CBSE Board Paper Solution-2020

Class	:	**XII**
Subject	:	**Physics**
Set	:	**1**
Code No	:	**55/2/1**
Time Allowed	:	**3 hours**
Maximum Marks	:	**70**

General Instructions:

Read the following instructions very carefully and strictly follow them :

(i) This question paper comprises **four** sections–A, B, C, and D.

(ii) There are **37** questions in the question paper. All questions are compulsory.

(iii) Section A : Q. no. **1** to **20** are very short-answer type questions carrying **1** mark each.

(iv) Section B : Q. no. **21** to **27** are short-answer type questions carrying **2** mark each.

(v) Section C : Q. no. **28** to **34** are long-answer type questions carrying **3** mark each.

(vi) Section A : Q. no. **35** to **37** are very long answer type questions carrying **5** mark each

(vii) There is no overall in the question paper. However, an internal choice has been provided in **two** questions of **one** mark, **two** questions of **two** marks, **one** question of **three** marks and all the **three** questions **five** marks. You have to attempt only one of the choices in such questions.

(viii) However, separate instructions are given with each section and question, wherever necessary.

(ix) Use of calculators and log tables is no permitted.

(x) You may use the following values of physical constants wherever necessary:

$$c = 3 \times 10^{8} \text{ m/s}$$
$$h = 6.63 \times 10^{-34} \text{ Js}$$
$$e = 1.6 \times 10^{-19} \text{ C}$$
$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$
$$\varepsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{m}^{-2}$$
$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9} \text{ Nm}^2 \text{ C}^{-2}$$

Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg

Mass of neutron $= 1.675 \times 10^{-27}$ kg

Mass of proton $= 1.673 \times 10^{-27}$ kg

Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

SECTION-A

Note : *Select the most appropriate option from those given below each question* :

1. **A cell of internal resistance r connected across an external resistance R can supply maximum current when** [1]

    (A) R = r

    (B) R > r

    (C) R = $\dfrac{r}{2}$

    (D) R = 0

    Answer : (A) An electric cell supplies maximum current when its internal resistance is equal to the external resistance.

2. **In a current carrying conductor, the ratio of the electric field and the current density at a point is called** [1]

    (A) Resistivity

    (B) Conductivity

    (c) Resistance

    (d) Mobility

Answer : (A)

By ohm's law, $\quad J = \sigma E$

Here, $\quad J =$ Current density

$\sigma =$ conductivity

$E =$ Electricb field

$\therefore \quad \dfrac{E}{J} = \dfrac{1}{\sigma} = \rho =$ Resistivity

3. **An electron is released from rest in a region of uniform electric and magnetic fields acting parallel to each other. The electron will** **[1]**

   (A) move in a straight line

   (B) move in circle

   (C) remain stationary

   (D) move in a helical path

   Answer: (A) As the electron is at rest, the electric field will apply force on the electron in a direction that is opposite to the direction of electric field.

   When the electron comes into motion, the angle between the velocity vector of electron and the magnetic field is 180°. So, the net force applied by the magnetic field will be zero.

   Combing the effect of electric and magnetic forces, the electron will follow a straight line opposite to the direction of the electric field.

4. **Above Curie temperature, a** **[1]**

   (A) ferromagnetic material becomes diamagnetic

(B) ferromagnetic material becomes paramagnetic

(C) paramagnetic material becomes ferromagnetic

(D) paramagnetic material becomes diamagnetic

Answer : (B) Above curie temperature, ferromagnetic material losses its magnetic properties and gets converted into a paramagnetic material.

5. **Displacement current exists only when** [1]

(A) electric field is changing.

(B) magnetic field is changing

(C) electric field is not changing

(D) magnetic field is not changing

Answer : (A) Displacement current exists only when electric field is changing.

6. **Electromagnetic waves us a diagnostic tool in medicine are** [1]

(A) X-rays

(B) ultraviolet rays

(C) infrared radiation

(D) ultrasonic waves

Answer : (A) X rays are widely used in medical technologies.

7. **At equilibrium, in a p-n junction diode the net current is** [1]

(A) due to diffusion of majority charge carriers.

(B) due to drift of minority charge carriers.

(C) zero as diffusion and drift currents are equal and opposite.

(D) zero as no charge carriers cross the junction.

Answer : (C) At equilibrium, the net current (diffusion and drift current) is zero because the diffusion current is equal and opposite to the drift current for both carriers.

8. **In an n-type semiconductor, the donor energy level lies** [1]

(A) at the centre of the energy gap.

(B) just below the conduction band.

(C) just above the valance band.

(D) in the conduction band.

Answer : (B) In n type semiconductor, the donor energy level lies, just below the conduction band.

9. **When two nuclei (A ≤ 10) fuse together to form a heavier nucleus, the** [1]

(A) binding energy per nucleon increases.

(B) binding energy per nucleon decreases.

(C) binding energy per nucleon does not change.

(D) total binding energy decreases.

Answer : (A) When two or more lighter nuclei fuse, they release a large amount of energy, that indicates the increase in the binding energy per nucleon.

10. In β^- decay, a   [1]

   (A) **neutron converts into a proton emitting antineutrino.**

   (B) **neutron converts into a proton emitting neutrino.**

   (C) **proton converts into a proton emitting antineutrino.**

   (D) **proton converts into a proton emitting neutrino.**

   Answer : (A)

   β^- decay is represented as :

   ^1_0n (neutron) $\rightarrow$ ^1_1p (proton) $+$ $^0_{-1}e$ (electron) $+ \bar{v}_e$ (antineutrino)
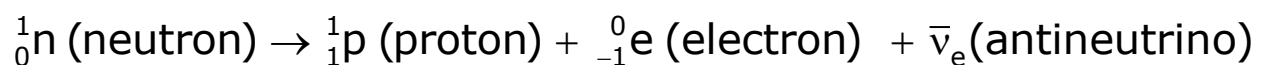
Note : *Fill in the blanks with appropriate answer :*

11. **If the electric flux entering and leaving a closed surface in air are ϕ_1 and ϕ_2 respectively, the net electric charge enclosed within the surface is _____.**   [1]

   Answer : Net charge $= \left(\phi_1 - \phi_2\right) \in_0$

12. **In Young's double slit experiment, the path difference between two interfering waves at a point on the screen is** $\dfrac{5\lambda}{2}$, λ **being wavelength of the light used. The _____ dark fringe will lie at this point.**

                                                                                             [1]

   Answer : Second.

OR

If one of the slits in Young's double slit experiment is fully closed, the new pattern has _____ central maximum in angular size.   [1]

Answer : Broader.

13. For a higher resolving power of a compound microscope, the wavelength of light used should be _____.   [1]

Answer : Shorter.

14. Unpolarised light passes from a rarer into a denser medium. If the reflected and the refracted rays are mutually perpendicular, the reflected light is linearly polarised _____ to the plane of incidence.   [1]

Answer : Perpendicular.

15. Out of red, blue and yellow lights, the scattering of _____ light is maximum.   [1]

Answer : Blue

Note : *Answer the following :*

16. What is the impedance of a capacitor of capacitance C in an ac circuit using source of frequency n Hz?   [1]

Answer :

Capacitance of the capacitor = C

Frequency of the source = n

Impedence = $2\pi nC$

OR

What is the value of impedance of a resonant series LCR circuit ? **[1]**

Answer : In series LCR circuit at resonance, the impedance will be equal to the net resistance of the circuit.

17. **A conducting rod of length l is kept parallel to a uniform magnetic field $\vec{B}$. It is moved along the magnetic field with a velocity $\vec{v}$. What is the value of emf induced in the conductor ?** **[1]**

Answer : As the magnetic flux lines cut by the moving rod is zero so the induced emf by the rod will be zero.

18. **Draw the graph showing variation of the value of the induced emf as a function of rate of change of current flowing through an ideal inductor.** **[1]**

Answer : As v = L (di/dt), so a straight line.

19. **What is the wavelength of a photon of energy 3.3×10^{-19} J ?** **[1]**

Answer :

Energy of the photon $= E = 3.3 \times 10^{-19}$ J

Energy of the photon $= h\dfrac{c}{\lambda}$

Plank's constant $= h = 6.626 \times 10^{-34}$ m^2 kg / s

Speed of light $= c = 3 \times 10^8$ m/s

$\therefore \quad 3.3 \times 10^{-19}$ J $= 6.626 \times 10^{-34}$ m^{2}kg / s $\times \dfrac{3 \times 10^8 \ \text{m/s}}{\lambda}$

$\Rightarrow \quad \lambda = \dfrac{6.626 \times 10^{-34} \times 3 \times 10^8}{3.3 \times 10^{-19}}$ m $= 602.36$ nm

20. Define the term 'threshold frequency' in photoelectric emission. [1]

Answer : The minimum frequency of the incident wave below which no emission of electron will take place if the light ray falls on the surface of the metal.

