CBSE

Class XII Physics

Board Paper – (Term 1 – 2021)

Time: 90 minutes **Maximum Marks: 35**

General Instructions:

(i) *This questions paper contains **55** questions out of which **45** questions are to be attempted. All questions carry equal marks.*
(ii) *The Question Paper consists of **three** sections, Section A, Section B and Section C.*
(iii) *Section A consists of **25** questions. Attempt any **20** questions from questions No. **1** to **25**.*
(iv) *Section B contains **24** questions. Attempt any **20** questions from questions No. **26** to **49**.*
(v) *Section C consists of **6** questions. Attempt any **5** questions from questions No. **50** to **55**.*
(vi) *The first **20** question attempted in section A and Section B and first 5 questions attempted in Section C by a candidate will be evaluated.*
(vii) *There is only **one** correct option for every multiple choice question (MCQ). Marks will not be awarded for answering more than one option.*
(viii) *There is **no** negative marking*

SECTION – A

This section consists of 25 multiple choice questions with over tilt choice to attempt any 20 questions. In case more than desirable number of questions are attempted, only first 20 questions will be considered for evaluation.

Q 1. An electric dipole placed in a non-uniform electric field will experience:
(A) Only a force
(B) Only a torque
(C) both force and torque
(D) Neither force nor torque

Q 2. Let NI be the number of electric field lines going out of an imaginary cube of side that encloses an isolated point charge 2q and N_2 be the corresponding number for an imaginary sphere of radius that encloses an isolated point charge 3q. Then (N_1/N_2) is:

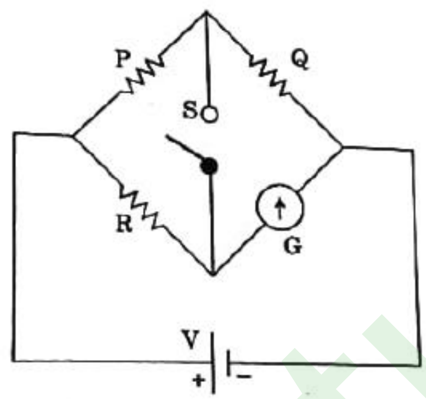
(A) $\frac{1}{x}$

(B) $\frac{2}{3}$

(C) $\frac{9}{4}$

(D) π

Q 3. In the circuit given below P ≠ R and the reading of the galvanometer is same with Switch S open or closed. Then:



(A) $I_Q = I_R$
(B) $I_R = I_G$
(C) $I_P = I_G$
(D) $I_Q = I_G$

Q 4. Two wires A and B, of the same material having length in the ratio 1: 2 and diameter in the ratio 2: 3 are connected in series with a battery. The ratio of the potential differences (V_A/ V_B) across the two wires respectively is:

(A) $\frac{1}{3}$

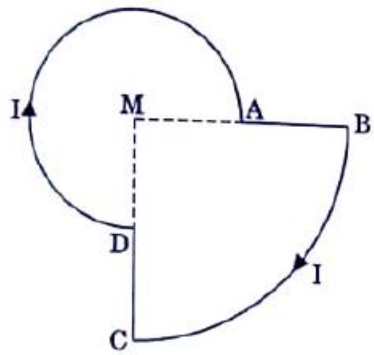
(B) $\frac{3}{4}$

(C) $\frac{4}{5}$

(D) $\frac{9}{8}$

Q 5. Two moving coil galvanometers G_1 and G_2 have the following particulars respectively:
N_1=30, A_1 = 3.6 x 10^{-3} m^2, B_1= 0.25 T
N_2= 42, A_2 = 1.8 x $10^{-3,}$ m^2, B_2 = 0.50 T
The spring constant is same for both the galvanometers. The ratio of current sensitivities of G_1 and G_2 is
(A) 5 : 7
(B) 7 : 5
(C) 1:4
(D) 1 : 1

Q 6. A current I is flowing through the loop as shown in the figure (MA = R, MB = 2R). The magnetic field at the centre of the loop is $\frac{\mu_o I}{R}$ times:



(A) $\frac{5}{16}$, into the plane of the paper

(B) $\frac{5}{16}$, out of the plane of the paper

(C) $\frac{7}{16}$, out of the plane of the paper

(D) $\frac{7}{16}$, into the plane of the paper

Q 7. A capacitor and an inductor are connected in two different ac circuits with a glowing in each circuit. The bulb glows more brightly when:

(A) the number of turns in the inductor is increased
(B) the separation between the plates of the capacitor is increased
(C) an iron rod is introduced into the inductor
(D) a dielectric is introduced into the gap between the plates of the capacitor

Q 8. A pure inductor of 318 mH and a pure resistor of 75 Ω are connected in series to an ac source Of 50 Hz. The voltage across 75 Ω resistor is found to be 150 V. The source voltage is:

(A) 150 V
(B) 175 V
(C) 220 V
(D) 250 V

Q 9. The electric potential at a point on the axis of a short electric dipole, at a distance x from the mid -point of dipole is proportional to:

(A) $\frac{1}{x^4}$

(B) $\frac{1}{x^{3/2}}$

(C) $\frac{1}{x^3}$

(D) $\frac{1}{x^2}$

Q 10. Let F_1 be the magnitude of the force between two small spheres, charged to a constant potential in free space and F_2 be the magnitude of the force between them in a medium of dielectric constant k. Then (F_1 / F_2) is:

(A) $\frac{1}{k}$

(B) k

(C) k^2

(D) $\frac{1}{k^2}$

Q 11. infinity resistance in a resistance box has:

(A) a resistance of $10^5\ \Omega$

(B) a resistance of $10^7\ \Omega$

(C) a resistance of ∞ resistance

(D) a gap only

Q 12. A battery of 15 V and negligible internal resistance is connected across a 50 Ω resistor. The amount of energy dissipated as heat in the resistor in one minute is:

(A) 122 J

(B) 270 J

(C) 420 J

(D) 720 J

Q 13. Lenz's law is the consequence of the law of conservation of:

(A) energy

(B) charge

(C) mass

(D) momentum

Q 14. The vertical component of earth's magnetic field at a place is $\left(\frac{1}{\sqrt{3}}\right)$, times the horizontal J3 component. The angle of dip at that place is:

(A) 0°

(B) 30°

(C) 45°

(D) 60°

Q 15. A long straight wire in the horizontal plane carries a current of 15 A in north to south direction. The magnitude and direction of magnetic field at a point 2.5 m east of the wire respectively are:

(A) 1.2 μT, vertically upward

(B) 1.2 μT, vertically downward
(C) 0.6 μT, vertically upward
(D) 0.6 μT, vertically downward

Q 16. The emf induced in a 10 H inductor in which current changes from 11 A to 2 A in 9×10^{-1} s is:
(A) 10^4 V
(B) 10^3 V
(C) 10^2 v
(D) 10 v

Q 17. A charge Q is placed at the centre of the line joining two charges q and q. The system of the three charges will be in equilibrium if Q is:
(A) $+\frac{q}{3}$
(B) $-\frac{q}{3}$
(C) $+\frac{q}{4}$
(D) $-\frac{q}{4}$

Q 18. Electric flux of an electric field $\vec{E}$ g through an area d $\vec{A}$ is given by:
(A) $\vec{E} \times d\vec{A}$
(B) $\frac{\vec{E} \times d\vec{A}}{\varepsilon_0}$
(C) $\vec{E} \cdot d\vec{A}$
(D) $\frac{\vec{E} \cdot d\vec{A}}{\varepsilon_0}$

Q 19. In a potentiometer experiment, the balancing length with a cell is 120 cm. When the cell is shunted by a 1 Ω resistance, the balancing length becomes 40 cm. The internal resistance of the cell is:
(A) 10 Ω
(B) 7 Ω
(C) 3 Ω
(D) 2 Ω

Q 20. An electron is projected with velocity $\vec{v}$ along the axis of a current carrying long solenoid. Which one of the following statements is true?
(A) The path of the electron will be circular about the axis.
(B) The electron will be accelerated along the axis.
(C) The path of the electron will be helical.

(D) The electron will continue to move with the same velocity $\vec{v}$ along the axis of the solenoid.

Q 21. If the speed v of a charged particle moving in a magnetic field $\vec{B}$ ($\vec{v}$ is perpendicular to $\vec{B}$) is halved, then the radius of its path will:

(A) not change
(B) become two times
(C) become one- fourth
(D) become half

Q 22. A metal plate is getting heated. Which one of following statements is **incorrect**?

(A) It is placed in a space varying magnetic field that does not vary with time.
(B) A direct current is passing through the plate.
(C) An alternating current is passing through the plate.
(D) It is placed in a time varying magnetic field.

Q 23. In an ac circuit the applied voltage and resultant current are $E = E_0 \sin \omega t$ and $I = I_0 \sin (\omega t + \frac{\pi}{2})$ respectively. The average power consumed in the circuit is:

(A) $E_0 I_0$
(B) $\frac{E_0 I_0}{2}$
(C) $\frac{E_0 I_0}{\sqrt{2}}$
(D) Zero

Q 24. The speed acquired by a free electron when accelerated from rest through a potential difference of 100 V is :

(A) 6×10^6 ms^{-1}
(B) 3×10^6 ms^{-1}
(C) 4×10^5 ms^{-1}
(D) 2×10^3 ms^{-1}

Q 25. Which one of the following is **not** affected by the presence of a magnetic field?

(A) A current carrying conductor
(B) A moving charge
(C) A stationary charge
(D) A rectangular current loop with its parallel to the felid

SECTION B

This section consists of **24** multiple choice questions with over all choice to attempt any **20** questions. In case more than desirable number of questions are attempted, only first **20** questions will be considered for evaluation.

Q 26. Two point charges + 16q and – 4q are located at x = 0 and x = L. The location of the point on x-axis at which the resultant electric field due to these charges is zero, is:

(A) 8 L

(B) 6 L

(C) 4 L

(D) 2 L

Q 27. An electric dipole of dipole moment 4×10^{-5} C-m, kept in a uniform electric field of 10^{-3} NC^{-1}, experience a torque of 2×10^{-8} Nm. The angle which the dipole makes with the electric field is :

(A) 30°

(B) 45°

(C) 60°

(D) 90°

Q 28. Three identical charges are placed on x-axis from left to right with adjacent charges separated by a distance d. The magnitude of the force on a charge from its nearest neighbour charge is F. Le $\hat{1}$ be the unit vector along + x axis, then the net force on each charge from left to right is :

(A) $(2\,E\hat{1}, -2\,F\hat{1}, 2\,F\hat{1})$

(B) $(F\hat{1}, 0, F\hat{1})$

(C) $(-\frac{5}{4}F\hat{1}, 0, +\frac{5}{4}F\hat{1})$

(D) $(2\,F\hat{1}, 0, 2\,F\hat{1})$

Q 29. Two students A and B calculate the charge flowing through a circuit. A concludes that 300 C of charges flows in 1 minute. B concludes that 3.125×10^{19} electrons flow in 1 second. IF the current measured in the circuit is 5A, then the correct calculation is done by :

(A) A

(B) B

(C) both A and B

(D) neither A nor B

Q 30. The resistance of two wires having same length and same area of cross-section are 2Ω and 8Ω respectively. If the resistivity of 2Ω wire is 2.65×10^{-8} Ω–m then the resistivity of 8Ω wire is :

(A) 10.60×10^{-8} Ω-m

(B) 8.32×10^{-8} Ω-m

(C) 7.61×10^{-8} Ωm

(D) 5.45×10^{-8}Ωm

Q 31. In a certain region field $\vec{E}$ and magnetic field $\vec{B}$ are perpendicular to each other. An electron enters the region perpendicular to the direction of both $\vec{E}$ and $\vec{B}$ moves undeflected. The speed of the electron is :

(A) $\vec{E} . \vec{B}$

(B) $|\vec{E} \times \vec{B}|$

(C) $\frac{|\vec{E}|}{|\vec{B}|}$

(D) $\frac{|\vec{B}|}{|\vec{E}|}$

Q 32. A test charge of 1.6×10^{-19} C is moving with a velocity $\hat{v} = (4\hat{i} + 3\hat{k}$ N) m s^{-1} in a magnetic field $\hat{B} = (3\hat{k} + 4\hat{i})$ T. The force on this test charge is :

(A) $24\hat{j}$ N

(B) $-24\hat{i}$ N

(C) $24\hat{k}$ N

(D) 0

Q 33. In a series LCR circuit, at resonance the current is equal to :

(A) $\frac{V}{R}$

(B) $\frac{V}{X_c}$

(C) $\frac{V}{X_L - X_C}$

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

Q 34. The frequency of an ac source for which a 10 μF capacitor has a reactance of 1000Ω is :

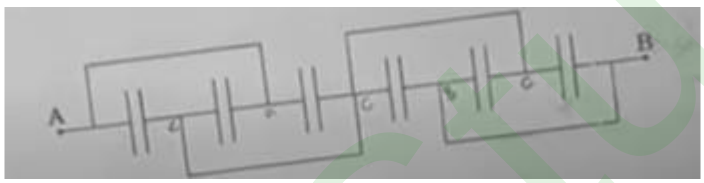
(A) $\frac{1000}{\pi}$Hz

(B) 50 Hz

(C) $\frac{50}{\pi}$Hz

(D) $\frac{100}{\pi}$Hz

Q 35. In the given network all capacitors used are identical and each one is of capacitance C. Which of the following is the equivalent capacitance between the points A and B?



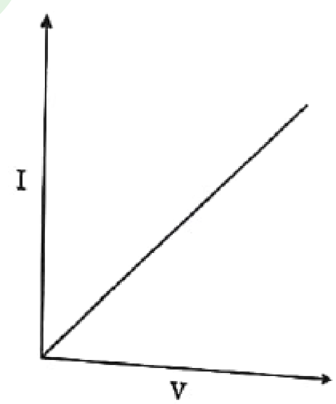
(A) 6C

(B) $\frac{5}{2}$C

(C) $\frac{3}{2}$C

(D) $\frac{5}{6}$C

Q 36. The given figure shows I – V graph of a copper wire whose length and area of cross-section are L and A respectively. The slope of this curve becomes :



(A) less if the length of the wire is increased
(B) more if the length of the wire is increased
(C) more if a wire of steel of same dimension is used
(D) more if the temperature of wire is increased

Q 37. When a potential difference V is applied across a conductor at temperature T, the drift velocity of the electrons is proportional to :

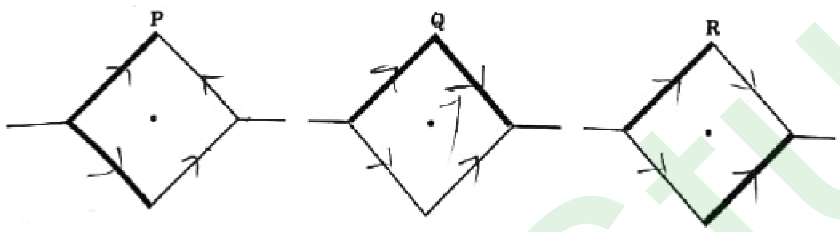
(A) T

(B) $\sqrt{T}$

(C) V

(D) $\sqrt{V}$

Q 38. Two identical thick wires and two identical thin wires, all of the same material and the same length form a square in three different ways P, Q and R as shown. Due to the current in these loops the magnetic field at the centre of the loop will be zero in case of :



(A) P and R only
(B) Q and R only
(C) P and Q only
(D) P, Q and R

Q 39. A circular current carrying coil produces a magnetic field B_0 at its centre. The coil is rewound so as to have three turns and the same current is passed through it. The new magnetic field at the centre is:

(A) $3\ B_0$

(B) $\frac{B_0}{3}$

(C) $\frac{B_0}{9}$

(D) $9\ B_0$

Q 40. Which one of the following statements is true?

(A) An inductor has infinite resistance in a dc circuit.
(B) A inductor and a capacitor both cannot conduct in a dc circuit.
(C) A capacitor can conduct in a dc circuit but not an inductor.
(D) An inductor can conduct in a dc circuit but not a capacitor.

Q 41. The magnetic flux linked with a coil is given by $\phi = 5t^2 + 3t + 16$, where is ϕ in webers and t in seconds. The induced emf in the coil at t = 5 s will be:

(A) 53 V
(B) 43 V
(C) 10V
(D) 6V

Q 42. If a charge is moved against a coulomb force of an electric field, then the:
(A) intensity of the electric field increases
(B) intensity of the electric field decreases
(C) work is done by the electric field
(D) work is done by the external source

Q 43. A charge Q is located at the centre of a circle of radius r. The work done in moving a test charge q_0 from point A to point B (at opposite ends of diameter AB) so as to complete a semicircle is $\left[k = \frac{1}{4\pi\varepsilon_0}\right]$:
(A) $k\frac{q_0 Q}{r}$
(B) $k\frac{Qq_0}{r^2}$
(C) kq_0Qr
(D) Zero

Q 44. A long solenoid carrying current produces a magnetic field B along its axis. If the number of turns in the solenoid is halved and current in it is doubled, the new magnetic field will be:
(A) $\frac{B}{2}$
(B) B
(C) 2B
(D) 4B

Question Nos. ***45*** *to* ***49*** *are Assertion (A) and statements Reason (R) type questions. Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below.*
(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false, but Reason (R) is true.

