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 $R_{Cu} = R_M$

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

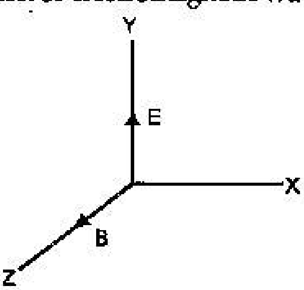
$$\frac{\rho_M}{\rho_{Cu}} = \frac{A_M}{A_{Cu}} > 1$$

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.

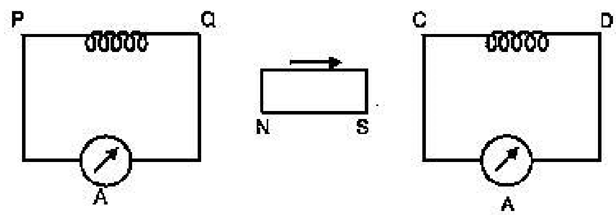
3. **How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled ?** **[1]**

Answer : We know angular separation is given as

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

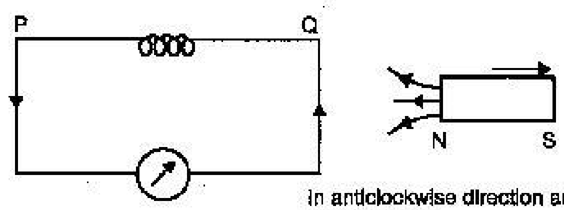
Since θ is independent of D *i.e.*, the distance of separation between the screen and the slit, so when D is doubled, angular separation would remain same.

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]**



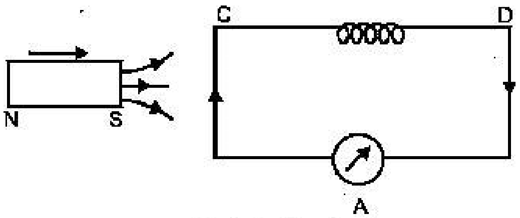
Answer : According to Lenz's, law the polarity of the induced emf is such that it opposes the change in magnetic flux responsible for its production.

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

As $m_p > m_e$

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

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,

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

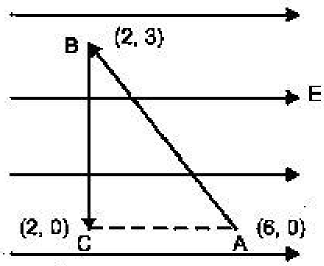
Now, the flux passing through all the six faces would be

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

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, $V_C - V_A = 4\,E$

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

Hence,

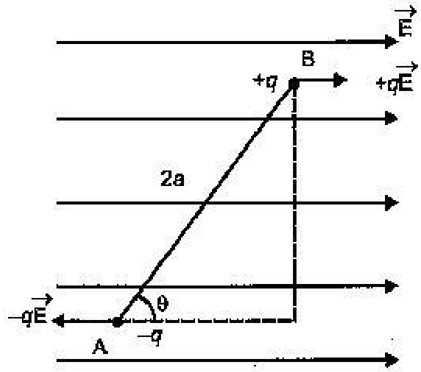
$$V_C > V_A.$$

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.

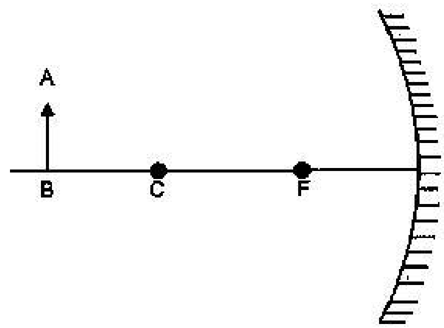
12. A capacitor of capacitance 'C' is being charged by connecting it across a dc source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging ? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit ?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

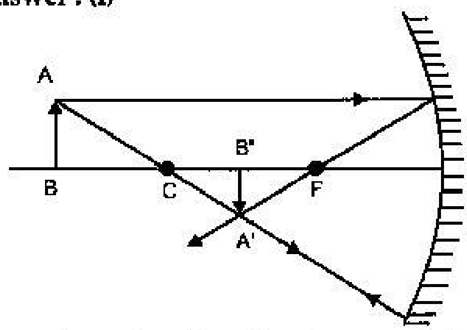
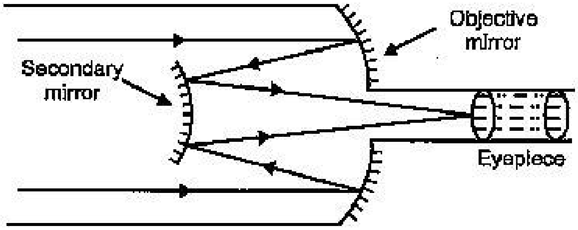


Image formed will real and inverted, between focus and center of curvature and small in size.

(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 314*t*, R = 50 Ω

(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

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

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

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

$$= \frac{Q^2}{2C}$$

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

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 $\quad K > 1$

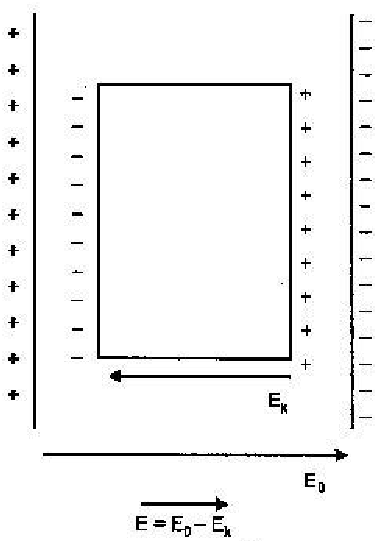
$\therefore \quad V_0 > V$

Thus, potential difference also decreases.

