LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNMENT PAPER 8**

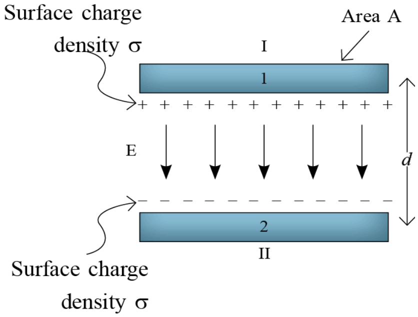
Section A

1. (B) **2.** (A) **3.** (C) **4.** (A) **5.** (B) **6.** (A) **7.** (A) **8.** (B) **9.** (A) **10.** (B) **11.** (D) **12.** (A) **13.** (D) **14.** (C) **15.** (B) **16.** (B) **17.** (B) **18.** (C) **19.** (B) **20.** (C) **21.** (A) **22.** (A) **23.** (A) **24.** (D) **25.** (C) **26.** (B) **27.** (C) **28.** (C) **29.** (C) **30.** (C) **31.** (D) **32.** (A) **33.** (C) **34.** (B) **35.** (C) **36.** (A) **37.** (B) **38.** (A) **39.** (C) **40.** (D) **41.** (B) **42.** (C) **43.** (A) **44.** (A) **45.** (B) **46.** (B) **47.** (A) **48.** (D) **49.** (C) **50.** (C)

Section A

➢ **Write the answer of the following questions : (Each carries 2 Mark)**

1.



- A capacitor made up of two large parallel conducting plates kept at a small distance is called parallel plate capacitor.
- Two parallel conducting plates are arranged parallel to each other as shown in figure. Area of each plate is A and perpendicular distance between the two plates is *d*. Charge on them is +Q and – Q respectively.
- Surface charge density on both the plates is

$$\sigma\left(=\frac{Q}{A}\right) \text{ and } -\sigma \text{ respectively.}$$

- Here the separation (d) between two plates is very small compared to the area of the plates. ($d^2 << A$) Therefore, the electric field between the two plates can be considered uniform (So that we can use the formula $E = \frac{\sigma}{2\varepsilon_0}$ to find out electric field due to both plates.)
- Electric field in the region above plate I,

$$E' = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

- Electric field in the region below plate II,

$$E'' = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

- Electric field in the region between two plates,

$$\therefore E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$\therefore E = \frac{\sigma}{\varepsilon_0}$$

$$\therefore E = \frac{Q}{\varepsilon_0 A} \quad \text{... (1)} \quad \left(\because \sigma = \frac{Q}{A}\right)$$

- Direction of this electric field is from +ve plate to –ve plate.
- The electric field is limited to the region between two plates and is uniform in that entire region.

Remember

For plates with finite area, this will not be true near the outer boundaries of the plates. The field lines bend outward at the edges - which is called 'Fringing of the field'.

By the same characteristic σ will not be strictly uniform on the entire plate.

However, for $d^2 << A$, these effects can be ignored in the regions sufficiently far from the edges.

➥ Now, for uniform electric field, p.d. between two plates,

$V = Ed$

Substituting value of E from eg. (1),

$$V = \frac{Qd}{\varepsilon_0 A} \quad ... (2)$$

➥ Now, capacitance,

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

$$\therefore C = \frac{Q}{\frac{Qd}{\varepsilon_0 A}} \quad \text{(From eq. (2))}$$

$$\therefore C = \frac{\varepsilon_0 A}{d} \quad ... (3)$$

➥ eq. (3) is formula for parallel plate capacitor

➥ Capacitance of a parallel plate capacitor depends on the dimensions of plate (/ on geometry of entire system) and on the dielectric medium between the two plates.

2.