Q 45. **Assertion (A):** A bar magnet experiences a torque when placed in a magnetic field.
Reason (R): A bar magnet exerts a torque on itself due to its own magnetic field.

Q 46. **Assertion (A):** In a series LCR circuit connected to an ac source, resonance can take place.
Reason (R): At resonance $X_L = X_C$.

Q 47. Assertion (A): When a charged particle moves with velocity $\vec{v}$ in a magnetic field $\vec{B}$ $(\vec{v} \perp \vec{B})$, the force on the particle does no work.

Reason (R): The magnetic force is perpendicular to the velocity of the particle.

Q 48. Assertion (A): Induced emf in two coils made of wire of the same length and the same thickness, one of copper and another of aluminium is same. The current in copper coil is more than the aluminium coil.
Reason (R): Resistance of aluminium coil is more than that of copper coil.

Q 49. Assertion (A): A transformer is used to increase or decrease ac voltage only.
Reason (R): A transformer works on the basis of mutual induction.

SECTION C

*This section consists of **6** multiple choice questions with an overall choice to attempt any **5** questions. In case more than the desirable number of questions are attempted, only the first **5** questions will be considered for evaluation.*

Q 50. Two charged spheres A and B having their radii in the ratio 1: 2 are connected together with a conducting wire. The ratio of their surface charge densities $\left(\frac{\sigma_A}{\sigma_B}\right)$ will be.

(A) $\frac{1}{2}$

(B) 2

(C) $\frac{1}{4}$

(D) 4

Q 51. A current carrying square loop is suspended in a uniform magnetic field acting in the plane of the loop. If the force on one arm of the loop is $\vec{F}$, the net force on the remaining three arms of the loop will be.

(A) $3\vec{F}$

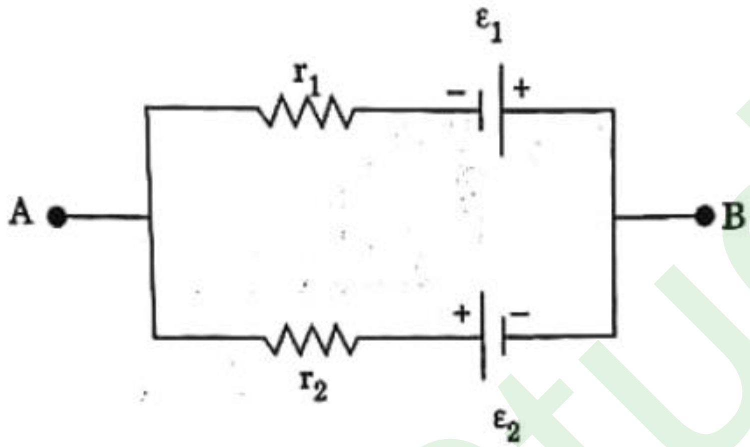
(B) $-3\vec{F}$

(C) $\vec{F}$

(D) $-\vec{F}$

Case – Study

A battery is a combination of two or more cells. In the following figure, a single batter is represented in which two cells of emf ε_1 and ε_2, and internal resistance r_1 and r_2 respectively are connected.



Answer the following questions:

Q 52. The equivalent emf of this combination is :

(A) $\frac{\varepsilon_1 r_1 + \varepsilon_2 r_2}{r_1 + r_2}$

(B) $\frac{\varepsilon_1 r_1 - \varepsilon_2 r_2}{r_1 + r_2}$

(C) $\frac{\varepsilon_1 r_2 - \varepsilon_2 r_1}{r_1 + r_2}$

(D) $\varepsilon_1 - \varepsilon_2$

Q 53. For terminal B to be negative :

(A) $\varepsilon_1 r_2 > \varepsilon_2 r_1$

(B) $\varepsilon_1 r_2 < \varepsilon_2 r_1$

(C) $\varepsilon_1 r_1 > \varepsilon_2 r_2$

(D) $\varepsilon_2 r_2 = \varepsilon_1 r_1$

Q 54. The current in the internal circuit is:

(A) $\frac{\varepsilon_1 + \varepsilon_2}{r_1 + r_2}$

(B) $\frac{\varepsilon_2 - \varepsilon_1}{r_1 + r_2}$

(C) $\frac{\varepsilon_1}{r_1} - \frac{\varepsilon_2}{r_2}$

(D) $\frac{\varepsilon_1}{r_2} - \frac{\varepsilon_2}{r_1}$

Q 55. The equivalent internal resistance of the combination is:

(A) $\frac{r_1 + r_2}{r_1 r_2}$

(B) $r_1 + r_2$

(C) $\frac{r_1 r_2}{r_1 + r_2}$

(D) $r_1 - r_2$

Solution

Section A

1. Correct option – c: Both force and torque
An electric dipole placed in a non-uniform electric field will experience both force and torque.

2. Correct option – b: 2/3
$\Phi = q/\varepsilon$
$= (2q/\varepsilon_0)/(3q/\varepsilon_0)$
Thus, $N_1/N_2 = 2/3$

3. Correct option – b: $I_R = I_G$
From given diagram, we can observe that when switch is closed or open the reading on galvanometer is same and resistance P and R are not same.
Using the balanced condition, we can say that
Current in resistance R and G will be same.
Thus, $I_R = I_G$

4. Correct option – d:
Given that,
Length of wire 1, $L_1 = L$
Diameter of 1st wire, $D_1 = 2D$
Area of cross-section, $A_1 = \pi\left(\frac{2D}{2}\right)^2 = \pi D^2$
$\therefore$ Resistance of wire 1, $R_1 = \frac{\rho L}{A} = \frac{\rho L}{\pi D^2}$
Similarly,
Length of wire 2, $L_2 = 2L$
Diameter of 2nd wire, $D_2 = 3D$
Area of cross-section, $A_2 = \pi\left(\frac{3D}{2}\right)^2 = \frac{9}{4} \times \pi D^2 = \frac{9}{4}A$
$\therefore\ R_2 = \frac{\rho(2L)}{\frac{9}{4}A} = \frac{8}{9}R$
Hence, the ratio of the potential difference of two wires are
$\frac{V_1}{V_2} = \frac{IR}{\frac{8}{9}IR} = \frac{9}{8}$

5. Correct option – a: $\frac{5}{7}$
Given that,
$N_1 = 30$
$A_1 = 3.6 \times 10^{-3}\ m^2$
$B_1 = 0.25\ T$
$N_2 = 42$
$A_2 = 1.8 \times 10^{-3}\ m^2$

B_2 =0.5 T

Now,

$$\frac{I_2}{I_1} = \frac{N_2B_2A_2}{N_1B_1A_1} = \frac{42 \times 0.5 \times 1.8 \times 10^{-3}}{30 \times 0.25 \times 3.6 \times 10^{-3}} = \frac{7}{5}$$

$$\therefore \frac{I_1}{I_2} = \frac{5}{7}$$

6. Correct option – d: $\frac{7}{16}$, into the plane of the paper.

Now for the given figure, the magnetic field at centre M due to current flowing through DA will be

$$B_{DA} = \frac{\mu_0 I}{4\pi R} \times \left(\frac{3\pi}{2}\right) = \frac{3\mu_0 I}{8R}$$

Similarly, the magnetic field due to the current flowing through BC is

$$B_{BC} = \frac{\mu_0 I}{4\pi(2R)} \times \left(\frac{\pi}{2}\right) = \frac{\mu_0 I}{16R}$$

Whereas, magnetic field due to AB and CD will be zero since point M lies on the straight line.

Hence net magnetic field for the given case will be

$B = B_{DA} + B_{BC} + B_{AB} + B_{CD} = \left(\frac{3\mu_0 I}{8R} + \frac{\mu_0 I}{16R} + 0 + 0\right) = \frac{7\mu_0 I}{16R}$ And by using the right-hand thumb rule we can conclude that direction of the magnetic field will be in the plane of the paper.

7. Correct option – d:

a dielectric is introduced into the gap between the plates of the capacitor.

From the given condition, the effective resistance for two circuits is

$$R_1 = \sqrt{r^2 + \left(\frac{1}{\omega C}\right)^2} \;\&\; R_2 = \sqrt{r^2 + (\omega L)^2}$$

Based on the preceding equations, we may conclude that increasing the gap between the plates of the capacitor reduces capacitance, which causes R1 to increase, resulting in a decrease in current.

As a result, the brightness of the bulb will diminish because its brightness is directly proportional to the current running through it.

Hence, the bulb will glow brighter when a dielectric is introduced into the gap between the plates of the capacitor.

8. Correct option – d: 250 V

Given that,

f = 50 Hz

L = 318 mH = 0.318

R = 75 Ω

V_R = 150 V

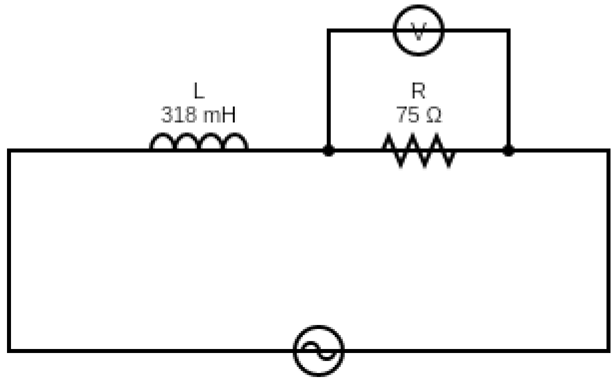
Current through R, $I = \frac{V}{R} = \frac{150}{75} = 2$ A

Now,

$$X_L = 2\pi f L = 2\pi \times 50 \times 0.318 \approx 100\ \Omega$$

$$V_L = IX_L = 2 \times 100 = 200\ V$$

Hence the total voltage, $V_{total} = (V_R^2 + V_L^2)^{\frac{1}{2}} = \sqrt{150^2 + 200^2} = 250$ V



9. Correct option – d: $\frac{1}{r^2}$

Now,

Electric potential for a dipole is given as

$V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2} \Rightarrow V \propto \frac{1}{r^2}$

10. Correct option – b: k

The force between two small spheres is given as

$F_1 = \frac{q_1q_2}{4\pi\epsilon_0 r^2}$ Whereas the force between them in the dielectric medium is

$F_2 = \frac{q_1q_2}{4\pi k\epsilon_0 r^2} \ldots (\because \epsilon = k\epsilon_0)$

$\therefore \frac{F_1}{F_2} = \frac{1}{1/k} = k$

11. Correct option – d: a gap only

Taking out the infinity plug introduces the air gap in the circuit. Since air is a bad conductor of electricity, no current flows, implying that the infinity resistance in the circuit is introduced.

12. Correct option – b: 270 J

Given that,

Voltage, V = 15 V

Time, t =60 s

Internal resistance, r = 50 Ω

Now,

Heat energy dissipated in time t is given gas

E =VIt

$\text{i.e.}, E = \frac{V^2}{r}t \ldots (\because V = Ir)$

$E = \frac{15^2}{50} \times 60 = 270\ J$

13. Correct option – a: Energy

Lenz's law is based on the principle of conservation of energy.

14. Correct option – b: 30°

Given that,

$B_v = \frac{1}{\sqrt{3}} B_H$

Also, $\tan\theta = \frac{B_V}{B_H} = \frac{\frac{B_H}{\sqrt{3}}}{B_H} = \frac{1}{\sqrt{3}}$

$\theta = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30°$

15. Correct option – a: 1.2 μT, Vertically upward

Given that,

Current, I = 15 A

Distance, d = 2.5 m

Now,

The magnitude of the magnetic field, $B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}\times15}{2\pi\times2.5}$

$\therefore B = 1.2\ \mu T$

And according to the right-hand thumb rule, the direction magnetic field will be upward.

16. Correct option – c: 10^2 V

Given that,

Inductance, L = 10 H

ΔI = 11 – 2 = 9 A

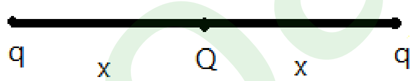
Time, t = 0.9 sec

Now,

$\epsilon = -L\frac{dI}{dt} = -\frac{10\times9}{0.9} = -100\ V$

17. Correct option – d: $-\frac{q}{4}$

A charge Q is placed at the centre of the line joining two charges q and q as shown below.



Now, for the system to be in equilibrium force between charges must be zero (ie., F =0).

$\therefore \frac{kq^2}{4x^2} + \frac{kqQ}{x^2} = 0 \Rightarrow Q = -\frac{q}{4}$

18. Correct option – c: $\vec{E}.d\vec{A}$

For the given case we know that electric flux is the dot product of the electric field and area of the cross section.

i.e., $\vec{\phi} = \vec{E}.d\vec{A}$

19. Correct option – d: 2 Ω

Given that,

Balancing length, l_1 = 120 cm

Shunted resistance, R = 1 Ω

New balancing length after shunting, l_2= 40 cm

Now,

Internal resistance, $r = R\left(\frac{120-40}{40}\right) = 2\ \Omega$

20. Correct option – d:

The electron will continue to move with the same velocity v along the axis of the solenoid.

As we know when an electron is projected with velocity v along the axis of a current-carrying long solenoid, it will continue to move with the same velocity v along the axis of the solenoid.

21. Correct option – d: Become half

Now,

$r = \frac{mv}{qB} \Rightarrow v \propto r$

22. Correct option –a:

It is placed in a space varying magnetic field that does not vary with time.

A metal plate can be heated by any of the flowing methods.

- Passing DC or AC through plates
- Keeping it time-varying magnetic field which produces induced current.

23. Correct option – d: Zero

Now,

Power = VI or EI

$\therefore P = E_0 I_0 \sin \omega t \times \sin\left(\omega t + \frac{\pi}{2}\right) = \text{zero}$

24. Correct option – a: $6 \times 10^6 m/s$

Given that,

Potential difference, V =100 V

Charge of electron, e = 1.6×10^{-19} C

Now,

$eV = \frac{1}{2} m_e v^2 \Rightarrow v = \sqrt{\frac{2eV}{m_e}} = 6 \times 10^6 m/s$

25. Correct option – c: A stationary charge

As we know charges at rest or rest remain unaffected by magnetic fields since force depends on velocity, and velocity is zero in the case of stationary charges.

