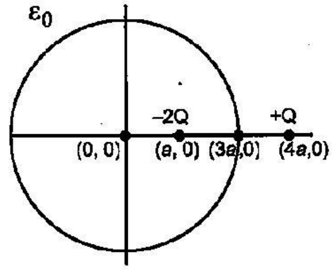
Physics 2013 (Outside Delhi) SET I

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

1. **Two charges of magnitudes −2Q and +Q are located at point (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '3a' with its centre at the origin ?** **[1]**

Answer : Gauss's theorem states that the electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed. The sphere encloses a charge of −2Q thus, $\phi = \frac{2Q}{\varepsilon_0}$



2. **How does the mutual inductance of a pairs of coils change when**
(i) distance between the coils is increased and
(ii) number of turns in the coils is increased ? **[1]**

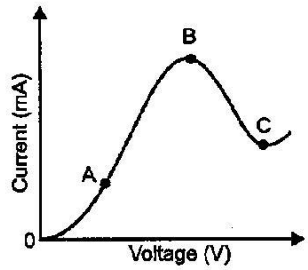
Answer : (i) As $\phi = MI$, with the increase in the distance between the coils, the magnetic flux linked with the stationary coil decreases and hence the mutual inductance of the two coils will decrease.

(ii) Mutual inductance of two coils can be found out by

$$M = \mu_0 n_1 n_2 AI$$

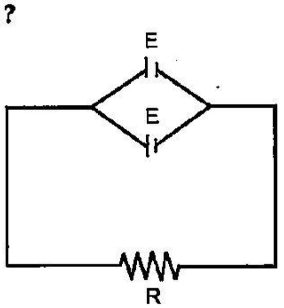
i.e., $M \propto n_1 n_2$ so with the increase in number of turns, mutual inductance increases.

3. **The graph shown in the figure represents a plot of current versus voltage for given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance.** **[1]**



Answer : Resistance of a material can be found out by the slope of the V-I curve. Part BC of the curve shows the negative resistance as with the increase in voltage, current decreases.

4. **Two identical cells, each of emf E , having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through this resistance ?** **[1]**



Answer : The cells are arranged as shown in the circuit diagram. As the internal resistance is negligible, so total resistance of the circuit = R.

So, current through the resistance, $I = \frac{E}{R}$.

5. **The motion of copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping ? [1]**

Answer : As the copper plates oscillate in the magnetic field between the two poles of the magnet, there is a continuous change of magnetic flux linked with the copper plate. Due to this, eddy currents are set up in the copper plate which try to oppose the motion of the plate according to the Lenz's law and finally bring it to rest.

6. **Define the activity of a given radioactive substance. Write its S.I. unit. [1]**

Answer : Activity of a radioactive substance is defined as number of radioactive disintegrations taking place in one second in the sample.

S. I. unit of activity is Becquerel (Bq).

1 Becquerel = 1 Bq = 1 decay per second.

7. **Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency. [1]**

Answer : Welders wear special goggles with glass windows to protect the eyes from ultraviolet rays (UV rays). The range of frequency of UV rays is 8×10^{14} Hz to 3×10^{16} Hz.

8. **Write the expression for the de-Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V. [1]**

Answer : Let v be the velocity gained by the given charge particle when it is accelerated through a potential difference of 'V' volts.

Kinetic energy of the particle = $\frac{1}{2}mv^2$.

Kinetic energy of the particle = Work done on the particle by electric field.

$$\therefore \quad \frac{1}{2}mv^2 = qV$$

or
$$\frac{p^2}{2m} = qV$$
$$p = \sqrt{2mqV}$$

de-Broglie wavelength (λ) associated with the particle,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

9. **Draw a typical output characteristics of an n-p-n transistor in CE configuration. Show how these characteristics can be used to determine output resistance.** [1]**

10. **A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit. [1]**

Answer : The distance of the n^{th} minimum from the centre of the screen is, $x_n = \frac{nD\lambda}{a}$

Where, D = distance of slit from screen = 1 m

λ = wavelength of the light = 500×10^{-9} m

a = width of the slit

For first minimum, $n = 1$

Thus, $$2.5 \times 10^{-3} = \frac{1(1)(500 \times 10^{-9})}{a},$$
$$a = 2 \times 10^{-4} \text{ m}$$
$$a = 0.2 \text{ mm}$$

11. **A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness $d/2$, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor. [2]**

Answer : Initially when there is vacuum between the two plates, the capacitance of the two parallel plate is

$$C_0 = \frac{\varepsilon_0 A}{d}$$

Where, A is the area of parallel plates.

Suppose that the capacitor is connected to a battery, an electric field E_0 is produced.

Now, if we insert the dielectric slab of thickness $t = \frac{d}{2}$, the electric field reduces to E.

Now, the gap between plates is divided in two parts, for distance t there is electric field E and for the remaining distance $(d - t)$ the electric field is E_0.

If V is the potential difference between the plates of the capacitor, then $V = Et + E_0(d-t)$.

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

$$V = \frac{Ed}{2} + \frac{E_0 d}{2} = \frac{d}{2}(E + E_0) \quad \left[\because t = \frac{d}{2}\right]$$

$$V = \frac{d}{2}E_0\left(\frac{E}{E_0} + 1\right) \quad \left[\because \frac{E_0}{E} = K\right]$$

$$= \frac{dE_0}{2K}(K+1)$$

Now $E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A}$

$$\Rightarrow \quad V = \frac{d}{2K}\frac{q}{\varepsilon_0 A}(K+1)$$

We know,

$$C = \frac{q}{V} = \frac{2K\varepsilon_0 A}{d(K+1)}$$

12. A capacitor, made of two parallel plates each of plate area A and separation d, being charged by an external ac source. Show that the displacement current inside the capacitor is same as the current charging the capacitor. [2]

Answer : Let the alternating emf charging the plates of capacitor be $E = E_0 \sin \omega t$.

Charge on the capacitor,

$$q = CE = CE_0 \sin \omega t$$

Instantaneous current is I.

$$I = \frac{dq}{dt} = \frac{d}{dt}(CE_0 \sin\omega t)$$

$$= \omega CE_0 \cos \omega t$$

$$= I_0 \cos \omega t \quad ...(i)$$

where, $I_0 = \omega CE_0$

Displacement current,

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

$$= \varepsilon_0 A \frac{d(E)}{dt} \quad [\phi = E \cdot A]$$

$$= \varepsilon_0 A \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A}\right) \quad \left[\because E = \frac{q}{\varepsilon_0 A}\right]$$

$$= \varepsilon_0 A \frac{d}{dt}\left(\frac{CE_0 \sin \omega t}{\varepsilon_0 A}\right)$$

$$= \frac{d}{dt}(CE_0 \sin \omega t)$$

$$= \omega CE_0 \cos \omega t$$

$$= I_0 \cos \omega t \quad ...(ii)$$

From equations (i) and (ii), the displacement current inside the capacitor is same as the current charging the capacitor.

13. Explain the term 'drift velocity' of electrons in a conductor. Hence obtain the expression for the current through a conductor in terms of 'drift velocity'. [3]

OR

Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a cell.

Answer : Drift velocity of electrons in a conductor : Metals contain a large number of free electrons. These electrons are in continuous random motion. Due to the random motion, the free electrons collide with positive metal ions with high frequency and undergo change in direction at each collision. So the average velocity for the electrons in a conductor is zero.

Now, when this conductor is connected to a source of emf, an electric field is established in the conductor, such that

$$E = \frac{V}{L}$$

Where, V = potential difference across the conductor and,

L = length of the conductor.

The electric field exerts an electrostatic force '$-Ee$' on each free electron in the conductor.

The acceleration of each electron is given by

$$\vec{a} = -\frac{e\vec{E}}{m}$$

Where, e = electric charge on the electron and m = mass of electron.

The negative sign indicates the force and hence the acceleration is in a direction opposite to the direction of the electric field. Due to this acceleration, the electrons attain a velocity in addition to thermal velocity in the direction opposite to that of electric field. The average velocity of all the free electrons in the conductor is called the drift velocity of free electrons of the conductor.

Thus, the expression for the drift velocity in electric field (E)

$$\vec{v} = \frac{e\vec{E}}{m}\tau \quad ...(i)$$

Where τ = relaxation time between two successive collision,

Let n = number density of electrons in the conductor.

No. of free electrons in the conductor = nAL

Total charge on the conductor, $q = nALe$

Time taken by this charge to cover the length L of the conductor,

$$t = \frac{L}{v_d}$$

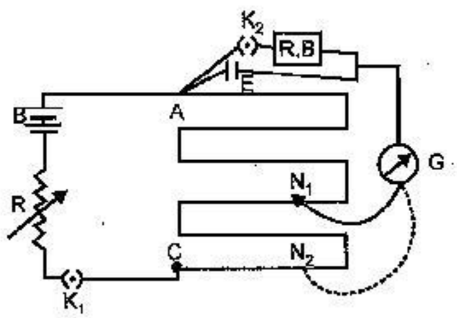
Current $$I = \frac{q}{t}$$

$$= \frac{n\,ALe}{L} \times v_d$$

$$= nAev_d$$

OR

Measurement of internal resistance of a cell using potentiometer is shown in figure. The cell of emf, E is connected across a resistance box (R) through key K_2.



When K_2 is open, balance length is obtained at length $AN_1 = l_1$

$$E \propto l_1$$

$$E = \phi\, l_1 \qquad \text{...(i)}$$

When K_2 is closed :

Let V be the terminal potential difference of cell and the balance is obtained at $AN_2 = l_2$

$$V \propto l_2$$

$$V = \phi\, l_2 \qquad \text{...(ii)}$$

From equations (i) and (ii), we get

$$\frac{E}{V} = \frac{l_1}{l_2} \qquad \text{...(iii)}$$

But $$E = I(r + R)$$

$$V = IR$$

$$\frac{E}{V} = \frac{r+R}{R} \qquad \text{...(iv)}$$

From equations (iii) and (iv), we get

$$\frac{R+r}{R} = \frac{l_1}{l_2}$$

$$\therefore \quad r = R\left(\frac{l_1}{l_2} - 1\right)$$

We know l_1, l_2 and R, so we can calculate r.

14. A convex lens of focal length f_1 is kept in contact with a concave lens of focal length f_2. Find the focal length of the combination. [2]

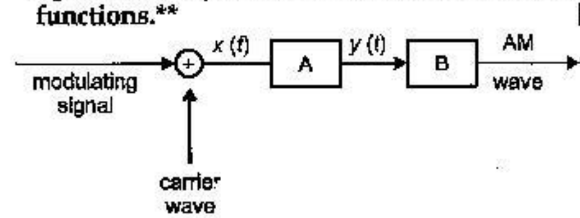
Answer : For convex lens, focal length, $f = f_1$ and for concave lens, the focal length, $f = -f_2$

The equivalent focal length of a combination of convex lens and concave lens is given as :

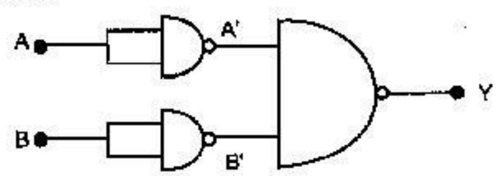
$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{-f_2}$$

$$F = \frac{f_1 f_2}{f_1 - f_2}$$

15. In the block diagram of a simple modulator for obtaining an AM signal, shown in the figure, identify the boxes A and B. Write their functions. [2]**



16. In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table. [2]**



17. (a) For a given a.c., $i = i_m \sin \omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_m^2 R$.

(b) A light bulb is rated at 100 W for a 220 V a.c. supply. Calculate the resistance of the bulb. [2]

Answer : (a) The average power dissipated

$$P = \left|i^2 R\right| = \left|i_m^2 R \sin^2 \omega t\right|$$

$$= i_m^2 R \left|\sin^2 \omega t\right|$$

$$\sin^2 \omega t = \frac{1}{2}(1 - \cos 2\omega t)$$

$$\Rightarrow \quad \left|\sin^2 \omega t\right| = \frac{1}{2}(1 - |\cos 2\omega t|) = \frac{1}{2}$$

$$[\because (|\cos 2\omega t|) = 0]$$

$$\therefore \quad \bar{P} = \frac{1}{2} i_m^2 R$$

(b) Power of the bulb, P = 100 W and voltage, V = 220 V.

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

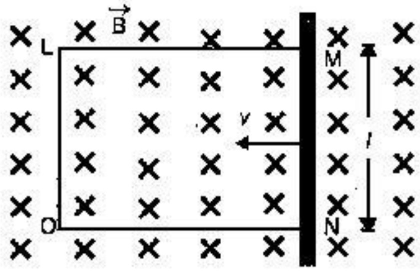
The resistance of the bulb is given as

$$R = \frac{V^2}{P}$$

$$= \frac{(220)^2}{100}$$

$$= 484\ \Omega$$

18. A rectangular conductor LMNO is placed in a uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm. [2]



OR

A wheel with 8 metallic spokes each 50 cm long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. The Earth's magnetic field at the place is 0.4 G and the angle of dip is 60°. Calculate the emf induced between the axle and the rim of the wheel. How will the value of emf be affected if the number of spokes were increased ?

Answer : Let ON be x at some instant.

The emf induced in the loop = e.

$$e = \frac{d\phi}{dt} = \frac{-d(Blx)}{dt}$$

$$e = Bl\left(\frac{-dx}{dt}\right)$$

$$= Blv = 0.5 \times 0.2 \times 10$$

$$\left[\because v = \frac{-dx}{dt}\right]$$

$$= 1\ V$$

Current in the arm,

$$I = \frac{e}{R} = \frac{1}{5} = 0.2\ A$$

OR

$H = B\cos\theta = 0.4\cos 60^\circ = 0.2\ G = 0.2 \times 10^{-4}\ T.$

This component is parallel to the plane of the wheel. Thus, the emf induced is given as,

$$E = \frac{1}{2}Bl^2\omega$$

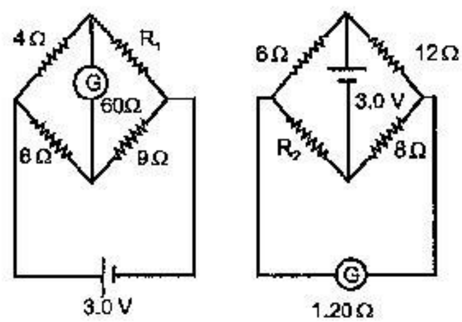
Where, $\omega = \frac{2\pi N}{t}$

$$E = \frac{1}{2} \times 0.2 \times 10^{-4} \times (0.5)^2 \times \frac{2 \times 3.14 \times 120}{60}$$

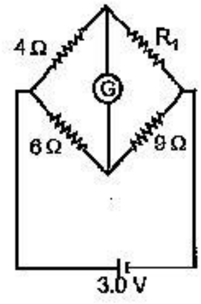
$$= 3.14 \times 10^{-5}\ V$$

The value of emf induced is independent of the number of spokes as the emf across the spokes are in parallel. So, the emf will be unaffected with the increase in spokes.