SECTION-B

21. Define the term 'mobility' of charge carriers in a current carrying conductor. Obtain the relation for mobility in terms of relaxation time.

[2]

Answer : Mobility of charge carriers (μ) is defined as the magnitude of the drift velocity of a charge carrier per unit electric field applied.

$$\mu = \dfrac{\text{drift velocity}}{\text{electric field}} = \dfrac{v_d}{E}$$

Here v_d and E represent the drift velocity of the charge carrier and the electric field through which this charge carrier is moving.

Drift velocity is expressed in terms of the mass (*m*) and the charge (*q*) of the charged particle and the electric field (*E*) through which it moves as:

$$v_d = \frac{qE\tau}{m}$$

Here τ is the average relaxation time of the charged particle while drifting towards an electrode with a polarity opposite to that of the charge carrier. The drift velocity of a charged carrier is directly proportional to the average relaxation time of the charged carrier.

OR

Define the term 'drift velocity' of electrons in a current carrying conductor. Obtain the relationship between the current density and the drift velocity of electrons. **[2]**

Answer : Drift velocity is average velocity with which free electrons in a current carrying conductor get drifted towards the positive end of the conductor under the influence of an externally applied electric field.

For a conductor having a length *L*, cross-sectional area *A*, and the number of free electrons per unit volume of the conductor, the total amount of charge within the conductor *q* is given by

Charge in the conductor,

$$q = ALne \qquad \qquad \text{...(1)}$$

Let a constant potential difference V be set up across the ends of the conductor. The electric field E developed across the conductor, $E = \dfrac{V}{L}$

Due to this electric field, free electrons within the conductor will begin to move from one end of the conductor to the other with a drift velocity v_d.

Time taken by the conductor to move across the length of the conductor,

$$t = \dfrac{L}{v_d} \dotfill (2)$$

Current in the conductor,

$$I = \dfrac{q}{t} \dotfill (3)$$

Substituting the values obtained in (1) and (2) in (3),

$$I = \dfrac{q}{t} = \dfrac{ALne}{L/v_d}$$

$$\Rightarrow \quad I = Anev_d \dotfill (4)$$

Current density of a conductor (J) is the amount of electric current flowing through a unit cross-sectional area of the conductor held perpendicular to the flow of electric current.

From (4),

$$I = Anev_d$$

$$\Rightarrow \quad \frac{I}{A} = nev_d$$

$$\Rightarrow \quad J = nev_d$$

22. An ammeter of resistance 0.8 Ω can measure a current up to 1.0 A. Find the value of shunt resistance required to convert this ammeter to measure a current up to 5.0 A. **[2]**

Answer :
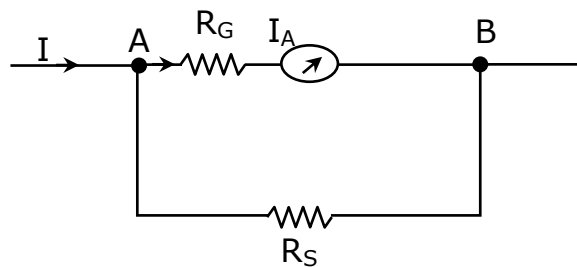
For measuring 5 A input current, we connect a shunt resistance in parallel to the ammeter.

As, the range of ammeter in 1 A so 1 A current flows through the ammeter and 4 A current flows through the shunt resistance.

Equating potential across AB,

$$I_A . R_G = (I - I_A).R_S$$

$$1\ A \times 0.8\ \Omega = 4\ A \times R_S$$

$$R_S = \frac{0.8}{4}\Omega$$

$$\Rightarrow \quad R_S = 0.2\ \Omega$$

23. (a) Explain the term sharpness of resonance' in ac circuit.

(b) In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of power factor for this circuit ? [2]

Answer : (a) The ratio of the resonant frequency of an AC circuit (ω_r) to the bandwidth at which the circuit operates ($2\Delta\omega$) is called the sharpness of resonance.

$$\text{Sharpness of resonance} = \frac{\omega_r}{2\Delta\omega}$$

If the bandwidth of the AC circuit is low, the resonance of the circuit will be sharper or narrower. When the resonance of an AC circuit is narrow, the maximum current flowing through the circuit will be less and the circuit will be able to attain resonance over a larger bandwidth of frequencies.

(b) Let $V_L = V_C = V$

Power factor, $\cos\phi = \dfrac{R}{Z}$

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

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

OR

An ac source of emf $V = V_0 \sin \omega t$ is connected to a capacitor of capacitance C. Deduce the expression for the current (I) flowing in it. Plot the graph of (i) V vs. ωt, and (ii) I vs. ωt.   [2]

Answer : A.C. circuit containing only a capacitor.
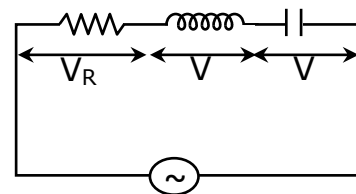
As shown in the fig, consider a pure capacitor C connected across a source of alternating emf v given by

$$v = v_0 \sin \omega t \qquad ....(1)$$

Due to the continuous charging and discharging of the capacitor plates, a continuous but alternating current exists in the circuit.

At any instant,

P.D. across the capacitor plates = Applied emf

i.e. $V = V = V_0 \sin \omega t$
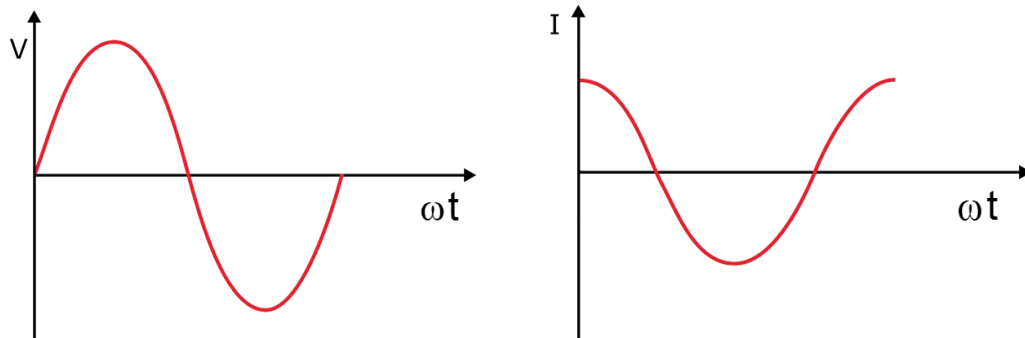
But $V = \dfrac{Q}{C}$

or $Q = CV = CV_0 \sin \omega t$

∴ Current at any instant is

$$I = \frac{dQ}{dt} = \frac{d}{dt}(CV_0 \sin t) = \omega CV_0 \cos \omega t$$

or $I = I_0 \cos \omega t = I_0 \sin (\omega t + \pi / 2)$ ...(2)

Where $I_0 = \omega CV_0 = \dfrac{V_0}{1 / \omega C}$ = the current amplitude

Phase relationship between ω and I On comparing equation (1) and (2), we find that in a capacitive a.c. circuit, the current leads the voltage or the voltage lags behind the current in phase by $\pi/2$ radian. The phase relationship between v and I is shown graphically in Fig.(a). We see that the current reaches its maximum value earlier than the voltage by one-fourth of a period.

Figure (b) shows the phasor diagram for a capacitive a.c. circuit. The phasor $\vec{v}$ makes and angle ωt with x-axis in anticlockwise direction. As the current leads the emf in phase by $\pi/2$ rad with $\vec{V}$ in anticlockwise direction.

24. **Which of the following electromagnetic waves has (a) minimum wavelength, and (b) minimum frequency ? Write one use of each of these two waves.**

    Infrared waves, Microwaves, γ-rays and X-rays[2]

    Answer : Among infrared rays, microwaves, γ–rays and X-rays.

    (a) γ-rays have the minimum wavelength.

    (b) microwaves have the minimum frequency.

    γ–rays are used for the treatment of malignant tumors in medicine. Microwaves are used for cooking in microwave ovens.

25. An object is kept 20 cm in front of a concave mirror of radius of curvature 60 cm. Find the nature and position of the image formed. [2]

Answer :
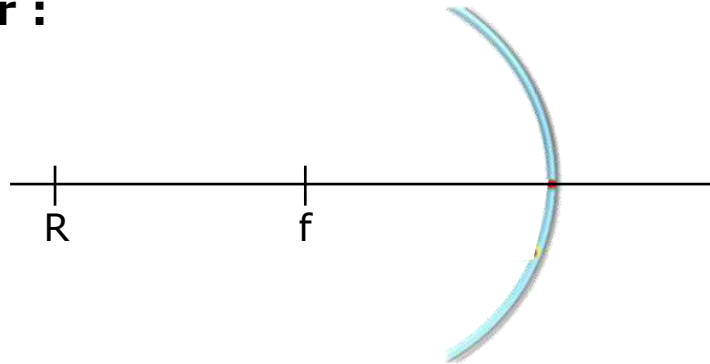
Focal length, $f = \dfrac{R}{2} = \dfrac{60}{2}$ cm $= 30$ cm

By mirror formula,

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

$$\Rightarrow \quad -\dfrac{1}{30} = \dfrac{1}{v} - \dfrac{1}{20} \Rightarrow \dfrac{1}{v} = \dfrac{1}{20} - \dfrac{1}{30}$$

$$\Rightarrow \quad \dfrac{1}{v} = \dfrac{3-2}{60} = \dfrac{1}{60}$$

$$\therefore \quad v = 60 \text{ cm}$$

Now, $m = \dfrac{-v}{u} = -\dfrac{60}{(-20)} = +3$

Nature : Virtual and Erect.