Section B

26. Correct option – d: 2L

Given that,

Two-point charge +16q and -4q and located at x =0 and x = L

Now, we know that

$E = \frac{Q}{4\pi\epsilon_0 r^2} \Rightarrow \frac{16}{(L+x)^2} = \frac{-4}{x^2}$

$\therefore x = 2L$

27. Correct option – a:
Given that,
Dipole moment, p = 4× 10^{-5} C-m.
Electric field, E = 10^{-3} N/C
Torque, τ =2× 10^{-8} Nm
Now,
The torque due to dipole is given as
$\tau = pE\sin\theta \Rightarrow \theta = \sin^{-1}\left(\frac{\tau}{pE}\right)$
$\therefore \theta = \sin^{-1}\left(\frac{2\times10^{-8}}{4\times10^{-5}\times10^{-3}}\right) = 30°$

28. Correct option – c: $(-\frac{5F}{4}\hat{\imath}, 0\,\hat{\imath}, +\frac{5F}{4}\hat{\imath})$
Charge, q = q_1 = q_2 = q_3
Distance between two charges = d
Now,
Force on the first charge due to charge q_3 will be

$$F_{12} = \frac{kq^2}{d^2}$$

Force on the first charge due to charge q_3 will be
$F_{13} = k\frac{q^2}{4d^2}$
Thus net force acting on charge q_1 is
$F_{net} = F_{12} + F_{13} = F + \frac{F}{4}$
$\therefore F_{net} = -\frac{5F}{4}\hat{\imath}$
Here, the negative sign shows that force will be along the negative x-axis.
From this, we can conclude that force acting on three charges are $(-\frac{5F}{4}\hat{\imath}, 0\,\hat{\imath}, +\frac{5F}{4}\hat{\imath})$

29. Correct option – c: Both A and B
Given that,
According to the conclusion of A:
Charge flowing in 1 min, Q = 300 C
Time, t = 1 min = 60 sec
According to the conclusion of B:
Number of electron flows in 1 sec, n = 3.125× 10^{19} electron
Now,
Total current trough circuit according to A, $I_A = \frac{Q}{t} = 5$ A
Similarly
The total current through circuit according to B, $I_B = \frac{ne}{t} = \frac{3.125\times1.6\times10^{19}\times10^{-19}}{1} = 5$ A

30. Correct option – a: $10.6 \times 10^{-8}\Omega - m$
Given that,
R_1 = 2 Ω
R_2 = 8 Ω
L_1 = L_2 =L
A_1 =A_2 = A
Now,

$R = \frac{\rho L}{A} \Rightarrow \frac{R_1}{R_2} = \frac{\rho_1}{\rho_2}$

$\therefore \rho_2 = 2.65 \times 10^{-8} \times \frac{8}{2} = 10.6 \times 10^{-8} \Omega - m$

31. Correct option – c: $\frac{|\vec{E}|}{|\vec{B}|}$

According to the equation of Lorentz force, the net force acting on electrons due to the electric and magnetic field is given as

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

$\therefore |\vec{E}| + (|\vec{v}| \times |\vec{B}|) = 0$ ... ($\because$ Electron moves undeflected)

$\overrightarrow{|v|} = \frac{|\vec{E}|}{|\vec{B}|}$

32. Correct option – d: 0

Given that,

Charge, q = 1.6× 10^{-19} C

Velocity, $\vec{v} = 4\hat{i} + 3\hat{k}$

Magnetic field, $\vec{B} = 3\hat{k} + 4\hat{i}$

Now the force acting on test charge is

$F_B = q(v \times B) = 0$ N

33. Correct option – a: $\frac{V}{R}$

At resonance, the value of current can be expressed as

$I = \frac{V}{R}$ ... ($\because X_c = X_L$)

34. Correct option – c: $\frac{50}{\pi}$ Hz

Now,

As we know reactance of capacitor can be expressed as

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

$f = \frac{1}{2\pi \times 1000 \times 10 \times 10^{-6}} = \frac{50}{\pi}$ Hz

The frequency of an ac source for which a 10μF capacitor have a reactance of 1000 Ω is $\frac{50}{\pi}$ Hz

35. Correct option – c:

36. Correct option – a: will be less if the length of wire is increased.

From Ohm's law, we know that,

$\frac{1}{R} = \frac{I}{V} = $ slope

Hence for the given case, we can modify the above equation as

slope $= \frac{1}{R} = \frac{A}{\rho L}$

Now from this, we can conclude that the slope will be less if the length of the wire is increased.

37. Correct option – c: V

When a potential difference V is applied across a conductor at temperature T, the drift velocity of the electrons is proportional to V as we can see below.

$v_d = \frac{eV}{mI}\tau \ldots \left(\because E = \frac{V}{I}\right)$

$\therefore v_d \propto V$

38. Correct option – a: P and R only

From the given figure we can see that the net magnetic field at the centre of loop P and R will be zero since the current is flowing in a closed loop.

39. Correct option – d: $9B_0$

Now,

For the given case 2πr =3× 2πr' ⇒ r'=r/3

Initial magnetic field

$\therefore B_0 = \frac{H_0 I}{2r} \Rightarrow B = \frac{9H_0 I}{2r} = 9B_0$

40. Correct option – d: An inductor can conduct in a dc circuit but not a capacitor.

As we know capacitors can be used for AC but not for DC, similarly, the inductor can conduct DC by obstructing AC.

41. Correct option – a: 53 V

The magnetic flux linked with a coil is given by ϕ

As we know according to Faraday's law of electromagnetic induction, the emf induced by the current-carrying coil is given as

$\epsilon = \frac{d\phi}{dt} = \frac{d(5t^2+3t+16)}{dt} = 10t + 3$

$\epsilon = 10(5) + 3 = 53\ V$

42. Correct option – d: Work is done by the external source

As we know the work is said to be done by an external source when a charge is moving against a coulomb's force of an electric field.

43. Correct option – d: Zero

A charge Q is at the centre of a circle with radius r. the work done in moving a test charge q_0 from point A to point B.

$\text{i.e.}, W = Fs\cos\theta = 0$

44. Correct option – b: B

The magnetic field produced by a solenoid of N turns will be given as

$B = \mu_0 NI$

And for our case, if the number of turns is reduced to half and the current flowing through it doubled its initial value then the magnetic field produced by them will be

$B' = \mu_0 \left(\frac{N}{2}\right)(2I) = B$

45. Correct option – c: Assertion (A) is true, but Reason (R) is false.

For the given case, we know that a bar magnet experiences torque when it placed in a magnetic field

Also, we must note that the bar magnet doesn't exert a net torque on itself due to its own magnetic field although some of its components do.

46. Correct option – b: Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
For an LCR circuit that is connected to an AC power source the resonating frequency is given as
$\omega = \frac{1}{\sqrt{LC}} \ldots (X_c = X_L)$
Here, X_c and X_L are Capacitive reactance & Inductive reactance respectively.
Hence we can conclude that both Assertion and Reason are correct but Reason is not the correct explanation for assertion.

47. Correct option – a: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
According to the equation of Lorentz force, the direction of the magnetic field is always perpendicular to the velocity of the particle and the force acting on it is expressed as.
$F_B = q(\vec{v} \times \vec{B})$ And from the above equation, we can see that force is also perpendicular to velocity or displacement.
Hence the force on the particle does not work because force is perpendicular to the displacement.
i.e., $W = F.dr = Fdr\cos\theta = 0$

48. Correct option – a: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
For the given case, we know that resistance of the material is directly proportional to resistivity which is the intrinsic property of material, as a result of this resistance offered to the current flowing through the aluminium coil will be greater than the copper coil.
Hence we can conclude that the current in the copper coil is more than the aluminium coil although the induced emf is the same for both.

49. Correct option – a: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
As we know, a transformer works on the principle of mutual inductance and it is used to increase or decrease AC voltage only.

Section C

50. Correct option – b: 2
For a uniform charged distribution the surface charged density for the sphere can be expressed as
$\sigma = \frac{q}{4\pi r^2} \Rightarrow \left(\frac{\sigma_A}{\sigma_B}\right) = \frac{q_A r_B^2}{q_B r_A^2}$
Now since both the spheres are connected, the electric potential across both surfaces will be
$V_A = V_B \Rightarrow \frac{q_A}{q_B} = \frac{r_A}{r_B}$

$\therefore \left(\frac{\sigma_A}{\sigma_B}\right) = \frac{r_B}{r_A} = 2:1$

51. Correct option – d: -F

As we know force on two parallel arms of the current-carrying square loop will be zero, since $\vec{dl} \times \vec{B} = 0$.

Thus the force on the arm opposite to the one on which force acting is F will be –F.

Hence option d is correct among all.

Case – study

52. Correct option – c: $\frac{r_2\epsilon_1+r_1\epsilon_2}{r_2+r_1}$

The equivalent emf of the given combination is given as shown below.

$$\epsilon_{eq} = \frac{\frac{\epsilon_1}{r_1}+\frac{\epsilon_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}} = \frac{r_2\epsilon_1+r_1\epsilon_2}{r_2+r_1}$$

53. Correct option – b: $r_2\epsilon_1 + r_1\epsilon_2$

As we know for the given combination the equivalent emf is given as shown below.

$$\epsilon_{eq} = \frac{r_2\epsilon_1+r_1\epsilon_2}{r_2+r_1}$$

Hence from this, we can conclude that for the given combination of cells, the thermal B can be negative only if $r_2\epsilon_1 < r_1\epsilon_2$.

54. Correct option – a: $\frac{\epsilon_1+\epsilon_2}{r_1+r_2}$

According to Ohm's law, we know that electric current in a circuit is directly proportional to potential difference or emf across any given circuit.

i.e., $I = \frac{\epsilon_1+\epsilon_2}{r_1+r_2}$

55. Correct option – c: $\frac{r_1r_2}{r_1+r_2}$

In the given combination the cells are connected in parallel hence the equivalent internal resistance for the given circuit will be

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} \Rightarrow r_{eq} = \frac{r_1r_2}{r_1+r_2}$$

Physics Delhi (Set 2)

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 marks each.
(v) Section C : Q. no. **28** to **34** are long-answer type questions carrying 3 marks each.
(vi) Section D : Q. no. **35** to **37** are also long answer type questions carrying **5** marks each.
(vii) There is no overall choice 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 of **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 not permitted.
(x) You may use the following values of physical constants wherever necessary.

$c = 3 \times 10^8$ m/s
$h = 6.63 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C
$\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}
$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}
Mass of electron (m_e) = 9.1×10^{-31} kg
Mass of neutron = 1.675×10^{-27} kg
Mass of proton = 1.673×10^{-27} kg
Avogadro's number = 6.023×10^{23} per gram mole
Boltzmann constant = 1.38×10^{-23} JK^{-1}

Question 1

The wavelength and intensity of light emitted by a LED depend upon
(a) forward bias and energy gap of the semiconductor
(b) energy gap of the semiconductor and reverse bias
(c) energy gap only
(d) forward bias only

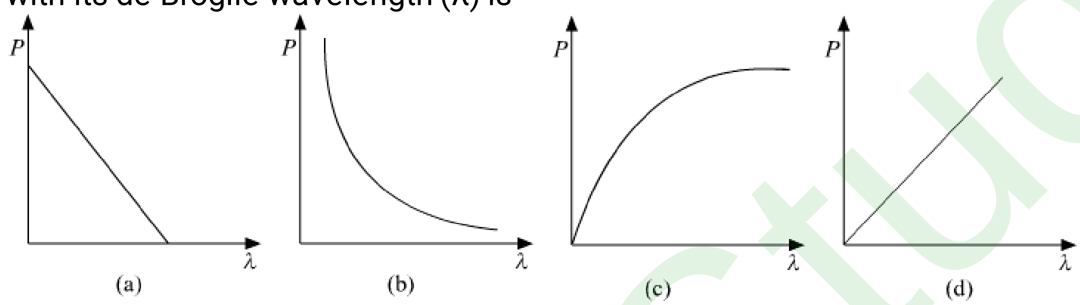
Solution:

The wavelength and intensity of light emitted by an LED depends on both energy gap and bias of the diode. Only when the diode is forward biased, it emits photons. The wavelength of the emitted light depends on the energy gap of the semiconductor.

Hence, the correct answer is option (a).

Question 2

The graph showing the correct variation of linear momentum (*p*) of a charge particle with its de-Broglie wavelength (λ) is -



Solution:

The relation between de-Broglie wavelength and the momentum is:

$$\lambda = \frac{h}{p}$$
$$\Rightarrow p = \frac{h}{\lambda}$$

By the above relation, we can conclude that the graph between the momentum and the de-Broglie wavelength is a rectangular hyperbola.

Hence, the correct answer is option (b).

Question 3

The selectivity of a series LCR a.c. circuit is large, when
(a) *L* is large and *R* is large
(b) *L* is small and *R* is small
(c) *L* is large and *R* is small
(d) *L* = *R*

Solution: Selectivity of a circuit depends on the quality of resonance. The quality factor is given by:

$$Q = \frac{\omega_0 L}{R}$$

High value of quality factor make sure that the resonance curve is sharp. Sharper the resonance curve is more selective is the LCR circuit. Thus, the selectivity of the LCR circuit is large when *L* is large and *R* is small.

Hence, the correct answer is option (c).

Question 4

Photo diodes are used to detect
(a) radio waves
(b) gamma rays
(c) IR rays
(d) optical signals

Solution: Photodiodes are used to detect the visible light, out of the given options optical signals is the most appropriate.

Hence, the correct answer is option (d).

Question 5

The relationship between Brewster angle θ and speed of light v in the denser medium is
(a) $c \cos\theta = v$
(b) $v \tan\theta = c$
(c) $c = v \tan\theta$
(d) $v \cos\theta = c$

Solution: Disclaimer: Two of the given option (b and c) are same.

Let the absolute refractive index of the given medium be μ and the speed of light in vacuum be c.

From Brewster's law:

$$\tan\theta = \mu$$

The refractive index can also be written as:

$$\mu = \frac{c}{v}$$

$$\Rightarrow \tan\theta = \frac{c}{v}$$

$$\Rightarrow c = v\tan\theta$$

Hence, the correct answer is option (b).

Question 6

A biconvex lens of focal length *f* is cut into two identical plano-convex lenses. The focal length of each part will be

(a) *f*

(b) *f*/2

(c) 2*f*

(d) 4*f*

Solution:

Let the focal of the equiconvex lens be *f* and that of the plano-convex lens be *f'*.

Let the radius of curvature for the equiconvex lens be *R*.

Applying Lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right) = \frac{2(\mu-1)}{R}$$

For the plano-convex lens, the focal length can be calculated as:

$$\frac{1}{f'} = (\mu - 1)\left(\frac{1}{R}\right) = \frac{(\mu-1)}{R}$$

Thus, *f'* = 2*f*

Thus, the focal length of the plano-convex lens is twice that of the equiconvex lens.

Hence, the correct answer is option (c)

Question 7

The phase difference between the current and the voltage in series LCR circuit at resonance is

(a) π

(b) π/2

(c) π/3

(d) zero

Solution:

At resonance the circuit is purely resistive and there is no phase difference between current and voltage.

Hence, the correct answer is option (d).

Question 8

Photons of frequency *v* are incident on the surface of two metals A and B of threshold frequency 3/4 *v* and 2/3 *v*, respectively. The ratio of maximum kinetic energy of electrons emitted from A to that from B is
(a) 2 : 3
(b) 4 : 3
(c) 3 : 4
(d) 3 : 2

Solution:

According to Einstein's photoelectric equation,
$h\nu = h\nu_0 + K_{\max}$
Where,
v = frequency of the incident light
v_0 = threshold frequency of the metal
K_{max} = maximum kinetic energy of the emitted photoelectrons

For the first metal,

$h\nu = h\left(\frac{3}{4}\nu\right) + K_1$
$\Rightarrow K_1 = \frac{h\nu}{4}$

For the second metal,

$h\nu = h\left(\frac{2}{3}\nu\right) + K_2$
$\Rightarrow K_2 = \frac{h\nu}{3}$

Thus, the ratio of the maximum kinetic energies is given as:

$\frac{K_1}{K_2} = \frac{3}{4}$

Hence, the correct answer is option (c).

Question 9

The electric flux through a closed Gaussian surface depends upon
(a) Net charge enclosed and permittivity of the medium
(b) Net, charge enclosed, permittivity of the medium and the size of the Gaussian surface
(c) Net charge enclosed only
(d) Permittivity of the medium only

Solution:
The electric flux through a closed Gaussian surface is given by:

$$\oint \overrightarrow{E}.\mathrm{d}\overrightarrow{s} = \frac{q}{\epsilon}$$

Where, q is the net charge enclosed by the Gaussian and∈∈is the permittivity of the medium.

Hence, the correct answer is option (a).

Question 10

A charge particle after being accelerated through a potential difference 'V' enters in a uniform magnetic field and moves in a circle of radius r. If V is doubled, the radius of the circle will become
(a) 2r
(b) √2r
(c) 4r
(d) r/√2

Solution: The relation between the accelerating potential and the accelerating voltage is given as:

$$r = \frac{\sqrt{2mqV}}{qB}$$

As the potential is doubled the radius of curvature becomes 2–√2 times.

Hence, the correct answer is option (b).

Question 11

A point charge is placed at the centre of a hollow conducting sphere of internal radius '*r*' and outer radius '2*r*'. The ratio of the surface charge density of the inner surface to that of the outer surface will be________.

Solution:

Let the point charge be q.
by gauss's law the charge on the inner surface will be $-q$
Surface charge density of the inner surface $\sigma_i = -\frac{q}{4\pi r^2}$
by charge conservation on the hollow sphere the outer surface will have charge q
Surface charge density of the inner surface $\sigma_o = \frac{q}{4\pi (2r)^2} = \frac{q}{16\pi r^2}$

$$\text{ratio} = \frac{\sigma_i}{\sigma_o} = \frac{\frac{-q}{4\pi r^2}}{\frac{q}{16\pi r^2}} = -\frac{4}{1}$$

Question 12

The __________, a property of materials C, Si and Ge depends upon the energy gap between their conduction and valence bands.

Solution: Conductivity

Question 13

The ability of a junction diode to _________ an alternating voltage, is based on the fact that it allows current to pass only when it is forward biased.

Solution: Rectify

Question 14

The physical quantity having SI unit $NC^{-1}m$ is _________.

Solution:

Electric Potential.

Question 15

A copper wire of non-uniform area of cross-section is connected to a d.c. battery. The physical quantity, which remains constant along the wire is _________.

Solution: Electric current.