➥ $T_0 = 0\ °C$ $R_0 = 5\ \Omega$

➥ $T_1 = 100\ °C$ $R_1 = 5.23\ \Omega$

$T_2 = ?$ $R_2 = 5.795\ \Omega$

➥ from equation

$R = R_0[1 + \alpha(T - T_0)]$

But, $T_0 = 0\ °C$

$R = R_0(1 + \alpha T)$

$\therefore R = R_0 + R_0\ \alpha T$

$\therefore R - R_0 = R_0 \alpha T$

from above equation

➥ $R_1 - R_0 = R_0 \alpha T_1$ ... (1)

and $R_2 - R_0 = R_0 \alpha T_2$ ... (2)

➥ Taking ratio of equation (2) and (1)

$$\frac{R_2 - R_0}{R_1 - R_0} = \frac{R_0 \alpha\ T_2}{R_0 \alpha\ T_1}$$

$$\frac{5.795 - 5}{5.23 - 5} = \frac{T_2}{100}$$

$$\therefore T_2 = \frac{0.795 \times 100}{0.23}$$

$= 345.65\ °C$

3.

➥ Torque acting on a magnetic needle (magnetic dipole) in a uniform magnetic field, $\vec{\tau} = \vec{m} \times \vec{B}$

Where, $\vec{m}$ - Magnetic dipole moment

$\vec{B}$ - External Magnetic field

θ - Angle between $\vec{m}$ and $\vec{B}$

➥ Work required to be done to displace the magnetic needle from this condition by a very small angle $d\theta$,

$dW = \tau\ d\theta$

➥ $\therefore$ Total Work $W = \int \tau \, d\theta$

$\therefore W = \int mB \sin\theta \, d\theta$

$\therefore W = mB \int \sin\theta \, d\theta$

$\therefore W = mB(-\cos\theta)$

$\therefore W = -mB\cos\theta$

➥ This work is stored in the form of potential energy.

$\therefore U = -mB\cos\theta$

$\therefore U = -\vec{m} \cdot \vec{B}$

Special Cases :

(i) When the magnetic needle is parallel to the field,

$\theta = 0$

$\therefore$ Potential energy (P.E.)

$\therefore U = -mB\cos\theta = -mB\cos 0$

$\therefore U = -mB$ (minimum)

➥ Which shows the maximum steady (stable) condition of the needle.

(ii) When the magnetic needle is anti parallel to the magnetic field,

$\theta = \pi\ (180°)$

$\therefore$ P.E. $U = -mB\cos\pi$

$\therefore U = mB$ (maximum)

➥ Which shows the most unstable position of the needle.

(iii) When the magnetic needle is perpendicular to the magnetic field,

$\theta = 90°\ (\frac{\pi}{2}$ rad)

$\therefore$ P.E. $U = -mB\cos 90°$

$\therefore U = 0$

4.

➥ Induced *emf* $\varepsilon = -L\frac{dI}{dt}$

If $\frac{dI}{dt} = 1\ \frac{A}{s}$

so, $\varepsilon = -L$

➥ *"If the rate of change of current passing through the coil is unit, then the emf induced in the coil is called self-induced emf and this phonomenon is called self inductance of the coil.*

Self inductance depends on the following factors :

(1) Dimensions of coil

(2) Shape and number of turns in coil

(3) Magnetic properties of medium.

➥ Unit : henry (H), $\frac{Wb}{A}$, $\frac{Vs}{A}$

➥ Dimensional Formula : $M^1L^2T^{-2}A^{-2}$

5.

➥ L = 25 mH

V = 220 V

$\upsilon = 50$ Hz

➥ Inductive reactance (X_L)

$X_L = \omega L = 2\pi\upsilon L$

$\therefore X_L = 2 \times 3.14 \times 50 \times 25 \times 10^{-3}$

$\therefore X_L = 7850 \times 10^{-3} = 7.85\ \Omega$

➥ rms value of current in the circuit,

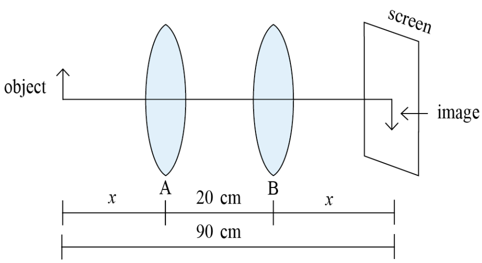
$\therefore I = \frac{V}{X_L}$

$\therefore I = \frac{220}{7.85}$

$\therefore I = 28$ A

6.

➥



➥ The figure shows two different states of the lens A and B. This is always reflected on the screen itself.