19. Define the current sensitivity of a galvanometer. Write S.I. unit. Figure shows two circuits each having a galvanometer and a battery of 3 V. When the galvanometers in each arrangement do not show any deflection, obtain the ratio R_1/R_2. [2]



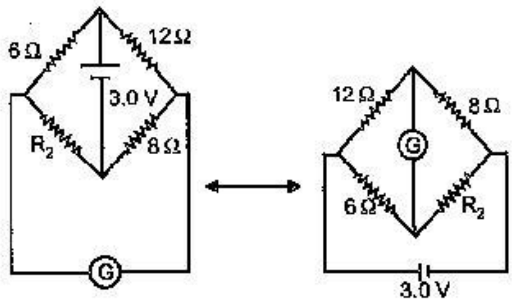
Answer : Current sensitivity of a galvanometer is defined as the deflection in galvanometer per unit current. Its SI unit is radians/ampere.



For balanced Wheatstone bridge, there will -- no deflection in the galvanometer.

$$\frac{4}{R_1} = \frac{6}{9}$$

$$R_1 = \frac{4 \times 9}{6} = 6\ \Omega$$



For the equivalent circuit, when the Wheatstone bridge is balanced, there will be no deflection in the galvanometer.

$$\frac{12}{8} = \frac{6}{R_2}$$

$$R_2 = \frac{6 \times 8}{12}$$

$$= 4\ \Omega$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$$

20. A wire AB is carrying a steady current 12 A and is lying on the table. Another wire CD carrying 5 A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. [Take the value of $g = 10\ \text{ms}^{-2}$] [2]

Answer : Force per unit length between the current carrying wires is given as :

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$

Let m be the mass per unit length of wire CD. As the force balances the weight of the wire,

$$\therefore \quad \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} = mg$$

Here, m is mass per unit length.

$$10^{-7} \times \frac{2 \times 12 \times 5}{1 \times 10^{-3}} = m \times 10$$

$$m = 10^{-7} \times \frac{2 \times 12 \times 5}{1 \times 10^{-3}} \times \frac{1}{10}$$

$$= 1.2 \times 10^{-3}\ \text{kg m}^{-1}$$

The direction of current in CD is opposite to the direction of current AB. because in this they will repel each other and CD will remain suspended.

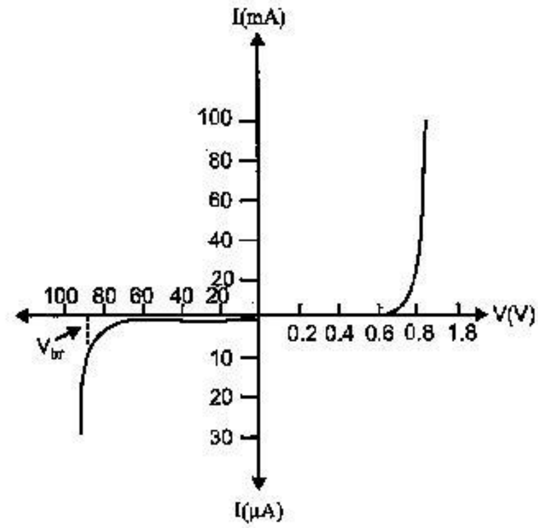
21. Draw V-I characteristics of a *p-n* junction diode. Answer the following questions, giving reasons :

(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage ?

(ii) Why does the reverse current show a sudden increase at the critical voltage ?

Name any semiconductor device which operates under the reverse bias in the breakdown region. [3]

Answer : V-I characteristics of *p-n* junction diode :



(i) Under the reverse bias condition, the holes of *p*-side are attracted towards the negative terminal of the battery and the electrons of the *n*-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However the minority charge carriers are drifted across the junction producing a small current. At any temperature the number of minority carriers is constant and very small so there is the small current at any applied potential. This is the reason for the current under reverse bias to be almost independent of applied potential. At the critical voltage, avalanche break down takes place which results in a sudden flow of large current.

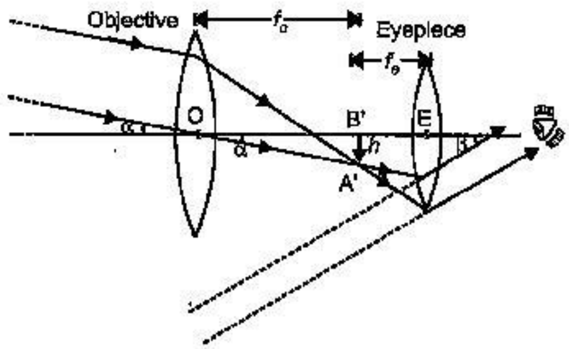
(ii) At the critical voltage, the holes in the *n*-side and conduction electrons in the *p*-side are accelerated due to the reverse-bias voltage. These minority carriers acquire sufficient kinetic energy from the electric field and collide with valence electrons. Thus, the bond is finally broken and the valence electrons move into the conduction band resulting in enormous flow of electrons and thus result in formation of hole-electron pairs. Thus, there is a sudden increase in the current at the critical voltage.

Zener diode is a semiconductor device which operates under the reverse bias condition in the breakdown region.

22. Draw a labelled ray diagram of a refracting telescope. Define its magnifying power and write the expression for it.

Write two important limitations of a refracting telescope over a reflecting type telescope. [3]

Answer : Refracting telescope :



Magnifying power : The magnifying power is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye.

$$m = -\frac{\beta}{\alpha} = -\frac{h}{f_e} \cdot \frac{f_o}{h} = -\frac{f_o}{f_e}$$

Limitations of refracting telescope over reflecting type telescope :

(i) Refracting telescope suffers from chromatic aberration as it uses large sized lenses.

(ii) The requirement of big lenses tend to be very heavy and therefore, difficult to make and support by their edges.

23. Write Einstein's photoelectric equation and point out any two characteristic properties of photons on which this equation is based.

Briefly explain the three observed features which can be explained by this equation. [4]

Answer : Einstein's photoelectric effect equation :

$$K_{max} = \frac{1}{2} m v_{max}^2 = (h\nu - \phi_0)$$

or $$K_{max} = h(\nu - \nu_0)$$

The two characteristics properties of the photon on which this equation is based :

(i) The light travel in the form of photons *i.e.* small packet of enery and each photon has energy $h\nu$.

(ii) Each photon interact with one electron.

Three observed features that can be explained by this equation.

(i) When $\nu < \nu_0$, K_{max} becomes negative. The negative value of K./E. has no physical significance. Hence, no photoelectric effect is possible below there shold frequency.

(ii) When $\nu > \nu_0$, $K_{max} \propto \nu$, *i.e.* max. K.E. of the emitted photo electrons depends linearly on the frequency of incident radiations.

(iii) It is clear from the photoelectric equation that the maximum K.E. of photoelectrons is independent of intensity of incident reactions.

24. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies ?

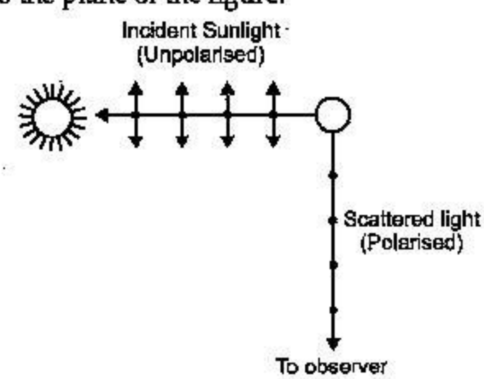
A transmitting antenna at the top of a tower has a height of 20 m and the height of the receiving antenna is 45 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4 × 10⁶m) [5]**

25. (a) What is linearly polarised light. Describe briefly using a diagram how sunlight is polarised.

(b) Unpolarised light is incident on a Polaroid. How would the intensity of transmitted light change when the Polaroid is rotated ? [5]

Answer : (a) The light in which the vibrations of electric vector are restricted to a particular plane, is called plane polarised light.

The incident sunlight is unpolarised. The dot and double arrows show the polarisation in the perpendicular and in the plane of the figure respectively. Under the influence of the electric field of the incident wave, the electrons in the molecules of the atmosphere acquire components of motion in both these directions. For an observer looking at 90° to the direction of the sun, the charges accelerating parallel to the double arrows do not radiate energy towards this observer since their acceleration has no transverse component. The radiation scattered by the molecule is therefore, represented by dots. It is linearly polarised light perpendicular to the plane of the figure.



(b) If the unpolarised light is incident on a polaroid, the intensity is reduced by half. Even if the polaroid is rotated by angle θ the average

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

over $\cos^2\theta = \frac{1}{2}$. Thus, from Malus' law : $I = I_0 \cos^2\theta$

$$|I| = |I_0 \cos^2\theta|$$

$$= I_0|\cos^2\theta| = \frac{I_0}{2}$$

Thus, the intensity of the transmitted light remains unchanged when the polaroid is rotated.

26. One day Chetan's mother developed a severe stomach ache all of a sudden. She rushed to the doctor who suggested for an immediate endoscopy test and gave an estimate of expenditure for the same. Chetan immediately contacted his class teacher and shared the information with her. The class teacher arranged for the money and rushed to the hospital. On realizing that Chetan belonged to a below average income group family, even the doctor offered concession for the test fee. The test was conducted successfully.

Answer the following questions based on the above information : [5]

(a) Which principle in optics is made use of in endoscopy ?

(b) Briefly explain the values reflected in the action taken by the teacher.**

(c) In what way do you appreciate the response of the doctor on the given situation ?

Answer : (a) Endoscopy is based on total internal reflection principle. It has tubes which are made up of optical fibres and are used for transmitting and receiving electrical signals, which are converted into light by suitable transducer.

(c) Doctor gave monetary help to Chetan by understanding his poor financial condition

27. (a) Using Biot-Savart's law, derive the expression for the magnetic field in the vector form at a point on the axis of a circular current loop.

(b) What does a toroid consist of ? Find out the expression for the magnetic field inside a toroid for N turns of the coil having the average radius r and carrying a current I. Show that the magnetic field in the open space inside and exterior to the toroid is zero. [5]

OR

(a) Draw a schematic sketch of a cyclotron. Explain clearly the role of crossed electric and magnetic field in accelerating the charge. Hence derive the expression for the kinetic energy acquired by the particles.

(b) An α-particle and a photon are released from the centre of the cyclotron and made to accelerate.

(i) Can both be accelerated at the same cyclotron frequency ? Give reason to justify your answer.

(ii) When they are accelerated in turn, which of the two will have higher velocity at the exit slit of the dees ?

Answer : (a) Magnetic field on the axis of a circular loop

$I \rightarrow$ Current

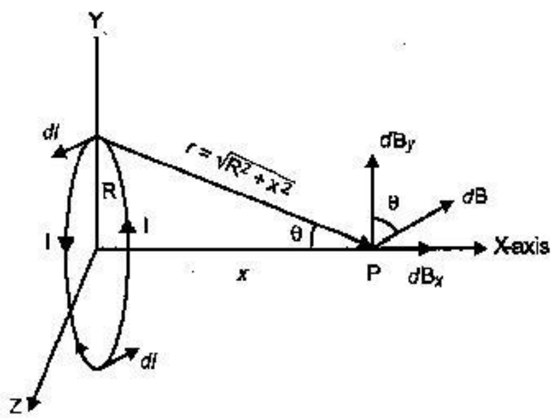
$R \rightarrow$ Radii

$X \rightarrow$ Axis

$x \rightarrow$ Distance of OP

$dl \rightarrow$ Conducting element of the loop

According to Biot-Savart's law, the magnetic field at P is



$$dB = \frac{\mu_0}{4\pi} \frac{I\vec{dl} \times \vec{r}}{r^2}$$

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

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

dB has two components dB_x and dB_y. dB_y components being in opposite direction cancel out each other and dB_x component being in same direction added up.

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

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

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

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

Total magnetic field at P

$$B = \int dB_x$$

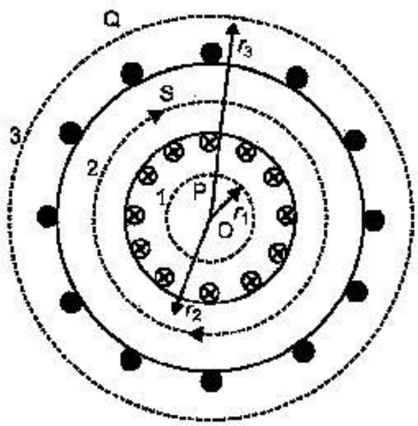
$$= \int \frac{\mu_0 I R\, dl}{4\pi (x^2 + R^2)^{3/2}}$$

$$\frac{\mu_0 I R}{4\pi (x^2 + R^2)^{3/2}} \int dl = \frac{\mu_0 I R}{4\pi \left(x^2 + R^2\right)^{3/2}} \times 2\pi R$$

$$B = \frac{\mu_0 I R^2}{2\left(x^2 + R^2\right)^{3/2}}$$

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

(b) Toroid is a hollow circular ring on which a large number of turns of a wire are closely wound. Figure shows a sectional view of the toroid. The direction of the magnetic field inside is clockwise as per the right-hand thumb rule for circular loops. Three circular Amperian loops 1, 2 and 3 are shown by dashed lines.



By symmetry, the magnetic field should be tangential to each of them and constant in magnitude for a given loop.

Let the magnetic field inside the toroid be B. Then by Ampere's circuital law,

$$\int \vec{B} \cdot \vec{dl} = \mu_0 I \Rightarrow BL = \mu_0 NI$$

Where, L is the length of the loop for which B is tangential, I is the current enclosed by one loop and N is the number of turns.

We find, $L = 2\pi r$

The current threads the ring as many times are there are turns in the solenoid, therefore total current in the solenoid is NI.

$$B(2\pi r) = \mu_0 NI$$

or $$B = \frac{\mu_0 NI}{2\pi r}$$

Open space inside the toroid encloses no current thus, I = 0.

Hence, B = 0

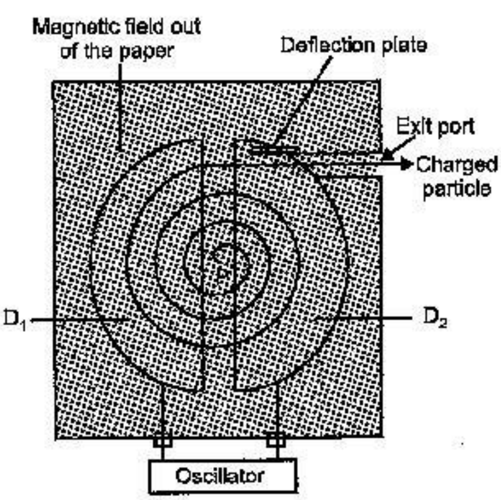
Open space exterior to the toroid :

Each turn of current carrying wire is cut twice by the loop 3. Thus, the current coming out of the plane of the paper is cancelled exactly by the current going into it. Thus,

I = 0, and B = 0

OR

(a) Schematic sketch of cyclotron : The combination of crossed electric and magnetic field is used to increase the energy of the charged particle. Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy. Inside the dees particle is shielded from the electric field and magnetic field acts on the particle and makes it to go round in a circular path. Every time the particle moves from one dee to the other it comes under the influence of electric field which ensures to increase the energy of the particles as the sign of the electric field changed alternately. The increase in energy increases the radius of the circular path so the accelerated particle moves in a spiral path.