Position : 60 cm in front of the mirror.

26. In Geiger-Marsden scattering experiment, the trajectory of α-particles in Coulomb's field of a heavy nucleus is shown in the figure.

Target nucleus
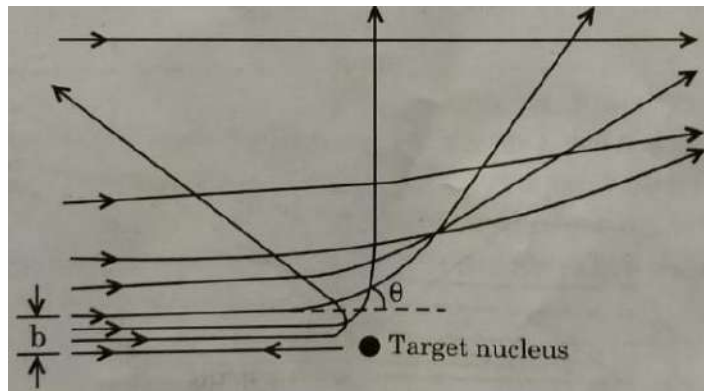
(a) **What do 'b' and 'θ' represent in the figure ?**

(b) **What will be the value of 'b' for (i) θ = 0°, and (ii) θ = 180° ?** **[2]**

Answer : (a) b represents impact parameter and θ represents scattering angle.

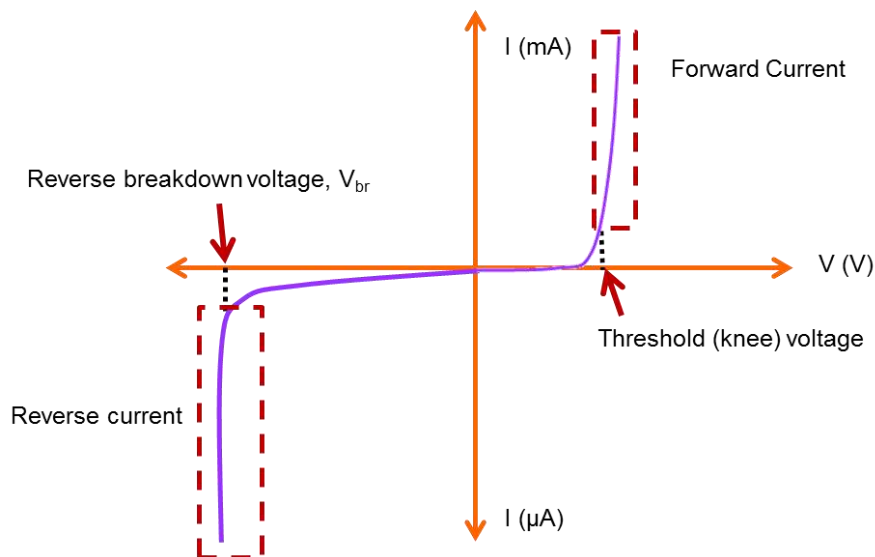(b) Impact parameter b and scattering angle θ are related as

$$b = \frac{1}{4\pi\varepsilon_0} \frac{Ze^2 \cot(\theta/2)}{E}$$

When $\theta = 0°$, $b = \infty$

When $\theta = 180°$, $b = 0$.

27. **Draw V-I characteristics of a p-n junction diode. Explain, why the current under reverse bias is almost independent of the applied voltage up to the critical voltage.** **[2]**

Answer : The V-I characteristics of a p-n junction diode

I (mA)

Forward Current

Reverse breakdown voltage, V_{br}

V (V)

Threshold (knee) voltage

Reverse current

I (µA)

When a p-n junction diode is reverse biased, minority charge carriers of the diode drift across the junction towards the ends of the diode. The movement of these minority charge carriers produces currents of very small value. At any temperature, the number of minority charge carriers is constant. So the current flow due to these charge carriers also remains constant and it is independent of any applied potential difference.

SECTION-C

28. Two small identical electric dipoles AB and CD, each of dipole moment $\vec{p}$ are kept at an angle of 120° to each other in an external electric field $\vec{E}$ pointing along the x-axis as shown in the figure. Find the

    (a) Dipole moment of the arrangement, and

    (b) Magnitude and direction of the net torque acting on it.
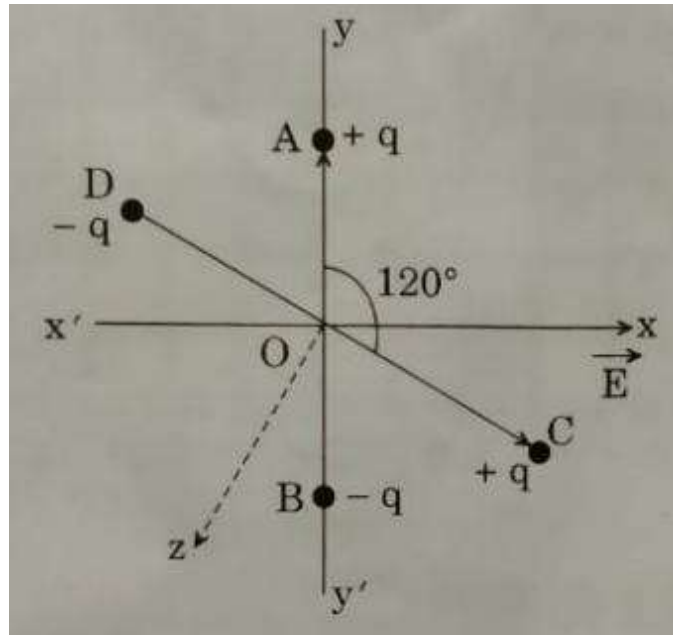
Answer : The direction of the two dipole moments and their resultant are shown in the figure.
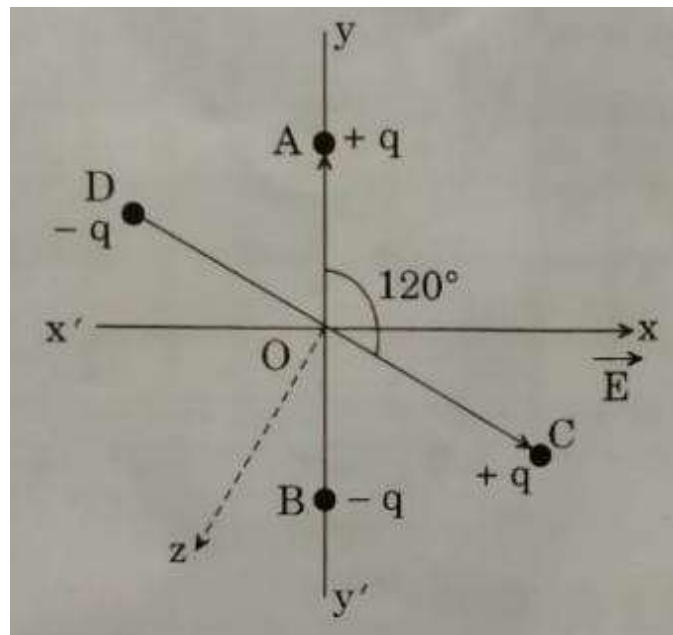
(a) Given $p_A = p_c = p$

Resultant dipole moment,

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

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

This dipole moment acts along the bisector of $\angle$ AOC i.e. at an angle of 30° with +X direction.

(b) Torque, $\tau = pE \sin 30° = \dfrac{1}{2} pE$

By right hand rule, the torque τ acts into the plane of paper along Z-direction.

OR

In the figure given below, find the

(a) Equivalent capacitance of the network between points A and B.

   Given : $C_1 = C_5 = 8\ \mu F$, $C_2 = C_3 = C_4 = 4\ \mu F$.

