \frac{R}{S}$$

This is condition of balance Wheatstone's bridge.

SECTION–C

11. Name the parts of the electromagnetic spectrum which is

(a) suitable for radar systems used in aircraft navigation

(b) used to treat muscular strain

(c) used as a diagnostic tool in medicine

Write in brief, how these waves can be produced.

Answer : (a) Microwaves are suitable for radar systems that are used in aircraft navigation.

These rays are produced by special vacuum tubes, namely klystrons, magnetrons and Gunn diodes.

(b) Infrared waves are used to treat muscular strain.

These rays are produced by hot bodies and molecules.

(c) X-rays are used as a diagnostic tool in medicine.

These rays are produced when high energy electrons are stopped suddenly on a metal of high atomic number.

12. (i) A giant refracting telescope has an objective lens of focal length 15 m. If an eye-piece of focal length 1.0 cm is used. What is the angular magnification of the telescope ?

(ii) If this telescope is used to view the moon. What is the diameter of the image of the moon formed by the objective lens ? The diameter of the moon is 3.48×10^6 m and the radius of lunar orbit is 3.8×10^8 m. [3]

Answer : (i) Let

f_o = Focal length of the objective lens = 15 m = 1500 cm

f_e = Focal length of the eye lens = 1.0 cm

Angular magnification of the giant refracting telescope is given by

$$m_0 = \left|\frac{f_o}{f_e}\right|$$

$$\therefore \quad m_0 = \left|\frac{1500}{1}\right| = 1500$$

(ii) Diameter of the image of the moon formed by the objective lens, $d = \alpha f_o$

$$\Rightarrow \quad d = \frac{\text{Diameter of the moon}}{\text{Radius of the lunar orbit}} \times f_o$$

$$\Rightarrow \quad d = \frac{3.48 \times 10^6}{3.8 \times 10^8} \times 1500 \times 10^{-2}$$

$$\Rightarrow \quad d = 0.1374 \text{ m.}$$

$$d = 13.74 \text{ cm}$$

13. Write Einstein's photoelectric equation and mention which important features in photoelectric effect can be explained with the help of this equation.

The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of light incident on the surface changes from λ_1 to λ_2. Derive the expressions for the threshold wavelength λ_0 and work function for the metal surface. [3]

Answer : Einstein's photoelectric equation is given by

$$K_{max} = \frac{1}{2} mv^2_{max}$$

$$K_{max} = h\nu - \phi_0$$

or $$h\nu = h\nu_0 + \frac{1}{2} mv^2_{max}$$

where

K_{max} = Maximum kinetic energy of the photoelectron

v_{max} = Maximum velocity of the emitted photoelectron

m = Mass of the photoelectron

ν = Frequency of the light radiation

ϕ_0= Work function

h = Planck's constant

If ν_0 is the threshold frequency, then the work function can be written as

$$W = \phi_0 = h\nu_0$$

$$\Rightarrow K_{max} = \frac{1}{2} mv^2_{max} = h\nu - h\nu_0 = h(\nu - \nu_0)$$

The above equations explains the following results :

1. If $\nu < \nu_0$, then the maximum kinetic energy is negative, which is impossible. Hence, photoelectric emission does not take place for the incident radiation below the threshold frequency. Thus, the photoelectric emission can take place if $\nu > \nu_0$.

2. The maximum kinetic energy of emitted photoelectrons is directly proportional to the frequency of the incident radiation. This means that maximum kinetic energy of photoelectron depends only on the frequency of incident light not on the intesity According to the photoelectric equation,

$$K_{max} = \frac{1}{2} mv^2_{max} = h\nu - \phi_0$$

$$K_{max} = \frac{hc}{\lambda_1} - \phi_0 \quad \text{...(i)}$$

Let the maximum kinetic energy for the wavelength λ_2 be K_2.

$$K_2 = \frac{hc}{\lambda_2} - \phi_0 \quad \text{...(ii)}$$

$$K_2 = 2K_1 \quad \text{(given)}$$

From (i) and (ii), we have

$$\frac{hc}{\lambda_2} - \phi_0 = 2\left(\frac{hc}{\lambda_1} - \phi_0\right)$$

$$\Rightarrow \quad \phi_0 = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow \quad h\nu_0 = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow \quad \frac{c}{\lambda_0} = c\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda_0} = \left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow \quad \lambda_0 = \left(\frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}\right)$$

Work function is the energy required to eject a photoelectron from the metal.

$$W = \frac{hc}{\lambda_0}$$

$$\therefore \quad W = \frac{hc\,(2\lambda_2 - \lambda_1)}{\lambda_1\lambda_2}$$

14. In the study of Geiger-Marsdon experiment on scattering of α-particles by a thin foil of gold, draw the trajectory of α-particles in the Coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

From the relation $R = R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A. [3]

OR

Distinguish between nuclear fission and fusion. Show how in both these processes energy is released. Calculate the energy release in MeV in the deuterium-tritium fusion reaction :

$${}^2_1H + {}^3_1H \rightarrow {}^4_2He + {}_0n^1$$

Using the data :

$$m\left({}^2_1H\right) = 2.014102\ u$$

$$m\left({}^3_1H\right) = 3.016049u$$

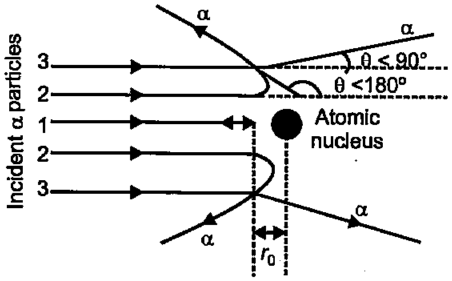
$$m\left({}^4_2He\right) = 4.002603u$$

$$mn = 1.008665u$$

$$1u = 931.5\ MeV/c^2$$

Answer :

Trajectory of a Particles in Coulomb Field of Target Nucleus



From this experiment, the following is observed :

1. Most of the alpha particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.

2. About one alpha particle in every 8000 alpha particles deflects by more than 90°.

As most of the alpha particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty and at the centre of the atom, there exists a nucleus. By the number of the alpha particles deflected, the information regarding size of the nucleus can be known.

If m is the average mass of a nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

Volume of the nucleus, $V = \frac{4}{3}\pi R^3$

Given $R = R_0A^{1/3}$

$$\Rightarrow \quad V = \frac{4}{3}\pi\left(R_0A^{1/3}\right)^3$$

$$\Rightarrow \quad V = \frac{4}{3}\pi R_0^3 A$$

Density of nuclear matter, $\rho = \frac{mA}{V}$

$$\Rightarrow \quad \rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$\Rightarrow \quad \rho = \frac{3m}{4\pi R_0^3}$$

This shows that the nuclear density is independent of A.

OR

Nuclear fission : Nuclear fission is a disintegration process, in which a heavier nucleus gets split up into two lighter nuclei, with the release of a large amount of energy.

$${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + Q$$

Here, the energy released per fission of ${}_{92}U^{235}$ is 200.4 MeV.

Nuclear fusion : When two or more light nuclei combine to form a heavy stable nuclide, part of mass disappears in the process and is converted into energy. This phenomenon is called nuclear fusion.

$${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + e^+ + \nu + 0.42\ MeV$$

$${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 + 3.27\ MeV$$

$${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + {}_1H^1 + 4.03\ MeV$$

Energy released in this process

$${}^2_1H + {}^3_1H \rightarrow {}^4_2He + {}_0n^1$$

$\therefore\ \Delta m = (2.014102 + 3.016049) - (4.002603 + 1.008665)$

$= 0.018883\ u$

Energy released, $Q = 0.018883 \times 931.5\ MeV/c^2$

$= 17.589\ MeV$

15. Draw a block diagram of a detector for AM signal and show, using necessary processes and the waveforms, how the original message signal is detected from the input AM wave.** **[3]**

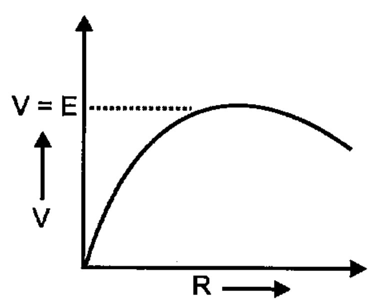
Answer :

16. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current i.

It is found that when R = 4 Ω, the current is 1 A when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r. **[3]**

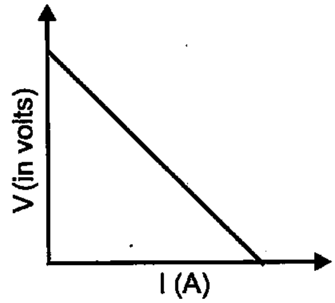
Answer :

(i) Graph between terminal voltage (V) and resistance (R) :



****Answers is not given due to change in the present syllabus.**

(ii) Graph between terminal voltage (V) and current (I) :



(iii) When R = 4 Ω and I = 1 A

We know,

Terminal voltage, $V = E - Ir$

So, we have

$$V = IR = 4 = E - Ir$$

$$E - r = 4 \quad \text{... (i)}$$

When R = 9 Ω and I = 0.5 A

$$V = IR = 0.5 \times 9 = E - 0.5r$$

$$E - 0.5r = 4.5 \quad \text{...(ii)}$$

Subtracting (i) from (ii), we get

$$E - 0.5r - E + r = 4.5 - 4$$

$$0.5r = 0.5$$

$$r = 1\,\Omega$$

Substituting value of r in (i)

$$E - 1 = 4$$

$$E = 5\,V$$

Thus $r = 1\,\Omega$ and E = 5 V.

17. Two capacitors of unknown capacitances C_1 and C_2 are connected first in series and then in parallel across a battery of 100 V. If the energy stored in the two combinations is 0.045 J and 0.25 J respectively, determine the value of C_1 and C_2. Also calculate the charge on each capacitor in parallel combination. [3]

Answer : When the capacitors are connected in parallel.

Equivalent capacitance, $C_p = C_1 + C_2$

The energy stored in the combination of the capacitors,

$$E_p = \frac{1}{2}C_pV^2$$

$$\Rightarrow \quad E_p = \frac{1}{2}(C_1 + C_2)(100^2) = 0.25J$$

$$\Rightarrow \quad (C_1 + C_2) = 5 \times 10^{-5} \quad \text{...(i)}$$

When the capacitors are connected in series.

Equivalent capacitance,

$$C_s = \frac{C_1C_2}{C_1 + C_2}$$

The energy stored in the combination of the capacitors,

$$E_s = \frac{1}{2}C_sV^2$$

$$\Rightarrow E_s = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(100)^2 = 0.045J$$

$$\Rightarrow \frac{1}{2}\frac{C_1C_2}{5 \times 10^{-5}}(100)^2 = 0.045J \; [\because c_1 + c_2 = 5 \times 10^{\text{æ}}]$$

$$\Rightarrow C_1C_2 = 0.045 \times 10^{-4} \times 5 \times 10^{-5} \times 2 = 4.5 \times 10^{-10} \quad \text{(ii)}$$

$$(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2$$

$$\Rightarrow (C_1 - C_2) = \sqrt{7 \times 10^{-10}} = 2.64 \times 10^{-5}$$

[using (i) & (iii)]

Now, $C_1 - C_2 = 2.64 \times 10^{-5}$ ...(ii)

Solving (i) and (iii), we get

$$C_1 = 38.2\,\mu F \text{ and } C_2 = 11.8\,\mu F$$

When the capacitors are connected in parallel, the charge on each of them can be obtained as follows :

$$Q_1 = C_1V = 38.2 \times 10^{-6} \times 100 = 38.2 \times 10^{-4}\,C$$

$$Q_2 = C_2V = 11.8 \times 10^{-6} \times 100 = 11.8 \times 10^{-4}\,C$$

18. State the principle of working of a galvanometer. A galvanometer of resistance G is converted into a voltmeter to measure upto V volts by connecting a resistance R_1 in series with the coil. If a resistance R_2 is connected in series with it, then it can measure upto V/2 volts. Find the resistance, in terms of R_1 and R_2, required to be connected to convert it into a voltmeter that can read upto 2 V. Also find the resistance G of the galvanometer in terms of R_1 and R_2. [3]

Answer : Principle : When a current-carrying coil is placed in a magnetic field, it experiences a torque. From the measurement of the deflection of the coil, the strength of the current can be computed. A high resistance is connected in series with the galvanometer to convert it into voltmeter. The value of the resistance is given by

$$R = \frac{V}{I_g} - G$$

Here,

V = Potential difference across the terminals of the voltmeter

I_g = Current through the galvanometer

G = Resistance of the galvanometer

When the resistance R_1 is connected in series with the galvanometer.

$$V = I_g (G + R_1)$$

When the resistance R_2 is connected in series with the galvanometer[7]

$$\frac{V}{2} = I_g (G + R_2)$$

$$\Rightarrow \quad 2 = \frac{G+R_1}{G+R_2}$$

$$G = R_1 - 2R_2$$

Let R_3 be the resistance required for conversion of galvanometer into voltmeter of range 2V

$$\therefore \quad 2V = I_g (G + R_3)$$

Also $$V = I_g (G + R_1)$$

$$\therefore \quad 2 = \frac{G+R_3}{G+R_1}$$

$\therefore R_3 = G + 2R_1 = R_1 - 2R_2 + 2R_1 = 3R_1 - 2R_2$

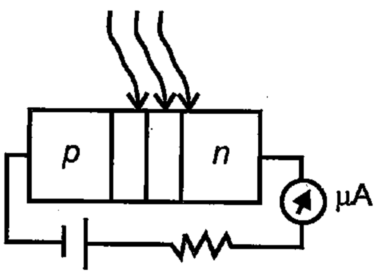
19. With what considerations in view, a photodiode is fabricated ? State its working with the help of a suitable diagram.

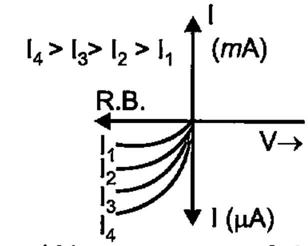
Even though the current in the forward bias is known to be more than in the reverse bias, yet the photodiode works in reverse bias. What is the reason ? **[3]**

Answer : A photodiode is used to observe the change in current with change in the light intensity under reverse bias condition.

In fabrication of photodiode, material chosen should have band gap –1.5 eV or lower so that solar conversion efficiency is better. This is the reason to choose Si or GaAs material.

Working : It is a *p-n* junction fabricated with a transparent window to allow light photons to fall on it. These photons generate electron hole pairs upon absorption. If the junction is reverse biased using an electrical circuit, these electron hole pair move in opposite directions so as to produce current in the circuit. This current is very small and is detected by the microammeter placed in the circuit.





I-V characteristics of photodiode for different illumination intensities

A photodiode is preferably operated in reverse bias condition. Consider an *n*-type semiconductor. Its majority carrier (electron) density is much larger than the minority hole density *i.e.* $n >> p$. When illuminated with light, both types of carriers increase equally in number

$$n' = n + \Delta n; \ p' = p + \Delta p$$

Now $n >> p$ and $\Delta n = \Delta p$

$$\frac{\Delta n}{n} << \frac{\Delta p}{p}$$

That is, the fractional increase in majority carriers is much less than the fractional increase in minority carriers. Consequently, the fractional change due to the photo-effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the majority carrier dominated forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

20. Draw a circuit diagram of a transistor amplifier in CE configuration.

Define the terms :

(i) Input resistance and (ii) Current amplification factor. How are these determined using typical input and output characteristics?** **[3]**

21. Answer the following questions : **[3]**

(a) In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.

(b) Light of wavelength 5000 Å propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected ?

Answer : (a) Angular width (θ) of fringe in double-slit experiment is given by $\theta = \frac{\lambda}{d}$

Where d = Spacing between the slits.

Given : Wavelength of light, λ = 600 nm

Angular width of fringe,

$$\theta = 0.1° = 0.1 \times \frac{\pi}{180} \text{ rad} = 0.0018 \text{ rad}$$

**Answers is not given due to change in the present syllabus.

$\therefore \quad d = \frac{\lambda}{\theta}$

$d = \frac{600 \times 10^{-9}}{18 \times 10^{-4}} = 33.33 \times 10^{-5}$

$\Rightarrow \quad d = 0.33 \times 10^{-3}$m

(b) The frequency and wavelength of reflected wave will not change.

The refracted wave will have same frequency, only wavelength will change.

The velocity of lighvt in water is given by

$$v = \lambda f$$

where, v = Velocity of light

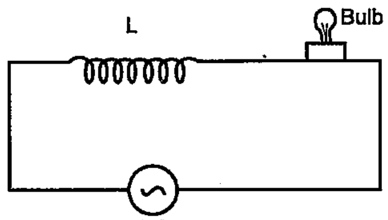
f = Frequency of light

λ = Wavelength of light

As light ray in travelling from rarer (air) medium to denser medium, its speed will decrease. Hence wavelength (λ) will also decrease.

22. An inductor L of inductance X_L is connected in series with a bulb B and an ac source. How would brightness of the bulb change when (i) number of turn in the inductor is reduced. (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit. Justify your answer in each case. [3]

Answer :



(i) When the number of turns in the inductor is reduced, its reactance X_L decreases. The current in the circuit increases and hence brightness of the bulb increases.

(ii) When an iron rod is inserted in the inductor, the self inductance increases. Consequently, the inductive reactance $X_L = \omega L$ increases. This decreases the current in the circuit and the bulb glows dimmer.

(iii) With capacitor of reactance $X_C = X_L$, the impedance

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = R$$

becomes minimum, the current in circuit becomes maximum. Hence, the bulb glows with maximum brightness.

SECTION–D

23. A group of students while coming from the school noticed a box marked "Danger H.T. 2200 V" at a substation in the main street. They did not understand the utility of such a high voltage, while they argued the supply was only 220 V. They asked their teacher this question the next day. The teacher thought it to be an important question and therefore, explained to the whole class. [4]

Answer the following questions :

(i) What device is used to bring the high voltage down to low voltage of a.c. current and what is the principle of its working ?

(ii) Is it possible to use this device for bringing down the high dc voltage to the low voltage? Explain.

(iii) Write the values displayed by the students and the teacher.**

Answer : (i) The device that is used to bring high voltage down to low voltage of an a.c. current is a transformer. It works on the principle of mutual induction of two windings or circuits. When current in one circuit changes, emf is induced in the neighbouring circuit.

(ii) The transformer cannot convert d.c. voltages because it works on the principle of mutual induction. When the current linked with the primary coil changes the magnetic flux linked with the secondary coil also changes. This change in flux induces emf in the secondary coil. If we apply a direct current to the primary coil the current will remain constant. Thus, there is no mutual induction and hence no emf is induced.

SECTION–E

24. (a) State Ampere's circuital law. Use this law to obtain the expression for the magnetic field inside an air cored toroid of average radius, having 'n' turns per unit length and carrying a steady current I.

(b) An observer to the left of a solenoid of N turns each of cross section area A observes that a steady current I in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic momentum M = NIA. [5]

OR

(a) Define mutual inductance and write its S.I. units.

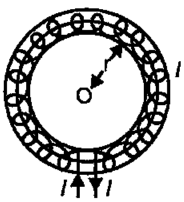
(b) Derive an expression for the mutual inductance of two long co-axial solenoids of same length wound one over the other.

**Answers is not given due to change in the present syllabus.

(c) In an experiment two coils c_1 and c_2 are placed close to each other. Find out the expression for the emf induced in the coil c_1 due to a change in the current through the coil c_2.

Answer : (a) Ampere's circuital law in electromagnetism is analogous to Gauss' law in electrostatics. This law states that "The line integral of resultant magnetic field along a closed plane curve is equal to μ_0 time the total current crossing the area bounded by the closed curve provided the electric field inside the loop remains constant. Thus $\oint B.dl = \mu_0 I_{enc}$ where μ_0 is permeability of free space and $I_{enc.}$ is the net current enclosed by the loop.

A toroid is a hollow circular ring on which a large number of turns of a wire are closely wound. Consider an air-cored toroid (as shown below) with centre O.

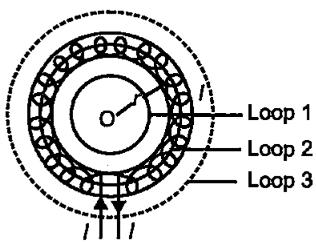


Given : r = Average radius of the toroid

I = Current through the solenoid

n = Number of turns per unit length

To determine the magnetic field inside the toroid, we consider three amperian loops (loop 1, loop 2 and loop 3) as shown in the figure below.



According to Ampere's circuital law, we have

$$\oint \vec{B}.\vec{dl} = \mu_0 \; I_{enc.} \text{ (Total current)}$$

Total current for loop 1 is zero because no current is passing through this loop

So, for loop 1

$$\oint \vec{B}.\vec{dl} = \mu_0 \text{ (Total current)}$$

For loop 3

According to Ampere's circuital law, we have

$$\oint \vec{B}.\vec{dl} = \mu_0 \text{ (Total current)}$$

Total current for loop 3 is zero because net current coming out of this loop is equal to the net current going inside the loop.

For loop 2 :

The total current flowing through the toroid is NI, where N is the total number of turns

$$\oint \vec{B}.\vec{dl} = 0 = \mu_0 (NI) \quad ...(i)$$

Now, $\vec{B}$ and $\vec{dl}$ are in the same direction

$$\oint \vec{B}.\vec{dl} = B\oint dl$$

$$\Rightarrow \quad \oint \vec{B}.\vec{dl} = B(2\pi r) \quad ...(ii)$$

Comparing (i) and (ii), we get

$$B(2\pi r) = \mu_0 NI$$

$$\Rightarrow \quad B = \frac{\mu_0 NI}{2\pi r}$$

Number of turns per unit length is given by

$$n = \frac{N}{2\pi r}$$

$$\therefore \quad B = \mu_0 nI$$

This is the expression for magnetic field inside air-cored toroid.

(b) Given that the current flows in the clockwise direction for an observer on the left side of the solenoid. This means that left face of the solenoid acts as south pole and right face acts as north pole. Inside a bar magnet the magnetic field lines are directed from south to north. Therefore, the magnetic field lines are directed from left to right in the solenoid.

Magnetic moment of single current carrying loop is given by $m' = IA$

where I = Current flowing through the loop

A = Area of the loop

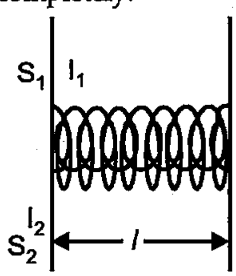
So, Magnetic moment of the whole solenoid is given by

$$M = Nm' = N(IA)$$

OR

(a) Mutual inductance is the property of two coils by the virtue of which each opposes any change in the value of current flowing through the other by developing an induced emf. The SI unit of mutual inductance is henry and its symbol is H.

(b) Consider two long solenoids S_1 and S_2 of same length l such that solenoid S_2 surrounds solenoid S_1 completely.



Let :

n_1 = Number of turns per unit length of S_1

n_2 = Number of turns per unit length of S_2

I_1 = Current passed through solenoid S_1

ϕ_{21} = Flux linked with S_2 due to current flowing through S_1

$\phi_{21} \propto I_1$

$\phi_{21} = M_{21}I_1$

where M_{21} = Coefficient of mutual induction of the two solenoids

When current is passed through solenoid S_1, an emf is induced in solenoid S_2.

Magnetic field produced inside solenoid S_1 on passing current through it is given by

$$B_1 = \mu_0 n_1 I_1$$

Magnetic flux linked with each turn of solenoid S_2 will be equal to B_1 times the area of cross-section of solenoid S_1.

Magnetic flux linked with each turn of the solenoid $\phi_{21} = B_1A$

Therefore, total magnetic flux linked with the solenoid S_2 is given by

$$\phi_{21} = B_1A = \mu_0 n_1 I_1 A$$

$$M_{21} = \frac{N_2\phi_{21}}{I_1}$$

$$M_{21} = \frac{N_2\mu_0 n_1 I_1 A}{I_1} = \mu_0 n_1 N_2 A$$

where N_2 is total number of turns wound over the secondary coil.

$\therefore$ $$M_{21} = \mu_0 n_1 N_2 A$$

Similarly the mutual inductance between the two solenoids when current is passed through solenoid S_2 and induced emf is produced in solenoid S_1 is given by

$$M_{12} = \mu_0 N_1 n_2 A$$

where N_1 total numbers of turns wound over primary coil.

(c) It is found that,

$$\phi \propto I$$

$$\phi = MI$$

Where, I is the strength of current in coil 2, and ϕ is the total amount of magnetic flux linked with coil 1.

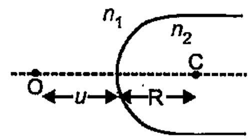
E.m.f. induced in neighbouring coil C_1 is,

$$e = -\frac{d\phi}{dt}$$

$$= -\frac{d(MI)}{dt} = -\frac{MdI}{dt}$$

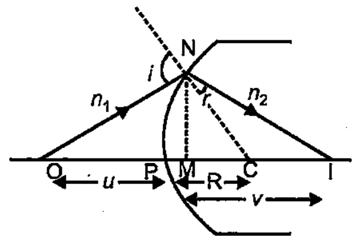
25. (a) A point object 'O' is kept in a medium of refractive index n in front of a convex spherical surface of radius of curvature R which separate the second medium of refractive index n_2 from the first one as shown in the figure.

Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of n_1, n_2 and R.



(b) When the image formed above acts as a virtual object for a concave spherical surface separating the medium n_2 from n_1 ($n_2 > n_1$) draw this ray diagram and write the similar (similar to (a)) relation. Hence obtain the expression for the Lens Maker's formula. [5]

Answer : (a) Let a spherical surface separate a rarer medium of refractive index n_1 from second medium of refractive index n_2. Let C be the centre of curvature and R = MC be the radius of the surface.



Consider a point object O lying on the principal axis of the surface. Let a ray starting from O incident normally on the surface along OM and pass straight. Let another ray of light incident on NM along ON and refract along NI.

From M, draw MN perpendicular to OI.

The above figure shows the geometry of formation of image I of an object O and the principal axis of a spherical surface with centre of curvature C and radius of curvature R.

Let us make the following assumptions :

(i) The aperture of the surface is small as compared to the other distance involved.

(ii) The object consists only of a point lying on the principal axis of the spherical refracting surface.

$$\tan\angle NOM = \frac{MN}{OM}$$

$$\tan\angle NCM \frac{MN}{MI}$$

$$\tan\angle NIM = \frac{MN}{MI}$$

For ΔNOC, i is the exterior angle.

$\therefore$ $$i = \angle NOM + \angle NCM$$

For small angles $\tan i \approx i$,

$$i = \frac{MN}{OM} + \frac{MN}{MC} \quad ...(i)$$

Similarly, $$r = \angle NCM - \angle NIM$$

$$r = \frac{MN}{MC} - \frac{MN}{MI} \quad ...(ii)$$

By Snell's law,

$$n_1 \sin i = n_2 \sin r$$

For small angles,

$$n_1 i = n_2 r$$

Substituting the values of i and r from (i) and (ii), we obtain

$$n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} + \frac{MN}{MI}\right)$$

or,
$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC} \quad ...(iii)$$

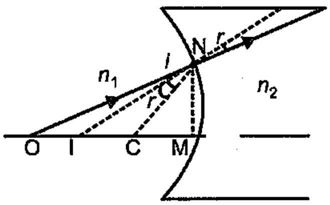
Applying new Cartesian sign conventions, we get

$$OM = -u, MI = +v, MC = +R$$

Substituting these values in equation (iii), we obtain

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \quad ...(iv)$$

(b)



Now the image I acts as virtual object for the second surface that will form real image at l. As refraction takes place from denser to rarer medium

$$\therefore \quad \frac{-n_2}{v} + \frac{n_1}{v'} = \frac{n_1 - n_2}{R} \quad ...(v)$$

Adding (iv) and (v) we get $\left[\because k = \frac{1}{4\pi\varepsilon_o}\right]$

$$\frac{n_1}{v'} - \frac{n_1}{u} = (n_2 - n_1)\left[\frac{1}{R} - \frac{1}{R'}\right]$$

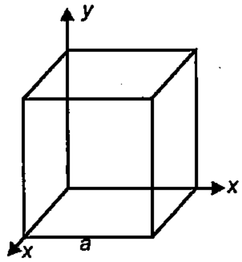
$$\frac{1}{f} = (n_{21} - 1)\left[\frac{1}{R} - \frac{1}{R'}\right]$$

$$\left[\because n_{21} = \frac{n_2}{n_1}, \frac{1}{f} = \frac{1}{v'} - \frac{1}{u}\right]$$

26. (a) An electric dipole of dipole moment $\vec{p}$ consists of point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit

$$x >> a, \vec{E} \rightarrow \frac{2\vec{p}}{4\pi\varepsilon_0 x^3}$$

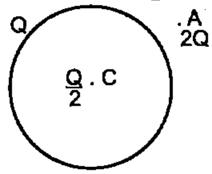
(b) Given the electric field in the region $\vec{E} = 2\,x\,\hat{i}$, find the net electric flux through the cube and the charge enclosed by it. [5]



OR

(a) Explain, using suitable diagrams, the difference in the behaviour of a (i) conductor and (ii) dielectric in the presence of external electric field. Define the terms polarization of a dielectric and write its relation with susceptibility.

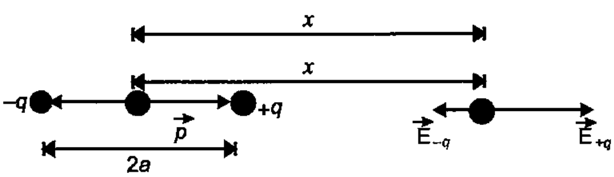
(b) A thin metallic spherical shell of radius carries a charge Q on its surface. A point charge $\frac{Q}{2}$ is placed at its centre C and another charge +2Q is placed outside the shell at a distance x from the centre as shown in the figure. Find (i) the force on the charge at the centre of shell and at the point A, (ii) the electric flux through the shell.



Answer : (a) Electric field at a point on the axial line

$$|\vec{E}_{+q}| = \frac{kq}{(x-a)^2}$$

$$|\vec{E}_{-q}| = \frac{kq}{(x+a)^2}$$



$$\vec{E} = \vec{E}_{+q} - \vec{E}_{-q} = \frac{kq}{(x-a)^2} - \frac{kq}{(x+a)^2}$$

$$\Rightarrow \quad |\vec{E}| = \frac{kq4ax}{(x^2 - a^2)^2}$$

$$\vec{E} = \frac{2k\vec{p}x}{(x^2 - a^2)^2} \text{ (Parallel to } \vec{p}) \quad [\because \vec{p} = 2aq]$$

If $x >> a$, $\vec{E} = \dfrac{2\vec{p}}{4\pi\varepsilon_0 x^3}$.

In vector form, $\vec{E} = \dfrac{2\vec{p}}{4\pi\varepsilon_0 x^3}$ $\left[\because k = \dfrac{1}{4\pi\varepsilon_o}\right]$

(b) Since, the electric field is parallel to the faces and parallel to xy and xz planes, the electric flux through them is zero.

Electric flux through the left face

$$\phi_L = (E_L)(a^2)\cos 180^\circ$$
$$= (0)(a^2)\cos 180^\circ = 0$$

Electric flux through the right face,

$$\phi_R = (E_R)(a^2)\cos 0^\circ$$
$$= (2a)(a^2) \times 1$$
$$= 2a^3$$

Total flux $(\phi) = 2a^3 = \dfrac{q_{enclosed}}{\varepsilon_0}$

$\therefore q_{enclosed} = 2a^3\varepsilon_0$

OR

(a) (i) Conductor :

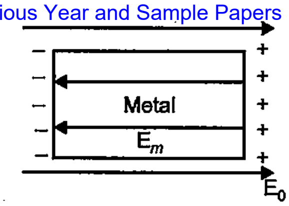
Let E_0 = external field, and

E_m= internal field created by the redistribution of electrons inside the metal.

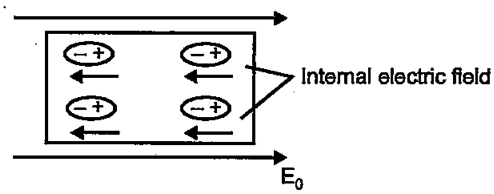
When a conductor like a metal is subjected to external electric field, the electrons experience a force in the opposite direction collecting on the left hand side.

A positive charge is therefore induced on the right hand side. This creates an opposite electric field (E_m) that balances out (E_0).

$\therefore$ The net electric field inside the conductor becomes zero.



(ii) Dielectric :



When an external electric field is applied, dipoles are created (in case of non-polar dielectrics). The placement of dipoles is as shown in the given figure. An internal electric field is created which reduces the external electric field.

Polarization of dielectric (P) is defined as the dipole moment per unit volume of the polarized dielectric.

$$P = \chi_e \varepsilon_0 E$$

Where χ_e = Susceptibility

E = Electric field

(b) (i) Net force on the charge $\dfrac{Q}{2}$, placed at the centre of the shell is zero.

Net Force on charge 2Q kept at a point A

$$F = E \times 2Q = \frac{1.\left(\frac{3Q}{2}\right)2Q}{4\pi\varepsilon_o r^2} = \frac{k3Q^2}{r^2}$$

(ii) Electric flux through the shell,

$$\phi = \frac{Q}{2\varepsilon_o} \qquad \left[\because \phi = \frac{q_{enclosed}}{\varepsilon_0}\right]$$

Note : All questions of Delhi Set II are from Delhi Set I and Delhi Set III are from Set I and Set II.

Physics 2014 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current. [1]

Answer : One ampere is the current which when flowing through each of the two parallel uniform long linear conductors placed in free space at a distance of one metre from each other will attract or repel each other with a force of 2×10^{-7} N per metre of their length.

2. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong ? [1]

Answer : The frequency 5×10^{19} Hz lies in the gamma region of the electromagnetic spectrum.

3. What is the force between two small charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air? [1]

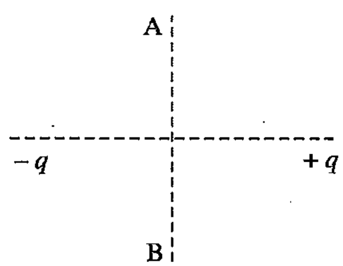
Physics 2016 (Outside Delhi)

SET I

Time allowed : 3 hours **Maximum marks : 70**

SECTION — A

1. **A charge 'q' is moved from a point A above a dipole of dipole moment 'p' to a point B below the dipole in equatorial plane without acceleration. Find the work done in the process. [1]**



Answer : Work done, $W = q(V_B - V_A) = q \times 0 = 0$

2. **In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field ? [1]**

Answer : The magnetic field lines pass through the paramagnetic material while the magnetic field lines move away from the diamagnetic material. or paramagnetic material get aligned along B and dianegnetic aliqied perpendicular to B.

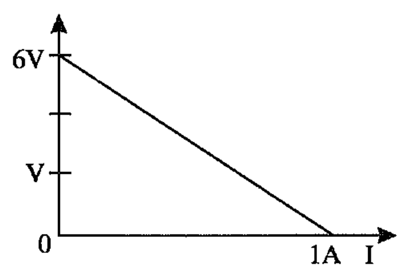
3. **Name the essential components of a communication system. [1]**

Answer : The essential components are : Transmitter, communication channel and receiver.

4. **Why does sun appear red at sunrise and sunset? [1]**

Answer : Sun appears red at sunrise and sunset due to the least scattering of red light as it has the longest wavelength.

5. **The plot of the variation of potential difference across a combination of three identical cells in series, versus current is shown below. What is the emf and internal resistance of each cell ? [1]**



Answer :

We know that,

$$V = E - Ir$$

Where E is the e.m.f. and r is the total internal resistance.

When $I = 0$,

$$\text{Total emf} = \text{Terminal voltage}$$

$$3E = 6\,V$$

emf. of each cell E = 2 V

When $V = 0$

$E = Ir$

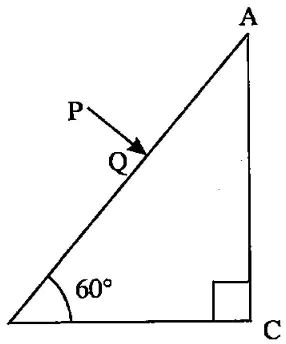
$$r = \frac{\text{Total E.m.f}}{I} = \frac{6}{1} = 6\,\Omega$$

As the cells are connected in series. So, the internal resistance of each cell = 2 Ω.

SECTION—B

6. Define modulation index. Why is it kept low ? What is the role of a bandpass filter ? [2]**

7. A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge ? Justify your answer. [2]



Answer :

We know that,

$$n = \frac{1}{\sin C}$$

Where, n = Refractive index

C = Critical angle.

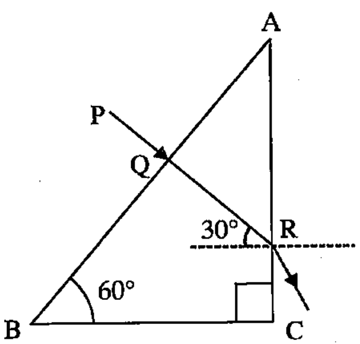
So, $\sin C = 1/n = 1/1.5 = 0.667$

$\sin C = \sin 41^\circ 49'$

$C = 41^\circ 49'$

$C > 30^\circ$

Angle on face AC. which as greater than incident



Thus, the light ray PQ will emerge out from face AC.

8. Calculate the de-Broglie wavelength of the electron orbitting in the $n = 2$ stage of hydrogen atom. [2]

Answer : The velocity of an orbitting electron,

$$v = \frac{Zc}{137n}$$

Where, c = Speed of light in vacuum.

So, $$v = \frac{1 \times 3 \times 10^8}{137 \times 2} = 1.09 \times 10^6 \text{ m/s.}$$

The de-Broglie wavelength, $\lambda = h/mv$

Where h is Planck's constant = 6.6×10^{-34} Js

and mass of electron = 9.1×10^{-31} kg

So, $\lambda = 6.6 \times 10^{-34}/(9.1 \times 10^{-31} \times 1.09 \times 10^6)$

$= 6.65 \times 10^{-9}\ \text{m}^{-9}$

9. Define ionization energy.

How would the ionization energy change when electron in hydrogen atom replaced by a particle of mass 200 times that of the electron but having the same charge? [2]

OR

Calculate the shortest wavelength of the spectral lines emitted in Balmer series. [Given Rydberg constant, R= 10^7 m^{-1}]

Answer : Ionization energy is defined as the amount of energy needed to remove the valence electron of an isolated gaseous atom.

The ionization energy of hydrogen atom is

$E_H \propto m_e$ ...(i)

When mass of electron is replaced by a particle having mass = 200 m_e, then

$E'_H \propto 200\, m_e$ ...(ii)

From (i) and (ii), we have

$E'_H = 200\, E_H = 200 \times (-13.6) = -2720$ eV

($\propto E_H = -13.6$ eV)

OR

For Balmer series, wavelength is given by :

$$\frac{1}{\lambda} = R[1/2^2 - 1/n^2]$$

Where, $n = 3, 4, 5$

For shortest wavelength, $n = \infty$

So, $$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

$$\frac{1}{\lambda} = 10^7\left[\frac{1}{4}\right]$$

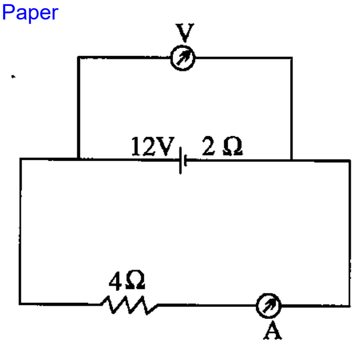
$$\lambda = 4 \times 10^{-7} \text{ m.}$$

10. A battery of emf 12 V and internal resistance 2 Ω is connected to a 4 Ω resistor as shown in the figure. [2]

(a) Show that a voltmeter when placed across the cell and across the resistor, in turn, gives the same reading.

(b) To record the voltage and the current in the circuit, why is voltmeter placed in parallel and ammeter in series in the circuit ?

**Answers is not given due to change in the present syllabus.



Answer : We know that,

(a) Effective resistance of the circuit $R_E = 6\,\Omega$

$\therefore I = \frac{12}{6} = 2A$

Terminal potential difference across the cell can be calculated as,

$$V = E - Ir = 12 - 2 \times 2 = 12 - 4 = 8\text{ V}$$

Also, Potential difference across 4Ω resistor can be calculated as

$$V = IR = 2 \times 4 = 8\text{ V.}$$

So, a voltmeter when placed across the cell and across the resistor, gives the same reading.

(b) An ammeter is connected in series because it has very low resistance. So, when, an ammeter is connected in series, then there is not much increase in the resistance of the circuit and hence the current through the circuit unchanged.

A voltmeter is connected in parallel because it has very high resistance. So, it draws a very small current from the circuit.

SECTION—C

11. Define an equipotential surface. Draw equipotential surfaces : **[3]**

(i) in the case of a single point charge and

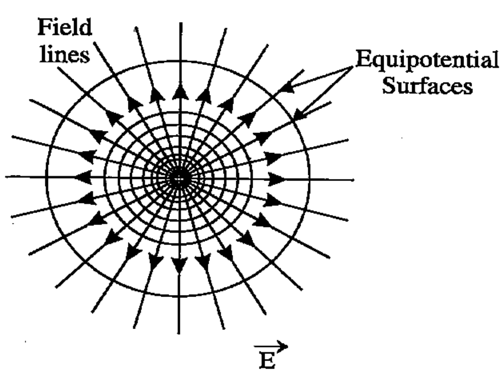
(ii) in a constant electric field in Z-direction.

Why the equipotential surfaces about a single charge are not equidistant ?

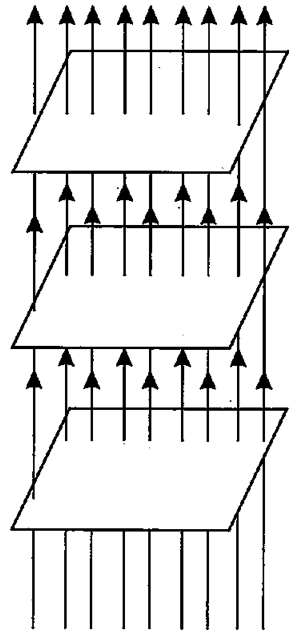
(iii) Can electric field exist tangential to an equipotential surface ? Give reason.

Answer : An equipotential surface is the surface which has same potential at its every point.

(i)



(ii)



The electric field due to single charge is not constant, this is the reason why the equipotential surfaces about a single charge are not equidistant and potential vary inversely with radius i.e., $V \propto \frac{1}{r}$

(iii) No, electric field cannot exist tangential to an equipotential surface. If it happen then a charged particle will experience a force along the tangential line and can move along it. As a charged particle can move only due to the potential difference *i.e.*, along the direction of charge of potential, this contradicts the concept of an equipotential surface.

12. (i) State law of Malus.

(ii) Draw a graph showing the variation of intensity (I) of polarised light transmitted by an analyser with angle (θ) between polariser and analyser.

(iii) What is the value of refractive index of a medium of polarising angle 60°? **[3]**

Answer : (i) Malus discovered that when a beam of completely plane polarized light is passed through the analyser, the intensity 'I' of transmitted light changes directly as the square of the cosine of the angle θ between the transmission directions of polarizer and analyzer.

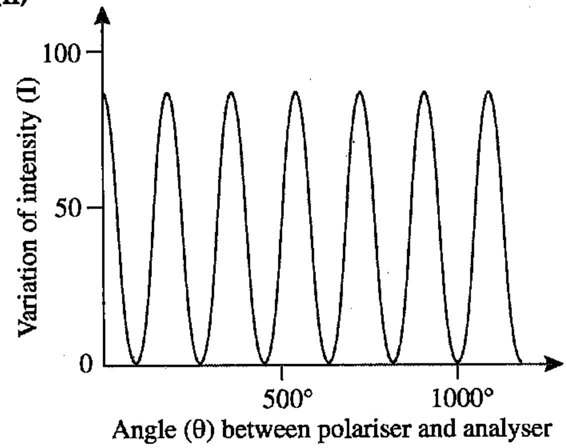
This is known as the law of Malus.

$$I \propto \cos^2\theta$$

or $$I = I_0 \cos^2\theta$$

Where, I_0 is the maximum intensity of the transmitted light.

(ii)



(iii) From the Brewster's law of polarization :

$$\mu = \tan i_p = \tan 60^\circ = \sqrt{3} = 1.7320$$

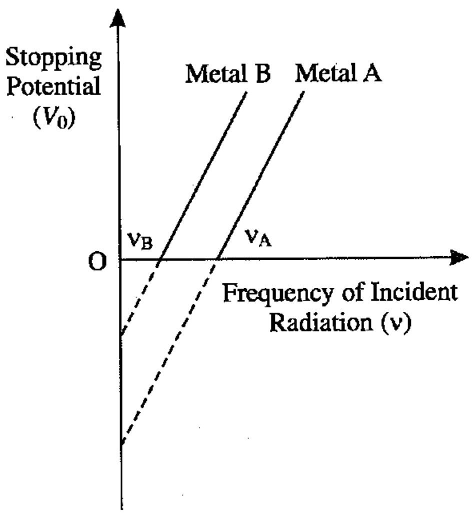
Thus, the refractive index of the material is 1.73.

13. Sketch the graphs showing variation of stopping potential with frequency of incident radiations for two photosensitive materials A and B having threshold frequencies $\nu_A > \nu_B$. **[3]**

(i) In which case is the stopping potential more and why ?

(ii) Does the slope of the graph depend on the nature of the material used ? Explain.

Answer :



(i) We know that,

$$V_0 = \frac{h}{e}(\nu - \nu_0)$$

For the same value of ν, stopping potential is more for which threshold frequency (ν_0) is less.

Given, $\nu_A > \nu_B$

Therefore, threshold frequency for metal B is less than the threshold frequency for metal A. Hence, stopping potential is more for metal B.

(ii) No, the slope of the graph tells us the value of h/e which is same for both the materials. So, it does not depend on the nature of the materials.

14. (a) Write the basic nuclear process involved in the emission of β^+ in a symbolic form, by a radioactive nucleus.

(b) In the reactions given below :

(i) ${}^{11}_{6}C \longrightarrow {}^{z}_{y}B + x + \nu$

(ii) ${}^{12}_{6}C + {}^{12}_{6}C \longrightarrow {}^{20}_{a}Ne + {}^{c}_{b}He$

Find the value of x, y, z and a, b, c. **[3]**

Answer : (a) In β^+-decay, the atomic number of the radioactive nucleus decreases by one and its mass number remains same. In this process, a positron (e^+) and a new particle neutrino (ν) are emitted from the nucleus.

Generally, ${}^{A}_{Z}X \rightarrow {}_{Z-1}{}^{A}Y + e^+ + \nu$

(b) (i) ${}^{11}_{6}C \rightarrow {}^{z}_{y}B + x + \nu$

${}^{11}_{6}C \rightarrow {}^{11}_{5}B + {}^{0}_{1}\beta + \nu$

The corresponding y and z are 5 and 11, respectively. The x is the positron.

(ii) ${}^{12}_{6}C + {}^{12}_{6}C \rightarrow {}^{20}_{a}Ne + {}^{c}_{b}He$

$\Rightarrow {}^{12}_{6}C + {}^{12}_{6}C \rightarrow {}^{20}_{10}Ne + {}^{4}_{2}He$

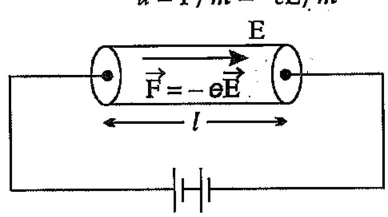
The corresponding values of a, b, c are 10, 2 and 4, respectively.

15. (i) Derive an expression for drift velocity of free electrons.

(ii) How does drift velocity of electrons in a metallic conductor vary with increase in temperature ? Explain. **[3]**

Answer : (i) Consider a conductor in which an electric field E is produced. Let a free electron experience a force ($-e$E) in this electric field. So, the acceleration of free electron is

$$a = F/m = -eE/m \quad ...(i)$$



Here, e = Charge on electron.

m = Mass of an electron.

So, the final velocity of the free electron in time interval t_1 is,

$$v_1 = u_1 + at_1$$

For n free electrons, the final velocities be v_2, $v_3, \ldots, v_n$.

So, the average velocity of the free electrons or the drift velocity

$$v_d = \frac{(v_1 + v_2 + v_3 + \ldots + v_n)}{n}$$

or $$v_d = \frac{(u_1 + at_1 + u_2 + at_2 + \ldots + u_n + at_n)}{n}$$

or $$v_d = \frac{[(u_1 + u_2 + \ldots + u_n) + (at_1 + at_2 + \ldots + at_n)]}{n}$$

or $$v_d = \frac{[(u_1 + u_2 + \ldots + u_n) + a(t_1 + t_2 + \ldots + t_n)]}{n}$$

But, $\frac{(u_1 + u_2 + \ldots + u_n)}{n}$ = average initial velocity of free electrons = 0.

and $\frac{(t_1 + t_2 + \ldots + t_n)}{n}$ = average time taken between two consecutive collision = τ

where τ is relaxation time.

So, $$v_d = a\tau$$

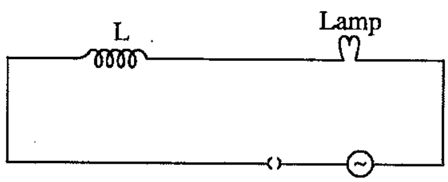
or, $$v_d = \frac{-e\vec{E}}{m}\tau \qquad \text{[from (i)]}$$

This is the required relation.

(ii) The drift velocity of free electrons in a metallic conductor decreases with increase in temperature. because, if we increase the temperature of the metallic conductor the collision between the electrons and ions increases, which decreases relaxation time. Hence, drift velocity decreases.

16. (i) When an AC source is connected to an ideal inductor show that the average power supplied by the source over a complete cycle is zero.

(ii) A lamp is connected in series with an inductor and an AC source. What happens to the brightness of the lamp when the key is plugged in and an iron rod is inserted inside the inductor ? Explain. **[3]**



Answer : (i) The average power supplied by the source over a complete cycle is

$$P_{av} = E_{rms}.I_{rms}.\cos\phi$$

When the circuit contains an ideal inductor, then the phase difference between the current and voltage is $\pi/2$.

So, $\phi = \pi/2$. So, $\cos\phi = \cos\pi/2 = 0$.

Hence $P_{av} = 0$.

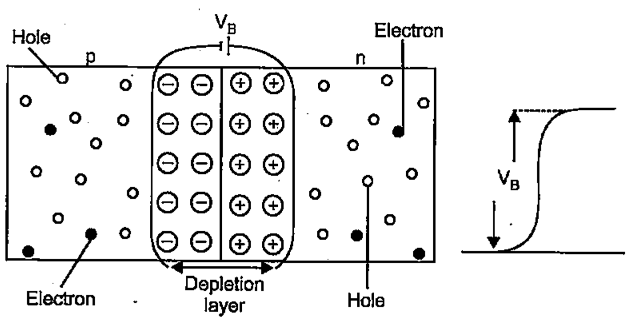
So, when an ac source is connected to an ideal inductor, the average power supplied by the source over a complete cycle is zero.

(ii) The brightness of the lamp will decrease. When the key is plugged in and the iron rod is inserted inside the inductor, it increases the inductance. Hence, the reactance of the inductor ($X_L = \omega L$) increases. So, the impedance of the circuit ($Z = R + j\omega L$) increases, which decreases the current in the circuit.

17. (i) Explain with the help of a diagram the formation of depletion region and barrier potential in a *p-n* junction.

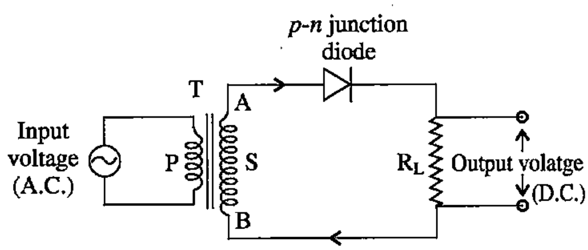
(ii) Draw the circuit diagram of a half wave rectifier and explain its working. **[3]**

Answer : (i) During the formation of p-n junction, the holes diffuse from p-type semiconductor to the n-type, and electrons diffuse from n-type to p-type. This is because of the concentration gradient across p-side and n-side.



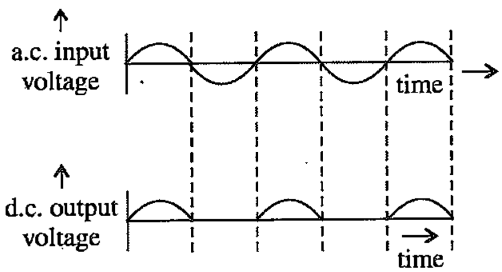
When a hole diffuse from p to n type, it leaves an unmovable negative charge. Similarly, when an electron diffuses from n to p type, it leaves an unmovable positive charge. When the diffusion of holes and electrons takes place continuously across the junction, a layer of unmovable positive and negative charges are developed on either side of the junction. This layer is called the depletion layer or the depletion region and the potential difference across the region is called barrier potential.

(ii) Half wave rectifier :



Working : When an input ac voltage is applied across the primary coil, a potential difference is developed across the ends of the secondary coil. Consider that in half cycle of input ac signal, the end A acts as the +ve end and B acts as the –ve end of the battery. So, the diode is in forward bias and we get output across the ends of the load resistance R_L.

In the second half cycle, ends A and B reverse in polarity. Now, A acts as the –ve end and B acts as the +ve end. So, the diode D is in reverse bias and no output is obtained due to the high resistance offered by the diode.



So, in this process, we get output alternately, and hence the diode is called the half wave rectifier.

18. (i) Which mode of propagation is used by short wave broadcast service having frequency range from a few MHz upto 30 MHz ? Explain diagrammatically how long distance communication can be achieved, by this mode.**

(ii) Why is there an upper limit to frequency of waves used in this mode ?** **[3]**

19. (i) Identify the part of the electromagnetic spectrum which is :

(a) suitable for radar system used in aircraft navigation,

(b) produced by bombarding a metal target by high speed electron.

(ii) Why does a galvanometer show a momentary deflection at the time of charging or discharging a capacitor ? Write the necessary expression to explain this observation. **[3]**

Answer : (i) (a) Microwaves, (b) X-rays

(ii) During the charging and discharging of a capacitor, a flow of charges take place from the battery to the plates of the capacitor. This produces a conduction current in the circuit and a displacement current between plates. Hence the galvanometer shows a momentary deflection.

$$\int B.dl = \mu_0 I + I_d$$

Where $I_d = \dfrac{\varepsilon_0 d\phi_E}{dt}$

20. For a CE-transistor amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. Suppose the current amplification factor of the transistor is 100, find the input signal voltage and base current, if the base resistance is 1 kΩ.** **[3]**

21. Define the term wave front. State Huygen's principle.

Consider a plane wave front incident on a thin convex lens. Draw a proper diagram to show how the incident wave front traverses through the lens and after refraction focusses on the focal point of the lens, giving the shape of the emergent wave front. **[3]**

OR

Explain the following, giving reasons :

(i) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.

(ii) When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave ?

(iii) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light ?

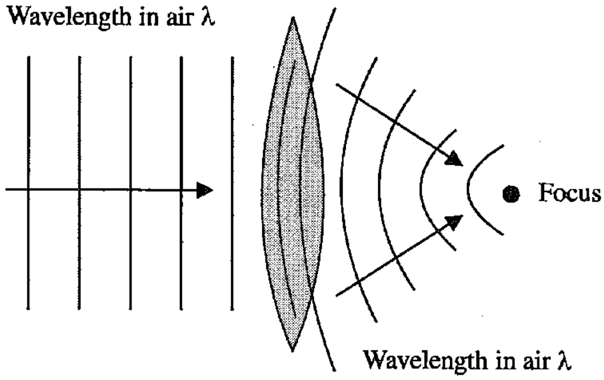
Answer : Wave front : A wave front is the locus of all the points in space that reach a particular distance by a propagating wave in same phase at any instant.

Huygen's principle : It is based on two assumptions :

(a) Each point of the wavefront behaves like a source of secondary disturbances and secondary wavelets from there points spread out in all directions with the same speed as that of the original wave front.

(b) When we draw an envelope in the forward direction of the secondary disturbances at any instant, And this envelope tells the new position of the wavefront at that instant.

**Answers is not given due to change in the present syllabus.



OR

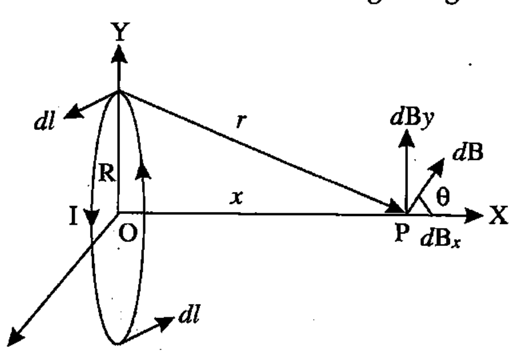
(i) Both the reflection and refraction takes place due to the interaction of light with the atoms at the surface of the separation. Light incident on these atoms, force them to vibrate with the frequency of light. But, the light emitted by these charged atoms is equal to their own frequency of oscillation. So, both the reflected and refracted lights have same frequency. hence frequency remains changed.