Since, magnetic force provides required centripetal force

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

or $$r = \frac{mv}{qB}$$

Here, r is the radius of semi-circular path which a particle covers inside a dee.

Hence, the kinetic energy of ions,

$$\text{K.E.} = \frac{1}{2}mv^2$$

$$\text{K.E.} = \frac{1}{2}m\frac{r^2q^2B^2}{m^2} \quad \left[\because v = \frac{rqB}{m}\right]$$

$$\text{K.E.} = \frac{1}{2}\frac{r^2q^2B^2}{m^2}$$

(b) (i) Let us consider :

$m \rightarrow$ mass of proton

$q \rightarrow$ charge of proton

$\therefore$ Mass of alpha particle = 4 m

Charge of alpha particle = 2 q

Cyclotron frequency is given by,

$$\nu = \frac{Bq}{2\pi m}$$

or $$\nu \propto \frac{q}{m}$$

For proton :

Frequency, $$\nu_p \propto \frac{q}{m}$$

For alpha particle,

Frequency, $$\nu_\alpha \propto \frac{2q}{4m}$$

or $$\nu_\alpha \propto \frac{q}{2m}$$

Thus, particles will not accelerate with same cyclotron frequency. The frequency of proton is twice than the frequency of alpha particle.

(ii) Velocity, $$v = \frac{Bqr}{m}$$

or $$v \propto \frac{q}{m}$$

For proton :

Velocity, $$v \propto \frac{q}{m}$$

For alpha particle :

Velocity, $$v_\alpha \propto \frac{2q}{4m} \text{ or } v_\alpha \propto \frac{q}{2m}$$

Thus, particles will not exit the dees with same velocity. The velocity of proton is twice the velocity of alpha particle.

28. (a) Define electric dipole moment. Is it a scalar or a vector ? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.

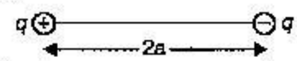
(b) Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero. [5]

OR

Using Gauss' law deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point (i) outside and (ii) inside the shell.

Plot a graph showing variation of electric field as a function of r > R and r < R. (r being the distance from the centre of the shell)

Answer : (a) Electric dipole moment : Electric dipole moment is defined as the product of magnitude of either charges and the distance between the positive and negative charge of the electric dipole. The strength of any electric dipole is measured by the magnitude of its electric dipole moment.

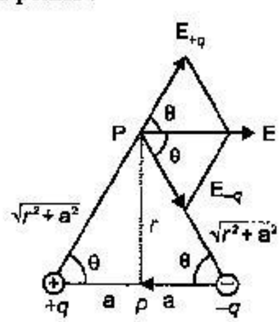


Electric dipole moment, $p = q \times 2a$

It is a vector quantity.

In vector form it is written as $\vec{p} = q \times 2\vec{a}$ where the direction of $\vec{a}$ is from negative charge to positive charge.

Electric Field of dipole at points on the equatorial plane :



Let P be the point on the equatorial plane of the dipole where electric field is to be calculated. Let its distance from either charge be 'r'. The magnitude of the electric field due to the two charges +q and −q at P is given by

$$E_{+q} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r^2+a^2} \quad \text{...(i)}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r^2+a^2} \quad \text{...(ii)}$$

From equations (i) and (ii),

$$E_{+q} = E_{-q} = E(\text{say})$$

The direction of E_{+q} and E_{-q} are shown in figure.

Total electric field at P,

$$\vec{E}_p = \vec{E}_{+q} + \vec{E}_{-q}$$

Magnitude of E (using || gm law of vector addition),

$$E_p = \sqrt{E_{+q}^2 + E_{-q}^2 + 2E_{+q}E_{-q}\cos 2\theta}$$

$$= \sqrt{E^2 + E^2 + 2E^2 \cos 2\theta}$$

$$= \sqrt{2E^2 + 2E^2 \cos 2\theta}$$

$$= \sqrt{2E^2 (1 + \cos 2\theta)}$$

$$= \sqrt{2E^2\, 2\cos^2 \theta}$$

$$= \sqrt{4E^2 \cos^2 \theta}$$

$$E_p = 2E\cos\theta$$

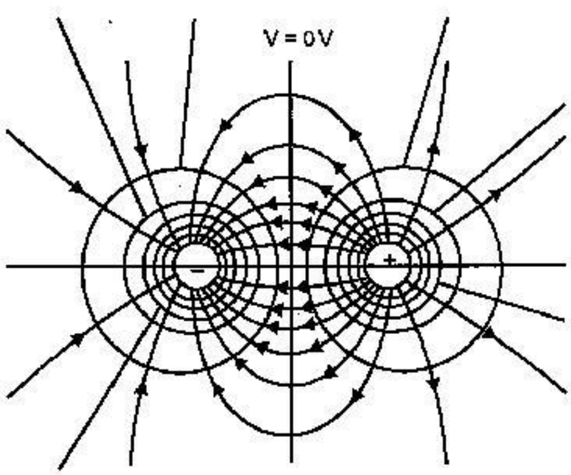
$$= 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)} \times \frac{a}{(r^2+a^2)^{1/2}}$$

$$E_p = \frac{2aq}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}$$

$$E_p = \frac{p}{4\pi\varepsilon_0(r^2+a^2)^{3/2}} \qquad [\because p = 2aq]$$

$$\vec{E}_p = \frac{\vec{p}}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}$$

(b) Equipotential surface due to electric dipole :

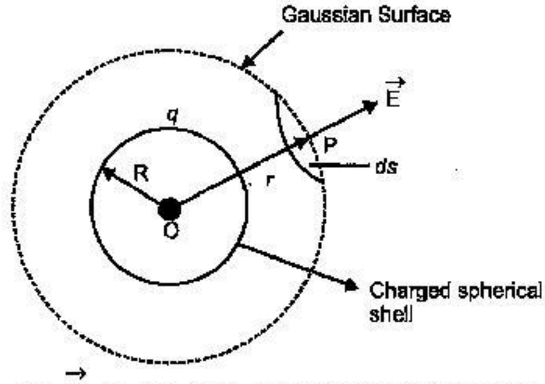


The potential due to the dipole is zero at the line bisecting the dipole length.

OR

Electric field due to a uniformly charged thin spherical shell :

(i) When point P lies outside the spherical shell : Consider a spherical shell of radius R and centre O. Let q be the charge on the spherical shell. Suppose that we have to calculate electric field at the point P at a distance r (r > R) from its centre. Draw the Gaussian surface through point P so as to enclose the charged spherical shell. The Gaussian surface is a spherical shell of radius r and centre O.



Let $\vec{E}$ be the electric field at point P. Then, the electric flux through area element $\vec{ds}$ is given by

$$d\phi = \vec{E}\cdot\vec{ds}$$

Since $\vec{ds}$ is also along normal to the surface,

$$\therefore \qquad d\phi = E\,ds$$

∴ Total electric flux through the Gaussian surface is given by

$$\phi = \oint_s E.ds$$

$$= E\oint_s ds$$

Now,

$$\oint ds = 4\pi r^2$$

$$\therefore \qquad \phi = E \times 4\pi r^2 \qquad ...(i)$$

Since the charge enclosed by the Gaussian surface is q, according to Gauss theorem,

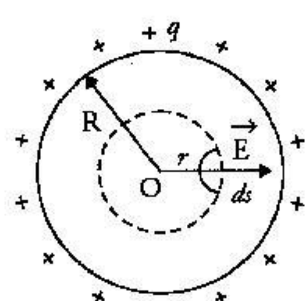
$$\phi = \frac{q}{\varepsilon_0} \qquad ...(ii)$$

From equations (i) and (ii), we get,

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

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2} \quad (\text{for } r > R)$$

(ii) When point P lies inside the spherical shell : In such a case the Gaussian surface encloses no charge,

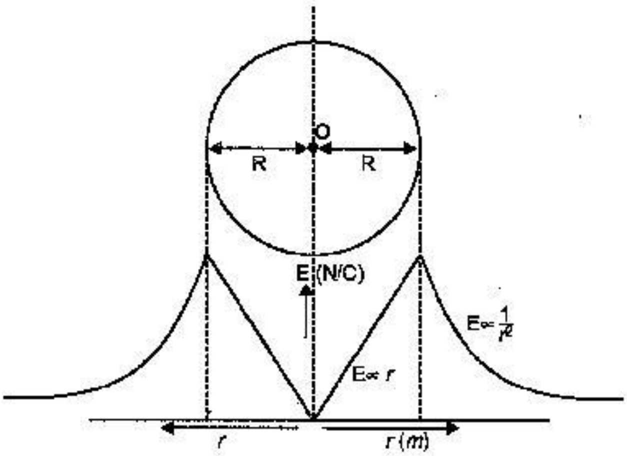


According to Gauss law,

$$E \times 4\pi r^2 = 0$$

i.e., $\quad E = 0 \ (r < R)$

Graph showing the variation of electric field as a function of r.



29. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f).

When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$, identify the spectral series to which the emission lines belong. [5]

OR

(a) Draw the plot of binding energy per nucleon (BE/A) as a function of mass number. Write two important conclusions that can be drawn regarding the nature of nuclear source.

(b) Use this graph to explain the release of energy in both the processes of nuclear fusion and fission.

(c) Write the basic nuclear process of neutron undergoing β-decay. Why is the detection of neutrinos found very difficult ?

Answer : In the hydrogen atom,

Radius of electron orbit,

$$r = \frac{n^2h^2}{4\pi^2kme^2} \qquad \text{...(i)}$$

Kinetic energy of electron,

$$E_k = \frac{1}{2}mv^2 = \frac{ke^2}{2r}$$

Using equation (i), we get

$$E_k = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$$

Potential energy,

$$E_p = \frac{-k(e)\times(e)}{r} = \frac{-ke^2}{r}$$

Using equation (i), we get

$$E_p = -ke^2 \times \frac{4\pi^2k\,kme^2}{n^2h^2}$$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2}$$

Total energy of electron,

$$E = \frac{2\pi^2k^2me^4}{n^2h^2} - \frac{4\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{h^2} \times \left(\frac{1}{n^2}\right)$$

Now, according to Bohr's frequency condition when electron in hydrogen atom undergoes transition from higher energy state to the lower energy state (n_f) is,

$$h\nu = E_{n_i} - E_{n_f}$$

or $$h\nu = -\frac{2\pi^2k^2me^4}{h^2} \times \frac{1}{n_i^2} - \left(\frac{-2\pi^2k^2me^4}{h^2} \times \frac{1}{n_f^2}\right)$$

or $$h\nu = \frac{2\pi^2k^2me^4}{h^2} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\nu = \frac{2\pi^2k^2me^4}{h^3} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\nu = \frac{c2\pi^2k^2me^4}{ch^3} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{2\pi^2k^2me^4}{ch^3} = R \text{ (Rydberg constant)}$$

$$R = 1.097 \times 10^7 \text{m}^{-1}$$

Thus,

$$\nu = Rc \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Now, higher state,

$$n_i = 4$$

Lower state,

$$n_f = 3, 2, 1$$

For the transition

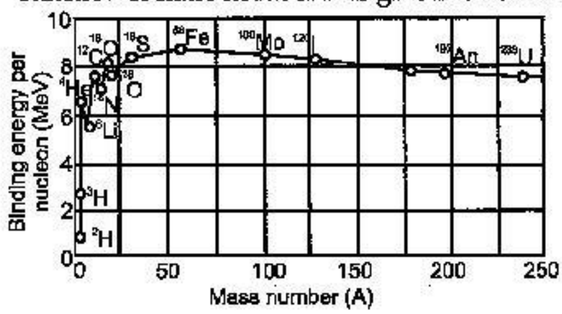
$n_i = 4$ to $n_f = 3 \rightarrow$ Paschen series

$n_i = 4$ to $n_f = 2 \rightarrow$ Balmer series

$n_i = 4$ to $n_f = 1 \rightarrow$ Lyman series

OR

(a) Plot of binding energy per nucleon as the function of mass number A is given as below :



Following are the two conclusion that can be drawn regarding the nature of the nuclear force :

(i) The force is attractive and strong enough to produce a binding energy of few MeV per nucleon.

(ii) The constancy of the binding energy in the range 30 <A<170 is a consequence of the fact that the nuclear force is short range force.

(b) Nuclear fission : A very heavy nucleus (say, A = 240) has lower binding energy per nucleon as compared to the nucleus with A = 120. Thus, if the heavier nucleus breaks to the lighter nucleus with high binding energy per nucleon, nucleons are tightly bound.

This implies that energy will be released in the process which justifies the energy release in fission reaction.

Nuclear fusion : When two light nuclei (A<10) are combined to form a heavier nuclei, the binding energy of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. Thus the final system is more tightly bound than the initial system. Again the energy will be released in fusion reaction.

(c) The basic nuclear process of neutron undergoing β-decay is given as :

$$n \rightarrow p + e^- + \bar{\nu}$$

Neutrinos are massless and chargeless particles. Neutrinos interact very weakly with matter that it becomes very difficult to detect them. That's why the detection of neutrinos is found very difficult.

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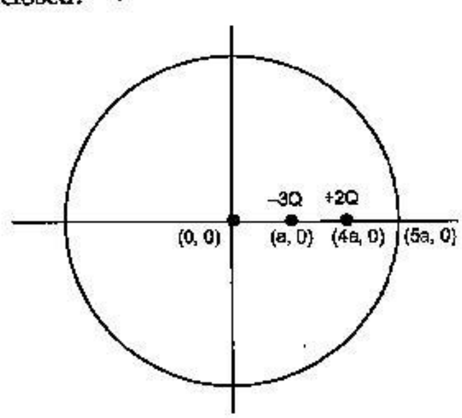
Physics 2013 (Outside Delhi) SET II

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

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

4. Two charges of magnitudes –3Q and +2Q are located at points (*a*, 0) and (4*a*, 0) respectively. What is the electric flux due to these charges through a sphere of radius '5*a*' with its centre at the origin ? **[1]**

Answer : According to Gauss' theorem, the electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.