We have energy stored as $U = \frac{1}{2}QV$

Since V decreases, U also decreases.

(ii)

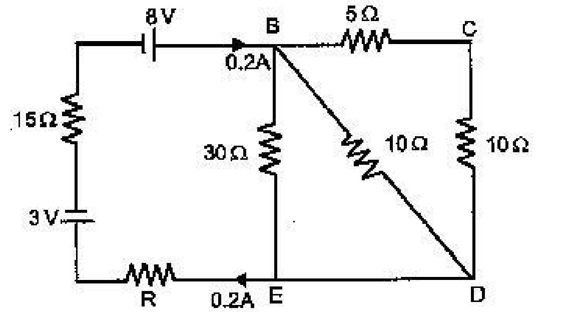


But $\quad K > 1 \; \frac{E_0}{E} = K$

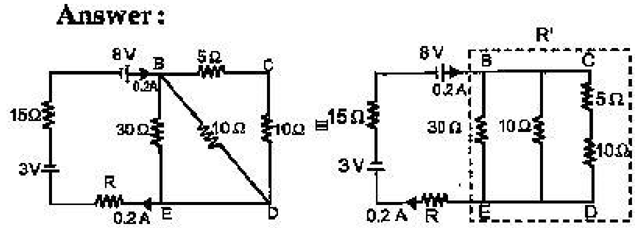
So, $\quad \frac{E_0}{E} > 1$ or $E_0 > E$

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 :

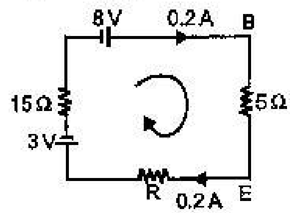


Equivalent resistance R' is given by

$$\frac{1}{R'} = \frac{1}{30} + \frac{1}{10} + \frac{1}{10+5}$$

$$= \frac{1}{30} + \frac{1}{10} + \frac{1}{15} = \frac{6}{30}$$

$\Rightarrow \quad R' = 5\,\Omega$



On applying Kirchhoff's second law, we get

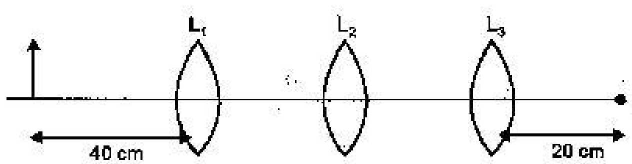
$\Rightarrow 5(0.2) + R(0.2) + 15(0.2) = 8 - 3$

$\Rightarrow$ and $\quad R = 5\,\Omega$

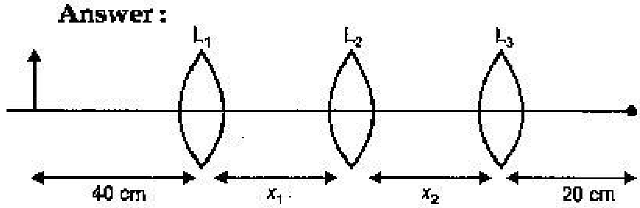
$V_{BE} = 5(0.2) = 1$ V

$[\because R_{BE} = R' = 5\,\Omega]$

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

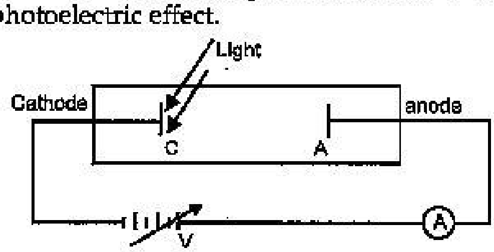
Again distance between L_2 and L_3 does not matter as the image by L_2 is formed at infinity.

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.



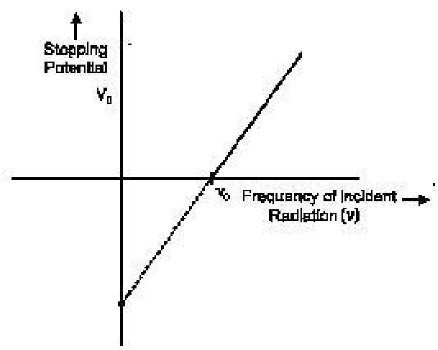
(i) The cathode is illuminated with light of some fixed frequency v and fixed intensity I_1. A small photoelectric current is observed due to few electrons that reach anode just because they have sufficiently large velocity of emission. If we make the potential of the anode negative with respect to cathode 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 v 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

$$K.E_{max} = \frac{hc}{\lambda} - \phi = hv - \phi$$

$$K.E_{max} = eV_0$$

$$\therefore \quad eV_0 = hv - \phi$$

$$V_0 = \left(\frac{h}{e}\right)v - \frac{\phi}{e} \quad \text{...(i)}$$

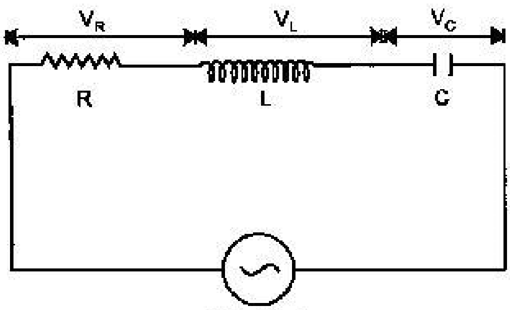
We can read the value of threshold frequency from graph.