(ii) The energy carried by a wave depends on the amplitude of the wave. It does not depend on the speed of the wave propagation. Hence the energy of the wave remains same and does not decrease.

(iii)The intensity of light is determined by the number of photons incident per unit area around the point at which intensity is to be determined.

22. Use Biot-Savart law to derive the expression for the magnetic field on the axis of a current carrying circular loop of radius R.
Draw the magnetic field lines due to a circular wire carrying current I. [3]

Answer : Imagine a circular coil of radius R with centre O. Let the current flowing through the circular loop be I. Suppose P is any point on the axis at a distance of r from the centre O. Let the circular coil be made up of a large number of small elements of current, each having a length of dl.



According to Biot-Savart's law, the magnetic field at Point P will be

$$dB = \frac{\mu_0 I}{4\pi} \times \frac{|dl \times r|}{r^3}$$

where, $r^2 = x^2 + R^2$

$|dl \times r| = rdl$

[∵ Both are perpendicular]

Here, r is the position vector of point O from the current element.

So, $$dB = \frac{\mu_0}{4\pi} \times \frac{I.\,dl}{r^2}$$

$$dB = \frac{\mu_0}{4\pi} \times \frac{I.dl}{(x^2 + R^2)}$$

dB has two components *i.e.*, dB_x and dB_y. dB_y is cancelled out and only the x– component remains.

∴ $$dB_x = dB \cos\theta$$

$$\cos\theta = \frac{R}{\sqrt{x^2 + R^2}}$$

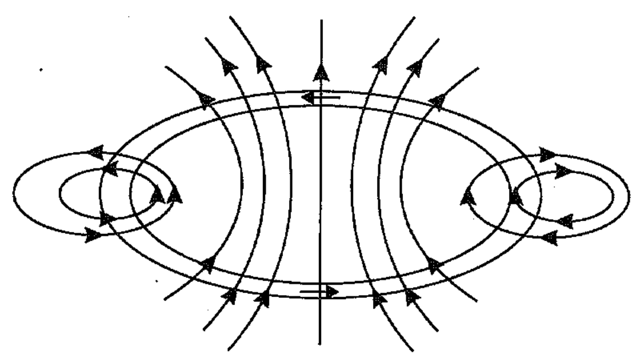
$$dB_x = \frac{\mu_0 Idl}{4\pi} \cdot \frac{R}{(x^2 + R^2)^{3/2}}$$

But, $$\int dl = 2\pi R$$

So, $$B = \frac{\mu_0 IR \times 2\pi R}{4\pi (x^2 + R^2)^{3/2}}$$

For n turns in the circular loop,

$$B = \frac{\mu_0 n I R^2}{2(x^2 + R^2)^{3/2}} \cdot \hat{i}$$



SECTION—D dB_y

23. Ram is a student of class X in a village school. His uncle gifted him a bicycle with a dynamo fitted in it. He was very excited to get it. While cycling during night, he could light the bulb and see the objects on the road. He, however, did not know how this device works. He asked this question to his teacher. The teacher considered it an opportunity to explain the working to the whole class.

Answer the following questions : [4]

(a) State the principle and working of a dynamo.

(b) Write two values each displayed by Ram and his school teacher. **

Answer : (a) A dynamo works on the principle of electro-magnetic induction.

A dynamo includes a coil attached to a small turbine fitted with a plastic cap.

The coil is placed in a magnetic field. When the plastic cap comes in contact with moving tyres of the bicycle, the coil placed between the poles of a magnet rotates, thus, the flux through the coil changes continuously. This induces a current in the coil which is connected to a bulb which lights up.

As long as the bicycle is moving, the coil keeps on rotating, and hence, the flux keeps on changing. At a steady rate, we get a steady current and hence a light of steady intensity is obtained.

SECTION—E

24. (i) Draw a labelled diagram of a step-down trans former. State the principle of its working.

(ii) Express the turns ratio in terms of voltages.

(iii) Find the ratio of primary and secondary currents in terms of turns ratio in an ideal transformer.

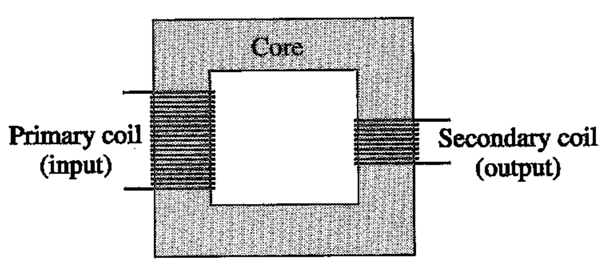
(iv) How much current is drawn by the primary of a transformer connected to 220 V supply when it delivers power to a 110 V— 550 W refrigerator ? [5]

OR

(a) Explain the meaning of the term mutual inductance. Consider two concentric circular coils, one of radius r_1 and the other of radius r_2 ($r_1 < r_2$) placed coaxially with centres coinciding with each other. Obtain the expression for the mutual inductance of the arrangement.

(b) A rectangular coil of area A, having number of turns N is rotated at 'f' revolutions per second in a uniform magnetic field B, the field being perpendicular to the coil. Prove that the maximum emf induced in the coil is $2\pi f$ NBA.

Answer : (i)



**Answers is not given due to change in the present syllabus.

Principle : A transformer works on the principle of mutual induction. Whenever the amount of magnetic flux linked with a coil changes, an emf is induced in the neighbouring coil.

Working : When an alternating current source is connected to the ends of primary coil, the current changes continuously in the primary coil, due to which magnetic flux linked with the secondary coil changes continuously. Therefore, the alternating emf of same frequency is developed across the secondary terminals. According to Faraday's laws the e.m.f. induced in the primary coil,

$$E_P = -N_P \frac{\Delta\phi}{\Delta t} \quad \text{...(i)}$$

and emf induced in the secondary coil

$$E_S = -N_S \frac{\Delta\phi}{\Delta t} \quad \text{...(ii)}$$

From (i) and (ii)

$$\frac{E_S}{E_P} = \frac{N_S}{N_P} = K \quad \text{...(iii)}$$

For step-down transformer, $K < 1$.

$$\therefore \quad E_S < E_P$$

(ii) The induced emf in primary coil,

$$E_P = -N_P\,(d\phi/dt)$$

The induced emf in secondary coil,

$$E_S = -N_S\,(d\phi/dt)$$

$$E_S/E_P = N_S/N_P = K$$

Where K is the turns ratio or the transformation ratio.

(iii) If the transformer is ideal, then

Input electrical power = Output electrical power

$$E_P I_P = E_S I_S$$

$$E_S/E_P = I_P/I_S$$

$$\frac{I_P}{I_S} = \frac{E_S}{E_P} = \frac{N_S}{N_P} = K$$

(iv) Given, Power , $P = 550$ W

Supply voltage, $V_S = 220$ V

$$\text{Power} = V_P I_P$$

$$550 = 220 \times I_P$$

$$\Rightarrow \quad I_P = 5/2 = 2.5 \text{ A}$$

OR

(a) Mutual inductance : It is the property of a pair of coils due to which an e.m.f. is induced in one coil due to the change in the flux or current in the other coil.

Let a current I_2 flow through the outer circular coil. The magnetic field at the centre of the coil is

$$B_2 = \frac{\mu_0 I_2}{2r_2} \quad ...(i)$$

As the inner coil placed co-axially has very small radius, therefore, B_2 may be taken as constant over its cross-sectional area. Hence, flux associated with inner coil is

$$\phi_1 = \pi r_1^2 B_2$$

$$= \pi r_1^2 \frac{\mu_0 I_2}{2r_2} \quad \text{[From (i)]}$$

$$= \left(\frac{\mu_0 \pi r_1^2}{2r_2}\right) I_2$$

$$= M_{12} I_2$$

$$\therefore \quad M_{12} = \frac{\mu_0 \pi r_1^2}{2r_2}$$

Now, $$M_{21} = M_{12} = \frac{\mu_0 \pi r_1^2}{2r_2}$$

(b) Let N be the number of turns of the rectangular coil and A be its cross-sectional area placed in a magnetic field B, then, the magnetic flux linked with the coil,

$$\phi = NBA \cos \theta$$

The induced emf,

$$e = -d\phi/dt$$

$$e = -\frac{d\phi}{dt} = \left(-NBA(-\sin\theta)\frac{d\theta}{dt}\right)$$

$$= NBA.\sin\theta\,(2\pi f) \quad \begin{bmatrix} \because \theta = \omega t \\ \frac{d\theta}{dt} = \omega = 2\pi f \end{bmatrix}$$

For maximum induced e.m.f.

$$\sin\theta = 1$$

$$\therefore \quad e = NBA\,(2\pi f)$$

25. (a) Derive the mathematical relation between refractive indices n_1 and n_2 of two media and radius of curvature R for refraction at a convex spherical surface. Consider the object to be a point since lying on the principle axis in rarer medium of refractive index n_1 and a real image formed in the denser medium of refractive index n_2. Hence, derive Lens Maker's formula.

(b) Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed ? [5]

OR

(a) Draw a labelled ray diagram to obtain the real image formed by an astronomical telescope in normal adjustment position. Define its magnifying power.

(b) You are given three lenses of power 0.5 D, 4 D and 10 D to design a telescope.

(i) Which lenses should be used as objective and eyepiece ? Justify your answer.

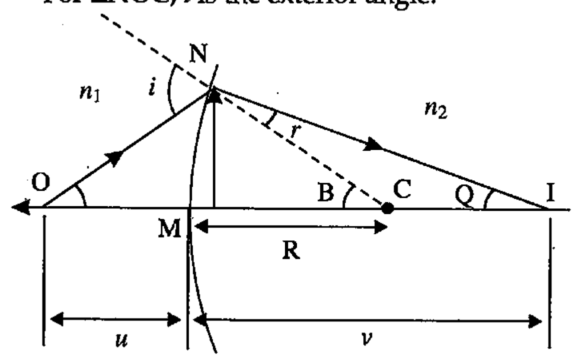
(ii) Why is the aperture of the objective preferred to be large ?

Answer : (a) $\tan \angle NOM = \frac{MN}{OM}$;

$$\tan\angle NCM = \frac{MN}{MC};$$

$$\tan \angle NIM = \frac{MN}{MI}$$

For ΔNOC, i is the exterior angle.



Assuming the incident ray is very close to the principal axis, all the angles are very small. Hence, for very small angles,

$$\tan x = x = \sin x$$

$$\therefore \quad i = \angle NOM + \angle NCM$$

$$i = \frac{MN}{OM} + \frac{MN}{MC} \quad ...(i)$$

Similarly, $r = \angle NCM - \angle NIM$

i.e., $$r = \frac{MN}{MC} - \frac{MN}{MI} \quad ...(ii)$$

By Snell's law,

$$n_1 \sin i = n_2 \sin r$$

For small angles,

$$n_1 i = n_2 r$$

On substituting the values of i and r in equations, we get

$$n_1\left(\frac{MN}{OM}+\frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC}-\frac{MN}{MI}\right)$$

$$\frac{n_1}{OM}+\frac{n_2}{MI} = \frac{n_2-n_1}{MC} \quad ...(iii)$$

On applying new Cartesian sign conventions,

$$OM = -u, MI = +v, MC = +R$$

Substituting these values in equation (iii), we get

$$\frac{n_2}{v}-\frac{n_1}{u} = \frac{n_2-n_1}{R} \quad ...(iv)$$

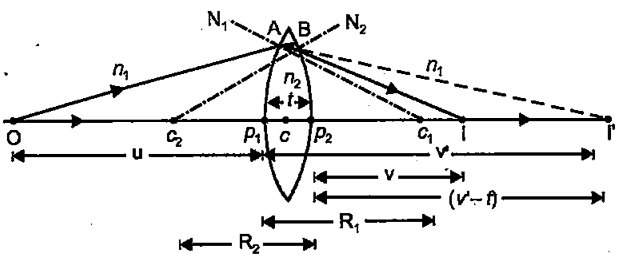
In deriving Lens maker's formula, we adopt the coordinate geometry sign convention and make the assumptions :

(i) The lens is thin so that the distances measured from the poles of its two surfaces can be taken as equal to the distances from its optical centre.

(ii) The aperture of the lens is small.

(iii) The object is a point-object placed on the principal axis of the lens.

(iv) The incident and the refracted rays make small angles with the principal axis.



Refraction at the first surface,

$$\frac{n_2}{v'}-\frac{n_1}{u} = \frac{n_2-n_1}{R_1}$$

Refraction at the second surface,

$$\frac{n_1}{v}-\frac{n_2}{v'-t} = \frac{n_1-n_2}{R_2}$$

The lens is 'thin', hence $t << v'$ and can be ignored. Then, we have

$$\frac{n_1}{v}-\frac{n_2}{v'} = \frac{n_1-n_2}{R_2} \quad ....(ii)$$

Adding equation (i) and (ii), we get

$$\frac{n_1}{v}-\frac{n_1}{u} = (n_2-n_1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Putting $n_2/n_1 = n$, the refractive index of the material of the lens with respect to the surrounding medium, we have

$$\frac{1}{v}-\frac{1}{u} = (n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ....(iii)$$

When the object is at infinity, the image will be formed at the principal focus of the lens, *i.e.*, when $u = \infty$,

$$\frac{1}{f}-\frac{1}{\infty} = (n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

This is the Lens Maker's formula.

(b) Given, refractive index, $n_2 = 1.5$, $n_1 = 1$ (air)

Radius of curvature, R = 20 cm

Object distance, $u = -100$ cm

To find , Image distance, v

$$\frac{n_2}{v}-\frac{n_1}{u} = \frac{n_2-n_1}{R}$$

$$\frac{1.5}{v}+\frac{1}{(100)} = \frac{1.5-1}{20} = \frac{1}{40}$$

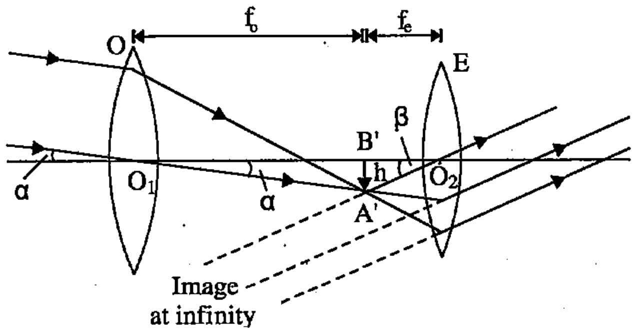
$$\frac{1.5}{v} = \frac{1}{40}-\frac{1}{100} = \frac{5-2}{200} = \frac{3}{200}$$

$$v = \frac{200}{3}\times 1.5 = 100 \text{ cm}$$

The image is formed at 100 cm in denser medium.

OR

(a)



Magnifying power : The magnifying power of a refracting type astronomical telescope is defined as the ratio of angle subtended by the final image at eye to the angle subtended by the object at eye.

(b) (i) We know that,

$$\text{Magnification, } m = \frac{f_o}{f_e} = \frac{P_e}{P_o}$$

Therefore, the lens of 0.5 D should be used as objective and the lens of 10 D should be used as eye-piece in order to achieve higher magnification.

(ii) The aperture of the objective lens is made larger so, that it receives as much light as coming from the distant object and the resolving power of the telescope increases.

26. (i) Use Gauss's law to find the electric field due to a uniformly charged infinite plane sheet. What is the direction of field for positive and negative charge densities ?

(ii) Find the ratio of the potential differences that must be applied across the parallel and series combination of two capacitors C_1 and C_2 with their capacitances in the ratio 1 : 2 so that the energy stored in the two cases becomes the same. [5]

OR

(i) If two similar large plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$ are separated by a distance in air, find the expressions for

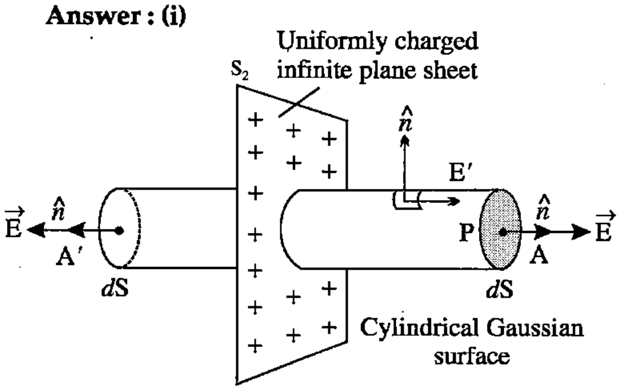
(a) field at points between the two plates and on outer side of the plates. Specify the direction of the field in each case.

(b) the potential difference between the plates.

(c) the capacitance of the capacitor so formed.

(ii) Two metallic spheres of radii R and 2R are charged so that both of these have same surface charge density σ. If they are connected to each other with a conducting wire, in which direction will the charge flow and why ?

Answer : (i)



Consider a thin infinite uniformly charged plane sheet having the surface charge density of σ. The electric field is normally outward to the plane sheet and is same in magnitude but opposite in direction.

Now, draw a Gaussian surface in the form of cylinder around an axis. Let its cross-sectional area be A. The cylinder is made from three surfaces A, S_2, and A′ and the electric flux linked with S_2 is 0. So, the total electric flux linked through the Gaussian surface is

ϕ_E = electric flux through A + electric flux through S_2 + electric flux through A′

$$\phi_E = EA\cos 0^0 + 0 + EA\cos 0^0.$$

$$\phi = 2EA \quad ...(i)$$

According to Gauss theorem,

$$\phi = \frac{q}{\varepsilon_0}$$

$$\phi = \frac{\sigma A}{\varepsilon_0} \quad (\because q = \sigma A)...(ii)$$

From equations (i) and (ii)

$$2EA = \frac{\sigma A}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

The direction of field for positive charge density is in outward direction away from sheet and perpendicular to the plane infinite sheet whereas for the negative charge density the direction becomes inward *i.e.*, tawards the sheet and perpendicular to the sheet.

(ii) Given, $C_1 : C_2 = 1 : 2$

$\Rightarrow \quad C_2 = 2C_1$

For parallel combination of capacitor,

$$C_p = C_1 + C_2$$
$$= C_1 + 2C_1 = 3C_1$$

The energy stored in capacitor

$$E = \frac{1}{2}C_pV_p^2$$
$$= \frac{1}{2}3C_1V_p^2 = \frac{3}{2}C_1V_p^2 \quad ...(i)$$

For series combination of capacitor,

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_s = \frac{2}{3}C_1$$

The energy stored in capacitor

$$E = \frac{1}{2}C_sV_s^2$$

$$E = \frac{C_1V_s^2}{3} \quad ...(ii)$$

Equating equation (i) and (ii), since energy stored in both cases are same

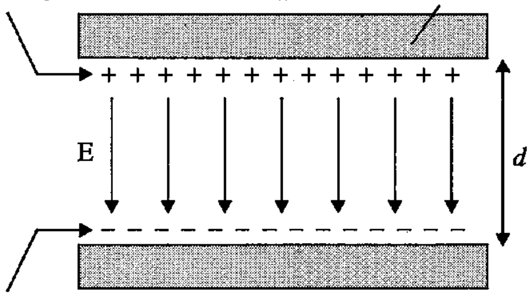
we get,

$$\frac{3}{2}C_1V_p^2 = \frac{C_1V_s^2}{3}$$

$$\frac{V_p}{V_s} = \frac{\sqrt{2}}{3}$$

OR

(i) (a) Consider a parallel plate capacitor with two identical plates X and Y, each having an area of A, and separated by a distance d. Let the space between the plates be filled by a dielectric medium with its dielectric constant as K and σ be the surface charge density on each of the plates.



Surface charge density of plate I

$$\sigma = Q/A$$

and that of plate II is $-\sigma$.

Electric field in outer region I,

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

Electric field in outer region II,

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

In the inner region between plates 1 and 2, the electric fields due to the two charged plates add up. So

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

(b) For uniform electric field, potential difference is simply the electric field multiplied by the distance between the plates, *i.e.*,

$$V = Ed = \frac{1}{\varepsilon_0}\frac{Qd}{A}$$

(c) Now, the capacitance of the parallel plate capacitor,

$$C = \frac{Q}{V} = \frac{Q.\varepsilon_0 A}{Qd} = \frac{\varepsilon_0 A}{d}$$

(ii) We know that the potential difference of the metallic sphere is given by,

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

where r is the radius of the sphere.

Now, the potential of the metallic sphere of radius R is given by,

$$V_R = \frac{Q}{4\pi\varepsilon_0 r}$$

$$V_R = \frac{\sigma(4\pi R^2)}{4\pi\varepsilon_0 R}$$

$$V_R = \frac{\sigma R}{\varepsilon_0} \qquad \text{...(i)}$$

Similarly, the potential of the metallic sphere of radius V_{2R} is given by

$$V_{2R} = \frac{Q}{4\pi\varepsilon_0 2R}$$

$$V_{2R} = \frac{\sigma(4\pi(2R)^2)}{4\pi\varepsilon_0 2R}$$

$$V_{2R} = \frac{\sigma 2R}{\varepsilon_0} \qquad \text{...(ii)}$$

From the relation (i) and (ii) we know that $V_{2R} > V_R$.

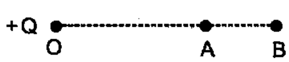
The charge will flow from the sphere of radius of 2R to the sphere of radius R, if the spheres are connected.

Physics 2016 (Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

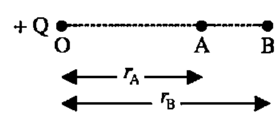
SECTION – A

1. A point charge +Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero? [1]



Answer : Potential at a distance r from a given point charge Q is given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$



$$V_A = \frac{1}{4\pi\varepsilon_0 r_A}$$

$$V_B = \frac{Q}{4\pi\varepsilon_0 r_B}$$

Since $r_A < r_B$

$\Rightarrow$ $V_A > V_B$

Hence, $V_A - V_B$ is positive.

2. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased ? [1]

Answer : According to Gauss's law

$$\phi = \int \vec{E}.\vec{ds} = \frac{q_{en}}{\varepsilon_0}$$

Flux depends only on the charge enclosed and not on the radius.

Hence, the electric flux remains constant.

3. Write the underlying principle of a moving coil galvanometer. [1]

Answer : When a current carrying coil is placed in magnetic field then it experiences a torque.

$$NIAB = k\alpha$$

$$\Rightarrow \quad I = \frac{k}{NAB}\alpha$$

where N = The number of turns.

I = Current.

A = Area of the loop.

B = Magnetic field.

k = Torsional constant of the wire

α = Angle of deflection

4. Why are microwaves considered suitable for radar systems used in aircraft navigation ? [1]

Answer : Microwaves are considered suitable because they have a short wavelenght range they are suitable for radar system used in aircraft navigation.

5. Define 'quality factor' of resonance in series LCR circuit. What is its SI unit ? [1]

Answer : The Q factor of series resonance circuit is defined as the ratio of the voltage developed across the inductor or capacitor at resonance to the impressed voltage, which is the voltage across R.

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

It is dimensionless quantity. Hence, it has no units.

SECTION–B

6. Explain the terms (i) Attenuation and (ii) Demodulation used in Communication System. [2]

Answer : (i) Attenuation : The loss of strength of a signal while propagating through a medium is known as attenuation.

(ii) Demodulation : The process of retrieval of information from the carrier wave at the receiver end is termed as demodulation. This is the reverse process of modulation.

7. Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1, m_2 ($m_1 > m_2$). Which one of the two represents a particle of smaller mass and why ? [2]

Answer : We know that,

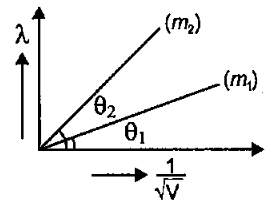
$$qV = \frac{1}{2}mv^2$$

$$qV = \frac{p^2}{2m}$$

$$\Rightarrow \quad p = \sqrt{2mqV}$$

$$= \frac{h}{\lambda}$$

$$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2mqV}}$$



$$\Rightarrow \quad \text{Slope} \propto \frac{1}{\sqrt{m}}$$

Hence, the particle with lower mass (m_2) will have greater slope.

8. A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks into two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the released energy. [2]

OR

Calculate the energy in fusion reaction :

${}^2_1H + {}^2_1H \longrightarrow {}^3_2He + n$, where BE of ${}^2_1H$ = 2.23 MeV and of ${}^3_2He$ = 7.73 MeV.

Answer : Binding energy of the nucleus,

$$B_1 = 7.6 \times 240 = 1824 \text{ MeV.}$$

Binding energy of each product nucleus,

$$B_2 = 8.5 \times 120 = 1020 \text{ MeV}$$

Then, energy released as the nucleus breaks,

$E = 2 B_2 - B_1 = 2 \times 1020 - 1824 = 216$ MeV.

OR

${}^2_1H + {}^2_1H \longrightarrow {}^3_2He + n$, where BE of ${}^2_1H$ = 2.23 MeV and of ${}^3_2He$ = 7.73 MeV.

The energy released in the fusion reaction is

$$\Delta E = (7.73) - 2\,(2.23)$$

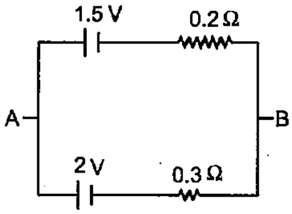
$$= 7.73 - 4.46$$

$$= 3.27 \text{ MeV}$$

9. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. [2]

Answer : Given, $E_1 = 1.5\text{ V}, r_1 = 0.2\ \Omega,$

$$E_2 = 2\text{ V}, r_2 = 0.3\ \Omega$$



Equivalent emf, $$E = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$$

$$= \frac{(1.5 \times 0.3) + (2 \times 0.2)}{0.2 + 0.3}$$

$$= \frac{0.45 + 0.4}{0.5}$$

$$= \frac{0.85}{0.5} = 1.7 \text{ volt}$$

Equivalent internal resistance

$$= \frac{r_1 r_2}{r_1 + r_2}$$

$$= \frac{0.2 \times 0.3}{0.2 + 0.3}$$

$$= \frac{0.06}{0.5}$$

$$r_{eq} = 0.12\ \Omega$$

10. State Brewster's law.

The value of Brewster angle for a transparent medium is different for light of different colours. Give reason. [2]

Answer : Brewster's law : The law states that the tangent of the polarising angle of incidence for a given medium is equal to the refractive index of the medium. The light incident at this angle when reflects back is perfectly polarised.

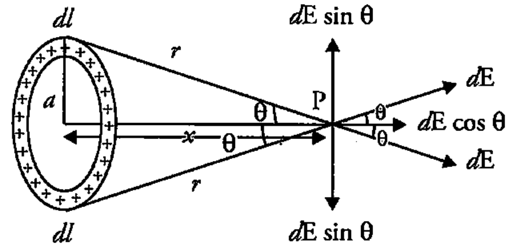
i.e. $$\mu = \tan i_p$$

The refractive index of a material depends on the colour or wavelength of light. As the polarising angle depends on refractive index ($\mu = \tan i_p$), so it also depends on wavelength of light.

SECTION–C

11. A charge is distributed uniformly over a ring of radius 'a'. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge. [3]

Answer : Suppose we have a ring of radius a that carries a uniformly distributed positive charge q.



As the total charge q is uniformly distributed, the charge dq on the element dl is

$$dq = \frac{q}{2\pi a} \cdot dl$$

∴ The magnitude of the electric field produced by the element dl at the axial point P is

$$dE = k \cdot \frac{dq}{r^2} = \frac{kq}{2\pi a} \cdot \frac{dl}{r^2}$$

The electric field dE has two components.

(i) The axial components $dE \cos\theta$ and

(ii) The perpendicular component $dE \sin\theta$.

Since the perpendicular component of any two diametrically opposite elements are equal and opposite, they cancel out in pairs. Only the axial components will add up to produce the resultant field.

E at point P is given by

$$E = \int_0^{2\pi a} dE \cos\theta$$

[∵ Only the axial components contribute towards E]

$$E = \int_0^{2\pi a} \frac{kq}{2\pi a} \cdot \frac{dl}{r^2} \cdot \frac{x}{r} \quad \left[\because \cos\theta = \frac{x}{r}\right]$$

$$= \frac{kqx}{2\pi a} \cdot \frac{1}{r^3} \int_0^{2\pi a} dl$$

$$= \frac{kqx}{2\pi a} \cdot \frac{1}{r^3} (l)_0^{2\pi a}$$

$$= \frac{kqx}{2\pi a} \cdot \frac{1}{(x^2 + a^2)^{3/2}} \cdot 2\pi a$$

$[\because r^2 = x^2 + a^2]$

$$E = \frac{kqx}{(x^2 + a^2)^{3/2}}$$

$\left[\text{where } k = \frac{1}{4\pi\varepsilon_0}\ \ a = \text{constant}\right]$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{qx}{(x^2 + a^2)^{3/2}}$$

If $x >> a$, then $x^2 + a^2 \approx x^2$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{qx}{(x^2)^{3/2}}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$$

This expression is similar to electric field due to a point charge.

12. Write three characteristic features in photo-electric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation. [3]

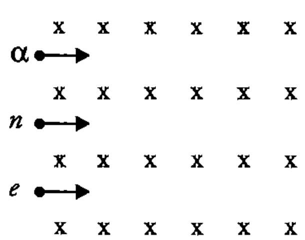
Answer : (i) Existence of threshold frequency : According to wave theory, there should not exist any threshold frequency but Einstein's theory explains the existence of threshold frequency.

(ii) Dependence of kinetic energy on frequency of incident light : According to wave theory, the maximum kinetic energy of emitted electrons should depend on intensity of incident light and not on frequency whereas Einstein's equation explains that it dependence on frequency and not on intensity of the incident light.

(iii) Instantaneous emission of electrons : According to wave theory there should be time lag between emission of electrons and incident of light whereas Einstein's equation explains why there is no time lag between incident of light and emission of electrons.

13. (a) Write the expression for the magnetic force acting on a charged particle moving with velocity v in the presence of magnetic field B.

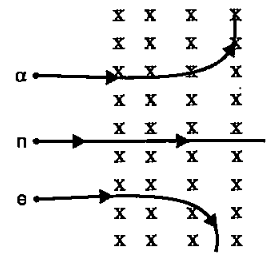
(b) A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going into the plane of the paper as shown. Trace their paths in the field and justify your answer. [3]



Answer : (a) A charge particle having charge q is moving with velocity 'v' in a magnetic field of field strength 'B' then the force acting on it is given by the formula $F = q(\vec{v} \times \vec{B})$ and $F = qvB \sin\theta$ (where θ is the angle between velocity vector and magnetic field).

Direction of force is given by the cross product of velocity and magnetic field.

(b)



α particle will trace circular path in anticlockwise direction as it's deviation will be in the direction of $(\vec{v} \times \vec{B})$.

Neutron will pass without any deviation as magnetic field does not exert and force on neutral particle.

Electron will trace circular path in clockwise direction as its deviation will be in the direction opposite to $(\vec{v} \times \vec{B})$ with a smaller radius due to large charge/mass ratio as $r = \frac{mv}{qB}$.

14. (a) Define mutual inductance.

(b) A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil ? [3]

Answer : (a) Mutual induction is the phenomenon of production of induced emf in one coil due to change of current or flux in the neighbouring coil. The coil in which the current changes is called primary coil and the coil in which emf is induced is called the secondary coil.

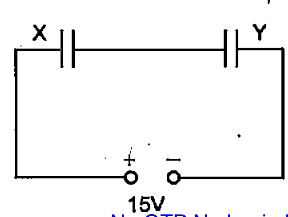
(b)

$$M = 1.5\text{ H}$$
$$I_i = 0\text{ A}$$
$$I_f = 20\text{ A}$$
$$dI = 20\text{ A}, \quad \Delta t = 0.5\text{ s}$$
$$e = \frac{-M dI}{dt} = -1.5 \times \frac{20}{0.5} = -60\text{ V}$$

So the flux linked with the other coil is given by

$$\Delta\phi = -e\Delta t = 60 \times 0.5 = 30\text{ Wb.}$$

15. Two parallel plate capacitors X and Y have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric medium of $\varepsilon_r = 4$. [3]



(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.

(ii) Calculate the potential difference between the plates of X and Y.

(iii) Estimate the ratio of electrostatic energy stored in X and Y.

Answer : (i) Let capacitance of X be C_1 and capacitance of Y be C_2.

$$C_1 = \frac{\varepsilon_0 A}{d}$$

$$C_2 = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

Taking the ratio of C_1 and C_2

$$\frac{C_1}{C_2} = \frac{1}{\varepsilon_r}$$

$\Rightarrow \quad C_2 = \varepsilon_r C_1$

Let $\quad C_1 = C$

Then $\quad C_2 = 4C \quad \{\because \varepsilon_r = 4\}$

Since two capacitance are connected in series so, equivalent capacitance will be

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$4\,\mu F = \frac{C \times 4C}{C + 4C}$$

$\Rightarrow \quad C = 5\,\mu F$

So, $\quad C_1 = 5\,\mu$ F and $C_2 = 20\,\mu F$

(ii) $\quad C_{eq} V_{net} = Q_{Total}$

$4\mu F \times 15V = Q_{Total}$

$Q_{Total} = 60\,\mu C$

Since in series configuration charge on each capacitor is equal.

Hence, $\quad Q_1 = Q_2 = Q_{Total}$

$= 60\,\mu C$

Using, $\quad Q = CV$

$$V_1 = \frac{Q_1}{C_1} = \frac{60\,\mu C}{5\,\mu F} = 12\,V$$

$$V_2 = \frac{Q_2}{C_2} = \frac{60\,\mu C}{20\,\mu F} = 3\,V$$

(iii) $$U_1 = \frac{1}{2}\frac{Q_1^2}{C_1} = \frac{1}{2}\frac{(60\,\mu C)^2}{5\,\mu F} = 360\,\mu J$$

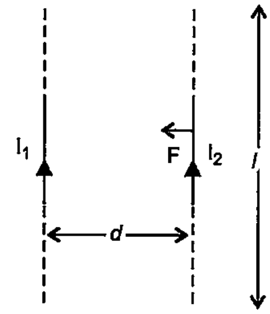
$$U_2 = \frac{1}{2}\frac{Q_2^2}{C_2} = \frac{1}{2}\frac{(60\,\mu C)^2}{20\,\mu F} = 90\,\mu J$$

$$\Rightarrow \quad \frac{U_1}{U_2} = \frac{4}{1}$$

$\Rightarrow \quad U_1 : U_2 = 4:1$

16. Two long straight parallel conductors carry steady current I_1 and I_2 separated by a distance d. If the currents are flowing in the same direction, show how the magnetic field set up if one produces an attractive force on the other. Obtain the expression for this force. Hence define one ampere. **[3]**

Answer : Magnetic field produced on the wire (carrying current I_2) due to I_1 will be



$$B = \frac{\mu_0 I_1}{2\pi d}$$

Force acting at l length is

$$F = I_2 l B$$

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d} \text{ towards } I_1$$

If $l = 1$ m, $d = 1$m, $I_1 = I_2 = I$ and $F = 2 \times 10^{-7}$ N

$\Rightarrow \quad I = 1$ A

So one ampere is defined as the current, which when maintained in two parallel infinite length conductors, held at a separation of one metre will produce a force of 2×10^{-7} N per metre on each conductor.

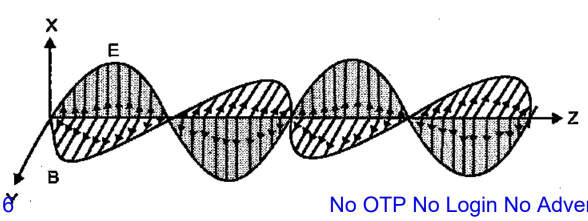
17. How are e.m. waves produced by oscillating charges ?

Draw a sketch of linearly polarized e.m. waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields. **[3]**

OR

Write Maxwell's generalization of Ampere's circuital law. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is $i = \varepsilon_0 \frac{d\phi_E}{dt}$ where ϕ_E is the electric flux produced during charging of the capacitor plates.

Answer : A charge oscillating with some frequency, produces an oscillating electric field in space, which in turn produces an oscillating magnetic field perpendicular to the electric field. This process goes on repeating, producing e.m. waves in space perpendicular to both the fields.



The direction of electric and magnetic fields are perpendicular to each other and are also perpendicular to the direction of propagation of the wave.

OR

Correction in Ampere's circuital law (Modified Ampere's law) : Maxwell removed the problem of current continuity and inconsistency observed in Ampere's circuital law by introducing the concept of displacement current. Displacement current arises due to change in electric flux with time and is given by $i_d = \varepsilon_0 \frac{d\phi_E}{dt}$

Electric flux through the loop[4]

$$\phi_E = EA$$

$$= \frac{\sigma}{\varepsilon_0} A = \frac{Q}{A}\frac{A}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

(where, Q = charge on either plates)

$$\phi_E = \frac{Q}{\varepsilon_0}$$

$$\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dQ}{dt}$$

$$\varepsilon_0 \frac{d\phi_E}{dt} = \frac{dQ}{dt}$$

$\frac{dQ}{dt}$ is called conduction current which is equal to $\varepsilon_0 \frac{d\phi_E}{dt}$ which is displacement current.

Hence, $i_c = i_d$

Generalization of Ampere's circuital law is :

$$\oint \vec{B}.\vec{dl} = \mu_0 (i_c + i_d)$$

Conduction current is due to the flow of charges but displacement current is not because of the flow of charges but it is due to the change in electric flux.

18. (a) Explain any two factors which justify the need of modulating a low frequency signal.

(b) Write two advantages of frequency modulation over amplitude modulation. [3]

Answer : (a) 1. Size of Antenna : The size of antenna required will be of order of $\lambda/4$. When frequency is small, the height of antenna should be large. So audio frequency signal should be modulated over a high frequency carrier wave to increase its frequency.

2. Effective power radiated by an Antenna : As power radiated $\propto \frac{1}{\lambda^2}$, hence when frequency is increased then the power radiated will be more.

(b) Advantages of frequency modulation over amplitude modulation :

1. Noise can be reduced.

2. Transmission efficiency is more because the amplitude of an FM wave is constant.

19. (a) Write the functions of three segments of a transistor.**

(b) Draw the circuit diagram for studying the input and output characteristics of *n-p-n* transistor in common emitter configuration. Using the circuit, explain how input, output characteristics are obtained. [3]**

20. (a) Calculate the distance of an object of height *h* from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also.

(b) Using mirror formula, explain why does a convex mirror always produce a virtual image. [3]

Answer : (a) Given, Height of object = h

Radius of curvature = – 20 cm

Magnification, $m = -2$

Object distance, u = ?

Image distance, v = ?

$$\text{Magnification, } M = \frac{-v}{u} = \frac{h_i}{h_o}$$

$$-2 = -\frac{v}{u}$$

$$v = 2u \quad \text{...(i)}$$

Using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{2u} + \frac{1}{u} = \frac{-2}{20}$$

$$\frac{+3}{2u} = \frac{-2}{20}$$

$$u = -\frac{60}{4} = -15 \text{ cm}$$

Putting in (i), we get

$$v = 2 \times -15 \text{ cm}$$
$$= -30 \text{ cm}$$

$$\frac{h_i}{h_o} = \left|\frac{v}{u}\right|$$

$$\frac{h_i}{h} = \left|\frac{2u}{u}\right|$$

Height of image, $h_i = 2h$ when object is placed at 15 cm from the mirro.

(b) For convex mirror,

$$f = +\text{ve (always)}$$

Mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

**Answers is not given due to change in the present syllabus.

$$\frac{1}{v} = \frac{1}{f} \quad \frac{1}{u}$$

As, $\quad u = -ve$ (for real object)

$$\frac{1}{v} = \frac{1}{f}\left(\frac{1}{-u}\right)$$

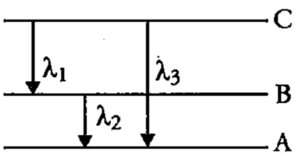
$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$v = +ve$$

Hence, it will form virtual and erect image.

21. (a) State Bohr's quantization condition for defining stationary orbits. How does de-Broglie hypothesis explain the stationary orbits ?

(b) Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below. [3]



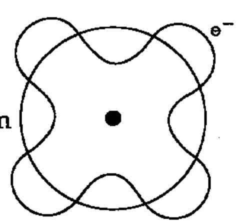
Answer : (a) Quantization condition : Of all possible circular orbits allowed by the classical theory, the electrons are permitted to circulate only in those orbits in which the angular momentum of an electron is an integral multiple of $\frac{h}{2\pi}$; h being Planck's constant.

Therefore, for any permitted orbit,

$$L = mvr = \frac{nh}{2\pi};\ n = 1, 2, 3, \ldots\ldots$$

Where L, m, and v are the angular momentum, mass and speed of the electron respectively, r is the radius of the permitted orbit and n is positive integer called principle quantum number.

The above equation is Bohr's famous quantum condition. When an electron of mass m is confined to move in a line of length l with velocity v, the de-Broglie wavelength λ associated with electron is :



$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

or $\quad p =$ Linear momentum

$$\Rightarrow \quad p = \frac{h}{\lambda} = \frac{h}{2l/n} = \frac{nh}{2l}$$

When electron revolves in a circular orbit of radius 'r' then $2l = 2\pi r$.

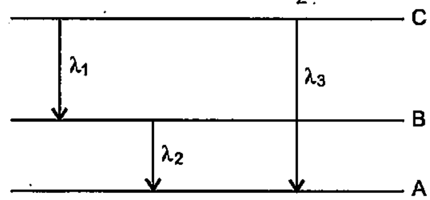
$$\therefore \quad p = \frac{nh}{2\pi r} \text{ or } p \times r = \frac{nh}{2\neq}$$

or angular momentum $\left|\vec{L}\right| = p \times r$ is an integral multiple of $h/2\pi$, which is Bohr's quantisation of angular momentum.

(b)

$$E_{CB} = \frac{hc}{\lambda_1}$$

$$E_{BA} = \frac{hc}{\lambda_2}$$



$$E_{CA} = \frac{hc}{\lambda_3}$$

Now, $\quad E_{CA} = E_{CB} + E_{BA}$

where E_{CB} = Energy gap between level B and C,
E_{BA} = Energy gap between level A and B,
E_{CA} = Energy gap between level A and C.

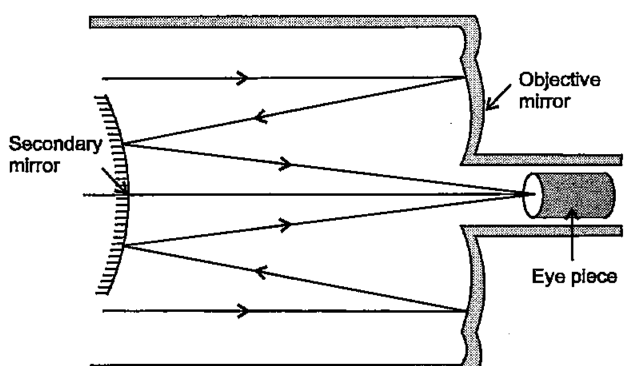
$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_2 + \lambda_1}$$

22. Draw a schematic ray diagram of reflecting telescope showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope. [3]

Answer : Reflecting Telescope : The reflecting telescope make use of a concave mirror as objective. The rays of light coming from distant object are incident on the objective (parabolic reflector). After reflection the rays of light meet at a point where another convex mirror is placed. This mirror focusses light inside the telescope tube. The final image is seen through the eye-piece. The images produced by the reflecting telescope is very bright and its resolving power is high.



Advantages :

(i) The resolving power (the ability to observe two object distinctly) is high, due to the large diameter of the objective.

(ii) There is no chromatic aberration as the object is a mirror.

SECTION – D

23. Meeta's father was driving her to the school. At the traffic signal she noticed that each traffic light was made of many tiny lights instead of a single bulb. When Meeta asked this question to her father, he explained the reason for this.

Answer the following questions based on above information:

(i) What were the values displayed by Meeta and her father?**

(ii) What answer did Meeta's father give ?

(iii) What are the tiny lights in traffic signals called and how do these operate ? [4]

Answer :

(ii) Meeta's father said that these are LED light which consume less power and have high reliability.

(iii) The tiny lights in traffic signals are Light Emitting Diode. These are operated by connecting the *p-n* junction diode in forward biased condition.

SECTION–E

24. (a) An a.c. source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L, C and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when current will be in phase with the voltage. What is the circuit in this condition called ?

(b) In a series LR circuit $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Calculate P_1/P_2. [5]

OR

(a) Write the function of a transformer. State its principle of working with the help of a diagram. Mention various energy losses in this device.

(b) The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculate :

(i) number of turns in secondary.

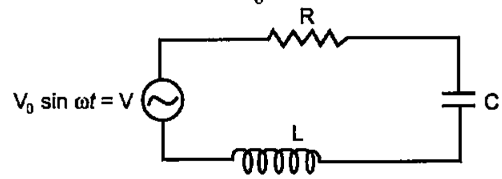
(ii) current in primary.

(iii) voltage across secondary.

(iv) current in secondary.

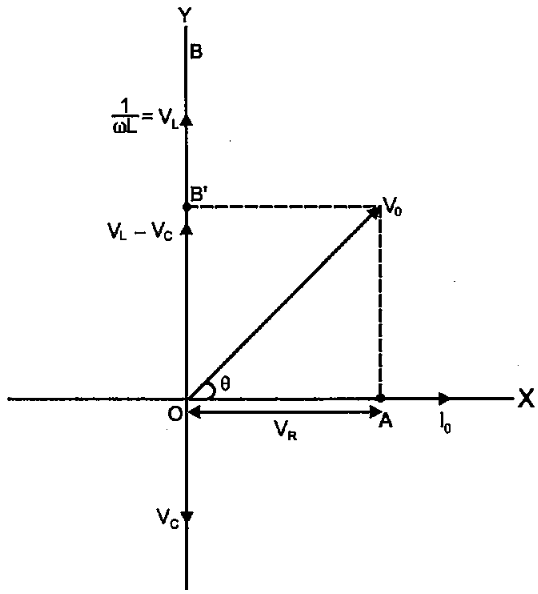
(v) power in secondary.

Answer : (a) Let a series LCR circuit is connected to an a.c. source V (Fig). We take the voltage of the source to be $V = V_0 \sin \omega t$



The a.c. current in each element is the same at any time, having the same amplitude and phase. It is given by,

$$I = I_0 \sin(\omega t + \phi)$$



Phasor diagram for LCR circuit

Let V_L, V_R, V_C and V represent the voltage across the inductor, resistor, capacitor and the source respectively. But $V_L = I_0X_L$, $V_R = I_0R$ and $V_c = I_0X_c$

Let $\quad V_L > V_C$

$\therefore \quad V_0^2 = V_R^2 + (V_L - V_C)^2$

$V_0^2 = (I_0R)^2 + (I_0X_L - I_0X_C)^2$

$V_0^2 = I_0^2\left[R^2 + (X_L - Xc)^2\right]$

and $\quad I_0 = \dfrac{V_0}{\sqrt{R^2 + (X_L - X_C)^2}}$

$\Rightarrow \quad I_0 = \dfrac{V_0}{Z}$

Where $\quad Z = \sqrt{R^2 + (X_L - X_C)^2}$

It is called the impedance in an a. c. circuit.

From the figure,

$$\tan\phi = \frac{V_L - V_C}{V_R}$$

**Answers is not given due to change in the present syllabus.

$$= \frac{I_0 X_L - I_0 X_C}{I_0 R}$$

$$\tan \phi = \frac{X_L - X_C}{R}$$

$$\Rightarrow \qquad \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Condition : The current will be in phase with the voltage at resonance condition.
At resonance condition,

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$2\pi f = \frac{1}{\sqrt{LC}}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

(b) As $\cos \phi = \dfrac{R}{Z}$

In LR circuit, $P_1 = \cos \phi$

$$P_1 = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{2R^2}} \qquad [X_L = R]$$

$$P_1 = \frac{1}{\sqrt{2}}$$

In LCR circuit when, $X_L = X_C$

$$P_2 = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$= \frac{R}{R} = 1 \qquad [X_L = X_C]$$

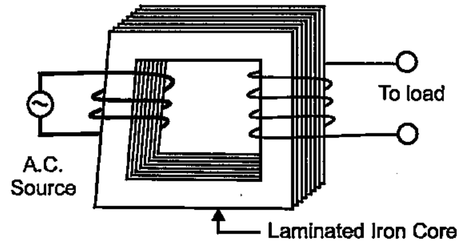
$$\therefore \qquad \frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

OR

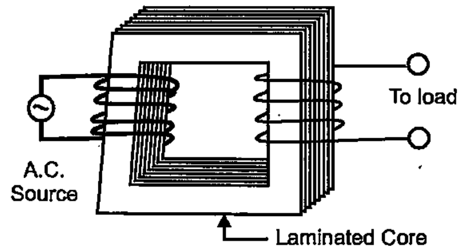
(a) A transformer is an electrical device for converting an alternating current at low voltage into high voltage or vice-versa.

1. If it increases the input a.c. voltage and decreases the, it is called step up tranformer.
2. If it decreases the input a.c. voltage and in ccreases the current, it is called step down transformer.

Principle : It works on the principle of mutual induction *i.e.*, when a changing current or flux is passed through one of the two inductively coupled coils, an induced emf is set up in the other coil.



Step-up transformer



Step-up transformer

Working Theory : As the a.c. flows through the primary, it generate an alternating magnetic flux in the core which passes through the secondary coil.

Let N_1 = No. of turns in primary coils
N_2 = No. of turns in secondary coils

This changing flux set up an induced emf in the secondary, also a self induced emf in the primary.

If there is no leakage of magnetic flux, then flux linked with each turn of the primary will be equal to that linked with each of the secondary. According to Faraday's law of induction

Induced emf in the primary coil, $\varepsilon_1 = -N_1 \dfrac{d\phi}{dt}$

Induced emf in the secondary coil, $e_2 = -N_2 \dfrac{d\phi}{dt}$

where, $\dfrac{d\phi}{dt}$ = Rate of change of magnetic flux associated with each turn.

ϕ = Magnetic flux linked with each turn of the primary or secondary at any instant.

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{N_2}{N_1}$$

Energy losses in transformer :

1. **Copper loss :** Some energy is lost due to the heating of copper wires used in the primary and secondary windings. This power loss ($P = I^2R$) can be minimised by using thick copper wires of low resistance.
2. **Eddy current loss or Iron loss :** The alternating magnetic flux induces eddy current in the iron core which leads to some energy loss in

the form of heat. This loss can be reduced by using laminated iron core.

3. **Hysteresis loss** : When the iron core is subjected to a cycle of magnetisation the core gets heated up due to hysteresis, having low hysteresis loop.
4. **Flux leakage** : The magnetic flux produced by the primary may not fully pass through the secondary. Some of the flux may leak into air. This loss can be minimised by winding the primary and secondary coils over one another.

(b) Given,

$$N_1 = 100$$
$$K = 100$$
$$V_1 = 220\text{ V}$$
$$P_1 = 1100\text{ W}$$

(i) As, $K = \dfrac{N_2}{N_1}$

$$N_2 = KN_1 = 100 \times 100$$
$$N_2 = 10000$$

(ii) $P_1 = V_1 I_1$

$$I_1 = \frac{P_1}{V_1} = \frac{1100}{220} = 5\text{ A}$$

(iii) $\dfrac{V_2}{V_1} = K$

$$V_2 = KV_1;\ V_2 = 100 \times 220$$
$$V_2 = 22000\text{ V}$$

(iv) $\dfrac{I_1}{I_2} = K$

$$I_2 = \frac{I_1}{K} = \frac{5}{100}$$
$$I_2 = 0.05\text{ A}$$

(v) $P_2 = V_2 I_2$

$$P_2 = 22000 \times \frac{5}{100};\ P_2 = 1100\text{ W}$$

25. **(a) In Young's double slit experiment, deduce the condition for (i) constructive, and (ii) destructive interference at a point on the screen. Draw a graph showing variation of intensity in the interference pattern against position 'x' on the screen.**

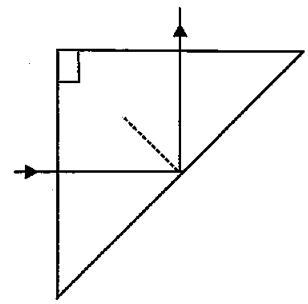
(b) Compare the interference pattern observed in Young's double slit experiment with single slit diffraction pattern, pointing out three distinguishing features. [5]

OR

(a) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism.

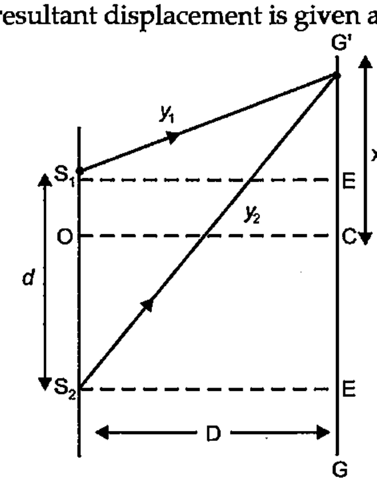
(b) What is dispersion of light ? What is its cause ?

(c) A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in fig. What must be the minimum value of refractive index of glass? Give relevant calculations.



Answer : (a) Let the two waves arising from the slits A and B have the amplitudes a and b and the phase difference ϕ. Such that $y_1 = a \sin \omega t$ and $y_2 = b \sin (\omega t + \phi)$.

The resultant displacement is given as :



$$y = y_1 + y_2$$
$$y = a \sin \omega t + b \sin (\omega t + \phi)$$
$$y = a \sin \omega t + b \sin \omega t \cos \phi + b \cos \omega t \sin \phi$$
$$y = (a + b \cos \phi) \sin \omega t + b \sin \phi \cos \omega t \quad \text{...(i)}$$

Let $a + b \cos \phi = A \cos \delta$ ...(ii)

and $b \sin \phi = A \sin \delta$ ...(iii)

Hence, $y = A \sin \omega t \cos \delta + A \cos \omega t \sin \delta$

$$y = A \sin (\omega t + \delta) \quad \text{...(iv)}$$

Where the amplitude A of the resultant wave can be given as:

$$A = \sqrt{a^2 + b^2 + 2ab\cos\phi} \quad ...(v)$$

and $$\tan\delta = \frac{b\sin\phi}{a + b\cos\phi} \quad ...(vi)$$

(i) **Constructive interference** : Intensity $I \propto A^2$ and for A to be maximum

$$\cos\phi = 1$$

or $$\cos\phi = \cos 2n\pi, n = 0, 1, 2, 3, ...$$

$$\phi = 2n\pi \quad ...(i)$$

and path difference

$$\Delta x = n\lambda \quad ...(ii)$$

$$A_{max} = a + b$$

$$I \rightarrow I_{max} = k(a+b)^2$$

(ii) **Destructive interference** : For I to be minimum

$$\cos\phi = -1$$

Phase difference :

$$\Delta\phi = (2n+1)\pi$$

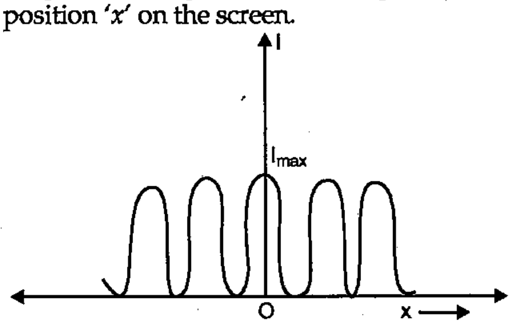
and path difference :

$$\Delta x = (2n+1)\frac{\lambda}{2}$$

$$A_{min} = a - b$$

$$I \rightarrow I_{min} = k(a-b)^2$$

Graph showing interference pattern against position '*x*' on the screen.

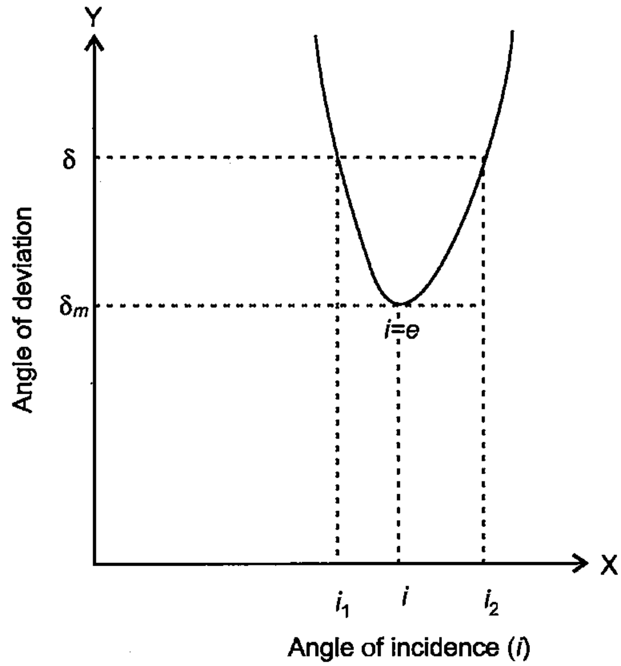


(b) Comparison of interference pattern observed in Young's double slits and the single slit diffraction :

S. No.	Interference	Diffraction
1.	Interference is the result of superposition of secon dary waves starting from two different wave fronts originating from two coherent sources.	Diffraction is the result of superposition of secondary waves starting from different part of same wavefront.
2.	All bright and dark fringes are of equal width.	Th e width of central bright fringe is twice the width of any secondary maximum.
3.	All bright fringes are of same intensity	Intensity of bright fringes decreases as we move away from central bright fringes on either side.