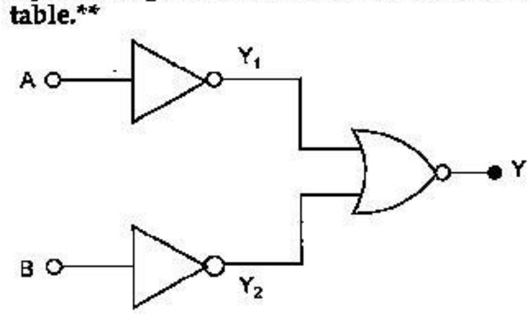
The sphere enclose charge = –3Q + 2Q = –Q

$\therefore$ Total electric flux, $\phi = \frac{Q}{\varepsilon_0}$

7. A light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why ? Give reason. **[2]**

Answer : A light metal disc on the top of an electromagnet is thrown up as the current is switched on because when the current flows through the electromagnet, the magnetic flux through the disc increases which leads in setting up an eddy current in the disc in the same direction of the electromagnetic current. So the upper surface of electromagnet and the lower surface of the disc acquire same polarity. Since body with same polarity repels, therefore, the disc is thrown up.

9. In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table.** **[2]**



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

13. A parallel beam of light of 600 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.2 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit. **[3]**

Answer : The distance of the n^{th} minimum from the centre of the screen is, $x_n = \frac{nD\lambda}{a}$

where, D= distance of slit from screen

λ = wavelength of the light

a = width of the slit

For first minimum, $n = 1$

$x_n = 3 \times 10^{-3}$ m

$\lambda = 600 \times 10^{-9}$ m

D = 1.2 m

$$3 \times 10^{-3} = \frac{1 \times 1.2 \times 600 \times 10^{-9}}{a}$$

$$a = \frac{1 \times 1.2 \times 600 \times 10^{-9}}{3 \times 10^{-3}}$$

$$= \frac{1.2 \times 6 \times 10^{-4}}{3}$$

$$= 2.4 \times 10^{-4} \text{ m}$$

$$= 0.24 \times 10^{-3} \text{ m}$$

$$a = 0.24 \text{ mm}$$

19. A wire AB is carrying a steady current of 10 A and is lying on the table. Another wire CD carrying 6 A is held directly above AB at a height of 2 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. [Take the value of $g = 10 \text{ ms}^{-2}$] **[3]**

Answer : Force per unit length between the current carrying wires is given as :

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$

where

The current in wire AB, $I_1 = 10$ A

The current in wire CD, $I_2 = 6$ A

The distance between wires, $r = 2 \text{ mm} = 2 \times 10^{-3}$m

Let m be the mass per unit length of wire CD.

As this force balances the weight of the wire CD.

$$\therefore \quad \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} = mg$$

$$\Rightarrow \quad 10^{-7} \times \frac{2 \times 10 \times 6}{2 \times 10^{-3}} = m \times 10$$

$$\therefore m = 10^{-7} \times \frac{2 \times 10 \times 6}{2 \times 10^{-3}} \times \frac{1}{10} = 6 \times 10^{-4} \text{ kg/m}$$

The direction of current in CD w.r.t. AB is opposite (antiparallel) because in this condition both the wires will repel each other.

23. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies ?

A transmitting antenna at the top of a tower has a height of 45 m and the height of the receiving antenna is 80 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4×10^6 m)** **[4]**

24. (a) For a given a.c., $i = i_m \sin \omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_m^2 R$R

(b) A light bulb is rated at 120 W for a 240 V a.c. supply. Calculate the resistance of the bulb. **[5]**

Answer : **(a)** The average power dissipated

$$P_{av} = (i^2R) = (i_m^2 R \sin^2 \omega t)$$

$$= i_m^2 R (\sin^2 \omega t)$$

since, $\quad \sin^2 \omega t = \frac{1}{2}(1 - \cos 2\omega t)$

$$\therefore \quad (\sin^2 \omega t) = \frac{1}{2}[1 - (\cos 2\omega t)] = \frac{1}{2}$$

$[\because \cos 2\omega t = 0]$

$$\therefore \quad P_{av} = \frac{1}{2} i_m^2 R$$

(b) Power of the bulb, P = 120 W

Voltage, V = 240 V

The resistance of the bulb is given as

$$R = \frac{V^2}{P} = \frac{240^2}{120} = 480 \ \Omega.$$

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

Physics 2013 (Outside Delhi) SET III

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

Note : Except for the following questions all the remaining question have been asked in previous Sets.

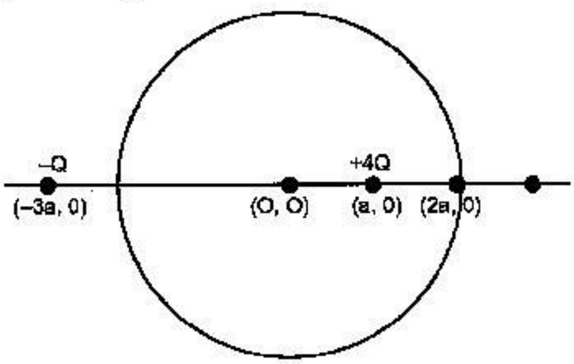
1. **Write the expression for the de-Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V.** [1]

Answer : de-Broglie wavelength associated with the particle,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

3. **Two charges of magnitudes + 4Q and –Q are located at points $(a, 0)$ and $(-3a, 0)$ respectively. What is the electric flux due to these charges through a sphere of radius '$2a$' with its centre at the origin ?** [1]

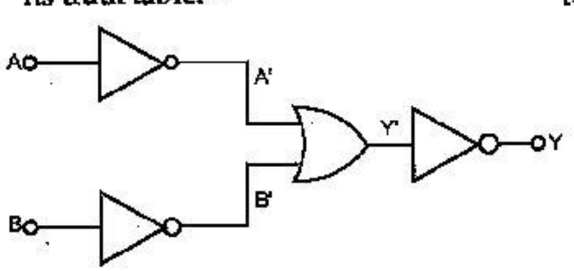
Answer : Gauss's theorem states that the electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.



The sphere enclose charge = + 4Q

Thus, total electric flux $\phi = \frac{4Q}{\varepsilon_0}$

9. **In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table.**** [1]



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

11. **A parallel beam of light of 450 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.5 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit.** [2]

Answer : The distance of the n^{th} minimum from the centre of the screen,

$$x_n = \frac{nD\lambda}{a}$$

Where, D → distance of slit from screen.

λ → wavelength of the light.

a → width of the slit

For first minimum, $n = 1$,

$$x_n = 3 \times 10^{-3} \text{ m}$$

$$D = 1.5 \text{ m}$$

$$\lambda = 450 \times 10^{-9} \text{ m}$$

$$3\times10^{-3} = \frac{1\times(1.5)\times(450\times10^{-9})}{a} \quad \frac{nD\lambda}{a}$$

$$a = \frac{1\times(1.5)\times(450\times10^{-9})}{3\times10^{-3}}$$

$$a = 0.255\text{mm}$$

17. **A wire AB is carrying a steady current of 6 A and is lying on the table. Another wire CD carrying 4 A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. [Take the value of $g = 10$ ms^{-2}]** [3]

Answer : Force per unit length between the current carrying wire is given as :

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$

Let m be the mass per unit length of wire CD. As the force balance the weight of the wire

$$\therefore \quad \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} = mg$$

Here m → Mass per unit length

$$\frac{10^{-7}\times2\times6\times4}{1\times10^{-3}} = m\times10$$

$$m = 4.8\times10^{-4} \text{ kg m}^{-1}$$

The current in CD is in opposite direction to that in AB than they will repel each other and CD wire remain suspended in air.

18. (b) A light bulb is rated at 125 W for a 250 V a.c. supply. Calculate the resistance of the bulb. [3]

Answer : (b) Power of the bulb, P = 125 W

Voltage, V = 250 V

The resistance of the bulb is given as

$$R = \frac{V^2}{P} = \frac{(250)^2}{125}$$

$$= 500\ \Omega$$

25. Name the type of waves which are used for line of sight (LOS) communication. What is the range of their frequencies ?

A transmitting antenna at the top of a power has a height of 45 m and the receiving antenna is on the ground. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4 × 10^6m) [5]**

●●

Physics 2013 (Delhi) SET I

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

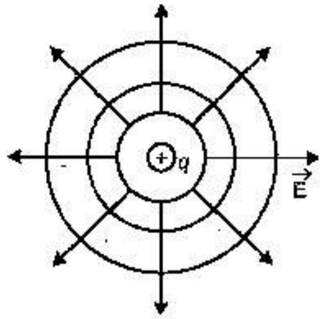
1. What are permanent magnets ? Give one example. [1]

Answer : The magnets which have high retentivity and high coercivity are known as permanent magnets.

For example : Steel, cobalt

2. What is the geometrical shape of equipotential surface due to a single isolated charge ? [1]

Answer : The equipotential surfaces of an isolated charge are concentric spherical shells and the distance between the shells increase with the decrease in electric field and vice-versa.



3. Which of the following waves can be polarized (i) Heat waves (ii) Sound waves ? Give reason to support your answer. [1]

Answer : Heat waves can be polarized as they are transverse waves whereas sound waves cannot be polarized as they are longitudinal waves.

Transverse waves can oscillate in the direction perpendicular to the direction of its transmission but longitudinal waves oscillate only along the direction of its transmission. So, longitudinal waves cannot be polarized.

4. A capacitor has been charged by a dc source. What are the magnitude of conduction and displacement current, when it is fully charged ? [1]

Answer : Electric flux through plates of capacitor,

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

Here charge q is constant as the capacitor is fully charged.

Displacement current,

$$I_D = \varepsilon_0 \frac{d\phi}{dt} = \varepsilon_0 \frac{d\left(\frac{q}{\varepsilon_0}\right)}{dt} = 0$$

[since q is constant]

Conduction current,

$$I = C\frac{dV}{dt} = 0$$

As voltage also becomes constant when capacitor is fully charged.

Therefore, magnitude of di splacement to and induction current is zero.

5. Write the relationship between angle of incidence 'i', angle of prism 'A' and angle of minimum deviations δ_m for a triangular prism. [1]

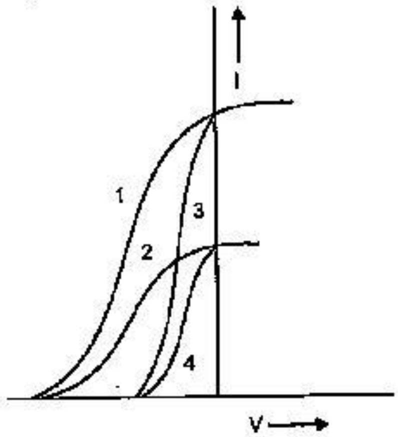
Answer : The relation between the angle of incidence i, angle of prism A, and the angle of minimum deviation δ_m, for a triangular prism is given by

$$i = \frac{A + \delta_m}{2}$$

6. The given graph shows the variation of photoelectric current (I) versus applied voltage (V) for two different photosensitive materials

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

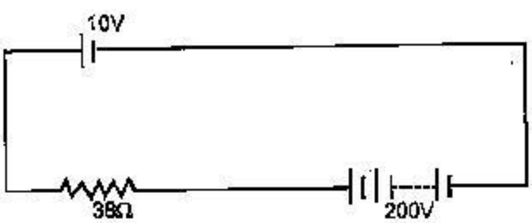
and for two different intensities of the incident radiations. Identify the pairs of curves that correspond to different materials but same intensity of incident radiation. **[2]**



Answer : Curves 1 and 2 correspond to similar materials while curves 3 and 4 represent different materials, since the value of stopping potential for 1, 2 and 3, 4 are the same. For the given frequency of the incident radiation, the stopping potential is independent of its intensity.

So, the pairs of curves (1 and 3) and (2 and 4) correspond to different materials but same intensity of incident radiation.

7. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current in circuit. [2]



Answer : Since, the positive terminal of the batteries are connected together (So they oppose each other), so the equivalent emf of the batteries is given by

$$E = 200 - 10 = 190 \text{ V}$$

Hence, the current in the circuit is given by

$$I = \frac{E}{R} = \frac{190}{38} = 5\text{A}$$

8. The emf of a cell is always greater than its terminal voltage. Why ? Give reason. [2]

Answer : The emf of a cell is greater than its terminal voltage because there is some potential drop across the cell due to its small internal resistance.

9. (a) Write the necessary conditions for the phenomenon of total internal reflection to occur.

(b) Write the relation between the refractive index and critical angle for a given pair of optical media. [2]

Answer : (a) Necessary conditions for total internal reflection to occur are :

1. The incident ray on the interface should travel in optically denser medium.
2. The angle of incidence should be greater than the critical angle for the given pair of optical media.

(b) $${}^{a}\mu_{b} = \frac{1}{\sin C}$$

Where a and b are the rarer and denser media respectively. C is the critical angle for the given pair of optical media.

10. State Lenz's law.

A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends ? Justify your answer. [2]

Answer : Lenz's law states that the polarity of induced emf is such that it produces a current which opposes the change in magnetic flux that produces it.

Yes, emf will be induced in the rod as there is change in magnetic flux.

When a metallic rod held horizontally along east-west direction, is allowed to fall freely under gravity *i.e.*, fall from north to south, the magnetic flux changes due to vertical component of Earth's magnetic field, which keeps on changing and the emf is induced in it.

11. A convex lens of focal length 25 m is placed coaxially in contact with a concave lens of focal length 20 cm. Determine the power of the combination. Will the system be converging or diverging in nature ? [2]

Answer : We have, focal length of convex lens,

$$f_1 = +25 \text{ cm} = +0.25 \text{ m}$$

Focal length of the concave lens,

$$f_2 = -20 \text{ cm} = -0.20 \text{ m}$$

Equivalent focal length,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} + \frac{1}{-20} = -\frac{1}{100}$$

$$\therefore \quad F = -100 \text{ cm}$$

Power of convex lens,

$$P_1 = \frac{1}{f_1} = \frac{1}{0.25}$$

Power of concave lens,

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.20}$$

Power of the combination,

$$P = P_1 + P_2$$

$$P = \frac{1}{0.25} + \frac{1}{-0.20} = \frac{100}{25} - \frac{100}{20} = \frac{400-500}{100}$$

$$= -\frac{100}{100} = -1$$

$\therefore \quad P = -1\text{ D}$

The focal length of the combination

$= -1\text{m} = -100\text{ cm}.$

As the focal length is negative, the system will be diverging in nature.

12. An ammeter of resistance 0.80 Ω can measure current up to 1.0 A. **[3]**

(i) What must be the value of shunt resistance to enable the ammeter to measure current up to 5.0 A ?

(ii) What is the combined resistance of the ammeter and the shunt ?

Answer : We have, resistance of ammeter, $R_A = 0.80\ \Omega$

Maximum current through ammeter, $I_A = 1.0$ A

So, voltage across ammeter, $V = IR = 1 \times 0.80 = 0.8V$

Let the value of shunt be x.