(b) Maximum charge supplied by the battery, and

(c) Total energy stored in the network.   **[3]**
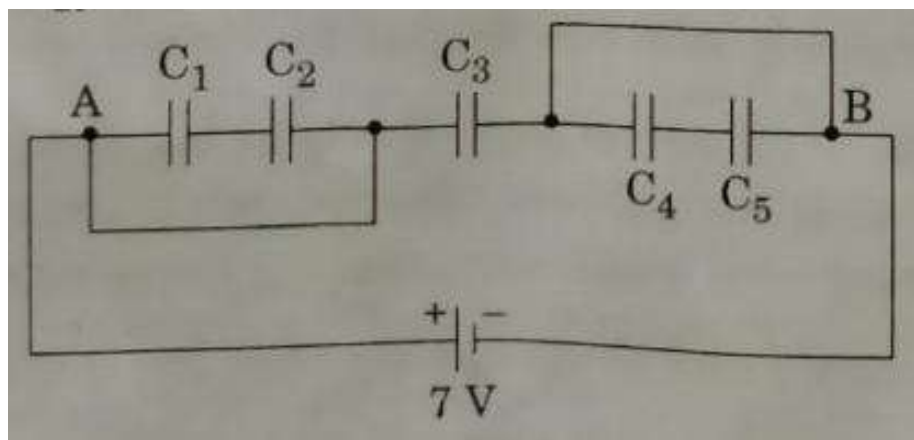
Answer : (a) The equivalent capacitance of the circuit will be equal to C_3.
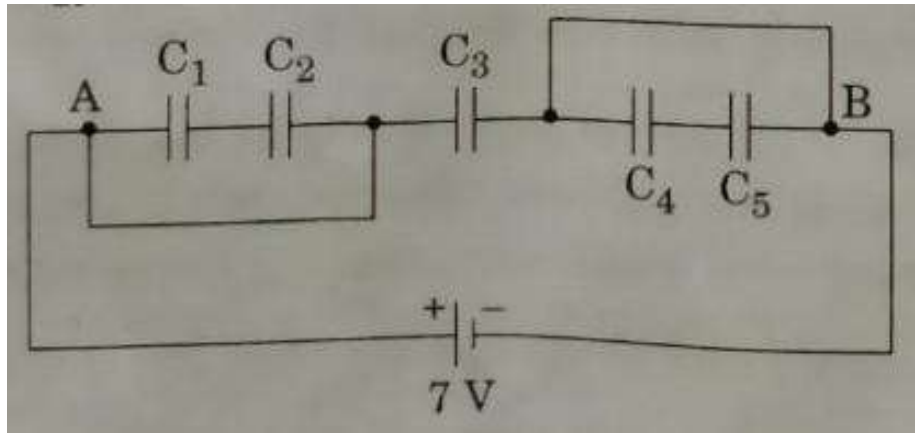
As the combination of C_1 and C_3 and C_4 and C_5 are shorted.

(b) As $Q = C_{eq} V$

$\quad C_{eq} = C_3 = 4\ \mu F$

$\quad Q_{max} = 4\ \mu F \times 7\ V = 28\ \mu C$

(c)

$$\text{Energy} = \frac{1}{2}CV^2$$

$$= \frac{1}{2} \times 4\ \mu F \times (7\ V)^2$$

$$= 98 \times 10^{-6}\ J$$

29. (a) Derive the condition of balance for Wheatstone bridge.

(b) Draw the circuit diagram of a meter bridge to explain how it is based on Wheatstone bridge. **[3]**

Answer : (a) A Wheatstone bridge is a special type of circuit which is in the shape of a rhombus. Each arm of this rhombus consists of a resistor. This circuit is used to determine the value of the unknown resistance.
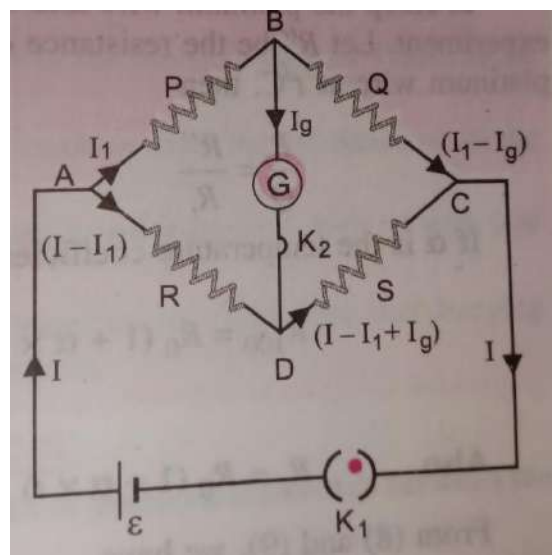
For four resistances P,Q, R and S, the Wheatstone Bridge is said to be balanced when:

$$\frac{P}{Q} = \frac{R}{S}$$

Let the current flow through the Wheatstone Bridge due to a cell having a potential difference E be I.

At point A, the current is divided into two parts: I_1 flowing through resistance P and $(I - I_1)$ flowing through R. At point B, I_1 is divided into two parts: I_g which flows through the galvanometer G and $(I_1 - I_g)$

which flows Q. The current I_g flowing through the galvanometer and the current $(I - I_1)$ flowing through R combine to form the current $(I - I_1 + I_g)$ which flows through S. When currents $(I - I_1 + I_g)$ and $(I_1 - I_g)$ reach point C, they combine to give a total current I.

Applying Kirchoff's Voltage Rule to loop ABDA,

$$I_1 P + I_g G - (I - I_1)R = 0 \qquad \qquad ...(1)$$

Here G is the resistance of the galvanometer.

Applying Kirchoff's Voltage Rule to loop BCDB,

$$(I_1 - I_g)Q - (I - I_1 - I_g)S - I_g G = 0 \qquad \qquad ...(2)$$

The value of R should be adjusted in such a way that the galvanometer G shows no deflection i.e. $I_g = 0$.

When $I_g = 0$, the bridge is said to be balanced.

$$I_1P + I_gG - (I - I_1)R = 0 \qquad \ldots(1)$$

Here G is the resistance of the galvanometer.

Applying Kirchoff's Voltage Rule to loop BCDB,

$$(I_1 - I_g)Q - (I - I_1 - I_g)S - I_gG = 0 \qquad \ldots(2)$$

The value of R should be adjusted in such a way that the galvanometer G shows no deflection i.e. $I_g = 0$.

When $I_g = 0$, the bridge is said to be balanced.

Substituting $I_g = 0$ in (1) and (2),
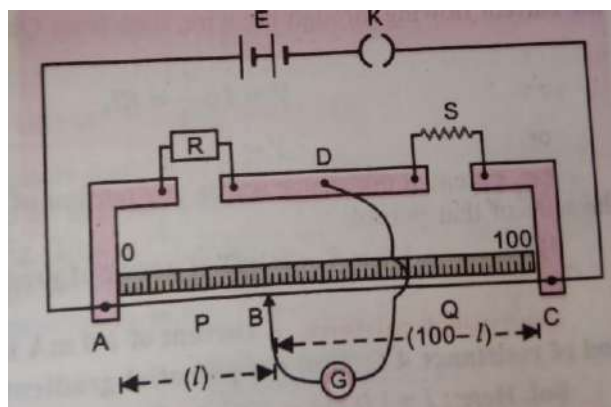
$$I_1P - (I - I_1)R = 0$$

or, $\qquad I_1P = (I - I_1)R \qquad \ldots(3)$

$$I_1Q - (I - I_1)S = 0$$

or, $\qquad I_1Q = (I - I_1)S \qquad \ldots(4)$

Dividing (3) by (4),

$$\frac{P}{Q} = \frac{R}{S}$$

(b)

In the metre bridge, a one metre long wire with a uniform cross-sectional area is stretched across points A and C. A metre scale is fitted parallel to the wire. Across the gaps between the copper strips, a resistance box R and an unknown resistance S are

connected to each other. A sliding contact in the form of a jockey B is capable of moving across the length of the wire. A galvanometer G is connected in such a way that its one terminal is connected to the jockey B and its other terminal to the terminal D of the copper strip.

Adjust the position of the jockey on the wire such that the galvanometer displays no deflection. If the jockey is at a distance l from point A, then AB = l cm and BC = (100 - l) cm.

If there's no deflection in the galvanometer, the bridge is said to be balanced. According to the Wheatstone bridge principle,

P/Q = R/S

If r is the resistance per centimetre of the length of the wire, then

Resistance of the length segment AB = lr

Resistance of the length segment BC = $(100 - l)r$

Here P = lr, Q = $(100 - l)r$
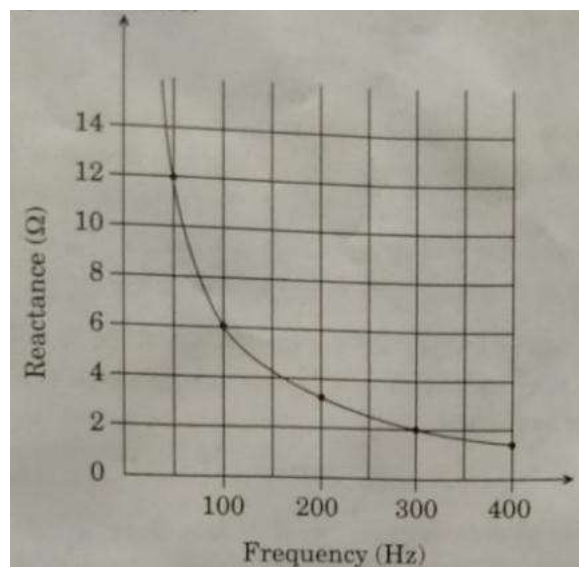
$$\frac{P}{Q} = \frac{R}{S}$$

$$\Rightarrow \quad \frac{lr}{(100 - l)r} = \frac{R}{S}$$

The value of the unkown resistance S can be calculated as:

$$S = \left(\frac{100 - l}{l}\right) \times R$$

30. The figure shows the graphical variation of the reactance of a capacitor with frequency of ac source.

Frequency (Hz)

(a) Find the capacitance of the capacitor.