OR

(a)



From figure, $\delta = \delta_m$, $i = e$ which implies $r_1 = r_2$

$$2r = A, \text{ or } r = A/2$$

Using $$\delta = i + e - A$$

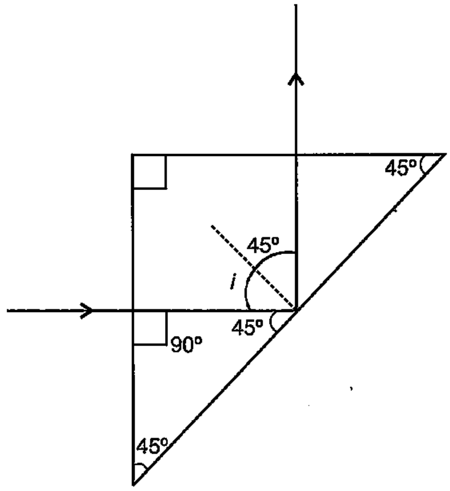
$$\delta_m = 2i - A$$

$$i = \frac{A + \delta_m}{2}$$

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$$

(b) **Dispersion of light** : Dispersion is often observed as light passes through a triangular prism. Upon passing through the prism, the white light is separated into its component colours : red, orange, yellow, green, blue, and voilet. The separation of visible light into its different colours is known as dispersion. Dispersion occurs because for different colour of light a transparent medium will have different refractive indices (μ). as defferent colours have different speed in transparent mdeium

(c) For total internal reflection :



$$i \geq Q_c$$
$$\sin i \geq \sin Q_c$$
$$\sin 45° \geq \frac{1}{\mu}$$
$$\frac{1}{\sqrt{2}} \geq \frac{1}{\mu}$$
$$\mu \geq \sqrt{2}$$
$$\mu_{min} = \sqrt{2}$$

26. (a) Define the term drift velocity.

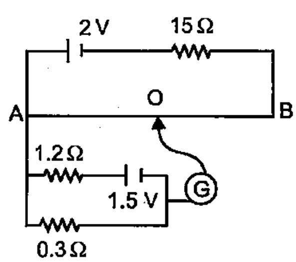
(b) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend ?

(c) Why alloys like constantan and manganin are used for making standard resistors ? [5]

OR

(a) State the principle of working of a potentiometer.

(b) In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the potential gradient along the wire and balance length AO (= l).



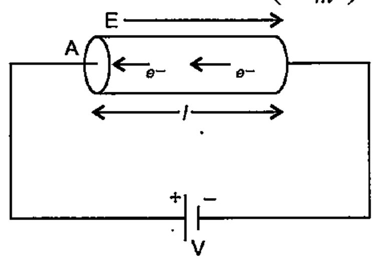
Answer : (a) Drift velocity is defined as the average velocity with which the free electrons are drifted towards the positive terminal under the effect of applied electric field. Thermal velocities are randomly distributed and average thermal velocity is zero.

$$\frac{\vec{u_1} + \vec{u_2} + \dots\dots\dots + \vec{u_N}}{N} = 0$$

i.e. $v_d = -\frac{eE\tau}{m}$

(b) We know that the current flowing through the conductor is :

$$I = nAev_d$$
$$\therefore \quad I = neA\left(-\frac{eE\tau}{m}\right)$$



Using $\quad E = -\frac{V}{l}$

$$I = neA\left(\frac{eV}{ml}\right)\tau$$
$$= \left(\frac{ne^2A\tau}{ml}\right)V = \frac{1}{R}V$$

$I \propto V \rightarrow$ by Ohm's law

Where, $R = \frac{ml}{nAe^2\tau}$ is a constant for a particular conductor at a particular temperature and is called the resistance of the conductor.

$$R = \left(\frac{m}{ne^2\tau}\right)\frac{l}{A} = \frac{\rho l}{A}$$
$$\rho = \left(\frac{m}{ne^2\tau}\right)$$

Where ρ is the specific resistance or resistivity of the material of the wire. It depends on number of free electron per unit volume and temperature.

(c) They are used to make standard resistors because :

1. They have high value of resistivity.
2. Temperature coefficient of resistance is less.
3. They are least affected by temperature.

OR

(a) Principle of potentiometer : The basic principle of potentiometer is that when a constant current flows through a wire of uniform cross-section area then the potential drop across any length of the wire is directly proportional to that length.

A potentiometer is a device used to measure an unknown emf or potential difference and internal resistance of a cell accurately.

(b) Total resistance of the primary circuit $= 15 + 10 = 25\ \Omega$,

$$\text{emf} = 2\text{ V}$$

∴ Current in the wire AB

$$I = \frac{2}{25} = 0.08\text{ A}$$

P. D. across the wire AB = Current × Resistance of wire AB

$$= 0.08 \times 10 = 0.8\text{ V}$$

$$\text{Potential gradient} = \frac{\text{P.D.}}{\text{Length}} = \frac{0.8}{100}$$

$$= 0.008\text{ V cm}^{-1}$$

Resistance of secondary circuit
$= 1.2 + 0.3 = 1.5\ \Omega$

$$\text{emf} = 1.5\text{ V}$$

$$\text{Current in the secondary circuit} = \frac{1.5}{1.5} = 1.0\text{ A}$$

The same is the current in $0.3\ \Omega$ resistor.

P. D. between points A and O,

P. D. across $0.3\ \Omega$ resistor in the zero-deflection condition.

$$= \text{Current} \times \text{Resistance}$$

$$= 1.0 \times 0.3 = 0.3\text{V}$$

$$\text{Length AO} = \frac{\text{Potential difference}}{\text{Potential gradient}}$$

$$= \frac{0.3\text{V}}{0.008\text{Vcm}^{-1}} = 37.5\text{ cm}$$

●●

Physics 2017 (Outside Delhi)

SET II

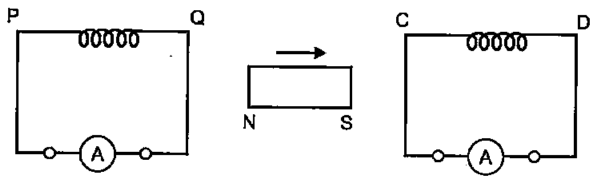
Time allowed : 3 hours

Maximum marks : 70

> **Note : Except for the following questions, all the remaining questions have been asked in previous set.**

SECTION-A

1. A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the direction of the induced current in each coil. [1]



Answer : From Q to P (*i.e.*, anticlockwise) as seen from the left end.

From C to D (*i.e.*, clockwise) as seen from the left end.

2. Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields. [1]

Answer : $c = \frac{E_0}{B_0}$

7. Identify the electromagnetic waves whose wavelengths lie in the range

(a) $10^{-11} < \lambda < 10^{-14}$ m

(b) 10^{-4} m $< \lambda < 10^{-6}$ m

Write one use of each. [2]

Answer : (a) γ-rays

Use : For treatment of cancer.

(b) Infrared rays

Use : In remote control of T.V., V.C.R, etc.

9. The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 Å. Calculate the short wavelength limit for Balmer series of the hydrogen spectrum. [2]

Answer : For short wavelength of Lyman series,

$$\frac{1}{\lambda_B} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$$

$$\frac{1}{913.4 \times 10^{-10}} = R$$

For short wavelength of Balmer series,

$$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$\frac{1}{\lambda_B} = \frac{1}{913.4 \times 10^{-10}} \times \frac{1}{4}$$

$$\lambda_B = 4 \times 913.4 \times 10^{-10}$$

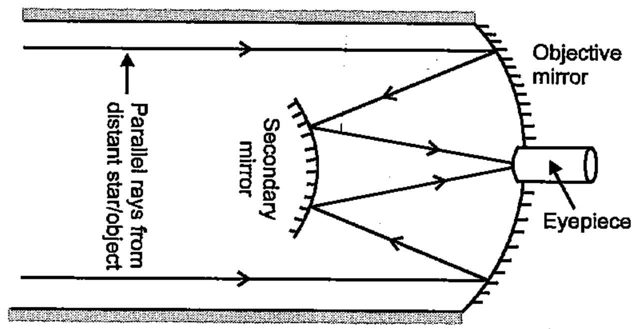
$$\lambda_B = 3653.6 \times 10^{-10} \text{ m}$$

$$= 3653.6 \text{ Å}$$

12. (a) Draw a ray diagram showing the formation of image by a reflecting telescope.

(b) Write two advantages of a reflecting telescope over a refracting telescope. [3]

Answer : (a)



(b) 1. The image is free from chromatic aberration.

2. Spherical aberration can be eliminated by using parabolic mirror.

3. Light gathering power is more in reflecting telescope

15. Explain giving reasons for the following : [3]

(a) Photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.

(b) The stopping potential (V_0) varies linearly with the frequency (ν) of the incident radiation for a given photosensitive surface with the slope remaining the same for different surfaces.

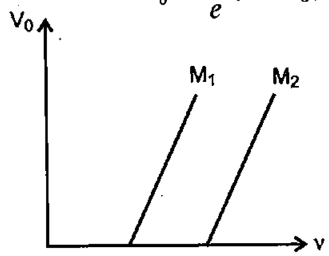
(c) Maximum kinetic energy of the photoelectrons is independent of the intensity of incident radiation.

Answer : (a) Since number of photoelectrons emitted is directly proportional to the intensity of incident radiation therefore, as intensity increases the electron-hole pairs also increases.

(b) $h\nu = h\nu_0 + eV_0$

$eV_0 = h(\nu - \nu_0)$

$$\Rightarrow \qquad V_0 = \frac{h}{e}(\nu - \nu_0)$$



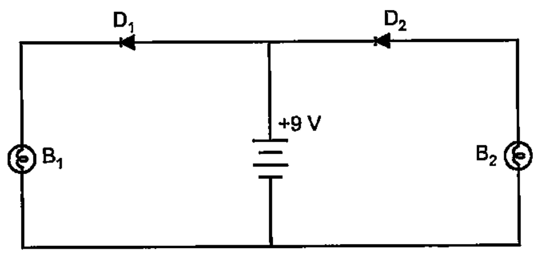
Further from graph, slope is h/e which is a constant and it does not depend on ν.

$$K.E_{map} = h(\nu - \nu_0)$$

Hence, It depends on the frequency and not on the intevsity of the incident roodition.

(c) As intensity increases, the number of photons increases but the energy remains same.

16. (a) In the following diagram which bulb out of B_1 and B_2 will glow and why ?

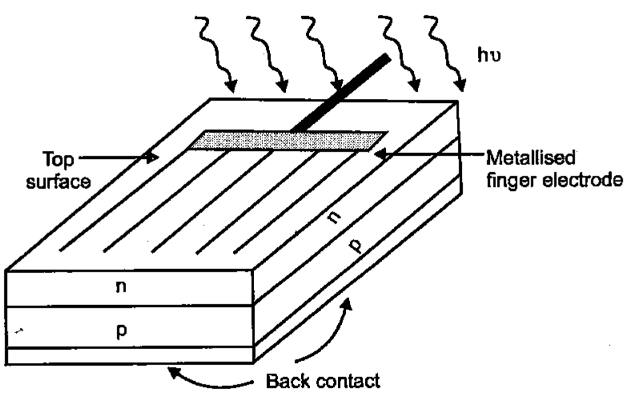


(b) Draw a diagram of an illuminated *p-n* junction solar cell.

(c) Explain briefly the three processes due to which generation of emf takes place in a solar cell. **[3]**

Answer : (a) B_1 will glow because only diode D_1 is forward biased.

(b)



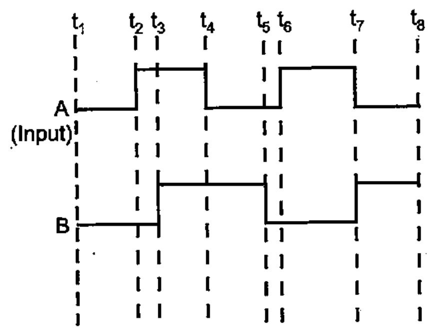
(c) Three process due to which generation of emf takes place in solar cell are :

1. Generation, 2. Separation, 3. Collection.

1. **Generation :** Generation of electron-hole pairs take place due to light.
2. **Separation :** Separation of electron-hole pairs are due to electric field of depletion region.
3. **Collection :** Electrons reach the *n*-side and are collected in front contact and holes are collected in the back contact.

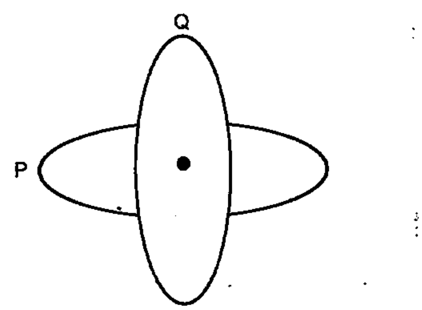
19. (a) Draw the circuit diagram for studying the characteristics of a transistor in common emitter configuration. Explain briefly and show how input and output characteristics are drawn.**

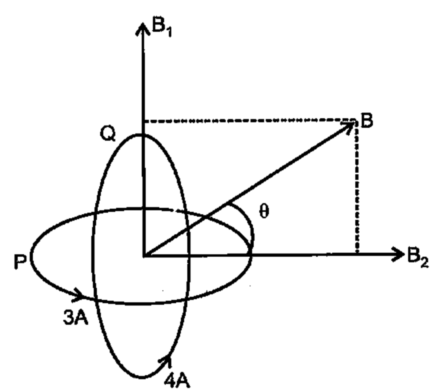
(b) The figure shows input waveforms A and B to a logic gate. Draw the output waveform for an OR gate. Write the truth table for this logic gate and draw its logic symbol.** **[3]**



20. Two identical loops P and Q each of radius 5 cm are lying in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils, if they carry currents equal to 3 A and 4 A respectively. **[3]**

Answer :





**Answers is not given due to change in the present Syllabus.

$$B_1 = \frac{\mu_0}{2R} \cdot I_1$$

Field due to coil P

$$(B_1) = \frac{\mu_0}{2} \times \frac{3}{5 \times 10^{-2}} \text{ tesla}$$

Similarly, Field due to coil Q

$$(B_2) = \frac{\mu_0}{2} \times \frac{4}{5 \times 10^{-2}} \text{ tesla}$$

Resultant magnetic field is,

$$B = \sqrt{B_1^2 + B_2^2}$$

$$B = \sqrt{\left(\frac{\mu_0}{2} \times \frac{3}{5 \times 10^{-2}}\right)^2 + \left(\frac{\mu_0}{2} \times \frac{4}{5 \times 10^{-2}}\right)^2}$$

$$B = \frac{\mu_0}{2 \times 5 \times 10^{-2}} \times 5$$

$$B = \frac{\mu_0}{2} \times 100 = 50\,\mu_0$$

$$= 50 \times 4\pi \times 10^{-7}$$

$$= 62.83 \times 10^{-6}\,T$$

Let the field make an angle θ with the vertical

$$\tan\theta = \frac{B_1}{B_2}$$

$$\tan\theta = \frac{3}{4}$$

$$\theta = \tan^{-1}\left(\frac{3}{4}\right)$$

Thus direction of magnetic field makes an angle θ with the vertical.

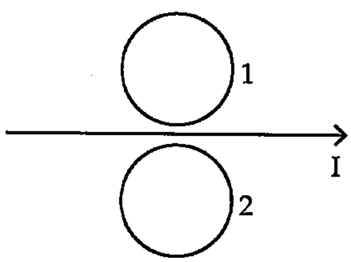
Physics 2017 (Outside Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in the previous sets.

SECTION-A

3. What is the direction of induced currents in metal rings 1 and 2 when current I in the wire is increasing steadily ? [1]



Answer : Ring - 1 → Clockwise

Ring - 2 → Anticlockwise

4. In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the x-axis ? [1]

Answer : Electric component → Y - axis

Magnetic component → Z - axis

8. Why does current in a steady state not flow in a capacitor connected across a battery ? However momentary current does flow during charging or discharging of the capacitor. Explain. [2]

Answer : When there is change in the electric flux there will be a displacement current and when flux is fixed the displacement as well as conduction current will be zero.

$$I_D = \epsilon_0 \frac{d\phi_E}{dt}$$

9. The ground state energy of hydrogen atom is – 13.6 eV. If an electron makes a transition from an energy level – 1.51 eV to – 3.4 eV, calculate the wavelength of the spectral line emitted and name the series of hydrogen spectrum to which it belongs. [2]

Answer : When energy is – 1.51 eV then $n = 3$.
When energy is – 3.4 eV then $n = 2$.

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda} = 1.1 \times 10^7 \left(\frac{1}{4} - \frac{1}{9}\right)$$

$$= 1.1 \times 10^7 \times \frac{5}{36}$$

$$\lambda = \frac{36}{5 \times 1.1} \times 10^{-7}\,m$$

$$\lambda = 6.545 \times 10^{-7}\,m$$

$$\lambda = 6545\,Å$$

It belongs to the Balmer series.

14. (a) Draw the circuit diagram of an *n-p-n* transistor amplifier in common emitter configuration.**

**Answer is not given due to change in the present Syllabus.

(b) Derive an expression for voltage gain of the amplifier and hence show that the output voltage is in opposite phase with the input voltage. ** [3]

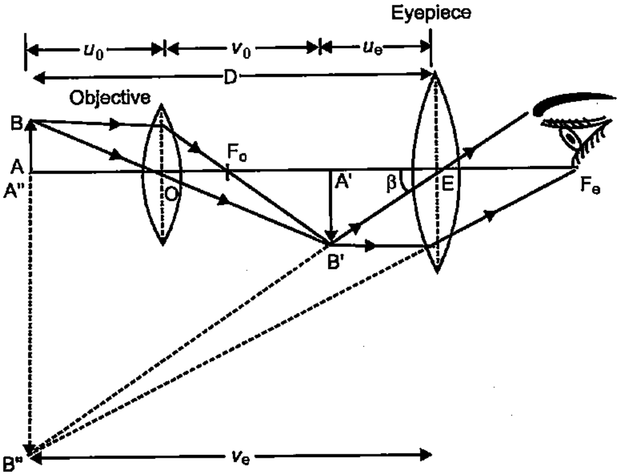
17. (a) Draw a ray diagram for the formation of image by a compound microscope.

(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct a compound microscope ?

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

(c) Define resolving power of a microscope and write one factor on which it depends. [3]

Answer : (a) Ray diagram for compound microscope :



(b) Objective lens → L_3

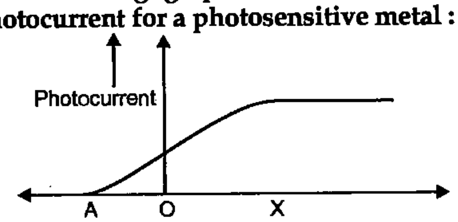
Eye lens → L_2

(c) The resolving power of a microscope is its ability to form distinctly separate images of two neighbouring objects.

$$R.P. = \frac{2\mu \sin\theta}{1.22\,\lambda}$$

It depends on the wavelength (λ) of the light used.

18. The following graph shows the variation of photocurrent for a photosensitive metal : [3]



(a) Identify the variable X on the horizontal axis.

(b) What does the point A on the horizontal axis represent ?

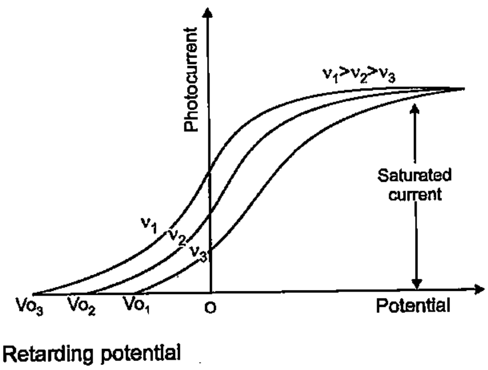
(c) Draw this graph for three different values of frequencies of incident radiation ν_1, ν_2, and ν_3 ($\nu_1 > \nu_2 > \nu_3$) for same intensity.

(d) Draw this graph for three different values of intensities of incident radiation I_1, I_2 and I_3 ($I_1 > I_2 > I_3$) having same frequency.

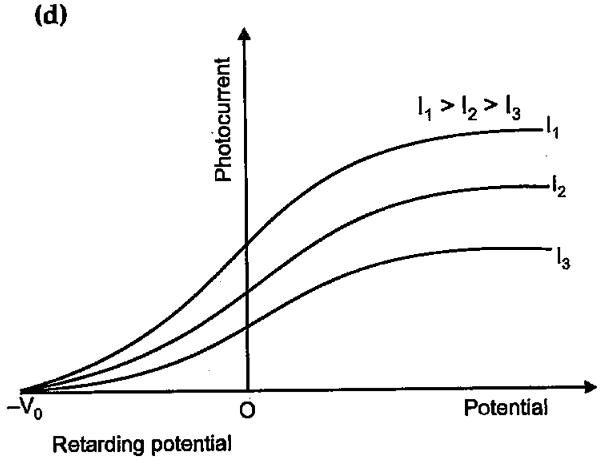
Answer : (a) X is collector plate potential.

(b) Stopping potential.

(c)

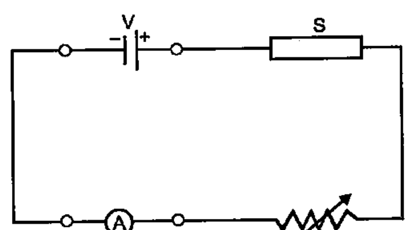


(d)



21. (a) In the following diagram 'S' is a semiconductor. Would you increase or decrease the value of R to keep the reading of the ammeter A constant when S is heated ? Give reason for your answer.

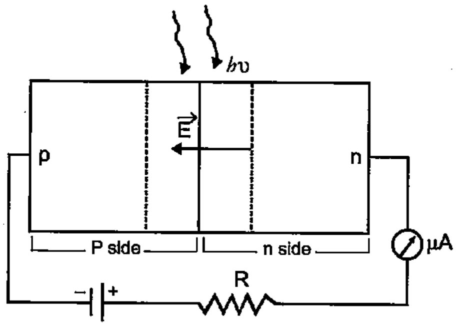
(b) Draw the circuit diagram of a photodiode and explain its working. Draw its I – V characteristics. [3]



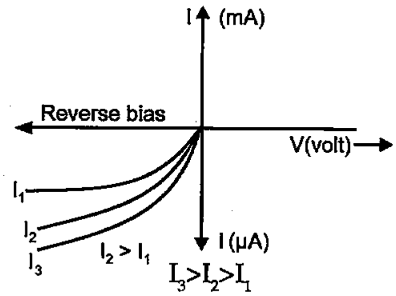
** Answers is not given due to change in the present Syllabus.

Answer : (a) The value of R has to be increase because on heating, the conductivity of a semiconductor increases. *i.e.* resistance of S decreases on heating.

(b)



Working : In photodiode an electric field exists across the junction from *n*-side to *p*-side. When visible light with energy hv greater than energy gap (E_g) illuminates the junction, then electron-hole pairs are generated in the depletion layer. Due to electric field electron moves towards *n* side and holes towards *p*-side give rise to an emf. when an external load is connected current flows.



I-V Characteristics of the diode

Physics 2017 (Delhi)

SET I

Time allowed : 3 hours **Maximum marks : 70**

SECTION – A

1. Does the charge given to a metallic sphere depend on whether it is hollow or solid ? Give reason for your answer. [1]

Answer : No, because all the charge resides on the surface of the sphere only.

2. A long straight current carrying wire passes normally through the centre of circular loop. If the current through the wire increases, will there be an induced emf in the loop ? Justify. [1]

Answer : No, the emf will not be induced as the magnetic field lines are parallel to the plane of the circular loop. So magnetic flux will remain zero.

$$\phi = BA\cos\theta = BA\cos 90°$$
$$= 0$$

Hence, induced emf, $\varepsilon = -\dfrac{d\phi}{dt} = 0$

3. At a place, the horizontal component of earth's magnetic field is B and angle of dip is 60°. What is the value of horizontal component of the earth's magnetic field at equator ? [1]

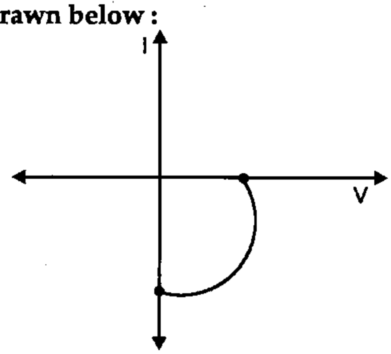
Answer :

$$B_H = B'\cos 60°$$
$$B = B'\cos 60° \text{ (given } B_H = B)$$
$$B = B'\left(\frac{1}{2}\right)$$
$$B' = 2B$$

At equator, $\theta = 0°$

$$B_H = B'\cos\theta$$
$$= B'\cos 0°$$
$$= 2B$$

4. Name the junction diode whose I-V characteristics are drawn below : [1]



Answer : This is the characteristic of solar cell.

5. How is the speed of em-waves in vacuum determined by the electric and magnetic fields? [1]

Answer : The speed of em waves are determined by the ratio of the peak values of electric and magnetic field vectors.

$$c = \frac{E_0}{B_0}$$

SECTION–B

6. How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery ? Write the expression for the displacement current in terms of the rate of change of electric flux. [2]

Answer : During the charging of capacitor, (electric flux between the plates of capacitor keeps on changing, due to which displacement current between the plates is produced. Hence circuit becomes complete and current flow through the circuit.

$$I_D = \epsilon_0 \frac{d\phi_E}{dt}$$

7. **Define the distance of closest approach. An α-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an α-particle of double the kinetic energy ?** **[2]**

OR

Write two important limitations of Rutherford nuclear model of the atom.

Answer : It is defined as the minimum distance of the charged particle from the nucleus at which initial kinetic energy of the particle is equal to the potential energy due to the charged nucleus.

At this distance, K.E = P.E

$$K = \frac{1}{4\pi\epsilon_0}\frac{Ze(2e)}{r}$$

$$r = \frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{K} \quad \text{...(i)}$$

If K is doubled,

$$r' = \frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{2K} \quad \text{...(ii)}$$

Dividing (ii) by (i), we get

$$\frac{r'}{r} = \frac{1}{2}$$

$$\Rightarrow \quad r' = \frac{r}{2}$$

OR

Limitations : (a) It is not in accordance with the Maxwell's theory and could not explain the stability of an atom.

(b) It did not say anything about the arrangement of electrons in an atom.

8. **Find out the wavelength of the electron orbiting in the ground state of hydrogen atom.** **[2]**

Answer : We know that, according to de Broglie relation,

$$2\pi r = n\lambda$$

For first orbit, $n = 1$

$$2\pi r = n\lambda$$

$$\lambda = 2\pi \times 0.53 \text{ Å} \quad [\because r = 0.53 \text{ Å}]$$

$$\lambda = 3.331 \text{ Å}$$

9. **Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and the eyepiece of a compound microscope has short focal lengths ? Explain.** **[2]**

Answer : Magnifying Power : The magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both the final image and the object are situated at the least distance of distinct vision from the eye.

Magnifying power of the compound microscope when the final image is at infinity,

$$m = -\frac{L}{f_0} \times \frac{D}{f_e}$$

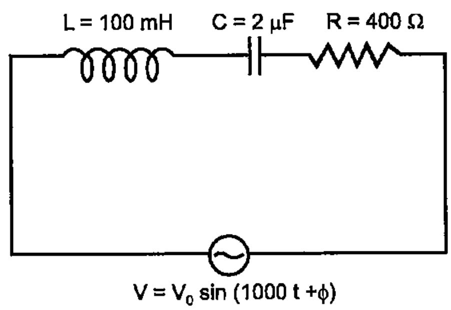
From the above equation, we can see that to achieve a large magnification, the objective and eyepiece should have small focal lengths.

10. **Which basic mode of communication is used in satellite communication ? What type of wave propagation is used in this mode ? Write, giving reason, the frequency range used in this mode of propagation.**** **[2]**

SECTION – C

11. **(a) Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase : current or voltage ?**

(b) Without making any other change, find the value of the additional capacitor C_1, to be connected in parallel with capacitor C, in order to make the power factor of the circuit unity. **[3]**



Answer : (a) Given :

$$L = 100 \times 10^{-3} \text{ H}$$
$$C = 2 \times 10^{-6} \text{ F}$$
$$R = 400\ \Omega$$
$$\omega = 1000$$

Now, $X_L = \omega L$

$$X_L = (1000 \times 100 \times 10^{-3})\ \Omega$$
$$X_L = 100\ \Omega$$

And $X_C = \dfrac{1}{\omega C}$

$$= \frac{1}{1000 \times 2 \times 10^{-6}}$$

$$= \frac{10^6}{2\times10^3}$$

$$X_C = \frac{1000}{2} = 500\,\Omega$$

Here $X_C > X_L$ so, the current will lead.

$$\tan\phi = \frac{X_L - X_C}{R}$$

$$= \frac{100-500}{400}$$

$$\tan\phi = -\frac{400}{400}$$

$$\tan\phi = -1$$

$\Rightarrow$ phase ongle $\phi = -45°$

(b) For unity power factor,

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega c_{eq}}$$

$$\omega^2 = \frac{1}{\omega c_{eq}}$$

$$C_{eq} = \frac{1}{LC_{eq}}$$

$$C_{eq} = \frac{1}{(1000)^2\times100\times10^{-3}} = 10\,\mu F$$

Now, $C_{eq} = C + C_1$

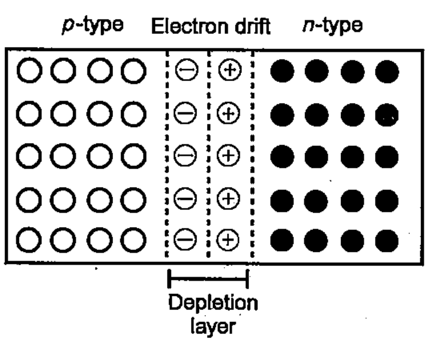
$$10 = 2 + C_1$$

$$10-2 = C_1$$

$$C_1 = 8\,\mu F$$

12. Write the two processes that take place in the formation of a *p-n* junction. Explain with the help of a diagram, the formation of depletion region and barrier potential in a *p-n* junction. [3]

Answer : Two important processes involved during the formation of p-n junction are diffusion and drift. Electron diffusion



Formation of depletion region and barrier potential : At the instant of *p-n* junction formation, the free electrons near the junction diffuse across the junction into the *p* region and combines with holes. Thus, on combining with the hole, it makes a negative ion and leaves a positive ion on n-side. These two layers of immobile positive and immobile negative charges form the depletion region.

Further, as electrons diffuse across the junction a point is reached where the negative charge repels any further diffusion of electron. This depletion region now acts as a barrier. Now the external energy is supplied to get the electrons to move across the barrier of electric field. The potential difference required to move the electrons through the electric field is called barrier potential.

13. (a) Obtain the expression for the cyclotron frequency.

(b) A deuteron and a proton are accelerated by the cyclotron. Can both be accelerated with the same oscillator frequency ? Give reason to justify your answer. [3]

Answer : (a) Suppose the positive ion with charge q moves in a dee with a velocity v, then

$$\frac{mv^2}{r} = qvB$$

$$r = \frac{mv}{qB} \quad \text{(i)}$$

where m is the mass and r is the radius of the path of ion in the dee and B is the strength of the magnetic field.

The time taken by the ion,

$$T = \frac{2\pi r}{v}$$

$$\frac{1}{f} = \frac{2\pi r}{v}$$

$$f = \frac{v}{2\pi r}$$

$$\therefore \quad f = \frac{v}{2\pi\times mv} \text{ [using(I)]}$$

This frequency is called the cyclotron frequency.

(b) Deuteron and proton have different masses and cyclotron on frequency depends inversly on mass. Hence, cannot be accelerated with the same oscillator frequency.

14. (a) How does one explain the emission of electrons from a photosensitive surface with the help of Einstein's photoelectric equation?

(b) The work function of the following metals is given : Na = 2.75 eV, K = 2.3 eV, Mo = 4.17 eV and Ni = 5.15 eV. Which of these metals will not cause photoelectric emission for radiation of wavelength 3300 Å from a laser source placed 1 m away from these metals ? What happens if the laser source is brought nearer and placed 50 cm away ? [5]

Answer : (a) According to Einstein's photoelectric equation,

$$h\nu = h\nu_0 + E_{max}$$
$$E_{max} = h\nu - h\nu_0$$
$$E_{max} = h(\nu - \nu_0)$$

If $\upsilon < \upsilon_0$ then E_{max} will be negative so, no emission takes place.
If $\upsilon > \upsilon_0$ then E_{max} will be positive and directly proportional to υ so, emission takes place.

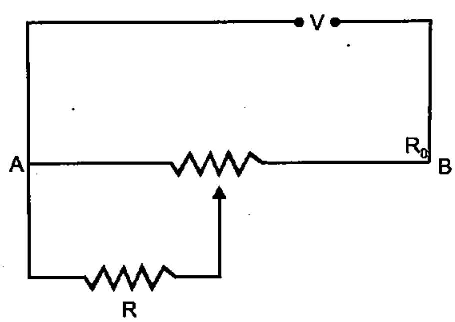
(b) $$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63\times10^{-34}\times3\times10^{8}}{3300\times10^{-10}\times1.6\times10^{-19}}$$

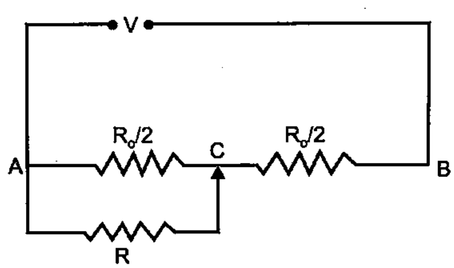
$$E = 3.76 \text{ eV}$$

The work function of Na and K is less than the energy of incident radiation.
Therefore, Na and K will cause photoelectric emission while Mo and Ni will not cause photoelectric emission.
There will be no effect on photoelectric emission if the source is brought nearer.

15. A resistance of R draws current from a potentiometer. The potentiometer wire, AB, has a total resistance of R_0. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of potentiometer wire. **[3]**



Answer :



The equivalent resistance between A and C,

$$\frac{1}{2} = \frac{1}{2} + \frac{1}{R_0/2}$$

$$R' = \frac{R\frac{R_0}{2}}{R+\frac{R_0}{2}} = \frac{RR_0}{2R+R_0} \quad ...(i)$$

Equivalent resistance between A and B,

$$R_{eq} = \frac{RR_0}{2R+R_0} + \frac{R_0}{2}$$

$$R_{eq} = \frac{R_0(4R+R_0)}{2(2R+R_0)} \quad ...(ii)$$

Current in the circuit,

$$I = \frac{V}{R_{eq}} = \frac{V.2(2R+R_0)}{R_0(4R+R_0)}$$

$\therefore$ Voltage across R,

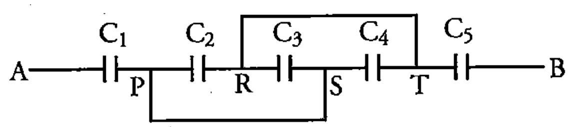
$$V_R = I.R'$$

$$V_R = \frac{V.2(2R+R_0)}{R_0(4R+R_0)} \times \frac{RR_0}{(2R+R_0)}$$

$$V_R = \frac{2VR}{4R+R_0}$$

16. Define the term 'amplitude modulation.' Explain any two factors which justify the need for modulating a low frequency base-band signal.** **[3]**

17. (a) Find equivalent capacitance between A and B in the combination given below. Each capacitor is of 2μF capacitance.



(b) If a dc source of 7 V is connected across AB, how much charge is drawn from the source and what is the energy stored in the network? **[3]**

Answer : (a) In the given figure, C_2, C_3 and C_4 are in parallel so, the equivalent capacitance of parallel capacitors is given by C'.

$$C' = C_2 + C_3 + C_4 = (2+2+2)\ \mu F$$

$$C' = 6\ \mu F$$

Again, C_1, C' and C_5 are in series. Therefore, the equivalent capacitance C_{eq} is given by

$$\frac{1}{C_{eq}} = \frac{1}{2}+\frac{1}{6}+\frac{1}{2}$$

$$\frac{1}{C_{eq}} = \frac{3+1+3}{6} = \frac{7}{6}$$

$$C_{eq} = \frac{6}{7}\ \mu F$$

(b) The charge remains same in series circuit.

**Answers is not given due to change in the present Syllabus.

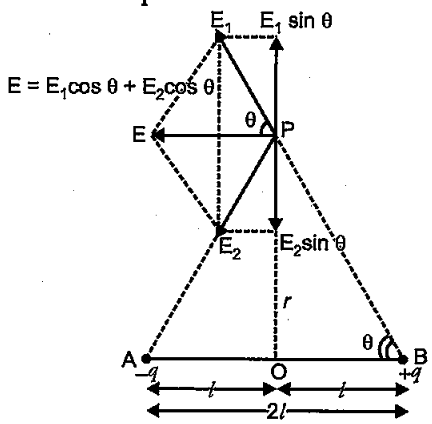
$$\therefore \quad Q = C_{eq}V$$
$$= \frac{6}{7}\times 7$$
$$Q = 6\ \mu F$$

Now,
$$U = \frac{1}{2}C_{eq}V^2$$
$$U = \frac{1}{2}\times\frac{6}{7}\times(7)^2\times 10^{-6}$$
$$U = 21\times 10^{-6}\text{ joule} = 21\ \mu J$$

18. (a) Derive the expression for electric field at a point on the equatorial line of an electric dipole.

(b) Depict the orientation of the dipole in (i) stable, (ii) unstable equilibrium in a uniform electric field. [3]

Answer : (a) Consider a point P on broad side position of dipole formed of charges $+q$ and $-q$ at separation $2l$. The distance of point P from mid point (O) of electric dipole is r. Let $\vec{E_1}$ and $\vec{E_2}$ be the electric field strengths due to charges $+q$ and $-q$ of electric dipole.



From the figure, $AP = BP = \sqrt{r^2+l^2}$

$$\therefore \quad \vec{E_1} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+l^2} \text{ along B to P}$$

$$\vec{E_2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+l^2} \text{ along P to A}$$

The components of $\vec{E_1}$ and $\vec{E_2}$ perpendicular to AB : $E_1 \sin\theta$ and $E_2 \sin\theta$ being equal and opposite cancel each other, while the cosine components of $\vec{E_1}$ and $\vec{E_2}$ parallel to AB : $E_1 \cos\theta$ and $E_2 \cos\theta$ being in the same direction add up and give the resultant electric field whose direction is parallel to BA.

$\therefore$ Resultant electric field at P is $E = E_1\cos\theta + E_2\cos\theta$

But
$$E_1 = E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)}$$

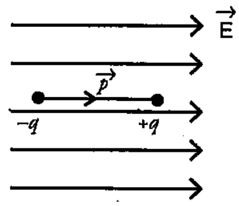
From the figure,
$$\cos\theta = \frac{OB}{PB} = \frac{l}{\sqrt{r^2+l^2}}$$
$$= \frac{l}{(r^2+l^2)^{1/2}}$$

$$E = 2E_1\cos\theta$$
$$= 2\times\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)}\cdot\frac{l}{(r^2+l^2)^{1/2}}$$
$$= \frac{1}{4\pi\varepsilon_0}\frac{2ql}{(r^2+l^2)^{3/2}}$$

But $q.2l = p$ = electric dipole moment

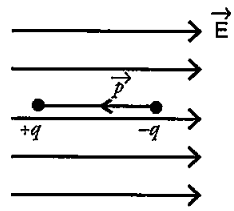
$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+l^2)^{3/2}}$$

(b) (i)



Stable equilibrium
i.e., $\theta = 0°$

(ii)



Unstable equilibrium
i.e., $\theta = 180°$

19. (a) A radioactive nucleus 'A' undergoes a series of decays as given below :

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

The mass number and atomic number of A_2 are 176 and 71 respectively. Determine the mass and atomic numbers of A_4 and A.

(b) Write the basic nuclear process underlying β^+ and β^- decays. [3]

Answer : (a)

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} {}^{176}_{71}A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

$${}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$$

$$A_4 \longrightarrow \begin{cases} 172 = \text{Mass number} \\ 69 = \text{Atomic number}\end{cases}$$

$${}^{180}_{72}A \xrightarrow{\alpha} {}^{176}_{70}A_1 \xrightarrow{\beta} {}^{176}_{71}A_2$$

$$A \longrightarrow \begin{cases} 180 = \text{Mass number} \\ 72 = \text{Atomic number}\end{cases}$$

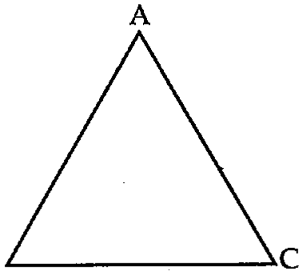
(b) The process of spontaneous emission of a positron (e^+) from nucleus is called β^+ decay.

$$p \rightarrow n + {}^{0}_{1}e + \bar{\nu}$$

The process of spontaneous emission of an electron (e^-) from nucleus is called β^- decay.

$$n \rightarrow p + {}^{0}_{-1}e + \bar{\nu}$$

20. (a) A ray of light incident on face AB of an equilateral glass prism, shows minimum deviation of 30°. Calculate the speed of light through the prism.



(b) Find the angle of incidence at face AB so that the emergent ray grazes along the face AC. **[3]**

Answer : (a) Given :

$$\delta_m = 30°$$
$$A = 60°$$

Refractive index of the prism,

$$\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\left(A/2\right)}$$

$$\mu = \frac{\sin\left(\frac{30° + 60°}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$\mu = \frac{\sin(45°)}{\sin(30°)}$$

$$\mu = \frac{1/\sqrt{2}}{1/2} = \frac{2}{\sqrt{2}} = \sqrt{2}$$

Now, $\mu = \frac{c}{v}$

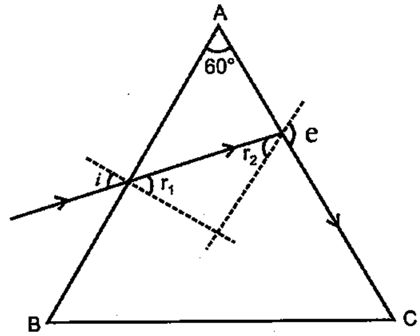
$$v = \frac{c}{\mu}$$

$$v = \frac{3 \times 10^8}{\sqrt{2}}$$

$$v = \frac{3 \times 10^8}{1.414}$$

$$v = 2.12 \times 10^8 \text{ m/s}$$

(b)



Since the light grazes along the face AC. Therefore, r_2 is the critical angle.

$$\sin r^2 = \frac{1}{\mu}$$

$$\sin r^2 = \frac{1}{\sqrt{2}}$$

$$\sin r^2 = \sin 45°$$

$$r_2 = 45°$$

$\therefore$ $r_1 + r_2 = A$

$$r_1 = A - r_2$$
$$= 60° - 45°$$
$$r_1 = 15°$$

Now, $\mu = \frac{\sin i}{\sin r_1}$

By snell's law $\sin i = \mu \sin r_1$

$$= \sqrt{2}\sin(15°)$$
$$= 1.414 \times 0.2588$$
$$\sin i = 0.366$$
$$i = 21° \text{ (approx)}$$

21. For a CE-transistor amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. Given the current amplification factor of the transistor is 100, find the input signal voltage and base current, if the base resistance is 1 kΩ.** **[3]**

22. Describe the working principle of a moving coil galvanometer. Why is it necessary to use (i) a radial magnetic field and (ii) a cylindrical soft iron core in a galvanometer? Write the expression for current sensitivity of the galvanometer.

Can a galvanometer as such be used for measuring the current ? Explain. **[3]**

OR

****Answers is not given due to change in the present Syllabus.**

(a) Define the term 'self-inductance' and write its S.I. unit.

(b) Obtain the expression for the mutual inductance of two long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.

Answer : Moving coil galvanometer :

Principle : It works on the principle that a current carrying coil placed in a magnetic field experiences a torque.

Radial magnetic field : It is necessary to eliminate the effect of θ on torque and hence enable us to make the scale of galvanometer linear.

Cylindrical soft iron core : It makes the magnetic lines of force pointing along the radii of the circle and also due to high permeability it intensifies the magnetic field and hence increases the sensitivity of the galvanometer.

Current sensitivity :

$$I_s = \frac{NBA}{K} \text{ or } \frac{Q}{I}$$

where Q is the deflection of coil

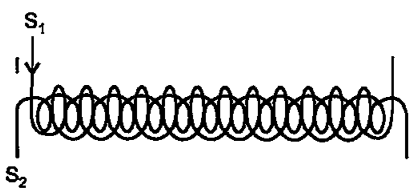
No, it can not be used to measure electric current because it is a highly current sensitive device which would show large deflection even with the passage of small current. And the galvanometer coil is likely to damaged by currents in (mA/A) rang.

OR

(a) Self-inductance : The self inductance of a coil may be defined as the induced emf set up in the coil due to a unit rate of change of current through it.

Its S.I. unit is Henry (H).

(b)



Magnetic field produced, $B = \mu_0 n_2 I$.

The flux produced in it, $\phi_1 = \mu_0 n_2 I \pi r_1^2$. [$\because = \phi BA$]

This flux is linked with all the turns of S_2,

$$\phi_1 = \mu_0 n_2 I \pi r_1^2 . n_1 L \quad \text{...(i)}$$

Also $$\phi = MI \quad \text{...(ii)}$$

Comparing (i) and (ii), we get

$$M = \mu_0 n_1 n_2 L \pi r_1^2$$

SECTION–D

23. Mrs. Rashmi Singh broke her reading glasses. When she went to the shopkeeper to order new spects, he suggested that she should get spectacles with plastic lenses instead of glass lenses. On getting the new spectacles, she found that the new ones were thicker than the earlier ones, she asked this question to the shopkeeper but he could not offer satisfactory explanation for this. At home, Mrs. Singh raised the same question to her daughter Anuja who explained why plastic lenses were thicker. [4]

(a) Write two qualities displayed each by Anuja and her mother.**

(b) How do you explain this fact using lens maker's formula ?

Answer :

(b) According to lens maker's formula,

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where f is the focal length, n is the refractive index and R_1 and R_2 is the radius of curvature of the lens.

Since $n_g > n_p$

where, g stands for glass and p stands for plastic.

Therefore, we get $(n_g - 1) > (n_p - 1)$

Now, using the lens maker's formula, we see that focal length is inversely proportional to $(\mu - 1)$.

Hence, $f_p > f_g$

Thus, in the case of plastic lens the thickness of the lens should be increased to keep the same focal length as that of the glass lens to give the same power.

SECTION–E

24. (a) Draw a labelled diagram of AC generator. Derive the expression for the instantaneous value of the emf induced in the coil.

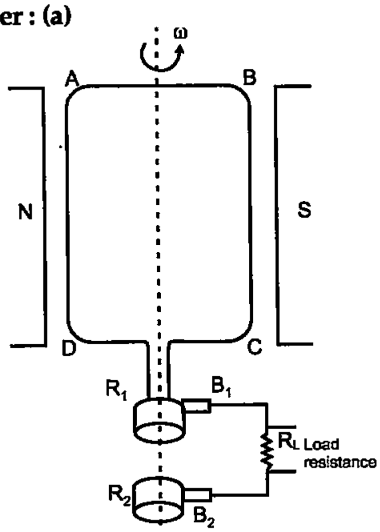
(b) A circular coil of cross-sectional area 200 cm² and 20 turns is rotated about the vertical diameter with angular speed of 50 rad s⁻¹ in a uniform magnetic field of magnitude 3.0 × 10⁻² T. Calculate the maximum value of the current in the coil. [5]

OR

(a) Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary to primary voltage in terms of number of turns and currents in the two coils.

(b) A power transmission line feeds input power at 2200 V to a step-down transformer with its primary windings having 3000 turns. Find the number of turns in the secondary to get the power output at 220 V.

Answer : (a)



where, B_1, B_2 } are brushes.

R_1, R_2 } are slip rings.

R_L is load resistance.

ABCD is armature.

If N is the number of turns in coil, A area of coil and B the magnetic induction then flux ϕ is given by

$$\phi = B.A$$
$$\phi = BA \cos \omega t$$

When the coil is rotated with constant angular speed 'ω' in time 't'

The emf induced in the coil is given by,

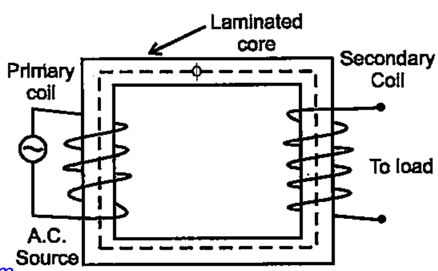
$$e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(BA \cos \omega t)$$
$$= -NBA(-\omega \sin \omega t)$$
$$= NBA\omega \sin \omega t$$
$$e = e_0 \sin \omega t \quad (\text{where } e_0 = NBA\omega)$$

(b) We know that,

$$e_0 = NBA\omega$$
$$e_0 = 20 \times 3 \times 10^{-2} \times 200 \times 10^{-4} \times 50$$
$$e_0 = 0.6 \text{ volt} = 600 \text{ mV}$$
$$I_0 = \frac{e_0}{R}$$
$$I_0 = \frac{0.6}{R} A = \frac{600}{R} mA$$

OR

(a)



Step up transformer

The emf induced in primary and secondary coil,

$$e_s = -N_s \frac{d\phi}{dt} \quad ...(i)$$
$$e_p = -N_p \frac{d\phi}{dt} \quad ...(ii)$$

Dividing (i) by (ii), we get

$$\frac{e_s}{e_p} = \frac{N_s}{N_p} \quad ...(iii)$$

According to the law of conservation of energy in an ideal transformer,

$$e_s I_s = e_p I_p$$
$$\frac{e_s}{e_p} = \frac{I_p}{I_s} \quad ...(iv)$$

From equation (iii) and (iv), we get

$$\frac{e_s}{e_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

(b) Given :

$$e_p = 2200 \text{ V}$$
$$N_p = 3000$$
$$N_s = ?$$
$$e_s = 220 \text{ V}$$
$$\therefore \quad \frac{e_s}{e_p} = \frac{N_s}{N_p}$$
$$\frac{220}{2200} = \frac{N_s}{3000}$$
$$\Rightarrow \quad N_s = 300$$

25. (a) Distinguish between unpolarised light and linearly polarised light. How does one get linearly polarised light with the help of a polaroid ?

(b) A narrow beam of unpolarised light of intensity I_0 is incident on a polaroid P_1. The light transmitted by it is then incident on a second polaroid P_2 with its pass axis making angle of 60° relative to the pass axis of P_1. Find the intenstity of the light transmitted by P_2. [5]

OR

(a) Explain two features to distinguish between the interference pattern in Young's double slit experiment with the diffraction pattern obtained due to a single slit.

(b) A monochromatic light of wavelength 500 nm is incident normally on a single slit of width 0.2 mm to produce a diffraction pattern. Find the angular width of the central maximum obtained on the screen.

Estimate the number of fringes obtained in Young's double slit experiment with fringe

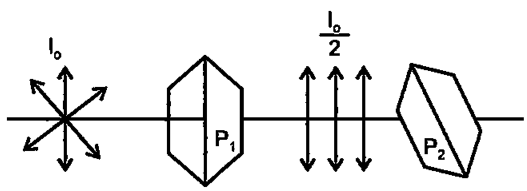
width 0.5 mm, which can be accommodated with the region of total angular spread of the central maximum due to single slit. [5]

Answer : (a) Unpolarised light : If the electric component of light vibrates in all the direction in the plane perpendicular to the direction of propagation, the light is known as unpolarised light.

Linearly polarised light : If the vibration of electric components of light are restricted in one direction only in the plane perpendicular to the propagation of light then light is known as linearly polarised light.

A polaroid consists of long chain molecules aligned in a particular direction. The electric vectors along the direction of the aligned molecules get absorbed. So, when an unpolarised light falls on a polaroid, it lets only those of its electric vectors that are oscillating along a direction perpendicular to its aligned molecules to pass through it. The incident light thus gets linearly polarised.

(b)



Intensity of light after passing through the polaroid

$P_1 (I') = \frac{I_0}{2}$

Intensity of light after passing through the polaroid P_2,

According Malus law $I = I_0 \cos^2\theta$

$$I = I' \cos^2 60° \qquad [\because \theta = 60°]$$

$$I = \frac{I_0}{2}\left(\frac{1}{2}\right)^2$$

$$I = \frac{I_0}{2} \times \frac{1}{4}$$

$$I = \frac{I_0}{8}$$

OR

(a)

Interference	Diffraction
1. All bright and dark fringes are of equal width.	The width of central bright fringe is twice the width of any secondary maxima.
2. All the bright fringes are of same intensity.	Intensity of bright fringes decreases as we move away from central bright fringe.

(b) Angular width of central maxima, $\omega = \frac{2\lambda}{a}$

$$= \frac{2 \times 500 \times 10^{-9}}{0.2 \times 10^{-3}}$$

$$= 5 \times 10^{-3} \text{ rad.}$$

Now, fringe width, $\beta = \frac{\lambda D}{d}$

Linear width of central maxima in the diffraction pattern 0.02

$$w' = \frac{2\lambda D}{a}$$

Let 'n' be the number of interference fringes which can be accommodated in the central maxima.

$$n \times \beta = w'$$

$$n = \frac{2\lambda D}{a} \times \frac{d}{\lambda D}$$

$$n = \frac{2d}{a}$$

26. (a) Derive an expression for drift valocity of electrons in a conductor. Hence deduce Ohm's law.

(b) A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire ?

(i) drift speed (ii) current density

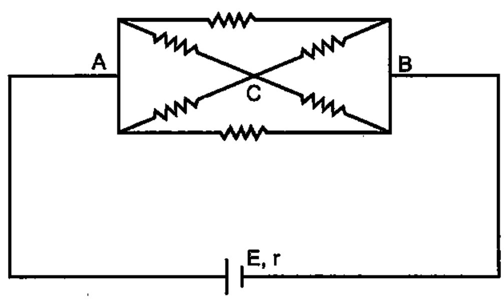
(iii) electric current (iv) electric field

Justify your answer. [5]

OR

(a) State the two Kirchhoff's laws. Explain briefly how these rules are justified.

(b) The current is drawn from a cell of emf E and internal resistance r connected to the network of resistors each of resistance r as shown in the figure. Obtain the expression for (i) the current drawn from the cell and (ii) the power consumed in the network.



Answer : (a) Expression of Drift velocity : It is defined as the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied electric field.

If an electron have initial velocity u_1 and accelerated for time τ_1 then velocity attain by it will be

$$\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$$

Similarly
$$\vec{v}_2 = \vec{u}_2 + \vec{a}\tau_2$$
$$\vec{v}_3 = \vec{u}_3 + \vec{a}\tau_3$$
$$\vec{v}_n = \vec{u}_n + \vec{a}\tau_n$$

Then average velocity,

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 + ...\vec{v}_n}{n}$$

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + ...(\vec{u}_n + \vec{a}\tau_n)}{n}$$

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{u}_2 + ...\vec{u}_n)}{n} + \frac{(\tau_1 + \tau_2 + ...\tau_n)}{n}$$

$$\vec{v}_d = 0 + \vec{a}\tau$$

$$\vec{v}_d = \vec{a}\tau$$

where $\tau = \frac{\tau_1 + \tau_2 + ... + \tau_n}{n}$ = average relaxation time.

$$\vec{v}_d = \frac{-e\vec{E}\tau}{m} \qquad \left[\because a = \frac{-e\vec{E}\tau}{m}\right]$$

$$|\vec{v}_d| = \left|\frac{-e\vec{E}\tau}{m}\right|$$

Now,

$$v_d = \frac{eE\tau}{m}$$

$$v_d = \frac{eV\tau}{ml} \qquad \left[\because E = \frac{V}{l}\right]$$

Nowcharge flowing through conductor at aninstant is

and $\quad I = neAv_d$

$$I = neA\frac{eV\tau}{ml}$$

$$\frac{V}{I} = \frac{ml}{ne^2\tau A}$$

If physical condition remain unchanged then right hand side will be constant.

$$\therefore \quad \frac{V}{I} = \text{Constant}$$

$$\frac{V}{I} = R \text{ or } V = IR$$

Hence, Ohm's law is derived.