Question 16

Write the conditions on path difference under which (i) constructive (ii) destructive interference occur in Young's double slit experiment.

Solution:

I_1 = intensity of light from slit 1
I_2 = intensity of light from slit 2
phase difference between 2 light waves $= \theta = \frac{2\pi\Delta x}{\lambda}$, where Δx = path difference
resultant intensity I is given by,
$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\theta$
for constructive interference I should by maximum $\Rightarrow \cos\theta = 1$
$\theta = 2n\pi$, n = Integer
$2n\pi = \frac{2\pi\Delta x}{\lambda}$
$\Delta x = n\lambda$
for distructive interference I should by minimum $\Rightarrow \cos\theta = -1$
$\theta = \left(2n+1\right)\pi$, n = Integer
$2n\pi = \frac{(2n+1)\pi\Delta x}{\lambda}$
$\Delta x = \frac{(2n+1)\lambda}{2}$

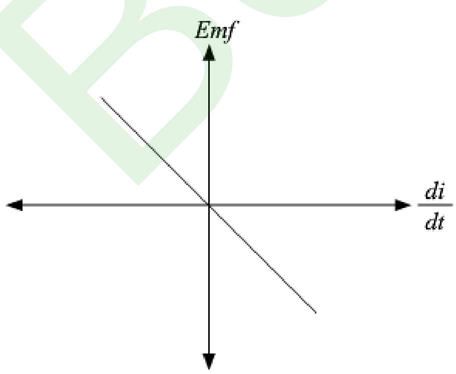
Question 17

Plot a graph showing variation of induced e.m.f. with the rate of change of current flowing through a coil.

OR

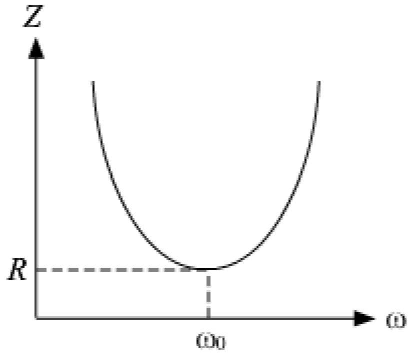
A series combination of an inductor (*L*), capacitor (*C*) and a resistor (*R*) is connected across an ac source of emf of peak value E_0, and angular frequency (ω). Plot a graph to show variation of impedance of the circuit with angular frequency (ω).

Solution:



OR

The graph showing the variation of impedance (Z) of the circuit with angular frequency (ω) is as shown below:

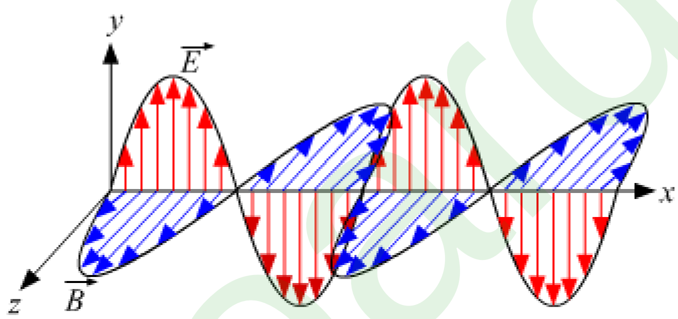


Here, ω_0 represents the resonance frequency for the LCR circuit and R is the resistance of the circuit.

Question 18

Depict the fields diagram of an electromagnetic wave propagating along positive X-axis with its electric field along Y-axis.

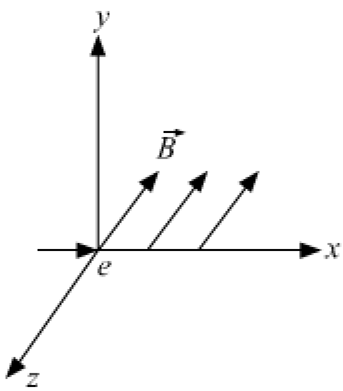
Solution:



Question 19

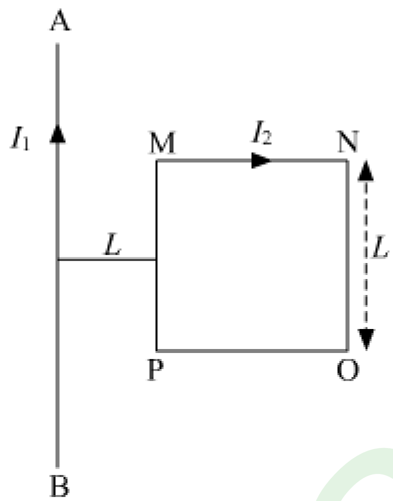
An electron moves along $+x$ direction. It enters into a region of uniform magnetic field.

$\overrightarrow{B}$ directed along $-z$ direction as show in fig. Draw the shape of trajectory followed by the electron after entering the field.



OR

A square shaped current carrying loop MNOP is placed near a straight long current carrying wire AB as shown in the fig. The wire and the loop lie in the same plane. If the loop experiences a net force *F* towards the wire, find the magnitude of the force on the side 'NO' of the loop.

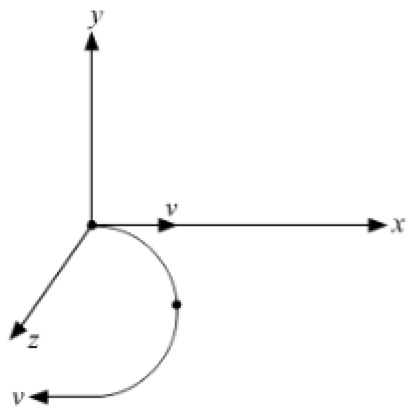


Solution:

Force on the electron is given by

$$\vec{F} = -q\left(\vec{v} \times \vec{B}\right)$$

So, the electron will follow a semi circular path in the magnetic field.



The force acting on the section MN and force on section PO will cancel as the wires are located at equal distance from the infinite wire but have current flowing in opposite directions.

The force acting on the whole loop,

$$F = \frac{\mu_o I_1 I_2 L}{2\pi L} - \frac{\mu_o I_1 I_2 L}{2\pi(2L)} = \frac{\mu_o I_1 I_2 L}{4\pi L}$$

Towards the wire.
The force acting on the side 'NO' is given by

$$F_{NO} = \frac{\mu_0 \ I_1 \ I_2}{2\pi(2L)} L = \frac{\mu_0 \ I_1 \ I_2}{4\pi} = F$$

Away from the wire.

Question 20

Define the term 'current sensitivity' of a moving coil galvanometer.

Solution:

Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit current flows through it.

Mathematically it can be given by:

$$I_S = \frac{NBA}{k}$$

where *k* is the couple per unit twist.

Question 21

(a) Define one Bacquerel.
(b) A radioactive substance disintegrates into two types of daughter nuclei, one type with disintegration constant λ_1 and the other type with disintegration constant λ_2. Determine the half-life of the radioactive substance.

Solution:

a) One Becquerel (Bq) is defined as the activity of a quantity of radioactive sample in which one nucleus decays per second. It is the S.I. unit of the activity.

b)

$$X \xrightarrow{\lambda_1} D_1$$

$$X \xrightarrow{\lambda_2} D_2$$

$$\lambda_{\text{effective}} = \lambda_1 + \lambda_2$$

$$\text{half life } \left(t_{1/2}\right) = \frac{\ln 2}{\lambda_{\text{effective}}} = \frac{0.693}{\lambda_1 + \lambda_2}$$

Question 22

In a single slit diffraction experiment, the width of the slit is increased. How will the (i) size and (ii) intensity of central bright band be affected? Justify your answer.

Solution: The size of the central maximum is given by $2\lambda/a$ where *a* is the slit width. It is clear from the above expression if a is increased, the size of the central maximum will decrease.

However, the intensity changes because of two factors.

1. Increasing the width of the slit, causes more light energy to fall on the screen as compared to that with the original width.

2. The light energy is now squeezed into a smaller area on the screen because the size of the central maximum is reduced. The two factors make the intensity increase manyfold.

Question 23

In case of photo electric effect experiment, explain the following facts, giving reasons.
(a) The wave theory of light could not explain the existence of the threshold frequency.
(b) The photo electric current increases with increase of intensity of incident light.

Solution:

(a) If light were strictly a wave, the energy in the light would be represented by the amplitude of the light wave. A more intense light source, even if it were of a lower frequency, would have enough energy to knock out electrons away from the metal surface, which is necessary to generate a photoelectric current.

What actually occurs is that the light below a certain threshold frequency does not generate any current, no matter how intense the light is.

(b) The intensity represents the number of photons, if the frequency of the incident light is more than the threshold frequency then more intensity will make ensure that more number of photons are falling over the metal surface and more photoelectrons will be emitted that increases the photoelectric current.

Question 24

Gamma rays and radio waves travel with the same velocity in free space. Distinguish between them in terms of their origin and the main application.

Solution:

Gamma rays are produced from radioactive decay of the nucleus while radio waves are produced from rapid acceleration and decelerations of electrons in aerials.

Gamma rays are used as catalyst in the manufacturing of some chemicals. They are also used in treatment of cancer.

Radio waves are used in radio and television communication and broadcasting.

Question 25

Use Bohr's model of hydrogen atom to obtain the relationship between the angular momentum and the magnetic moment of the revolving electron.

Solution:

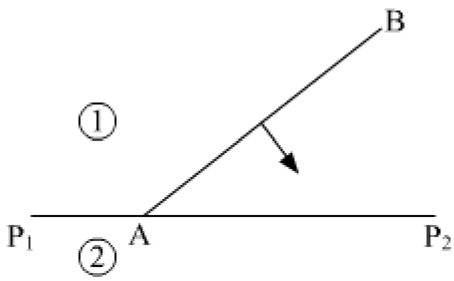
According to Bohr's second postulate of the allowed values of angular momentum are integral multiples of $h/2\pi$.

Let n be the principal quantum number, r_n be the radius of nth possible orbit and v_n be the speed of moving electron in n^{th} orbit

$L_n = m_n v_n r_n = \frac{nh}{2\pi}$
magnetic moment, μ = current $\times$ area
$\mu = \frac{e}{T} \times \pi {r_n}^2 = \frac{ev_n}{2\pi r_n} \times \pi {r_n}^2 = \frac{ev_n r_n}{2} = \frac{emv_n r_n}{2m} = \frac{eL_n}{2m}$
or $\mu = \frac{eL}{2m}$

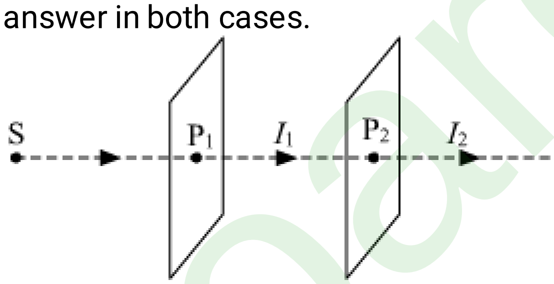
Question 26

Define the term 'wave front of light'. A plane wave front AB propagating from denser medium (1) into a rarer medium (2) is incident of the surface P_1P_2 separating the two media as shown in fig.
Using Huygen's principle, draw the secondary wavelets and obtain the refracted wave front in the diagram.

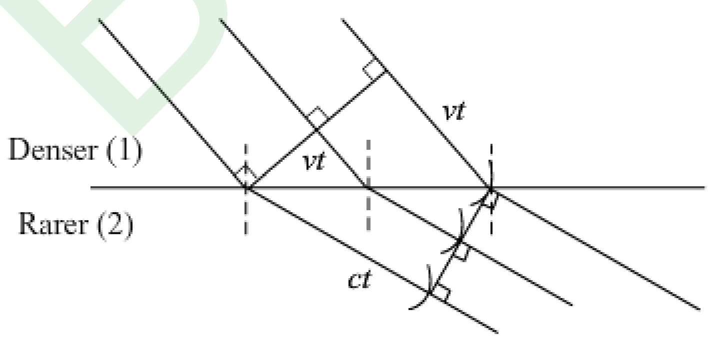


OR

Light from a sodium lamp (S) passes through two polaroid sheets P_1 and P_2 as shown in fig. What will be the effect on the intensity of the light transmitted (i) by P_1 and (ii) by P_2 on the rotating polaroid P_1 about the direction of propagation of light? Justify your answer in both cases.



SOLUTION: It is defined as the locus of all the particles of a medium vibrating in the same phase at a given instant of time.



(i) There is no change in I_1 on rotation of P_1, because the intensity of light does not change irrespective of the orientation of pass–axis of the polaroid.

(ii) I_1 = intensity of polarised light from P_1

I_2 = intensity of polarised light from P_2

θ = Angle between pass axis of polaroid P_1 and P_2

by Malus's Law, $I_2 = I_1 \cos^2 \theta$

Thus I_2 changes when P_1 is rotated as θ changes

$I_2 = 0$, when $\theta = 90^o$

$I_2 = I_1$, when $\theta = 0^o$

Question 27

Obtain the expression for the energy stored in a capacitor connected across a dc battery. Hence define energy density of the capacitor.

OR

Derive the expression for the torque acting on an electric dipole, when it is held in a uniform electric field. identify the orientation of the dipole in the electric field, in which it attains a stable equilibrium.

SOLUTION: Energy Stored in a Charged Capacitor

The energy of a charged capacitor is measured by the total work done in charging the capacitor to a given potential.

Let us assume that initially both the plates are uncharged. Now, we have to repeatedly remove small positive charges from one plate and transfer them to the other plate.
Let

q →Total quantity of charge transferred
V →Potential difference between the two plates

Then,

$q = CV$

Now, when an additional small charge dq is transferred from the negative plate to the positive plate, the small work done is given by,

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

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

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

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

This work done is stored as electrostatic potential energy U in the capacitor.

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

Hence energy stored in the capacitor $= \frac{1}{2}\frac{Q^2}{C} = \frac{(A\sigma)^2}{2} \times \frac{d}{\varepsilon_0 A}$

The surface charge density σ is related to the electric field E between the plates, $E = \frac{\sigma}{\varepsilon_0}$

So, energy stored in the capacitor $= \frac{1}{2}\varepsilon_0 E^2 \times Ad$

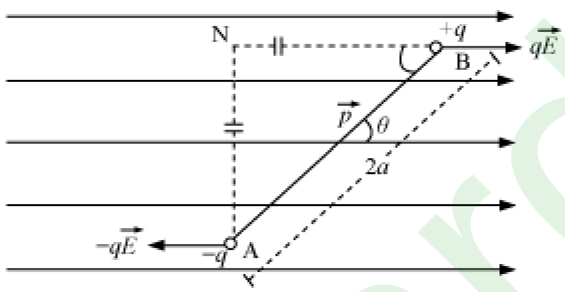
Here, Ad is volume between the plates of capacitor.

We define energy density as energy stored per unit volume of space.

Energy density of electric field $= U = \frac{1}{2}\varepsilon_0 E^2$

OR

Dipole in a Uniform External Field



Consider an electric dipole consisting of charges −*q* and +*q* and of length 2*a* placed in a uniform electric field $\vec{E}$ making an angle *θ* with the electric field.

Force on charge −*q* at $A = -q\vec{E}$ (opposite to $\vec{E}$)

Force on charge +*q* at $B = q\vec{E}$ (along $\vec{E}$)

The Electric dipole is under the action of two equal and unlike parallel forces, which give rise to a torque on the dipole.

τ = Force × Perpendicular distance between the two forces

τ = *qE* (AN) = *qE* (2*a* sin *θ*)

τ = *q*(2*a*) *E* sin*θ*

τ = *pE* sin*θ*

$\therefore \vec{\tau} = \vec{p} \times \vec{E}$

In a uniform electric field, the net force on dipole will always be zero but torque is zero for θ = 0° and θ = 180°

Now Potential Energy of a dipole in a uniform external electric field is given by the expression $P.E = -\vec{p}\,.\,\vec{E}$

1. For θ = 0°, U = -pE (minimum), the equilibrium will be stable and if the dipole is slightly displaced, it performs oscillations.

2. For θ=180°, U = +pE (maximum), it will be an unstable equilibrium.

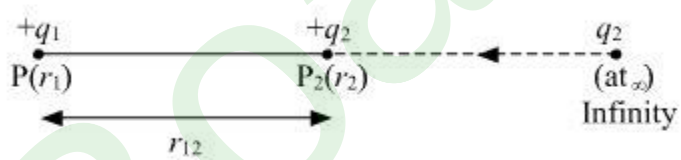
Question:

(a) Two point charges q_1 and q_2 are kept at a distance of r_{12} in air. Deduce the expression for the electrostatic potential energy of this system.
(b) If an external electric field (E) is applied on the system, write the expression for the total energy of this system.