➥ From figure,

$x + 20 + x = 90$

$\therefore 2x = 90 - 20$

$\therefore 2x = 70$

$\therefore x = 35$ cm

➥ If the lens is at A,

object distance $u = -x = -35$ cm

image distance $\upsilon = 20 + x = 20 + 35 = 55$ cm

➥ from lens formula,

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

$\therefore \frac{1}{55} + \frac{1}{35} = \frac{1}{f}$

$\therefore \frac{35+55}{55 \times 35} = \frac{1}{f}$

$\therefore f = \frac{1925}{90}$

$\therefore f = 21.4$ cm

7.

➥ $E_i - E_f = 2.3\ eV$

$v = ?$

➥ As we know,

$E_i - E_f = hv_{if}$

$\therefore v_{if} = \frac{E_i - E_f}{h}$

$$\therefore \nu_{if} = \frac{2.3 \times 1.6 \times 10^{-19}}{6.625 \times 10^{-34}}$$

$\nu_{if} = 5.6 \times 10^{19}$ Hz

8.

- The nucleus is made up of neutrons and protons. Therefore, it may be expected that the mass of the nucleus is equal to the total mass of its individual protons and neutrons.
- But the nuclear mass M is found to be always less than the total mass of its individual protons and neutrons.
- For example :

  ${}_8O^{16}$, a nucleus which has 8 neutrons and 8 protons.

  Mass of 8 neutrons = $8 \cdot 1.00866\ u$

  Mass of 8 protons = $8 \cdot 1.00727\ u$

  Mass of 8 electrons = $8 \cdot 0.00055\ u$

- Therefore, the expected mass of ${}_8O^{16}$ nucleus

  $= (8 \cdot 1.00866 + 8 \cdot 1.00727)$

  $= 8(1.00866 + 1.00727)$

  $= 8 \cdot 2.01593\ u$

  $= 16.12744\ u$

- The atomic mass of ${}_8O^{16}$ found from mass spectroscopy experiments is seen to be 15.99493 u.
- Subtracting the mass of 8 electrons

  ($8 \cdot 0.00055\ u = 0.0044\ u$) from this we get the experimental mass of ${}_8O^{16}$ nucleus to be 15.99053 u.

- Thus, the mass of the ${}_8O^{16}$ nucleus is less than the total mass of its constituents by

  $(16.12744 - 15.99053) = 0.13691\ u$.

- *"The difference in mass of a nucleus and its constituents, ΔM is called the mass defect"* and is given by

  $\Delta M = [Zm_p + (A - Z)m_n] - M$

  Where, Z = number of protons

  A – Z = N = neutron number

  m_p - mass of proton

  m_n - mass of neutron

  M - mass of a nucleus

- The energy equivalent to this mass defect is called the binding energy of nucleus.

  $\therefore$ Binding energy $E_b = \Delta M c^2$

- Binding energy per nucleon is the binding energy divided by the total number of nucleons.

  $$\therefore E_{bn} = \frac{E_b}{A}$$

- The binding energy per nucleon gives a measure of the stability of the nucleus.
- A nucleus for which the value of E_{bn} is comparatively higher is said to be more stable and for a nucleus for which the value of E_{bn} is comparatively less is said to be less stable.

9.

- (1) Linear distribution of electric charge.
  - If there is a continuous electric charge on a line, it is called linear distribution of electric charge.
  - The electric charge per unit length on an electrically charged line is called linear density of electric charge.
  - Assume there is a total charge of Q on the line length of l.
  - Linear density of charge,

$$\lambda = \frac{\text{Total electric charge}}{\text{length}} = \frac{Q}{l}$$

- SI unit of linear density is C/m

(2) Surface distribution of charge :

If there is a continuous electric charge on a surface, it is called surface distribution of charge.

- The electric charge per unit surface is called surface density of charge.
- Assume there is a total charge of Q on the Surface of Area A,

∴ Surface density of charge,

$$\sigma = \frac{\text{Total electric charge}}{\text{Area}} = \frac{Q}{A}$$

- SI unit : C/m^2

(3) Volume distribution of charge :

If there is a continuous electric charge on a volume, it is called volume distribution of charge.