(b) The electric current will remain constant in the wire as it does not depend upon the cross-sectional area whereas the drift speed, current density, electric field depends upon the increasing area of cross-section with the following relations :

Drift speed, $v_d = \frac{I}{neA}$

Current density, $J = \frac{I}{A}$

Electric field, $E = \frac{J}{\sigma}$

OR

(a) Kirchhoff's laws :

1. **Kirchhoff's first law or junction rule :** In an electric circuit, the algebraic sum of currents at any junction is zero.

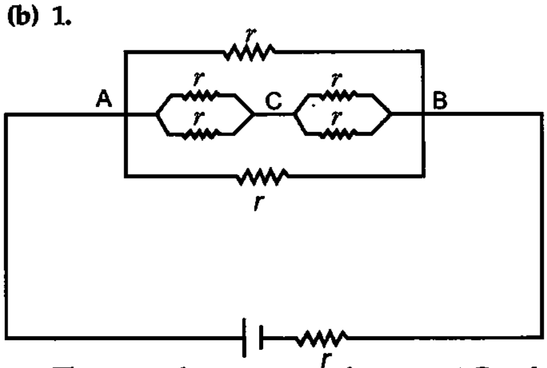
$$\Sigma I = 0$$

2. **Kirchhoff's second law or loop rule :** Around any closed loop of a network, the algebraic sum of changes in the potential must be zero.

$$\Sigma \Delta V = 0$$

Justification : First law is based on the law of conservation of charge and second law is based on the law of conservation of energy.

(b) 1.

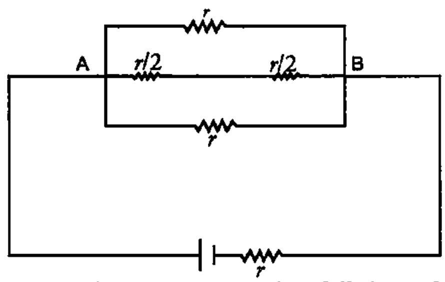


The equivalent resistance between AC and CB is given by

$$\frac{1}{r'} = \frac{1}{r} + \frac{1}{r}$$

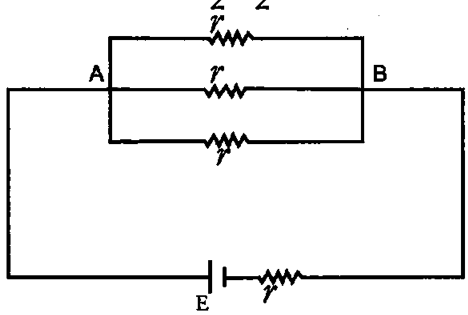
$$\frac{1}{r'} = \frac{2}{r}$$

$$r' = \frac{r}{2}$$



The equivalent resistance of middle branch is given by,

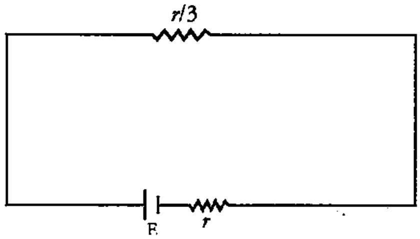
$$r'' = \frac{r}{2} + \frac{r}{2} = r$$



The equivalent resistance between A and B is given by

$$\frac{1}{r'''} = \frac{1}{r}+\frac{1}{r}+\frac{1}{r}$$

$$r''' = \frac{r}{3}$$



Total resistance of the circuit is given by,

$$R = \frac{r}{3} + r$$

$$R = \frac{4r}{3}$$

Now current through the circuit is given by

$$I = \frac{E}{\frac{4r}{3}}$$

$$I = \frac{3E}{4r}$$

2. Power consumption $= I^2R$

$$= \left(\frac{3E}{4r}\right)^2 \frac{4r}{3}$$

$$P = \frac{3E^2}{4r}$$

Physics 2017 (Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

> **Note : Except for the following questions, all the remaining questions have been asked in previous set.**

6. Find the wavelength of the electron orbiting in the first excited state in hydrogen atom. [2]

Answer : Radius of n^{th} orbit,

$$r_n = r_0 n^2 = 0.53\, n^2 \text{Å}$$

For 1^{st} excited state n = 2.

$$\therefore \quad r_2 = 0.53 \times 4 \text{Å} = 2.12 \text{Å}$$

For an electron revolving in n^{th} orbit, according to de Broglie relation,

$$2\pi r_n = n\lambda,$$

$$2 \times 3.14 \times 2.12 \times 10^{-10} = 2\lambda$$

$$\lambda = 3.14 \times 2.12 \times 10^{-10}\, m = 6.67 \text{Å}$$

7. Distinguish between a transducer and a repeater. [2]**

10. Why should the objective of a telescope have large focal length and large aperture ? Justify your answer. [2]

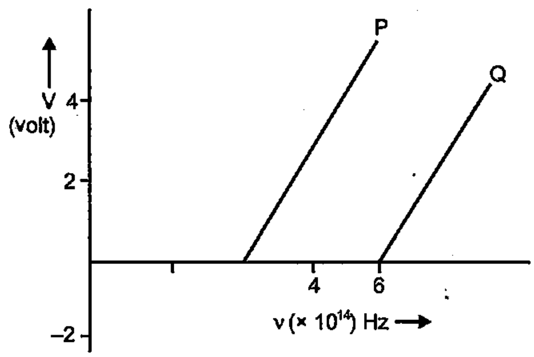
Answer : Magnifying power of telescope, $m = -\frac{f_0}{f_e}$

$\therefore f_0$ should be large.

Also, R.P. of telescope $= \frac{A}{1.22\lambda}$

$\therefore$ Aperture should also be large to increase resolving power.

12. In the study of a photoelectric effect the graph between the stopping potential V and frequency ν of the incident radiation on two different metals P and Q is shown below : [3]



(i) Which one of the two metals has higher threshold frequency ?

(ii) Determine the work function of the metal which has greater value.

(iii) Find the maximum kinetic energy of electron emitted by light of frequency 8×10^{14} Hz for this metal.

Answer : (i) Q has higher threshold frequency.

(ii) Work function of Q

$$\phi_0 = h\nu_0$$

$$h\nu_0 = (6.6 \times 10^{-34}) \times \frac{6\times10^{14}}{1.6\times10^{-19}}\ eV$$

$$= 2.5\ eV$$

(iii) $K_{max} = h(\nu - \nu_0)$

$$= \frac{6.6\times10^{-34}(8\times10^{14} - 6\times10^{14})}{1.6\times10^{-19}}\ eV$$

**Answers is not given due to change in the present Syllabus.

$$= \frac{6.6\times10^{-34}\times2\times10^{14}}{1.6\times10^{-19}}\ eV$$

$$K_{max} = 0.83\ eV$$

13. A 12 pF capacitor is connected to a 50 V battery. How much electrostatic energy is stored in the capacitor ? If another capacitor of 6 pF is connected in series with it with the same battery connected across the combination, find the charge stored and potential difference across each capacitor. [3]

Answer : Energy stored in the capacitor of capacitance 12 pF,

$$U = \frac{1}{2}CV^2$$

$$= \frac{1}{2} \times 12 \times 10^{-12} \times 50 \times 50\ J$$

$$= 1.5 \times 10^{-8}\ J$$

Let C be the equivalent capacitance of 12 pF and 6 pF capacitor connected in series and it is given by

$$\frac{1}{C} = \frac{1}{12}+\frac{1}{6} = \frac{1+2}{12}$$

$\therefore$ $C = 4\ pF$

As the capacitors are connected in series, so the charge remains same

$\therefore$ Charge stored across each capacitor,

$$q = CV = 4 \times 10^{-12} \times 50$$

$$= 2 \times 10^{-10}\ C$$

Potential difference across capacitor C_1,

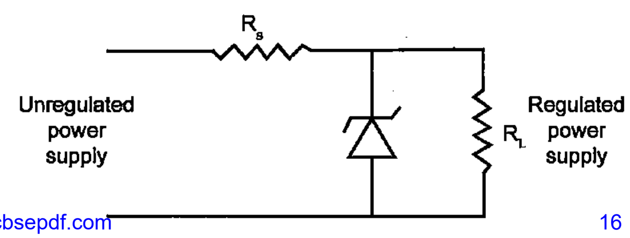
$$V_1 = \frac{2\times10^{-10}}{12\times10^{-12}}\ \text{volt} = \frac{50}{3}\ V$$

Potential difference across capacitor C_2,

$$V_2 = \frac{2\times10^{-10}}{6\times10^{-12}}\ \text{volt} = \frac{100}{3}\ V$$

18. A zener diode is fabricated by heavily doping both *p* and *n*- sides of the junction. Explain, why ? Briefly explain the use of zener diode as a dc voltage regulator with the help of a circuit diagram. [3]

Answer : By heavily doping both p and n sides of the junction, depletion region formed is very thin, *i.e.* $< 10^{-6}$ m. Hence, electric field across the junction is very high ($\sim 5 \times 10^6$ V/m) even for a small reverse bias voltage. This can lead to a break down during reverse biasing.



If the input voltage increases/decreases then current through resistor R_s and Zener diode also increases/decreases. This increases/decreases the voltage drop across R_s without any change in voltage across the zener diode.

This is because in the breakdown region, zener voltage remains constant even though the current through the zener diode changes.

21. A electron of mass m_e revolves around a nucleus of charge +Ze. Show that it behaves like a tiny magnetic dipole. Hence prove that the magnetic moment associated with it is expressed as $\vec{\mu} = -\frac{e}{2m_e}\vec{L}$, where $\vec{L}$ is the orbital angular momentum of the electron. Give the significance of negative sign. [3]

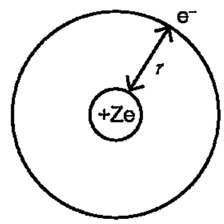
Answer : Electron in circular motion around the nucleus, constitutes a current loop which behaves like a magnetic dipole.

Current associated with the revolving electron,

$$I = \frac{e}{T}$$

and $$T = \frac{2\pi r}{v}$$

$\therefore$ $$I = \frac{e}{2\pi r}v$$



Magnetic moment of the loop,

$$\mu = IA$$

$$\mu = IA = \frac{ev}{2\pi r}\pi r^2$$

$$= \frac{evr}{2} = \frac{e.m_e vr}{2m_e} \quad \text{(i)}$$

Orbital angular momentum of the electron,

$$L = m_e vr$$

Put the value of L in equation (i) (ii)

$$\vec{\mu} = \frac{-e}{2m_e}\vec{L}$$

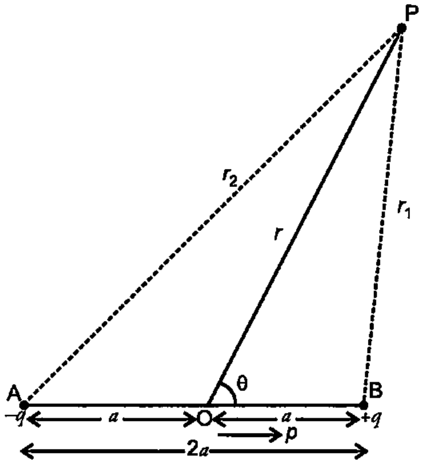
The negative sign signifies that the angular momentum of the revolving electron is opposite in direction to the magnetic moment associated with it.

22. (a) Derive the expression for the electric potential due to an electric dipole at a point on its axial line.

(b) Depict the equipotential surfaces due to an electric dipole. [3]

Answer : (a) Consider an electric dipole having charges $-q$ and $+q$ at separation '$2a$'. The dipole moment of dipole is $\vec{p} = q(2\vec{a})$, directed from $-q$ to $+q$.

The electric potential due to dipole is the algebraic sum of potentials due to charges $+q$ and $-q$.



If r_1 and r_2 are distances of any point P from charge $+q$ and $-q$ respectively as shown in the figure, then the potential due to electric dipole at point P, is

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\epsilon_0}\frac{q}{r_2}$$

$$= \frac{q}{4\pi\epsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \quad \text{...(i)}$$

If (r, θ) are polar coordinates of point P with respect to mid-point O of dipole, then

By geometry,

$$r_1^2 = r^2 + a^2 - 2ar\cos\theta \quad \text{...(ii)}$$

and $$r_2^2 = r^2 + a^2 + 2ar\cos\theta \quad \text{...(iii)}$$

From (ii), $$r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$$

If r >> a i.e., $\frac{a}{r} << 1$, then it is sufficient to retain terms only upto first order in $\left(\frac{a}{r}\right)$.

$$\therefore \quad r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r}\right]$$

$$\Rightarrow \quad r_1 = r\left[1 - \frac{2a\cos\theta}{r}\right]^{1/2} \quad \text{...(iv)}$$

Similarly from (iii),

$$r_2^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right]$$

$$\Rightarrow \quad r_2 = r\left[1 + \frac{2a\cos\theta}{r}\right]^{1/2} \quad \text{...(v)}$$

From (iv) and (v),

$$\frac{1}{r_1} = \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{-1/2}$$

and $$\frac{1}{r_2} = \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{-1/2}$$

Using binomial theorem and retaining terms upto first order in $\frac{a}{r}$ only, we have

$$\frac{1}{r_1} = \frac{1}{r}\left[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r}\right]$$

$$= \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right] \quad \text{...(vi)}$$

and $$\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right] \quad \text{...(vii)}$$

Substituting these values in (i), we get

$$V = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) - \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)\right]$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{r}\left[1 + \frac{a}{r}\cos\theta - 1 + \frac{a}{r}\cos\theta\right]$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{r}\left[\frac{2a}{r}\cos\theta\right]$$

$$= \frac{1}{4\pi\epsilon_0}\frac{(q.2a)\cos\theta}{r^2}$$

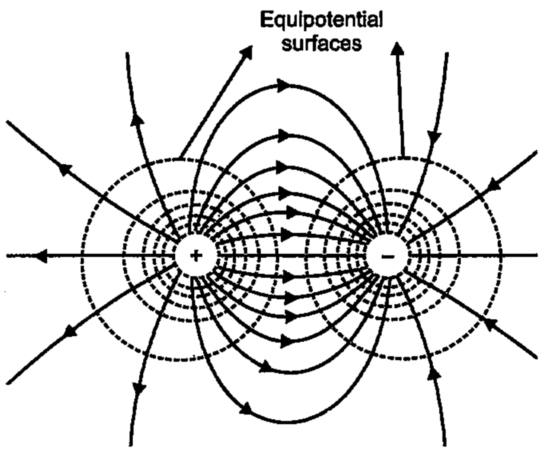
or $$V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2} \quad \text{...(viii)}$$

When point P lies on the axis of dipole, then $\theta = 0°$

$$\therefore \quad \cos\theta = \cos 0° = 1$$

$$\therefore \quad V = \frac{1}{4\pi\epsilon_0}\cdot\frac{p}{r^2}$$

(b)



Equipotential surfaces get closer to each other near the point charges, as strong electric field is produced there.

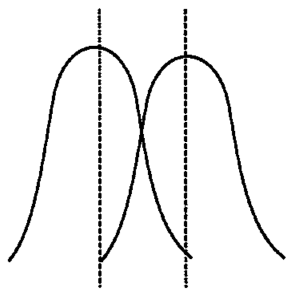
Physics 2017 (Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous sets.

7. When are two objects just resolved ? Explain. How can the resolving power of a compound microscope be increased ? Use relevent formula to support your answer. [2]

Answer : When the maxima of diffraction pattern from one object coincide with the minima of second object then they are just resolved.



$$R.P. = \frac{2\mu \sin\theta}{\lambda}$$

The resolving power of a compound microscope can be increased by increasing μ and by decreasing λ.

8. (a) What is the line of sight communication ?**

(b) Why is it not possible to use sky waves for transmission of T.V. signals ? Upto what distance can a signal be transmitted using an antenna of height '*h*' ? [2]**

9. An α-particle and a proton are accelerated through the same potential difference. Find the ratio of their de Broglie wavelengths. [2]

Answer : de Broglie wavelength,

$$\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}}$$

$$\therefore \quad \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p q_p}{m_\alpha q_\alpha}}$$

$$= \sqrt{\frac{me}{4m.2e}} \quad \left[\because mx = 4m_p, \; qx = 2qp\right]$$

$$\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{1}{8}} = \frac{1}{2\sqrt{2}}$$

$$\therefore \quad \lambda_a : \lambda_p = 1 : 2\sqrt{2}$$

14. (a) State two important features of Einstein's photoelectric equation.

(b) Radiation of frequency 10^{15} Hz is incident on two photosensitive surfaces P and Q. There is no photoemission from surface P. Photoemission occurs from surface Q but photoelectrons have zero kinetic energy. Explain these observations and find the value of work function for surface Q. [3]

Answer : (a) 1. By Einstein's photoelectric equation we can explain the laws of photoelectric emission.

2. By this we can find the value of Planck's constant and work function.

(b) Given : $\nu = 10^{15}$ Hz

$$\text{Wavelength, } \lambda = \frac{c}{\nu} = \frac{3\times10^8}{10^{15}} = 300 \text{ nm}$$

$$\text{Energy, } E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^8}{300\times10^{-9}}$$

$$= \frac{6.6\times10^{-19}}{1.6\times10^{-19}} \text{ eV}$$

$$= 4.125 \text{ eV}$$

The work function of P is more than the 4.125 eV Therefore there is no photoemission from surface P.

For surface Q, the kinetic energy is zero,

$$\therefore \quad K.E_{max} = E - \phi_0$$

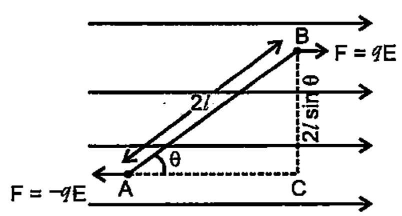
$$0 = E - \phi_0$$

$\Rightarrow$ Work function, $\phi_0 = E = 4.15$ eV

16. (a) Obtain the expression for the torque $\vec{\tau}$ experienced by an electric dipole of dipole moment $\vec{p}$ in a uniform electric field, $\vec{E}$.

(b) What will happen if the field were not uniform ? [3]

Answer : (a)



τ = Force × Perpendicular distance

τ = F × BC

τ = qE × 2l sin θ

τ = pE sin θ $\quad (\because p = q \times 2l)$

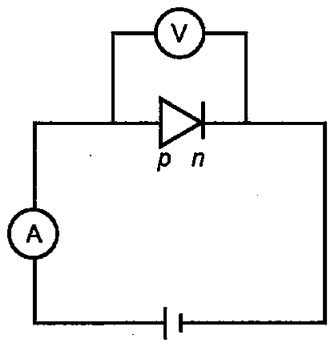
**Answers is not given due to change in the present Syllabus.

$$\vec{\tau} = \vec{p} \times \vec{E}$$

(b) If the field is non-uniform then there will be a net force acting on the dipole. Also, a net torque acting on the dipole which depends on the location of the dipole.

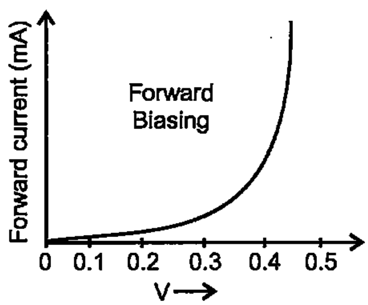
17. Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases. [3]

Answer : Forward biasing : If the positive terminal of the battery is connected to the p type semiconductor and negative terminal to the n type semiconductor then it is said to be in forward biased.

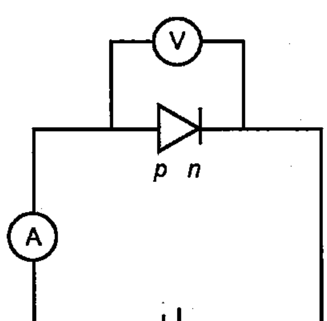


Forward biasing

Characteristics :

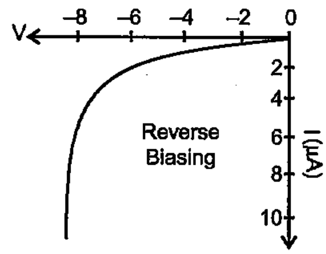


Reverse Biasing : If the positive terminal of the battery is connected to the n type semiconductor and the negative termal to the p type semiconductor then it is said to be reverse biased.



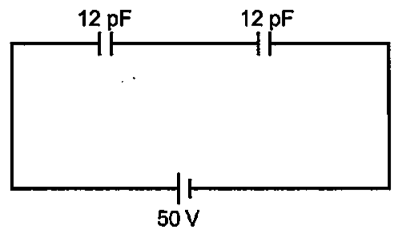
Reverse biasing

Characteristics :



20. Two identical capacitors of 12 pF each are connected in series across a battery of 50 V. How much electrostatic energy is stored in the combination ? If these were connected in parallel across the same battery, how much energy will be stored in the combination now ? Also find the charge drawn from the battery in each case. [3]

Answer : Case I : When the capacitors are connected in series.



The equivalent capacitance is given by

$$C_{eq} = \frac{12 \times 12}{12 + 12} = \frac{12 \times 12}{24}$$

$$C_{eq} = 6 \text{ pF} = 6 \times 10^{-12} \text{F}$$

Electrostatic energy,

$$U = \frac{1}{2} CV^2$$

$$= \frac{1}{2} \times 6 \times 10^{-12} \times 50 \times 50$$

$$U = 75 \times 10^{-10} \text{ J.}$$

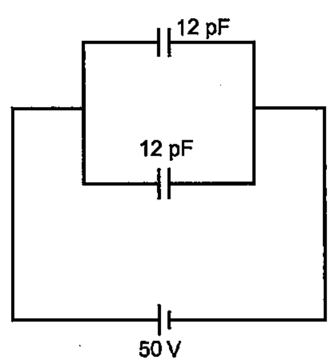
As the capacitors are connected in series so, the charge remains the same.

$\therefore$ $Q = C_{eq}V$

$Q = 6 \times 10^{-12} \times 50$

$Q = 300 \text{ pF} = 300 \times 10^{-12} \text{F}$

Case II : When the capacitors are connected is parallel.



The equivalent capacitance is given by,

$$C_{eq} = (12 + 12)\ pF$$
$$= 24\ pF = 20 \times 10^{-12} F$$

Electrostatic energy,

$$U = \frac{1}{2} \times 24 \times 10^{-12} \times (50)^2$$
$$U = 3 \times 10^{-8}\ J$$

As the capacitors are connected in parallel so, the charge on each capacitor is different but potential difference remains the same.

Charge on C_1,

$$Q_1 = C_1 V$$
$$Q_1 = 12 \times 10^{-12} \times 50$$
$$= 600 \times 10^{-12}\ F$$

Similarly, $Q_2 = 600 \times 10^{-12}\ F$

Total charge, $Q = Q_1 + Q_2$
$$= (600 + 600) \times 10^{-12}$$
$$= 1200 \times 10^{-12}$$
$$= 12 \times 10^{-10}\ F$$

21. (a) Write the expression for the force $\vec{F}$ acting on a particle of mass m and charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Under what conditions will it move in (i) a circular path and (ii) a helical path ?

(b) Show that the kinetic energy of the particle moving in magnetic field remains constant. **[3]**

Answer : (a) $\vec{F} = q(\vec{v} \times \vec{B}) = qvB \sin\theta$

(i) If the angle between v and B is 90° then it will move in circular path.

(ii) If the angle is other than, 0°, 90° and 180° the path will be helical.

(b) Since the work done on the charged particle moving in the magnetic field is zero because force experienced is perpendicular cannot bring any change in speed of charged particuler. Hence the change in K.E. is zero.

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Physics 2018

Time allowed : 3 hours **Maximum marks : 70**

SECTION–A

1. **A proton and an electron travelling along parallel paths enter a region of uniform magnetic field, acting perpendicular to their paths. Which of them will move in a circular path with higher frequency? [1]**

Answer : Frequency of revolution of a particle,

$$f = \frac{Bq}{2\pi m}$$

or $$f \propto \frac{1}{m}$$

Since mass of electron is less than that of proton, therefore, its frequency of revolution will be higher than that of proton.

2. **Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery. [1]**

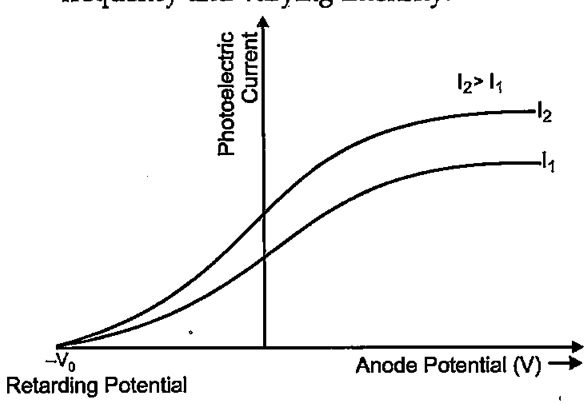
Answer :

(a) Water purification : Ultraviolet radiation.

(b) Eye surgery : Ultraviolet radiation/laser.

3. **Draw graphs showing variation of photoelectric current with applied voltage for two incident radiations of equal frequency and different intensities. Mark the graph for the radiation of higher intensity. [1]**

Answer : Graph for photoelectric current (I) versus applied potential for radiations of same frequency and varying intensity.



4. **Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two— the parent or the daughter nucleus—would have higher binding energy per nucleon? [1]**

Answer : When lighter nuclei combine to form a heavier nucleus, binding energy per nucleon increases and energy is released. Thus, the daughter nucleus would have higher binding energy per nucleon.

5. **Which mode of propagation is used by short wave broadcast services** [1]**

SECTION–B

6. **Two electric bulbs P and Q have their resistances in the ratio of 1 : 2. They are connected in series across a battery. Find the ratio of the power dissipation in these bulbs. [2]**

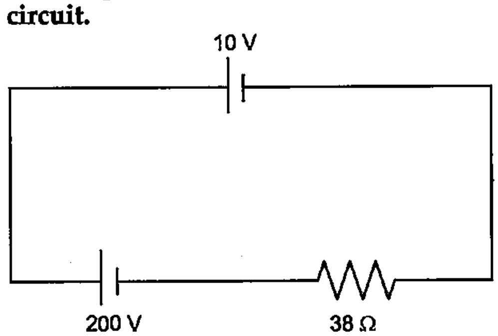
Answer : Let resistances of bulbs P and Q be R and 2R respectively.

As they are connected in series, so current through each bulb is same. Let the current be I.

$$\therefore \quad \frac{P_1}{P_2} = \frac{I^2R_1}{I^2R_2} = \frac{R_1}{R_2} = \frac{1}{2}$$

i.e. $$P_1 : P_2 = 1 : 2$$

7. **A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit. [2]**



OR

In a potentiometer arrangement for determining the emf of a cell, the balance point of the cell in open circuit is 350 cm. When a resistance of 9 Ω is used in the external circuit of the cell, the balance point shifts to 300 cm. Determine the internal resistance of the cell.

Answer: Given : $E_1 = 10\text{ V}; E_2 = 200\text{ V}, r = 38\ \Omega$, I = ?

Net emf, $E = E_2 - E_1$ ($\because$ two cells being in opposition)

$$= 200\text{ V} - 10\text{ V} = 190\text{ V}$$

$$\therefore \quad \text{Current, } I = \frac{\text{Net emf}}{\text{Resistance}} = \frac{190\text{ V}}{38\Omega} = 5\text{ A.}$$

OR

Balance point in open circuit, $l_1 = 350$ cm.

$R = 9\ \Omega$,

**Answers is not given due to change in the present Syllabus.

New balance point l_2 = 300 cm.

Internal resistance of a cell is given by,

$$r = R\left(\frac{l_1 - l_2}{l_2}\right) = 9\left(\frac{350-300}{300}\right) = 1.5\ \Omega.$$

8. (a) Why are infra-red waves often called heat waves ? Explain.

(b) What do you understand by the statement, "Electromagnetic waves transport momentum" ? **[1]**

Answer :

(a) Infra-red waves are called heat waves because they raise the temperature of the object on which they fall and hence increase their thermal motion. They also affect the photographic plate and are readily absorbed by most of the materials.

(b) Electromagnetic waves transport momentum. This means that when an electromagnetic wave travels through space with energy U and speed c, then it transports linear momentum $p = \frac{U}{c}$. If a surface absorbs the waves completely, then momentum 'p' is delivered to the surface. If the surface reflects the wave, then momentum delivered by both incident and reflected wave adds on to give '$2p$' momentum.

9. If light of wavelength 412.5 nm is incident on each of the metals given below, which ones will show photoelectric emission and why? **[2]**

Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

Answer : Wavelength of incident light,

$$\lambda = 412.5 \text{ nm}$$
$$= 412.5 \times 10^{-9} \text{n}$$

∴ Energy of incident light

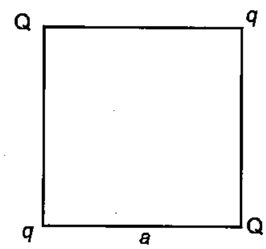
$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{412.5\times10^{-9}}$$
$$= 4.82 \times 10^{-19} \text{ J}$$
$$= \frac{4.82\times10^{-19}}{1.6\times10^{-19}} \text{ ev}$$
$$= 3.01 \text{ eV}$$

Since, the energy of incident radiation is greater than the work function of sodium and potassium, but less than that of calcium and molybdenum, therefore, photoelectric emission will take place in sodium and potassium.

10. A carrier wave of peak voltage 15 V is used to transmit a message signal. Find the peak voltage of the modulating signal in order to have a modulation index of 60%.** **[2]**

SECTION–C

11. Four point charges Q, q, Q and q are placed at the corners of a square of side 'a' as shown in the figure.



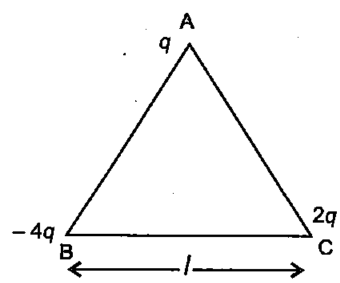
Find the

(a) resultant electric force on a charge Q, and

(b) potential energy of this system. **[3]**

OR

(a) Three point charges q, – 4q and 2q are placed at the vertices of an equilateral triangle ABC of side 'l' as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q.

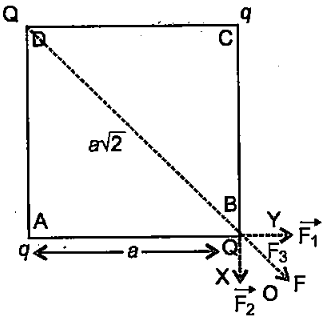


(b) Find out the amount of the work done to separate the charges at infinite distance.

Answer : (a) Force on charge Q at B due to charge q at A

$$F_1 = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{a^2} \text{ along } \overrightarrow{BY}$$

**Answers is not given due to change in the present Syllabus.



Force on charge Q at B due to charge q at c.

$$F_2 = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{a^2} \text{ along } \overrightarrow{BX}$$

Resultant force, $F = \sqrt{F_1^2 + F_2^2}$ along $\overrightarrow{BO}$

$$= \sqrt{2\left(\frac{1}{4\pi\varepsilon_0}\frac{qQ}{a^2}\right)^2}$$

$$= \frac{qQ\sqrt{2}}{4\pi\varepsilon_0 a^2}$$

Force due to charge Q = F_3

$$= \frac{1}{4\pi\varepsilon_0}\frac{QQ}{(\sqrt{2}a)^2} \text{ along } \overrightarrow{BO}$$

Total resultant force = F + F_3 along $\overrightarrow{BO}$

$$= \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}\,Qq}{a^2} + \frac{1}{4\pi\varepsilon_0}\frac{QQ}{2a^2}$$

$$= \left[\frac{1}{4\pi\varepsilon_0}\frac{Q}{a^2}\left(\sqrt{2}q + \frac{Q}{2}\right)\right] \text{ along } \overrightarrow{BO}$$

(b) Total potential energy of the system,

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Qq}{a} + \frac{Qq}{a} + \frac{Qq}{a} + \frac{Qq}{a} + \frac{QQ}{\sqrt{2}a} + \frac{qq}{\sqrt{2}a}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{4Qq}{a} + \frac{Q^2}{\sqrt{2}a} + \frac{q^2}{\sqrt{2}a}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[4Qq + \frac{Q^2 + q^2}{\sqrt{2}}\right]$$

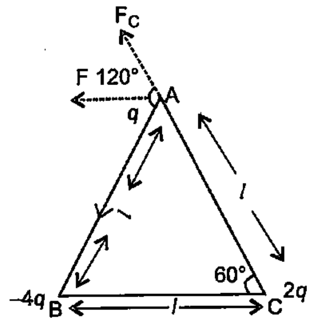
OR

(a) Electric force at A due to charge $2q$

$$F_C = \frac{1}{4\pi\varepsilon_0}\frac{q \times 2q}{l^2} \text{ along } \overrightarrow{CA}$$

Electric force at A due to charge $(-4q)$,

$$F_B = \frac{1}{4\pi\varepsilon_0}\frac{q \times (-4q)}{l^2} \text{ along } \overrightarrow{AB}$$



Resultant force,

$$F = \sqrt{F_B^2 + F_C^2 + 2F_BF_C \cos 120°}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q^2}{l^2}\sqrt{(-4)^2 + (2)^2 + 2(-4)(2)\left(-\frac{1}{2}\right)}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\sqrt{7}q^2}{l^2}$$

(b) Work done to separate the charges to infinity :

Initial potential energy,

$$U_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{(-4q)q}{l} + \frac{(-4q)(2q)}{l} + \frac{(q)(2q)}{l}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q^2}{l}[-4-8+2]$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{-10q^2}{l}\right)$$

Final potential energy, $U_f = 0$

Thus, work done

$$= U_f - U_i = 0 - \left(\frac{-10q^2}{4\pi\varepsilon_0 l}\right) = \frac{10q^2}{4\pi\varepsilon_0 l} = \frac{5q^2}{2\pi\varepsilon_0 l}$$

12. (a) Define the term 'conductivity' of a metallic wire. Write its SI unit.

(b) Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E. [3]

Answer :

(a) Conductivity of a metallic wire is defined as its ability to allow electric charges or heat to pass through it.

Numerically, conductivity of a material is reciprocal of its resistivity.

SI unit : ohm^{-1} m^{-1} or mho m^{-1} or Siemen m^{-1}.

(b) Consider a potential difference V be applied across a conductor of length l and cross-section A.

Electric field inside the conductor, $E = \frac{V}{l}$.

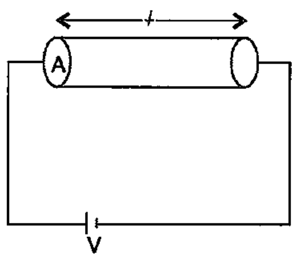
Due to the external field the free electrons inside the conductor drift with velocity v_d.

Let, number of electrons per unit volume = n,

charge on an electron = e

$\therefore$ Total electrons in length, $l = nAl$

And, total charge, $q = neAl$



Time taken by electrons to enter and leave the conductor,

$$t = \frac{l}{v_d}$$

$$\text{Current, } I = \frac{q}{t} = \frac{neAl}{l/v_d}$$

$$= neAv_d$$

$$\text{Current density, } J = \frac{I}{A} = nev_d \quad \text{....(i)}$$

$$\text{We know, } v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

$$\therefore \quad I = neAv_d = \frac{neAVe\tau}{ml}$$

$$\Rightarrow \quad \frac{V}{I} = \frac{ml}{ne^2\tau A}$$

$$\Rightarrow \quad R = \frac{ml}{ne^2\tau A}$$

$$[\because \frac{V}{I} = R;\ \text{Ohm's law}]$$

$$\text{Resistivity, } \rho = \frac{RA}{l} = \frac{mlA}{ne^2\tau A \times e}$$

$$\text{or} \quad \rho = m/ne^2\tau$$

$$\text{Since conductivity, } \sigma = \frac{1}{\rho}$$

$$\therefore \quad \sigma = \frac{ne^2\tau}{m} \quad \text{....(ii)}$$

Relation between current density and field :

For an electron, charge $q = -e$

And,

$$\text{current density, } J = \frac{I}{A} = -nev_d \quad \text{[from (i)]}$$

$$J = (-ne)\left(\frac{eE\tau}{m}\right)$$

$$= \left(\frac{ne^2\tau}{m}\right)E$$

$$\Rightarrow \quad J = \sigma E \quad \text{[from (ii)]}$$

which is the required relation.

13. A bar magnet of magnetic moment 6 J/T is aligned at 60° with a uniform external magnetic field of 0.44 T. Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii). **[3]**

Answer : Given, magnetic momentum, $m = 6$ JT^{-1}

External magnetic field, B = 0.44 T

$\theta_1 = 60° \Rightarrow \cos\theta_1 = \cos 60° = \frac{1}{2}$.

(a) Work done in turning the magnet normal to the field,

$$W = -mB(\cos\theta_2 - \cos\theta_1)$$

(i) Here, $\theta_2 = 90°$

$$\therefore \quad W = +mB\cos\theta_1$$

$$= 6 \times 0.44 \times \frac{1}{2} = 1.32\text{ J}$$

(ii) Here $\theta_2 = 180°$

$$\therefore \quad W = -mB(\cos\theta_2 - \cos\theta_1)$$

$$W = -6 \times 0.44\left(-1 - \frac{1}{2}\right)$$

$$= 3.96\text{ J}$$

(b) Torque on magnet when moment is aligned opposite to the field,

$$\text{Torque} = |\vec{m} \times \vec{B}|$$

$$\tau = mB\sin\theta$$

$$= 6 \times 0.44 \times \sin 180°$$

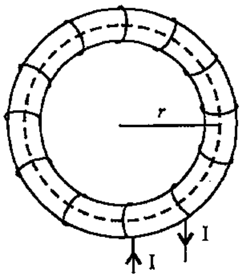
$$= 0 \quad (\because \sin 180° = 0)$$

14. (a) An iron ring of relative permeability μ_r has windings of insulated copper wire of n turns per metre. When the current in the windings is I, find the expression for the magnetic field in the ring.

(b) The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field. **[3]**

Answer : (a) Consider a ring of radius r having n turns per metre. Then total number of turns in the ring $= 2\pi rn = N$

Current enclosed $= NI = 2\pi r n I$.



By Ampere's circuital law, $\oint \vec{B}.\vec{dl} = \mu_0 \mu r I$

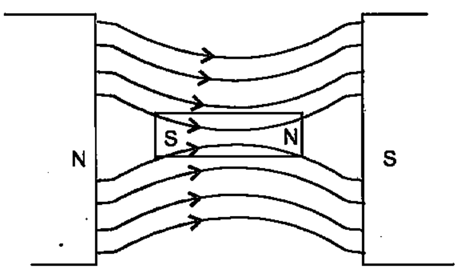
$$B \times 2\pi r = \mu_0 \mu r 2\pi r n I$$

or $$B = \mu_0 \mu r n I$$

(b) Given, susceptibility, $\chi = 0.9853$.

The material is paramagnetic in nature.

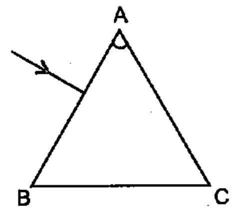
If a piece of this material is kept in uniform magnetic field, then field pattern gets modified as follows :



The lines of force tend to pass through the material rather than the surrounding air.

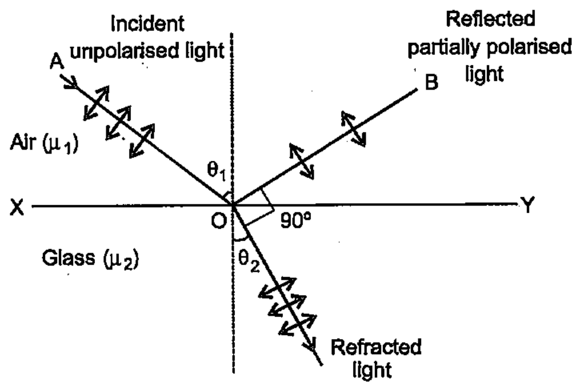
15. (a) Show using a proper diagram how unpolarised light can be linearly polarised by reflection from a transparent glass surface.

(b) The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index $\frac{3}{2}$, placed in water of refractive index $\frac{4}{3}$. Will this ray suffer total internal reflection on striking the face AC ? Justify your answer. **[3]**



Answer :

(a) Polarisation of light by reflection from a transparent glass surface :



(b) Given, ${}^a\mu_g = \frac{3}{2}$ and ${}^a\mu_g = \frac{4}{3}$

$${}^w\mu_g = \frac{{}^a\mu_g}{{}^a\mu_w} = \frac{3/2}{4/3} = \frac{9}{8} = 1.125$$

We know at critical angle C,

$${}^w\mu_g = \frac{1}{\sin C}$$

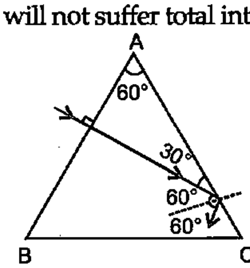
or $$\sin C = \frac{1}{{}^w\mu_g} = \frac{1}{1.125} = 0.88$$

i.e. $$C = 62.73°$$

But from the figure, light will incident on face AC making an angle 60° with the normal *i.e.*, $i = 60°$

So, $i < C$

$\therefore$ Light will not suffer total internal reflection.



16. (a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced

to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.

(b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light? [3]

Answer : (a) The resultant intensity in Young's experiment is given by

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

When slit is not covered, then I_0 is the intensity from each slit.

Maximum intensity (I_{max}) occurs when $\phi = 0°$.

Minimum intensity (I_{min}) occurs when $\phi = 180°$.

If one slit is covered with glass to reduce its intensity by 50%, then

$$I_{max} = I_0 + \frac{I_0}{2} + 2\sqrt{I_0 \times \frac{I_0}{2}}\cos 0°$$

$$= 1.5\,I_0 + 2 \times 0.707\,I_0 = 2.914\,I_0$$

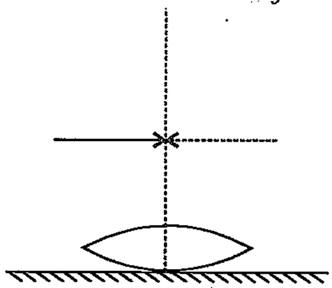
$$I_{min} = I_0 + \frac{I_0}{2} + 2\sqrt{I_0 \times \frac{I_0}{2}}\cos 180°$$

$$= 1.5\,I_0 - 2 \times 0.707\,I_0 = 0.086\,I_0$$

$$\text{Ratio} = \frac{I_{max}}{I_{min}} = \frac{2.914 I_0}{0.086 I_0} = 33.884 \simeq 34$$

(b) If instead of monochromatic light, white light is used, then the central fringe will be white and the fringes on either side will be coloured. Blue colour will be nearer to central fringe and red will be farther away. The path difference at the centre on perpendicular bisector of slits will be zero for all colours and each colour produces a bright fringe thus resulting in white fringe. Further, the shortest visible wave, blue, produces a bright fringe first.

17. A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle itself. The distance of the needle from the lens is measured to be x. On removing the liquid layer and repeating the experiment, the distance is found to be y. Obtain the expression for the refractive index of the liquid in terms of x and y. [3]



Answer :

Given, refractive index of lens, $\mu_g = 1.5$

The distance of the needle from the lens in the first case = The focal length of the combination of convex lens and plano-concave lens formed by the liquid, $f = x$

And, the distance measured in the second case = Focal length of the convex lens, $f_1 = y$

If the focal length of plano-concave lens formed by the liquid be f_2, then

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \quad \frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{1}{x} - \frac{1}{y}$$

$$= \frac{y-x}{xy}$$

$$\text{or} \quad f_2 = \frac{xy}{y-x}$$

Now, refractive index of lens, $\mu = 1.5$, radius of curvature of one surface = R and radius of curvature of other surface = – R

$$\therefore \quad \frac{1}{f_1} = (\mu_g - 1)\left(\frac{1}{R} - \frac{1}{-R}\right)$$

$$\frac{1}{y} = (1.5 - 1)\left(\frac{2}{R}\right) \Rightarrow R = y$$

And, if refractive index of liquid is μ_l,

Radius of curvature on the side of plane mirror = ∞

Radius of curvature on the side of lens = – R

$$\because \quad \frac{y-x}{xy} = (\mu_l - 1)\left(\frac{1}{-R} - \frac{1}{\infty}\right)$$

$$= (\mu_l - 1)\left(-\frac{1}{y}\right)$$

$$\Rightarrow \quad (\mu_l - 1) = -\left(\frac{y-x}{x}\right)$$

$$\text{or} \quad \mu_l = \frac{x-y}{x} + 1$$

$$= \frac{2x-y}{x}$$

18. (a) State Bohr's postulate to define stable-orbits in hydrogen atom. How does de Broglie's hypothesis explain the stability of these orbits ?

(b) A hydrogen atom initially in the ground state absorbs a photon which excites it to the $n = 4$ level. Estimate the frequency of the photon. [3]

Answer : (a) Bohr's postulate for stable orbits in hydrogen atom : An electron can revolve only in those circular orbits in which its angular momentum is an integral multiple of $h/2\pi$, where h is planck's constant.

If n is the principal quantum number of orbit, then an electron can revolve only in certain orbits or definite radii. These are called stable orbits.

de Broglie explanation of stability of orbits: According to de Broglie, orbiting electron around the nucleus is associated with a stationary wave. Electron wave is a circular standing wave. Since destructive interference will occur if a standing wave does not close upon itself, only those de Broglie waves exist for which the circumference of circular orbit contains a whole number of wavelengths *i.e.,* for orbit circumference of n^{th} orbit as $2\pi r_n$,

$$2\pi r_n = n\lambda$$

$$2\pi r_n = n\left(\frac{h}{mv}\right)$$

or $$mvr_n = n\left(\frac{h}{2\pi}\right)$$

which is quantum condition proposed by Bohr.

(b) In ground state, $n = 1$

In excited state, $n = 4$

$$\frac{1}{\lambda} = R\left[\frac{1}{(1)^2} - \frac{1}{(4)^2}\right], \text{ where R is Rydberg constant}$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{15}{16} = 10284375$$

$$\doteq 1.028 \times 10^7 \text{ m}^{-1}$$

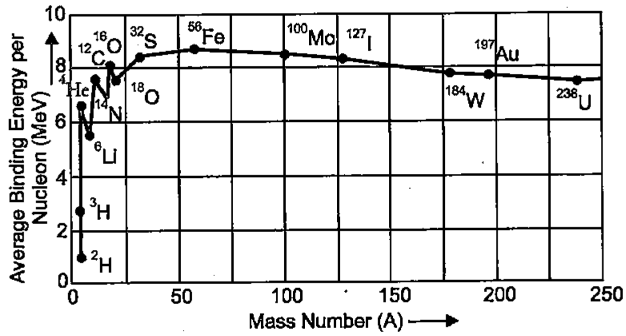
$$\text{Frequency, } \nu = \frac{c}{\lambda} = 3 \times 10^8 \times 1.028 \times 10^7$$

$$= 3.09 \times 10^{15} \text{ Hz}$$

19. (a) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A.

(b) A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3.125% ? [3]

Answer : (a) Plot of binding energy per nucleon mass number :



1. When we move from the heavy nuclei region to the middle region of the plot, we find that there will be a gain in the overall binding energy and hence results in release of energy. This indicates that energy can be released when a heavy nucleus ($A \approx 240$) breaks into two roughly equal fragments. This process is called nuclear fission.
2. Similarly, when we move from lighter nuclei to heavier nuclei, we again find that there will be gain in the overall binding energy and hence release of energy takes place. This indicates that energy can be released when two or more lighter nuclei fuse together to form a heavy nucleus. This process is called nuclear fusion.

(b) We know that, $\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$

Given, $$\frac{R}{R_0} = 3.125\% = \frac{3.125}{100}$$

$$\therefore \quad \frac{3.125}{100} = \left(\frac{1}{2}\right)^n$$

or $$\frac{1}{32} = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \quad \left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \quad n = 5$$

Given, T = 10 years

As $$n = \frac{t}{T}$$

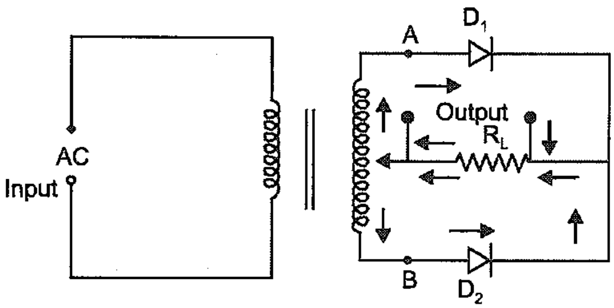
$$\therefore \quad \frac{t}{T} = 5 \quad [\because T = 10 \text{ year}]$$

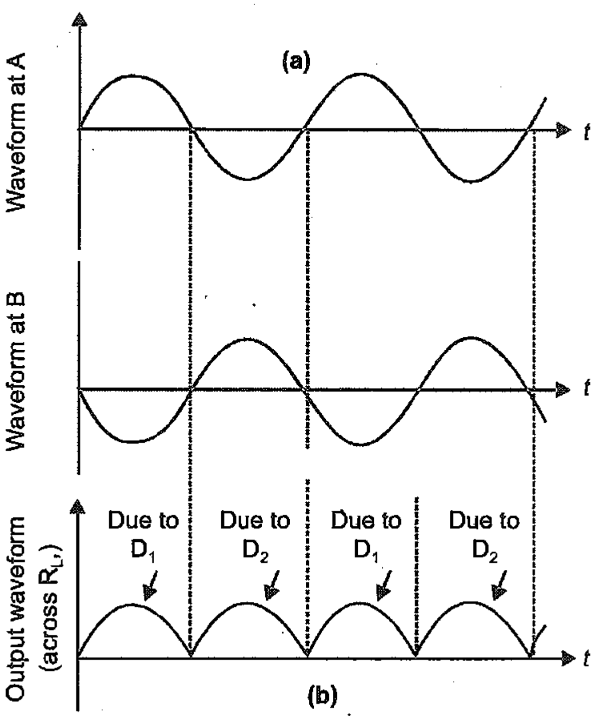
or $$t = 5 \times 10 = 50 \text{ years}$$

20. (a) A student wants to use two *p-n* junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works.

(b) Give the truth table and circuit symbol for NAND gate. [3]**

Answer : (a) Full wave rectifier :





Explanation : In positive half cycle of AC, end A becomes positive and D_1 becomes forward biased and D_2 is reverse biased, so D_1 conducts and D_2 doesn't. So conventional current flows through D_1, R_L and upper half of secondary winding. Similarly, during negative half cycle of AC, diode D_2 becomes forward biased and D_1 is reverse biased, current flows through D_2, R_L and lower half of secondary winding. Thus, current flows in same direction in both half cycles of input AC voltage.

21. Draw the typical input and output characteristics of an *n-p-n* transistor in CE configuration. Show how these characteristics can be used to determine (a) the input resistance (r_i), and (b) current amplification factor (β). [3]**

22. (a) Give three reasons why modulation of a message signal is necessary for long distance transmission.**

(b) Show graphically an audio signal, a carrier wave and an amplitude modulated wave. [3]**

SECTION–D

23. The teachers of Geeta's school took the students on a study trip to a power generating station, located nearly 200 km away from the city. The teacher explained that electrical energy is transmitted over such a long distance to their city, in the form of alternating current (ac) raised to a high voltage. At the receiving end in the city, the voltage is reduced to operate the devices. As a result, the power loss is reduced. Geeta listened to the teacher and asked questions about how the ac is converted to a higher or lower voltage. [4]

(a) Name the device used to change the alternating voltage to a higher or lower value. State one cause for power dissipation in this device.

(b) Explain with an example, how power loss is reduced if the energy is transmitted over long distances as an alternating current rather than a direct current.

(c) Write two values each shown by the teachers and Geeta.**

Answer : (a) The device used to change alternating voltage to a higher or lower value is a transformer.

Causes of power dissipation in this device are :

1. Core losses due to eddy currents and hysteresis loop due to alternating flux.
2. Copper losses due to resistance of winding in primary and secondary coils.

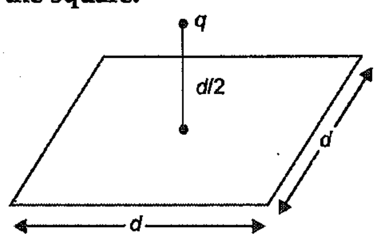
**Answers is not given due to change in the present Syllabus.

3. Loss of power due to leakage of magnetic flux in coil.

(b) The loss of power in the transmission lines is I^2R, where I is the strength of current and R is the resistance of the wires. To reduce the power loss a.c. is transmitted over long distances at extremely high voltages. This reduces I in the same ratio. Therefore, I^2R becomes negligibly low.
For the same reason, at the generating stations, the voltage is stepped up to transmit it over long distances to minimize power loss. Therefore a.c. is used because stepping up is not possible for direct current.

SECTION–E

24. (a) Define electric flux. Is it a scalar or a vector quantity ? A point charge q is at a distance of $d/2$ directly above the centre of a square of side d, as shown in the figure. Use Gauss' law to obtain the expression for the electric flux through the square.



(b) If the point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected. [5]

OR

(a) Use Gauss' law to derive the expression for the electric field (E) due to a straight uniformly charged infinite line of charge density λ C/m.

(b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.

(c) Find the work done in bringing a charge q from perpendicular distance r_1 to r_2 ($r_2 > r_1$).

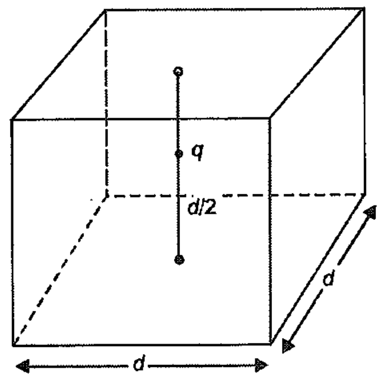
Answer : (a) Electric flux : Electric flux through an area is defined as the product of electric field strength E and area dS perpendicular to the field. It represents the field lines crossing the area. It is a scalar quantity.
Imagine a cube of edge d, enclosing the charge. The square surface is one of the six faces of this cube. According to Gauss' theorem in electrostatics,

Total electric flux through the cube $= \dfrac{q}{\varepsilon_0}$

This is the total flux through all six surtace

∴ Electric flux through the square surface

$$= \frac{q}{\sigma\varepsilon_0}$$



(b) On moving the charge to distance d from the centre of square and making side of square $2d$, does not change the flux at all because flux is independent of side of square or distance of charge in this case.

OR

(a) Electric field $(\vec{E})$ due to a straight uniformly charged infinite line of charge density λ : Consider a cylindrical Gaussian surface of radius r and length l coaxial with line charge. The cylindrical Gaussian surface may be divided into three parts : (i) curved surface S_1 (ii) flat surface S_2 and (iii) flat surface S_3.
By symmetry, the electric field has the same magnitude E at each point of curved surface S_1 and is directed radially outward. We consider small elements of surfaces S_1, S_2 and S_3. The surface element vector $\vec{dS}$ is directed along the direction of electric field (*i.e.,* angle between $\vec{E}$ and $d\vec{S_1}$ is 0°); the elements $d\vec{S_2}$ and $d\vec{S_3}$ are directed perpendicular to field vector $\vec{E}$ (*i.e.,* angle between $d\vec{S_2}$ and $\vec{E}$, and $d\vec{S_3}$ and $\vec{E}$ is 90°).
Electric flux through the cylindrical surface,

$$\oint_S \vec{E}.d\vec{S} = \oint_{S_1} \vec{E}.d\vec{S_1} + \oint_{S_2} \vec{E}.d\vec{S_2} + \oint_{S_3} \vec{E}.d\vec{S_3}$$

$$= \oint_{S_1} E dS_1 \cos 0° + \oint_{S_2} E dS_2 \cos 90° + \oint_{S_3} E dS_3 \cos 90°$$

$$= E\int dS_1 + 0 + 0$$

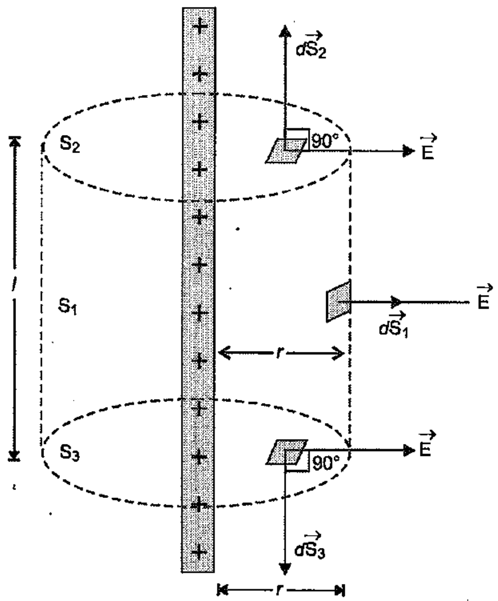
$= E \times$ area of curved surface $= E \times 2\pi rl$

Total Charge enclosed, $q = \lambda l$
and flux,
By Gauss' theorem,

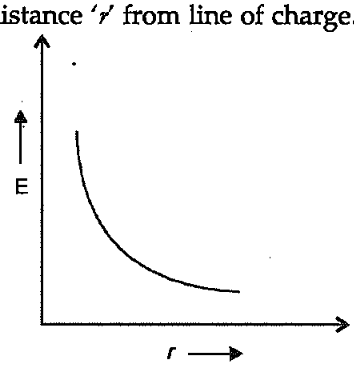
$$\oint_E = \frac{\lambda l}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$$

$$E.\ 2\pi r l = \frac{\lambda l}{\varepsilon_0}$$

or $$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$



(b) Graph showing variation of E with perpendicular distance from line of charge : The electric field is inversely proportional to distance 'r' from line of charge.