SOLUTION:

(a) Electrostatic potential energy of a system is defined as the total amount of the work done in bringing the various charges to their respective position from infinitely large mutual seperation.

Let us consider a charge q_1 at a postion vector r_1 and q_2 at at infinity which is to be brought at point P_2 having position vector r_2. and d*W* is the small amount of work done in moving a charge to a distance d*x*.



$$dW = \vec{F}\,.\,\vec{dx}$$

$$dW = -\frac{kq_1q_2}{r^2}\,.\,dx$$

$$W = -\int_{\infty}^{r_{12}} \frac{kq_1q_2}{r^2}\,.\,dx$$

$$W = -Kq_1q_2\int_{\infty}^{r_{12}} \frac{1}{r^2}\,.\,dx$$

$$W = -Kq_1q_2\left[-\frac{1}{r}\right]^{r_{12}}_{\infty}$$
$$W = Kq_1q_2\left[\frac{1}{r_{12}}\right]$$
$$W = U = \frac{Kq_1q_2}{r_{12}}$$

(b) Let us consider a system of two charges q1 and q2 located at a distance r1 and r2 from the origin. Let these charges be placed in an external field of magnitude E.

Let the work done in bringing the charge q1 from infinity to r1 be given as q1V(r1)and the work done in bringing the charge q2 from infinity to r2 against the external field can be given as q2V(r2).

We note that, in the latter case, the work required to be done on q2 will include the field due to the charge q1 along with the electric field E, which can be given as,

$$= \frac{Kq_1q_2}{r_{12}}$$

The potential energy of the point q at a distance r from the origin in an external electric field is given as *qV*(r).
Where *V*(r) is the external potential at that point.

Here, r12 is the distance between q1 and q2. we can add these two to get the total work done in bringing q2 from infinity to r2

$$= q_2V\left(r_2\right) + \frac{Kq_1q_2}{r_{12}}$$

Thus, the total work done required to bring both the charges from infinity to the present configuration or the total potential energy of the system can be given as

$$= q_1V\left(r_1\right) + q_2V\left(r_2\right) + \frac{Kq_1q_2}{r_{12}}$$

Question 29

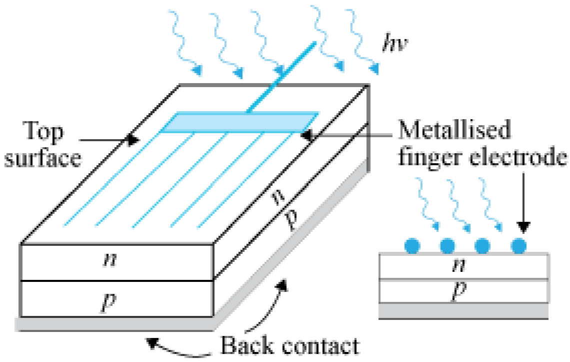
What is a solar cell? Draw its V-I characteristics. Explain the three processes involved in its working.

OR

Draw the circuit diagram of a full wave rectifier. Explain its working showing its input and output waveforms.

SOLUTION:

• It is a semiconductor device used to convert photons of solar light into electricity.

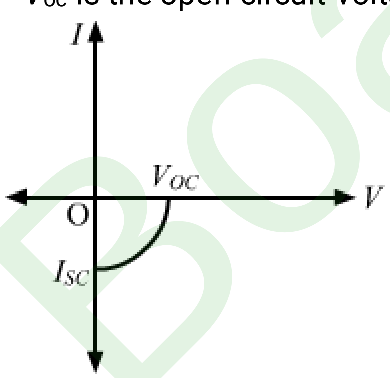


It generates emf when solar radiation fall on the *p-n* junction. A *p*-type silicon wafer of about 300 μm is taken over which a thin layer of *n*-type silicon is grown on one side by diffusion process.

The generation of emf by a solar cell, when light falls on, it is due to the following three basic processes: **generation, separation and collection**

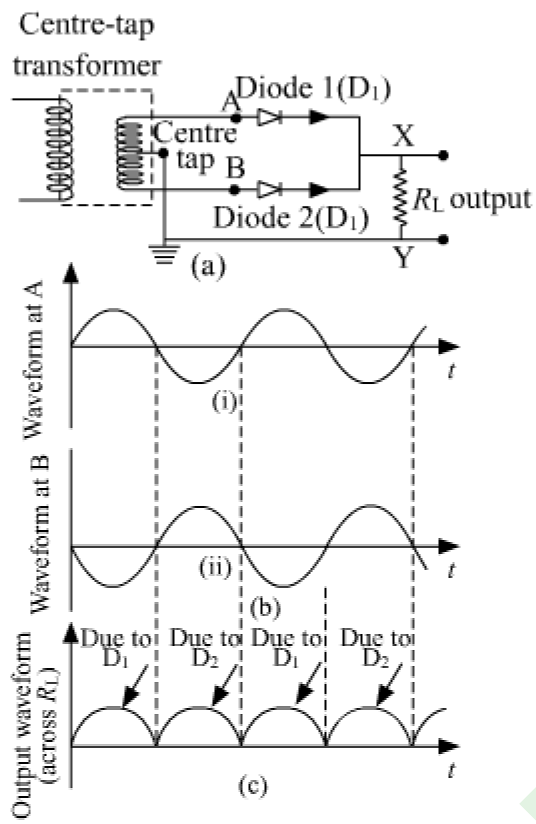
(i) generation of e-h pairs due to light (with hv > E_g) close to the junction
(ii) separation of electrons and holes due to electric field of the depletion region. Electrons are swept to n-side and holes to p-side
(iii) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photo-voltage.

***V-I* characteristic of a solar cell:**
The *V-I* characteristic of a solar cell as follows:
• I_{sc} is the short-circuit current when the load resistance R_L is zero.
• V_{oc} is the open-circuit voltage when R_L is infinity.



OR

The circuit diagram and the associated waveforms are shown below:



(a) Full wave rectifier circuit
(b) Input wave forms given to the diode D_1 at A and to the diode D_2 at B
(c) Output wave form across the load R_L connected in the full-wave rectifier circuit

A Full Wave Rectifier is a circuit, which converts an ac voltage into a pulsating dc voltage using both half cycles of the applied ac voltage. It uses two diodes of which one conducts during one half cycle while the other conducts during the other half cycle of the applied ac voltage.

During the positive half cycle of the input voltage, diode D_1 becomes forward biased and D_2 becomes reverse biased. Hence D_1 conducts and D_2 remains OFF. The load current flows through D_1 and the voltage drop across R_L will be equal to the input voltage.

During the negative half cycle of the input voltage, diode D_1 becomes reverse biased and D_2 becomes forward biased. Hence D_1 remains OFF and D_2 conducts. The load current flows through D_2 and the voltage drop across R_L will be equal to the input voltage.

Question 30

(a) Define internal resistance of a cell.
(b) A cell of emf E and internal resistance r is connected across a variable resistor R.

Plot the shape of graphs showing variation of terminal voltage V with (i) R and (ii) circuit current I.

Solution:

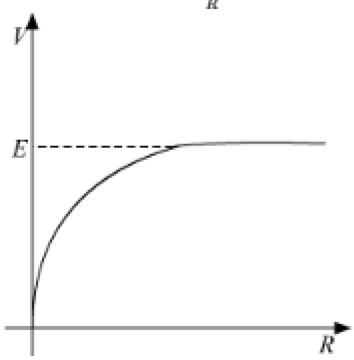
(a) Internal Resistance is the resistance which is present within the battery that resists the current flow when connected to a circuit.

(b) Terminal Voltage V can be related to R by the following relation:

(i)

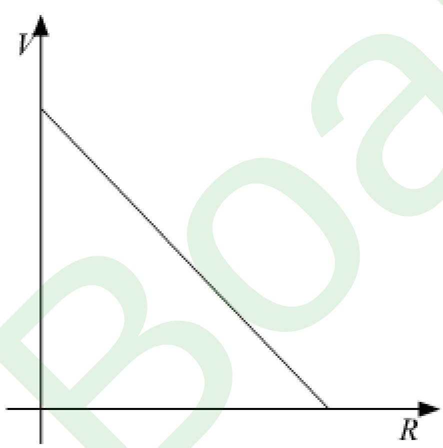
$$V = \frac{ER}{R+r}$$

$$\Rightarrow V = \frac{E}{1+\frac{r}{R}}$$



(ii) Terminal Voltage *V* can be related to *I* by the following relation:

V = *E* − *IR*



Question 31

Calculate the de-Broglie wavelength associated with the electron revolving in the first excited state of hydrogen atom. The ground state energy of the hydrogen atom is −13.6 eV.

Solution:

de-Broglie wavelength $\lambda = \frac{h}{mv} = \frac{h}{p}$, where p is momentum of electron

Kinetic energy (KE) and momentum (p) are related by , $\mathrm{KE} = \frac{p^2}{2m}$ (m = mass)

$\Rightarrow p = \sqrt{2m(\mathrm{KE})}$

$\Rightarrow \lambda = \frac{h}{\sqrt{2m(\mathrm{KE})}}$

According to Bohr's model , $\text{Kinetic Energy of } e^- = |\text{Total Energy of } e^-| = \left|-\frac{13.6 \times Z^2}{n^2}\right| eV$

for Hydrogen Z = 1 and first excited state implies n = 2

$$\begin{aligned}\mathrm{KE} &= \frac{13.6 \times 1^2}{2^2} = 3.4 \text{ eV} \\ &= 3.4 \times 1.6 \times 10^{-19} \text{ J} \\ &= 5.44 \times 10^{-19} \text{ J}\end{aligned}$$

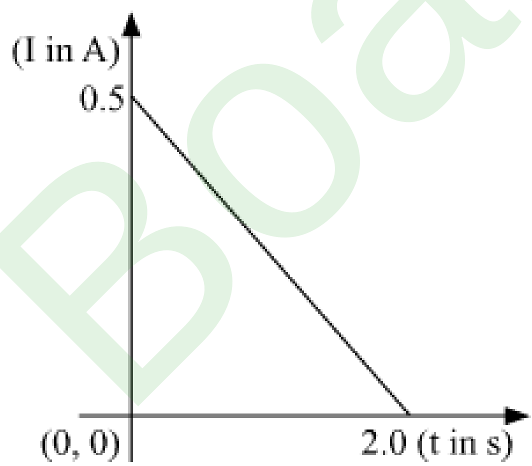
putting the values in formula for wavelength we get,

$$\lambda = \frac{h}{\sqrt{2m(\mathrm{KE})}} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 5.44 \times 10^{-19}}} = 6.66 \times 10^{-10} \text{ m} = 6.66 \overset{0}{\text{A}}$$

Question 32

When a conducting loop of resistance 10 Ω and area 10 cm^2 is removed from an external magnetic field acting normally, the variation of induced current-I in the loop with time t is as shown in the figure.

Find the
(a) total charge passed through the loop.
(b) change in magnetic flux through the loop
(c) magnitude of the field applied



Solution:

$I = \frac{dq}{dt} \Rightarrow dq = Idt$

Hence area under the *I-t* curve gives charge flown.
Area of the *I-t* curve (as given in the question)= $\frac{1}{2} \times 2 \times \frac{1}{2} = 0.5$
Total charge passed through the loop = 0.5 C

Now we know

$$\Delta Q = \frac{\Delta \varphi}{R}$$
$$\Delta \varphi = \Delta Q \times R = \frac{1}{2} \times 10\Omega = 5 \text{ Wb}$$

Charge in magnetic flux through the loop= 5 Wb

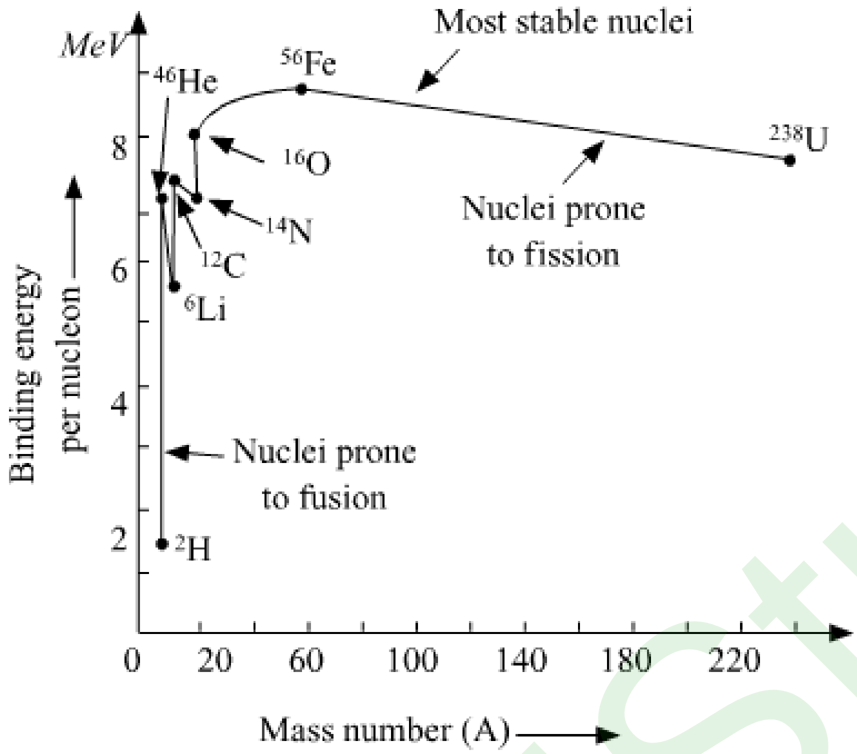
$$\Delta\varphi = B\ (\Delta A)$$
$$5 = B\ (0.001)$$
$$B = 5000 \text{ T}$$

The magnitude of the field applied = 5000 T

Question 33

Draw the curve showing the variation of binding energy per nucleon with the mass number of nuclei. Using it explain the fusion of nuclei lying on ascending part and fission of nuclei lying on descending part of this curve.

Solution:



The above curve tells us that the binding energy per nucleon is smaller for heavier nuclei as well as for lighter nuclei than for the middle order nuclei (with mass number lying between 30 to 170). Meaning heavier nuclei are less stable thus they undergo fission and lighter nuclei undergo fusion in order to form the nucleus lying in the range of the mass number 30 to 170.

Question 34

An optical instrument uses a lens of 100 D for the objective lens and 50 D for its eye piece. When the tube length is kept at 20 cm, the final image is formed at infinity.
(a) Identify the optical instrument.
(b) Calculate the magnification produced by the instrument.

Solution:

(a)
Power of lens $= \frac{1}{\text{focal length}}$

So, focal length of objective lens $= \frac{1}{100}\text{ m} = 1\text{ cm}$

focal length of eye piece $= \frac{1}{50}\text{ m} = 2\text{ cm}$

Since the obejective has a smaller focal length than the eye piece, the instrument is a Compound Microscope.

(b)
Magnification produced when the image is formed at infinty is given by, $m = \left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$ where L is the tube length.

So, $m = \frac{20\times25}{1\times2} = 250$

Question 35

(a) Write two important characteristics of equipotential surfaces.
(b) A thin circular ring of radius *r* is charged uniformly so that its linear charge density becomes *λ*. Derive an expression for the electric field at a point P at a distance *x* from it along the axis of the ring. Hence, prove that at large distances (*x* >> *r*), the ring behaves as a point charge.

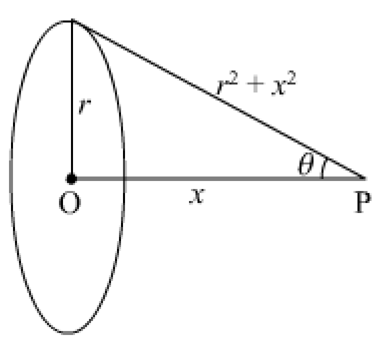
OR

(a) State Gauss's law on electrostatics and drive an expression for the electric field due to a long straight thin uniformly charged wire (linear charge density λ) at a point lying at a distance r from the wire.
(b) The magnitude of electric field (in NC^{-1}) in a region varies with the distance r(in m) as
E = 10r + 5
By how much does the electric potential increase in moving from point at r = 1 1 m to a point at r = 10 m.

SOLUTION: (a) Two important characteristics of equipotential surfaces are:

• Potential remains at all the points on equipotential surface.
• No work is required to move a charge on an equipotential surface.

(b) Let consider a thin circular ring of radius r with charge density as λλ



We need to find the electric field due to this charged ring at a point on the axis of the ring at a distance x from its centre.

Let us consider a small charge element (dxdx) on the ring having small charge dqdq

dq=λdx

the electric field due to this charge element at the point P is given by

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{(r^2+x^2)}$$

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{\lambda dx}{(r^2+x^2)}$$

Electric field at the point P will have two components one in the vertical direction and the other one in the horizontal direction.

dEcosθ along the horizontal direction.

dEsinθ along the vertical direction.