(b) An ideal inductor has the same reactance at 100 Hz frequency. Find the value of inductance of the inductor.

(c) Draw the graph showing the variation of the reactance of this inductor with frequency.   [3]

Answer : (a)

$$X_c = \frac{1}{2\pi f C}$$

$$C = \frac{1}{2\pi f X_c}$$

For point A

$f = 100 \ H_z$

$$C = \frac{1}{2\pi(100 \ H_z) \times 6}$$

$$C = \frac{1}{1200\pi}F$$

(b)

Given $f = 100 \ H_z$

$X_L = 6 \ \Omega$

$X_L = 2\pi f \, l$

$$L = \frac{X_L}{2\pi f}$$

$$L = \frac{6}{2\pi \, 100} = \frac{3}{100\pi}H$$

(c)

As, $X_L = 2\pi f L$

$X_L \ \alpha \ L$
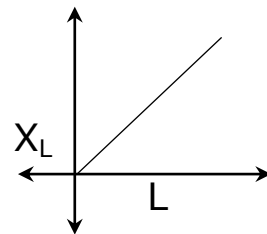
31. **What is the difference in the construction of an astronomical telescope and a compound microscope? The focal lengths of the objective**

and eyepiece of a compound microscope are 1.25 cm and 5.0 cm, respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 when the final image is formed at the near point. **[3]**

Answer : In a compound microscope, the objective lens has a smaller focal length than the focal length of the eyepiece. The distance between the objective lens and the eyepiece of a compound microscope is fixed. In an astronomical telescope, the objective lens has a larger focal length than the focal length of the eyepiece. The distance between the objective lens and the eyepiece of an astronomical telescope can be increased.

Given, F_0 = objective focal length

= 1.25 cm

F_e = focal length of eyepiece

= 5 cm.

M = magnification = 30

D = Least distance of distinct vision = 25 cm

$$m = \frac{L}{f}\left(1 + \frac{D}{f}\right)$$

$$30 = \frac{L}{1.25}\left(1 + \frac{25}{5}\right)$$

$$L = \frac{30 \times 1.25}{6} = 6.25 \text{ cm}$$

32. **The maximum kinetic energy of the photoelectrons emitted is doubled when the wavelength of light incident on the photosensitive surface changes from λ_1 to λ_2. Deduce expressions for the threshold wavelength and work function for the metal surface in terms of λ_1 and λ_2.** **[3]**

Answer :

Let v is the maximum velocity of photoelectrons when light of wavelength λ_1 is incident.

From photo-electric equation;

$$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_0} + v \quad ....(i)$$

when light of wavelength λ_2 is incident;

$$\frac{hc}{\lambda_2} = \frac{hc}{\lambda_0} + 2v \quad ....(ii)$$

On multiplying equation (i) by 2 and subtracting equation (ii) from (i);

$$\frac{2}{\lambda_1} - \frac{1}{\lambda_2} = \frac{1}{\lambda_0}$$

$$\Rightarrow \qquad \lambda_0 = \frac{\lambda_1 \lambda_2}{2\lambda_2 - \lambda_1}$$

This is the required expression for threshold wavelength.

Work function, $W_0 = \dfrac{hc}{\lambda_0}$

On putting value of $\lambda_0 = \dfrac{\lambda_1 \lambda_2}{2\lambda_2 - \lambda_1}$

$$W_0 = \frac{hc\,(2\lambda_2 - \lambda_1)}{\lambda_1 \lambda_2}$$

33. (a) Differentiate between half-life and average life of a radioactive substance.

(b) A radioactive substance decays for an interval of time equal to its mean life. Find the fraction of the amount of the substance which is left undecayed after this time interval. **[3]**

Answer : (a) Half-life of a radioactive substance is the time during which the nuclei of half of the atoms of the radioactive substance will disintegrate. Average life of a radioactive substance is the average time for which the nuclei of the atoms of the radioactive substance exist.

Half-life of a radioactive substance is equal to 0.693 times the average life of the substance.

(b)

Decayed substance, $N = N_0 e^{-\lambda t}$

For $t = \dfrac{1}{\lambda}$

$N = N_0 e^{-\frac{\lambda}{\lambda}} = N_0 e^{-1} = \dfrac{N_0}{e}$

Undecayed subtance, $N_{rem} = N_0 - N$

$$= N_0 - \dfrac{N_0}{e}$$

$\therefore \qquad\qquad N_{rem} = N_0\left(1 - \dfrac{1}{e}\right)$

Now, $\quad$ Fraction $= \dfrac{N_{rem}}{N_0} = 1 - \dfrac{1}{e}$

34. **What is the function of a solar cell? Briefly explain its working and draw its I-V characteristic curve.** **[3]**

Answer : A solar cell converts photons from sunlight into electricity.

A solar cell is based on the photovoltaic effect due to which light is directly converted to electricity.

When light falls on the n-type layer, located on the top of the solar cell, it gets absorbed. The energy from the absorbed light knocks out electrons. These electrons flow across the p-n junction and the flow of electrons constitutes an electric current. This current flows through the p-layer. A load resistance is

connected across the metal contacts of the n-type and the p-type layers to store electricity. After flowing through the load resistance, the current flows back to the n-layer. In this way a current is generated without the usage of any mechanical apparatus or mechanical energy.
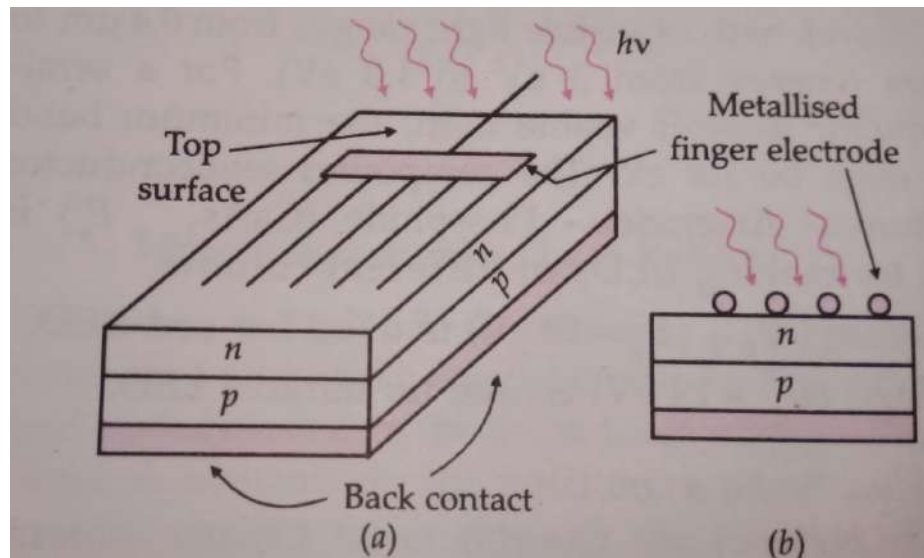
Here fig. (a) represents a typical p-n junction solar cell and fig. (b) represents the sectional view of the same solar cell.