(c) Work done in bringing a charge q through a small displacement 'dr'.

$$dW = \vec{F}.\vec{dr}$$

$$dW = q\vec{E}.\vec{dr}$$

$$= qEdr \cos 0°$$

$$dW = q \times \frac{\lambda}{2\pi\varepsilon_0 r} dr$$

Work done in moving the given charge from r_1 to r_2 $(r_2 > r_1)$

$$W = \int_{r_1}^{r_2} dW = \int_{r_1}^{r_2} \frac{\lambda q dr}{2\pi\varepsilon_0 r}$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}[\log_e r_2 - \log_e r_1]$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}.\log^e\left(\frac{r_2}{r_1}\right)$$

25. (a) State the principle of an ac generator and explain its working with the help of a labelled diagram. Obtain the expression for the emf induced in a coil having N turns each of cross-sectional area A, rotating with a constant angular speed 'ω' in a magnetic field $\vec{B}$, directed perpendicular to the axis of rotation.

(b) An aeroplane is flying horizontally from west to east with a velocity of 900 km/hour. Calculate the potential difference developed between the ends of its wings having a span of 20 m. The horizontal component of the Earth's magnetic field is 5×10^{-4} T and the angle of dip is 30°. **[5]**

OR

A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current through X is given as $I = I_0 \sin \left(\omega t + \frac{\pi}{2}\right)$

(a) Identify the device X and write the expression for its reactance.

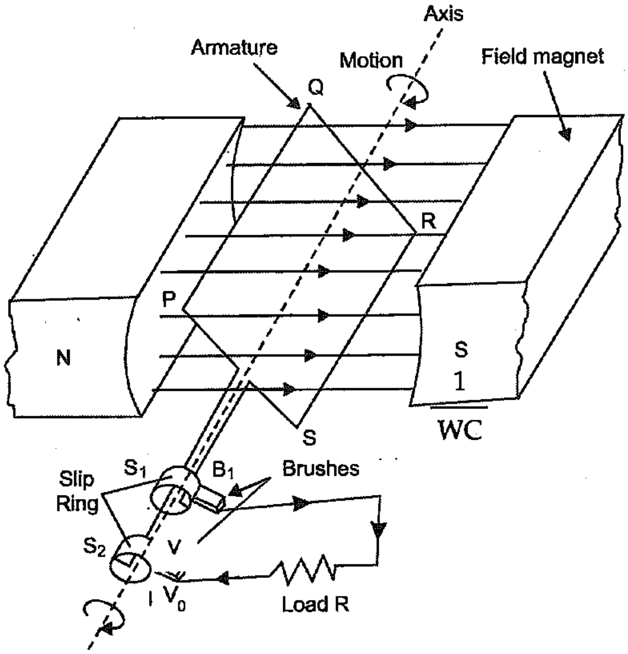
(b) Draw graphs showing variation of voltage and current with time over one cycle of ac, for X.

(c) How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.

(d) Draw the phasor diagram for the device X.

Answer : (a) Principle of ac generator : The ac generator is based on the principle of electromagnetic induction. When closed coil is rotated in a uniform field with its axis perpendicular to field, then magnetic flux changes and emf is induced.

Working : When the armature coil rotates, the magnetic flux linked with it changes and produces induced current. If initially, coil PQRS is in vertical position and rotated clockwise, then PQ moves down and SR moves up. By Fleming's right hand rule, induced current flows from Q to P and S to R which is the first half rotation of coil. Brush B_1 is positive terminal and B_2 is negative. In second half rotation, PQ moves up and SR moves down. So induced current reverses and the alternating current is produced in this manner by the generator.



Expression for emf ind$\frac{3\pi}{2}$1 : If number of turns in coil = N, cross-section = A, angular speed of rotation = ω, magnetic field = $\vec{B}$, then to find emf induced,

Flux through the coil when its normal makes angle θ with the field,

$$\phi = BA \cos \theta$$

When coil rotates with angular velocity ω and turns through θ in time 't' then $\theta = \omega t$

$$\Rightarrow \quad \phi = BA \cos \omega t$$

When coil rotates, ϕ changes to set an induced emf.

$$\varepsilon = \frac{-d\phi}{dt} = -\frac{d}{dt}(BA \cos \omega t)$$

$$= BA\,\omega \sin \omega t$$

For N turns, total induced emf,

$$\varepsilon = NBA\,\omega \sin \omega t$$

(b) Given : Velocity (v)

$$= 900 \text{ km/h} = 900 \times \frac{5}{18} \text{ m/s}$$

$$= 250 \text{ ms}^{-1}$$

Wing span (l) = 20 m

Horizontal component of earth's field (B_H) = 5×10^{-4} T

Angle of dip (δ) = 30°

Pontential difference

$$B_V = B_H \tan \delta$$

$$= 5 \times 10^{-4} \times \tan 30°$$

$$= 5 \times 10^{-4} \times \frac{1}{1.732}$$

emf induced $= B_V lv$

$$= \frac{5 \times 10^{-4}}{1.732} \times 20 \times 250$$

$$= 1.44\text{V}$$

OR

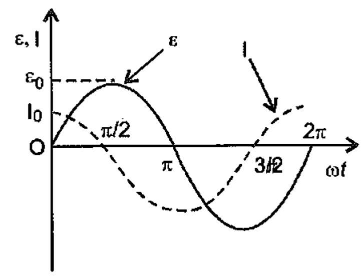
$$V = V_0 \sin \omega t \,;\, I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right).$$

(a) Since current leads the voltage by $\frac{\pi}{2}$ radians, X is a capacitor.

Capacitive reactance, X_C = $= \frac{1}{2\pi f C}$

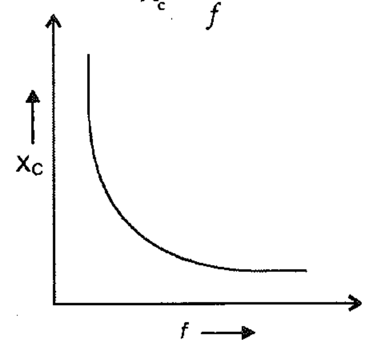
where, ω = angular velocity, C = capacitance.

(b)

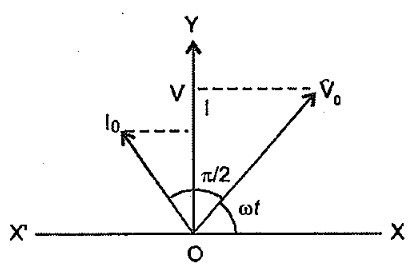


(c) Capacitive reactance varies inversely with frequency as $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

$$X_c \times \frac{1}{f}$$



(d)



26. (a) **Draw a ray diagram to show image formation when the concave mirror produces a real, inverted and magnified image of the object.**

(b) **Obtain the mirror formula and write the expression for the linear magnification.**

(c) **Explain two advantages of a reflecting**

telescope over a refracting telescope. [5]

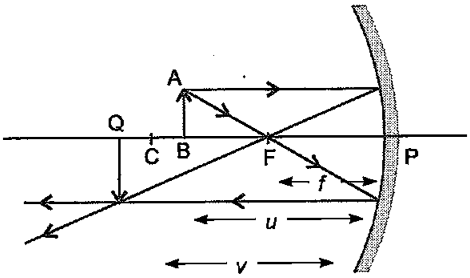
OR

(a) Define a wavefront. Using Huygens' principle, verify the laws of reflection at a plane surface.

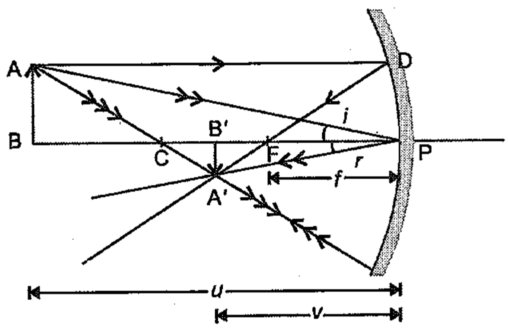
(b) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ? Explain.

(c) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the obstacle. Explain why ?

Answer : (a) Concave mirror produces real, inverted and magnified image for object placed between F and C :



(b) Derivation for mirror formula and magnification: Consider an object AB be placed in front of a concave mirror beyond centre of curvature C.



If F is the focus, focal length = f; object distance = u; image distance = v

As Δs ABC and A'B'C are similar,

$$\frac{AB}{A'B'} = \frac{CB}{CB'} \quad \text{... (i)}$$

Again, as Δs ABP and A'B'P are similar

$$\frac{AB}{A'B'} = \frac{PB}{B'P} \quad \text{... (ii)}$$

$$\Rightarrow \quad \frac{CB}{CB'} = \frac{PB}{PB'} \quad \text{... (iii)}$$

$$\therefore \text{ From (iii), } \frac{PB-PC}{PC-PB'} = \frac{PB}{PB'}$$

$$\Rightarrow \quad \frac{-u+R}{-R+v} = \frac{-u}{v}$$

$[\because PB = -u, PC = -R, PB' = -v]$

$$\Rightarrow \quad uR + vR = 2uv$$

$$\Rightarrow \quad \frac{1}{v}+\frac{1}{u}=\frac{2}{R}$$

$$\Rightarrow \quad \boxed{\frac{1}{v}+\frac{1}{u}=\frac{1}{f}} \quad (\because R = 2f)$$

$$\text{Linear magnification, } m = \frac{\text{Image height } (h_i)}{\text{Object height } (h_0)}$$

$$\text{From equation (ii), } \frac{A'B'}{AB} = \frac{PB'}{PB}$$

Using new Cartesian sign conventions, A'B' $= -h_2$, AB $= +h_1$, PB' $= -v$, PB $= -u$

$$\therefore \quad \frac{-h_2}{h_1} = \frac{-v}{u} = \frac{v}{u}$$

$$\text{or} \quad m = \frac{h_2}{h_1} = \frac{-v}{u}$$

(c) Advantages of reflecting telescope over a refracting telescope are :

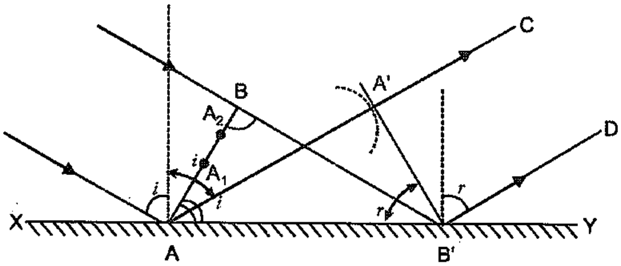
1. Reflecting telescope is free from chromatic and spherical aberrations unlike refracting telescope. Thus image formed is sharp and bright.
2. It has a larger light gathering power so that a bright image of even far off object is obtained.
3. Resolving power of reflecting telescope is large.

OR

(a) Wavefront is defined as the continuous locus of all the particles of a medium which are vibrating in the same phase.

Verification of laws of reflection using Huygen's principle : Let XY be a reflecting surface at which a wavefront is being incident obliquely. Let v be the speed of the wavefront and at time $t = 0$, the wavefront touches the surface XY at A. After time t, point B of wavefront reaches the point B' of the surface.

According to Huygen's principle each point of wavefront acts as a source of secondary waves. When the point A of wavefront strikes the reflecting surface, then due to presence of reflecting surface, it cannot advance further; but the secondary wavelet originating from point A begins to spread in all directions in the first medium with speed v. As the wavefront AB advances further, its points A_1, A_2, A_3 .... etc. strike the reflecting surface successively and send spherical secondary wavelets in the first medium.



First of all the secondary wavelet starts from point A and traverses distance AA′ (= vt) in first medium in time t. In the same time t, the point B of wavefront, after travelling a distance BB′, reaches point B′ (of the surface), from where the secondary wavelet now starts. Now taking A as centre we draw a spherical arc of radius AA′(= vt) and draw tangent A′B′ on this arc from point B′. As the incident wavefront AB advances, the secondary wavelets starting from points between A and B′, one after the other and will touch A′B′ simultaneously. According to Huygen's principle wavefront A′B′ represents the new position of AB, *i.e.*, A′B′ is the reflected wavefront corresponding to incident wavefront AB.

Now in right-angled triangles ABB' and AA′B′

$$\angle ABB' = \angle AA'B' = 90^\circ$$
$$BB' = AA' = vt$$

and AB′ is common

i.e., both triangles are congruent.

$$\therefore \quad \angle BAB' = \angle AB'A'$$

i.e, incident wavefront AB and reflected wavefront A′B′ make equal angles with the reflecting surface XY. As the rays are always normal to the wavefront, therefore the incident and the reflected rays make equal angles with the normal drawn on the surface XY, *i.e.*,

angle of incidence i = angle of reflection r

This is the second law of reflection.

Since AB, A'B' and XY are all in the plane of paper, therefore the perpendiculars dropped on them will also be in the same plane. Therefore, we conclude that the incident ray, reflected ray and the normal at the point of incidence, all lie in the same plane. This is the first law of reflection. Thus, Huygen's principle explains both the laws of reflection.

(b) Width of central diffraction band = $2D.\frac{\lambda}{a}$

where a is the width of the slit.

So, on doubling the width of the slit, the size of the central diffraction band reduces to half value. But, the light amplitude becomes double, which increases the intensity four fold.

(c) If a tiny circular obstacle is kept in the path of light, a bright spot is seen at the centre of the obstacle. This is because the waves which get diffracted from the edge of the circular obstacle interfere constuctively at the centre of the shadow producing a bright spot.

Note : All the sets of outside Delhi and Delhi are same.

Physics 2017 (Outside Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

SECTION – A

1. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more ? Justify your answer. [1]

Answer :

We know that, $R = \rho\frac{l}{A}$

$$\frac{R_{Cu}}{R_{Ni}} = \frac{\rho_{Cu}}{\rho_{Ni}}$$

$$\because \quad \rho_{Cu} < \rho_{Ni}$$

$$\therefore \quad R_{Cu} < R_{Ni}$$

$$\because \quad H = I^2Rt$$

$$H \propto R$$

$\therefore$ Nichrome wire will get heated up more.

2. Do electromagnetic waves carry energy and momentum ? [1]

Answer : Yes, the electromagnetic waves carry energy and momentum because,

$$\text{Energy, } E = h\upsilon$$

$$\text{Momentum, } p = \frac{h}{\lambda}$$

3. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light ? Give reason. [1]

Answer : We have, $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)}$

$\therefore \qquad \mu \propto \delta_m$

And $\qquad \mu_{red} < \mu_{violet}$

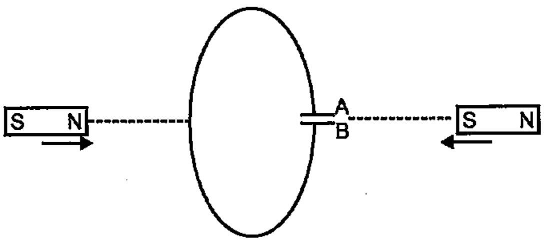
angle of minimum deviation

$\therefore$ Angle of minimum deviation (Sm) ill decrease.

4. Name the phenomenon which shows the quantum nature of electromagnetic radiation. [1]

Answer : Photoelectric effect.

5. Predict the polarity of the capacitor in the situation described below : [1]



Answer : A will be positive and B will be negative.

SECTION – B

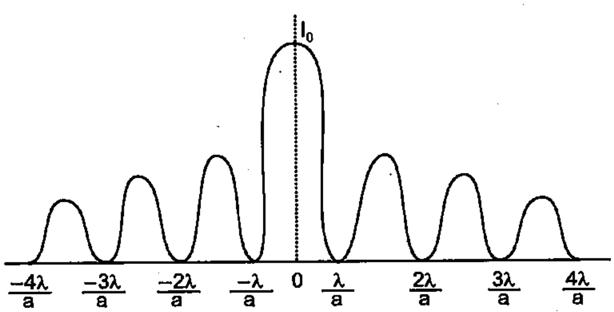
6. Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns. [2]

OR

Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. Draw a plot showing the variation of intensity when θ varies from 0 to 2π.

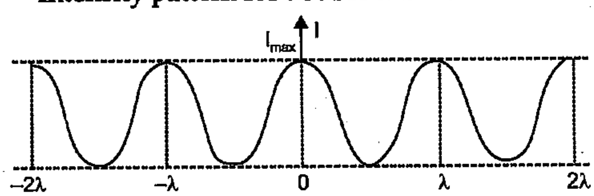
Answer :

Intensity pattern for single slit diffraction :



Path difference

Intensity pattern for double slit interference :



Path difference

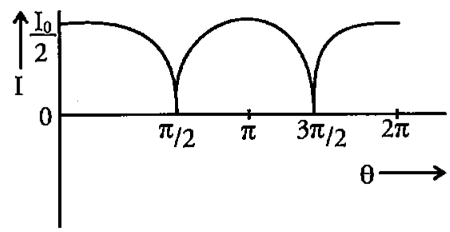
Difference between interference and diffraction patterns :

(a) Interference fringes are of the same width while diffraction fringes are not of the same width.

(b) In interference pattern all bright bands are of same intensity while in diffraction pattern all bright bands are not of same intensity.

OR

$$I = \frac{I_0}{2}\cos^2\theta$$



7. Identify the electromagnetic waves whose wavelengths vary as

(a) 10^{-12} m $< \lambda < 10^{-8}$ m

(b) 10^{-3} m $< \lambda < 10^{-1}$ m

Write one use for each. [2]

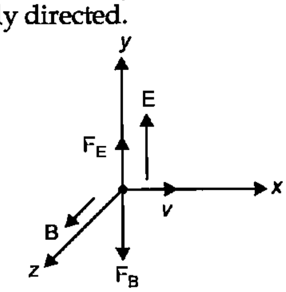
Answer : (a) X-rays $\rightarrow$ To detect fractures in the human body.

(b) Microwaves $\rightarrow$ For aircraft navigation in RADAR systems.

8. Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed. [2]

Answer : (a) The velocity $\vec{v}$, of the charged particles, and the $\vec{E}$ and $\vec{B}$ vectors, should be mutually perpendicular.

Also the forces on q, due to $\vec{E}$ and $\vec{B}$, must be oppositely directed.



(b) If magnetic force = electrostatic force

$$F_m = F_e$$

$$qvB = qE$$

$$v = \frac{E}{B}$$

9. A 12.5 eV electron beam is used to excite a gaseous hydrogen atom at room temperature. Determine the wavelengths and the corresponding series of the lines emitted. [2]

Answer : Given : $\Delta E = 12.5$ eV

Let the electron jump from $n = 1$ to $n = n$ level.

$$\Delta E = E_n - E_1$$

$$\therefore \quad 12.5 = -\frac{13.6}{n^2} - \left(\frac{-13.6}{1^2}\right)$$

$$12.5 = 13.6\left(1 - \frac{1}{n^2}\right)$$

$$1 - \frac{12.5}{13.6} = \frac{1}{n^2}$$

$$\frac{1.1}{13.6} = \frac{1}{n^2}$$

$$\frac{13.6}{1.1} = n^2$$

$$12.36 = n^2$$

$$n = 3.5$$

$$\therefore \quad n = 3^{rd}$$

For $n = 3$ to $n = 1$,

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(1 - \frac{1}{9}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{8}{9}$$

$$\lambda = 102.55 \text{ nm}$$

For $n = 2$ to $n = 1$,

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{3}{4}\right)$$

$$\lambda = 121.54 \text{ nm}$$

For $n = 3$ to $n = 2$,

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{5}{36}$$

$$\lambda = 656.33 \text{ nm}$$

Hence, λ = 102.5 nm and 121.5 nm → Lyman series

and λ = 656.33 nm → Balmer series

10. Write two properties of a material suitable for making (a) a permanent magnet, and (b) an electromagnet. [2]

Answer : Properties of a material suitable for making permanent magnet :

1. High retentivity.
2. High coercivity.

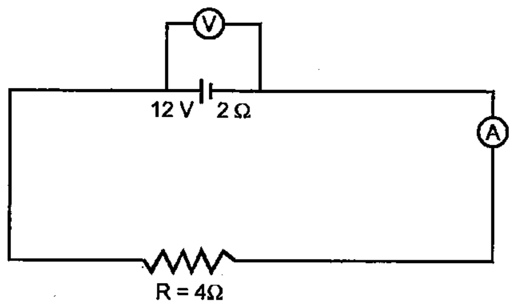
Properties of a material suitable for making electromagnet :

1. High permeability.
2. Low retentivity.

SECTION – C

11. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change ?

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having the internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings. [3]



Answer : (a) Heat produced,

$$H = \frac{V^2}{R}t$$

$$\Rightarrow \quad H \propto V^2$$

$$\frac{H'}{H} = \frac{V'^2}{V^2}$$

$$\frac{9H}{H} = \frac{V'^2}{V^2} \qquad [\because H' = 9H]$$

$$V'^2 = 9V$$

$$V' = 3V$$

So, potential difference is increased by a factor of 3.

(b) Current, $I = \dfrac{E}{R+r}$

$$I = \frac{12}{4+2} = \frac{12}{6} = 2\text{ A}$$

Ammeter reading = 2 A

Potential difference,

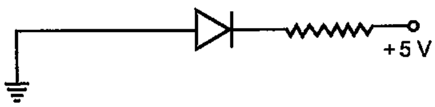
$$V = E - Ir$$
$$V = 12 - 2 \times 2$$
$$= 12 - 4$$
$$V = 8\text{ V}$$

Voltmeter reading = 8 V.

12. (a) How is amplitude modulation achieved ?**

(b) The frequencies of two side bands in an AM wave are 640 kHz and 660 kHz respectively. Find the frequencies of carrier and modulating signal. What is the bandwidth required for amplitude modulation ? [3]**

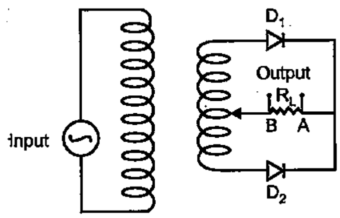
13. (a) In the following diagram, is the junction diode forward biased or reverse biased ?

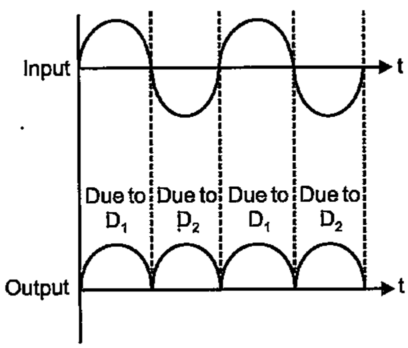


(b) Draw the circuit diagram of a full wave rectifier and state how it works. [3]

Answer : (a) Reverse biased.

(b) Full wave Rectifier :





Diode D_1 conducts only when the junction is forward biased. Hence during first half cycle of input A.C., D_1 will conduct while D_2 will not and current in R_L will flow from A to B. Diode D_2 is reverse biased. During second half cycle of input A.C., diode D_2 will conduct while D_1 will not conduct and current will again flow from A to B in R_L. Hence complete cycle will become unidirectional.

14. Using photon picture of light, show how Einstein's photoelectric equation can be established. Write two features of photoelectric effect which cannot be explained by wave theory. [3]

Answer : Einstein's photoelectric equation : Einstein explained the various laws of photoelectric emission on the basis of Planck's quantum theory. According to Planck's quantum theory, light radiations consist of tiny packets of energy called quanta. One quantum of light radiation is called a photon which travels with the speed of light.

The energy of a photon is given by,

$$E = h\nu$$

where h is Planck's constant and υ is the frequency of light radiation.

Einstein assumed that one photoelectron is ejected from a metal surface if one photon of suitable light radiation falls on it.

Consider a photon of light of frequency υ, incident on a photosensitive metal surface. The energy of the photon $(= h\nu)$ is spent in two ways :

(a) A part of the energy of the photon is used in liberating the electron from the metal surface which is equal to the work function ϕ_0 of the metal.

(b) The rest of the energy of the photon is used in imparting the kinetic energy to the emitted photo electron.

If v_{max} is the maximum velocity of the emitted photoelectron and m is its mass, then

Max. K.E. of the photoelectron,

$$K_{max} = \frac{1}{2} mv^2_{max}$$

$$\therefore \quad h\upsilon = \phi_0 + \frac{1}{2} mv^2_{max}$$

This equation is called Einstein's photoelectric equation.

Features of photoelectric effect which can not be explained by wave theory :

1. The wave theory could not explain the instantaneous process of photoelectric effect.
2. Maximum fcinetic energy' of the emitted photoetectrous is independent of intensity of incident light.

15. (a) Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light.

(b) A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of

curvature required, if the focal length is 20 cm. **[3]**

Answer :

(a) Given : $\mu = 1.33$

$\lambda_a = 589$ nm

We know that, $\mu = \frac{c}{v}$

$$v = \frac{c}{\mu} = \frac{3\times10^8}{1.33}$$

Speed, $v = 2.26 \times 10^8$ m/s

Frequency remains same.

$$\therefore \quad \nu = \frac{c}{\lambda_a} = \frac{3\times10^8}{589\times10^{-9}}$$

Frequency, $\nu = 5.09 \times 10^{14}$ Hz

$$\text{Wavelength, } \lambda_w = \frac{\lambda a}{\mu} = \frac{589\,nm}{1.33} = 442.8 \text{ nm}$$

(b) Given : $\mu = 1.55, f = 20$ cm

We know that, $$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{20} = (1.55-1)\left(\frac{1}{R}+\frac{1}{R}\right)$$

$$\frac{1}{20} = 0.55 \times \frac{2}{R}$$

$$R = 20 \times 0.55 \times 2$$

$$R = 22 \text{ cm}$$

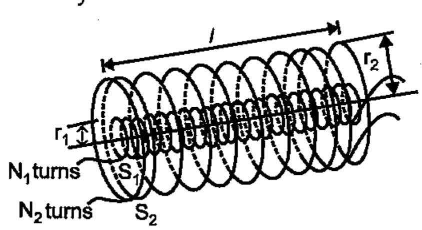
16. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other. **[3]**

OR

Define self-inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf.

Answer : Mutual inductance is numerically equal to the induced e.m.f in the secondary coil when the current in the primary coil changes by unity.

Suppose two long co-axial solenoids each of length l. We denote the area of the inner solenoid S_1 by A_1 and the number of turns per unit length by n_1. The corresponding quantities for the outer solenoid S_2 are A_2 and n_2 respectively. Let N_1 and N_2 be the total number of turns of coils S_1 and S_2 respectively.



When a current I_2 is set up through S_2, it in turn sets up a magnetic flux through S_1. Let us denote it by ϕ_1.

The magnetic field due to current I_1 in S_1 is given by

$$B_1 = \mu_0 n_1 I_1$$

Flux linked with each coil of second solenoid,

$$\phi_2 = B_1 A_1$$

$\therefore$ Total flux linked with N_2 turns,

$$\phi_2 = B_1 A_1 N_2$$

$$\phi_2 = \mu_0 n_1 I_1 A_1 N_2 \quad \text{...(i)}$$

Also $$\phi_2 = M_{21} I_1 \quad \text{...(ii)}$$

Comparing,

$$M_{21} = \mu_0 n_1 N_2 A_1$$

$$M_{21} = \mu_0 n_1 n_2 l A_1 \quad [\because N_2 = n_2 l]$$

Similarly $$M_{12} = \mu_0 n_1 n_2 l A_1$$

OR

Self inductance : Self inductance of a coil is equal to the magnitude of induced emf produced in the coil when rate of change of current through the coil is unity.

now, $$\phi = LI$$

$\therefore$ Induced emf (e) $$e = -\frac{d\phi}{dt}$$

$$e = -L\frac{dI}{dt}$$

Energy stored in an inductor : For the current I at an instant in a circuit, the rate of work done is

$$\frac{dW}{dt} = |e|\,I$$

$$\frac{dW}{dt} = LI\frac{dI}{dt}$$

$$dW = L\,I\,dI$$

Total work done in increasing the current from 0 to I is given by

$$W = \int_0^I LI\,dI$$

$$W = L\left[\frac{I^2}{2}\right]_0^1$$

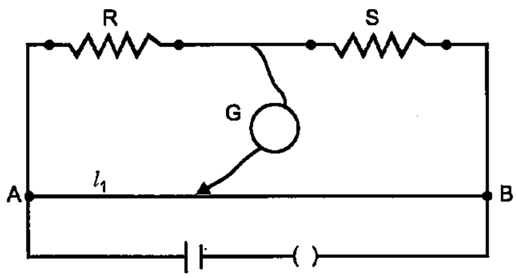
$$W = \frac{1}{2}LI^2$$

This work done is stored as magnetic potential energy.

$$\therefore \quad U = \frac{1}{2}LI^2$$

17. (a) Write the principle of working of a metre bridge.

(b) In a metre bridge, the balance point is found at a distance l_1 with resistances R and S as shown in the figure.



An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance l_2. Obtain a formula for X in terms of l_1, l_2 and S. **[3]**

Answer : (a) Meter bridge works on the principle of balanced Wheatstone bridge *i.e.*, when the bridge is balanced,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

where R_1, R_2, R_3 and R_4 are resistances connected in four arms of Wheatstone's bridge.

(b) In first case,

$$\frac{R}{S} = \frac{l_1}{100-l_1} \qquad ...(i)$$

In second case,

$$\frac{R}{XS/(X+S)} = \frac{l_2}{100-l_2} \qquad ...(ii)$$

Dividing (ii) by (i),

$$\frac{X+S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)$$

$$1+\frac{S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)$$

$$X = \frac{S}{\frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)-1}$$

$$X = \frac{l_1(100-l_2)}{100(l_2-l_1)}S$$

18. Draw a block diagram of a generalized communication system. Write the functions of each of the following :** **[3]**

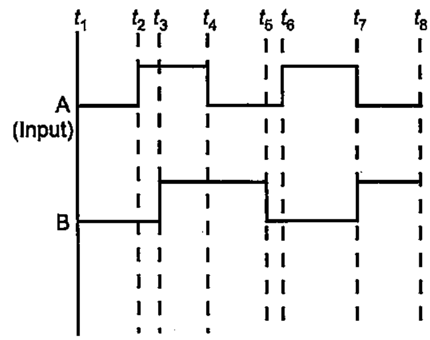
(a) Transmitter

(b) Channel

(c) Receiver

19. (a) Write the functions of the three segments of a transistor.**

(b) The figure shows the input waveforms A and B for 'AND' gate. Draw the output waveform and write the truth table for this logic gate.** **[3]**



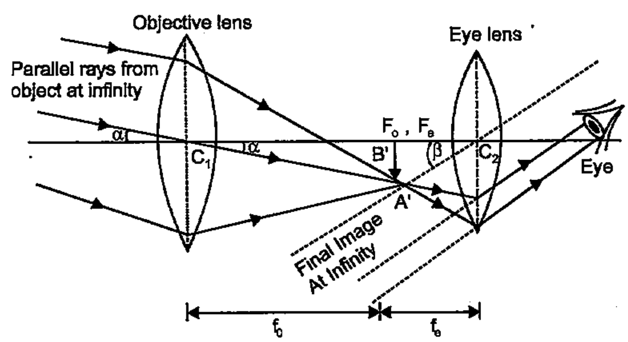
20. (a) Draw a ray diagram depicting the formation of the image by an astronomical telescope in normal adjustment.

(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope ? Give reason. **[3]**

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

Answer :

(a)



(b) An astronomical telescope should have an objective of large aperture and longer focal length while an eyepiece of small aperture and small focal length.

Therefore, we will use L_1 as an objective and L_3 as an eyepiece.

21. (a) State Biot–Savart law and express this law in the vector form.

(b) Two identical circular coils, P and Q each of radius R, carrying currents 1 A and $\sqrt{3}$

**Answers is not given due to change in the present Syllabus.

A respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and direction of the net magnetic field at the centre of the coils. **[3]**

Answer : (a) Biot-Savart Law :

It states that the magnetic field strength (dB) produced due to a current element I and length dl at a point having position vector $\vec{r}$ relative to current element is

(i) directly proportional to the current I *i.e.*, $dB \propto I$.

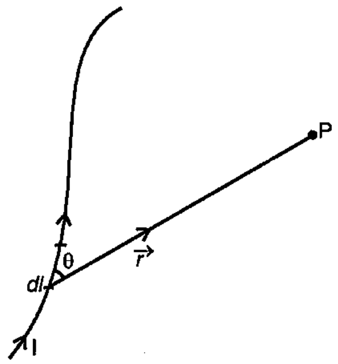
(ii) directly proportional to the length dl of the element *i.e.*, $dB \propto dl$.

(iii) directly proportional to sin θ, where θ is the angle between dl and r, *i.e.*, $dB \propto \sin\theta$.

(iv) inversely proportional to the square of the distance r from the current element *i.e.*, $dB \propto \frac{1}{r^2}$.

$$\therefore \quad dB \propto \frac{Idl\sin\theta}{r^2}$$

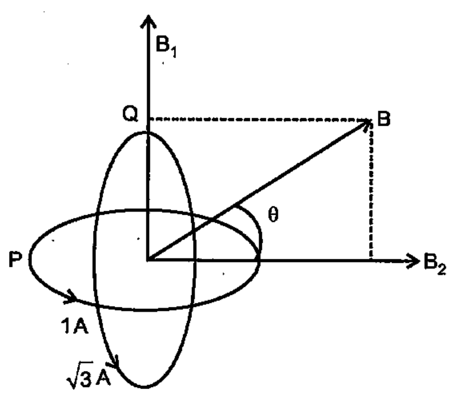
$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$



In vector form,

$$d\vec{B} = \frac{\mu_0}{4\pi}\cdot\frac{I\,\vec{dl}\times\vec{r}}{r^3}$$

(b)



We know that,

$$B = \frac{\mu_0}{2R}I$$

$$B_1 = \frac{\mu_0}{2R}.1 \text{ (along 3 - direction)}$$

$$B_2 = \frac{\mu_0}{2R}.\sqrt{3} \text{ (along x - direction)}$$

$$B = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{\left(\frac{\mu_0}{2R}\right)^2 + \left(\frac{\mu_0}{2R}.\sqrt{3}\right)^2}$$

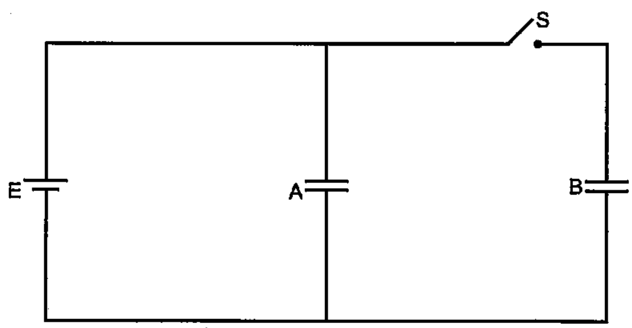
$$B = \frac{\mu_0}{2R}\sqrt{1+3} = \frac{\mu_0}{2R}.\sqrt{4}$$

$$B = \frac{\mu_0}{R}$$

$$\tan\theta = \frac{B_1}{B_2} = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \quad \theta = 30° \text{ in XZ - plane}$$

22. Two identical parallel plate capacitors A and B are connected to battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric. **[3]**



Answer :

$$\text{Energy stored} = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q_2}{C}$$

Net capacitance with switch S closed = C + C = 2C

$$\therefore \quad \text{Energy stored} = \frac{1}{2}\times 2C\times V^2 = CV^2$$

After the switch S is opened, capacitance of each capacitor = KC

$$\therefore \text{ Energy stored in capacitor A} = \frac{1}{2}KCV^2$$

For capacitor B,

Energy stored

$$= \frac{1}{2}\frac{Q^2}{KC} = \frac{1}{2}\frac{C^2V^2}{KC} = \frac{1}{2}\frac{CV^2}{K}$$

∴ Total energy stored

$$= \frac{1}{2}KCV^2 + \frac{1}{2}\frac{CV^2}{K}$$

$$= \frac{1}{2}CV^2\left(K+\frac{1}{K}\right)$$

$$= \frac{1}{2}CV^2\left(\frac{K^2+1}{K}\right) \quad \text{(ii)}$$

on dividing (i) and (ii)

$$\therefore \text{ Required ratio} = \frac{2CV^2K}{CV^2(K^2+1)} = \frac{2K}{(K^2+1)}$$

SECTION – D

23. Asha's mother read an article in the newspaper about a disaster that took place at Chernobyl. She could not understand much from the article and asked a few questions from Asha regarding the article. Asha tried to answer her mother's questions based on what she learnt in Class XII Physics. [4]

(a) What was the installation at Chernobyl where the disaster took place ? What, according to you, was the cause of this disaster ?

(b) Explain the process of release of energy in the installation at chernobyl.

(c) What, according to you, were the values displayed by Asha and her mother ?**

Answer : (a) Nuclear power plant was installed at Chernobyl where the disaster took place.

The causes of this disaster are deficiencies in the reactor design and in operating regulations.

(b) Nuclear fission.

SECTION – E

24. (a) Derive an expression for the electric field E due to a dipole of length '$2a$' at a point distant r from the centre of the dipole on the axial line.

(b) Draw a graph of E versus r for $r >> a$.

(c) If this dipole were kept in a uniform external electric field E_0, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases. [5]

OR

(a) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

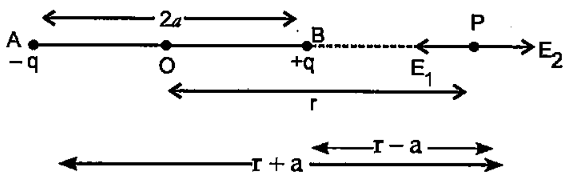
(b) An infinitely large thin plane sheet has a uniform surface charge density + σ. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

Answer : (a) Consider an electric dipole AB. The charges $-q$ and $+q$ of dipole are situated at A and B respectively, as shown in the figure. The separation between the charges is $2a$. Electric dipole moment is given by

$$p = q.2a \quad ...(i)$$

Consider a point P on the axis of dipole at a distance r from mid point O of electric dipole. The distance of point P from charge $+q$ at B is, $BP = r - a$

and distance of point P from charge $-q$ at A is, $AP = r + a$ Let E_1 and E_2 be the electric field strengths at point P due to charges $+q$ and $-q$ respectively.



The resultant electric field due to electric dipole is given by

$$E = E_2 - E_1$$

$$= \frac{1}{4\pi\epsilon_0}.\frac{q}{(r-a)^2} - \frac{1}{4\pi\epsilon_0}.\frac{q}{(r+a)^2}$$

$$E = \frac{1}{4\pi\epsilon_0}.q\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$$

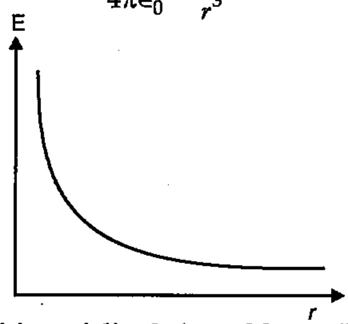
$$E = \frac{1}{4\pi\epsilon_0}.q\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2(r+a)^2}\right]$$

$$E = \frac{1}{4\pi\epsilon_0}.q\left[\frac{4ra}{(r^2-a^2)^2}\right]$$

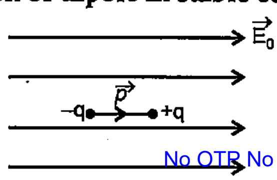
$$E = \frac{1}{4\pi\epsilon_0}.\frac{2pr}{(r^2-a^2)^2} \quad \text{[From (i)]}$$

(b) If $r >> a$,

$$E = \frac{1}{4\pi\epsilon_0}.\frac{2p}{r^3}$$



(c) Position of dipole in stable equilibrium :

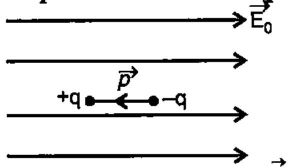


In stable equilibrium, $\theta = 0°$ ($\vec{P}$ is parallel to $\vec{E}_0$)

$$\vec{\tau} = \vec{p} \times \vec{E} = pE \sin\theta = pE \sin 0°$$

$$\vec{\tau} = 0$$

Position of dipole in unstable equilibrium :



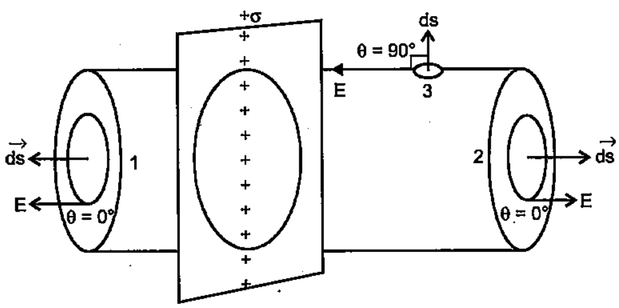
In unstable equilibrium, $\theta = 180°$ ($\vec{P}$ is autiparallel to $\vec{E}_0$)

$$\vec{\tau} = pE \sin 180°$$

$$\vec{\tau} = 0$$

OR

(a)



Let electric charge be uniformly distributed over the surface of a thin non-conducting infinite sheet. Let the surface charge density be σ.

According to Gauss theorem :

$$\int_1 \vec{E}\cdot\vec{ds} + \int_2 \vec{E}\cdot\vec{ds} + \int_3 \vec{E}\cdot\vec{ds} = \frac{q}{\epsilon_0}$$

$$\int_1 E\,ds \cos 0° + \int_2 E\,ds \cos 0° + \int_3 E\,ds \cos 90° = \frac{q}{\epsilon_0}$$

$$\int_1 E\,ds + \int_2 E\,ds = \frac{q}{\epsilon_0}$$

$$2\int E\,ds = \frac{q}{\epsilon_0}$$

$$2E.S = \frac{\sigma S}{\epsilon_0}$$

$$E = \frac{\sigma}{2\epsilon_0}$$

(b) The electric field due to a uniformly charged infinitely large thin sheet with surface charge density σ is,

$$E = \frac{\sigma}{2\epsilon_0} \quad \text{...(i)}$$

The amount of work done in bringing a point charge q from infinity to a point, at a distance r is given by

$$W = \int_{\infty}^{r} F.dr$$

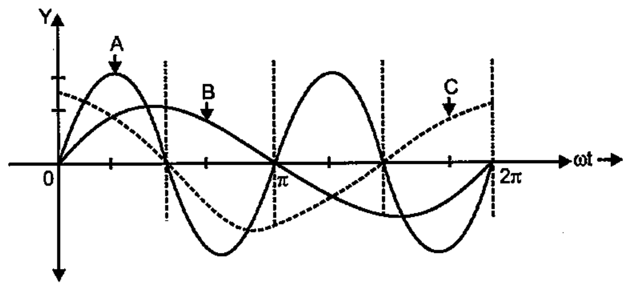
Where F is the force experienced by charge q.

Now, $$W = q\int_{\infty}^{r} -E.\,dr \qquad [\because F = -Eq]$$

$$W = -q\frac{\sigma}{2\epsilon_0}\int_{\infty}^{r} dr \qquad \text{[From (i)]}$$

$$W = q\frac{\sigma}{2\epsilon_0}[\infty - r] = \infty$$

25. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph : [5]



(a) Identify the device 'X'.

(b) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit ? Justify your answer.

(c) How does its impedance vary with frequency of the ac source ? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with ac voltage.

OR

(a) Draw a labelled diagram of an ac generator. Obtain the expression for the emf induced in the rotating coil of N turns each of cross-sectional area A, in the presence of magnetic field $\vec{B}$.

(b) A horizontal conducting rod 10 m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angles to the horizontal component of the Earth's magnetic field, 0.3×10^{-4} Wb m^{-2}. Find the instantaneous value of the emf induced in the rod.

Answer : (a)The device X is a capacitor.

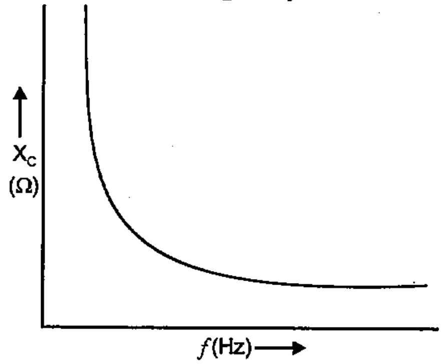
(b) The curves A,B and C represents power consumption,voltage and currentrespectively. Since, it is given $V = V_0 \sin \omega t$; this sinusoidal variation is represented by the curve B. In case of capacitor, current (I) leads the voltage by 90° which is being represented by curve C. Now, we know power is given by

$$P = V \times I$$

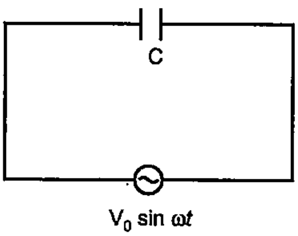
So, the power would be positive for those cycles where both V and I are either positive or negative. Power would be negative when one of the two voltage or current, is negative. This illustration is followed by the curve A.

(c) Capacitive reactance, $X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

This shows that capacitive reactance vary inversely with the frequency.



(d)



In the given figure,

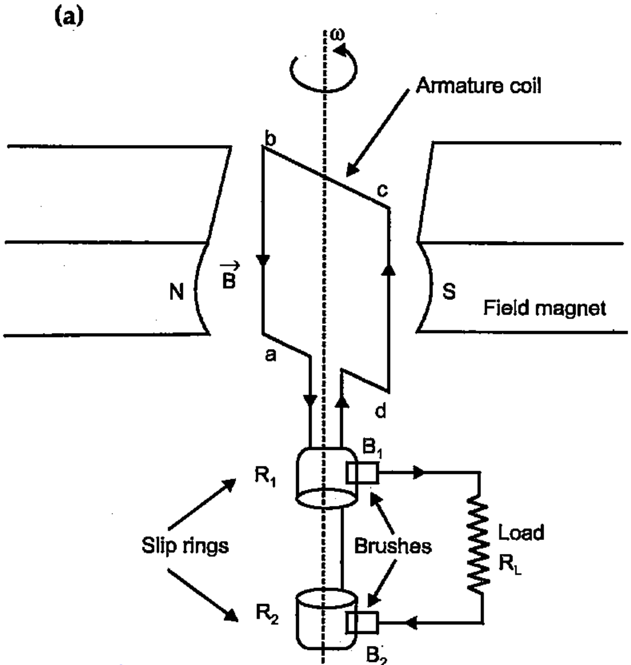
$$V = V_0 \sin \omega t$$
$$Q = CV = CV_0 \sin \omega t$$
$$I = \frac{dq}{dt} = \omega CV_0 \cos \omega t$$
$$= I_0 \sin(\omega t + \pi/2)$$

Where $I_0 = \omega CV_0$

Current leads the voltage by a phase angle of 90°.

OR

(a)



If N is the number of turns in coil, A is the area of coil and B the magnetic induction, then flux ϕ is given by

$$\phi = B.A$$
$$\phi = BA \cos \omega t$$

The e.m.f induced in the coil is given by

$$e = -N\frac{d\phi}{dt}$$
$$e = -N\frac{d}{dt}(BA \cos \omega t)$$
$$e = +NBA\omega \sin \omega t$$
$$e = e_0 \sin \omega t$$

Where, $e_0 = NAB\omega$

(b) $e = B_H l v$

$$= 0.3 \times 10^{-4} \times 10 \times 5$$
$$e = 1.5 \times 10^{-3}\ V = 1.5\ mV$$

26. (a) Define wavefront. Use Huygens' principle to verify the laws of refraction.

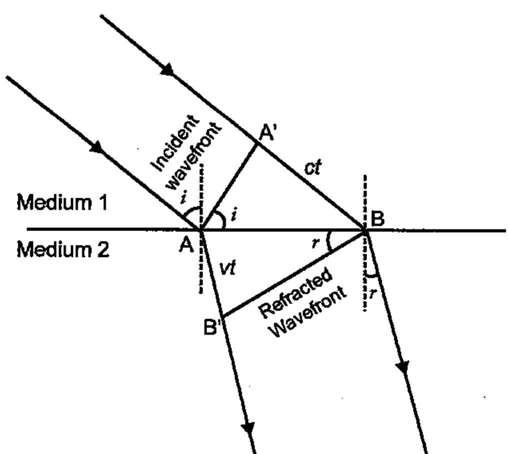
(b) How is linearly polarised light obtained by the process of scattering of light ? Find the Brewster angle for air-glass interface, when the refractive index of glass = 1.5. [5]

OR

(a) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.

(b) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$th of the angle of prism. Calculate the speed of light in the prism.

Answer : (a) **Wavefront :** A wavefront is a continuous locus of all the particles of a medium which are vibrating in the same phase.



In $\Delta AA'B$,

$$\sin i = \frac{A'B}{AB} \quad ...(i)$$

In $\Delta AB'B$,

$$\sin r = \frac{AB'}{AB} \quad ...(ii)$$

Dividing equation (i) by (ii),

$$\frac{\sin i}{\sin r} = \frac{A'B/AB}{AB'/AB}$$

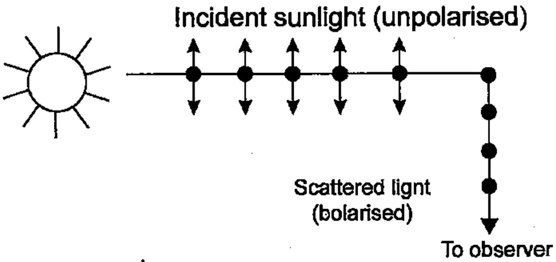
$$\frac{\sin i}{\sin r} = \frac{A'B}{AB'}$$

$$= \frac{ct}{vt}$$

$$\frac{\sin i}{\sin r} = \frac{c}{v} = \mu$$

This is the snell's law of refraction.

(b) When a beam of white light is passed through a medium containing particles whose size is of the order of wavelength of light, then the beam gets scattered. When the scattered light is viewed through an analyser in a direction at the right angle to the direction of indcidence, it is found to be plane polarised. This is called polarisation by scattering.



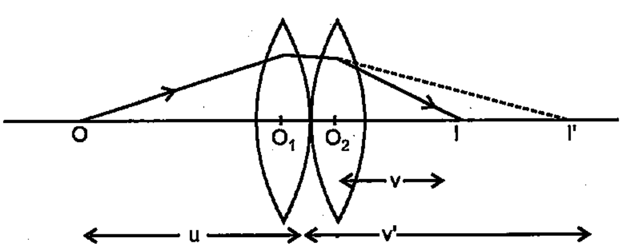
We know that, $\tan i_p = \mu$

$\Rightarrow \tan i_p = 1.5$

$\Rightarrow i_p = \tan^{-1}(1.5) = 56.31°$

OR

(a)



For first lens, object is at O, and image is at I'.

$$\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u} \quad ...(i)$$

For second lens, object is at I and image is at I.

$$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v'} \quad ...(ii)$$

Adding (i) and (ii),

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u} \quad ...(iii)$$

If f is the combined focal length then

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

From equation (iii),

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$P = \frac{1}{f_1} + \frac{1}{f_2} \quad \left[\because \frac{1}{f} = P\right]$$

$$P = \frac{f_1 + f_2}{f_1 f_2}$$

(b) Given : $A = 60°$

$$i = \frac{3}{4}A$$

$$i = \frac{3}{4} \times 60°$$

$$i = 45°$$

For angle of minimum deviation,

$$r = A/2 = \frac{60°}{2}$$

$$r = 30°$$

$$\because \quad \mu = \frac{\sin i}{\sin r}$$

$$\frac{c}{v} = \frac{\sin 45°}{\sin 30°} \quad \left[\because \mu = \frac{c}{v}\right]$$

$$\frac{3\times10^8}{v} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}}$$

$$\frac{3\times10^8}{v} = \sqrt{2}$$

$$v = \frac{3\times10^8}{1.414} \text{ m/s}$$

$\therefore$ Speed of light in the prism

$$vs = 2.12 \times 10^8 \text{ m/s}$$

Physics 2019 (Outside Delhi)

SET I

Time allowed : 3 hours **Maximum marks : 70**

General Instructions :

(i) All questions are compulsory. There are 27 questions in all.

(ii) This question paper has four sections: Section A, Section B, Section C, and Section D.

(iii) Section A contains five questions of one mark each, Section B contains seven questions of two marks each, Section C contains twelve questions of three marks each, Section D contains three questions of five marks each.

(iv) There is no overall choice. However, an internal choice (s) has been provided in two questions of one mark, two questions of two marks, four questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary :

$$c = 3 \times 10^8 \text{ m/s}$$
$$h = 6{\cdot}63 \times 10^{-34} \text{ Js}$$
$$e = 1{\cdot}6 \times 10^{-19} \text{ C}$$
$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$
$$\varepsilon_0 = 8{\cdot}854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$
$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

Mass of electron (m_e) = $9{\cdot}1 \times 10^{-31}$ kg

Mass of neutron = $1{\cdot}675 \times 10^{-27}$ kg

Mass of proton = $1{\cdot}673 \times 10^{-27}$ kg

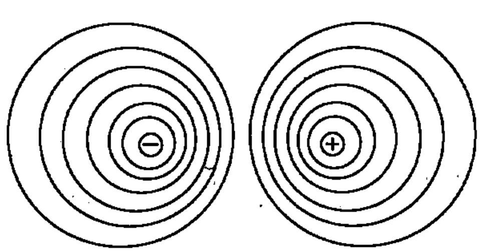
Avogadro's number = $6{\cdot}023 \times 10^{23}$ per gram mole

Boltzmann constant = $1{\cdot}38 \times 10^{-23}$ JK^{-1}

SECTION-A

1. Draw equipotential surfaces for an electric dipole. **[1]**

Answer :



Equipotential surface for an electric dipole.

2. A proton is accelerated through a potential difference V, subjected to a uniform magnetic field acting normal to the velocity of the proton. If the potential difference is doubled, how will the radius of the circular path described by the proton in the magnetic field change ? **[1]**

Answer :

Given, proton accelerated through potential difference V, the direction of magnetic field is normal to velocity of proton.

As we know

$$\frac{1}{2} m_p v^2 = eV$$

[during acceleration of proton, P.E. will converted to kinetic energy]

$$v = \sqrt{\frac{2eV}{m_p}}$$

When V is doubled,

$$V' = 2V,$$

$$\therefore \quad v' = \sqrt{\frac{2e.2V}{m_p}} = \sqrt{2}\, v$$

$$qvB = \frac{m_p v}{r}$$

$$\Rightarrow \quad r = \frac{m_p v}{qB}$$

$$\Rightarrow \quad r' = \frac{m_p}{qB} v'$$

$$\Rightarrow \quad r' = \frac{m_p}{qB} \sqrt{2}\, v$$

$$\therefore \quad r' = \sqrt{2} r$$

3. The magnetic susceptibility χ of magnesium at 300 K is $1{\cdot}2 \times 10^5$. At what temperature will its magnetic susceptibility become $1{\cdot}44 \times 10^5$? **[1]**

OR

The magnetic susceptibility χ of a given material is – 0·5. Identify the magnetic material.

Answer :

Given, χ_{mg} at 300 K = $1{\cdot}2 \times 10^5$

χ'_{mg} at t temp. = $1{\cdot}44 \times 10^5$

t = ?

From Curies law,

$$\chi \propto \frac{1}{T}$$

$$\frac{\chi'_{mg}}{\chi_{mg}} = \frac{300}{t}$$

$$\Rightarrow \quad \frac{1{\cdot}44\times10^5}{1{\cdot}2\times10^5} = \frac{300}{t}$$

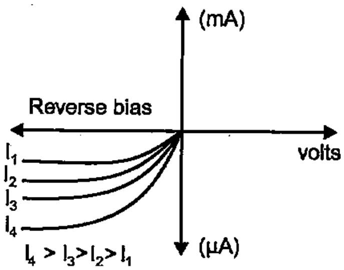
$$t = \frac{300\times1{\cdot}2}{1{\cdot}44}$$

$$= 250 \text{ K}$$

OR

Diamagnetic as $1 < \chi < 0$.

4. Identify the semiconductor diode whose V-I characteristics are as shown. [1]



Answer : Photodiode.

5. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.[1]

OR

How are electromagnetic waves produced by accelerating charges ?

Answer : Microwaves [1GHz to 100 GHz].