The vertical components will cancel out the effect of each other due to the presence of the diametrically opposite element.

So the horizontal component of the electric field will survive at the point P.

From the figure we have the value of $\cos\theta = \frac{x}{\sqrt{r^2+x^2}}$

Now the integration of the horizontal component dEcosθ will be carried out.

$$dE\cos\theta = \frac{\lambda x dx}{4\pi\varepsilon_0(r^2+x^2)^{3/2}}$$

Since the value of $dq = \lambda dx$

$$dE\cos\theta = \frac{x dq}{4\pi\varepsilon_0(r^2+x^2)^{3/2}}$$

Now integrating the above equation and taking x and r quantities as constants we get

$$E_x = \int dE \cos\theta = \int \frac{x dq}{4\pi\varepsilon_0 (r^2+x^2)^{3/2}}$$

$$E_x = \int \frac{x dq}{4\pi\varepsilon_0 (r^2+x^2)^{3/2}} = \frac{xQ}{4\pi\varepsilon_0 (r^2+x^2)^{3/2}}$$

where Q is the total charge on the ring.

Here Ex is the value of the total electric field at the point P
Special case:

when x >> r, the denominator of the above equation gets modified in the following way:

$$r^2 + x^2 \approx x^2$$

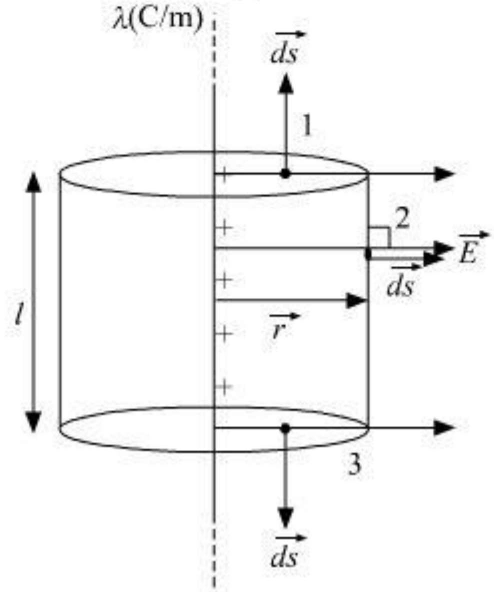
$$E_x = \frac{xQ}{4\pi\varepsilon_0 (x^2)^{3/2}} = \frac{xQ}{4\pi\varepsilon_0 x^3} = \frac{Q}{4\pi\varepsilon_0 x^2}$$

So at large distances (x >> r), the ring behaves as a point charge.

OR

a) Gauss' Law states that the net electric flux through any closed surface is equal to 1/ε0 times the net electric charge within that closed surface.

$$\oint \vec{E}.d\vec{s} = \frac{q_{enclosed}}{\varepsilon_o}$$



In the diagram we have taken a cylindrical gaussian surface of radius = *r* and length = *l*.

The net charge enclosed inside the gaussian surface qenclosed = λlqenclosed = λl

By symmetry we can say that the Electric field will be in radially outward direction.

According to gauss' law,

$$\oint \vec{E}.d\vec{s} = \frac{q_{enclosed}}{\varepsilon_o}$$

$$\int_1 \vec{E}.d\vec{s} + \int_2 \vec{E}.d\vec{s} + \int_3 \vec{E}.d\vec{s} = \frac{\lambda l}{\varepsilon_o}$$

$$\int_1 \vec{E}.d\vec{s} \ \& \ \int_3 \vec{E}.d\vec{s} \ \text{are zero , Since } \vec{E} \text{ is perpendicular to } d\vec{s}$$

$$\int_2 \vec{E}.d\vec{s} = \frac{\lambda l}{\varepsilon_o}$$

$$\text{at 2, } \vec{E} \text{ and } d\vec{s} \text{ are in the same direction, we can write}$$

$$E.2\pi rl = \frac{\lambda l}{\varepsilon_o}$$

$$E = \frac{\lambda}{2\pi\varepsilon_o r}$$

b) point A be given at *r* = 1 m, point B be given at *r* = 10 m
V_A = potential at A

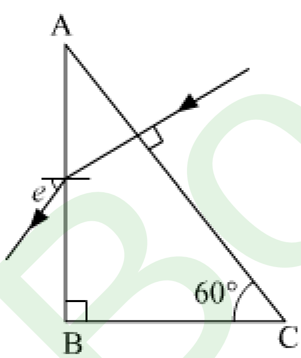
V_B = potential at B

The relation between the electric field and potential potential difference is given by the relation,

$$V_B - V_A = -\int_A^B \vec{E} . d\vec{r}$$
$$V_B - V_A = -\int_1^{10} \left(10r + 5\right) . dr$$
$$= -\left[\frac{10r^2}{2} + 5r\right]_1^{10}$$
$$= -\left[\left(\frac{10(10)^2}{2} + 5 \times 10\right) - \left(\frac{10(1)^2}{2} + 5 \times 1\right)\right]$$
$$= -\left[550 - 10\right]$$
$$= -540\ V$$

Question 36

(a) Define the term 'focal length of a mirror'. With the help of a ray diagram, obtain the relation between its focal length and radius of curvature.
(b) Calculate the angle of emergence (e) of the ray of light incident normally on the face AC of a glass prism ABC of refractive index √3. How will the angle of emergence change qualitatively, if the ray of light emerges from the prism into a liquid of refractive index 1.3 instead of air?



OR

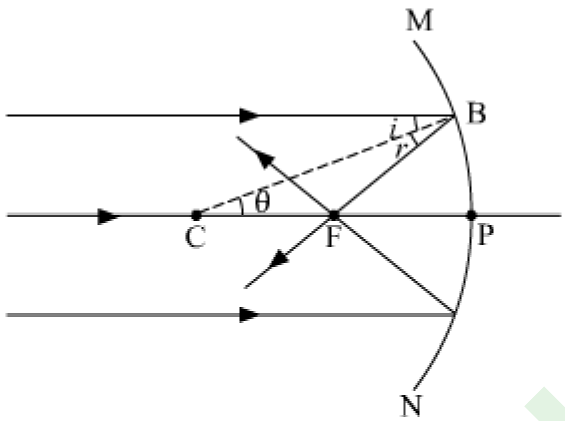
(a) Define the term 'resolving power of a telescope'. How will the resolving power be effected with the increase in
(i) Wavelength of light used.
(ii) Diameter of the objective lens.

Justify your answers.

(b) A screen is placed 80 cm from an object. The image of the object on the screen is formed by a convex lens placed between them at two different locations separated by a distance 20 cm. determine the focal length of the lens.

SOLUTION:
(a) The distance between the centre of a lens or curved mirror and its focus.

The relationship between the focal length *f* and the radius of curvature $R = 2f$.



Consider a ray of light AB, parallel to the principal axis and incident on a spherical mirror at point B. The normal to the surface at point B is CB and CP = CB = R is the radius of curvature. The ray AB, after reflection from a mirror, will pass through F (concave mirror) or will appear to diverge from F (convex mirror) and obeys the law of reflection i.e. i = r.

From the geometry of the figure,
$\angle BCP = \theta = i$
In D CBF, $\theta = r$

$\therefore BF = FC$ (because i = r)

If the aperture of the mirror is small, B lies close to P, and therefore BF = PF
Or FC = FP = PF
Or PC = PF + FC = PF + PF
Or $R = 2\ PF = 2f$
Or $f = R/2$

Similar relation holds for convex mirror also. In deriving this relation, we have assumed that the aperture of the mirror is small.

(b)

Snell's law says $\mu_1 \mathrm{Sin(i)} = \mu_2 \mathrm{Sin(r)}$

$\mu_{\text{Prism}} = \sqrt{3}$

$\mu_{\text{Prism}} \sin(30^{\circ}) = \sin(e)$

$\sqrt{3} \times \frac{1}{2} = \sin(e)$

$e = 60^{\circ}$

Now when the external medium is changed to liquid of $\mu_{\mathrm{L}} = 1.3$ then,

$\mu_{\text{prism}} \mathrm{Sin}\left(30\right) = \mu_{\mathrm{L}} \mathrm{Sin}\left(\mathrm{e}\right)$

$\sqrt{3}\,\mathrm{Sin}\left(30^{\circ}\right) = 1.3\,\mathrm{Sin}\left(\mathrm{e}\right)$

$\mathrm{e} = \mathrm{Sin}^{-1}\left(\frac{\sqrt{3}}{2\times1.3}\right) = 41.83^{\circ}$

Hence the angle of emergence reduces to 41.83° from 60°.

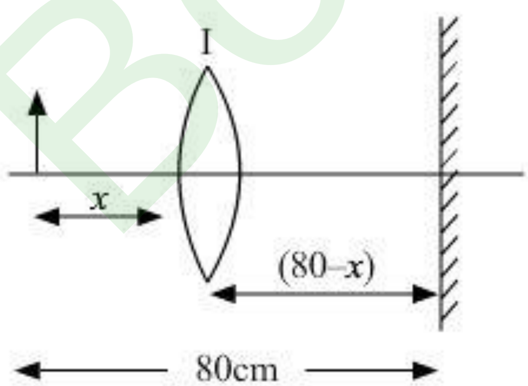
(a) The resolving power of an astronomical telescope is defined as the reciprocal of the smallest angular separation between two point objects whose images can just be resolved by the telescope.

$$R.P = \frac{1.22\lambda}{D}$$

With the increase in wavelength of light, the resolving power increases whereas with the increase in diameter of the lens, the resolving power decreases.

(b) We have ,

case 1)



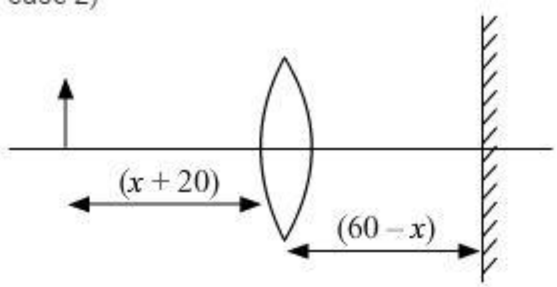
let object distance, $u = x$
image distance, $v = 80 - x$
focal length = f
According to the lens formula:

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

$$\frac{1}{f} = \frac{1}{80-x} + \frac{1}{x} \qquad \dots(1)$$

Similarly,

case 2)



$u = x + 20$
$v = 60 - x$

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

$$\frac{1}{f} = \frac{1}{60-x} + \frac{1}{20+x} \qquad \dots(2)$$

On comparing equations 1 and 2 , we get:

$$\frac{1}{f} = \frac{1}{80-x} + \frac{1}{x} = \frac{1}{60-x} + \frac{1}{20+x}$$

$$\frac{80}{x(80-x)} = \frac{80}{(60-x)(20+x)}$$

$$80x - x^2 = 1200 + 40x - x^2$$

$$40x = 1200$$

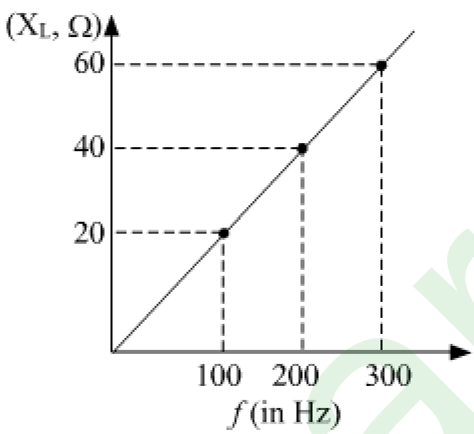
$$x = 30 \text{ cm}$$

Putting the value of x in equation (1)

$$\frac{1}{f}=\frac{1}{80-30}+\frac{1}{30}$$
$$\frac{1}{f}=\frac{1}{50}+\frac{1}{30}$$
$$\frac{1}{f}=\frac{8}{150}$$
$$f=18.75\ \text{cm}$$

Question 37

(a) Show that an ideal inductor does not dissipate power in an ac circuit.
(b) The variation of inductive reactance (X_L) of an inductor with the frequency (f) of the ac source of 100 V and variable frequency is shown in the fig.



(i) Calculate the self-inductance of the inductor.
(ii) When this inductor is used in series with a capacitor of unknown value and resistor of 10 Ω at 300 s^{-1}, maximum power dissipation occurs in the circuit. Calculate the capacitance of the capacitor.

OR

(a) A conductor of length 'l' is rotated about one of its ends at a constant angular speed 'ω' in a plane perpendicular to a uniform magnetic field B. Plot graphs to show variations of the emf induced across the ends of the conductor with (i) angular speed ω and (ii) length of the conductor l.

(b) Two concentric circular loops of radius 1 cm and 20 cm are placed coaxially.
(i) Find mutual inductance of the arrangement.
(ii) If the current passed through the outer loop is changed at a rate of 5 A/ms, find the emf induced in the inner loop. Assume the magnetic field on the inner loop to be uniform.

SOLUTION:

(a)

Power = $VI\cos\phi$

For pure inductive circuit, the phase difference between current and voltage is $\frac{\pi}{2}$.

$$\therefore \phi = \frac{\pi}{2}, \cos\phi = 0$$

Therefore, zero power is dissipated. This current is sometimes referred to as watt-less current.

(b)

(i)

We know that $X_L = \omega L$ and $\omega = 2\pi f$ where f is frequency in Hz.

So, $L = \frac{X_L}{2\pi f} = \frac{20}{2\pi(100)} = \frac{40}{2\pi(200)} = \frac{60}{2\pi(300)} = 31.84 \times 10^{-3} \approx 32$ mH

(ii)

we know that power dissipation is maximum when $X_L = X_C$

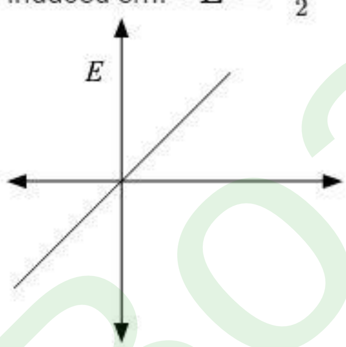
or $\omega L = \frac{1}{\omega C}$ or $C = \frac{1}{\omega^2 L}$

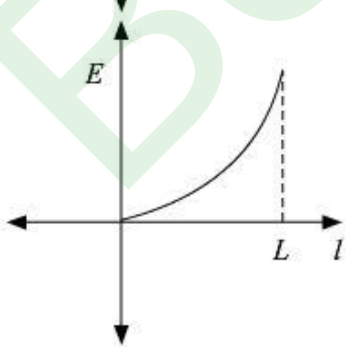
$\Rightarrow C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\times3.14\times3.14\times300\times300\times32\times10^{-3}} = 8.8\ \mu F$

OR

(a)

Induced emf = $E = \frac{B\omega l^2}{2}$





(b)

We know $\varphi = \mathrm{MI}$

And magnetic field at the center of the bigger loop $\overrightarrow{\mathrm{B}} = \frac{\mu_0 \mathrm{I}}{2\mathrm{R}} = \frac{4\pi\times10^{-7}\mathrm{I}}{2\times20\times10^{-2}} = \pi \times 10^{-6}\mathrm{I}$

Flux through the smaller loop

$$\varphi = \mathrm{BA_s} = \frac{4\pi\times10^{-5}\mathrm{I}}{40} \times \pi(0.01)^2 = \pi^2 \times 10^{-10} \times \mathrm{I}$$

$$\mathrm{M} = \frac{\varphi}{\mathrm{I}} = \pi^2 \times 10^{-10} = 9.86 \times 10^{-10}\ \mathrm{H}$$

Now emf induced

$$\mathrm{e} = -\frac{\mathrm{d}\varphi}{\mathrm{dt}} = -9.86 \times 10^{-10} \times \frac{\mathrm{dI}}{\mathrm{dt}}$$

$$\mathrm{e} = -9.86 \times 10^{-10} \times 5 = -4.93 \times 10^{-9}\ \mathrm{V}$$

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) $R = \frac{r}{2}$

(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, $J = \sigma E$

Here, $J =$ Current density

$\sigma =$ conductivity

$E =$ Electricb field

$\therefore \quad \frac{E}{J} = \frac{1}{\sigma} = \rho =$ 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 ($A \le 10$) 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 :

$^{1}_{0}n$ (neutron) $\rightarrow$ $^{1}_{1}p$ (proton) + $^{0}_{-1}e$ (electron) + $\bar{\nu}_e$(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 $= (\phi_1 - \phi_2) \in_0$

12. In Young's double slit experiment, the path difference between two interfering waves at a point on the screen is $\frac{5\lambda}{2}$, 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 = 3×10^8 m/s

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

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

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.