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

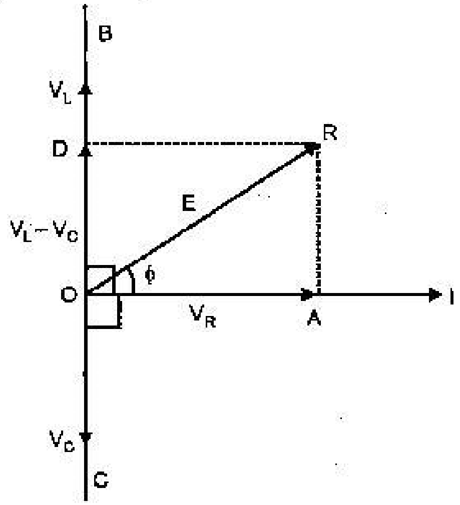
$$V_L = IX_L,\ V_C = IX_C \text{ and } V_R = IR$$

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

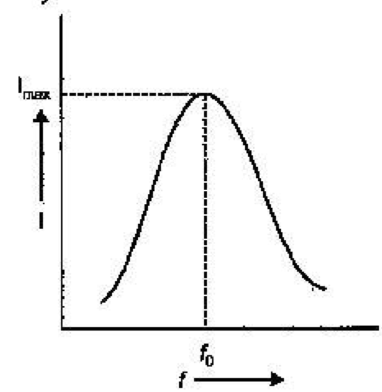
$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} = \frac{L\omega - \frac{1}{C\omega}}{R}$$

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.

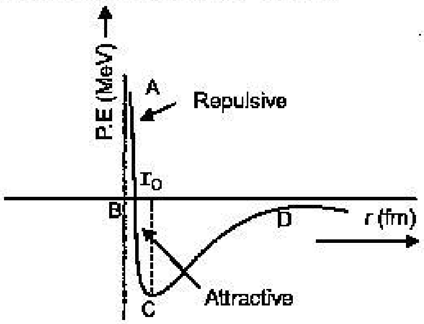
24. **Mention three different modes of propagation used in communication system. Explain with the help of a diagram how long distance communication can be achieved by ionospheric reflection of radiowaves.** [3]**

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 $$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{E_k}$$

$$= \frac{9\times10^9\times80\times2(1.6\times10^{-19})^2}{8\times10^6\times1.6\times10^{-19}}$$

$$= \frac{18\times10\times10^9\times1.6\times10^{-19}}{8\times10^6}$$

$= 2.88 \times 10^{-14}$ m

$= 28.8$ 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, $R = 1.0974 \times 10^7 m^{-1}$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_q^2} - \frac{1}{n_p^2}\right)$$

$$\frac{1}{\lambda} = 1.0974\times10^7\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{1.0974\times10^7\times12}{4\times16}$$

$$\frac{1}{\lambda} = 0.2057 \times 10^7$$

$\lambda = 4.861 \times 10^{-7}$ m

$\lambda = 4861$ 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,

$$R = \frac{ml}{ne^2\tau A} = \frac{m}{me^2\tau}\cdot\frac{l}{A}$$

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.

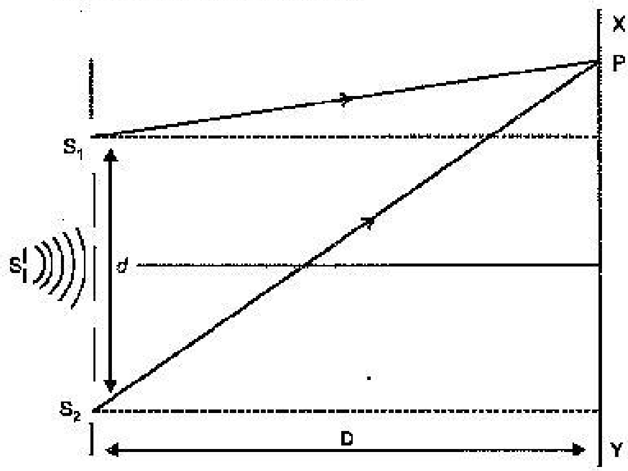
(b) A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum where the bright fringes 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, 3^{rd} maximum corresponding to wavelength 800 nm coincides with 4^{th} maximum corresponding to wavelength 600 nm.