SECTION-D

35. (a) **Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for r ≤ R and r ≥ R.**

(b) Two point charges + 1 μC and + 4 μC are kept 30 cm apart. How far from the + 1 μC charge on the line joining the two charges, will the net electric field be zero? **[5]**

Answer : (a) Consider a uniformly charged spherical shell with a radius R and a centre O. Let a charge +q be distributed uniformly over the surface of the shell. Consider a point P outside t the sphere such that $OP = r$. In order to calculate the electric field at P, consider a sphere S_1 with a centre O and the radius r. The sphere with radius r is a Gaussian surface. The electric field at every point on this surface is the same and is directly radially outwards.
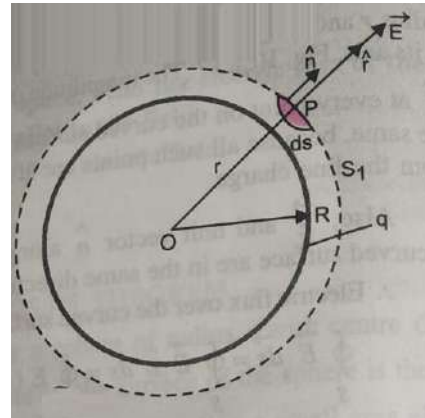
According to Gauss's Theorem,

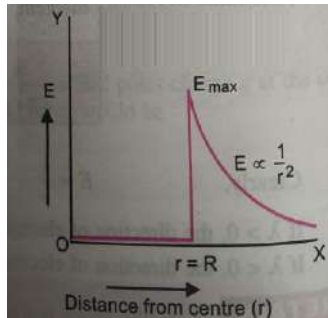$$\oint_S \vec{E}.\vec{ds} = \oint_S \vec{E}.\hat{n}\,ds = \frac{q}{\varepsilon_0}$$

or, $\quad E\oint_S ds = \frac{q}{\varepsilon_0}$

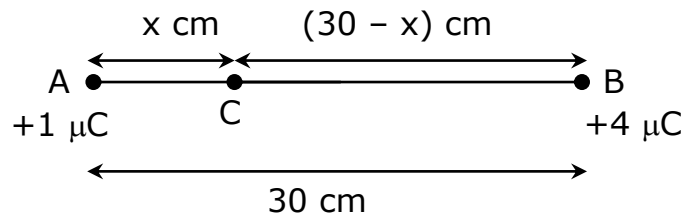$\therefore \quad E.(4\pi r^2) = \frac{q}{\varepsilon_0}$

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

For all points outside a uniformly charged electrical shell, the electric field due to the shell is as if the entire charge of the shell is concentrated at the centre of the shell.

(b) Let at point C, the net electric field is zero.

Electric field at point C,

$$E_C = \frac{kq_1}{r_1} - \frac{kq_2}{r_2}$$

$$E_C = \frac{k(1\ \mu C)}{x} - \frac{k(4\ \mu C)}{30 - x}$$

For $E_C = 0$

$$\frac{k(1\ \mu C)}{x} = \frac{k(4\ \mu C)}{30 - x}$$

$$\Rightarrow \quad 30 - x = 4x$$

$$\Rightarrow \quad 5x = 30$$

$$\therefore \quad x = 6\ cm$$

At a distance of 6 cm from 1 μC towards 4 μC change, the electric field is zero.
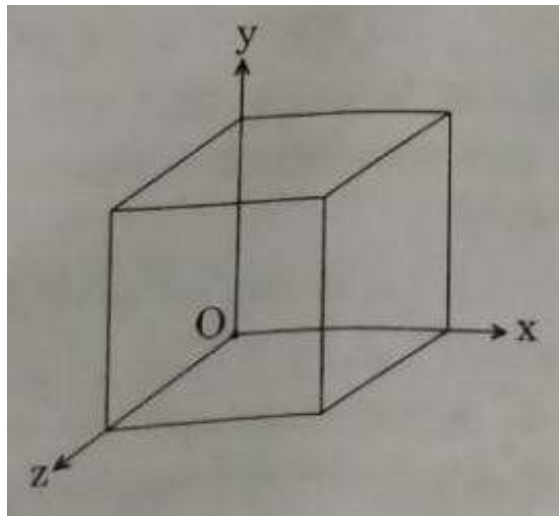
OR

(a) Two point charges q_1 and q_2 are kept r distance apart in a uniform external electric

field $\vec{E}$. **Find the amount of work done in assembling this system of charges.**

(b) A cube of side 20 cm is kept in a region as shown in the figure. An electric field $\vec{E}$ exists in the region such that the potential at a point is given by V = 10x + 5, where V is in volt and x is in m.
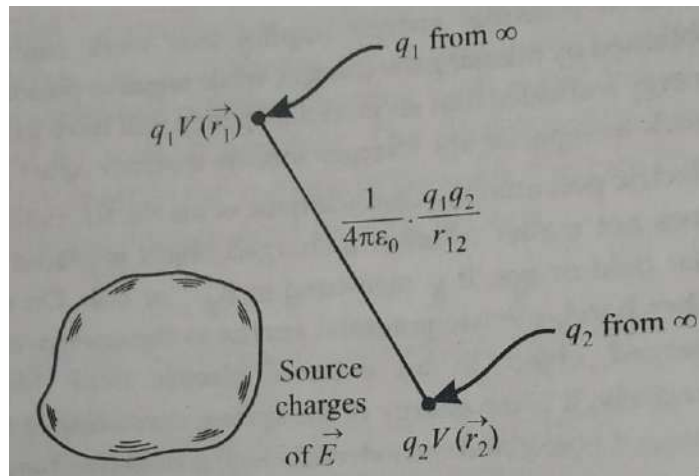

   Find the

   (i)   Electric field $\vec{E}$, and

   (ii)   Total electric flux through the cube.[5]

Answer : (a) $V(\vec{r}_1)$ and $V(\vec{r}_2)$ be the electric potential of the field $\vec{E}$ at the points having position vectors $\vec{r}_1$ and $\vec{r}_2$ as shown in fig.

Work done in bringing q_1 from ∞ to $\vec{r}_1$ against the external field $= q_1 V(\vec{r}_1)$

Work done in bringing q_1 from ∞ to $\vec{r}_2$ against the external field $= q_2 V(\vec{r}_2)$

Work done on q_2 against the force exerted by q_1

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_{12}}$$

Where r_{12} is the distance between q_1 and q_2.

Total potential energy of the system

= The work done in assembling the two charges

Or $U = q_1 V(\vec{r}_1) + q_2 V(\vec{r}_2) + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_{12}} \cdot$

(b) (i) Given,

Side of cube, $a = 20$ cm

Electric potential, $V = 10x + 5$

Electric field, $E = -\dfrac{dV}{dx} = -\dfrac{d(10x+5)}{dx} = -10$ NC^{-1}

$E = -10$ NC^{-1} (along negative X – axis)

(ii) Total electric flux, $\phi = \phi_1 + \phi_2 + \phi_3 + \phi_4 + \phi_5 + \phi_6$

$\phi = \vec{E}.\vec{A}_1 + \vec{E}.\vec{A}_2 + \vec{E}.\vec{A}_3 + \vec{E}.\vec{A}_4 + \vec{E}.\vec{A}_5 + \vec{E}.\vec{A}_6$

$\phi = -10$ NC^{-1} (20 cm $\times$ 20 cm) $\cos 0°$

$\qquad + \left(-10 \text{ NC}^{-1}\right)(20 \text{ cm} \times 20 \text{ cm}) \cos 90°$

$\qquad + \left(-10 \text{ NC}^{-1}\right)(20 \text{ cm} \times 20 \text{ cm}) \cos 90°$

$\qquad + \left(-10 \text{ NC}^{-1}\right)(20 \text{ cm} \times 20 \text{ cm}) \cos 90°$

$\qquad + \left(-10 \text{ NC}^{-1}\right)(20 \text{ cm} \times 20 \text{ cm}) \cos 90°$

$\qquad + \left(-10 \text{ NC}^{-1}\right)(20 \text{ cm} \times 20 \text{ cm}) \cos 180°$

$\phi = (-10 \text{ NC}^{-1})(400 \text{ cm}^2)(1) + 0 + 0 + 0 + 0 + \left(-10 \text{ NC}^{-1}\right)(400 \text{ cm}^2)(-1) = 0$

36. (a) A circular loop of radius R carries a current I. Obtain an expression for the magnetic field at a point on its axis at a distance x from its centre.

(b) A conducting rod of length 2 m is placed on a horizontal table in north-south direction. It carries a current of 5A from south to north. Find the direction and magnitude of the magnetic force acting on the rod. Given that the Earth's magnetic field at the place is 0.6 × 10^{-4} T and angle of dip is $\dfrac{\pi}{6}$. **[5]**

Answer : (a)

Consider a circular coil of radius R with centre O such that the plane of the coil is perpendicular to the plane of the paper. A current I is flowing in the coil in the direction as shown.
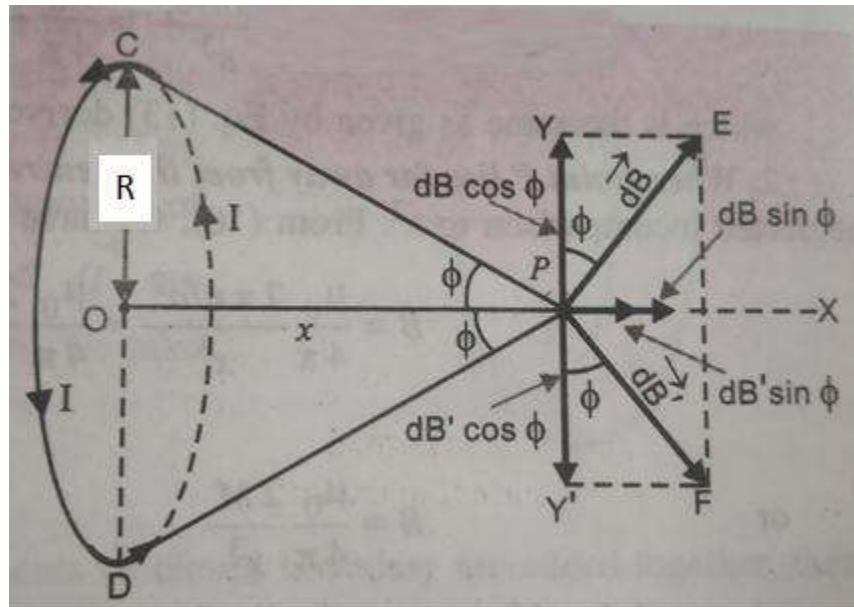
Let P be any point on the axis of the circular coil at a distance x from its centre O.