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

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,

$$q = ALne \qquad ...(1)$$

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

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,

$$t = \frac{L}{v_d} \text{.................................(2)}$$

Current in the conductor,

$$I = \frac{q}{t} \text{.................................(3)}$$

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

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

$$\Rightarrow \quad I = Anev_d \text{.................................(4)}$$

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),

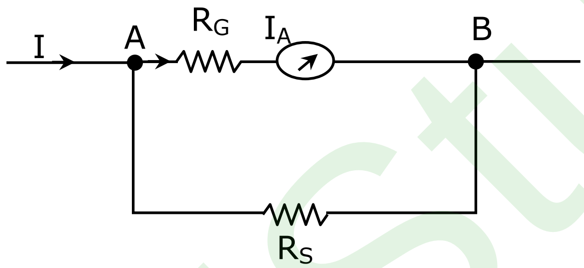
$$I = Anev_d$$

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

$$\Rightarrow \quad J = nev_d$$

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,

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

$$1 \text{ A} \times 0.8\ \Omega = 4 \text{ A} \times R_S$$

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

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

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

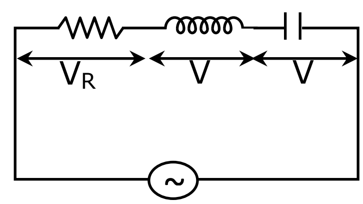
(b) In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of power factor for this circuit ?[2]

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.

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, $\cos\phi = \frac{R}{Z}$

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

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

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 $V = \frac{Q}{C}$

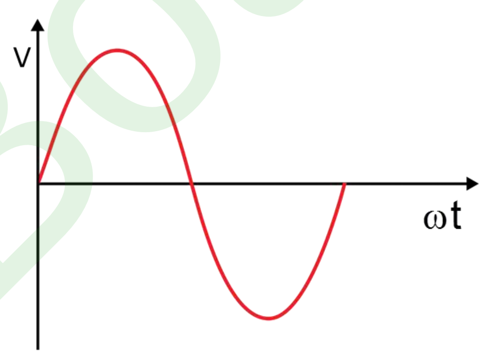
or $Q = CV = CV_0 \sin\omega t$

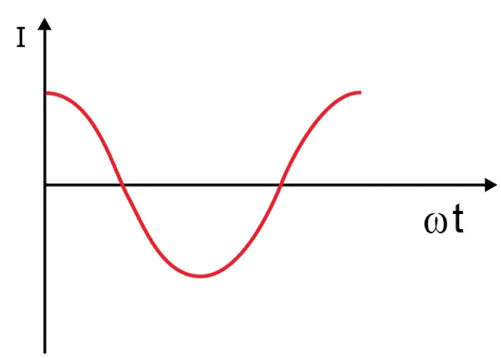
$\therefore$ Current at any instant is

$$I = \frac{dQ}{dt} = \frac{d}{dt}\left(CV_0 \text{ sint}\right) = \omega CV_0 \cos\omega t$$

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

Where $I_0 = \omega CV_0 = \frac{V_0}{1/\omega C}$ = 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.

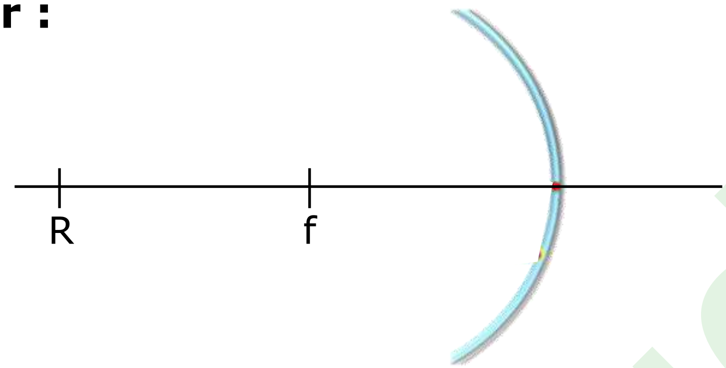
(a) γ-rays have the minimum wavelength.

(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, $f = \frac{R}{2} = \frac{60}{2} \text{cm} = 30 \text{ cm}$

By mirror formula,

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

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

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

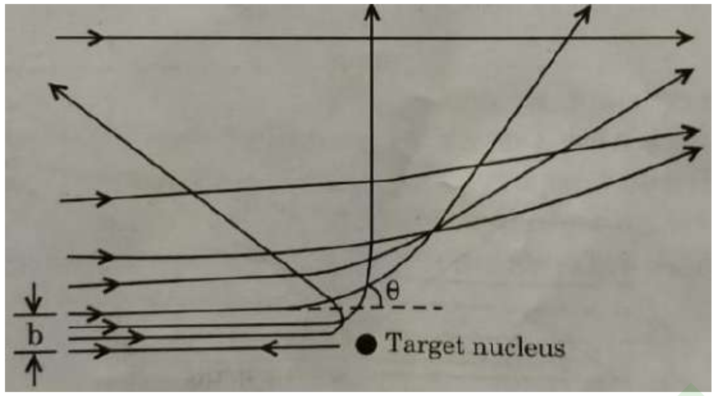
$$\therefore \quad v = 60 \text{ cm}$$

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

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.



(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

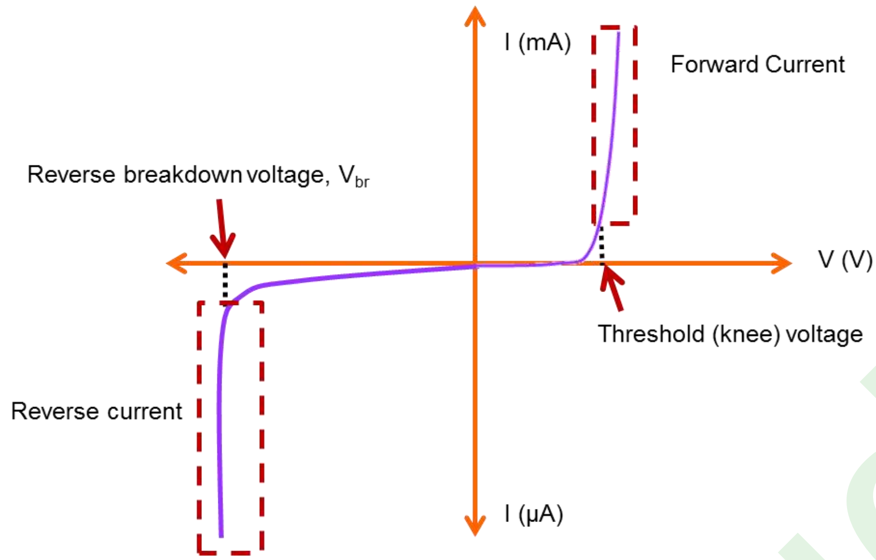
$$b = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2 \cot(\theta/2)}{E}$$

When $\theta = 0^\circ, b = \infty$

When $\theta = 180^\circ, b = 0$.

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



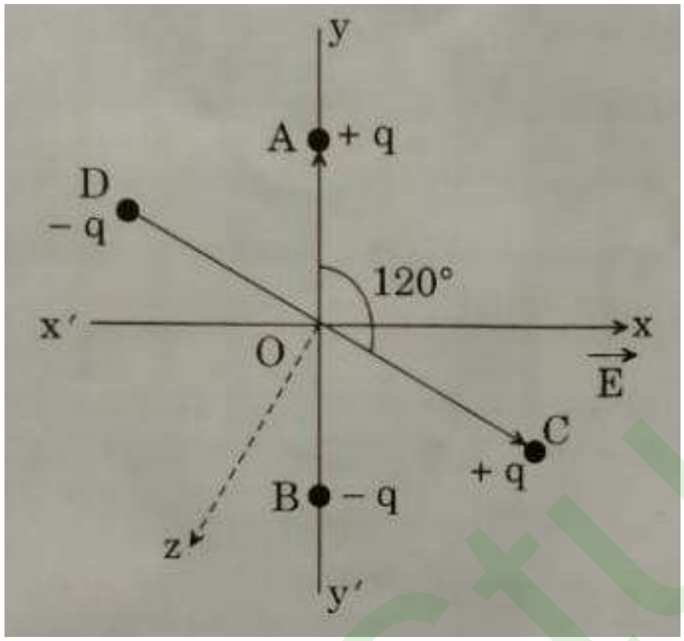
When a p-n junction diode is reverse biased, minority charge carriers of the diode drift across the junction towards the ends of the diode. The movement of these minority charge carriers produces currents of very small value. At any temperature, the number of minority charge carriers is constant. So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

SECTION-C

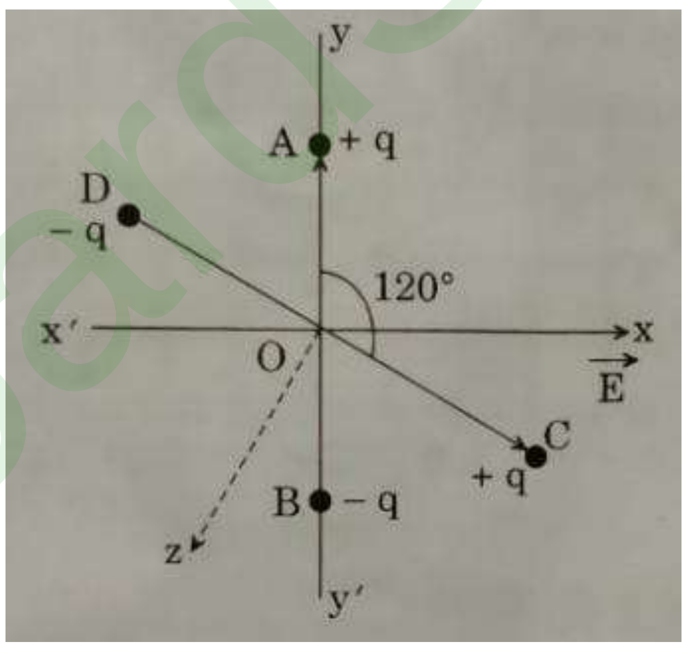
28. Two small identical electric dipoles AB and CD, each of dipole moment $\vec{p}$ are kept at an angle of 120° to each other in an external electric field $\vec{E}$ pointing along the x-axis as shown in the figure. Find the

(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,

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

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

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

(b) Torque, $\tau = pE \sin 30^\circ = \frac{1}{2} pE$

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

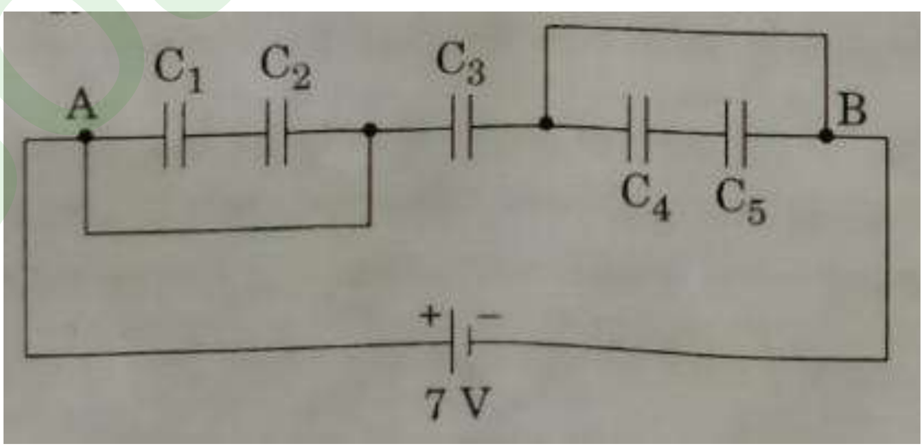
OR

In the figure given below, find the

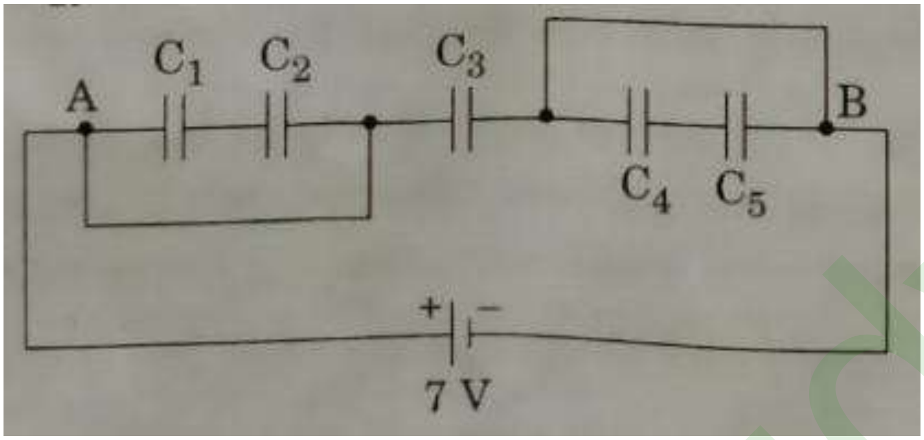
(a) Equivalent capacitance of the network between points A and B.
Given : $C_1 = C_5 = 8\ \mu F$, $C_2 = C_3 = C_4 = 4\ \mu F$.

(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 $Q = C_{eq} V$

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

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

(c)

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

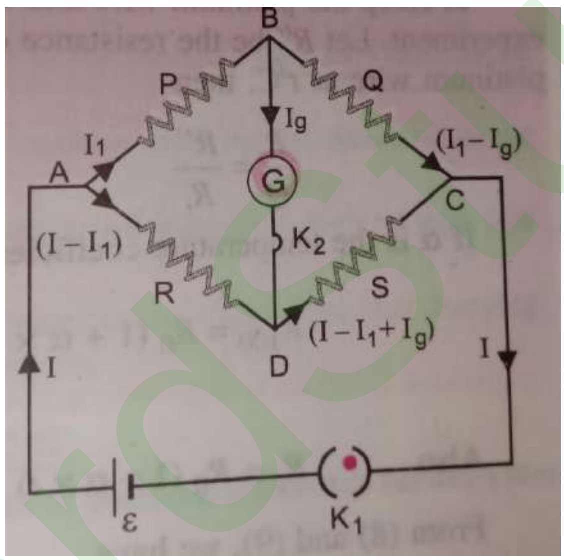
$$= \frac{1}{2} \times 4\ \mu F \times (7\ V)^2$$

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

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,

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

Here G is the resistance of the galvanometer.

Applying Kirchoff's Voltage Rule to loop BCDB,

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

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.

$I_1P + I_gG - (I - I_1)R = 0$ ...(1)

Here G is the resistance of the galvanometer.