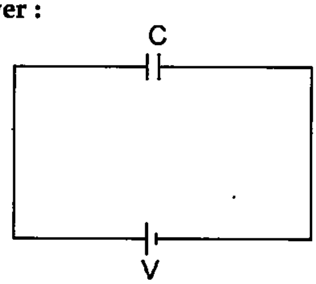
OR

An oscillating electric field in space, produces an oscillating magnetic field, which in turn, is a source of oscillating electric field, and so on. The oscillating electric and magnetic fields thus regenerate each other.

SECTION B

6. A capacitor made of two parallel plates, each of area 'A' and separation 'd' is charged by an external d.c.-source. Show that during charging, the displacement current inside the capacitor is the same as the current charging the capacitor. [2]

Answer :

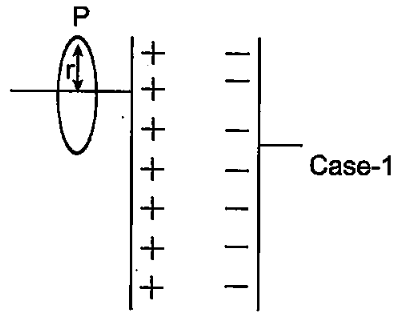


From Ampere's law,

$$\oint B dl = \mu_0 i(t)$$

Let the case-1, where a point P is considered outside the capacitor charging.

From Ampere's law magnetic field at point P will be :

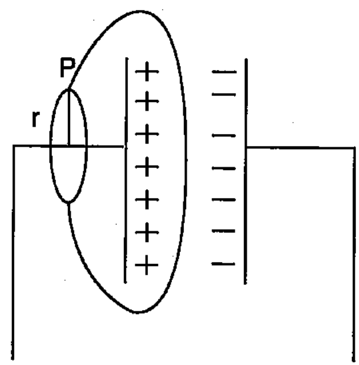


Case-1

$$B.(2\pi r) = \mu_0 i \cdot (t)$$

$$B = \frac{\mu_0 i}{2\pi r}(t)$$

Now, take case-2 where shape of surface under consideration covers capacitor's plate as we consider there is no current through capacitor then this value of B will be zero.



Case-2

Hence, there is a contradiction.

Therefore, this Ampere's law was modified with addition of displacement current inside capacitor.

$$\phi_E = |E|A = \frac{1}{\varepsilon_0}\cdot\frac{Q}{A}.A = \frac{Q}{\varepsilon_0}$$

$$\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0}\cdot\frac{dQ}{dt}$$

$$\varepsilon_0\frac{d\phi_E}{dt} = \frac{dQ}{dt} = i_d$$

Where, i_d is displacement current.

During charging of capacitor, outside the capacitor, i_c (conduction current) flows and inside i_d (displacement current) flows.

$$i = i_c + i_d = i_c + \varepsilon_0 \frac{d\phi_E}{dt}$$

outside the capacitor, $i_d = 0$ hence, $i = i_c$

and inside the capacitor, $i_c = 0$ hence, $i = i_d$.

Thus, $i_c = i_d$ as capacitor gets charged.

7. A photon and a proton have the same de-Broglie wavelength λ. Prove that the energy of the photon is (2mλc/h) times the kinetic energy of the proton. [2]

Answer :

$$\lambda_{pr} = \frac{h}{m_p v} \text{ de-Broglie wavelength of proton}$$

$$\lambda_{ph} = \frac{hc}{E}, \qquad \left(\because E_{ph} = \frac{hc}{\lambda}\right)$$

(de-Broglie wavelength of photon)

$$KE_{proton} = \frac{1}{2} m_p v^2$$

$$\Rightarrow \quad \lambda_{pr} = \lambda_{ph}$$

Hence, $$\frac{hc}{E} = \frac{h}{m_p v}$$

$$v = \frac{h}{m_p} \cdot \frac{E}{hc} = \frac{E}{m_p c}$$

$$K.E. = \frac{1}{2} \cdot \frac{E}{m_p c} \cdot \frac{E}{m_p c} m_p$$

$$= \frac{1}{2} \cdot \frac{E \cdot E}{m_p \, c.c}$$

$$= \frac{1}{2} \cdot \frac{E}{m_p} \cdot \frac{hc}{\lambda c.c}$$

$$K.E. = \frac{1}{2} \frac{E}{m_p} \cdot \frac{h}{c\lambda}$$

$$K.E. \left(\frac{2m_p c\lambda}{h}\right) = E$$

$$K.E. \left(\frac{2mc\lambda}{h}\right) = E$$

8. A photon emitted during the de-excitation of electron from a state n the first excited state in a hydrogen atom, irradiates a metallic cathode of work function 2 eV, in a photo cell, with a stopping potential of 0.55V. Obtain the value of the quantum number of the state n. [2]

OR

A hydrogen atom in the ground state is excited by an electron beam 12·5 eV energy. Find out the maximum number of lines emitted by atom from its excited state.

Answer : $E_n = 13.6 \left[\frac{1}{1^2} - \frac{1}{n^2}\right] \text{eV}$

Work function = 2eV

∴ Maximum kinetic Energy

$$= 13.6 \left[\frac{1}{4} - \frac{1}{n^2}\right] - 2\text{eV}$$

$$= 0.55 \text{ eV}$$

$$\therefore \quad \frac{13.6}{4} - \frac{13.6}{n^2} - 2 = 0.55$$

$$\frac{13.6}{4} - 2 - 0.55 = \frac{13.6}{n^2} = 0.85$$

$$n^2 = \frac{13.6}{0.85} = 16,$$

$$n = 4$$

OR

Given : ΔE = 12.5 eV

Let the electron jump from $n = 1$ to $n = n$ level.

$$\Delta E = E_n - E_1$$

$$\therefore \quad 12.5 = -\frac{13.6}{n^2} - \left(\frac{-13.6}{1^2}\right)$$

$$12.5 = 13.6 \left(1 - \frac{1}{n^2}\right)$$

$$1 - \frac{12.5}{13.6} = \frac{1}{n^2}$$

$$\frac{1.1}{13.6} = \frac{1}{n^2}$$

$$\frac{13.6}{1.1} = n^2$$

$$12.36 = n^2$$

$$n = 3.5$$

$$n = 3^{rd}$$

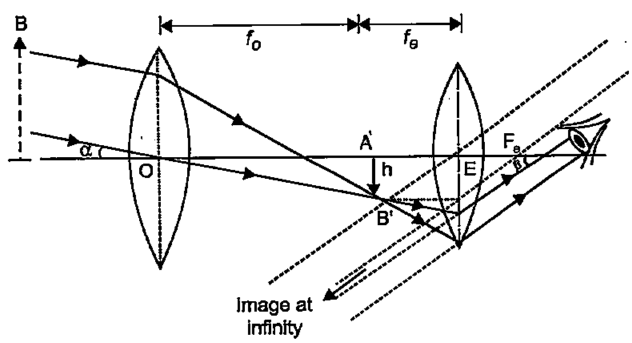
Maximum number of lines = 3

9. Draw the ray diagram of an astronomical telescope showing image formation in the normal adjustment position. Write the expression for its magnifying power. [2]

OR

Draw a labelled ray diagram to show image formation by a compound microscope and write the expression for its resolving power.

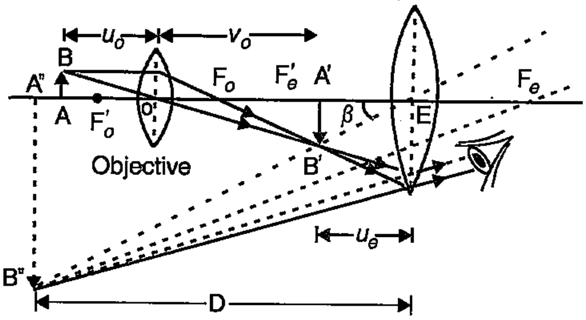
Answer :



The magnifying power m is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye. Hence,

$$m = \frac{\beta}{\alpha} = \frac{h}{f_e} \cdot \frac{f_o}{h} = \frac{f_o}{f_e}$$

OR



The resolving power of microscope is the reciprocal of the minimum distance.
Therefore, we have

$$\text{R.P.} = \frac{1}{d_{\min}} = \frac{2n\sin\beta}{1.22\lambda}$$

10. Write the relation between the height of a TV antenna and the maximum range up to which signals transmitted by the antenna can be received. How is this expression modified in the case of line of sight communication by space waves? In which range of frequencies, is this mode of communication used? [2]**

11. Under which conditions can a rainbow be observed? Distinguish between a primary and a secondary rainbow. [2]

Answer : The rainbow is an example of the dispersion of sunlight by the water drops in the atmosphere. This is a phenomenon due to combined effect of dispersion, refraction and reflection of Sunlight by spherical water droplets of rain. The conditions for observing a rainbow are that the Sun should be shining in one part of the sky (say near western horizontal while it is raining in the opposite part of the sky (say eastern horizon).

Difference between Primary and Secondary Rainbow :

S.N.	Primary Rainbow	Secondary Rainbow
1	Three Step process (Refraction-Reflection and Refraction).	Four Step process (Refraction–Reflection and Refraction)
2.	Appearance intensity better than Secondary.	Appearance intensity lesser than Primary.
3.	Single reflection occurs.	Double reflection occurs.
4.	2 Degree range occurs.	3 Degree range.
5.	Fig.1	Fig.2

**Answer is not given due to change in the present syllabus.

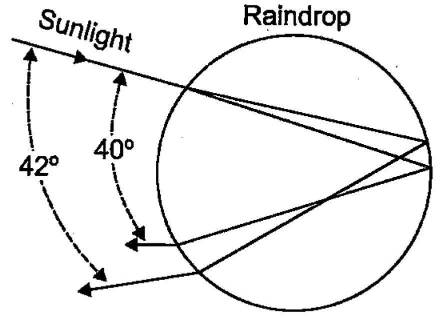


Fig. (1)

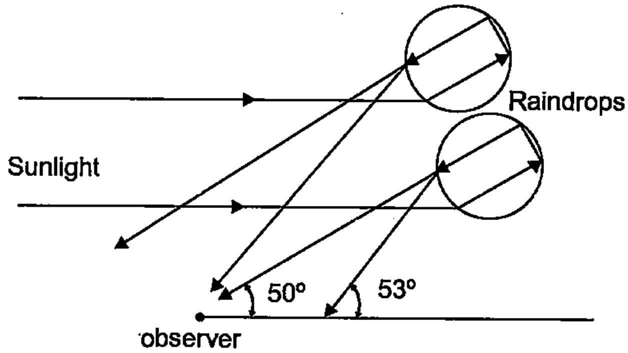


Fig. (2)

12. Explain the following : [2]
(a) Sky appears blue.
(b) The Sun appears reddish at
(i) sunset, (ii) sunrise.

Answer :

(a) Light from the sun reaches the atmosphere that is comprised of the tiny particles of the atmosphere. These act as a prism and cause the different components to scatter. As blue light travels in shorter and smaller waves in comparison to the other colours of spectrum. It is scattered the most , causing the sky to appear bluish.

(b) The molecules of the atmosphere and other particles that are smaller than the longest wavelength of visible light are more effective in scattering light of shorter wavelengths than light of longer wavelengths. The amount of scattering is inversely proportional to the fourth power of the wavelength. (Rayleigh Effect) Light from the Sun near the horizon passes through a greater distance in the Earth's atmosphere than does the light received when the Sun is overhead. The correspondingly greater scattering of short wavelengths accounts for the reddish appearance of the Sun at rising and at setting.

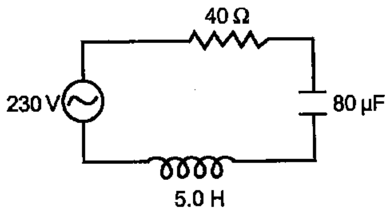
SECTION-C

13. A capacitor (C) and resistor (R) are connected in series with an ac source of voltage of frequency 50 Hz. The potential difference across C and R

are respectively 120 V, 90 V, and the current in the circuit is 3 A. Calculate (i) the impedance of the circuit (ii) the value of the inductance, which when connected in series with C and R will make the power factor of the circuit unity. **[3]**

OR

The figure shows a series LCR circuit connected to a variable frequency 230 V source.

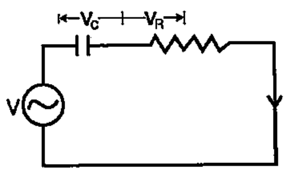


(a) Determine the source frequency which drives the circuit in resonance.

(b) Calculate the impedance of the circuit and amplitude of current at resonance.

(c) Show that potential drop across LC combination is zero at resonating frequency.

Answer :



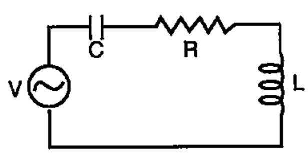
Given,

$$V_c = 120 \quad V_R = 90\,V \quad I = 3A \quad Z = ?$$

(i) From Kirchhoff's voltage law

$$V = V_c + V_R$$
$$= 230\ V$$
$$I = \frac{V}{Z}$$
$$Z = \frac{V}{I} = 230/3 = 76.67\ \Omega$$

(ii)

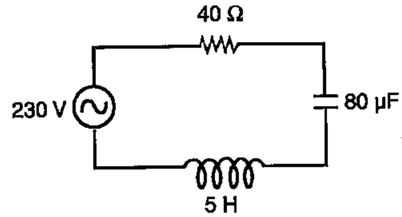


$$\cos\phi = \frac{R}{Z} = 1$$
$$R = Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

Hence, $$L = \frac{1}{C}$$

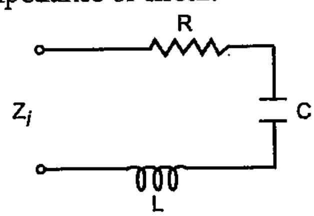
OR

(a) Source frequency will be same as resonance frequency of LC circuit,



$$f_R = \frac{1}{2\pi\sqrt{LC}}$$
$$= \frac{1}{2\pi\sqrt{5\times80\times10^{-6}}}$$
$$= \frac{1}{2\pi\sqrt{400\times10^{-6}}}$$
$$= \frac{1}{2\pi\times2\times10^{-2}}$$
$$= \frac{100}{4\pi}$$
$$= 7.957\ \text{Hz} \qquad (\because w = 2\pi f)$$
$$\omega_r = 50\ \text{Hz}$$

(b) Impedance of circuit



$$z_i = R + j\omega L + \frac{1}{j\omega c}$$
$$= 40 + 50j\times5 + \frac{1}{j\times50\times80\times10^{-6}}$$
$$= 40 + 250j + \frac{10^3}{4j}$$
$$z_i = 40 + 250j - 250j \text{ (at resonance)}$$
$$z_i = 40\ \Omega$$

Amplitude of current,

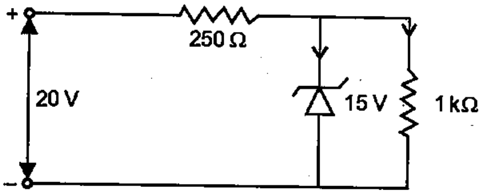
$$I = \frac{230}{z_i}$$
$$= 230/40 = 5.75\ A$$

(c) As at resonance frequency impedance of combination of L and C is 0.

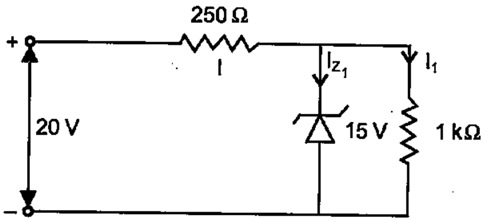
Hence, voltage drop across LC combination is zero at resonating frequency.

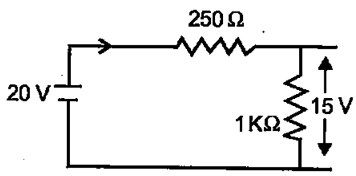
14. Give reason to explain why n and p regions of a Zener diode are heavily doped. Find the current through the Zener diode in the circuit given below : **[3]**

(Zener breakdown voltage is 15 V)



Answer : By heavily doping both p and n sides of the junction, depletion region formed is very thin, *i.e.*, $< 10^{-6}$ m. Hence, electric field across the junction is very high ($\sim 5 \times 10^6$ V/m) even for a small reverse bias voltage. This can lead to a break down during reverse biasing.





$$I = I_z + I_1$$

$$I_1 = \frac{15}{1} \times 10^{-3} = 1500\text{A}$$

$$I = \frac{20-15}{250} = \frac{5}{250}$$

$$= 20 \text{ mA}$$

Hence, $I_z = 20 - 15$ mA

$$= 5 \text{ mA}$$

15. Draw a labelled diagram of cyclotron. Explain its working principle. Show that cyclotron frequency is independent of the speed and radius of the orbit. [3]

OR

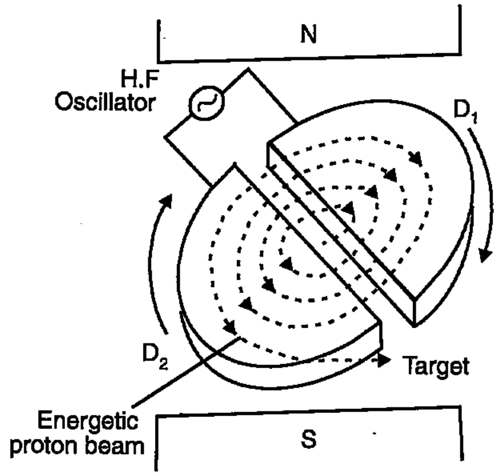
(a) Derive, with the help of a diagram, the expression for the magnetic field inside a very long solenoid having n turns per unit length carrying a current I.

(b) How is a toroid different from a solenoid?

Answer :

Cyclotron : Cyclotron is a device by which the positively charged particles like protons, deutrons, etc. can be accelerated.

Principle : Cyclotron works on the principle that a positively charged particle can be acclerated by making it to cross the same electric field repeatedly with the help of a mgnetic field.



Construction : The construction of a simple cyclotron is shown in figure above. it consist of two-semi cylindrical boxes D_1 and D_2, which are called Dees They are enclosed in an evacuated chamber.

Chamber is kept between the poles of a powerful magnet so that uniform magnetic field acts perpendicular to the plane of the dees. An alternating voltage is applied in the gap between the two dees by the help of a high frequency oscillator. The electric field is zero inside the dees.

Working and theory : At a certain instant, let D_1 be positive and D_2 be negative. A proton from an ion source will be accelerated towards D_2, it describes a semi-circular path with a constant speed and is acted upon only by the magnetic field. The radius of the circular path is given by.

$$qvB = \frac{mv^2}{r}$$

From the above equation we get,

$$r = \frac{mv}{qB} \quad \text{...(i)}$$

The period of revolution is given by.

$$T = \frac{2\pi r}{v} = \frac{2\pi}{v} \cdot \frac{mv}{qB}$$

$$T = \frac{2\pi m}{qB}$$

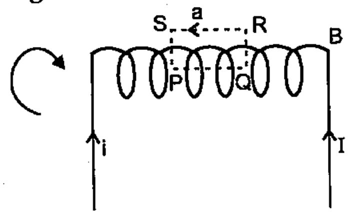
The frequency of revolution is given by,

$$f = \frac{1}{T} = \frac{qB}{2\pi m}$$

From the above equation it follows that frequency f is independent of both v and r and is called cyclotron frequency. Also if we make the frequency of applied a.c. equal to f, then every time the proton reaches the gap between the dees, the direction of electric field is reversed and proton receives a push and finally it gains very high kinetic energy. The proton follows a spiral path and finally gets directed towards the target and comes out from it.

OR

(a) Magnetic field inside the solenoid



$$\oint \vec{B}.\vec{dl} = \mu_0 I_0 = \mu_0 naI \quad ...(i)$$

$$\oint \vec{B}.\vec{dl} = \oint_{PQ} \vec{B}\vec{dl} + \oint_{QR} \vec{B}\vec{dl} + \oint_{RS} \vec{B}\vec{dl} + \oint_{SP} \vec{B}\vec{dl}$$

$$= B\oint dl \cos 0^\circ + \oint B.dl \cos 90^\circ + 0.dl \cos 0^\circ + \oint B.dl \cos 90^\circ$$

$$= B\oint dl = B.a \quad ...(ii)$$

From equation (i) and (ii),

$$\Rightarrow \quad B = \mu_0 nI$$

$$\mu_0 I_0 = \mu_0 naI$$

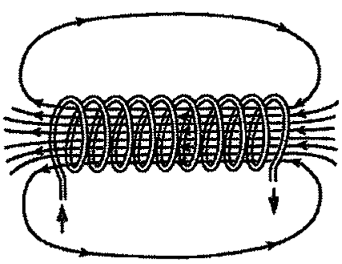
n = No. of turn per unit length.

a = length of the path.

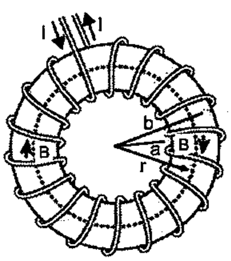
I = current passing through

(b) Toroid is a form in which a conductor is wound around a circular body. In this case we get magnetic field inside the core but poles are absent because circular body don't have ends. Toroid is used in toroidal inductor, toroidal transformer.

Solenoid is a form in which conductor is wound around a cylindrical body with limb. In this case magnetic field creates two poles N and S. Solenoids have some flux leakage. This is used in relay, motors, electro-magnetes.



Solenoid Coil



Toroidal Coil

16. Prove that the magnetic moment of the electron revolving around a nucleus in an orbit of radius r with orbital speed v is equal to evr/2. Hence using Bohr's postulate of quantization of angular momentum, deduce the expression for the magnetic moment of hydrogen atom in the ground state. [3]

Answer :

$$\mu = -\left(\frac{e}{2m}\right)L$$

where, (–) indicates μ direction is opposite to L.

As Bohr's atomic model

$$L = mvr$$

$$\therefore \quad \mu = -\left(\frac{e}{2m}\right) \times mvr$$

$$\mu = \frac{evr}{2}$$

But from Bohr's second postulate

$$m_e v_r = \frac{nh}{2\pi}.\frac{h}{2\pi} \qquad \text{for } (n = 1)$$

$$v_r = \frac{nh}{2\pi m_e}$$

Hence the magnetic moment is

$$m = \frac{e}{2}\frac{h}{2\pi m_e} \qquad (\text{Here } n = 1)$$

$$m = \frac{eh}{4\pi m_e}$$

17. Two large charged plane sheets of charge densities σ and –2σ C/m² are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points (i) to the left of the first sheet, (ii) to the right of the second sheet, and (iii) between the two sheets. [3]

OR

A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q.

(a) A charge q is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell.

(b) Is the electric field inside a cavity (with no charge) zero; independent of the fact whether the shell is spherical or not? Explain.

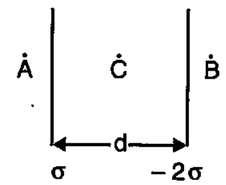
Answer :

(i) Electric field due to plane sheet toward

$$\text{right} = \frac{\sigma}{\varepsilon_0}$$

Where, σ is charge density.

$$\text{towards left} = \frac{-\sigma}{\varepsilon_0}$$



Electric field at point A *i.e.*, to the left of first sheet and due to large plane sheet.

$$\vec{E}_A = -\frac{\sigma}{\varepsilon_0} + \left(+\frac{2\sigma}{\varepsilon_0}\right) = \frac{\sigma}{\varepsilon_0}$$

(ii) Electric field at point B *i.e.*, to the right of second sheet,

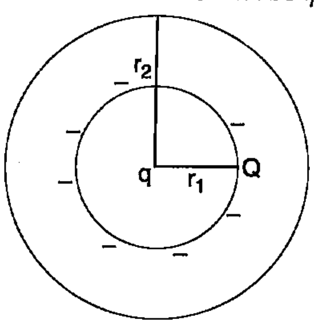
$$\vec{E}_B = \frac{\sigma}{\varepsilon_0} - \frac{2\sigma}{\varepsilon_0} = \frac{-\sigma}{\varepsilon_0}$$

(iii) Electric field at point C *i.e.*, between two plates,

$$\vec{E}_C = \frac{\sigma}{\varepsilon_0} + \frac{2\sigma}{\varepsilon_0} = \frac{3\sigma}{\varepsilon_0}$$

OR

(a) Charge on inner surface will be $-q$ and charge on outer surface will be q.



Electric field inside conductor will be zero.

$$\oint E.da = 0 = \frac{q}{\varepsilon_0} + \frac{q}{\varepsilon_0} = 0$$

$q' = -q$ inner surface is equal to zero.

As total charge on spherical shall is Q

Hence, $Q = q_{inner} + q_{outer}$

$q_{inner} = -q$ From Gauss's law

$$q_{outer} = Q = q$$

Hence, inner surface charge density $\dfrac{-q}{4\pi r_1^2}$

and outer $\dfrac{Q+q}{4\pi r_2^2}$

(b) Electric field inside a cavity with no charge will be zero as from Gauss's law

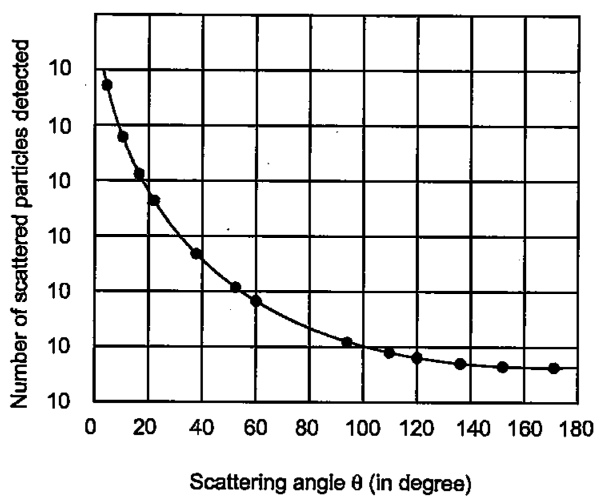
$$\phi_E = \frac{q_{enclosed}}{\varepsilon_0}$$

as $q_{enclosed} = 0$. Thus ϕ_E will also be zero. electric field will also be zero.

18. **A signal of low frequency f_m is to be transmitted using a carrier wave of frequency f_c. Derive the expression for the amplitude modulated wave and deduce expression for the lower and upper sidebands produced. Hence, obtain the expression for modulation index.**** **[3]**

19. **Draw a plot of α-particle scattering by a thin foil of gold to show the variation of the number of the scattered particles with scattering angle. Describe briefly how the large angle scattering explains the existence of the nucleus inside the atom, Explain with the help of impact parameter picture, how Rutherford scattering serves a powerful way to determine and upper limit on the size of the nucleus.** **[3]**

Awswer :



From the plot it is clear that Most of the α-particles passed through the foil,. only 0.14% of the incident α particles scatter by more than 1% and about 1 in 8000 deflect by more than 90° α-particles deflected backward due to strong repulsive force. This force will come from positive charge concentrated at the centre as most of the particles get deflected by small angles.

The α-particles trajectory depends on collision's impact parameter (b) for a given beam of α-particles, distribution of impact parameters

**Answer is not given due to change in the present syllabus.

as beam gets scattered in different directions with different probabilities.

fig.2 shows α-particle close to nucleus suffers large scattering.

Impact parameter is minimum for head on collision α-particles rebound by 180°.

Impact parameter is high, for undeviated α-particles.

With deflection angle ≅ 0°.

As these of nucleus was 10^{-14} m to 10^{-15} m w.r.t. 10^{-10} m size of an atom which is 10,000 to 100,000 times larger hence most of the space is empty, only small % of the incident particles rebound back indicates that number of α-particle goes head on collision. Hence most of the mass of the atom is concentrated in small volume.

Thus, Rutherford scattering is a strong tool to determine upper limit to the size of the nucleus.

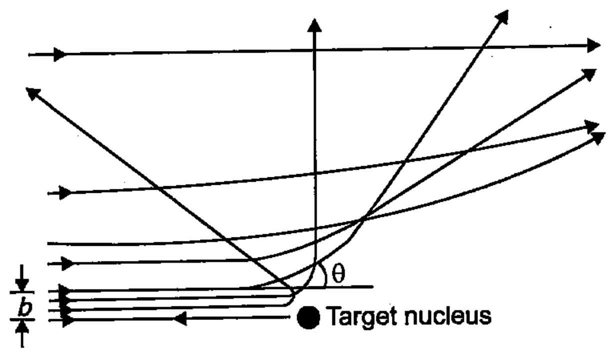


Fig. 2

20. A 200 μF parallel plate capacitor having plate separation of 5 mm is charged by a 100 V dc source. It remains connected to the source. Using an insulated handle, the distance between the plates is doubled and a dielectric slab of thickness 5 mm and dielectric constant 10 is introduced between the plates. Explain with reason, how the (i) capacitance, (ii) electric field between the plates, (iii) energy density of the capacitor will change ? [3]

Answer : Given, $C = 200 \times 10^{-6}$ F,

$$d = 5 \text{ mm} = 5 \times 10^{-3} \text{ m}$$

$$\theta = CV = 200 \times 16^{-6} \times 100$$

$$= 2 \times 10^{-2} \text{ coulomb.}$$

$$\varepsilon_0 A = Cd = 200 \times 10^{-6} \times 5 \times 10^{-3} = 10^{-6}$$

$$A = 10^{-6}/\varepsilon_0$$

As dielectric of 5 mm is inserted with spacing between the dielectric doubled then it will act as following-Fig.A and Fig-B.

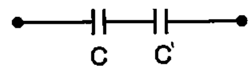


Fig-B

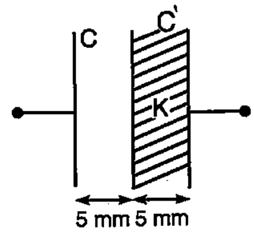


Fig-A

(i) Here, C' will be the capacitance with dielectric of 5 mm dielectric with 5 mm separation between plates.

$$C' = KC = 10 \times 200 \times 10^{-6} = 2 \times 10^{-3} \text{ F}$$

Thus, equivalent capacitance will be

$$\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C'}$$

$$= \frac{1}{200 \times 10^{-6}} + \frac{1}{2 \times 10^{-3}}$$

$$= \frac{10^3}{2} + \frac{10^3}{2}$$

$$= 5 \times 10^3 + 0.5 \times 10^3$$

$$\frac{1}{C_{eq}} = 5.5 \times 10^3$$

$$C_{eq} = \frac{1}{5.5 \times 10^3}$$

$$= \frac{1}{5.5} \times 10^{-3} = 0.181 \times 10^{-3}$$

$$= 1.81 \times 10^{-4} \text{ F}$$

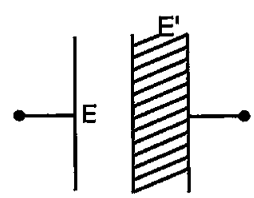
(ii) Electric field inside – dielectric will be

$$E' = \frac{E}{K}$$

$$= \frac{100}{5.5 \times 10^{-3} \times 10}$$

$$= 18182 \text{ V/m}$$

Electric field remains same, other than dielectric area,



(iii) $$U = \frac{Q^2}{2C}$$

$$U'' = U' + U$$

$$= \frac{1}{2} \cdot \frac{Q^2}{C} + \frac{1}{2} \cdot \frac{Q^2}{C'}$$

$$= \frac{1}{2} \cdot \frac{Q^2}{C} \left[\frac{1}{C} + \frac{1}{C'}\right]$$

$$= \frac{1}{2} \times 2 \times 10^{-2} \left[\frac{1}{0.2 \times 10^{-3}} + \frac{1}{2 \times 10^{-3}} \right]$$

$$\left[\because \frac{1}{C} + \frac{1}{C'} = \frac{1}{C_{eq}} \right]$$

$$= \left[\frac{1000}{0.2} + \frac{1000}{2} \right]$$

$$= 10^{-2} \times 5.5 \times 10^3 \times 2 \times 10^{-2}$$

$$U'' = 1.1 \text{ J}$$

21. Why is it difficult to detect the presence of an anti-neutrino during β-decay ? Define the term decay constant of a radioactive nucleus and derive the expression for its mean life in terms of the decay constant. **[3]**

OR

(a) State two distinguishing features of nuclear force.

(b) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions on the graph where the force is (i) attractive, and (ii) repulsive.

Answer : The symbols $\bar{v}$ and v present antineutrino and neutrino respectively during β decay : both are neutral particles. With very little or no mass. These particles are emitted from the nucleus along with the electron or positron during the decay process. Neutrions interact very weakly with matter, they can even penetrate the earth without being absorbed. It is for this reason that their detection is extremely difficult and their presence went unnoticed for long.

Decay constant : Decay constant of a radioactive element is the reciprocal of time during which the number of atoms left in the sample reduces to $\frac{1}{e}$ times the number of atoms in the original sample.

Derivation of mean life :

Let us consider, N_0 be the total number of radioactive atoms present initially. After time t, total no. of atoms present (undecayed) be N. In further dt time dN be the no. of atoms disintegrated. So, the life of dN atoms ranges lies between $t + dt$ and dt. Since, dt is very small time, the most appropriate life of dN atom is t. So the total life of N atom = $t.d$N

$$\text{sum of ages of all atoms} = \int_0^{N_0} t dN \qquad ...(i)$$

$$N = N_0 e^{-\lambda t}$$

$$dN = N_0 (-\lambda) e^{-\lambda t} dt$$

Now, substituting the value of dN and changing the limit in equation (i) from (ii) we get

$$= \int_{\infty}^{0} t N_0 (-\lambda) e^{-\lambda t} dt$$

$$= -\int_0^{\infty} t N_0 (-\lambda) e^{-\lambda t} dt$$

$$= N_0 \lambda \int_0^{\infty} t e^{-\lambda t} dt$$

= sum of life of all atoms

$$\text{Mean life } (\tau) = \frac{N_0 \lambda \int_0^{\infty} t e^{-\lambda t} dt}{N_0}$$

$$\tau = \lambda \int_0^{\infty} t e^{-\lambda t} dt$$

$$\tau = \lambda \times \frac{1}{\lambda^2}$$

$$\tau = \frac{1}{\lambda}$$

This expression gives the relation between mean life and decay constant. Hence, mean life is reciprocal of decay constant.

OR

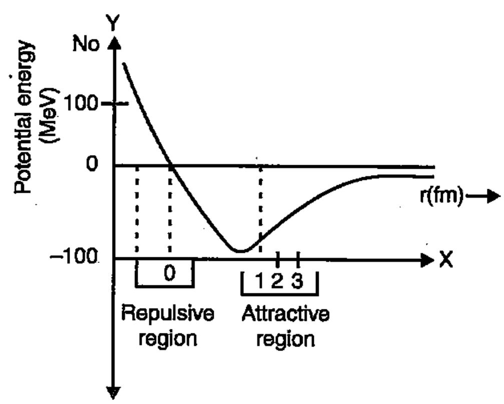
(a) Distinguish features of nuclear force are :

(i) Nuclear forces are very strong binding forces (attractive force.)

(ii) It is independent of the charges protons and neutrons (charge independent.)

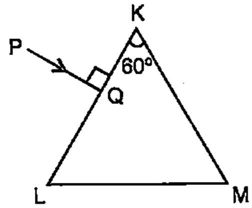
(iii) It depends on the spins of the nucleons.

(b) Plot showing variation of potential energy of a pair of nucleons as a function of separation mark attractive and repulsive region.

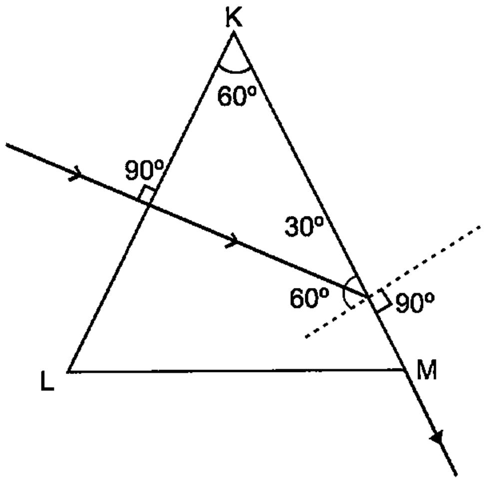


X-axis shows separation between pair of nucleons and Y-axis shows variation of potential energy w.r.t. separation (in $\times 10^{-15}$ m).

22. A triangular prism of refracting angle 60° is made of a transparent material of refractive index $2/\sqrt{3}$. A ray of light is incident normally on the face KL as shown in the figure. Trace the path of the ray as it passes through the prism and calculate the angle of emergence and angle of deviation. **[3]**



Answer : From diagram it is clear that incidence angle at face KM is 60°.



$$\sin C = \frac{1}{\mu} = \frac{\sqrt{3}}{2}$$

Hence, critical angle is also 60°.

Therefore, incident light ray will not emerge from KM face due to total internal reflection at this face. Hence, it will move along face KM

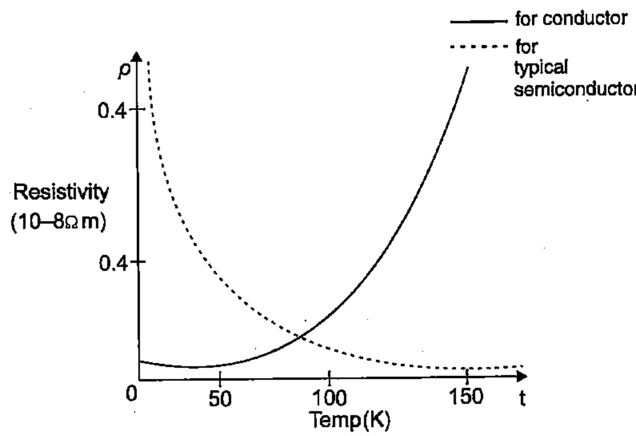
Angle of emergence = 90°.

Hence angle of deviation = 30° (from fig.)

23. Prove that in a common-emitter amplifier, the output and input differ in phase by 180°. In a transistor, the change of base current by 30 μA produces change of 0·02 V in the base-emitter voltage and a change of 4 mA in the collector current. Calculate the current amplification factor and the load resistance used, if the voltage gain of the amplifier is 400.** **[3]**

24. Show, on a plot, variation of resistivity of (i) a conductor, and (ii) a typical semiconductor as a function of temperature.
Using the expression for the resistivity in terms of number density and relaxation time between the collisions, explain how resistivity in the case of a conductor increases while it decreases in a semiconductor, with the rise of temperature. **[3]**

Answer :



$$\rho = \frac{1}{\sigma} = \frac{m}{ne^2\tau}$$

$n \to$ number of free electrons
$\tau \to$ Average time between collisions.
In metals n is not dependent on temperature to any appreciable extent and thus the decrease in the value of τ with rise in temperature causes ρ to increases.

for semiconductors, n increases with temperature. This increases more than compensates any decrease in t, so that for such materials, ρ decreases with temperature.

SECTION D

25. (a) Derive an expression for the induced emf developed when a coil of N turns, and area of cross-section A, is rotated at a constant angular speed ω in a uniform magnetic field B.

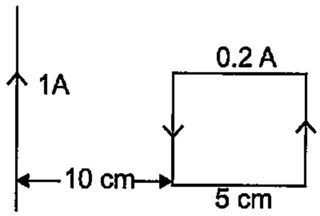
(b) A wheel with 100 metallic spokes each 0·5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. If the resultant magnetic field at that place is 4×10^{-4} T and the angle of dip at the place is 30°, find the emf induced between the axle and the rim of the wheel. **[5]**

OR

(a) Derive the expression for the magnetic energy stored in an inductor when a current I develops in it. Hence, obtain the expression for the magnetic energy density.

(b) A square loop of sides 5 cm carrying a current of 0·2 A in the clockwise direction is placed at a distance of 10 cm from an inifinitely long wire carrying a current of 1 A as shown. Calculate (i) the resultant magnetic force, and (ii) the torque, if any, active on the loop.

** Answer is not given due to change in the present syllabus.



Answer :

(a) As the armature coil is rotated in the magnetic field, angle θ between the field and normal to the coil changes continuously. Therefore, magnetic flux linked with the coil changes. An e.m.f. is induced in the coil. According to Fleming's right hand rule, current induced in AB is from A to B and it is from C to D in CD in the external circuit current flows from B_2 to B_1.

To calculate the magnitude of e.m.f. induced :

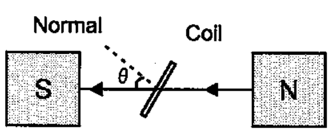
Suppose,

A → Area of each turn of the coil

N → Number of turns in the coil

B → Strength of magnetic field

θ → Angle which normal to the coil makes with $\vec{B}$ at any instant t



∴ Magnetic flux linked with the coil in this position.

$\phi = N(\vec{B}.\vec{A}) = \text{NBA} \cos \theta = \text{NBA} \cos \omega t$ ....(i)

Where, ω is angular velocity of the coil

As the coil rotates, angle θ changes. Therefore, magnetic flux ϕ linked with the coil changes and hence, an e.m.f. is induced in the coil. At this instant t, if e is the e.m.f. induced in the coil, then

$$e = -\frac{d\theta}{dt} = -\frac{d}{dt}(\text{NAB} \cos \omega t)$$

$$= -\text{NAB}\frac{d}{dt}(\cos \omega t)$$

$$= -\text{NAB}(-\sin \omega t)\,\omega$$

$$\therefore e = \text{NAB}\,\omega \sin \omega t$$

$e = \varepsilon_0 \sin \omega t$ (Here $\varepsilon_0 = \text{NBA}\omega$)

(b) We have number spokes (N) = 100

Length of each spoke (L) = 0.5 m

Magnetic field (B) = $0.4 \times 10^{-4}\,\text{T} = 4 \times 10^{-5}\,\text{T}$

Frequency (f) = 120 rpm = 2 rps

induced e.m.f. between axle and rim is given by

$$e = \text{N} \times \text{B} \times l^2 \times \pi \times f$$

$$= 100 \times 4 \times 10^{-5} \times (0.5)^2 \times 3.14 \times 2$$

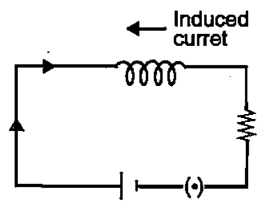
$$= 6.28 \times 10^{-3}\,\text{V}$$

OR

(a) Energy stored in an inductor : When a current flows through an inductor, a back e.m.f. is set up which opposes the growth of current. So, work needs to be done against back e.m.f. (e) in building up the current. This work done is stored as magnetic potential energy.

Let, I be the current through the inductor L at any instant t.

$$\text{L} = \frac{\Phi}{\text{I}}$$



The current rises at the rate $\frac{d\text{I}}{dt}$.

So, the induced e.m.f. is :

$$e = \frac{-\text{L}d\text{I}}{dt}$$

The work done against induced e.m.f. in dt is:

$$d\text{W} = \text{P}dt$$

$$= -e\text{I}dt$$

$$= \frac{-\text{L}d\text{I}}{dt}\text{I}dt$$

$$= \text{LI}d\text{I}$$

For total work from 0 to I_0 current,

$$\text{W} = \int_0^{\text{I}_0} d\text{W}$$

$$= \int_0^{\text{I}_0} \text{LI}d\text{I}$$

$$= \text{L}\left[\frac{\text{I}^2}{2}\right]_0^{\text{I}_0}$$

$$= \frac{1}{2}\text{LI}_0^2$$

Hence, this work done is stored as the magnetic potential energy U in the inductor

$$\text{U} = \frac{1}{2}\text{LI}^2$$

The magnetic energy is given by

$$\text{U}_\text{B} = \frac{1}{2}\text{LI}^2$$

$$= \frac{1}{2}L\left(\frac{B}{\mu_0 n}\right)^2 \quad (\text{since } B = \mu_0 nI)$$

$$= \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B}{\mu_0 n}\right)^2$$

$$(\because \ L = \mu_0 n^2 Al)$$

$$= \frac{1}{2\mu_0}B^2 Al$$

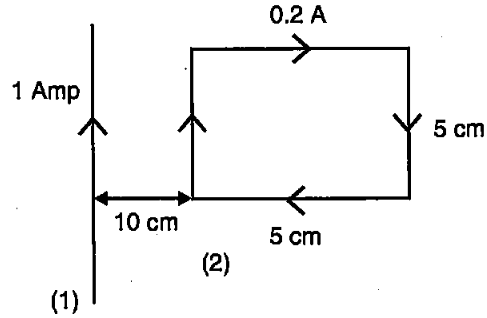
The magnetic energy per unit volume or magnetic energy density is given by,

$$u_B = \frac{U_B}{V} \quad (\text{where, V is volume that contains flux})$$

$$= \frac{U_B}{Al}$$

$$= \frac{B^2}{2\mu_0}Al$$

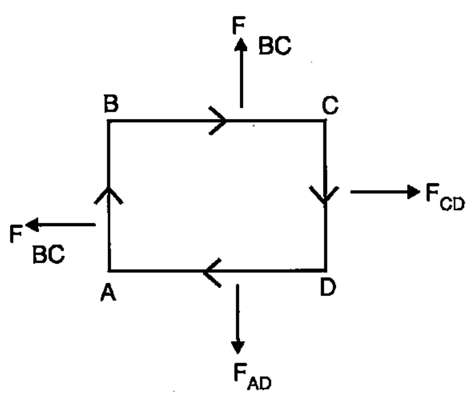
(b)



To calculate resultant magnetic force,

$$F = I(\vec{L} \times \vec{B})$$

$$F_{AB} = I_2(\vec{L} \times \vec{B_1})$$



Direction of field B due to current in long wire inward ⊗

$$B = \frac{\mu_0 I_1}{2\pi r}$$

Where, r = distance from long wire

$$\frac{\mu_0}{2\pi r}I_1 I_2 L_{AB} = I_2 \times 5 \times 10^{-2} \times \frac{\mu_0 \times I_1 \sin\theta}{2\pi \times 10 \times 10^{-2}}$$

$$= 0.2 \times 5 \times 10^{-2} \times \frac{\mu_0 \times I}{2\pi \times 10 \times 10^{-2}}$$

$$(\because \theta = 0°)$$

$$|\vec{F}_{AB}| = \frac{\mu_0}{2\pi} \cdot \frac{1}{10} \quad (\text{in the direction shown in fig})$$

$$|\vec{F}_{CB}| = I_2(\vec{L} \times \vec{B_1})$$

$$= 0.2 \times 5 \times 10^{-2} \times \frac{\mu_0}{2\pi} \times \frac{1}{15 \times 10^{-2}}$$

$$= \frac{\mu_0}{2\pi} \times \frac{1}{15}$$

$$|\vec{F}_{BC}| = |\vec{F}_{AD}| \qquad \because |F_Y Net| = 0$$

Thus net magnetic force,

$$F_{net} = |\vec{F}_{AB}| - |\vec{F}_{CD}|$$

$$= \frac{\mu_0}{2\pi}\left[\frac{1}{10} - \frac{1}{15}\right]$$

$$= \frac{4\pi \times 10^{-7}}{2\pi} \times [0.0333]$$

$$= 0.067 \times 10^{-7}$$

$$= 67 \times 10^{-10} \text{ N}$$

The forces acting on all sides of the square due to current of infinite length wire are lying in the plane of coil. Thus, there is no net torque. Thus torque is zero.

26. Explain, with the help of a diagram, how plane polarized light can be produced by scattering of light from the Sun.
Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I is incident on P_1. A third polaroid P_3 is kept between P_1 and P_2 such that its pass axis makes an angle of 45° with that of P_1. Calculate the intensity of light transmitted P_1, P_2 and P_3. [5]

OR

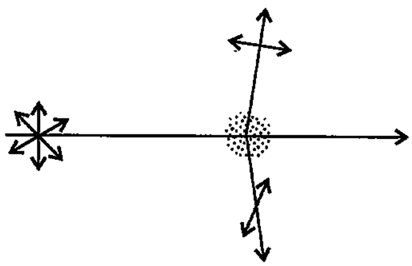
(a) Why cannot the phenomenon of interference be observed by illuminating two pin holes with two sodium lamps?

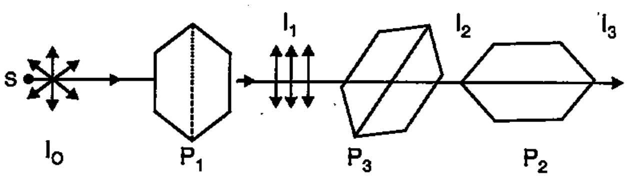
(b) Two monochromatic waves having displacements $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ from two coherent sources interfere to produce an interference pattern. Derive the expression for the resultant intensity and obtain the conditions for constructive and destructive interference.

(c) **Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^{-6} m. If the distance between the slit and the screen is 1·5 m, calculate the separation between the positions of the second maxima of diffraction pattern obtained in the two cases.**

Answer :

Molecules behave like dipole radiators and scatter no energy along the dipole axis by this way plane polarized light can be produced during scattering of light.





Intensity of light after passing through the polaroid P_1(I')

$$I_1 = I_o/2$$

Intensity of light after passing through P_3

$$I_2 = I_1 \cos^2 45°$$

$$I_2 = \frac{I_1}{2} = \frac{I}{4}$$

Intensity of light after passing through P_2

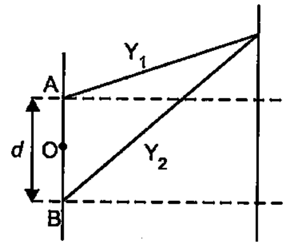
$$I_3 = I_2 \cos^2 45°$$

$$= \frac{I}{4} \times \frac{I}{2} = \frac{I}{8}$$

OR

(a) Phenomenon of interference can't be observed by illuminating two pin holes with two sodium lamps because these sources are not coherent source (it means they are not in same phase).

(b) Consider two monochromatic coherent sources A and B with waves $y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \phi)$ respectively.



From principle of superposition,

$$y = y_1 + y_2$$
$$= a \sin \omega t + b \sin (\omega t + \phi)$$
$$= a \sin \omega t + b \sin \omega t \cos\phi + b \cos\omega t \sin\phi$$
$$= (a + b \cos \phi) \sin \omega t + b \sin\phi \cos \omega t$$

Let,

$$a + b \cos \phi = A \cos\delta$$
$$b \sin\phi = A \sin\delta$$
$$y = A \sin \omega t \cos\delta + A \cos \omega t \sin\delta$$
$$= A \sin (\omega t + \delta)$$
$$A = \sqrt{a^2 + b^2 + 2ab\cos\phi}$$
$$\tan\delta = \frac{b \sin\phi}{a + b\cos\phi}$$

1. constuctive interference

For I-maxima,

$$I \propto A^2$$

and for A to be maximum,

$$\cos \phi = 1$$
$$\cos \phi = \cos 2n\pi, n = 0, 1, 2, 3.....$$
$$\phi = 2n\pi$$

and path difference,

$$\Delta x = n\lambda$$
$$A_{max} = a + b$$
$$I \to I_{max} = k(a + b)^2$$

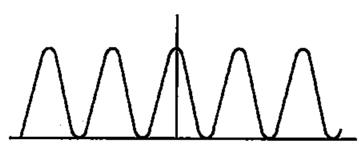
2. Destructive Interference

For I – minima

$$\cos\phi = -1$$
$$\Delta\phi = (2n + 1)\pi$$

Path difference,

$$\Delta x = (2n + 1)\lambda/2$$
$$A_{min} = a - b$$
$$I \to I_{min} = k(a - b)^2$$



(c) $\theta = (n + 1/2)\lambda/a$

$a = 2 \times 10^{-6}$ (aperture of slit)

$$\theta_1 = \frac{\lambda}{2a} = \frac{590 \times 10^{-9}}{4 \times 10^{-6}} = \frac{590}{4} \times 10^{-3}$$

$= 147.5 \times 10^{-3}$

$$\theta_1 = \frac{\lambda'}{2a} = \frac{596 \times 10^{-9}}{4 \times 10^{-6}} = 149 \times 10^{-3}$$

$\theta_2 - \theta_1 = 1.5 \times 10^{-3}$ (Angular difference)

$\lambda_1 = 596$ nm, $\lambda_2 = 590$ nm

$a = 2 \times 10^{-6}$

$D = 1.5$ m

$$y = \frac{3\lambda D}{2a}$$

$$y_1 - y_2 = \frac{3D}{2a}(\lambda_1 - \lambda_2)$$

$$= \frac{3 \times 1.5}{2 \times 2 \times 10^{6}}(596 - 590) \times 10^{-9} \text{ m}$$

$$= \frac{4.5}{4 \times 10^{-6}} \times 6 \times 10^{-9} \text{m}$$

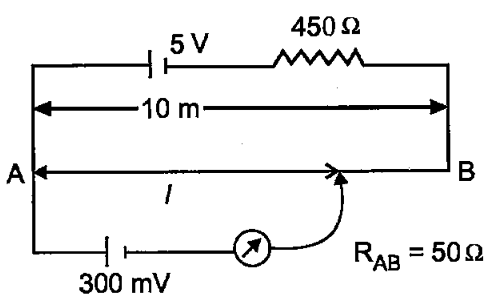
$$= \frac{4.5 \times 6}{4} \times 10^{-3} \text{m}$$

$= 6.78$ nm

27. (a) Describe briefly, with the help of a circuit diagram, the method of measuring the internal resistance of a cell.

(b) Give reason why a potentiometer is preferred over a voltmeter for the measurement of emf of a cell.

(c) In the potentiometer circuit given below, calculate the balancing length *l*. Give reason, whether the circuit will work, if the driver cell of emf 5 V is replaced with a cell of 2 V, keeping all other factors constant. [5]



OR

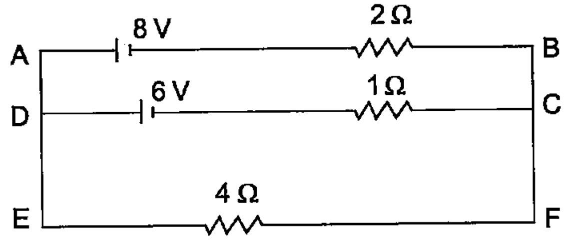
(a) State the working principle of a meter bridge used to measure an unknown resistance.

(b) Give reason.

(i) why the connections between the resistors in a metre bridge are made of thick copper strips.

(ii) why is it generally preferred to obtain the balance length near the mid-point of the bridge wire.

(c) Calculate the potential difference across the 4 Ω resistor in the given electrical circuit, using Kirchhoff's rules.



Answer :

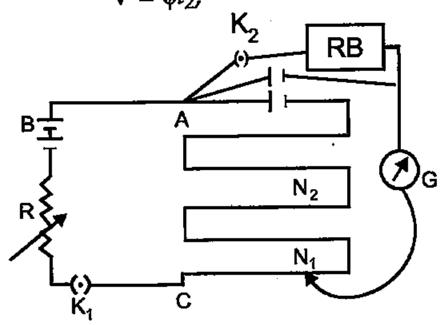
(a) When K_2 is open, balance is obtained at

$l_1 = AN_1$

$\varepsilon = \phi l_1$

when K_2 is closed

$V = \phi l_2$,



Circuit for determining internal resistance of cell.

$$\frac{\varepsilon}{V} = \frac{l_1}{l_2}$$

But,

$$\varepsilon = I(r + R) \text{ and } V = IR$$

Thus,

$$\frac{\varepsilon}{V} = \frac{r+R}{R} = \frac{l_1}{l_2}$$

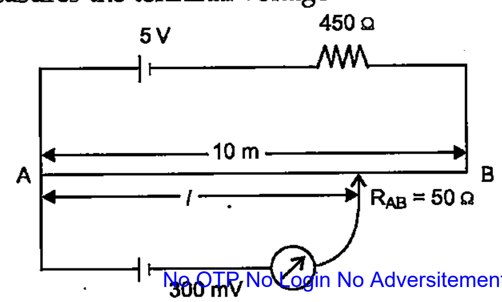
$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

Where, r is the internal resistance of cell.

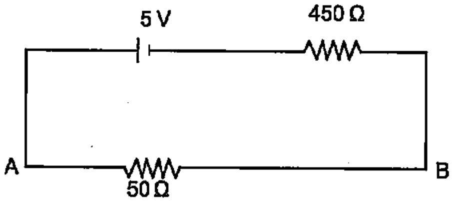
(b) Potentiometer is preferred over voltmeter for measurement of e.m.f. of cell because a voltmeter draws some current from the cell while potentiometer draws no current.

Therefore, the potentionmeter measures the actual e.m.f. of cell whereas voltmeter measures the terminal voltage.

(c)



For current through AB,



$$I = \frac{V}{R}$$

$$= \frac{5}{500} = 10 \text{ mA}$$

10 mA current passes through AB. Thus, voltage drop through AB = $V_{AB} = 10 \times 10^{-3} \times 50 = 500$ mV

Voltage drop per unit length

$$(\text{volts/m}) = \frac{500 \text{ mV}}{10}$$

$$= 50 \text{ mV/m}$$

balancing point is at 300 mV

Hence, l will be 6m.