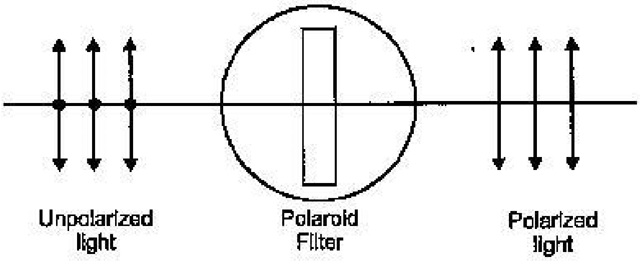
And the minimum distance is given by,

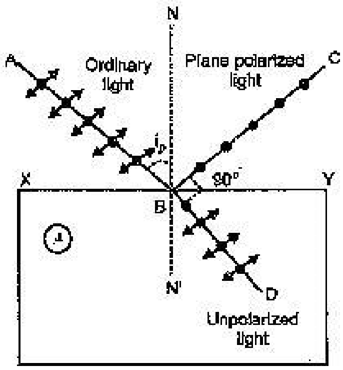
$$x_{min} = n_1 \frac{\lambda_1 D}{d} = \frac{3 \times 800 \times 10^{-9} \times 1.4}{0.28 \times 10^{-3}}$$

$$x_{min} = 12 \text{ mm}$$

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 $(90° - \theta)$ 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'.

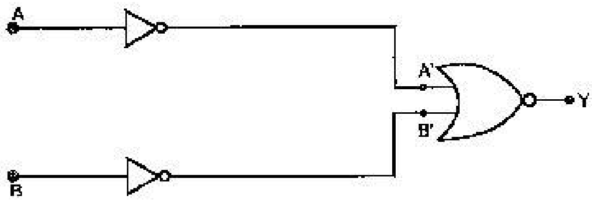
29. (a) Describe briefly, with the help of a diagram, the role of the two important processes involved in the formation of a *p-n* junction.

(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.

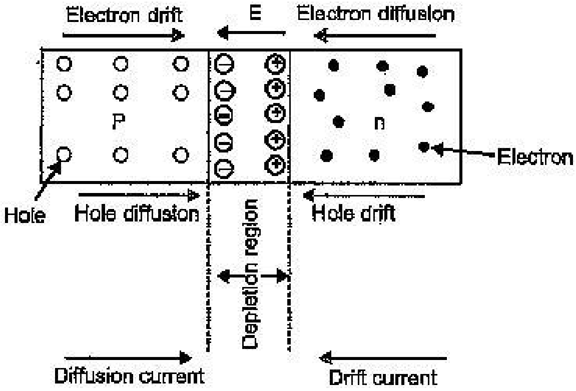
When an electron diffuses from *n* to *p* side, it leaves behind a positive charge. In such a manner a positively charged layer forms on *n*-side of the junction.

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.

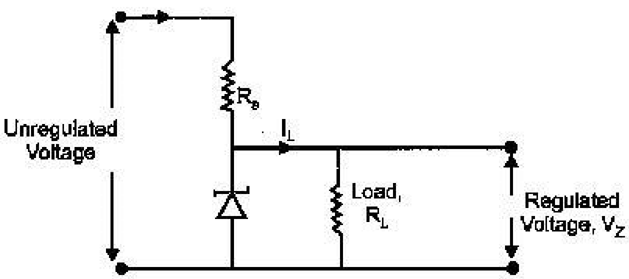
Drift current is opposite in direction to the diffusion current.

**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 $l \times b$ 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

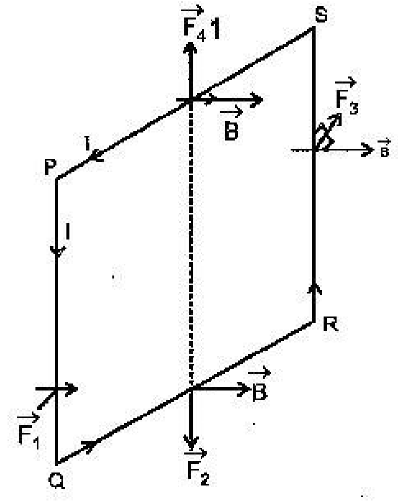


Fig. (a)

tends to rotate the loop so that area of the loop is perpendicular to the direction of the magnetic field.

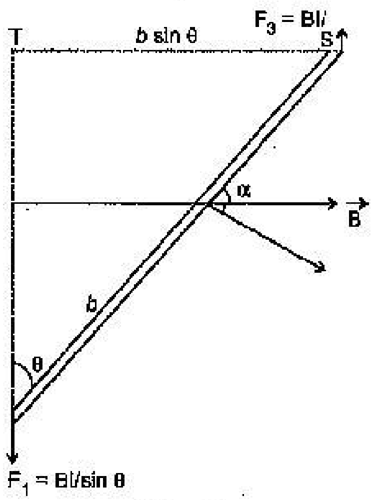


Fig. (b)

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 $\quad \vec{F_1} = I(\vec{PQ} \times \vec{B})$

$$F_1 = IlB \qquad (\because \theta = 90^\circ)$$

($\vec{F_1}$ acts in direction perpendicular to the plane of paper)

Similarly, $\quad \vec{F_3} = I(\vec{RS} \times \vec{B})$

$$F_3 = IlB$$

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

$$\theta + \alpha = 90^\circ$$

$$\cos\theta = \cos(90 - \alpha) = \sin\alpha$$

$$\therefore \quad \tau = NIAB\sin\alpha$$

$$\tau = mB\sin\alpha$$

or $\quad \vec{\tau} = \vec{m} \times \vec{B}$

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.