(i) Resistance of ammeter with shunt,

$$R = \frac{R_A x}{R_A + x} = \frac{0.8x}{0.8+x}$$

Current through ammeter, I = 5 A

$$\therefore \quad \left(\frac{0.8x}{0.8+x}\right) \times 5 = 0.8$$

$$\Rightarrow \quad 0.8x \times 5 = 0.8(0.8+x)$$

$$4x = 0.64 + 0.8x$$

$$x = \frac{0.64}{3.2}$$

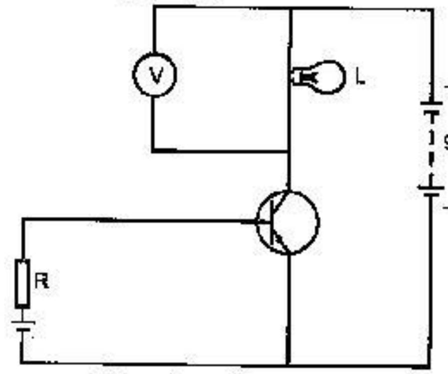
$$x = 0.2$$

Thus, the shunt resistance is 0.2 Ω

(ii) Combined resistance of the ammeter and the shunt,

$$R = \frac{0.8x}{0.8+x} = \frac{0.8 \times 0.2}{0.8+0.2} = \frac{0.16}{1} = 0.16\ \Omega$$

13. In the given circuit diagram a voltmeter 'V' is connected across a lamp 'L'. How would (i) the brightness of the lamp and (ii) voltmeter reading 'V' be affected, if the value of resistance 'R' is decreased ? Justify your answer. **[3]**



Answer : The given figure is Common Emitter (CE) configuration of an *n-p-n* transistor. The input circuit is forward biased and collector circuit is reverse biased.

If resistance R decreases, forward biased in the input circuit will increase, thus the base current (I_B) will decrease and the emitter current (I_E) will increase. This will increase the collector current (I_C) as $I_E = I_B + I_C$.

When I_C increases which flows through the lamp, the voltage across the bulb will also increase making the lamp brighter and since the voltmeter is connected in parallel with the lamp, the reading in the voltmeter will also increase.

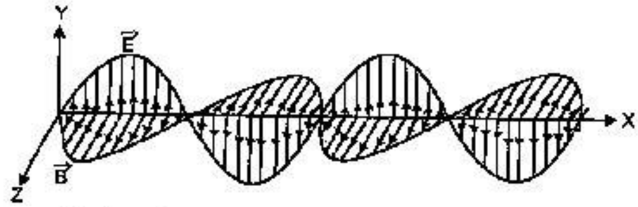
14. (a) An EM wave is travelling in a medium with a velocity $v = v\hat{i}$. Draw a sketch showing the propagation of the EM wave, indicating the direction of the oscillating electric and magnetic fields.

(b) How are the magnitudes of the electric and magnetic fields related to velocity of the EM wave ? **[3]**

Answer : (a) Given.

Velocity, $v = v\hat{i}$ and electric field, E along Y-axis and magnetic field, B along Z-axis.

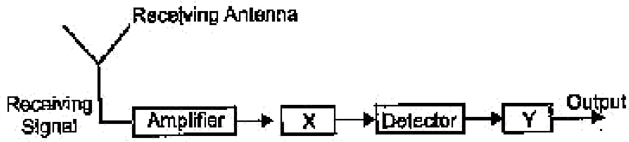
The propagation of EM wave is shown below :



(b) Speed of EM wave can be given as the ratio of magnitude of electric field (E_0) to the magnitude of magnetic field (B_0),

$$c = \frac{E_0}{B_0}$$

15. Block diagram of a receiver is shown in the figure :**



(a) Identify 'X' and 'Y'.

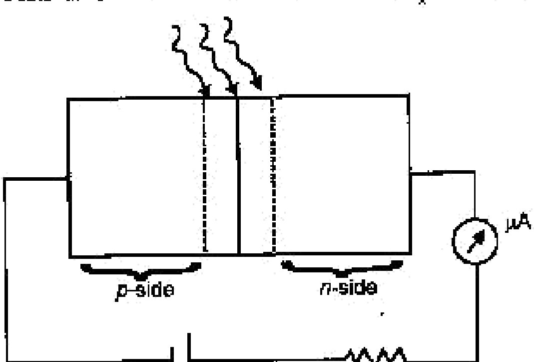
(b) Write their functions.

16. Explain, with the help of a circuit diagram, the working of a photodiode. Write briefly how it is used to detect the optical signals. [3]

OR

Mention the important consideration required while fabricating a *p-n* junction diode to be used as a Light Emitting Diode (LED). What should be the order of band gap of an LED if it is required to emit light in the visible range ?

Answer : A junction diode made from light sensitive semiconductor is called a photodiode.



An electrical device that is used to detect and convert light into an energy signal with the use of a photo detector is known as a photodiode. The light that falls on it controls the function of *pn*-junction. Suppose, the wavelength is such that the energy of a photon $\frac{hc}{\lambda}$ is enough to break a valence bond. There is an increase in number of charge carriers and hence the conductivity of the junction also increases. New hole-electron pairs are created when such light falls on the junction. If the junction is connected in a circuit, the intensity of the incident light controls the current in the circuit.

OR

(i) The reverse breakdown voltage of LEDs are very low, which is around 5V. So enough care is to be taken while fabricating a *pn*-junction diode such that the high reverse voltages do not occur across them.

(ii) There exist very small resistance to limit the current in LED. So, a resistor must be placed in series with the LED such that no damage is occurred to the LED.

The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV.

17. Write three important factors which justify the need of modulating a message signal. Show diagrammatically how an amplitude modulated wave is obtained when a modulating signal is superimposed on a carrier wave. [3]**

18. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 360 μC. When potential across the capacitor is reduced by 120 V, the charge stored in it becomes 120 μC.

Calculate :

(i) The potential V and the unknown capacitance C.

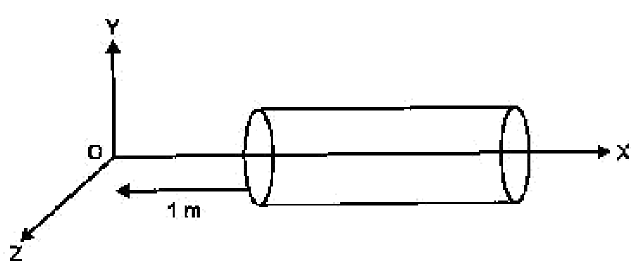
(ii) What will be the charge stored in the capacitor, if the voltage applied had increased by 120 V ? [3]

OR

A hollow cylindrical box of length 1 m and area of cross-section 25 cm^2 is placed in a three-dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50x\,\hat{i}$ where E is NC^{-1} and x is in metres. Find :

(i) Net flux through the cylinder.

(ii) Charge enclosed by the cylinder.



Answer :

(i) Initial voltage, $V_1 = V$ volts and charge stored,

$$Q_1 = 360\ \mu C$$

$$Q_1 = CV_1 \quad ...(i)$$

Changed potential, $V_2 = V - 120$

$$Q_2 = 120\ \mu C$$

$$Q_2 = CV_2 \quad ...(ii)$$

By dividing (ii) from (i), we get

$$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2}$$

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

$$\Rightarrow \quad \frac{360}{120} = \frac{V}{V-120}$$

$$V = 180 \text{ volts}$$

$$\therefore \quad C = \frac{Q_1}{V_1} = \frac{360 \times 10^{-6}}{180}$$

$$= 2 \times 10^{-6}\text{ F} = 2\ \mu\text{F}$$

(ii) If the voltage applied had increased by 120 V, then

$$V_3 = 180 + 120 = 300 \text{ V}.$$

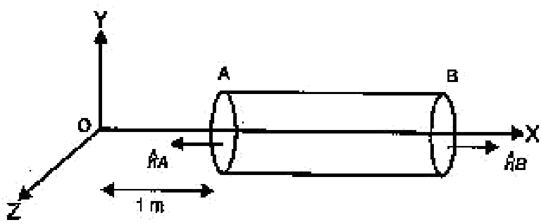
Hence, charge stored in the capacitor,

$$Q_3 = CV_3 = 2 \times 10^{-6} \times 300 = 600\ \mu\text{C}$$

OR

(i) Given,

$$\vec{E} = 50x\hat{i}, \text{ and } \Delta s = 25 \text{ cm}^2 = 25 \times 10^{-4} \text{ m}^2$$



As the electric field is only along the X-axis, so, flux will pass only through the cross-section of cylinder.

Magnitude of electric field at cross-section A,

$$E_A = 50 \times 1 = 50 \text{ NC}^{-1}$$

Magnitude of electric field at cross-section B,

$$E_B = 50 \times 2 = 100 \text{ NC}^{-1}$$

The corresponding electric fluxes are :

$$\phi_A = \vec{E}\cdot\vec{\Delta s} = 50 \times 25 \times 10^{-4} \times \cos 180° = -0.125 \text{ Nm}^2/\text{C}$$

$$\phi_B = \vec{E}\cdot\vec{\Delta s} = 100 \times 25 \times 10^{-4} \times \cos 0° = 0.25 \text{ Nm}^2/\text{C}$$

So, the net flux through the cylinder,

$$\phi = \phi_A + \phi_B = -0.125 + 0.25 = 1.25 \text{Nm}^2/\text{C}$$

(ii) Using Gauss's Law :

$$\oint E.ds = \frac{q}{\varepsilon_0}$$

$$\Rightarrow \quad 0.125 = \frac{q}{8.85 \times 10^{-12}}$$

$$q = 8.85 \times 0.125 \times 10^{-12} = 1.1 \times 10^{-12}\text{C}$$

19. (a) In a typical nuclear reaction, *e.g.*

$${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^3_2\text{He} + {}^1_0n + 3.27 \text{ MeV},$$

although number of nucleons is conserved, yet energy is released. How ? Explain.

(b) Show that nuclear density in a given nucleus is independent of mass number A. **[3]**

Answer :

(a) In a nuclear reaction, the aggregate of the masses of the target nucleus (${}^2_1\text{H}$) and the bombarding particle may be greater or less than the aggregate of the masses of the product nucleus (${}^3_2\text{He}$) and the outgoing particle (${}^1_0n$). So from the law of conservation of mass-energy some energy (3.27 MeV) is evolved or involved in a nuclear reaction. This energy is called Q-value of the nuclear reaction.

(b) Density of the nucleus = $\frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

Mass of the nucleus = A amu = A × 1.666 × 10^{-27} kg

Volume of the nucleus

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

Where, $R = R_0 A^{1/3}$

$$V = \frac{4}{3}\pi R_0^3 A$$

$$\text{Thus, density} = \frac{A \times 1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)A}$$

$$= \frac{1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)} \qquad \left[\because f = \frac{M}{V}\right]$$

which shows that the density is independent of mass number A.

20. (a) Why photoelectric effect cannot be explained on the basis of wave nature of light ? Give reasons.

(b) Write the basic features of photon picture of electro-magnetic radiation on which Einstein's photoelectric equation is based. **[3]**

Answer : (a) Wave nature of radiation cannot explain the following :

1. The immediate ejection of photoelectrons.

2. The presence of threshold frequency for a metal surface.

3. The fact that kinetic energy of the emitted electrons is independent of the intensity of light and depends upon its frequency.

Thus, the photoelectric effect cannot be explained on the basis of wave nature of light.

(b) Photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based on particle nature of light.

Its basic features are :

1. In interaction with matter, radiation behaves as if it is made up of particles called photons.

2. Each photon has energy ($E = h\nu$), momentum $\left(p = \frac{h\nu}{c}\right)$, where c is the speed of light

3. All photons of light of a particular frequency ν, or wavelength λ, have the same energy $\left(E = h\nu = \frac{hc}{\lambda}\right)$ and momentum $\left(p = \frac{h\upsilon}{c}\right)$

4. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons emitted per second crossing a given area, with each photon having the same energy. Thus, photon energy is independent of intensity of radiation.

5. Photons are electrically neutral and are not deflected by electric and magnetic fields.

6. In a photon–particle collision (such as photon-electron collision), the total energy and total momentum are conserved. However, number of photons may not be observed.

21. A metallic rod of length 'l' is rotated with a frequency ν with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius r, about an axis passing through the centre and perpendicular to the plane of the ring. A constant uniform magnetic field B parallel to the axis is present everywhere. Using Lorentz force, explain how emf is induced between the centre and the metallic ring and hence obtained the expression for it. **[3]**

Answer : Suppose the length of the rod is greater than the radius of the circle and rod rotates anticlockwise and suppose the direction of electrons in the rod at any instant be along $+y$ direction.

Suppose the direction of the magnetic field is along +z direction.

Then, using Lorentz law, we get the following :

$$\vec{F} = e(\vec{v} \times \vec{B})$$

$$\vec{F} = -(n\hat{j} \times B\hat{k})$$

$$\vec{F} = -eB\hat{i}$$

Thus, the direction of force on the electrons is along $-x$ axis.

So, the electrons will move towards the centre *i.e.*, the fixed end of the rod. This movement of electrons will effect in current and thus it will generate an emf in the rod between the fixed end and the point touching the ring.

Let θ be the angle between the rod and radius of the circle at any time t.

Then, area swept by the rod inside the circle = $\frac{1}{2}\pi r^2\theta$

Induced emf

$$= B \times \frac{d}{dt}\left(\frac{1}{2}\pi r^2\theta\right) = \frac{1}{2}\pi r^2 B\frac{d\theta}{dt} = \frac{1}{2}\pi r^2 B\omega$$

$$= \frac{1}{2}\pi r^2 B(2\pi v) = \pi^2 r^2 Bv$$

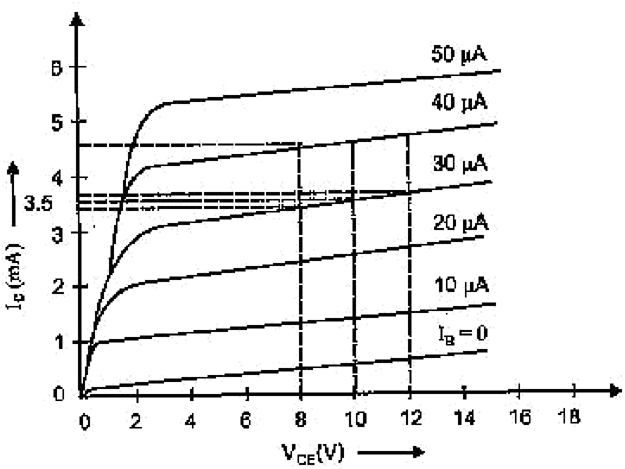
22. Output characteristics of an n-p-n transistor in CE configuration is shown in the figure. **[3]**

Determine :

(i) dynamic output resistance

(ii) dc current gain and

(iii) ac current gain at an operating point V_{CE} = 10 V, when I_B = 30 μA.**



23. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels. **[4]**

Answer : In a hydrogen atom,

Radius of electron orbit,

$$r = \frac{n^2h^2}{4\pi^2 k\, me^2} \quad ...(i)$$

and, angular momentum

$$m\upsilon r = \frac{nh}{2\pi}$$

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

or

$$v = \frac{nh}{2\pi mr}$$

$$v = \frac{nh}{2\pi m\left(\frac{n^2h^2}{4\pi^2 k me^2}\right)}$$

$$= \frac{2\pi ke^2}{nh}$$

So, kinetic energy,

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{2\pi ke^2}{nh}\right)^2$$

$$= \frac{4\pi^2k^2e^4m}{2n^2h^2} = \frac{2\pi^2k^2e^4m}{n^2h^2}$$

Potential energy

$$E_p = \frac{-k(e)\times(e)}{r} = -\frac{ke^2}{r}$$

Using equation (i), we get

$$E_p = -ke^2 \times \frac{4\pi^2kme^2}{n^2h^2}$$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2}$$

Hence, total energy of the electron in the n^{th} orbit

$$E = E_p + E_k$$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{n^2h^2}$$

We know $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$

h (Planck's constant) $= 6.6 \times 10^{-34}$ Js

m for H-atom $= 1.67 \times 10^{-27}$ kg

$e = 1.6 \times 10^{-19}$ C

Substituting these values, we get

$$E = \frac{-13.6}{n^2} \text{eV}$$

When the electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a spectral line.