Applying Kirchoff's Voltage Rule to loop BCDB,

$(I_1 - I_g)Q - (I - I_1 - I_g)S - I_gG = 0$ ...(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, $$I_1P = (I - I_1)R \quad ...(3)$$

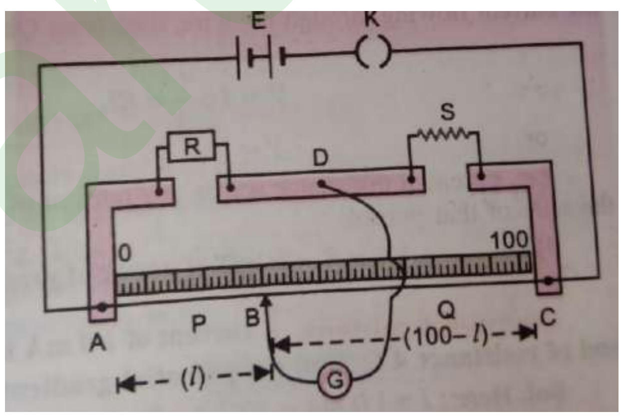
$$I_1Q - (I - I_1)S = 0$$

or, $$I_1Q = (I - I_1)S \quad ...(4)$$

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*

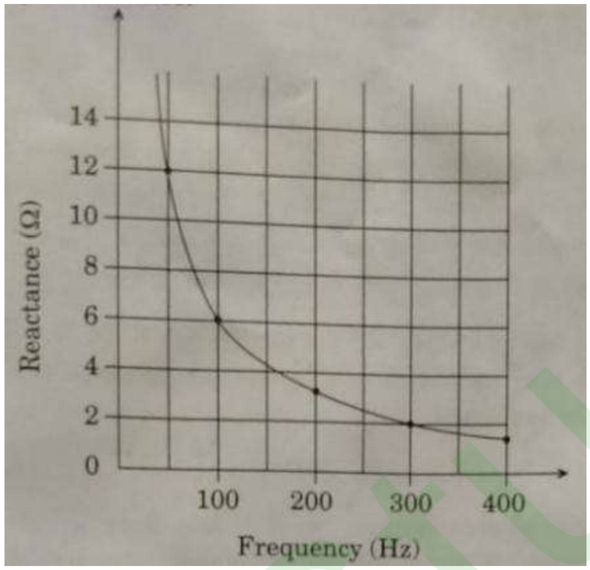
$$\frac{P}{Q} = \frac{R}{S}$$

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

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.**



(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 $f = 100 \ H_z$

$$X_L = 6 \ \Omega$$

$$X_L = 2\pi \ f \ l$$

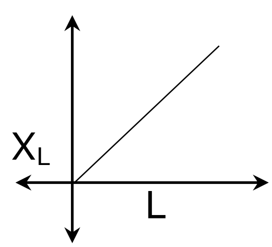
$$L = \frac{X_L}{2 \pi f}$$

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

(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, $W_0 = \frac{hc}{\lambda_0}$

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

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

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 $t = \frac{1}{\lambda}$

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

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

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

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

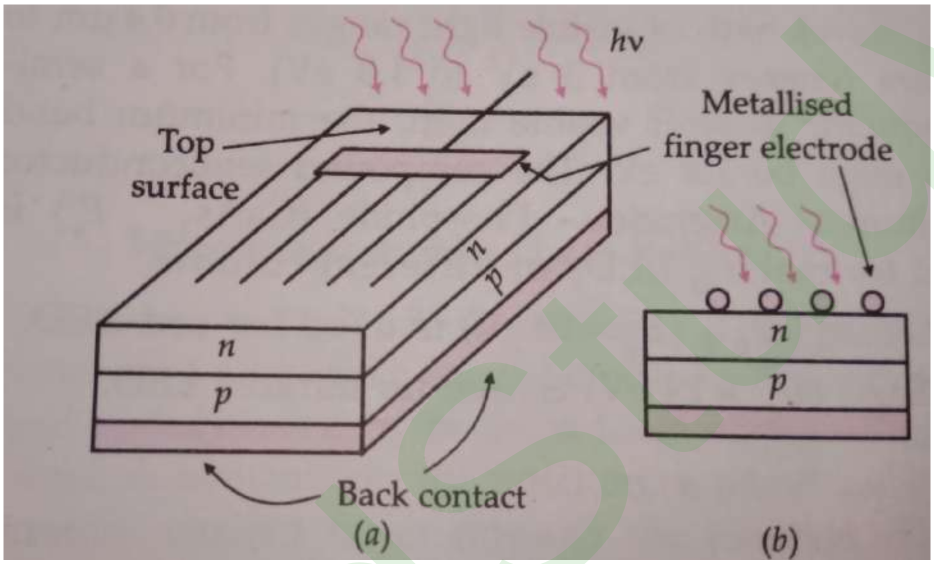
Now, Fraction $= \frac{N_{rem}}{N_0} = 1 - \frac{1}{e}$

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 $r \leq R$ and $r \geq R$.

(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.

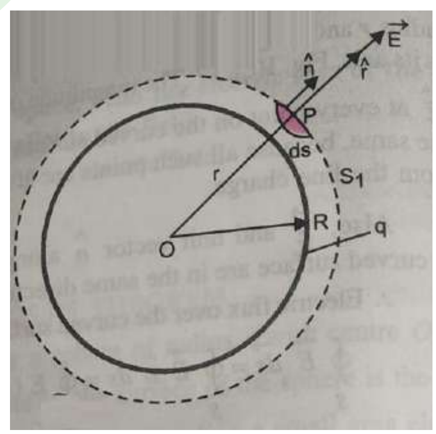
According to Gauss's Theorem,

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

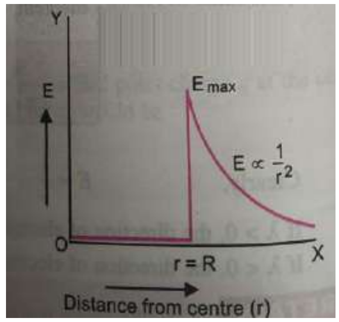
or, $$E\oint_S ds = \frac{q}{\varepsilon_0}$$

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

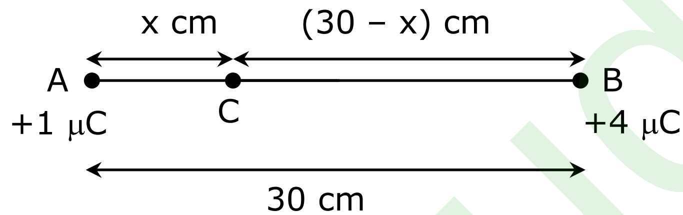
$$\Rightarrow \quad E = \frac{q}{4\pi r^2 \varepsilon_0}$$



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

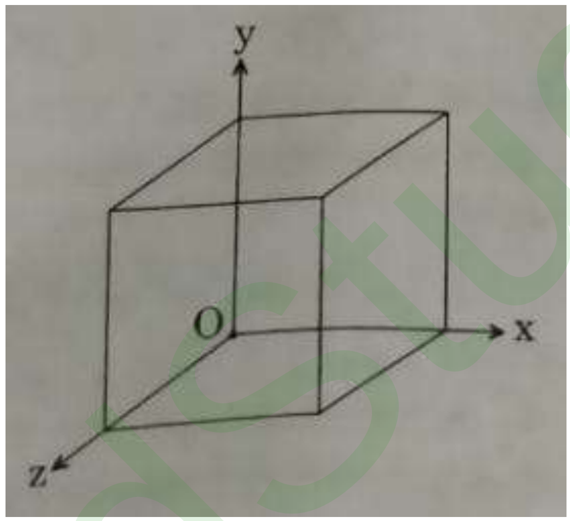
At a distance of 6 cm from 1 μC towards 4 μC change, the electric field is zero.

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.



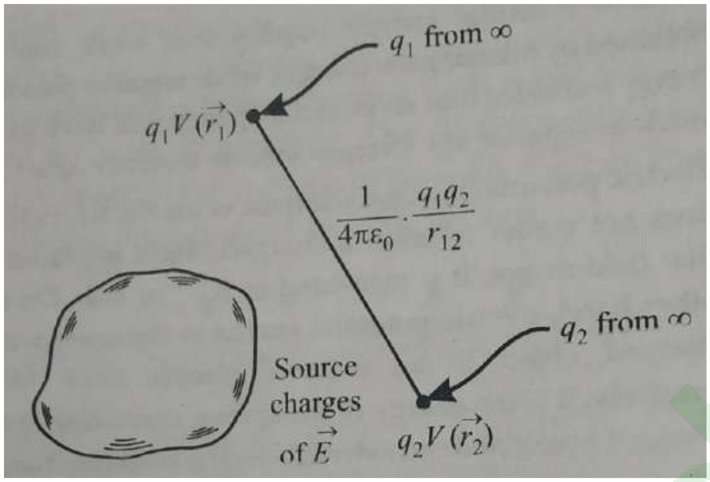
Find the

(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

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

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

(b) (i) Given,

Side of cube, $a = 20$ cm

Electric potential, $V = 10x + 5$

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

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

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

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

$$\phi = -10\ NC^{-1}(20\ cm \times 20\ cm)\cos 0^\circ$$
$$+\left(-10\ NC^{-1}\right)(20\ cm \times 20\ cm)\cos 90^\circ$$
$$+\left(-10\ NC^{-1}\right)(20\ cm \times 20\ cm)\cos 90^\circ$$
$$+\left(-10\ NC^{-1}\right)(20\ cm \times 20\ cm)\cos 90^\circ$$
$$+\left(-10\ NC^{-1}\right)(20\ cm \times 20\ cm)\cos 90^\circ$$
$$+\left(-10\ NC^{-1}\right)(20\ cm \times 20\ cm)\cos 180^\circ$$

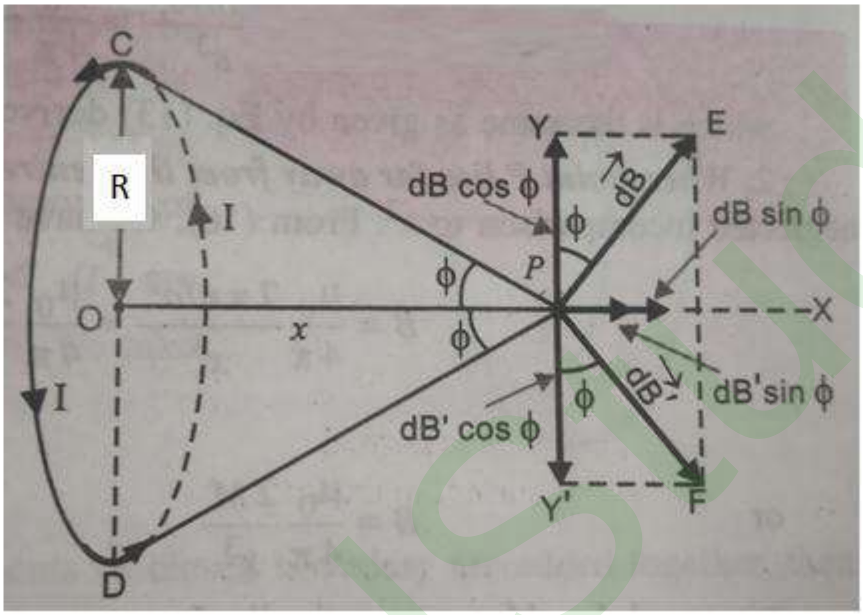
$$\phi = (-10\ NC^{-1})(400\ cm^2)(1) + 0 + 0 + 0 + 0 + \left(-10\ NC^{-1}\right)(400\ cm^2)(-1) = 0$$

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 $\frac{\pi}{6}$. [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.

Then, $PC = PD = r = \sqrt{R^2 + x^2}$

Let $\angle CPO = \phi = \angle DPO$

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

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

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

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

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

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

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) $dB\cos\phi$ acts along PY and $dB\sin\phi$ acts along PX,

(ii) $dB'\cos\phi$ acts along PY' and $dB'\sin\phi$ 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 $\int dl = 2\pi R$

$$\therefore \quad B = \frac{\mu_o \; I \qquad\qquad a}{4\pi \left(R^2 + x^2\right)\sqrt{R^2 + x^2}} 2\pi R = \frac{\mu_o}{4\pi}$$

(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, $F = BIl \sin\theta$

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

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

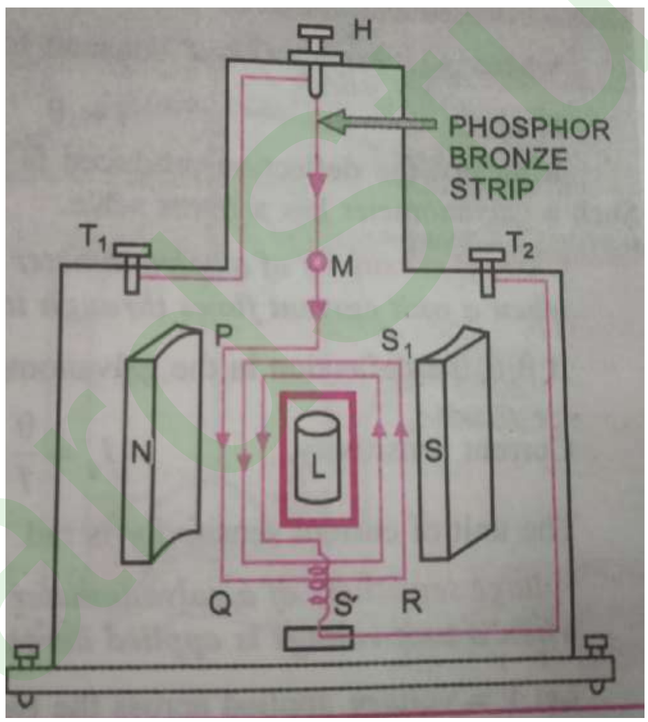
OR

(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 *PQRS₁*. The current in the coil flows in the direction *PQRS₁*.

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 $\alpha = 90^\circ$.

$\therefore \sin\alpha = 1$

$\therefore$ 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

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

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

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

$$\text{Kinetic Energy} = \frac{1}{2}mv^2$$

$$= \frac{1}{2}(1.6 \times 10^{-27}\ kg)(16 \times 10^{6}\ m/s)^2$$

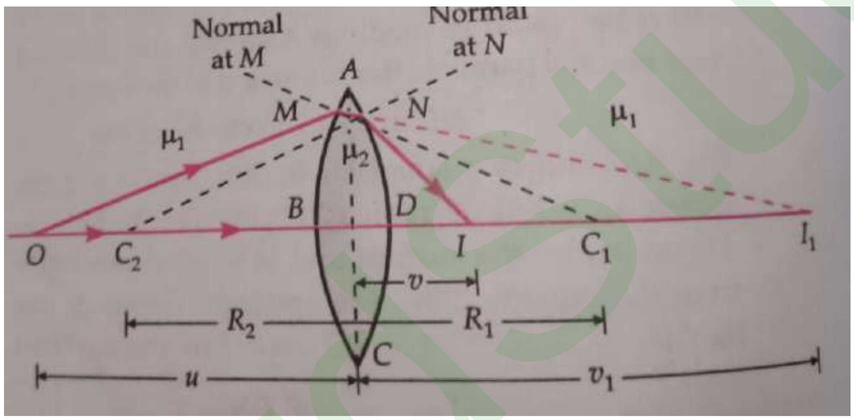
$$= 2.04 \times 10^{-13} J$$

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:

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

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:

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

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

For an object placed at infinity, u = ∞.

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

∴ v = f

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

For a lens with refractive index μ placed in air,

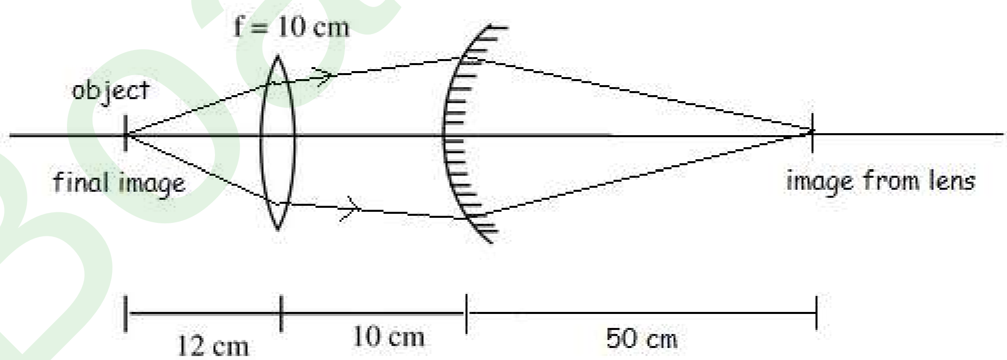
$\mu_1 = 1$ and $\mu_2 = \mu$.

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

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,

$$R = 60 \text{ cm} - 10 \text{ cm} = 50 \text{ cm}$$

Therefore, focal length of the convex mirror,

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

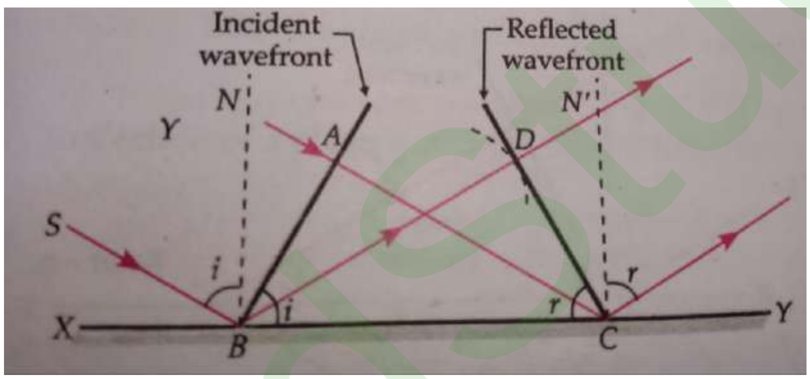
OR

(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 $\angle i$ and $\angle r$ denote the angle of incidence and angle of reflection respectively.

In ΔABC and ΔDBC,

$\angle BAC = \angle CDB$ [Both are right angles]

BC = BC [Common side]

AC = BD [Both have the same legnth]

$\therefore \Delta ABC \cong \Delta DBC$

Hence, $\angle ABC = \angle DCB$

or, $\angle i = \angle r$

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, $x = 2.5\ \text{mm} = 2.5 \times 10^{-3}\ \text{m}$

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

For first minima, n = 1.

Therefore, width of the slit,

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

Now, for secondary maxima

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

For first secondary maxima, n = 1

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

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