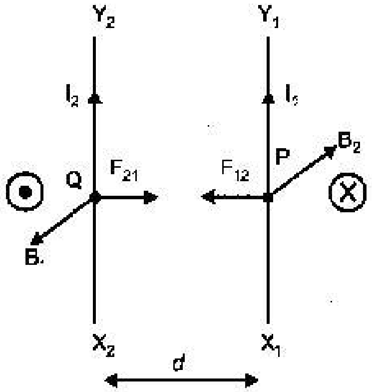
(b) **Assumption** : Current flowing in the conductors are in the same direction.

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

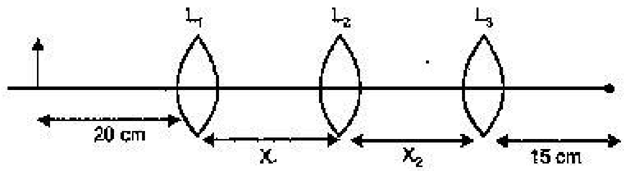
λ = wavelength of light used

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,

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$

$$\frac{1}{v_1} - \frac{1}{-20} = \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{1}{-20} + \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{1}{60}$$

$\Rightarrow$ $v_1 = 60$ 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 100πt 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, $V = 70 \sin 100\pi t$

$\therefore \quad \omega = 100\pi$ and $V_0 = 70$ V

(i) Frequency of the source,

$$f = \frac{\omega}{2\pi} = \frac{100\pi}{2\pi} = 50\text{ Hz}$$

(ii) $$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{70}{\sqrt{2}} = 49.5\text{ V}$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{49.5}{25} = 1.98\text{ A}$$

20. Explain briefly the following terms used in communication system : [3]**

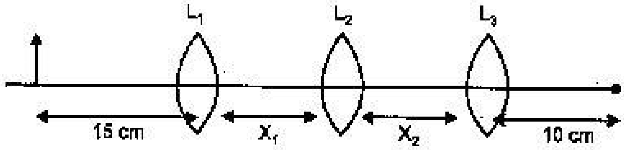
(i) Transducer

(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,

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$

$$\frac{1}{v_1} - \frac{1}{-15} = \frac{1}{10}$$

$$\frac{1}{v_1} = \frac{1}{10} - \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{3-2}{30} = \frac{1}{30}$$

$$\frac{1}{v_1} = \frac{1}{30}$$

$$\Rightarrow \qquad v_1 = 30 \text{ cm}$$

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]**

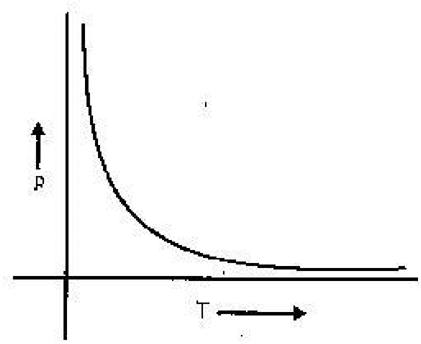
Answer : No, when electric field is applied, the electrons will have net drift from lower to higher field but locally electrons may collide with ions and may change their direction of motion.

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.

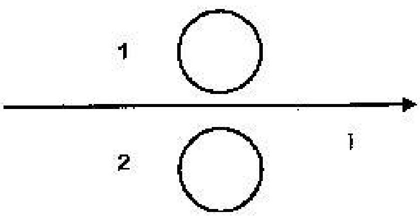
5. Name the physical quantity which remains same for microwaves of wavelength 1 mm and UV radiations of 1600 Å in vacuum. [1]

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).

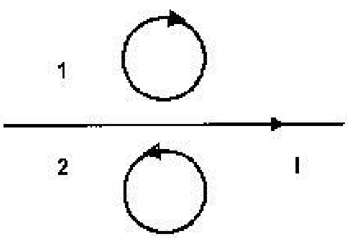
6. Under what condition does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid ? [1]

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°.

The angle of refraction in case of a prism,

$$r = \frac{A}{2} = 30°$$

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

$$\sin i = \left(\frac{\mu_g}{\mu_a}\right)\sin r = \left(\frac{\mu_g}{\mu_a}\right)\sin 30°$$

$$\sin i = \frac{\sqrt{3}}{2}$$

So, the angle of incidence is $i = 60°$.

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, $I_1 = 4.2$ 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, $I_2 = 1.05$ 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, $I_3 = 0.42$ 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, $I_4 = 1.4$ 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.

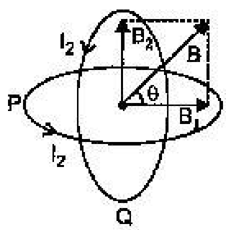
Two properties of diamagnetic material :

(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 $N_1 = N_2 = 1$, $I_1 = I_2 = I$, $a_1 = a_2 = R$

$$B = \sqrt{\left(\frac{\mu_0 \times 1 \times I}{2R}\right)^2 + \left(\frac{\mu_0 \times 1 \times I}{2R}\right)^2}$$

$$= \frac{\mu_0 I}{2R}\sqrt{1+1} = \sqrt{2}\left(\frac{\mu_0 I}{2R}\right)$$

Direction of B, $\tan\theta = \frac{B_2}{B_1} = 1$

$\therefore$ $\theta = 45°$

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.