In H-atom, when an electron jumps from the orbit n_i to orbit n_f, the wavelength of the emitted radiation is given by,

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

Where,

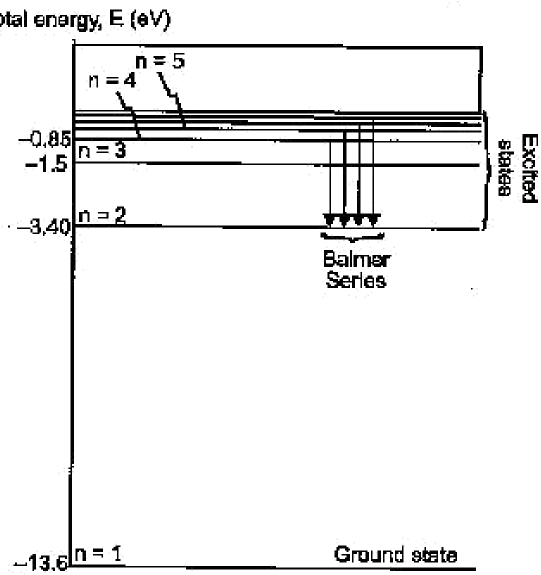
R → Rydberg's constant $= 1.09678 \times 10^7 \text{ m}^{-1}$

For Balmer series, $n_f = 2$ and $n_i = 3, 4, 5, \ldots$

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

Where, $n_i = 3, 4, 5, \ldots$

These spectral lines lie in the visible region.



24. (a) In what way is diffraction from each slit related to the interference pattern in a double slit experiment.

(b) Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases. [5]

Answer : (a) If the width of each slit is comparable to the wavelength of light used, the interference pattern thus obtained in the double-slit experiment is modified by diffraction from each of the two slits.

(b) Given that : Wavelength of the light beam,

$\lambda_1 = 590 \text{ nm} = 5.9 \times 10^{-7}$m

Wavelength of another light beam,

$\lambda_2 = 596 \text{ nm} = 5.96 \times 10^{-7}$m

Distance of the slits from the screen = D = 1.5 m

Distance between the two slits, $a = 2 \times 10^{-4}$m

For the first secondary maxima, $\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$

$x_1 = \frac{3\lambda_1 D}{2a}$ and $x_2 = \frac{3\lambda_2 D}{2a}$

$$x_1 = \frac{3 \times 590 \times 10^{-9} \times 15}{2 \times 2 \times 10^{-4}}, \quad x_2 = \frac{3 \times 596 \times 10^{-9} \times 1.5}{2 \times 2 \times 10^{-4}}$$

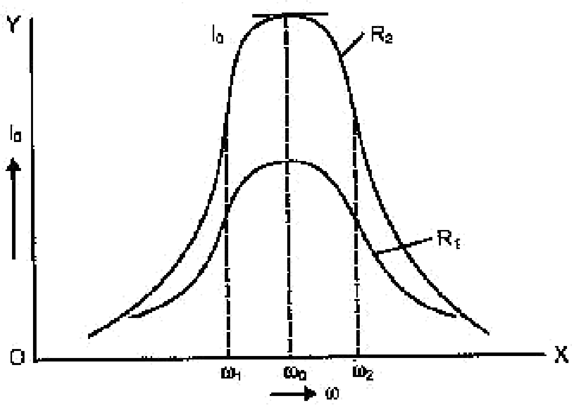
$x_1 = 663.75 \times 10^{-5}$, $\quad x_2 = 670.50 \times 10^{-5}$

$\therefore$ Spacing between the positions of first secondary maxima of two sodium lines

$x_2 - x_1 = 6.75 \times 10^{-5}$ m = 0.0675 mm.

25. In a series LCR circuit connected to an ac source of variable frequency and voltage $v = v_m \sin \omega t$, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and R_2 ($R_1 > R_2$). Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced ? Define Q-factor of the circuit and give its significance. **[5]**

Answer : Figure shows the variation of i_m with ω in a LCR series circuit for two values of Resistance R_1 and R_2 ($R_1 > R_2$).



The condition for resonance in the LCR circuit is,

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

We can observe that the current amplitude is maximum at the resonant frequency ω_0. Since $i_m = V_m/R$ at resonance, the current amplitude for case R_2 is sharper to that for case R_1.

Quality factor or simply the Q-factor of a resonant LCR circuit is defined as the ratio of voltage drop across the capacitor (or inductor) to that of applied voltage.

It is given by $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

The Q factor determines the sharpness of the resonance curve and if the resonance is less sharp, the maximum current decreases and also the circuit is close to the resonance for a larger range $\Delta\omega$ of frequencies and the regulation of the circuit will not be good. So, less sharp the resonance, less is the selectivity of the circuit while higher is the Q, sharper is the resonance curve and lesser will be the loss in energy of the circuit and circuit will be more selective.

26. While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for thunderstorm to stop. Suddenly he noticed a child walking alone on the road. He asked the boy to come inside the car till the thunderstorm stopped. Dr. Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child.

Answer the following questions based on the above information : **[5]**

(a) Why is it safer to sit inside a car during a thunderstorm ?

(b) Which two values are displayed by Dr. Pathak in his action ?**

(c) Which values are reflected in parents' response to Dr. Pathak ?**

(d) Give an example of similar action on your part in the part from everyday life.

Answer : (a) It is safer to be inside a car during thunderstorm because the car acts like a Faraday cage.

(d) Once I came across to a situation where a puppy was struck in the middle of a busy road during rain and was not able to cross due to heavy flow, So I quickly rushed and helped him.

27. (a) Draw a ray diagram showing the image formation by a compound microscope. Hence obtain expression for total magnification when the image is formed at infinity.

(b) Distinguish between myopia and hypermetropia. Show diagrammatically how these defects can be corrected. **[5]**

OR

(a) State Huygen's principle. Using this principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence verify Snell's law of refraction.

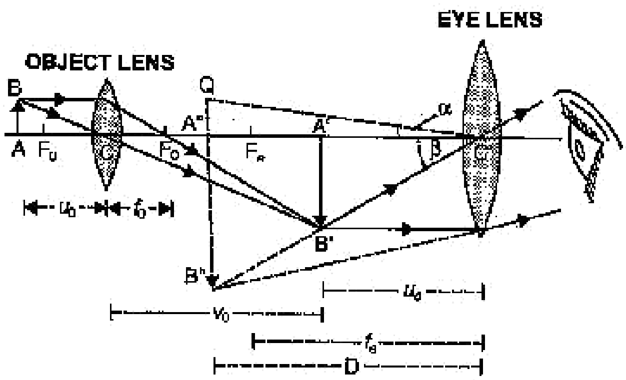
(b) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons :

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

(i) **Is the frequency of reflected and refracted light same as the frequency of incident light ?**

(ii) **Does the decrease in speed imply a reduction in the energy carried by light wave ?**

Answer : (a) A compound microscope consists of two convex lenses parallel separated by some distance. The lens nearer to the object is called the objective. The lens through which the final image is viewed is called the eyepiece.



Magnifying power when final image is at infinity : The magnification produced by the compound microscope is the product of the magnifications produced by the eyepiece and objective.

$$\therefore \qquad M = M_e \times M_o \qquad ...(i)$$

Where, M_e and M_c are the magnifying powers of the eyepiece and objective respectively.

If u_0 is the distance of the object from the objective and v_0 is the distance of the image from the objective, then the magnifying power of the objective is

$$M_o = \frac{h'}{h} = \frac{L}{f_o}$$

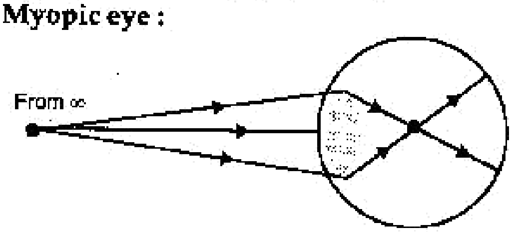
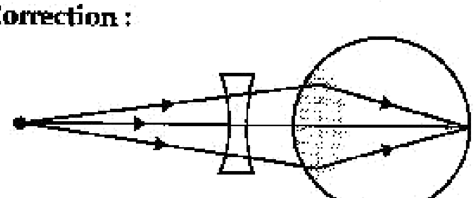
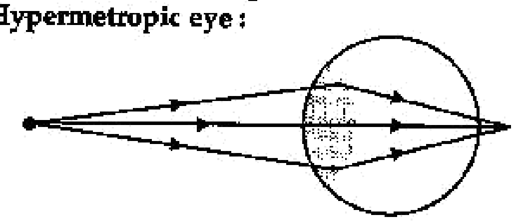
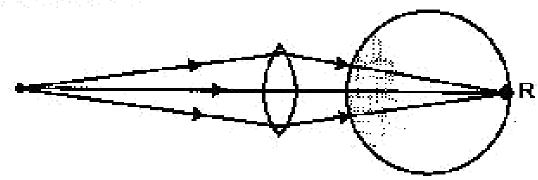
Where, h, h' are object and image heights respectively and f_o is the focal length of the objective and L is the tube length *i.e.*, the distance between the second focal point of the objective and the first focal point of the eyepiece.

When the final image is at infinity,

$$M_e = \frac{D}{f_e}$$

Magnifying power of compound microscope,

$$M = M_o \times M_e = \frac{L}{f_o} \times \frac{D}{f_e}$$

	Myopia		Hypermetropia
1.	Also known as nearsightedness.	1.	Also known as farsightedness.
2.	Person is not able to see far objects clearly.	2.	Person is not able to see near objects clearly.
3.	For myopic eye, far point is less than infinity.	3.	For hypermetropic eye, near point is greater than D *i.e.*, 25 cm (least distance of distinct vision).
4.	To correct myopia, concave lens of appropriate focal length is used. **Myopic eye :**  **Correction :** 	4.	To correct hypermetropia convex lens of appropriate focal length is used. **Hypermetropic eye :**  **Correction :** 

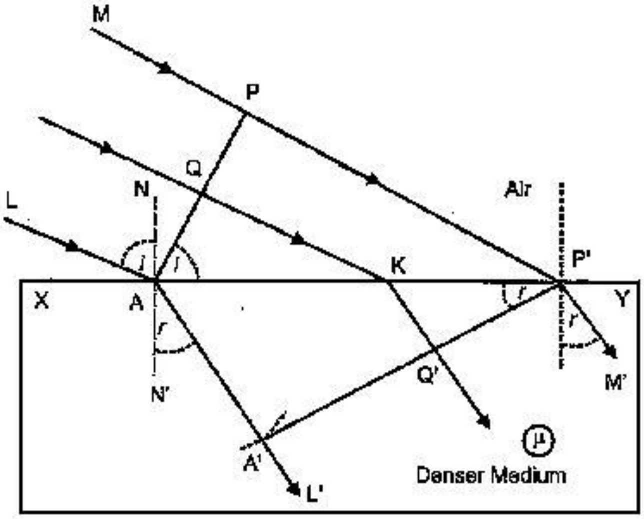
OR

(a) **Huygen's Principle :**

1. Each point on the primary wave front acts as a source of secondary wavelets, transferring out disturbance in all directions in the same way as the original source of light does.
2. The new position of the wave front at any instant is the envelope of the secondary wavelets at that instant.

Refraction on the basis of wave theory

1. Consider any point Q on the incident wave front.
2. Suppose when disturbance from point P on incident wave front reaches point P' on the refracted wave front, the disturbance from point Q reaches Q' on the refracting surface XY.



3. Since P'A' represents the refracted wave front, the time taken by light to travel from a point on incident wave front to the corresponding point on refracted wave front should always be the same. Now, time taken by light to go from Q to Q' will be

$$t = \frac{QK}{c} + \frac{QK}{v} \quad ...(i)$$

In right-angled ΔAQK, $\angle QAK = i$

$$\therefore \quad QK = AK \sin i \quad ...(ii)$$

In right-angled ΔP'Q'K, $\angle Q'P'K = r$ and $Q'K = KP' \sin r$ ...(iii)

Substituting (ii) and (iii) in equation (i),

$$t = \frac{AK \sin i}{c} + \frac{KP' \sin r}{v}$$

$$t = \frac{AK \sin i}{c} - \frac{(AP' - AK \sin r)}{v}$$

$[\because KP' = AP' - AK]$

$$t = \frac{AP'}{v} \sin r + AK\left(\frac{\sin i}{c} - \frac{\sin r}{v}\right) \quad ...(iv)$$

The rays from different points on the incident wave front will take the same time to reach the corresponding points on the refracted wave front *i.e.*, given equation (iv) is independent of AK. It will happen so, if

$$\frac{\sin i}{c} - \frac{\sin r}{v} = 0$$

$$\Rightarrow \quad \frac{\sin i}{\sin r} = \frac{c}{v}$$

$$\Rightarrow \quad n = \frac{\sin i}{\sin r}$$

This is the Snell's law for refraction of light.

(b) (i) The frequency of reflected and refracted light remains constant as the frequency of incident light because frequency only depends on the source of light.

(ii) Since the frequency remains same, hence there is no reduction in energy.

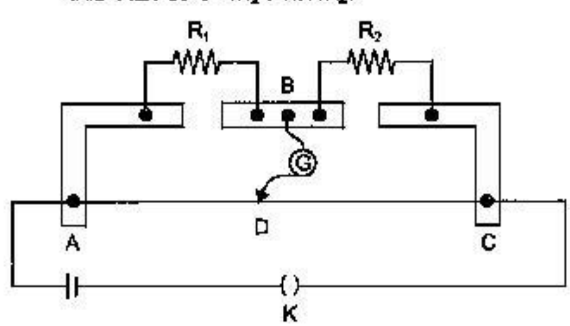
28. (a) State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs.