$$OP = x.$$

Two small elements of the coil each of length dl, at C and D are situated at diametrically opposite edges.

$$\text{Then,} \quad PC = PD = r = \sqrt{R^2 + x^2}$$
$$\text{Let} \quad \angle CPO = \phi = \angle DPO$$

The magnitude of magnetic field at P due to current element $I \overrightarrow{dt}$ a C is given by

$$dB = \frac{\mu_o}{4\pi}\frac{Idl\sin 90°}{r^2} \quad (\because \text{ R is small, therefore } \theta=90°)$$

$$= \frac{\mu_o}{4\pi}\frac{Idl}{\left(R^2 + x^2\right)} \qquad ....(1)$$

Similarly, the magnitude of magnetic field induction at P due to current element of length dl at D is given by

$$dB' = \frac{\mu_o}{4\pi}\cdot\frac{I\,dl\,\sin 90°}{r^2} = \frac{\mu_o I\,dl}{4\,\pi\left(R^2 + x^2\right)} \qquad .....(2)$$

From (1) and (2), $dB = dB' = \dfrac{\mu}{4\pi}\dfrac{Idl}{\left(R^2 + x^2\right)}$

Here, $\angle YPE = \angle Y'PF = \angle CPO = \angle DPO = \phi$

The magnetic fields $d\vec{B}$ and $d\vec{B'}$ are resolved into two rectangular components such that
(i) dB cos ϕ acts along PY and dB sin ϕ acts along PX,
(ii) dB' cos ϕ acts along PY' and dB' sin ϕ acts along PX.

The components of the magnetic field acting along PY and PY' are equal and opposite to each other. They cancel each other. The components of the magnetic field act along PX (i.e. along the axis of the coil) are in the same direction. Hence these components are added up.

Thus total magnetic field induction at P due to current through the whole circular coil is given by

$$B = \int dB \sin\phi = \int \frac{\mu_o \, I \, dl \sin\phi}{4\pi \left(R^2 + x^2\right)} = \frac{\mu_o \, I}{4\pi \left(R^2 + x^2\right)} \sin\phi \int dl$$

Since, $\sin\phi = \dfrac{R}{\sqrt{R^2 + x^2}}$ and $\int dl = 2\pi R$

$\therefore \quad B = \dfrac{\mu_o \, I}{4\pi \left(R^2 + x^2\right) \sqrt{R^2 + x^2}} \overset{a}{2\pi R} = \dfrac{\mu_o}{4\pi}$

(b)

Given,

Length of conductor, $l = 2$ m

Current, $I = 5$ A

Earth's magnetic field, $B = 0.6 \times 10^{-4}$ T

Angle of dip, $\delta = \dfrac{\pi}{6}$

Angle between current element

and magnetic field, $\theta = \dfrac{\pi}{2} - \dfrac{\pi}{6} = \dfrac{\pi}{3}$

Force, $F = BIl\sin\theta$

$$= 0.6 \times 10^{-4} \text{ T} \times 5 \text{ A} \times 2 \text{ m} \times \sin\frac{\pi}{3}$$

$$= 0.5196 \times 10^{-3} \text{ N (Downward)}$$

OR

(a) Obtain the expression for the deflecting torque acting on the current carrying rectangular coil of a galvanometer in a uniform magnetic field. Why is a radial

magnetic field employed in the moving coil galvanometer ?

(b) Particles of mass 1.6×10^{-27} kg and charge 1.6×10^{-19} C are accelerated in a cyclotron of dee radius 40 cm. It employs a magnetic field 0.4 T. Find the kinetic energy (in MeV) of the particle beam imparted by the accelerator. [5]

Answer : (a) A coil $PQRS_1$ is wound over a metallic frame which is non-magnetic.
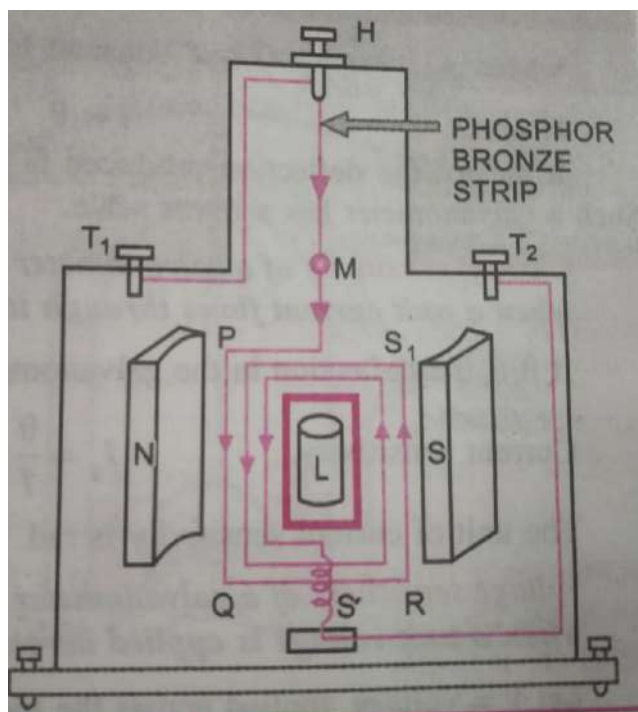
Consider that the coil is suspended freely in the space between the magnetic poles N and $S.$ Let,
l = length (PQ or RS_1) of the coil
b = breadth (QR or S_1P) of the coil
n = number of turns in the coil.
$A = l \times b$ = Area of each turn of the coil,

Let B and I represent the strength of the magnetic field in which the coil is suspended and the current passing through the coil $PQRS_1$. The current in the coil flows in the direction $PQRS_1$.

Let α be the angle made between the direction of the magnetic field and the normal drawn on the plane of the coil.

The torque experienced by a current-carrying rectangular coil when placed in a magnetic field has a magnitude, $\tau = nIBA \sin \alpha$

If the plane of the coil is parallel to the direction of the magnetic field, then $\alpha = 90°$.

$\therefore \sin \alpha = 1$

$\therefore$ Torque, $\tau = nIBA$

The coil rotates due to the action of this torque on it. When the coil rotates, the bronze strip of the coil with which the coil is suspended in the magnetic field gets twisted. This leads to the production of a restoring torque in the bronze strip. This restoring torque tries to restore the coil back to its original state.

If the strip is twisted by an angle θ and the restoring force acting per unit length of the twist of the strip is k, then the total restoring force produced = $k\,\theta$.

When the coil is in equilibrium,
deflecting torque = restoring torque

$\therefore \quad nIBA = k\theta$

or, Deflecting torque, $\tau = nIBA$

A radial magnetic field is used in a moving coil galvanometer to produce a constant torque on the coil irrespective of the rotation of the coil.