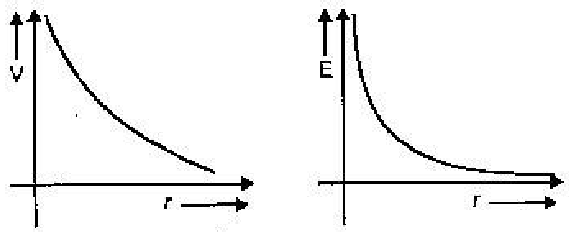
Electric potential, $V = \frac{Q}{4\pi\varepsilon_0 r}$

or $V \propto \frac{1}{r}$

Electric field, $E = \frac{Q}{4\pi\varepsilon_0 r^2}$

or $E \propto \frac{1}{r^2}$

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

$$W = \int_0^I LI\,dI = L\int_0^I I\,dI = L\left[\frac{I^2}{2}\right]$$

$$= \frac{1}{2}LI^2$$

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,

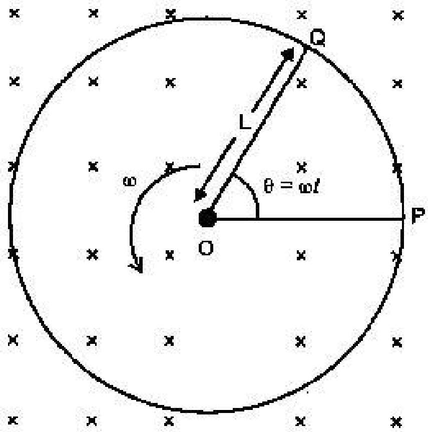
$$e = \frac{d\phi_B}{dt}$$

$$e = \frac{d}{dt}(BA\cos\phi)$$

$[\because \phi_B = BA\cos\phi]$

$$= B\frac{dA}{dt} \qquad [\because \phi = 0°]$$

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.

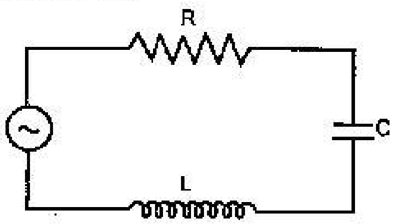
Hence $e = B \times \frac{d}{dt}\left(\frac{1}{2}L^2\theta\right) = \frac{1}{2}BL^2\frac{d\theta}{dt} = \frac{B\omega L^2}{2}$

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

$$I_{rms} = \frac{V_{rms}}{R} = \frac{240}{40} = 6 \text{ A}$$

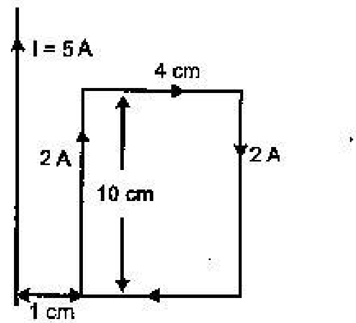
(iii) rms potential drop across inductor

$$V_L = I_{rms} \times X_L$$
$$= I_{rms} \times \omega L$$
$$= 6 \times 50 \times 5 = 1500 \text{ V}$$

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) $\vec{\tau} = \vec{m}\times\vec{B} = \vec{m}\,B\sin\theta$

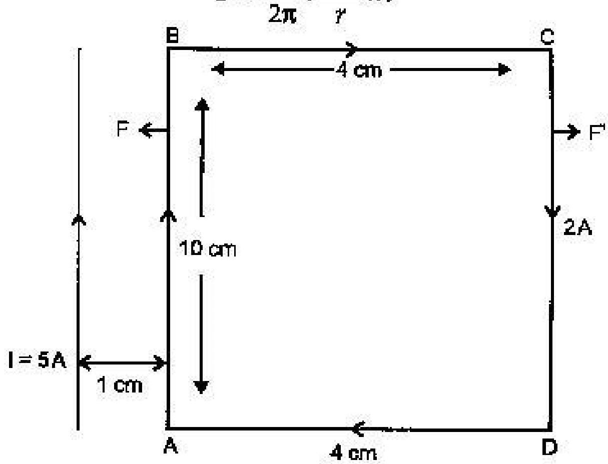
Here, *m* and B have the same direction

∴ $\theta = 0°$

$|\vec{\tau}| = mB\sin\theta = 0$

(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

$$mvr = n\frac{h}{2\pi} \quad ...(1)$$

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 $$mvr = \frac{hr}{\lambda} \quad ...(2)$$

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

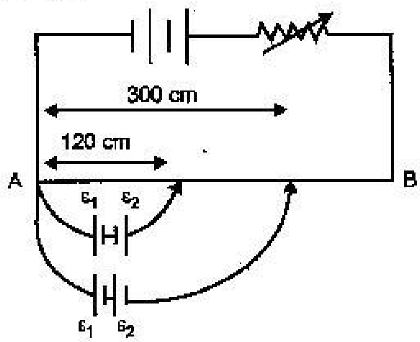
$$N = \frac{4(4-1)}{2}$$

$$= \frac{4 \times 3}{2} = 6$$

The maximum possible number of spectral lines is 6.

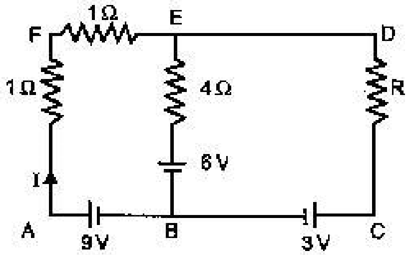
22. In the figure a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end A. Find (i) $\varepsilon_1/\varepsilon_2$ and (ii) position of null point for the cell ε_1. [3]

How is the sensitivity of a potentiometer increased ?