(b) Write two possible causes for one sided deflection in a potentiometer experiment. **[5]**

OR

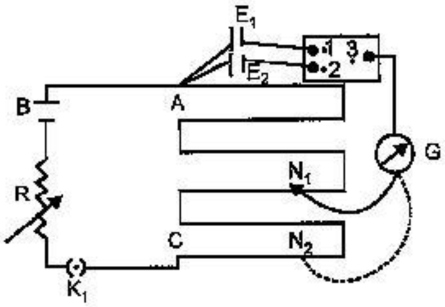
(a) State Kirchhoff's rules for an electric network. Using Kirchhoff's rules, obtain the balance condition in terms of the resistance of four arms of Wheatstone bridge.

(b) In the meter bridge experimental set-up, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of the meter bridge wire. If a resistance of 10 Ω is connected in series with R_1, null point is obtained at AD = 60 cm. Calculate the values of R_1 and R_2.



Answer : (a) Working principle of Potentiometer : When a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.

Applications of Potentiometer for comparing emf's of two cells : The following figure shows an application of the potentiometer to compare the emf of two cells of emf E_1 and E_2.



E_1, E_2 are the emf of the two cells.
1, 2, 3 form a two way key.
When 1 and 3 are connected, E_1 is connected to the galvanometer (G).
Jockey is moved to N_1, which is at a distance L_1 from A, of cell E the balancing length.
By the potentiometer principle

$E_1 = kl_1$ where k is the potential gradient

Similarly for E_2 is balanced at l_2 (AN_2)

$E_2 = kl_2$

By (i) and (ii)

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} \quad ...(iii)$$

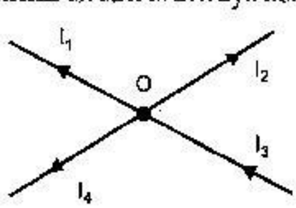
Thus, we can compare the emf's of any two sources. Generally, one of the cells is chosen as a standard cell whose emf is known to a high degree of accuracy. The emf of the other cell is then calculated from equation (iii).

(b) **(i)** The emf of the cell connected in main circuit may not be more than the emf of the primary cells whose emfs are to be compared.

(ii) The positive ends of all cells are not connected to the same end of the wire.

OR

(a) Kirchhoff's first law – Junction rule : The algebraic sum of the currents meeting at a point in an electrical circuit is always zero.



Let the currents be I_1, I_2, I_3, and I_4.

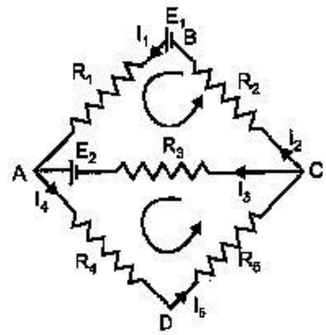
Convention : Current towards the junction positive

Current away from the junction negative

$$I_3 + (-I_1) + (-I_2) + (-I_4) = 0$$

This law is in accordance with conservation of charge

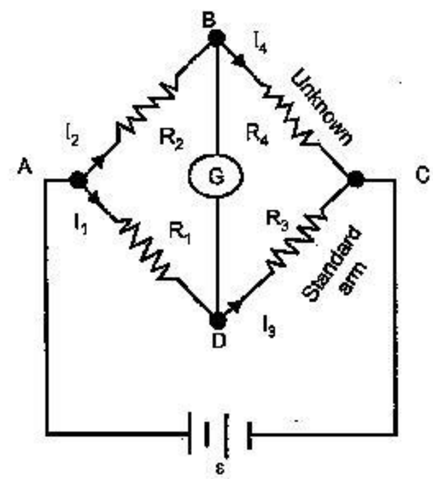
Kirchhoff's second law–Loop rule : In a closed loop, the algebraic sum of the emfs is equal to the algebraic sum of the products of the resistance and current flowing through them.



For closed part BACB, $E_1 - E_2 = I_1R_1 + I_1R_2 - I_3R_3$

For closed part CADC, $E_2 = I_3R_3 + I_4R_4 + I_5R_5$

Wheatstone bridge : The Wheatstone bridge is an arrangement of four resistances as shown in the following figure.



R_1, R_2, R_3, and R_4 are the four resistances.

Galvanometer (G) has a current I_g flowing through it.

At balanced condition, $I_g = 0$

Applying junction rule at B,

$\therefore \quad I_2 = I_4$

Applying loop rule to closed loop ADBA,

$-I_1 R_1 + 0 + I_2 R_2 = 0$

$$\therefore \quad \frac{I_1}{I_2} = \frac{R_2}{R_1} \quad ...(i)$$

Applying loop rule to closed loop CBDC,

$I_2R_4 + 0 - I_1R_3 = 0$

$(\because I_3 = I_1, I_4 = I_2)$

$$\therefore \quad \frac{I_1}{I_2} = \frac{R_4}{R_3} \quad ...(ii)$$

From equations (i) and (ii),

$$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$

This is the required balanced condition of Wheatstone bridge.

(b) Considering both the situations and writing them in the form of equations Let R′ be the resistance per unit length of the potentiometer wire,

$$\frac{R_1}{R_2}=\frac{l_1 R'}{(100-l_1)R'}$$

$$\Rightarrow \quad \frac{R_1}{R_2}=\frac{R'\times 40}{R'(100-40)}=\frac{40}{60}=\frac{2}{3} \quad ...(i)$$

$$\Rightarrow \quad \frac{R_1+10}{R_2}=\frac{R'\times 60}{R'(100-60)}=\frac{60}{40}=\frac{3}{2} \quad ...(ii)$$

Putting the value of R_1 from equation (i) and substituting in equation (ii)

$$\frac{2}{3}+\frac{10}{R_2}=\frac{3}{2}$$

$$R_2 = 12\ \Omega$$

Recalling equation (i) again

$$\frac{R_1}{12}=\frac{2}{3}$$

$$R_1 = 8\ \Omega$$

29. (a) Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

(b) A proton and a deuteron having equal momenta enter in a region of a uniform magnetic field at right angle to the direction of the field. Depict their trajectories in the field. [5]

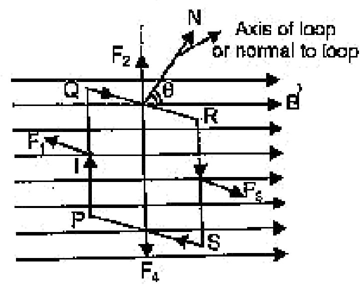
OR

(a) A small compass needle of magnetic moment '*m*' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period.

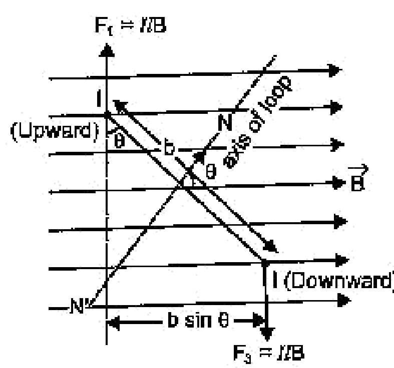
(b) A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.

Answer :

(a) Consider a rectangular loop PQRS of length *l*, breadth *b* suspended in a uniform magnetic field $\vec{B}$. The length of loop = PQ = RS = *l* and breadth = QR = SP = *b*. Let at any instant the normal to the plane of loop make an angle θ with the direction of magnetic field $\vec{B}$ and *I* be the current in the loop. We know that a force acts on a current carrying wire placed in a magnetic field. Therefore, each side of the loop will experience a force. The net force and torque acting on the loop will be determined by the forces acting on all sides of the loop. Suppose that the forces on sides



PQ, QR, RS and SP are $\vec{F}_1, \vec{F}_2, \vec{F}_3$ and $\vec{F}_4$ respectively. The sides QR and SP make angle (90° – θ) with the direction of magnetic field. Therefore each of the forces $\vec{F}_2$ and $\vec{F}_4$ acting on these sides has same magnitude F = B*Ib* sin (90° – θ) = B*Ib* cos θ. According to Fleming's left hand rule the forces $\vec{F}_2$ and $\vec{F}_4$ are equal and opposite but their line of action is same. Therefore, these forces cancel each other *i.e.*, the resultant of $\vec{F}_2$ and $\vec{F}_4$ is zero.



The sides PQ and RS of current loop are perpendicular to the magnetic field, therefore, the magnitude of each of forces $\vec{F}_1$ and $\vec{F}_3$ is zero.

$$F = IlB \sin 90° = IlB.$$

According to Fleming's left hand rule the forces $\vec{F}_1$ and $\vec{F}_3$ acting on side PQ and RS are equal and opposite, but their lines of action are different; therefore, the resultant force of $\vec{F}_1$ and $\vec{F}_3$ is zero, but they form a couple called the deflecting couple. When the normal to plane of loop makes and angle θ with the direction of magnetic field B, the perpendicular distance between F_1 and F_3 is *b* sin θ.

∴ Moment of couple or Torque,

τ = (Magnitude of one force F) × Perpendicular distance

$= (BIl).(b \sin\theta) = I(lb) B \sin\theta$

But lb = area of loop = A (say)

∴ Torque, $\tau = IAB \sin\theta$

If the loop contains N-turns, then $\tau = NI AB \sin\theta$

In vector form $\vec{\tau} = NI \vec{A} \times \vec{B}$.

The magnetic dipole moment of rectangular current loop

$= M = NIA$

∴ $\vec{\tau} = \vec{M} \times \vec{B}$

Direction of torque is perpendicular to direction of area of loop as well as the direction of magnetic field *i.e.,* along $(\vec{A} \times \vec{B})$

(b) We know, Lorentz force, $F = Bqv \sin\theta$

Where θ = angle between velocity of particle and magnetic field = 90°

So, Lorentz force, $F = Bqv$

Thus, the particles will move in circular path and required centripetal force is provided by this Lorentz force.

$$Bqv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{Bq}$$

Let m_p = mass of proton, m_d = mass of deuteron, v_p = velocity of proton and v_d = velocity of deuteron.

$$r_p = \frac{m_p v_p}{Bq} \quad ...(i)$$

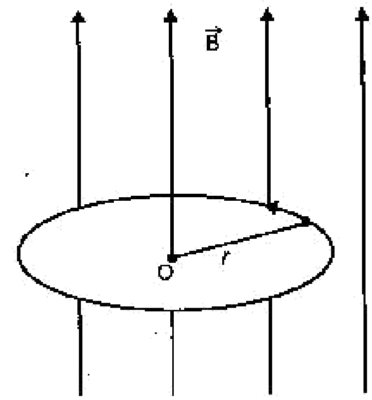
$$r_d = \frac{m_d v_d}{Bq} \quad ...(ii)$$

The charge of proton and deuteron are equal.

Given that, $m_p v_p = m_d v_d$

Since, RHS of equation (i) and (ii) are equal, so $r_p = r_d = r$.

Thus, the trajectory of both the particles will be same.



OR

(a) The torque on the needle is $\tau = m \times B$

In magnitude $\tau = mB \sin\theta$

Here τ is restoring torque and θ is the angle between m and B.

Therefore, in equilibrium $I \frac{d^2\theta}{dt^2} = mB \sin\theta$

Negative sign with $mB \sin\theta$ implies that restoring torque is in a position to deflecting torque. For small values of θ in radians, we approximate $\sin\theta \approx \theta$ and get

$$I\frac{d^2\theta}{dt^2} = -mB \sin\theta$$

or $$\frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta$$

This represents a simple harmonic motion.

The square of the angular frequency $\omega^2 = mB/I$ and the time period is,

$$T = 2\pi\sqrt{\frac{I}{mB}} \quad [\because \omega = \frac{2\pi}{T}]$$

(b) Since the needle rotates in vertical plane, so the place here is magnetic pole of earth.

Therefore, $B_H = 0$

and, angle of dip at magnetic pole, $\delta = 90°$

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Physics 2013 (Delhi) SET II

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

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

1. A cell of emf 'E' and internal distance 'r' draws a current 'I'. Write the relation between terminal voltage 'V' in terms of E, I, r. **[1]**

Answer : When the current I draws from a cell of emf E and internal resistance r, then the terminal voltage is $V = E - Ir$

2. Which of the following substances are diamagnetic ? **[1]**

Bi, Al, Na, Cu, Ca and Ni

Answer : Bi and Cu are diamagnetic substances.

3. **A heating element is marked 210 V, 630 W. What is the value of current drawn by the element when connected to a 210 V dc source ? [1]**

Answer : In dc source, P = VI

Given that P = 630 W and V = 210 V.

So,

$$I = \frac{P}{V} = \frac{630}{210} = 3A$$

10. **An ammeter of resistance 1 Ω can measure current upto 1.0 A. (i) What must be the value of the shunt resistance to enable the ammeter to measure upto 5.0 A ? (ii) What is the combination resistance of the ammeter and the shunt ? [1]**

Answer : We have, Resistance of ammeter, $R_A = 1\ \Omega$

Maximum current across ammeter, $I_A = 1.0$ A

So, Voltage drop across ammeter, V = IR = 1.0 × 1.0 = 1V

(i) Resistance of ammeter with shunt,

$$R = \frac{R_A x}{R_A + x} = \frac{x}{1+x}$$

Current through ammeter,

$$I = 5A$$

Now, V = IR

$$\left(\frac{x}{1+x}\right) \times 5 = 1.0$$

$$x \times 5 = 1 + x$$

$$4x = 1$$

$$x = 0.25$$

Thus the shunt resistance is 0.25 Ω

(ii) Combined resistance of the ammeter and the shunt

$$R = \frac{x}{1+x}$$

$$R = \frac{0.25}{1+0.25}$$

$$R = \frac{0.25}{1.25}$$

$$R = 0.2\ \Omega$$

14. **A convex lens of focal length 20 cm is placed coaxially in contact with a concave lens of focal length 25 cm. Determine the power of the combination. Will the system be converging or diverging in nature ? [2]**

Answer : We have, Focal length of concave lens, $f_1 = +20$ cm = +0.20 m

Focal length of concave lens, $f_2 = -25$ cm = –0.25 m

Power of convex lens,

$$P_1 = \frac{1}{f_1} = \frac{1}{0.20}$$

Power of concave lens,

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.25}$$

Power of the combination lens,

$$P = P_1 + P_2$$

$$= \frac{1}{0.20} + \frac{1}{-0.25}$$

$$= \frac{100}{20} + \frac{100}{-25}$$

$$= \frac{500-400}{100}$$

$$= \frac{100}{100}$$

$$= 1D$$

As the power is positive, the system will be converging in nature.

15. **Using Bohr's postulates, obtain the expressions for (i) kinetic energy and (ii) potential energy of the electron in stationary state of hydrogen atom.**

Draw the energy level diagram showing how the transitions between energy levels result in the appearance of Lyman series. [2]

Answer : According to Bohr's postulates, in a hydrogen atom, a single electron revolves around a nucleus of charge + *e*.