- The electric charge per unit volume is called volume density of charge.
- Assume there is a total charge Q on the matter with volume V,

∴ Volume density of charge

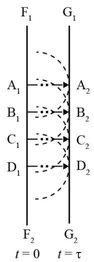
$$\rho = \frac{\text{Total charge}}{\text{volume}} = \frac{Q}{V}$$

- SI unit : C/m^3

10.

Huygen's principle :

- "Every point or particle of a wavefront behaves as an independent secondary source, emits by itself secondary spherical waves. After a very small time interval the surface tangential to all such secondary spherical wavelets gives the position and shape of the new wavefront."



- A plane wavefront F_1F_2 is shown in the fig. at time $t = 0$.
- To determine the shape of the wavefront at time $t = \tau$, we draw spheres of radius $\upsilon\tau$, from each point (points A_1, B_1, C_1 .... etc.) on the wavefront. (Where υ is the speed of waves in the medium.)
- A tangent common to all such points is drawn, which gives the position and shape of the new wavefront at time $t = \tau$.

11.

(i) During the interaction of radiation with matter, the radiation behaves as if it is made up of particles called photons.

(ii) The energy of each photon is

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

momentum $p = \frac{hv}{c}$

(iii) If the frequency v and wave lenght λ of a radiation are constant,

its energy $E = hv = \frac{hc}{\lambda}$ and momentum

$p = \frac{hv}{c}$ remains constant.

➠ If the intensity of the radiation is changed, the number of photons emitted (or incident) per unit time changes, but the energy remains constant.

(iv) Photons are electrically neutral and are not affected by electric or magnetic fields.

(v) Energy and momentum are conserved during photon-particle collision, but the number of photons is not conserved.

➠ During the collision the number of photons may decrease such that in photoelectric emission the number of photons decreases and an electron is emitted.

➠ The number of photons can also increase during the collision. For example, x-rays (photons) are emitted from high-energy electrons striking a metal such as Mo (molybdenum).

12.

➥

Forward Bias	Reverse Bias
p - type semiconductor of p - n junction is connected to positive terminal and n - type is connected with negative terminal of battery. Such a biasing is called forward biasing.	p - type semiconductor of p - n junction is connected to negative terminal and n - type is connected with positive terminal of battery. Such a biasing is called reverse biasing.
In forward bias, the current is due to majority charge carriers.	In Reverse bias, the current is due to minority charge carriers.
Current obtained in forward bias is of the order of mA.	Current obtained in Reverse bias is of the order of $\propto$A.
When diode is connected in forward bias, width of its depletion layer and height of potential barrier reduces.	When diode is connected in reverse bias, width of its depletion layer and height of potential barrier increases.
Resistance is of the order of 10 Ω to 100 Ω.	Resistance is of the order of 10 MΩ.

Section B

➢ **Write the answer of the following questions : (Each carries 3 Mark)**

13.

➥ B = 0.3 T

$l = 8$ cm $= 8 \times 10^{-2}$ m

b = 2 cm $= 2 \times 10^{-2}$ m

Speed of loop $\upsilon = 1$ cm/sec $= 10^{-2}$ m/sec

(a) In direction perpendicular to longer side : ($\vec{\upsilon}$ as per fig. a)

➠ As shown in figure, a small cut is between B and C. AB side is outside magnetic field, thus no induced *emf* is obtained in it.

➠ Here, for sides AE and CD, $\vec{\upsilon} \parallel \vec{B}$. Thus, no induced *emf* obtained in these sides.

➠ Only for side DE, $\vec{\upsilon} \perp \vec{B}$

Thus, induced *emf*

$\varepsilon = B\upsilon l$

$= 0.3 \times 10^{-2} \times 8 \times 10^{-2}$

$= 2.4 \times 10^{-4}$ V

$= 2.4 \times 10^{-3}$ V

= 0.24 mV

➠ Induced *emf* will be produced till small side comes out of magnetic field.

Suppose, time is t,

$$t_1 = \frac{\text{length of smaller side}}{\text{Speed}} = \frac{b}{\upsilon}$$

$$= \frac{2 \times 10^{-2}}{10^{-2}}$$

$= 2$ sec

Thus, induced *emf* will remain for 2 sec.

(b) In direction perpendicular to shorter side : ($\vec{\upsilon}$ as per fig. b)

Smaller side CD is outside magnetic field. Thus, no *emf* is induced in it.