When 5V is replaced with 2V

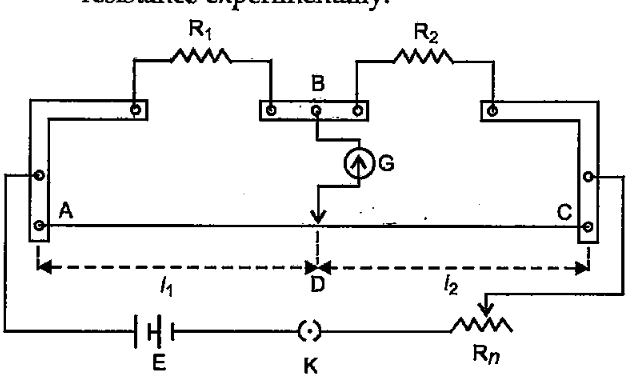
$$I_{AB} = \frac{2}{500} = 4\text{mA}$$

$$V_{AB} = 4 \text{ mA} \times 50 = 200 \text{ mV}$$

Hence, balancing will not possible as it needs to cater 300 mV.

OR

(a) Meter bridge is the practical apparatus which works on principle of Wheat-Stone bridge. It is used to measure unknown resistance experimentally.



Hence, as per Wheat-Stone bridge balance condition :

$$\frac{R_1}{R_2} = \frac{\text{Resistance of wire AD}}{\text{Resistance of wire DC}}$$

Where, D is point of balance.

$$\frac{R_1}{R_2} = \frac{\rho l_1}{\rho l_2} = \frac{l_1}{l_2} = \frac{l_1}{(100 - l_1)}$$

$$(\because \ l_1 + l_2 = 100 \text{ cm})$$

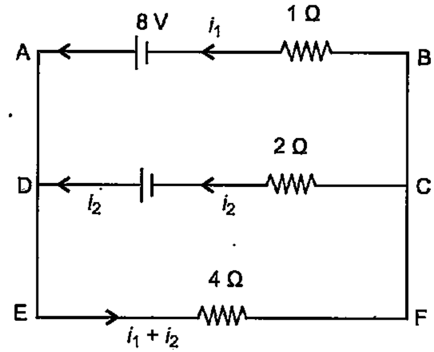
ρ = resistance per unit length of wire.

$$R_1 = R_2 \frac{l_1}{(100 - l_1)}$$

(b) (i) Connection between resistors are made of thick copper strips so that it will have maximum resistance and location of point of balance (D) will be more accurate which results in correct measurement of unknown resistance.

(ii) It is preferred to obtain the balance length near the mid-point of the bridge wire because it increase the sensitivity of meter bridges.

(c) From KCL (Kirchhoff's current lw) at point D



Current flowing through 4Ω resistance

$$i_1 + i_2 = i$$

KVL in loop DEFCD,

$$\Sigma V = 0$$

$$-(i_1 + i_2)4 - i_2 + 6 = 0$$

$$-4i_1 - 5i_2 + 6 = 0$$

(Voltage drop is negative and gain is positive)

$$4i_1 + 5i_2 = 6$$

KVL in loop AEFBA,

$$-(i_1 + i_2)\ 4 - 2i_1 + 8 = 0$$

$$-4i_1 - 4i_2 - 2i_1 + 8 = 0$$

$$-6i_1 - 4i_2 + 8 = 0$$

$$6i_1 + 4i_2 = 8 \quad \text{....(i)}$$

$$4i_1 + 5i_2 = 6 \quad \text{....(ii)}$$

Afer solving both (i) and (ii)

$$i_1 = 8/7$$

$$i_2 = 2/7$$

Physics 2019 (Outside Delhi)

SET II

Time allowed : 3 hours **Maximum marks : 70**

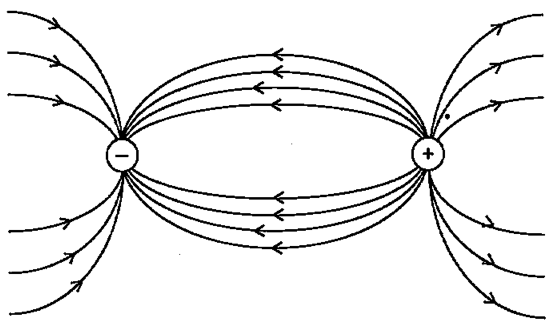
Note : Except for the following questions, all the remaining questions have been asked in previous set.

1. Write the relation for the force acting on a charged particle q moving with velocity $\vec{v}$ in the presence of a magnetic field $\vec{B}$. [1]

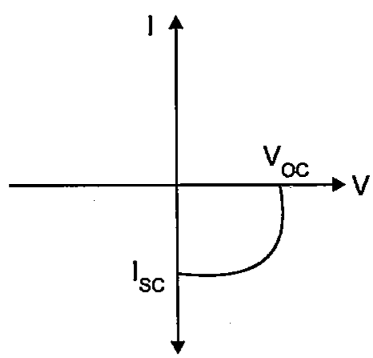
Answer : $\vec{F} = q(\vec{V} \times \vec{B})$

3. Draw the pattern of electric field lines due to an electric dipole. [1]

Answer :



5. Identify the semiconductor diode whose I-V characteristics are as shown. [1]

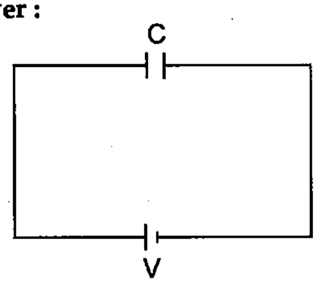


Answer : Photodiode/Solar cell.

SECTION-B

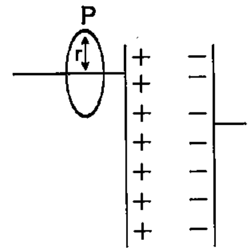
7. How is the equation for Ampere's circuital law modified in the presence of displacement current? Explain. [2]

Answer :



From Ampere's law,

$$\oint B \cdot dl = \mu_0 i(t)$$



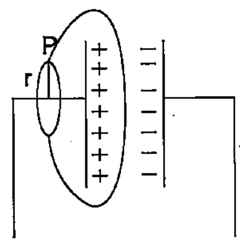
Case-1

Let, the case-1 where a point P is considered outside capacitor charging from Ampere's law.

Magnetic field at point will be

$$B. (2\pi r) = \mu_0\, i(t)$$

$$B = \frac{\mu_0}{2\pi r}\, i(t)$$



Case-2

Now take case-2 where shape surface under consideration covers capacitor's plate as we consider there is no current through capacitor then this value of B will be zero.

Hence, there is a contradiction.

Therefore this Ampere's law was modified with addition of displacement current inside capacitor.

$$\phi_E = |E|A = \frac{1}{\varepsilon_0} \cdot \frac{Q}{A} \cdot A = \frac{Q}{\varepsilon_0}$$

$$\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0} \cdot \frac{dQ}{dt}$$

$$\varepsilon_0 \frac{d\phi_E}{dt} = \frac{dQ}{dt} = i_d$$

Where, i_d is displacement current.

During charging of capacitor, outside the capacitor, i_c (conduction current) flows and inside i_d displacement current flows.

$$i = i_c + i_d = i_c + \varepsilon_0 \frac{d\phi_E}{dt}$$

Outside the capacitor $i_d = 0$ hence, $i = i_c$

and inside the capacitor $i_c = 0$ hence, $i = i_d$

8. Under what conditions does the phenomenon of total internal reflection take place? Draw a ray diagram showing how a ray of light deviates by 90° after passing through a right-angled isosceles prism. [2]

Answer :

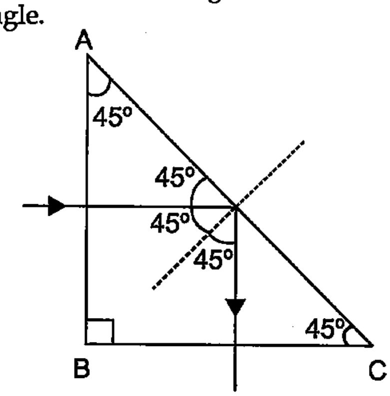
The phenomenon of total internal reflection occurs when,

1. Angle of incidence is equal or greater than critical angle.

$$i \geq C$$

2. When light travels from more denser medium to less denser medium.

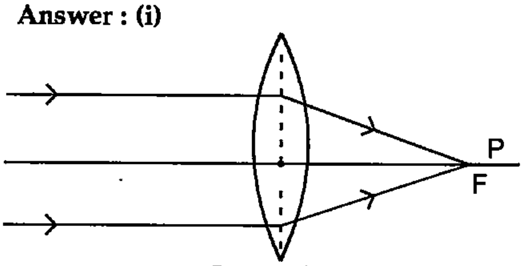
In case of right angle isosceles triangle if light rays fall normally on AB then light incident of face AC with angle of incidence > critical angle.



Hence, total internal reflection will occur with normal to the surface of BC.

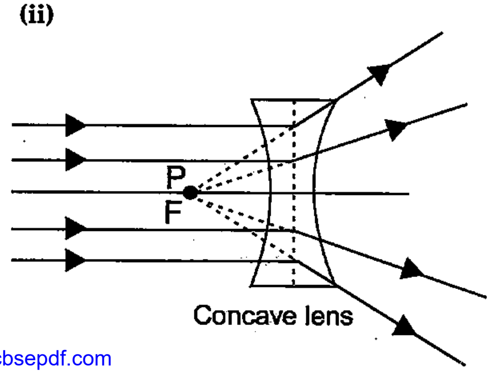
11. A beam of light converges at a point P. Draw ray diagrams to show where the beam will converge if (i) a convex lens, and (ii) a concave lens is kept in the path of the beam. [2]

Answer : (i)



Convex lens

(ii)



Concave lens

SECTION-C

14. (a) How is the stability of hydrogen atom in Bohr model explained by de-Broglie's hypothesis?

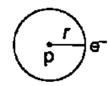
(b) A hydrogen atom initially in the ground state absorbs a photon which excites it to n = 4 level. When it gets de-excited, find the maximum number of lines which are emitted by the atom. Identify the series to which these lines belong. Which of them has the shortest wavelength? [3]

Answer :

(a) From Bohr's model-An atom has a number of stable orbits in which an electron can reside without the emission of radiant energy. Each orbit corresponds to a certain energy level.

$\because$ Electron revolves is circular orbit

$$\therefore \quad \frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$$



The motion of an electron in circular orbits is restricted in such a manner that its angular momentum is an integral multiple of $h/2\pi$

Thus, $L = mvr = \frac{nh}{2\pi}$

$$E_n = \frac{-13.6}{r^2} z^2 \text{ eV}$$

$Z = 1$ for H_2 atom

$$E_n = \frac{-13.6}{r^2} \text{ eV}$$

From de-Broglie hypothesis

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

And from Bohr model

$$n\lambda = 2\pi r$$

$$\lambda = \frac{2\pi r}{r}$$

$$\frac{h}{mv} = \frac{2\pi r}{n}$$

$$\frac{nh}{2\pi} = mvr = L$$

(b) $n_i = 1$, $n_f = 4$.

Possible transitions are :

$\Rightarrow \quad 4 \to 3, 4 \to 2, 4 \to 1$

or $\quad 3 \to 2, 3 \to 1,$

or $\quad 2 \to 1$

Hence, Six lines are possible.

$$\left.\begin{matrix} 4 \to 1 \\ 3 \to 1 \\ 2 \to 1 \end{matrix}\right\} \text{Lyman series}$$

$\left.\begin{array}{l}3 \rightarrow 2 \\ 4 \rightarrow 2\end{array}\right\}$ Balmer series

$4 \rightarrow 3$ Paschen series

$4 \rightarrow 1$ has smallest wavelength.

16. What is the reason to operate photodiodes in reverse bias?

A *p-n* photodiode is fabricated from a semiconductor with a band gap of range of 2·5 to 2·8 eV. Calculate the range of wavelengths of the radiation which can be detected by the photodiode. [3]

Answer : Photodiode are reverse biased for working in photo-conductive mode. This reduces the response time because the additional reverse bias increases the width of the depletion layer, which decreases the junction capacitance. The reverse bias also increases the dark current without much change in the photo current.

Given, E = 2.5 - 2.8 eV

$$E = \frac{hc}{\lambda}$$

$$\lambda_1 = \frac{hc}{E_1}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{2.5\times1.6\times10^{-19}}$$

$$= \frac{3\times6.63\times10^{-7}}{-2.5\times1.6}$$

$$= 497.25 \text{ nm}$$

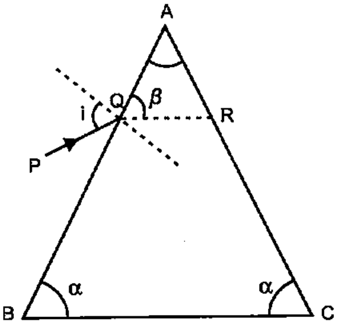
$$\lambda_2 = \frac{hc}{E_2}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{2.8\times1.6\times10^{-19}}$$

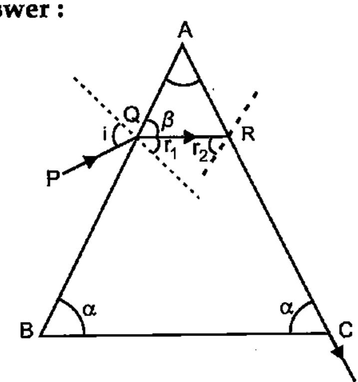
$$= 443.97 \text{ nm}$$

The range of wavelengths of radiation which can be detected by the photodiode is 443.97 nm to 497.25 nm.

18. A ray of light incident on the face AB of an isosceles triangular prism makes an angle of incidence (i) and deviates by angle β as shown in the figure. Show that in the position of minimum deviation ∠β = ∠α. Also find out the condition when the refracted ray QR suffers total internal reflection. [3]



Answer :



$$\frac{\sin i}{\sin r} = \mu$$

(i) Condition for minimum deviation :

1. $A = 180 - 2\alpha$

2. $\dfrac{\sin i}{\sin(90-\beta)} = \mu$

when, $r_1 = r_2 = r >$ critical angle

$$r_1 + r_2 = 180 - 2\alpha$$

$$2r = 180 - 2\alpha \qquad [\because r_1 = r_2]$$

$$r_1 = r = 90 - \alpha$$

$$\beta = 90 - r_1$$

$$= 90 - 90 + \alpha$$

$$\beta = \alpha$$

condition when QR have total internal reflection :

$\angle QRC \geq$ critical angle for the prism

$\angle 180° - \beta \geq$ critical angle

or

$\angle 180° - \alpha \geq$ critical angle

$\because \quad \angle 180° - \alpha = \angle BAC$

$\therefore \quad \angle BAC \geq$ critical angle

22. A 100 μF parallel plate capacitor having plate separation of 4 mm is charged by 200 V dc. The source is now disconnected. When the distance between the plates is doubled and a dielectric slab of thickness 4 mm and dielectric constant 5 is introduced between the plates, how will (i) its capacitance, (ii) the electric field between the plates, and (iii) energy density of the capacitor get affected? Justify your answer in each case. [3]

Answer : Given,

c = 100 μF
d = 4 × 10–3m.
V = 200V
k = 5
Q = CV
= 200 × 100 × 10^{-6}
= 2 × 10^{-2} Coulomb

As dielectric of 4 mm is inserted between the plates of capacitor and the spacing between the plates is doubled then it will acts as following Fig-A and Fig-B.

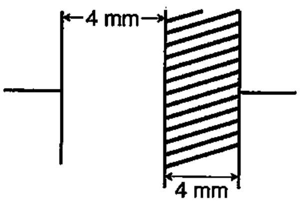


Fig-A

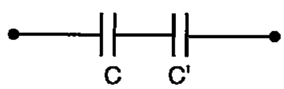


Fig-B

Here, C' will be capacitance with dielectric of 4 mm & 8 mm separation between the plates.
C' = KC = 5 × 100 × 10^{-6} = 0.5 × 10^{-3} F

(i) Thus, equivalent capacitance

$$\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C'} = \frac{1}{100 \times 10^{-6}} + \frac{1}{0.5 \times 10^{-3}}$$
$$= 10 \times 10^3 + 2 \times 10^3$$
$$= 12 \times 10^3$$
$$\frac{1}{C_{eq}} = 12 \times 10^3$$
$$C_{eq} = \frac{1}{12 \times 10^3}$$
$$= \frac{1}{12} \times 10^{-3}$$
$$C_{eq} = 83.33\ \mu F$$

(ii) Electric field inside dielectric will be

$$(E') = \frac{E}{K} = \frac{50}{5 \times 4 \times 10^{-3}}$$
$$= \frac{50 \times 10^3}{5} = 10 \times 10^3$$
$$= 1000\ V/m.$$

and Electric field inside capacitor but out of dielectric Area will be

$$E = 50 \times 10^3\ V/m$$

(iii) Energy density of capacitor is given by :

$$U = \frac{Q^2}{2C}$$
$$= U' + U$$
$$= \frac{Q^2}{2C} + \frac{Q^2}{2C'}$$
$$\Rightarrow \frac{Q^2}{2}\left[\frac{1}{C} + \frac{1}{C'}\right] = \frac{2 \times 10^{-2} \times 2 \times 10^{-2}}{2}[12 \times 10^3]$$
$$\left(\because \frac{1}{C} + \frac{1}{C'} = \frac{1}{C_{eq}}\right)$$
$$= 2 \times 10^{-1} \times 12$$
$$= 2.4\ J$$

●●

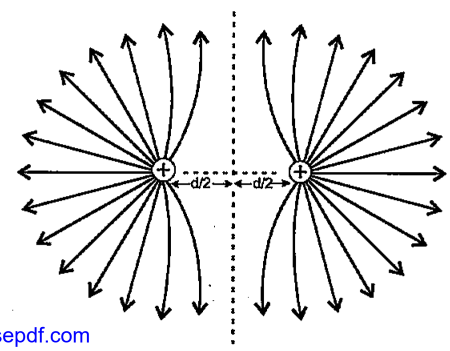
Physics 2019 (Outside Delhi) SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous sets.

2. Draw a pattern of electric field lines due to two positive charges placed a distance d apart. [1]

Answer : Electric field lines due to two positive charge placed to at distance d apart :

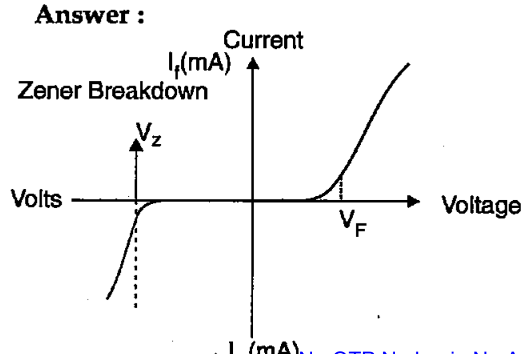


4. When a charge q is moving in the presence of electric (E) and magnetic (B) fields which are perpendicular to each other and also perpendicular to the velocity v of the particle, write the relation expressing v in terms of E and B. [1]

Answer : $v = E/B$

5. Draw the I-V characteristics of a Zener diode. [1]

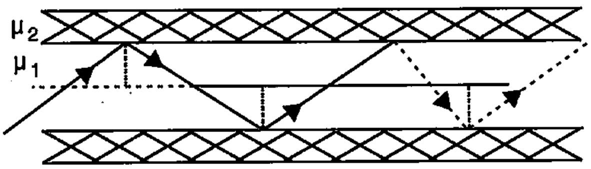
Answer :



SECTION-B

6. State, with the help of a ray diagram, the working principle of optical fibres. Write one important use of optical fibres. [2]

Answer :



Optical fibre works on principle of total internal reflection. When angle of incidence is greater than Critical angle then incident rays are totally reflected back in same media.

When, $\theta_i > \theta_C$, Total internal reflection occurs and if $\theta_i < \theta_C$, refraction occurs.

Application : Optical fibre are used for communication due to very high bandwidth of media.

8. How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the em waves [2]

Answer : Oscillating charges are responsible for generation of periodically varying electric field in the space. The oscillating charges generate varying electric current which in turn is responsible for the generation of periodical varying magnetic field. This way the electromagnetic waves are generated.

9. The wavelength of light from the spectral emission line of sodium is 590 nm. Find the kinetic energy at which the electron would have the same de-Broglie wavelength. [2]

Answer : Given, $\lambda = 590 \text{ nm} = 590 \times 10^{-9}\text{m}$

KE = ?

For same de-Broglie wavelength,

De-Broglie wavelength $(\lambda) = \dfrac{h}{mv}$

h-planck constant

$$= 590\times10^{-9}$$

$$\frac{h}{m_e \times 590\times10^{-9}} = v$$

$$\text{KE} = \frac{1}{2} m_e v^2$$

$$= \frac{1}{2} \times m_e \times \frac{h^2}{m_e^2 \times (590\times10^{-9})^2}$$

$$= \frac{1}{2} \times \frac{6.62\times10^{-34} \times 6.62\times10^{-34} \times 10^9 \times 10^9}{9.1\times10^{-31} \times 590 \times 590}$$

$$\text{KE} = 6.91 \times 10^{-17} \text{ J}$$

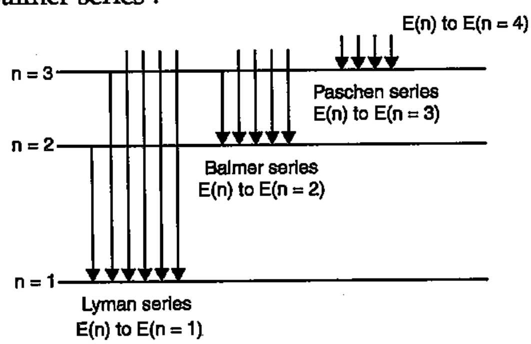
SECTION-C

13. (a) Draw the energy level diagram for the line spectra representing Lyman series and Balmer series in the spectrum of hydrogen atom.

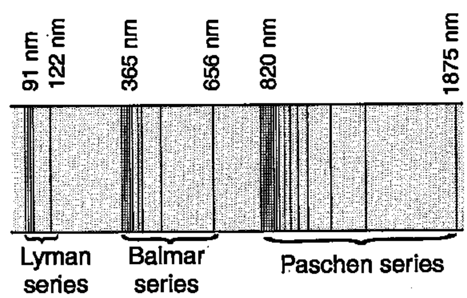
(b) Using the Rydberg formula for the spectrum of hydrogen atom, calculate the largest and shortest wavelengths of the emission lines of the Balmer series in the spectrum of hydrogen atom. (Use the value of Rydberg constant $R = 1.1 \times 10^7 \text{ m}^{-1}$ [3]

Answer :

(a) Energy level diagram showing lyman and balmer series :



Spectrum wavelngths of both series for hydrogen atom



(b) Rydberg formula,

$$\frac{1}{\lambda} = 1.1 \times 10^7 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda_1} = 1.1\times10^7 \left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda_1} = 1.1\times10^7 \times 0.1389$$

$$\lambda_1 = \frac{1}{1.1}\times10^7 \times 0.1389$$

$$\lambda_1 = \frac{100\times10^{-9}}{0.153}$$

$$\lambda_{max}\ (\lambda_1) = 653.6 \text{ nm}$$

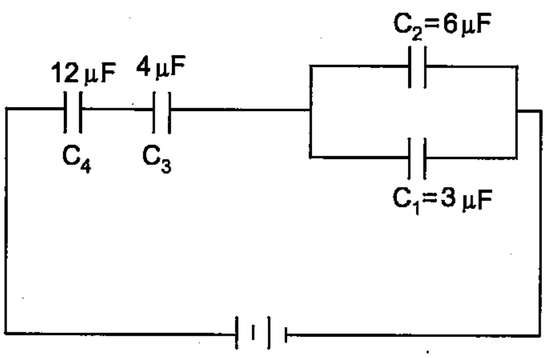
$$\frac{1}{\lambda_2} = \frac{1.1\times10^{7}}{4}$$

$$\lambda_2 = \frac{4}{1.1\times10^{7}}$$

$$= \frac{400}{1.1}\times10^{-9}$$

$$\lambda_{min}\ (\lambda_2) = 363.6 \text{ nm}$$

15. In a network, four capacitors C_1, C_2, C_3 and C_4 are connected as shown in the figure. [3]

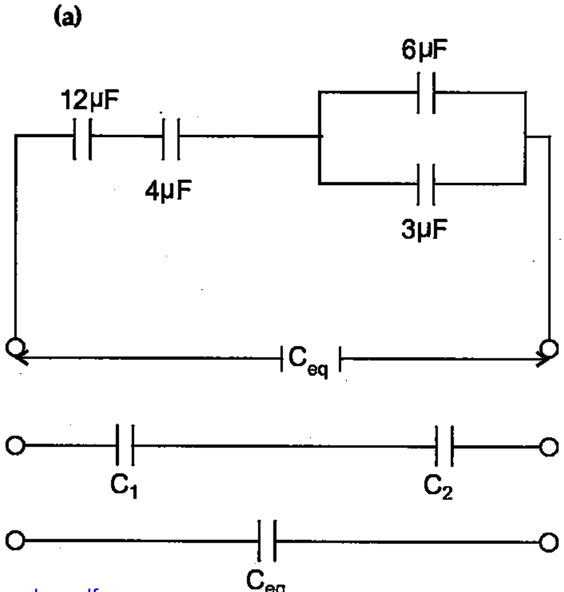


(a) Calculate the net capacitance in the circuit.

(b) If the charge on the capacitor C_1 is 6 µC, (i) calculate the charge on the capacitors C_3 and C_4, and (ii) net energy stored in the capacitors C_3 and C_4 connected in series.

Answer :

(a)



$$\frac{1}{C_1} = \frac{1}{12}+\frac{1}{4}$$

$$\frac{1}{C_1} = \frac{4}{12}\ \mu F$$

$$C_1 = 3\ \mu F$$

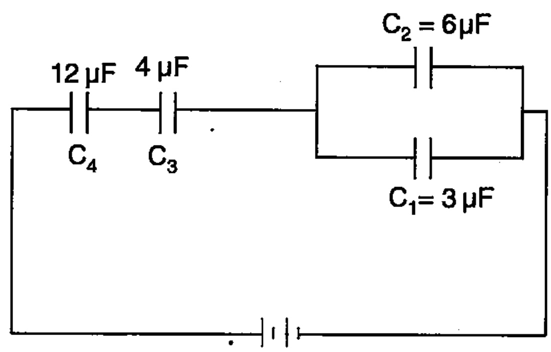
$$C_2 = 3 + 6 = 9\mu F$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1}+\frac{1}{C_2} = \frac{1}{9}+\frac{1}{3}$$

$$\frac{1}{C_{eq}} = \frac{4}{9}$$

$$C_{eq} = 9/4\ \mu F$$

(b) (i) Given, $Q_1 = 6\ \mu C$, $C_2 = 6\ \mu F$



Q_1 is charge on C_1

Q_2 is charge on C_2

Q is net charge flows through C_3 and C_4

$$\frac{Q_1}{C_1} = V = \frac{Q_2}{C_2}$$

$$Q_2 = \frac{Q_1}{C_1}\times C_2$$

$$= \frac{6}{3}\times 6$$

$$Q_2 = 12\ \mu C$$

$$Q = Q_1 + Q_2$$

$$= 12 + 6$$

$$= 18\ \mu C$$

(ii) Voltage across C_1 and C_2 is 2 volts.

Thus, voltage across combination of C_4 and C_3 will be

$$V = 8 - 2 = 6V$$

$$\frac{1}{C} = \frac{1}{C_3}+\frac{1}{C_4}$$

$$\frac{1}{C} = \frac{1}{4}+\frac{1}{12}$$

$$\frac{1}{C} = \frac{3+1}{12}=\frac{4}{12}$$

$$C = 3\ \mu F$$

Hence, Energy

$$E = \frac{1}{2}CV^2$$

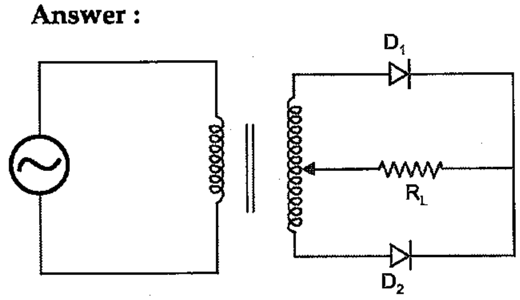
$$= \frac{1}{2}\times 3\times 6^2$$

$$= \frac{36\times 3}{2}$$

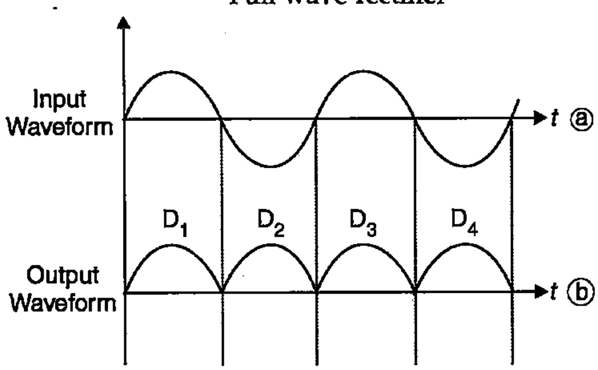
$$= 54 \times 10^{-6}\ J$$

17. Draw the circuit diagram of a full wave rectifier. Explain its working principle. Show the input waveforms given to the diodes D_1 and D_2 and the corresponding output waveforms obtained at the load connected to the circuit. [3]

Answer :



Full wave rectifier



During first half of input sinusoidal ac signal diode D_1 conducts as it is forward bias and during second half of input ac signal diode D_2 conducts as it is forward bias now. D_2 and D_1 are inverse bias conditions during first and second half respectively and doesn't conduct. Due to this output appears as waveform (b).

21. (a) When a convex lens of focal length 30 cm is in contact with a concave lens of focal length 20 cm, find out if the system is converging or diverging.

(b) Obtain the expression for the angle of incidence of a ray of light which is incident on the face of a prism of refracting angle A so that it suffers total internal reflection at the other face. (Given the refractive index of the glass of the prism is μ) [3]

Answer :

(a) $f_1 = f_{convex} = 30$ cm

$f_2 = f_{concave} = -20$ cm

$$\frac{1}{f} = \frac{1}{f_1}+\frac{1}{f_2}$$

$$= \frac{1}{30}-\frac{1}{20}$$

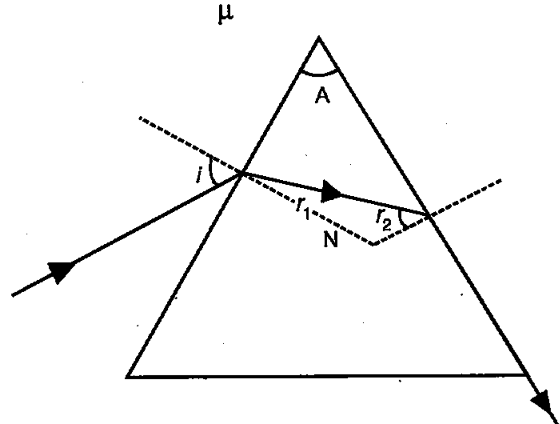
$$= \frac{2-3}{60}$$

$$\frac{1}{f} = -\frac{1}{60}$$ [∴ concave (diverging) lens]

(b) $$\mu = \frac{\sin\left(\frac{\delta_{min}+A}{2}\right)}{\sin A/2}$$

Let C is the critical angle,

$$\sin C = \frac{1}{\mu}$$



$r_2 = C$ for total internal reflection

$$r_1 + r_2 = A$$

$$r_1 + C = A$$

$$r_1 = A - C$$

$$\mu = \frac{\sin i}{\sin r_1}$$

⇒ $$\sin i = \mu \sin r_1$$

$$\sin i = \mu \sin (A-C)$$

$$i = \sin^{-1} \mu \sin (A-C)$$

Physics 2019 (Delhi) SET I

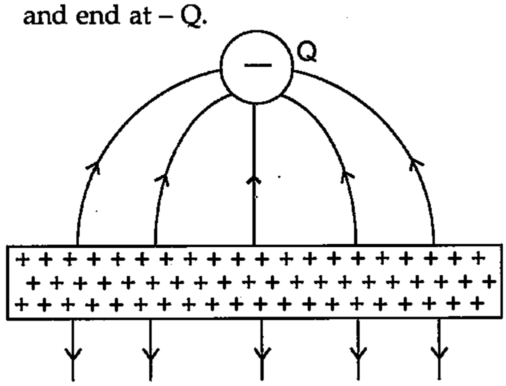
Time allowed : 3 hours **Maximum marks : 70**

SECTION-A

1. Draw the pattern of electric field lines, when a point charge $-Q$ is kept near an uncharged conducting plate. [1]

Answer :

The positive charge will be induced on the uncharged conducting plate, kept near it. So, the lines of forces will start from metal plate and end at – Q.



2. How does the mobility of electrons in a conductor change, if the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor constant ? [1]

Answer :

The mobility of electrons is given by the expression, $\mu = \frac{e\tau}{m}$

As it's independent of the applied potential difference, so it will not change if the applied potential difference will be doubled.

3. Define the term "threshold frequency" in the context of photoelectric emission. [1]

OR

Define the term 'Intensity' in photon picture of electromagnetic radiation.

Answer :

The minimum frequency of the radiation incident on a metal surface below which there is no photoelectric emission is called threshold frequency. It is a characteristic property of a photosensitive material.

OR

The amount of light energy or photon energy incident per meter square per second is called intensity of radiation. SI unit of intensity of radiation is $\frac{W}{Sr}$.

4. What is the speed of light in a denser medium of polarising angle 30° ? [1]

Answer :

Given : $i_p = 30°$

since, $\mu = \tan i_p$ (By Brewster's law)

$\therefore \quad \mu = \tan 30°$

$\Rightarrow \quad \mu = \frac{1}{\sqrt{3}}$

Since, $\mu = \frac{C}{v}$

$\therefore \quad v$ = velocity of light in medium $= \frac{C}{\mu}$

$= \frac{3\times10^8}{1/\sqrt{3}}$

$= 3\sqrt{3} \times 10^8$ m/s

$= 5.196 \times 10^8$ m/s

5. In sky wave mode of propagation, why is the frequency range of transmitting signals restricted to less than 30 MHz ? [1]**

OR

On what factors does the range of coverage in ground wave propagation depend?**

SECTION-B

6. Two bulbs are rated (P_1, V) and (P_2, V). If they are connected (i) in series and (ii) in parallel across a supply V, find the power dissipated in the two combinations in terms of P_1 and P_2. [2]

Answer : (i) In series combination :

Net resistance, $R' = R_1 + R_2$ .....(i)

As heating elements are operated at same voltage V, we have

$R = \frac{V^2}{P}, R_1 = \frac{V^2}{P_1}$ and $R_2 = \frac{V^2}{P_2}$

$\therefore$ From equation (i)

$$\frac{V^2}{P} = \frac{V^2}{P_1} + \frac{V^2}{P_2}$$

$$\Rightarrow \quad \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$$

$\Rightarrow$ Net power dissipated :

$$\Rightarrow \quad P = \frac{P_1P_2}{P_1+P_2}$$

**Answer is not given due to change in the present syllabus.

(ii) In parallel combination :

Net resistance,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{...(ii)}$$

$$\Rightarrow \quad \frac{P}{V^2} = \frac{P_1}{V^2} + \frac{P_2}{V^2}$$

$$\left[\because R = \frac{V^2}{P}, R_1 = \frac{V^2}{P_1}, R_2 = \frac{V^2}{P_2}\right]$$

$$\Rightarrow \quad P = P_1 + P_2$$

Hence, net power dissipated is $P = P_1 + P_2$.

7. Calculate the radius of curvature of an equi-concave lens of refractive index 1.5, when it is kept in a medium of refractive index 1.4, to have a power of –5 D ? [2]

OR

An equilateral glass prism has a refractive index 1.6 in air. Calculate the angle of minimum deviation of the prism, when kept in a medium of refractive index $4\sqrt{2}/5$.

Answer :

In an equi-concave lens, radius of curvature of both surfaces are equal

$$\therefore \quad \frac{1}{f} = (\mu - 1)\left(-\frac{1}{R} - \frac{1}{R}\right)$$

since, P = –5 D

$$\therefore \quad \frac{1}{f(\text{m})} = P = -5$$

and $\mu_e = 1.5$ and $\mu_m = 1.4$

$$\therefore \quad 5 = \left(\frac{1.5}{1.4} - 1\right)\left(\frac{-2}{R}\right)$$

$$\Rightarrow \quad -5 = \frac{0.1}{1.4} \times \frac{-2}{R}$$

$$\Rightarrow \quad R = \frac{0.1 \times (-2)}{1.4 \times (-5)}$$

$$= 0.03 \text{ m}$$

OR

As we know,

$$_1n_2 = \frac{\sin\left(\frac{A + \delta_{min}}{2}\right)}{\sin\frac{A}{2}}$$

where $n_2 = 1.6$, refractive index of glass prism

$n_1 = \frac{4\sqrt{2}}{5}$, refractive index of medium

$A = 60°$, angle of prism

δ_{min} = angle of minimum deviation

$$\therefore \quad \frac{1.6}{4\sqrt{2}/5} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin 30}$$

$$\Rightarrow \quad \frac{0.4 \times 5}{\sqrt{2}} = \sin\left(\frac{60° + \delta_m}{2}\right) \times 2 \quad \left[\because \sin 30° = \frac{1}{2}\right]$$

$$\Rightarrow \sin\left(\frac{60° + \delta_m}{2}\right) = \frac{1}{\sqrt{2}}$$

$$\Rightarrow \quad \frac{60° + \delta_m}{2} = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$$

$$= \sin^{-1}(\sin 45°) = 45°$$

$$\Rightarrow \quad \delta_m = 30°$$

8. An α-particle and a proton of the same kinetic energy are in turn allowed to pass through a magnetic field $\vec{B}$, acting normal to the direction of motion of the particles. Calculate the ratio of radii of the circular paths described by them. [2]

Answer :

As we know, radius of the charged particle is given by

$$r = \frac{\sqrt{2mK}}{qB}$$

Since, K. E. of particles and $\vec{B}$ are equal.

∴ For α- particle

$$r_\alpha = \frac{\sqrt{2m_\alpha K}}{q_\alpha B} \quad \text{...(i)}$$

For proton,

$$r_p = \frac{\sqrt{2m_p K}}{q_p B} \quad \text{...(ii)}$$

on comparing equation (i) and (ii)

$$\frac{r_\alpha}{r_p} = \frac{\sqrt{m_\alpha} \times q_p}{q_\alpha \times \sqrt{m_p}}$$

since, $m_\alpha = 4m_p$ and $q_\alpha = q_p$

$$\therefore \quad \frac{r_\alpha}{r_p} = \frac{\sqrt{4m_p}}{\sqrt{m_p}} = \frac{2}{1}$$

$$r_\alpha : r_p = 2 : 1$$

9. State Bohr's quantization condition of angular momentum. Calculate the shortest wavelength of the Bracket series and state to which part of the electromagnetic spectrum does it belong. [2]

OR

Calculate the orbital period of the electron in the first excited state of hydrogen atom.

Answer : According to Bohr's quantization of angular momentum, the stationary orbits are those in which angular momentum of electron is an integral multiple of $\frac{h}{2\pi}$ *i.e.,*

$$mvr = n\frac{h}{2\pi} \quad \text{Where, } n = 1, 2, 3$$

For Brackett series,

$$\frac{1}{\lambda_{min}} = n = \frac{1}{\sin C}$$

$$\Rightarrow \quad \frac{1}{\lambda_{min}} = \frac{R}{16}$$

Where, R = Rydberg constant

$= 1.096 \times 10^7 \text{ m}^{-1}$

$$\Rightarrow \quad \lambda_{min} = \frac{16}{1.096 \times 10^7} \text{m}$$

$$= 14.599 \times 10^{-7}$$

$$\Rightarrow \quad = 14599 \text{ Å}$$

Brackett series is found in infrared region (10^6 Å to 7000 Å) of electromagnetic spectrum.

OR

For hydrogen atom z =1 and n = 1

∴ Velocity of electron,

$$v = \frac{ze^2}{2h\varepsilon_0 n}$$

$$v = \frac{e^2}{2h\varepsilon_0}$$

Therefore, $v = \frac{c}{137}$, Where, c is velocity of light.

$$\text{Orbital period} = \frac{\text{Distance}}{\text{Velocity}} = \frac{2\pi r}{c} \times 137$$

$$= \frac{2 \times 3.14 \times 5.29 \times 10^{-11} \times 137}{3 \times 10^3}$$

$$= 1.517 \times 10^{-16} \text{ sec.}$$

10. Why a signal transmitted from a TV tower cannot be received beyond a certain distance? Write the expression for the optimum separation between the receiving and the transmitting antenna.** **[2]**

11. Why is wave theory of electromagnetic radiation not able to explain photo electric effect ? How does photon picture resolve this problem ? [2]

Answer :

Wave theory cannot explain the following laws of photoelectric effect.

(i) The instantaneous emission of photoelectrons.

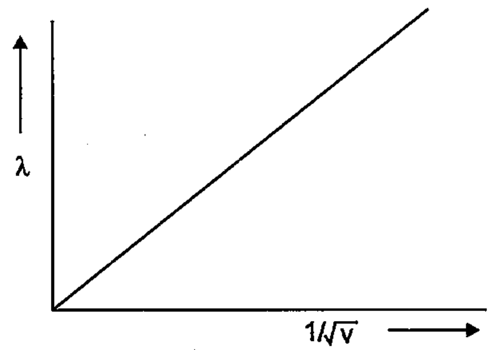
(ii) Existence of threshold frequency for metal surface.

(iii) K.E. of emitted electrons is independent of intensity of light and depends on frequency.

The concept of photon explained that energy is not only emitted and absorbed in discrete energy quanta, but also it propagates through space in definite quanta with the speed of light. It can explain all the above photoelectric effect, which wave theory cannot explain.

12. Plot a graph showing variation of de Broglie wavelength (λ) associated with a charged particle of a mass *m*, versus $1/\sqrt{V}$, where V is the potential difference through which the particle is accelerated. How does this graph give us the information regarding the magnitude of the charge of the particle ? [2]

Answer :



Since, $$\lambda = \frac{h}{\sqrt{2meV}}$$

i.e., $$\lambda \propto \frac{1}{\sqrt{e}}$$

Therefore, more the wavelength lesser is the charge.

SECTION-C

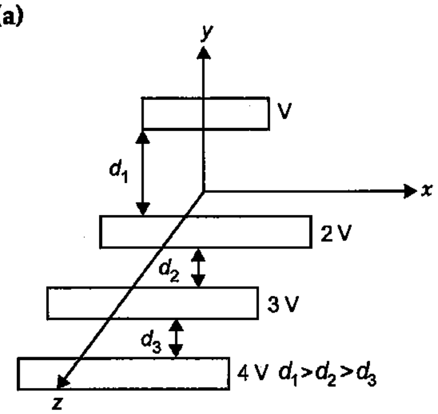
13. (a) Draw the equipotential surfaces corresponding to a uniform electric field in the z-direction.

(b) Derive an expression for the electric potential at any point along the axial line of an electric dipole. [3]

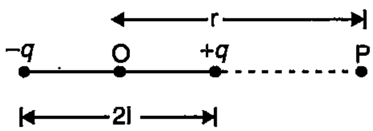
**Answer is not given due to change in the present syllabus.

Answer :

(a)



(b) Electric potential due to dipole along axial line :



The figure shows a dipole consisting of two equal and opposite charges $+q$ and $-q$ separated by a distance $2l$. Let, P be a point on the end- on position of the dipole. OP is the axial line of dipole.

The potential due to charge + q at point

$$P = V_1$$

$$V_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r-l)}$$

The potential due to charge $-q$ at point P = V_2

$$V_2 = \frac{1}{4\pi\varepsilon_0} \times \frac{(-q)}{(r+l)}$$

Total potential at point P = V = $V_1 + V_2$

$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r-l)} + \frac{1}{4\pi\varepsilon_0} \times \frac{(-q)}{(r+l)}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r-l} - \frac{1}{r+l}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{r+l-r+l}{(r-l)(r+l)}\right]$$

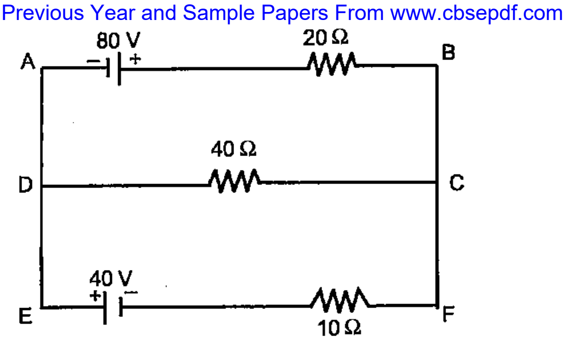
$$= \frac{1}{4\pi\varepsilon_0} \frac{2ql}{(r-l)(r+l)}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{2ql}{(r^2-l^2)}$$

But the dipole moment, P = $2lq$

So, $$V = \frac{1}{4\pi\varepsilon_0} \times \frac{P}{(r^2-l^2)}$$

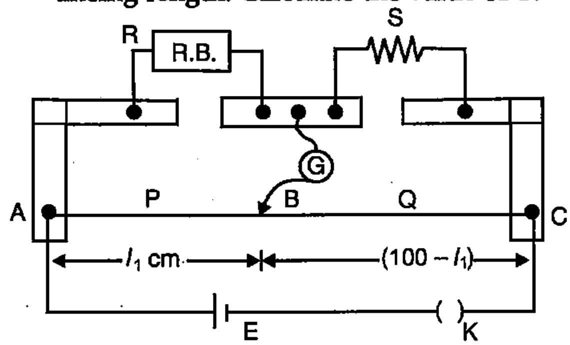
14. Using Kirchhoff's rules, calculate the current through the 40 Ω and 20 Ω resistors in the following circuit : **[3]**



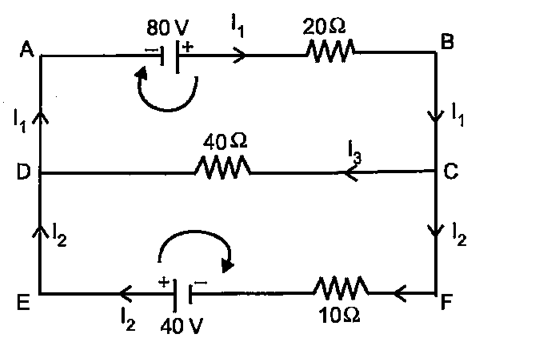
OR

What is end error in a metre bridge? How is it overcome? The resistances in the two arms of the metre bridge are R = 5 Ω and S respectively.

When the resistance S is shunted with an equal resistance, the new balance length found to be 1.5 l_1, where l_1 is the initial balancing length. Calculate the value of S.



Answer :



Applying Kirchhoff's first law at junction C

$$I_1 = I_2 + I_3$$

$$I_2 = I_1 - I_3 \quad \text{...(i)}$$

Applying the Kirchhoff's second law in closed loop ABCDA

$$80 - 20\, I_1 - 40 I_3 = 0 \quad \text{...(ii)}$$

Applying Kirchhoff's second law in closed loop DCFED

$$40 I_3 - 10\, I_2 + 40 = 0 \quad \text{...(iii)}$$

From equations (i) and (iii),

$$40\, I_3 - 10\,(I_1 - I_3) - 40 = 0$$

$$50\, I_3 - 10\, I_1 + 40 = 0 \quad \text{...(iv)}$$

From equations (ii) and (iv)

$$80 = 20 I_1 + 40 I_3$$
$$40 = 10 I_1 + 50 I_3$$

We get, $I_3 = 0$

and $I_1 = 4$ A

$I_2 = 4$ A

Therefore, current through 40 Ω resistor is 0 and current through 20 Ω resistor is 4 A.

OR

The shifting of zero of the scale at different points give rise to the end error in metre bridge wire.

This can be overcome by,

1. By trying to obtain the balance point in the middle of the metre bridge.
2. By taking metre bridge wire of uniform cross-section
3. By taking the copper strips thick, so that their resistance can be ignored.

As we know that,

$$\frac{R}{S} = \frac{l_1}{100-l_1} \quad ...(i)$$

When resistance S is shunted with equal resistance. Then, $S' = \frac{S}{2}$

Therefore, new balancing point is,

$$\Rightarrow \frac{R}{S/2} = \frac{1.5\, l_1}{100-1.5\, l_1}$$

$$\Rightarrow \frac{R}{S} = \frac{1.5\, l_1}{2(100-1.5\, l_1)} \quad ...(ii)$$

On comparing equations (i) and (ii)

$$\frac{l_1}{100-l_1} = \frac{1.5\, l_1}{2(100-1.5\, l_1)}$$

$$200 - 3l_1 = 150 - 1.5l_1$$

$$1.5\, l_1 = 50$$

$$l_1 = \frac{50}{1.5}$$

From equatoin (i),

$$\therefore \frac{5}{S} = \frac{50}{1.50}\left(100-\frac{50}{1.5}\right)$$

$(\because R = S)$

$$\Rightarrow \frac{5}{S} = \frac{50\times 1.5}{1.5(100)}$$

$$\Rightarrow S = \frac{500}{50} = 10\ \Omega$$

15. (a) Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range.

(b) Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field. [3]

Answer : (a)

(i) Radar—Microwaves are used in radar. The frequency range is from 3×10^{11} Hz to 1×10^{9} Hz.

(ii) Eye Surgery—Infrared waves are used. The frequency range is from 4×10^{14} Hz to 3×10^{11} Hz.

(b) Energy density in oscillating electric field is –

$$u_E = \frac{1}{2}\varepsilon_0 E^2$$

Energy density in oscillating magnetic field is-

$$u_B = \frac{1}{(2\mu_0)} B^2$$

We know, $E = cB$

And $$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

So, $$u_E = \frac{1}{2}\varepsilon_0 (cB)^2 = \frac{1}{2}\varepsilon_0 \frac{1}{\mu_0\varepsilon_0}\times B^2$$

$$= \frac{1}{(2\mu_0)}B^2$$

So, $u_E = u_B$

16. Define the term wavefront. Using Huygen's wave theory, verify the law of reflection. [3]

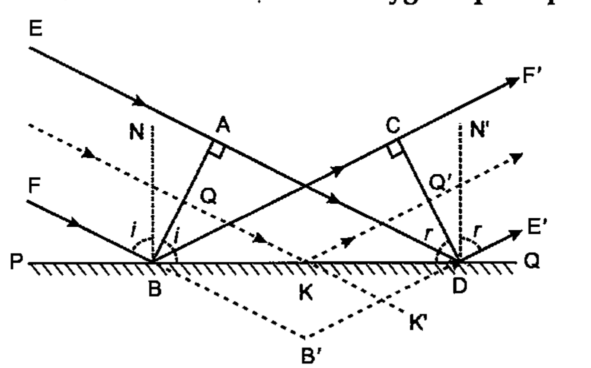
OR

Define the term, "refractive index" of a medium. Verify Snell's law of refraction when a plane wavefront is propagating from a denser to a rarer medium.

Answer :

A wavefront is the continuous locus of vibrating particles which are in the same state of vibration or phase.

Laws of Reflection from Huygen's principle



Consider a plane wavefront AB incident on a plane reflecting surface PQ, Let v be the velocity of the wave. At time $t = 0$ one end of the wavefront just touches the reflecting surface at B. Draw normal NB to PQ. When the wavefront strikes the reflecting surface, then due to the presence of it, it cannot advance further. When wavefront strikes at B, secondary wavelets starts emitting from B. The secondary wavelets will travel a distance AD = vt during the time the other end A of the wavefront AB reaches the surface PQ at Q.

To find the reflected wavefront, B as a centre and AD as radius draw an arc, which represent the secondary wavelets originating from B. As the incident wavefront AB advances, the secondary wavelets will touch CD simultaneously.

According to Huygen's principle CD represents the reflected wavefront corresponding to incident wavefront AB. BD is common triangles BAD and CBD and BC = AD = vt. Therefore, two triangles are congruent.

So, $\angle ABD = \angle CDB$

i.e., $\angle i = \angle r$

Thus, angle of incidence is equal to the angle of reflection. This is the second law of reflection. Also, the incident wavefront AB, reflecting surface PQ and the reflected wavefront CD are perpendicular to the plane of the paper. So, the incident ray, reflected ray and the normal at the point of incidence, all lie in same plane. This is first law of reflection.

Thus, Huygen's principle explains both the law of reflection.

OR

The refractive index of a medium is defined as the ratio of speed of light in vacuum to that of the speed of the light in medium.

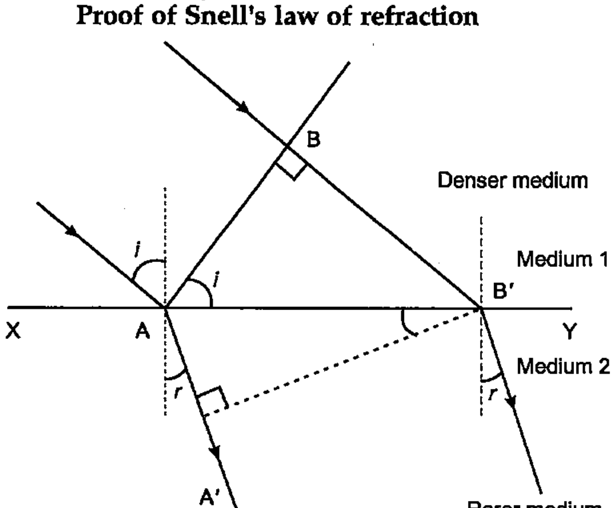
i.e., $n = \frac{c}{v}$

Where, n = refractive index of medium when light ray passes from vaccum into a medium.

c = velocity of light in vacuum

v = velocity of light in the medium

Proof of Snell's law of refraction



when a wavefront travels from one medium to other, it deviates from its path. In travelling from one medium to other, the frequency of wave remains same and speed and wavelength changes. Let, XY be a surface separating two media '1' and '2'. Let the speed of waves of v_1 and v_2.

Suppose, a plane wavefront AB in first medium is incident obliquely on the boundary surface XY and its end touches the surface at A at time $t = 0$, while the other end B reaches the surface at point B' after time-interval 't'

Clearly, BB' = $v_1 t$.

In the same time, wavelets starts from A and reaches A' in time 't' with velocity v_2.

Therefore, AA' = $v_2 t$

According to Huygen's principle, A'B' is the new position of the wavefront in second medium. A'B' is a refracted wavefront.

Let, the incident wavefront (AB) and reflected wavefront (A'B') makes angle i and r with surface XY.

In ΔAB'B,

$$\angle ABB' = 90^\circ$$

$$\therefore \quad \sin i = \frac{BB'}{AB'} = \frac{v_1 t}{AB'} \quad \text{...(i)}$$

In ΔAA'B',

$$\angle AA'B' = 90^\circ$$

$$\therefore \quad \sin r = \frac{AA'}{AB'} = \frac{v_2 t}{AB'} \quad \text{...(ii)}$$

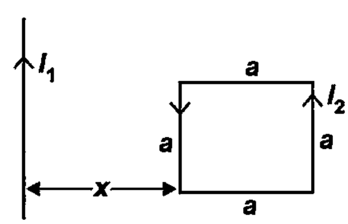
Dividing equation (i) by (ii), we get

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \text{constant}$$

Hence, ratio of sine of angle of incidence and the sine of angle of refraction for a given pair of media is constant. This is Snell's law of refraction.

17. **(a) Define mutual inductance and write its S.I. unit.**

(b) A square loop of side 'a' carrying a current I_2 is kept at distance x from an infinitely long straight wire carrying a current I_1 as shown in the figure. Obtain the expression for the resultant force acting on the loop. **[3]**

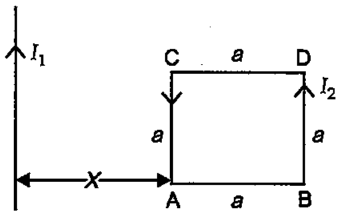


Answer :

(a) Mutual inductance : It is a property of two coils due to which each coil opposes any change of current flowing in the other. The mutually induced e.m.f, in one coil produces the opposition in other coil.

Its SI unit is henry (H).

(b)



The resultant magnetic force of sides AB and DC is zero. The force on side AD is repulsive and on side BC is attractive. Since, AD is near the straight wire. So, the net force will be repulsive.