And the radius of orbit in which the electron revolves, is given by

$$r = \frac{n^2h^2}{4\pi^2kme^2} \quad ...(i)$$

(i) Kinetic energy of electron,

$$E_K = \frac{1}{2}mv^2 = \frac{ke^2}{2r}$$

Using equation (i), we get

$$E_K = \frac{ke^2}{2} \frac{4\pi^2kme^2}{n^2h^2}$$

(ii) Potential energy

$$E_P = \frac{-k(e)\times(e)}{r} = \frac{-ke^2}{r}$$

Using equation (i), we get

$$E_P = -ke^2 \times \frac{4\pi^2 kme^2}{n^2h^2}$$

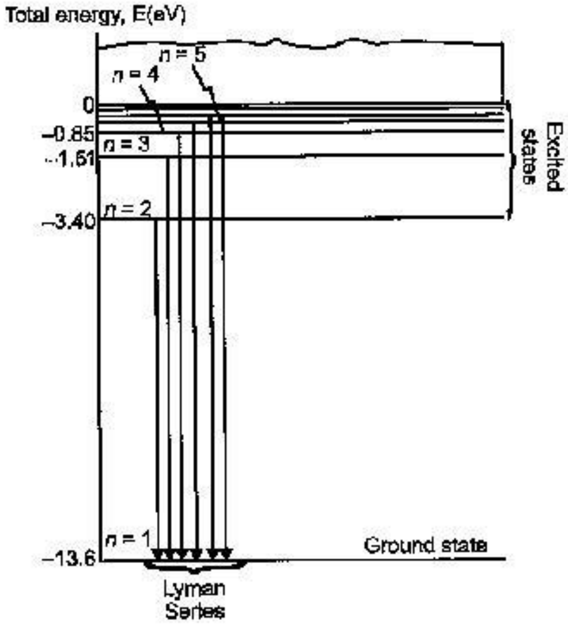
$$= -\frac{4\pi^2 k^2 me^4}{n^2h^2}$$

Energy level diagram showing the transitions between energy levels result in the appearance of Lyman series :

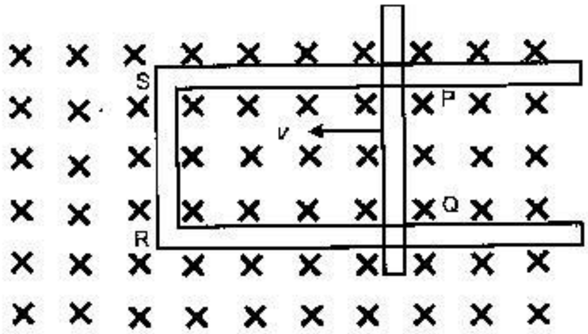
For Lyman series, $n_f = 1$ and $n_i = 2, 3, 4, 5, \ldots$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

Where, $n_i = 2, 3, 4, 5, \ldots$



22. Figure shows a rectangular loop conducting PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity v towards the arm RS Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance r, obtain the expression for (i) the current in the loop (ii) the force and (iii) the power required to move the arm PQ.



[3]

Answer : Let the length RQ = x and RS = l.

Let the magnitude of the uniform magnetic field be B.

(i) The magnetic flux ϕ enclosed by the loop PQRS is given by, $\phi = Blx$

As, x is changing with time, the rate of change of flux $\frac{d\phi}{dt}$ will induce an emf given by :

$$E = -\frac{d\phi}{dt} = -\frac{d(Blx)}{dt} = -Bl\frac{dx}{dt} = Blv$$

$$\left[as, \frac{dx}{dt} = -v\right]$$

Current in the loop is given by,

$$I = \frac{E}{r} = \frac{Blv}{r}$$

(ii) The magnetic force on the PQ is,

$$F = BIl = B\left(\frac{Blv}{r}\right) \times l = \frac{B^2l^2v}{r}$$

(iii) Power required to move the arm PQ is,

$$P = F \times v = \frac{B^2l^2v}{r} \times v = \frac{B^2l^2v^2}{r}$$

23. Distinguish between 'sky waves' and 'space waves' modes of propagation in communication system.** **[4]**

(a) Why is sky wave mode propagation restricted to frequencies upto 40 MHz ?

(b) Give two examples where space wave mode of propagation is used.

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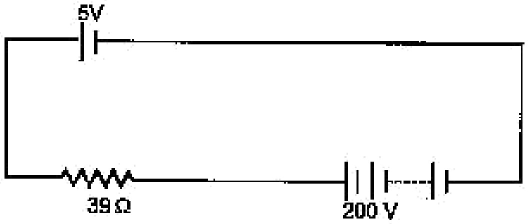
**Answers is not given due to change in the present syllabus.

Time allowed : 3 hours | Maximum marks : 70

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

6. A 5 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 39 Ω as shown in the figure. Find the value of the current. [2]



Answer : Let I be the current flowing in the circuit.

Using Kirchhoff's law,

$$39\,I = 200 - 5$$

$$I = \frac{195}{39}$$

$$I = 5\text{ A}.$$

7. Which of the following substances are paramagnetic ? [2]

Bi, Al, Cu, Ca, Pb, Ni

Answer : Paramagnetic substances are Aluminium (Al) and Calcium (Ca).

9. An ammeter of resistance 0.6 Ω can measure current upto 1.0 A. Calculate (i) The shunt resistance required to enable the ammeter to measure current upto 5.0 A. (ii) The combined resistance of the ammeter and the shunt. [2]

Answer : We have, resistance of ammeter, R_A = 0.60 ohm.

Maximum current across ammeter, $I_A = 1.0$ A

So, voltage across ammeter,

$$V = IR$$

$$= 1.0 \times 0.60$$

$$V = 0.6\text{ V}$$

Let the value of shunt be x.

(i) Resistance of ammeter with shunt

$$R = \frac{R_A x}{R_A + x}$$

$$= \frac{0.6x}{0.6 + x}$$

Current through ammeter I = 5A

$\because$ V = IR

Now, $$\left(\frac{0.6x}{0.6+x}\right) \times 5 = 0.6$$

$$0.6x \times 5 = 0.6(0.6 + x)$$

$$3x = 0.36 + 0.6x$$

$$3x - 0.6x = 0.36$$

$$x = \frac{0.36}{2.4}$$

$$x = 0.15\,\Omega$$

Therefore, the shunt resistance is 0.15 ohm.

(ii) Combined resistance of the ammeter and the shunt is given by

$$R = \frac{0.6x}{0.6 + x}$$

$$R = \frac{0.6 \times 0.15}{0.6 + 0.15}$$

$$R = 0.12\,\Omega$$

15. A convex lens of focal length 30 cm is placed coaxially in contact with a concave lens of focal length 40 cm. Determine the power of the combination. Will the system be converging or diverging in nature ? [3]

Answer : We have, focal length of convex lens,

$$f_1 = +30\text{ cm}$$

$$= 0.30\text{ m}$$

Focal length of concave lens

$$f_2 = -40\text{ cm}$$

$$= -0.40\text{ m}$$

Equivalent focal length

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$= \frac{1}{30} + \frac{1}{-40}$$

$$= \frac{40-30}{1200} = \frac{1}{120}$$

$\therefore$ $$F = 120\text{ cm}$$

$$= 1.2\text{ m}$$

$\therefore$ Power of the combination,

$$P = \frac{1}{F} = \frac{1}{1.2} = 0.83\text{ D}$$

The focal length of combination = 1.2 m = 120 cm.

As the focal length is positive the system will be converging in nature.

18. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 300 μC. When potential across the capacitor is reduced by 100 V, the charge stored in it becomes 100 μC. Calculate the potential V and the unknown capacitance. What will be the charge stored in the capacitor if the voltage applied had increased by 100 V ? **[3]**

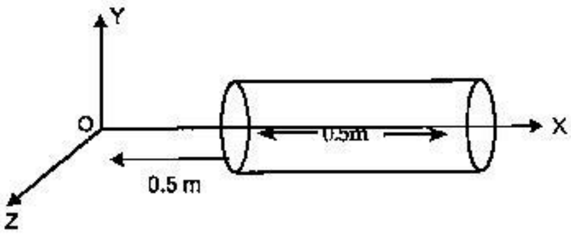
OR

A hollow cylindrical box of length 0.5 m and area of cross-section 20 cm is placed in a three-dimensional coordinate system as shown in the figure. The electric field in the region is given by

$E = 20x\hat{i}$, where E is NC^{-1} and x is in meters. Find

(i) Net flux through the cylinder

(ii) Charge enclosed in the cylinder.



Answer : (i) Initial voltage

$$V_1 = V \text{ volts}$$

Charge stored,

$$Q_1 = 300\ \mu C$$

$$Q_1 = CV_1 \quad ...(i)$$

Changed potential, $V_2 = V - 100\ V$

$$Q_2 = 100\ \mu C$$

$$Q_2 = CV_2 \quad ...(ii)$$

By dividing (ii) from (i), we get

$$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2}$$

$$\frac{Q_1}{Q_2} = \frac{V_1}{V_2}$$

$$\frac{300}{100} = \frac{V}{V-100}$$

$$V = 150 \text{ volts}$$

$$C = \frac{Q_1}{V_1} = \frac{300 \times 10^{-6}}{150}$$

$$= 2 \times 10^{-6} F$$

$$C = 2\mu F$$

If the voltage applied had increased by 100 V, then

$$V_3 = 150 + 100$$

$$= 250\ V$$

Hence, charge stored in the capacitor,

$$Q_3 = CV_3 - 2 \times 10^{-6} \times 250$$

$$= 500\ \mu C$$

OR

(i) Given, $\vec{E} = 20x\hat{i}$

and $\Delta s = 20\ cm^2$

$$= 20 \times 10^{-4} m^2$$

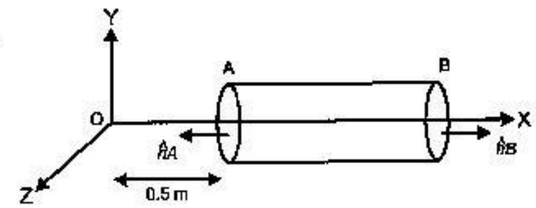
As the electric field is only along the X-axis, so flux will pass only through the cross-section of cylinder.

Magnitude of electric field at A,

$$E_A = 20 \times 0.5 = 10\ N/C$$

Magnitude of electric field at cross-section B.

$$E_B = 20 \times 1 = 20\ N/C$$



The corresponding electric fluxes are :

$$\phi_A = \vec{E} \cdot \Delta\vec{s}$$

$$= 10 \times 20 \times 10^{-4} \times \cos 180^\circ$$

$$= -0.02\ Nm^2C^{-1}$$

$$\phi_A = \vec{E} \cdot \Delta\vec{s}$$

$$= 20 \times 20 \times 10^{-4} \times \cos 0^\circ$$

$$= 0.04\ Nm^2C^{-1}$$

So, the net flux through the cylinder,

$$\phi = \phi_A + \phi_B$$

$$= -0.02 + 0.04$$

$$= 0.02\ Nm^2C^{-1}$$

(ii) Using Gauss's law :

$$\int \vec{E} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$$

$$0.02 = \frac{q}{8.85 \times 10^{-12}}$$

$$q = 8.85 \times 0.02 \times 10^{-12}$$

$$q = 0.177 \times 10^{-12} C$$

19. (a) Write two characteristic features distinguishing the diffraction pattern from the interference fringes obtained in Young's double slit experiment.

(b) Two wavelength of sodium light 590 nm and 596 nm are used, in turn, to study the

diffraction taking place due to a single slit of aperture 1×10^{-4} m. The distance between the slit and the screen is 1.8 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases. **[3]**

Answer : (a) Two characteristic features distinguishing the diffraction pattern from the interference fringes obtained in Young's double slit experiment are :

(i) The interference fringes may or may not be of the same width whereas the fringes of diffraction pattern are always of varying width.

(ii) In interference the bright fringes are of same intensity whereas in diffraction pattern the intensity falls as we go to successive maxima away from the centre, on either side.

(b) Wavelength of the light beam, $\lambda_1 = 590$ nm $= 5.9 \times 10^{-7}$ m

Wavelength of another light beam, $\lambda_2 = 596$ nm $= 5.96 \times 10^{-7}$ m

Distance of the slits from the screen = D = 1.8 m

Distance between the two slits = 1×10^{-4} m

For the first secondary maxima,

$$\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$$

$$x_1 = \frac{3\lambda_1 D}{2a}$$

and $$x_2 = \frac{3\lambda_2 D}{2a}$$

$\therefore$ Spacing between the positions of first secondary maxima of two sodium lines

$$= x_2 - x_1$$

$$= \frac{3D}{2a}(\lambda_2 - \lambda_1)$$

$$= \frac{3 \times 1.8 \times 6 \times 10^{-9}}{2 \times 10^{-4}} = 1.62 \times 10^{-4}\text{m}$$

21. (a) In a nuclear reaction

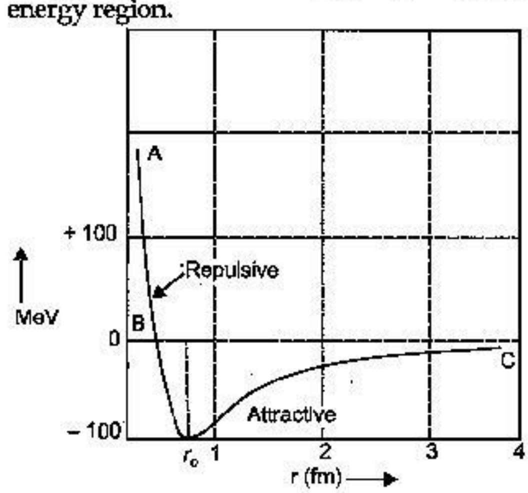
$${}^3_2\text{He} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + {}^1_1\text{H} + {}^1_1\text{H} + 12.86\,\text{MeV},$$

though the number of nucleons is conserved on both sides of the reaction, yet the energy is released. How ? Explain.

(b) Draw a plot of potential energy between a pair of nucleons as a function of their separation. Mark the regions where potential energy is (i) positive and (ii) negative. **[3]**

Answer : (a) In a nuclear reaction, the sum of the masses of the target nucleus ${}^3_2$He may be greater or less the sum of the masses of the product nucleus ${}^4_2$He and the ${}^1_1$H . So from the law of conservation of mass energy, some energy, (12.86 MeV) is evolved in nuclear reaction. This energy is called Q-value of the nuclear reaction. The binding energy of the nucleus on the left side is not equal to the right side. The difference in the binding energies on two sides appears as energy released or absorbed in the nuclear reaction.

(b) The potential energy is minimum at r_0. For distance larger than r_0 the negative potential energy goes on decreasing and for the distances less than r_0 the negative potential energy decrease to zero and then becomes positive and increases abruptly. Thus, A to B is the positive potential energy region and B to C is the negative potential energy region.



25. (b) What is the significance of negative sign in the expression for the energy ?

(c) Draw the energy level diagram showing how the line spectra corresponding to Paschen series occur due to transition between energy levels. **[5]**

Answer : (b) Negative sign indicates that revolving electron is bound to the positive nucleus.

(c) For Paschen series, $n = 3$ and $n_i = 4, 5, \ldots$

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n_i^2}\right)$$

where, $n_i = 4, 5, \ldots..$