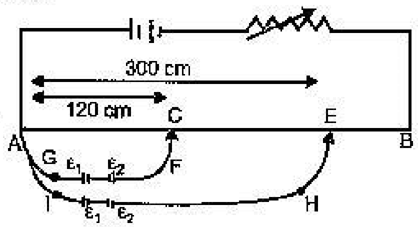


OR

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 $\quad \varepsilon_1 = \varepsilon_2 + k\,(120)$ ...(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, $\quad \varepsilon_2 = 90\,k$ ...(ii)

Thus, $\quad \varepsilon_1 = 90\,k + 120\,k$

$\varepsilon_1 = 210\,k$ ...(iii)

Hence, $\dfrac{\varepsilon_1}{\varepsilon_2} = \dfrac{210}{90} = \dfrac{7}{3}$

(ii) As we know, $\varepsilon = kl$

Thus, from equations (ii) and (iii),

Null point for cell ε_2 is 90 cm

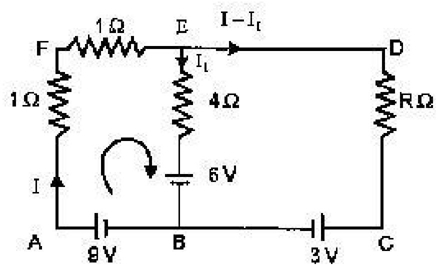
And for cell ε_1, it is 210 cm.

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 :

$$I + I + 4I_1 = 9 - 6$$

$$2I + 4I_1 = 3 \quad \text{...(i)}$$

As there is no current flowing through the 4 Ω resistance,

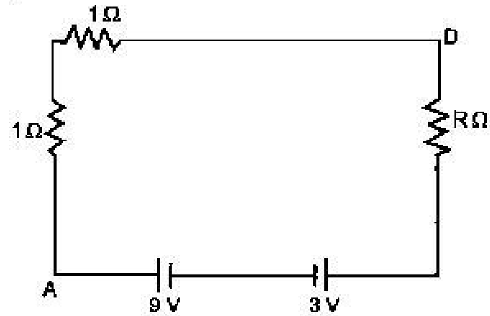
$\therefore \quad I_1 = 0$

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 $= \dfrac{4}{3}\pi R^3$

$$= \frac{4}{3}\pi (R_0 A^{1/3})^3$$

$[\because R = R_0 A^{1/3}]$

**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 λ/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

$$\therefore \quad K = 4I_0 \cos^2 \frac{2\pi}{2}$$

$$\text{or} \quad K = 4I_0$$

$$\text{or} \quad I_0 = \frac{K}{4}$$

$$\text{Now, at path difference} = \frac{\lambda}{3}$$

$$\phi' = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

$$\text{Intensity, } I' = 4I_0 \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right)$$

$$I' = 4 \times \frac{K}{4} \cos^2 \frac{\pi}{3}$$

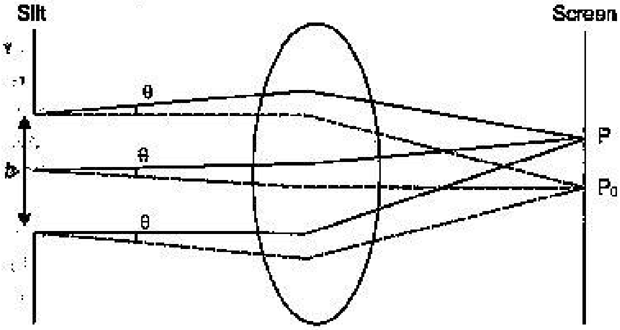
$$= K \times \left(\frac{1}{2}\right)^2$$

$$= \frac{1}{4}K$$

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.

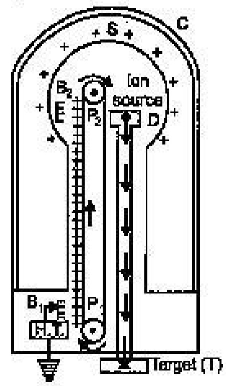
(c) How is the field directed if (i) the sheet is positively charged, (ii) negatively charged?

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.

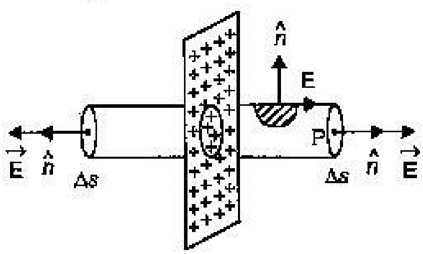
$$\phi = \vec{E} \cdot \vec{A}$$

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. [3]

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

$$-30 = \frac{v_0}{u_0}\left(1 + \frac{25}{5}\right)$$

$$v_0 = -5u_0$$

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

$A_V = \frac{-\beta_{ac} R_L}{r_i}$, 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]**