Sides AB and DE have $\vec{\upsilon} \parallel \vec{B}$. Thus, no *emf* induced in these sides.

Only for side AE, $\vec{\upsilon} \perp \vec{B}$

Thus, induced *emf*

$\varepsilon = B\upsilon b$

$= 0.3 \times 10^{-2} \times 2 \times 10^{-2}$

$= 0.6 \times 10^{-4}$ V

$= 0.06 \times 10^{-3}$ V

$= 0.06$ mV

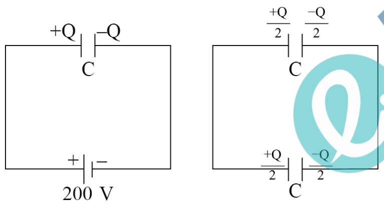
Induced *emf* will be produced till longer side comes out of magnetic field suppose, time is t_2

$$t_2 = \frac{\text{length of longer side}}{\text{Speed}} = \frac{l}{\upsilon}$$

$$= \frac{8 \times 10^{-2}}{10^{-2}} = 8 \text{ sec}$$

Thus, induced *emf* will remain for 8 sec.

14.



(a) (b)

C = 600 pF

V = 200 V

Energy stored in the capacitor initially,

$$U_1 = \frac{1}{2} CV^2$$

$$U_1 = \frac{1}{2} \times 600 \times 10^{-12} \times (200)^2$$

$U_1 = 12 \times 10^{-6}$ J

Charge on the capacitor,

Q = CV

$\therefore Q = 600 \times 10^{-12} \times 200$

$\therefore Q = 12 \times 10^{-8}$ C

As shown in fig. (b), after removal of the battery, when a new uncharged capacitor is connected, the charge is distributed equally, on both the capacitors.

Hence, the charge on each capacitor becomes $\frac{Q}{2}$ but the total charge Q remains constant.

➥ As shown in fig.(b), for the parallel connection, equivalent capacitance will be C' = 2C.

➥ Energy stored in the system in the final condition,

$$U' = \frac{Q^2}{2C'} = \frac{Q^2}{2(2C)}$$

$$\therefore U' = \frac{(12 \times 10^{-8})^2}{4 \times 600 \times 10^{-12}}$$

$$\therefore U' = 6 \times 10^{-6} \text{ J}$$

➥ Energy loss (/ lost) during the process,

$$\Delta U = U - U' = 12 \times 10^{-6} - 6 \times 10^{-6}$$

$$\Delta U = 6 \times 10^{-6} \text{ J}$$

15.

➥ $B = 6 \times 10^{-4}$ T $\upsilon = 3 \times 10^{7}$ m/s

$m = 9 \times 10^{-31}$ kg $q = 1.6 \times 10^{-19}$ C

$1eV = 1.6 \times 10^{-19}$ J

(i) The radius of the path (r)

$$r = \frac{m\upsilon}{qB}$$

$$\therefore r = \frac{9 \times 10^{-31} \times 3 \times 10^{7}}{1.6 \times 10^{-19} \times 6 \times 10^{-4}}$$

$$\therefore r = \frac{9 \times 3}{1.6 \times 6} \times 10^{-1}$$

$$\therefore r = 2.812 \times 10^{-1} \text{ m}$$

$$\therefore r = 28.12 \text{ cm}$$

(ii) Frequency (v)

$$v = \frac{qB}{2\pi m}$$

$$\therefore v = \frac{1.6 \times 10^{-19} \times 6 \times 10^{-4}}{2 \times 3.14 \times 9 \times 10^{-31}}$$

$$\therefore v = \frac{1.6 \times 6}{2 \times 3.14 \times 9} \times 10^{8}$$

$$\therefore v = 0.17 \times 10^{8}$$

$$\therefore v = 17 \times 10^{6} \text{ Hz}$$

$$= 17 \text{ MHz}$$

(iii) Kinetic energy or energy

$$K = \frac{1}{2} m\upsilon^2$$

$$\therefore K = \frac{1}{2} \times 9 \times 10^{-31} \times (3 \times 10^{7})^2$$

$$\therefore K = \frac{1}{2} \times 9 \times 10^{-31} \times 9 \times 10^{14}$$

$$\therefore K = 40.5 \times 10^{-17} \text{ J}$$

$$\therefore K = \frac{40.5 \times 10^{-17}}{1.6 \times 10^{-19}} \; eV$$

$$\therefore K = 25.3 \times 10^{2}$$

$$= 2.53 \; keV$$

16.