Force on side AD,

$$F_1 = \frac{\mu_0}{2\pi}\frac{I_1 I_2 a}{x} \quad \text{(away from wire)}$$

Force on side BC,

$$F_2 = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{(x+a)} \times a$$

(towards the wire)

Therefore, resultant force,

$$F = F_1 - F_2$$

$$= \frac{\mu_0}{2\pi} I_1 I_2 a\left(\frac{1}{x} - \frac{1}{x+a}\right)$$

$$F = \frac{\mu_0}{2\pi} I_1 I_2 a\left(\frac{a}{x(x+a)}\right)$$

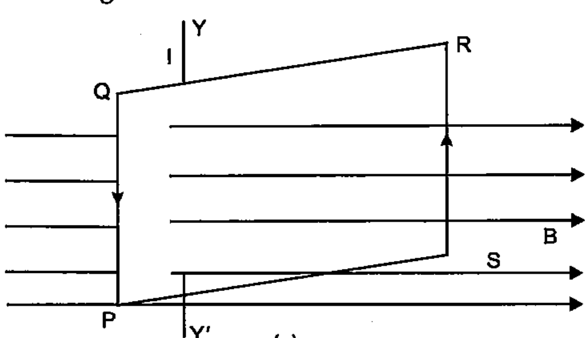
$$F = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2 a^2}{x(x+a)},$$

(away from wire)

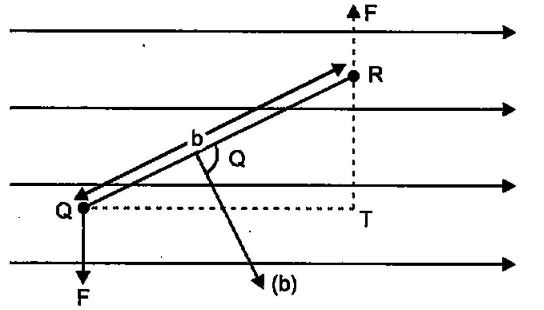
18. (a) Derive the expression for the torque acting on a current carrying loop placed in a magnetic field.

(b) Explain the significance of a radial magnetic field when a current carrying coil is kept in it. [3]

Answer : Torque on current carrying loop in magnetic field :



(a)



Consider a coil PQRS placed in a magnetic field. Let θ be the angle between the plane of the coil and direction of B. When current flow through coil each side experiences a force. The forces on vertical side will constitute a couple.

Moment of torque = One of forces × Perpendicular distance between lines of action of force

$$\tau = F \times QT = F \times b \sin\theta$$

$$= IlB\, b \sin\theta$$

$$\tau = I\,(lb)\,B \sin\theta$$

$$\tau = I\left(\vec{A} \times \vec{B}\right) \qquad (\because \text{Area} = lb)$$

If there are N turns, then

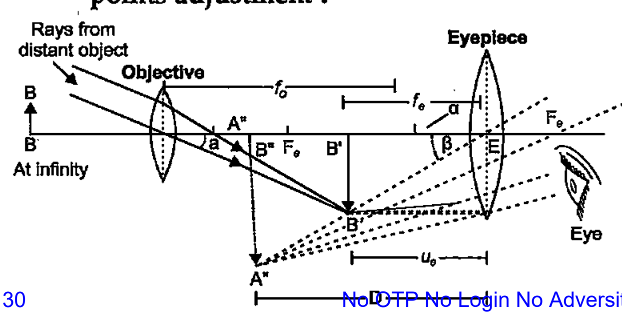
$$\tau = N I\left(\vec{A} \times \vec{B}\right) = \vec{M} \times \vec{B}$$

Where, $\vec{M} = NI\vec{A}$ is magnetic moment of loop.

(b) A magnetic field, in which the plane of the coil in all positions remains parallel to the direction of magnetic field is called radial magnetic field. In a radial magnetic field, magnetic torque remains maximum for all the positions of the coil.

19. Draw a labelled ray diagram of an astronomical telescope in the near point adjustment position. A giant refracting telescope at an observatory has an objective lens of focal length 15 m and an eyepiece of focal length 1.0 cm. If this telescope is used to view the Moon, find the diameter of the image of the Moon formed by the objective lens. The diameter of the Moon is 3.48×10^6 m and the radius of lunar orbit is 3.8×10^6 m. [3]

Answer : Astronomical telescope in near points adjustment :



Here, f_0 = 15 m, fe = 1 cm = 0.1 m

Diameter of moon, $d = 3.48 \times 10^6$ m

Radius of lunar orbit $u_0 = 3.8 \times 10^8$ m

size of the image of moon, I = ?

The angle subtended by the moon at the objective lens,

$$\alpha = \frac{d}{|u_0|} \quad ...(i)$$

And the angle subtended by the image of the moon at the objective lens,

$$\beta = \frac{I}{f_o} \quad ...(ii)$$

Both these angles in equations (i) and (ii) will be equal.

$$\therefore \quad \frac{d}{|u_0|} = \frac{I}{f_o}$$

$$\Rightarrow \quad I = \frac{d \times f_0}{|u_0|}$$

$$= \frac{3.48 \times 10^6 \times 15}{3.8 \times 10^8} \text{ m}$$

$$= 13.73 \times 10^{-2} \text{ m}$$

$$= 13.73 \text{ cm}$$

20. (a) State Gauss' law for magnetism. Explain its significance.

(b) Write the four important properties of the magnetic field lines due to a bar magnet. [3]

OR

Write three points of differences between para-, dia- and ferro-magnetic materials, giving one example for each.

Answer :

(a) Gauss law for magnetism : If a closed surface is imagined in a magnetic field, the number of lines of force emerging from the surface must be equal to the number entering it. That is, the net magnetic flux out of any closed surface is zero.

Gauss law signifies that magnetic monopoles does not exist.

(b)

1. In a bar magnet, each lines of force, starts from a north pole and reaches the south pole externally and then goes from south pole to a north pole internally. Thus, magnetic line of force forms a closed loop.

2. No two lines of force will never intersect each other.

3. In a uniform field, the lines are parallel and equidistant from each other.

4. The lines of force are crowded near the poles.

OR

Properties	Ferro-magnetic Materials	Para-magnetic Materials	Dia-magnetic Materials
State	They are solid	They can be solid, liquid or gas.	They can be solid, liquid or gas.
Effect of Magnet	Strongly attracted by a magnet	Weakly attracted by a magnet.	Weakly repelled by a magnet.
Effect of Temperature	Above curie point, it becomes a paramagnetic.	With the rise of temperature, it becomes a diamagnetic.	No effect.
Examples	Iron, Nickel, Cobalt	Lithium, Molybdenum, magnesium	Copper, Silver, Gold

Note : Any three difference can be written in exam.

21. Define the term 'decay constant' of a radioactive sample. The rate of disintegration of a given radioactive nucleus is 10000 disintegrations/s and 5,000 disintegrations/s after 20 hr. and 30 hr. respectively from start. Calculate the half life and initial number of nuclei at $t = 0$. [3]

Answer :

'Decay constant' of a radioactive sample is defined as the ratio of its instantaneous rate of disintegration to the number of atoms present at that time.

$$i.e., \quad \frac{dN}{dt} = -\lambda n,$$

$$\lambda = \frac{-dN/dt}{N}$$

Let, the initial number of nuclei be N_0 at $t = 0$

$$\frac{dN}{dt} = 10{,}000 \quad \text{at } t = 20 \text{ hr}$$

$$\text{and} \quad \frac{dN'}{dt} = 5{,}000 \quad \text{at } t = 30 \text{ hr}$$

$$\text{We have,} \quad \frac{dN}{dt} = \lambda N,$$

For first case,

$$10{,}000 = \lambda N, \Rightarrow N = \frac{10{,}000}{\lambda}$$

and $$N = N_0 e^{-\lambda t},$$

$$\frac{10,000}{\lambda} = N_0 e^{-20\lambda} \quad ...(i)$$

For second case,

$$5,000 = \lambda N'$$

$$N' = \frac{5,000}{\lambda}$$

and $$N' = N_0 e^{-30\lambda}$$

$$\frac{5,000}{\lambda} = N_0 e^{-30\lambda} \quad ...(ii)$$

on dividing equation (i) by equation (ii), we get

$$\Rightarrow \quad \frac{e^{-20\lambda}}{e^{-30\lambda}} = 2$$

Taking log on both sides,

$$\Rightarrow \quad -20\lambda + 30\lambda = \log_e 2$$

$$\Rightarrow \quad 10\lambda = 2.302 \times 0.3010$$

$$\Rightarrow \quad \lambda = 0.0693$$

$\therefore$ Half life, $$\tau = \frac{0.693}{0.0693} = 10 \text{ hr}$$

22. (a) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which of them will not be able to detect light of wavelength 600 nm ?

(b) Why photodiodes are required to operate in reverse bias? Explain. [3]

Answer :

(a) Energy corresponding to wavelength 600 nm is,

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9}} \text{ J} = 3.3 \times 10^{-19} \text{ J}$$

$$= \frac{3.3 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 2.06 \text{ eV}$$

The photon energy (E = 2.06 eV) is greater than the band gap for diode D_2 only.

Hence, diode D_1 and D_3 will not be able to detect the given wavelength.

(b)A photodiode is operated reverse bias because in reverse bias it is easier to observe change in current with change in light intensity.

23. (a) Describe briefly the functions of the three segments of n-p-n transistor.**

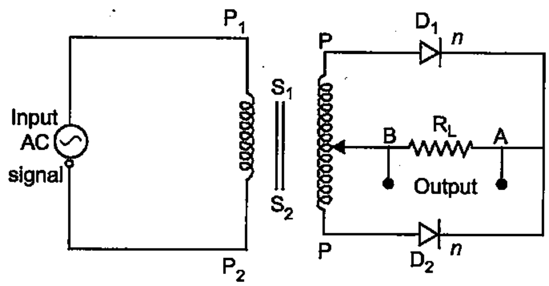
(b) Draw the circuit arrangement for studying the output characteristics of n-p-n transistor in CE configuration. Explain how the output characteristics is obtained. [3]**

OR

Draw the circuit diagram of a full wave rectifier and explain its working. Also, give the input and output waveforms.

Answer :

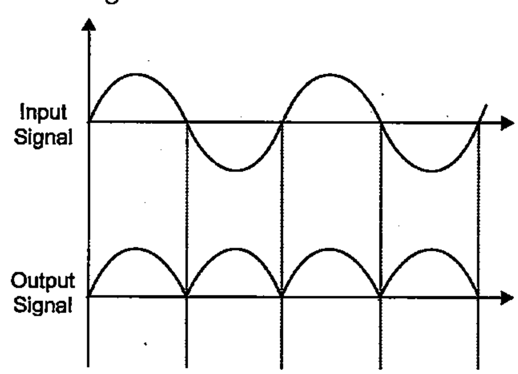
OR



For full wave rectifier, we use two junction diodes as shown in figure.

During first half cycle of input a.c. signal the terminal S_1 is positive relative to S and S_2 is negative, then diode D_1 is in forward biased and diode D_2 is reverse biased. Therefore, current flows in D_1 not in D_2. In next half cycle, S_1 is negative and S_2 is positive relative to S. Then D_1 is in reverse biased and D_2 is in forward biased. Therefore, current flows in D_2 not in D_1. Thus, for input a.c. signal the output current is a continuous series of unidirectional pulse.

The input and output waveforms are shown in the figure.



24. (a) If A and B represent the maximum and minimum amplitudes of an amplitude modulated wave, write the expression for the modulation index in terms of A & B.**

(b) A message signal of frequency 20 kHz and peak voltage 10 V is used to modulate a carrier of frequency 2 MHz and peak voltage

Answer is not given due to change in the present syllabus of 15 V. Calculate the modulation index. Why the modulation index is generally kept less than one ? [3]

SECTION-D

25. (a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source.

(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit ?

(c) When an inductor is connected to 200 V dc voltage, a current of 1 A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why ? Also, calculate the self inductance of the inductor. [5]

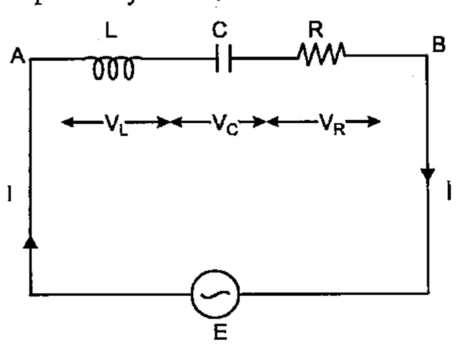
OR

(a) Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device.

(b) A small town with a demand of 1200 kW of electric power at 220V is situated 20 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the form of heat.

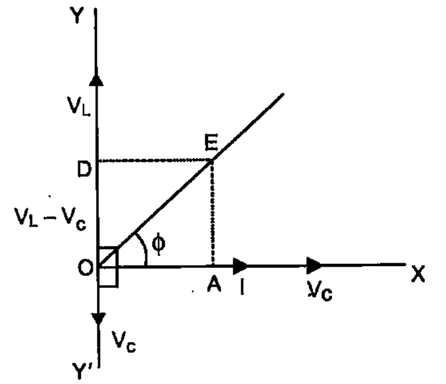
Answer :

(a) Consider an alternating e.m.f. is connected in series with an inductor, resistance R and capacitance C. Let, E and I be the instantaneous values of e.m.f. and current in the LCR circuit V_L, V_C and V_R be the instantaneous values of voltage across inductor, capacitor and resistor respectively. Then,



$V_L = IX_L$, $V_C = IX_C$ and $V_R = IR$

Here, $X_L = \omega L$ and $X_C = \dfrac{1}{\omega C}$



In an a.c. circuit V_R and I are in same phase, V_L leads I by $\pi/2$ and V_C lags I by $\pi/2$.

From the graph, in right angled ΔOEA

$$OE = \sqrt{OA^2 + AE^2} = \sqrt{OA^2 + OD^2}$$

$$= \sqrt{V_R^2 + (V_L - V_c)^2}$$

$$\therefore \quad E = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

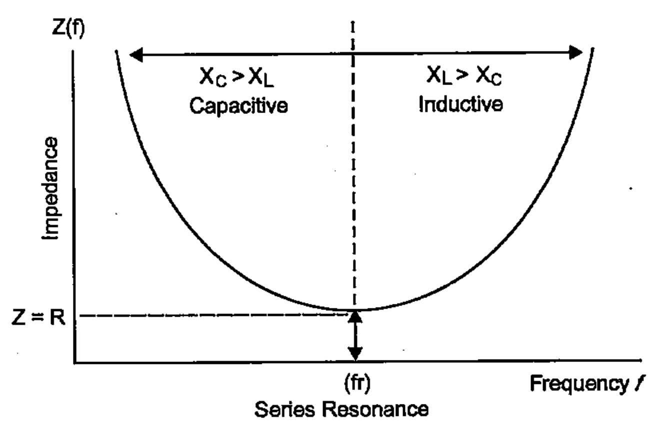
$$E = I\sqrt{R^2 + (X_L - X_C)^2}$$

$$I = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}}$$

Therefore, effective resistance or impedance of LCR circuit is–

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$



Graph showing variation of Impedance with frequency

**Answer is not given due to change in the present syllabus.

(b) At resonance, $X_L = X_C$

i.e., $iX_L = iX_C$

or $V_L = V_C$

The voltage across inductance and capacitance are equal and have a phase difference of 180° at resonance.

(c) Since the reactance of an inductor is zero for d.c. circuit. But the inductor offers resistance to an a.c. circuit. Therefore, the current decreases for the same inductor when it is connected with an a.c. source.

When inductor is connected in a.c. circuit :

$$V = 200 \text{ V}$$
$$f = 50 \text{ Hz}$$
$$i = 0.5 \text{ A}$$
$$i = \frac{V}{R} = \frac{V}{X_L} = \frac{V}{\omega L}$$
$$0.5 = \frac{200}{2\pi \times 50 \text{ L}} \quad [\because \omega = 2\pi f]$$
$$L = \frac{200}{100 \times 0.5 \times 3.14}$$
$$= \frac{4}{3.14} = 1.27 \text{ H}$$

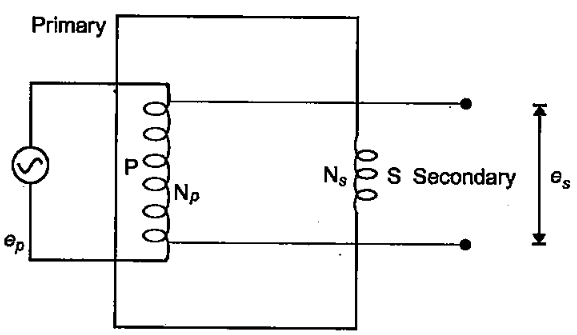
OR

(a) Step-down transformer :

It is a device used for converting high alternating voltage at low current into low alternating voltage at high current and vice-versa.

The device works on the principle of mutual induction *i.e.,* if the current or magnetic flux linked with a coil changes then an e.m.f. is induced in the other coil.

In step-down transfomer $N_p > N_s$ and transformation ratio is less than 1.



Energy losses are :

1. Copper losses : Due to resistance of windings in primary and secondary coils, some electrical energy is converted into heat energy.

2. Flux losses : Some of the flux produced in primary coil is not linked up with secondary coils.

3. Hysteresis losses : When the iron core is subjected to a cycle of magnetisation the core gets heated up due to hysteresis known as hysteresis loss.

4. Iron losses : The varying magnetic flux produces eddy current in the iron core, which leads to the wastage of energy in the form of heat.

(b) Length of wire line = 20 × 2 = 40 km

Resistance of wire line, $r = 40 \times 0.5 = 20\ \Omega$

Power to be supplied = 1200 kW = 1200×10^3 W

Voltage at which power supplied = 4000 V

Since, $P = VI$

$$\Rightarrow \quad I = \frac{P}{V}$$
$$\Rightarrow \quad I = \frac{1200 \times 10^3}{4000}$$
$$= 300 \text{ A}$$

Therefore, line power loss

$$= I^2 \times R$$
$$= (300)^2 \times 200$$
$$= 36 \times 10^5 \text{ W}$$
$$= 360 \text{ kW}$$

∴ Line power loss in the form of heat is 360 kW.

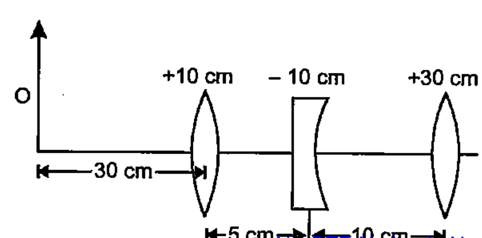
26. (a) Describe any two characteristic features which distinguish between interference and diffraction phenomena. Derive the expression for the intensity at a point of the interference pattern in Young's double slit experiment.

(b) In the diffraction due to a single slit experiment, the aperture of the slit is 3 mm. If monochromatic light of wavelength 620 nm is incident normally on the slit, calculate the separation between the first order minima and the 3rd order maxima on one side of the screen. The distance between the slit and the screen is 1.5 m. [5]

OR

(a) Under what conditions is the phenomenon of total internal reflection of light observed? Obtain the relation between the critical angle of incidence and the refractive index of the medium.

(b) Three lenses of focal length + 10 cm, –10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.

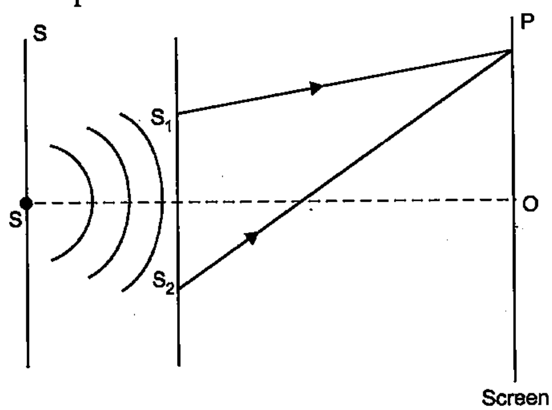


Answer : (a)

	Interference	Diffraction
1.	It is the result of interaction of light coming from two different wavefronts originating from two coherent sources.	1. It is the result of interaction of light come from different parts of same wavefronts.
2.	All the bright fringes are of same intensity.	2. The bright fringes are of varying intensity (Intensity of bright fringes decreases from central bright fringe on either sides.)

A sources of monochromatic light illuminates two narrow slits S_1 and S_2.The two illuminated slits act as the two coherent sources. The two slits is very close to each other and at equal distance from source. The wavefront S_1 and S_2 spread in all direction and superpose and produces dark and bright fringe on screen.

Let the displacement of waves from S_1 and S_2 at point P on screen at time t is-



$$y_1 = a_1 \sin \omega t$$
$$y_2 = a_2 \sin (\omega t + \phi)$$

The resultant displacement at point P is given by

$$y = y_1 + y_2$$
$$= a_1 \sin \omega t + a_2 \sin (\omega t + \phi)$$
$$= a_1, \sin \omega t + a_2 \sin \omega t \cos \phi + a_2 \cos \omega t \sin \phi$$
$$= (a_1 + a_2 \cos \phi) \sin \omega t + a_2 \sin \phi \cos \omega t \quad ....(i)$$

Let, $a_1 + a_2 \cos \phi = A \cos \phi$ ....(ii)

$a_2 \sin \phi = A \sin \phi$ ...(iii)

Therefore, equation (i) becomes

$$y = A \cos \theta \sin \omega t + A \sin \theta \cos \omega t$$
$$= A \sin (\omega t + \theta)$$

This is the resultant displacement.

Now, squaring and adding equations (ii) and (iii)

$$A^2 \cos^2 \theta + A^2 \sin^2 \theta = (a_1 + a_2 \cos \phi)^2 + a_2^2 \sin^2 \phi$$
$$A^2 = a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi$$

The is intensity of light is directly proportional to the square of the amplitude

i.e., $I = a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi$

This is the expression for intensity at a point of interference pattern.

or $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$

(b) Here, $\lambda = 620$ nm $= 620 \times 10^{-9}$ m

$a = 3\times10^{-3}$ m, $D = 1.5$ m

Distance of first order minima from the centre,

$$y_1 = \frac{D\lambda}{a} = \frac{1.5\times620\times10^{-9}}{3\times10^{-3}}$$
$$= 3.1 \times 10^{-4} \text{ m}$$

Distance of third order maxima on the same side,

$$y_2 = \frac{7D\lambda}{2a} = \frac{7\times1.5\times620\times10^{-9}}{2\times3\times10^{-3}}$$
$$= 10.85 \times 10^{-4} \text{ m}$$

Separation between them.

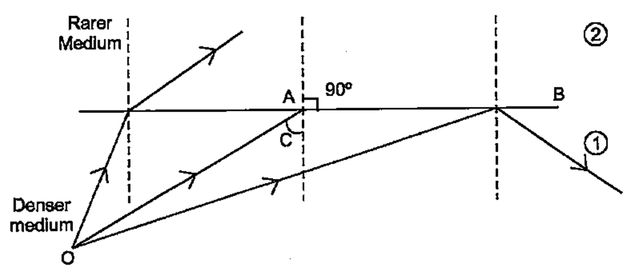
$$y = y_2 - y_1$$
$$= 10.85 \times 10^{-4} - 3.1 \times 10^{-4}$$
$$= 7.75 \times 10^{-4} \text{ m}$$

OR

(a) Conditions for total internal refraction :

1. The ray must travel from a denser medium into a rarer medium.
2. The angle of incidence in the denser medium must be greater than the critical angle for the pair of media.

Relation between critical angle and refractive index :



When a ray of light travels from denser to rarer medium, the ray bends away from the normal. When the angle of incidence is equal to the critical angle then the refracted ray grazes the surface of separation represented by ray $\overrightarrow{OA}$ and $\overrightarrow{AB}$.

By Snell's law

$$\frac{\sin i}{\sin r} = \frac{1}{n}$$

where, $i = C$, $r = 90°$ and n = refractive index of denser medium.

$$\therefore \quad \frac{\sin C}{\sin 90°} = \frac{1}{n}$$

$$n = \frac{1}{\sin C}$$

(b) For first lens, $u_1 = -30$ cm, $f_1 = 10$ cm

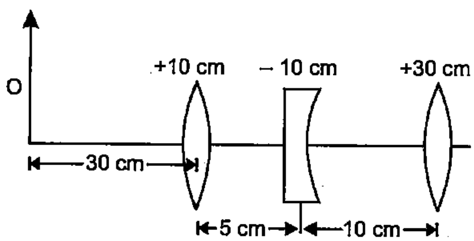
$\therefore$ From lens formula,

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$$

$$\Rightarrow \quad \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1}$$

$$= \frac{1}{10} - \frac{1}{30}$$

$$\Rightarrow \quad v_1 = 15 \text{ cm}$$



This means that image formed by first lens is at a distance of 15 cm to the right of the first lens. This image serves as the virtual object for second lens.

For second lens,

$f_2 = -10$ cm, $u = 15 - 5 = +10$ cm

$$\therefore \quad \frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2}$$

$$= -\frac{1}{10} + \frac{1}{10}$$

$$\Rightarrow \quad v_2 = \infty$$

This means that the real image is formed by second lens at infinite distance. This acts as an object for third lens.

for third lens, $f_3 = +30$ cm, $u_3 = \infty$

$$\therefore \quad \frac{1}{v_3} = \frac{1}{f_3} + \frac{1}{u_3}$$

$$= \frac{1}{30} + \frac{1}{\infty}$$

$$\therefore \quad v_3 = 30 \text{ cm}$$

i.e., final image is formed at a distance of 30 cm to the right of third lens.

27. (a) Describe briefly the process of transferring the charge between the two plates of a parallel plate capacitor when connected to a battery. Derive an expression for the energy stored in a capacitor.

(b) A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from battery and then connected to another uncharged capacitor of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor. [5]

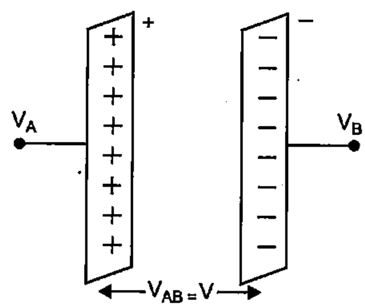
OR

(a) Derive an expression for the electric field at any point on the equatorial line of an electric dipole.

(b) The identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

Answer :

(a) When the plates of the parallel plate capacitor is connected to a battery. Then the first insulated metal plate gets, the positive charge till its potential become maximum. Then, the charge will leak to surroundings. So, the negative charge will be induced on the nearer face of the second plate and the positive charge will be induced on its farther plate.



Consider a capacitor of capacitance C. Initial charge and potential difference be zero. Let, a charge Q be given in small steps. Let at any instant when charge on capacitor be q, the potential difference between its plates,

$$V = \frac{q}{C}$$

Now work done in giving an additional charge dq is,

$$dW = V\,dq = \frac{q}{C}\,dq$$

Total work done in giving charge from 0 to Q is,

$$W = \int_0^Q V dq = \int_0^Q \frac{q}{C} dq$$

$$= \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{C}\left[\frac{Q^2}{2} - \frac{0}{2}\right] = \frac{Q^2}{2C}$$

$$W = \frac{(CV)^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV \quad [\because Q = CV]$$

∴ Electrostatic potential energy,

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

(b) Here, $C_1 = C$, $C_2 = C$

$$V_1 = V, V_2 = 0$$

Now initially, energy stored in first capacitor, as second capacitor is uncharged.

$$U_1 = \frac{1}{2}C V_1^2$$

$$= \frac{1}{2}CV^2 \quad ...(i)$$

Now, when C_1 and C_2 are connected the two capacitor form a parallel combination. Equivalent capacitance,

$$C' = C_1 + C_2 = 2C$$

$$\text{Final potential} = \frac{\text{Total charge}}{\text{Total capacitance}}$$

$$V' = -\frac{q}{2C}$$ [Total charge will be of first capacitor, which is distributed]

$$= \frac{CV}{2C} = \frac{V}{2}$$

Final energy stored in combination,

$$U_2 = \frac{1}{2}C'V'^2 = \frac{1}{2} \times 2C \times \left(\frac{V}{2}\right)^2 = \frac{CV^2}{4} \quad ...(ii)$$

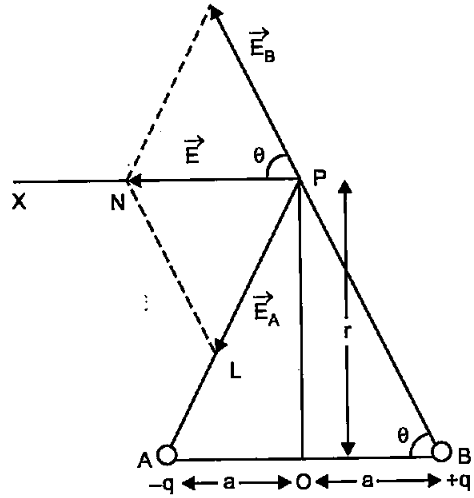
On dividing equations (i) with (ii), we get

$$\frac{U_2}{U_1} = \frac{\frac{1}{4}CV^2}{\frac{1}{2}CV^2} = \frac{1}{2}$$

$$U_2 : U_1 = 1 : 2$$

OR

(a) Consider an electric dipole of charges $-q$ and $+q$ separated by a distance $2a$ and placed in a free space. Let P be a point on equitorial line of dipole at a distance r from the centre of a dipole.



Let, $\vec{E}_A$ and $\vec{E}_B$ be the electric field at point P due to charges $-q$ and $+q$

Then resultant electric field at point P is

$$\vec{E} = \vec{E}_A + \vec{E}_B$$

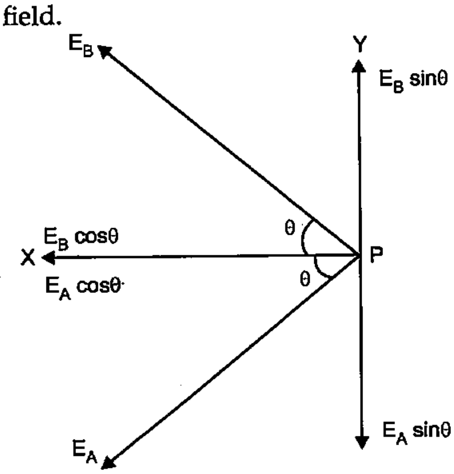
Now,

$$|\vec{E}_A| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{AP^2} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2 + a^2)} \text{ (along PA)}$$

$$|\vec{E}_B| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{BP^2} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2 + a^2)} \text{ (along BP)}$$

The, resultant intensity is the vector sum of E_A and E_B.

E_A and E_B can be resolved into two components. The Y-components cancel out each other. And X-component will add up to give the resultant field.



$$\therefore |\vec{E}| = E_A \cos\theta + E_B \cos\theta$$

Now in right, triangle ORB

$$\cos\theta = \frac{OB}{BP} = \frac{a}{\sqrt{r^2 + a^2}}$$

$$\therefore \quad E = 2 \times \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2 + a^2} \frac{a}{(r^2 + a^2)^{1/2}}$$

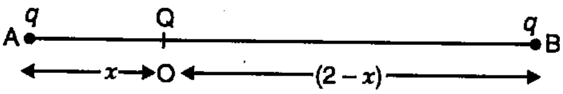
$$= \frac{2qa}{4\pi\varepsilon_0 (r^2 + a^2)^{3/2}}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{p}{(r^2 + a^2)^{3/2}}$$

$[\because 2qa = p]$

This is the required expression.

(b) Let the two charges of + q each placed at point A and B at a distance 2 m apart in air.



Suppose, the third charge Q (unknown magnitude and charge) is placed at a point O, on the line joining the other two charges, such that OA= x and OB = 2–x.

For the system to be in equilibrium, net force on each 3 charges must be zero.

If we assume that charge Q placed at O is positive, the force on it at O may be zero. But the force on charge q at point A or B will not be zero. It is because, the forces on a charge q due to the other two charges will act in same direction. If charge Q is negative, then the forces on q due to other two charges will act in opposite direction.

Hence, Q will be negative in nature.

For charge (–Q) to be in equilibrium

Force on charge (–q) due to charge (+q) at point A should be equal and opposite to charge (+Q) at B

$$\frac{1}{4\pi\varepsilon_0} \frac{Qq}{x^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qq}{(2-x)^2}$$

or $\quad (2–x)^2 = x^2$

$\Rightarrow \quad x = (2–x) \Rightarrow x = 1$ m

Therefore, for the system to be in equilibrium a charge – Q is placed at a mid point between the two charges of + q each.

Physics 2019 (Delhi)

SET II

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous set.

SECTION-A

2. When unpolarised light is incident on the interface separating the rarer medium and the denser medium. Brewster angle is found to be 60°. Determine the refractive index of the denser medium. [1]

Answer :

According to Brewster's law,

$$\tan i_p = n$$

Since, $\quad i_p = 60°$

$\therefore$ Refractive index of medium,

$$n = \tan 60°$$

$$n = \sqrt{3}$$

$$n = 1.732$$

4. When a potential difference is applied across the ends of a conductor, how is the drift velocity of the electrons related to the relaxation time? [1]

Answer :

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$$

where, m = mass of electron

e = charge of electron

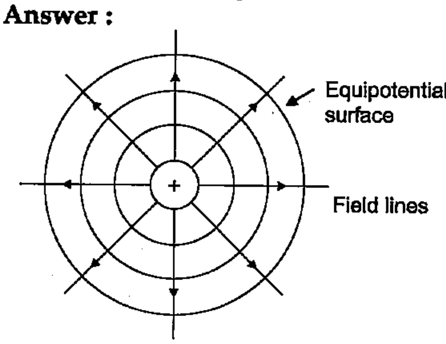
E = potential difference applied

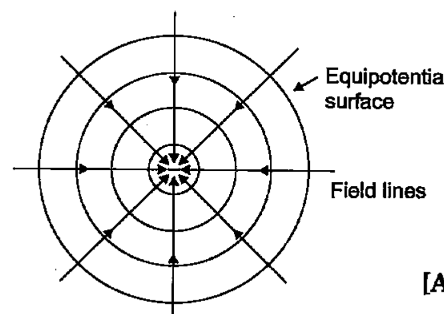
τ = relaxation time

$\therefore v_d \propto \tau$ *i.e.* drift velocity is directly proportional to relaxation time.

5. Draw the equipotential surfaces due to an isolated point charge. [1]

Answer :





[Any one]

SECTION-B

6. Explain with the help of Einstein's photoelectric equation any two observed features in photoelectric effect which cannot be explained by wave theory. [2]

Answer :

Features of photoelectric equation which can not be explained by wave theory :

(a) The wave theory could not explain the instantaneous process of photoelectric effect.

(b) 'Maximun kinetic energy' of the emitted photoelectrons is independent of intensity of incident light.

7. A deuteron and an alpha particle having same momentum are in turn allowed to pass through a magnetic field $\vec{B}$, acting normal to the direction of motion of the particles. Calculate the ratio of the radii of the circular paths described by them. [2]

Answer :

Radius of circular path

$$r = \frac{mv}{qB}$$

i.e., $$r = \frac{p}{qB} \qquad [\because p = mv]$$

Momentum of deuteron and alpha-particle are same and in same magnetic field

$$\therefore \quad r_d = \frac{p}{q_d B} = \frac{p}{eB} \qquad [\because q_d = q_\alpha = e]$$

Now $$r_\alpha = \frac{p}{q_\alpha B} = \frac{p}{2eB} \qquad [\because q_\alpha = 2e]$$

Therefore, $r_d : r_\alpha = 2 : 1$

11. (a) Plot a graph showing variation of de Broglie wavelength (λ) associated with a charged particle of mass *m*, versus $\sqrt{V}$, where V is the accelerating potential.

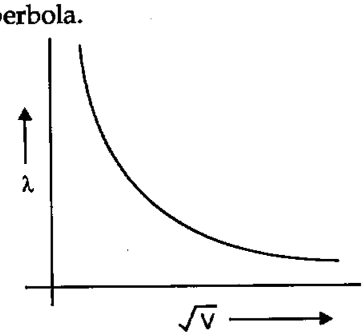
(b) An electron, a proton and an alpha particle have the kinetic energy. Which one has the shortest wavelength ? [2]

Answer :

(a) We know, $$\lambda = \frac{1.22}{\sqrt{V}} \text{Å}$$

$$\lambda\sqrt{V} = \text{constant}$$

The nature of the graph between λ and $\sqrt{V}$ is hyperbola.



(b) According to de-Broglie wavelength

$$\lambda = \frac{h}{\sqrt{2mE_k}}$$

For same kinetic energy,

$$\lambda_\alpha = \frac{1}{\sqrt{m}}$$

We know that

$$m_\alpha > m_p > m_e$$

Since, alpha-particle have the maximum mass. Therefore, alpha-particle will have minimum wavelength.

SECTION-C

13. (a) State the underlying principle of a moving coil galvanometer.

(b) Give two reasons to explain why a galvanometer cannot as such be used to measure the value of the current in a given circuit.

(c) Define the terms : (i) voltage sensitivity and (ii) current sensitivity of a galvanometer. [3]

Answer :

(a) The Principle : When a current flows through the conductor coil, a torque acts on it due to the external radial magnetic field. Counter torque due to supension balances coil after appropriate deflection due to current in the circuit.

(b) A galvanometer can be used as such to measure current due to following two reasons.

(i) A galvanometer has a finite large resistance and is connected in series in the circuit, so it will increase the resistance of circuit and hence change the value of current in the circuit.

(ii) A galvanometer is a very sensitive device, it gives a full scale deflection for the current of the order of microampere, hence if connected as such it will not measure current of the order of ampere.

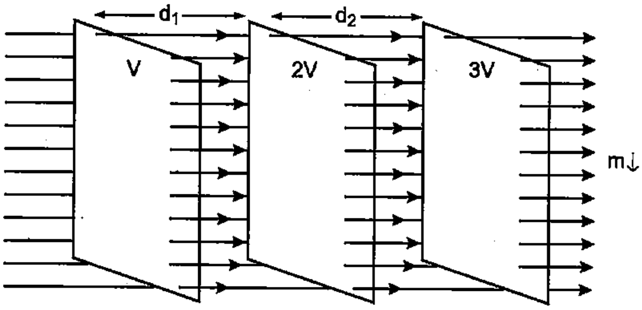
(c) (i) Voltage sensitivity : It is defined, as the deflection produced in the galvanometer when a unit voltage is applied across it.

(ii) Current Sensitivity : The ratio of deflection produced by the coil ϕ to the current in the coil is called the current sensitivity. It is the deflection of the meter per unit current.

15. (a) Draw equipotential surfaces corresponding to the electric field that uniformly increases in magnitude along with the *z*-directions.

(b) Two charges −*q* and + *q* are located at point (0, 0, − *a*) and (0, 0, *a*). What is the electrostatic potential at the points (0, 0, ± z) and (*x*, *y*, 0) ? [3]

Answer : (a)



(b) Since, two charges are on Z-axis. Therefore, the electric potential on an arrival position *i.e.,* at (0, 0, ±2) is given by

$$V_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{2lq}{r^2 - l^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{2aq}{(z^2 - a^2)} \quad [\because l = a \because r = \pm z]$$

Now electric potential at the position (*x*, *y*, 0) is given by

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2aq\cos\theta}{r^2}$$

But $\theta = 90°$

$\therefore V_2 = 0$ at the position of (*x*, *y*, 0) due to an electric dipole, placed on Z-axis.

17. (a) Write the relation between half life and average life of a radioactive nucleus.

(b) In a given sample two isotopes A and B are initially present in the ratio of 1 : 2. Their half lives are 60 years and 30 years respectively. How long will it take so that the sample has these isotopes in the ratio of 2 : 1 ? [3]

Answer. (a) Half life period $= \frac{0.693}{\lambda} = 0.693\,\tau$

$= 69.3\%$ of average life

(b) We have, $N = N_0\, e^{-\lambda t}$

For two isotopes, we can write

$$N_A = N_0 e^{-\lambda_A t_A} \quad ...(i)$$

$$N_B = N_0 e^{-\lambda_B t_B} \quad ...(ii)$$

Let the time be *t* after which,

$$\frac{N_A}{N_B} = \frac{2}{1}$$

i.e., $t_A = t_B = t$

$\therefore \quad N_0 e^{-\lambda_A t} = 2N_0 e^{-\lambda_B t}$

$\Rightarrow \quad e^{-\lambda_A t} e^{\lambda_B t} = 2$

$\Rightarrow \quad e^{\lambda_B t - \lambda_A t} = 2$

$\Rightarrow \quad (\lambda_B t - \lambda_A t) = \log_e 2$

$\Rightarrow \quad (\lambda_B - \lambda_A)t = \log_e 2$

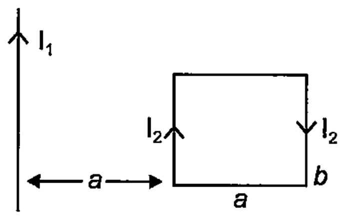
$\Rightarrow \quad \left[\frac{\log_e 2}{T_B} - \frac{\log_e 2}{T_A}\right] t = \log_e 2 \quad \left[\because \lambda = \frac{\log_e 2}{T}\right]$

$\Rightarrow \quad \left[\frac{1}{30} - \frac{1}{60}\right] t = 1$

$\Rightarrow \quad t = \frac{30 \times 60}{30} = 60$ years

19. (a) Define the term 'self inductance' of a coil. Write its S.I. unit.

(b) A rectangular loop of sides *a* and *b* carrying current I_2 is kept at a distance '*a*' from an infinitely long straight wire carrying current I_1 as shown in the figure. Obtain an expression for the resultant force acting on the loop. [3]



Answer :

(a) Self-inductance : Self-inductance of a coil is numerically equal to the amount of magnetic flux linked with the coil when and current flows through the coil.

The S.I. unit of Self-inductance is henry (H) or weber per Ampere 1 H = 1 *wb*/A

(b) The force on the side AB of rectangle is attractive as current is flowing in the same direction and on side CD will be repulsive the current is flowing in opposite direction with respect to straight conductor. The resultant magnetic force. On sides AD and BC is zero. The side AB is the straight wire. So, the net force will be attractive and rectangular loop will move towards the straight wire.

Now, force between AB and straight wire

$$F_1 = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{a} \quad ......(i)$$

Force between CD and straight wire

$$F_2 = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2}{(a+b)} \quad \text{...(ii)}$$

$$\therefore F_{net} = F_1 - F_2$$

$$= \frac{\mu_0}{2\pi} \cdot \frac{I_1 I_2}{a} - \frac{\mu_0}{2\pi} \frac{I_1 I_2}{(a+b)}$$

$$= \frac{\mu_0}{2\pi} I_1 I_2 \left[\frac{1}{a} - \frac{1}{a+b}\right]$$

$$= \frac{\mu_0}{2\pi} \times I_1 I_2 \frac{b}{a(a+b)}$$

$$F_{net} = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2 b}{a(a+b)} \quad \text{[Towards the wire]}$$

Physics 2019 (Delhi)

SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous set.

SECTION-A

1. Distinguish between unpolarized and linearly polarized light. **[1]**

Answer :

Unpolarized light : The light having vibration of electric field vector in all possible directions perpendicular to the direction of wave propagation the light is known as unpolarized light.

Linearly polarized light : The light having vibrations of electric field vector in only one direction perpendicular to the direction of propagation of light is as plane or linearly polarized light

3. How is the drift velocity in a conductor affected with the rise in temperature ? **[1]**

Answer :

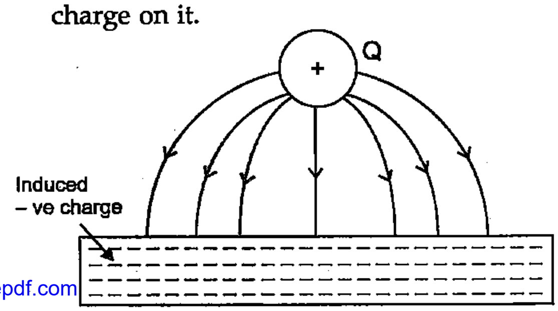
With the rise in temperature, the collision of electrons occurs more frequently, so relaxation time decreases and hence drift velocity increases.

$$v_d = \frac{eE}{m}\tau$$

$$v_d \propto \tau$$

5. Draw the pattern of electric field lines when a point charge + q is kept near an uncharged conducting plate. **[1]**

Answer : The lines of force start from + Q and terminates at metal plate inducing negative charge on it.

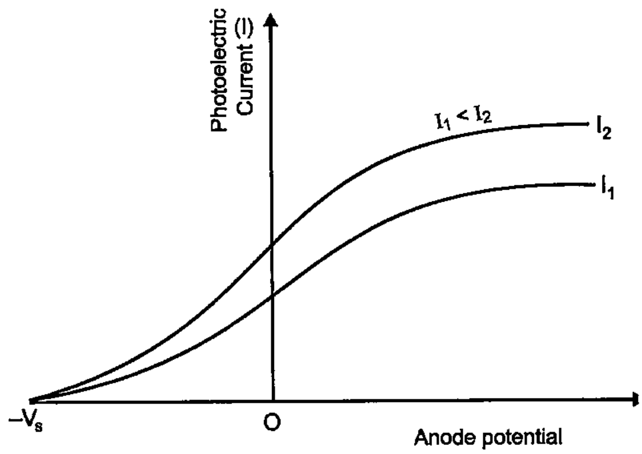


SECTION - B

6. (a) Define the terms, (i) threshold frequency and (ii) stopping potential in photoelectric effect. **[2]**

Answer : (a) (i) Threshold frequency : The minimum frequency of incident light which is just capable of ejecting electrons from a metal is called the threshold frequency. It is denoted by ν_0.

(ii) Stopping potential : The minimum retarding potential applied to anode of a photoelectric tube which is just capable of stopping photoelectric current is called the stopping potential. It is denoted by V_0 (or V_s).



11. Obtain the expression for the ratio of the de-Broglie wavelengths associated with the electron orbiting in the second and third excited states of hydrogen atom. **[2]**

Answer :

According to Bohr's postulate,

$$mvr = \frac{nh}{2\pi}$$

i.e., $$2\pi r = \frac{nh}{mV}$$

or $$\frac{h}{mV} = \frac{2\pi r}{n}$$

since, $\frac{h}{mv} = \frac{h}{p} = \lambda$, by de -Broglie hypothesis

Therefore, $\frac{2\pi r}{n} = \lambda$

Now for second excited state

$$\lambda_2 = \frac{2\pi r_3}{2} \quad ...(i)$$

and for third excited state

$$\lambda_3 = \frac{2\pi r_2}{3} \quad ...(ii)$$

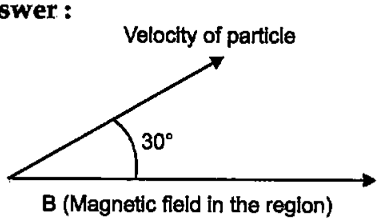
on dividing equations (i) by (ii),

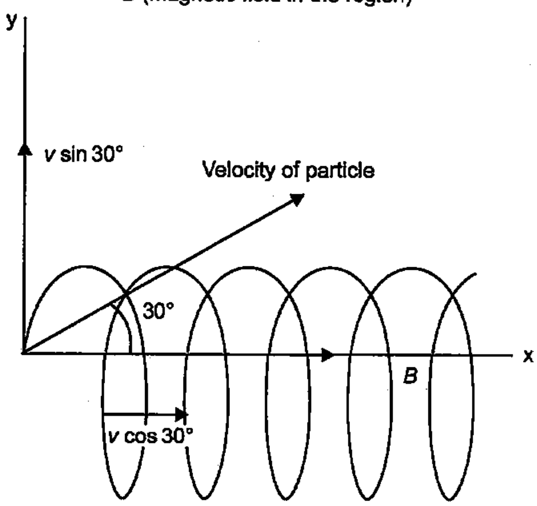
$$\frac{\lambda_2}{\lambda_3} = \frac{3r_2}{2r_3}$$

This is the required expression.

12. A charged particle q is moving in the presence of a magnetic field B which is inclined to an angle 30° with the direction of the motion of the particle. Draw the trajectory followed by the particle in the presence of the field and explain how the particle describes this path. [2]

Answer :





When a charged particle enter in a magnetic field making angle at 30°. Then velocity component is resolved into 2 components. $v \cos\theta$ (along the magnetic field) and $v \sin\theta$ (normal to the magnetic field).

As the charged particle moves along XY-plane due to velocity component $v \sin\theta$, it also advances linearly due to the velocity component $v \cos\theta$. As a result, the charged particle will move in a helical path as shown in figure.

SECTION-C

13. (a) Explain briefly how Rutherford scattering of α–particle by a target nucleus can provide information on the size of the nucleus.

(b) Show that density of nucleus is independent of its mass number A. [3]

Answer :

(a) In Rutherford's scattering experiment of α-particle, it was observed that the fast and heavy α-particles could be deflected through 180°. But only very small number of particles *i.e.*, 1 in about 8,000 α-particles are deflected through 180° that too from centre only.

So by this it was assumed that the size of central part *i.e.*, nucleus is about $\frac{1}{10,000}$ th of the size of the atom and whole positive charge is concentrated in it.

(b) Consider an atom whose mass number is A and R be the radius of the nucleus. If we neglect the mass of orbital electrons, then mass of the nucleus of the atom of mass number A = A a.m.u.

Mass of nucleus, $m = A \times 1.66 \times 10^{-27}$ kg

Volume of nucleus,

$$V = \frac{4}{3}\pi R^3$$

$$= \frac{4}{3}\pi (R_0 A^{1/3})^3 \left[\because R = R_0 A^{1/3}\right]$$

where, $R_0 = 1.1 \times 10^{-15}$, range of nuclear force

Therefore, $V = \frac{4}{3}\pi(1.1\times10^{-15})^3 \times A m^3$

Density of nucleus, $\rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$$= \frac{A\times1.66\times10^{-27}}{\frac{4}{3}\pi(1.1\times10^{-15})^3\times A}\times A$$

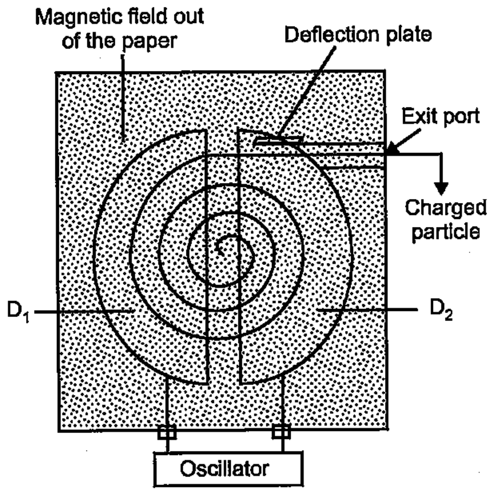
$$= 2.97 \times 10^{17}\ \text{kg/m}^3$$

Therefore density of nucleus is independent of mass number.

14. State the underlying principle of a cyclotron. Explain its working with the help of a schematic diagram. Obtain the expression for cyclotron frequency. [3]

Answer :

(a) Principle : It is based on a principle that a positive ion can acquire sufficiently large energy with a comparatively smaller alternating potential difference by making it to cross the same electric field again and again by making use of a strong magnetic field.



Working : The positive ions are produced from the source at the centre are accelerated by a dee which is at negative potential at that moment. Due to the presence of perpendicular magnetic field the ion will move in a circular path inside the dees. The magnetic field and the frequency of a.c source are so chosen that as the ions comes out of a dee, it changes its polarity and the ion is further accelerated and moves with higher velocity along a circular path of greater radius. This phenomenon is continued till the ion reaches at the periphery of the dees where an deflecting plate deflects the accelerated ion on the target to be bombarded.

Expression for cyclotron frequency

Suppose a position ion with charge q moving with a velocity v, then

$$qvB = \frac{mv^2}{r}$$

or

$$r = \frac{mv}{qB}$$

Therefore, angular velocity ω is

$$\omega = \frac{v}{r} = \frac{qB}{m}$$

The time taken by ion in describing a semi circle is (*i.e.*, an angle π)

$$t = \frac{\pi}{\omega} = \frac{\pi m}{qB}$$

This is a semi-periodic time (T/2)

$$\therefore \quad \frac{T}{2} = t = \frac{\pi m}{qB}$$

i.e., $T = \dfrac{2\pi m}{qB}$, time period of revolution

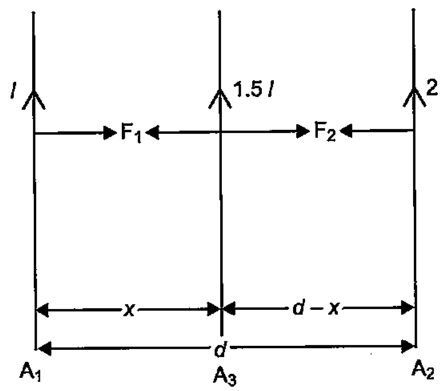
∴ Frequency of revolution is

$$f = \frac{1}{T} = \frac{qB}{2\pi m}$$

This frequency is called the cyclotron frequency.

15. Two infinitely long straight wire A_1 and A_2 carrying currents I and 2 I flowing in the same direction are kept 'd' distance apart. Where should a third straight wire A_3 carrying current 1.5 I be placed between A_1 and A_2 so that it experiences no net force due to A_1 and A_2 ? Does the net force acting on A_3 depend on the current flowing throught it ? [3]

Answer :



Let the wire A_3 placed at a distance x from the wire A_1. And the distance of wire A_3 from A_2 be $(d - x)$ The current flowing through them is I, 1.5 I and 2I in A_1, A_3 and A_2 respectively. Let the current flowing in the wire A_3 be in the same direction as A_1 and A_2.

Therefore, force between A_1 and A_3 is,

$$F_1 = \frac{\mu_0}{2\pi}.\frac{I \times 1.5\,I}{x} \quad ...(i)$$

Force between A_3 and A_2 is,

$$F_2 = \frac{\mu_0}{2\pi}.\frac{2\,I \times 1.5\,I}{(d-x)} \quad ...(ii)$$

Since, the net force on A_3 is zero,

$\therefore \quad F_1 = F_2$

$$\Rightarrow \quad \frac{\mu_0}{2\pi} \times \frac{I \times 1.5\, I}{(x)} = \frac{\mu_0}{2\pi} \times \frac{2\, I \times 1.5\, I}{(d-x)}$$

$$\Rightarrow \quad \frac{1.5}{x} = \frac{3}{d-x}$$

$\Rightarrow \quad 1.5\, d - 1.5x = 3x$

$\Rightarrow \quad 4.5\, x = 1.5\, d$

Therefore, $x = \frac{d}{3}$

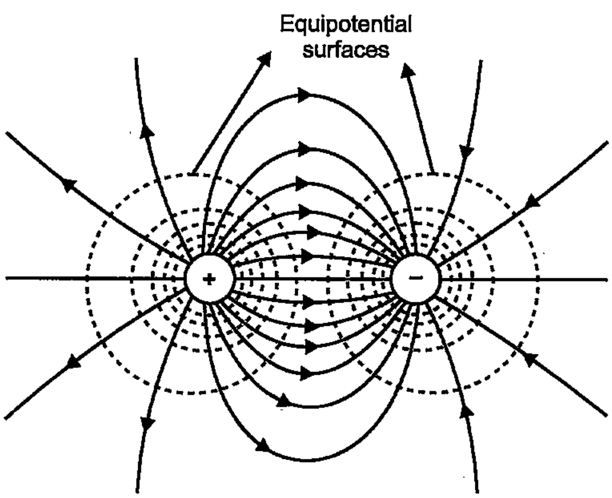
The wire A_3 is placed at a distance of $\frac{d}{3}$ from A_1 and $\frac{2d}{3}$ from A_2.

No, at a same distance the force on the wire A_3 is independent of the direction of the current. As if current is in opposite direction then F_1 and F_2 will be in opposite direction, but will be in equilibrium.

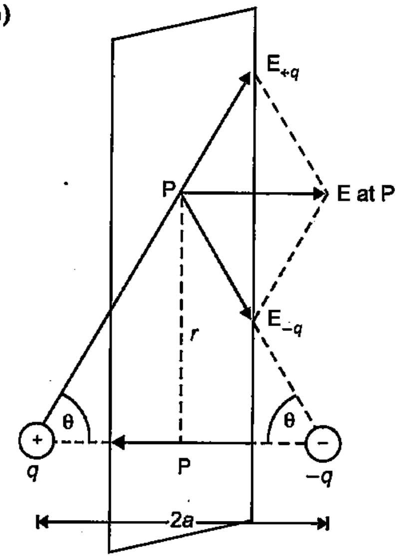
16. (a) Draw the equipotential surfaces due to an electric dipole.

(b) Derive an expression for the electric field due to a dipole of dipole moment $\vec{p}$ if at a point on its perpendicular bisector. [3]

Answer : (a)



(b)



The Magnitudes of the electric field due to the two charges $+q$ and $-q$ given by.

$$E_{+q} = \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2 + a^2} \qquad \text{...(i)}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2 + a^2} \qquad \text{...(ii)}$$

$\therefore \quad E_{+q} = E_{-q}$

The directions of E_{+q} and E_{-q} are as shown in the figure. The components normal to the dipole axis cancel away. The components along the dipole axis add up.

$\therefore$ Total electric field

$E = -(E_{+q} + E_{-q}) \cos\theta\, \hat{p}$ [Negative sign shows that field is opposite to $\hat{p}$]

$$E = -\frac{2qa}{4\pi\varepsilon_0 (r^2 + a^2)^{\frac{3}{2}}} \hat{p} \qquad \text{...(iii)}$$

At large distances ($r >> a$), this reduces to

$$E = -\frac{2qa}{4\pi\varepsilon_0 r^3} \hat{p} \qquad \text{...(iv)}$$

$$\because \quad \vec{p} = q \times 2\vec{a}\,\hat{p}$$

$$\therefore \quad E = \frac{-\vec{p}}{4\pi\varepsilon_0 r^3} \, (r >> a)$$