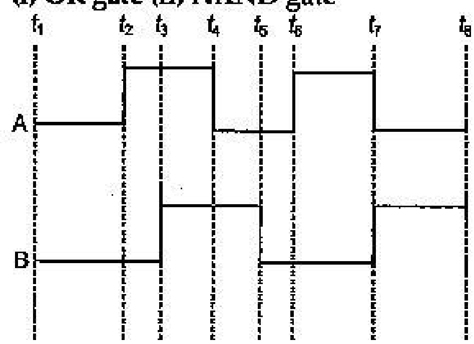
OR

(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**



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Physics 2012 (Delhi) SET II

Time allowed : 3 hours

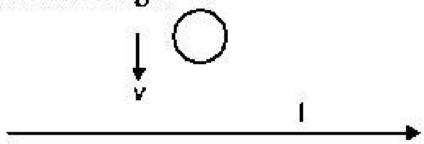
Maximum marks : 70

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,

$$B = \frac{\mu_0 NI}{l} \quad ...(i)$$

Where, μ_0 = Absolute magnetic permeability of free space

N = Total number of turns in the solenoid

$\therefore$ 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

$$\phi = \frac{\mu_0 NIA}{l} \times N \quad ...(ii)$$

If L is coefficient of self-inductance of the solenoid, then

$$\phi = LI \quad ...(iii)$$

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,

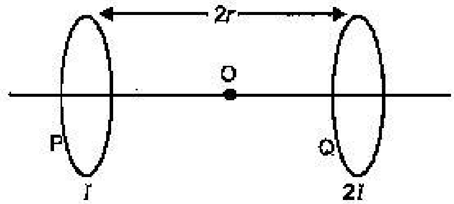
$$L = \mu_r\mu_0 N^2 A/l.$$

If n is the number of turns per unit length then

$$L = \mu_r \mu_0 n^2 Al$$

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

$$\vec{B} = \vec{B}_Q - \vec{B}_P$$

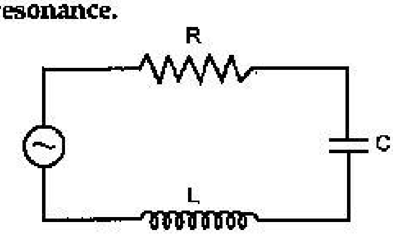
$$= \frac{\mu_0(2I)}{4\sqrt{2}r} - \frac{\mu_0 I}{4\sqrt{2}r} = \frac{\mu_0 I}{4\sqrt{2}r} \text{ towards Q.}$$

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.

$$Z = R = 60\ \Omega$$

$\therefore$ The current at resonant frequency

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{240}{60}$$

$$= 4 \text{ A}$$

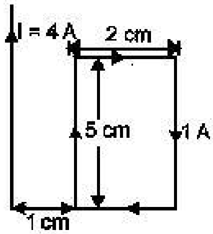
(iii) rms potential drop across inductor at resonance

$$V_L = I_{rms} \cdot X_L = I_{rms} \cdot \omega L$$

$$= 4 \times 50 \times 4 = 800 \text{ V}$$

**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) $|\vec{\tau}| = \vec{m} \times \vec{B} = mB \sin\theta$

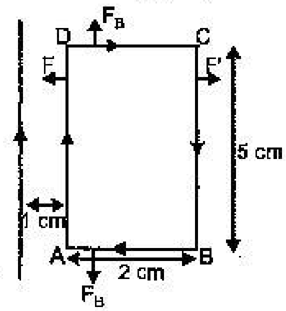
Here m and B have the same direction

$$\theta = 0$$

$$\Rightarrow \quad |\vec{\tau}| = mB \sin\theta = 0$$

(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]**

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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

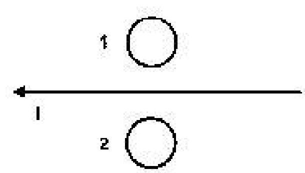
$$E = -\frac{dV}{dr}.$$

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.

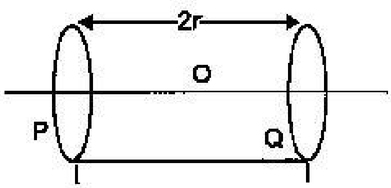
9. The relative magnetic permeability of a magnetic material is 800. Identify the nature of magnetic material and state its two properties. [2]

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

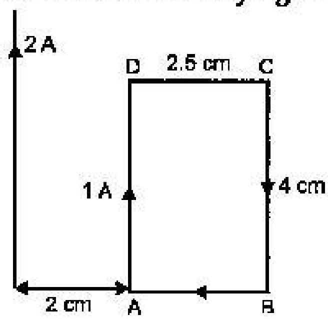
$$B_Q = \frac{\mu_0 I(r)^2}{2\left[r^2+\left(\frac{2r}{2}\right)^2\right]^{3/2}} = \frac{\mu_0 I}{2\pi}$$

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,

$$F = \frac{\mu_0}{2\pi}.\frac{I_1 I_2}{r}l$$

On line AB and CD, the magnetic forces are equal and opposite. So they cancel out each other.

Magnetic force on line AD,

$$F = \frac{\mu_0}{2\pi}.\frac{2\times1\times0.04}{0.02} \quad \text{(Attractive)}$$

$$= \frac{\mu_0}{2\pi}\times 4$$

Magnetic force on line CB,

$$F' = \frac{\mu_0}{2\pi}.\frac{2\times1\times0.04}{0.045}$$

$$= \frac{\mu_0}{2\pi}\times\frac{16}{9}$$

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.