(b)

$m = 1.6 \times 10^{-27}$ kg

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

$r = 40$ cm $= 0.40$ m

$B = 0.4$ T

$v = \dfrac{qBr}{m}$

$v = \dfrac{\left(1.6 \times 10^{-19} \text{ C}\right)\left(0.4 \text{ T}\right)\left(0.40 \text{ m}\right)}{\left(1.6 \times 10^{-27} \text{ kg}\right)}$

$v = 16 \times 10^{6}$ m/s

Kinetic Energy $= \dfrac{1}{2}mv^2$

$\qquad = \dfrac{1}{2}\left(1.6 \times 10^{-27} \text{ kg}\right)\left(16 \times 10^{6} \text{ m/s}\right)^2$

$\qquad = 2.04 \times 10^{-13} \text{J}$

37. **(a) Derive lens maker's formula for a biconvex lens.**

(b) A point object is placed at a distance of 12 cm on the principal axis of a convex lens of focal length 10 cm. A convex mirror is placed coaxially on the other side of the lens at a distance of 10 cm. If the final

image coincides with the object, sketch the ray diagram and find the focal length of the convex mirror. **[5]**

Answer : (a) Consider a thin biconvex lens made of material of refractive index μ_2. This lens is placed in a medium with a refractive index μ_1 where $\mu_1 < \mu_2$. Consider the two surfaces of the lens ABC and ADC such that their poles are B and D, and their centres of curvature are C_1 and C_2 respectively. The radius of curvature of ABC and ADC are R_1 and R_2 respectively.
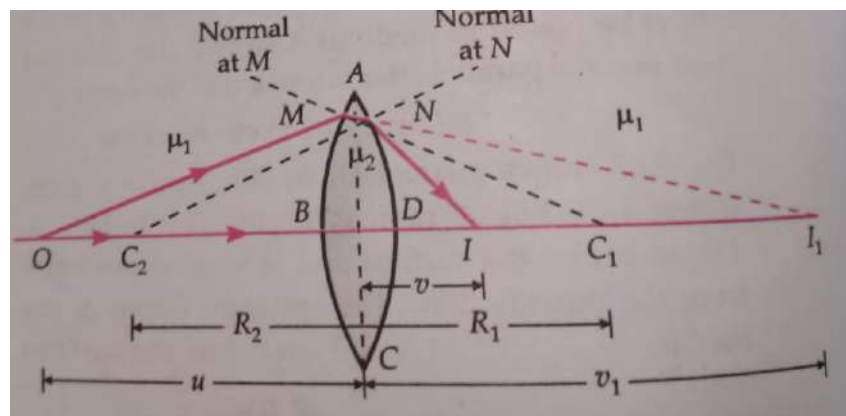
Let a point object O be placed on the principal axis of the biconvex lens. The object is present in the medium of the rarer refractive index μ_1. Ray OM is incident on the curved surface ABC. It undergoes refraction along MN and bends towards the normal at this surface. Had the second curved surface i.e. ADC been absent in the lens, MN would have met the principal axis at I_1. Thus I_1 can be treated the real image formed by ABC in the medium having a refractive index μ_2.

The object distance u_1, image distance v_1 and the radius of curvature R_1 are related as:

$$\frac{\mu_2}{v_1} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \qquad \ldots(1)$$

Ray MN undergoes refraction again at the curved surface ADC. It bends away from the normal at N. The ray emerging meets the principal axis at point I. Here the final image of O is formed by the lens.

For refraction at the second surface, I_1 behaves as a virtual object placed in the medium of refractive index μ_2. Similarly, I is the real image formed in the medium of refractive index μ_1. The radius of curvature R_2 is related between the object distance v_1 and the image distance v by the relation:

$$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_2} \qquad \ldots(2)$$

Adding equations (1) and (2)

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

or, $\qquad \dfrac{1}{v} - \dfrac{1}{u} = \left[\dfrac{\mu_2 - \mu_1}{\mu_1}\right]\left[\dfrac{1}{R_1} - \dfrac{1}{R_2}\right]$ $\qquad$ ...(3)

For an object placed at infinity, $u = \infty$.

The image will be formed at the focus of the lens.

$\therefore \qquad v = f$

$$\frac{1}{f} = \left[\frac{\mu_2 - \mu_1}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad \text{...(4)}$$

For a lens with refractive index μ placed in air,

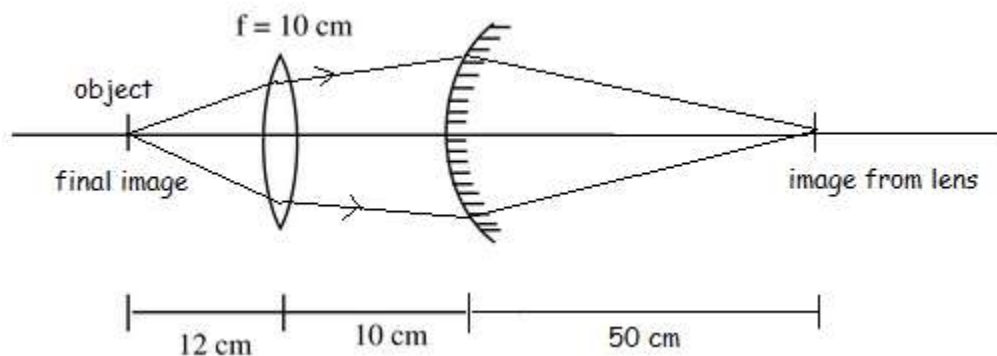$\qquad \mu_1 = 1 \text{ and } \mu_2 = \mu.$

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

Comparing equations (3) and (4),

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

(b)

The final image, formed by the combination, is coinciding with the object itself. This implies that the rays, from the object, are retracing their path, after refraction from the

lens and reflection from the mirror. The (refracted) rays are, therefore, falling normally on the mirror. Thus, the image of the convex lens should form at the center of curvature of the convex mirror.

The image distance of the convex lens using the lens formula

$$\frac{1}{v} - \frac{1}{-12} = \frac{1}{10}$$

On solving,   v = 60 cm

So the center of curvature of convex mirror is at a distance of 60 cm from the convex lens.

Thus, radius of curvature of the convex mirror,

R = 60 cm − 10 cm = 50 cm

Therefore, focal length of the convex mirror,

$$f = \frac{R}{2} = \frac{50 \text{ cm}}{2} = 25 \text{ cm}$$

OR

(a) What is a wavefront ? How does it propagate ? Using Huygens' principle, explain reflection of a plane wavefront from a surface and verify the laws of reflection.

(b) A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is obtained on a screen 1 m away. If the first minimum is formed at a

distance of 2.5 mm from the centre of the screen, find the (i) width of the slit, and (ii) distance of first secondary maximum from the centre of the screen. **[5]**

Answer : A wavefront is defined as the continuous locus of all particles of a medium which are vibrating in the same phase at any instant. Propagation of a wavefront in a medium takes place in the form of secondary waves or wavelets which spread out in all directions in the medium.
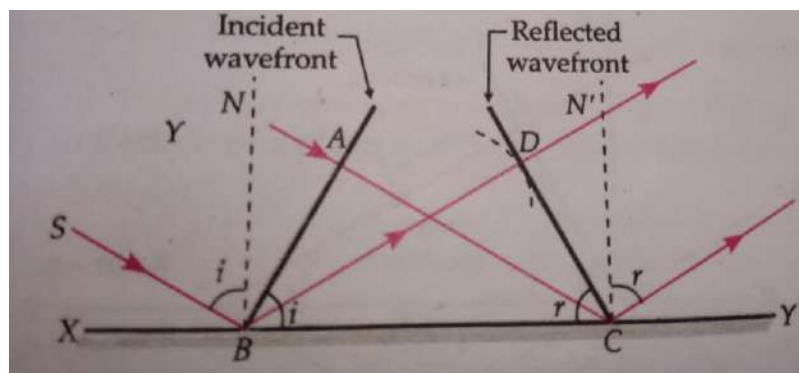
Consider a plane wavefront AB which is incident on the plane reflecting surface XY. The wavefront touches the reflecting surface at B and then at successive points towards C. From each point on BC, secondary wavelets arise with a speed c. By the time a disturbance from A reaches C, the secondary wavelets spread over a hemisphere of radius BD = AC = ct, where t is the time taken by the disturbance to travel from A to C. The tangent plane CD is drawn from C over a hemisphere of radius ct forms the new reflected wavefront.

Let ∠i and ∠r denote the angle of incidence
and angle of reflection respectively.
In △ABC and △DBC,

∠BAC = ∠CDB   [Both are right angles]

BC = BC   [Common side]

AC = BD   [Both have the same legnth]

∴ △ABC ≅ △DBC

Hence, ∠ABC = ∠DCB

or, ∠i = ∠r

The angle of incidence and angle of reflection
are equal to each other.

The incident ray, the normal, and the reflected ray
are denoted by SB, BN, and BD respectively.
These rays are perpendicular to the wavefront AB.
the reflecting surface XY, and the reflected
wavefront CD. AB, XY and CD are surfaces
which lie in the same plane.

(b) Given: Wavelength of light beam,

$$\lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}$$

Distance of the screen from the slit, D = 1 m

Distance of the first minima from the centre of the
screen, $x = 2.5 \text{ mm} = 2.5 \times 10^{-3}$ m

Now, $n\lambda = \dfrac{xd}{D}$

For first minima, n = 1.

Therefore, width of the slit,

$$d = \frac{\lambda D}{x} = \frac{(500 \times 10^{-9} \text{ m}) \times (1 \text{ m})}{2.5 \times 10^{-3} \text{ m}} = 0.2 \text{ mm}$$

Now, for secondary maxima

$$\frac{xd}{D} = (2n + 1)\frac{\lambda}{2}$$

For first secondary maxima, n = 1

$$\Rightarrow \quad \frac{xd}{D} = 3\frac{\lambda}{2}$$

$$\Rightarrow \quad x = 3\frac{\lambda D}{2d} = 3\frac{(500 \times 10^{-9} \text{ m}) \times (1 \text{ m})}{2 \times 2.5 \times 10^{-3} \text{ m}} = 0.3 \text{ mm}$$