- As shown in fig.(c), consider two needles S_1 and S_2 moving periodically up and down in an identical fashion in a trough of water.
- Here, they produce two water waves, and at a particular point, the phase difference between the displacements produced by each of the waves does not change with time.
- When this happens, the two sources (here S_1 and S_2) are said to be coherent sources.
- As shown in fig. (a), consider a point R for which,

  $S_2R - S_1R = -2.5\ \lambda$
- The waves emanating from S_1 will arrive exactly two and a half cycles later than the waves from S_2. Hence the wave coming from S_2 will be ahead in phase by 5π rad.
- Hence, displacement produced by S_1 is given by

  $y_1 = a\ cos\ \omega t$
- then the displacement produced by S_2 will be given by,

  $y_2 = a\ cos\ (\omega t + 5\pi)$

  $y_2 = -\ a\ cos\ \omega t$
- Resultant (/ Net) displacement at R,

  $y = y_1 + y_2$

  $\therefore y = a\ cos\ \omega t + (-\ a\ cos\ \omega t)$

  $\therefore y = 0$
- As the net displacement at point R is zero, the resultant intensity at R will also be zero. (That is because, here, the two displacement are now out of phase and they will cancel out to give zero intensity.)
- This is referred to as Destructive interference.

17.

- $r = 1.5 \times 10^{11}$ m

  $\upsilon = 3 \times 10^4$ m/s

  m = 6×10^{24} kg

  $n = ?$
- According to Bohr hypothesis, angular momentum

  $L = \frac{nh}{2\pi}$

  $\therefore m\upsilon r = \frac{nh}{2\pi}$ ($\because L = mvr$)

  $\therefore n = \frac{2\pi\ m\upsilon r}{h}$

  $\therefore n = \frac{2 \times 3.14 \times 6 \times 10^{24} \times 3 \times 10^4 \times 1.5 \times 10^{11}}{6.625 \times 10^{-34}}$

  $\therefore n = 25.59 \times 10^{73}$

  $\therefore n = 2.6 \times 10^{74}$

18.

- (a) $v = 5.4 \times 10^6$ m/s

  $m = 9.1 \times 10^{-31}$ kg

  $\lambda = ?$
  - The de-Broglie wave length of electron.

    $\lambda = \frac{h}{p} = \frac{h}{mv}$ ($\because p = mv$)

$$\therefore \lambda = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 5.4 \times 10^{6}}$$

$\therefore \lambda = 0.13492 \times 10^{-9}$

$\therefore \lambda = 0.135$ nm

➥ (b) $v = 30.0$ m/s

$m = 150$ g $= 150 \times 10^{-3}$ kg

$\lambda = ?$

➠ The de-Broglie wave length of the ball is,

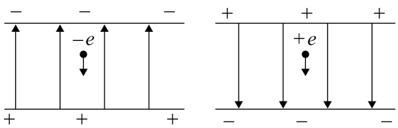
$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\therefore \lambda = \frac{6.63 \times 10^{-34}}{150 \times 10^{-3} \times 30}$$

$\lambda = 0.001473 \times 10^{-31}$

$\lambda = 1.473 \times 10^{-34}$ m

19.

➥ 

(a) (b)

➥ $E = 2.0 \cdot 10^{4}$ N/C

$\upsilon_0 = 0$

$d = 1.5 \cdot 10^{-2}$ m

➥ Force due to electric field,

$$F = qE \therefore ma = qE \therefore a = \frac{qE}{m}$$

➥ From the equation of uniform accelerated linear motion,

$$\therefore d = \upsilon_0 t + \frac{1}{2} at^2$$

$$\therefore d = 0 + \frac{1}{2} at^2$$

$$\therefore d = \frac{1}{2} \frac{qE}{m} t^2$$

$$\therefore t^2 = \frac{2md}{qE}$$

$$\therefore t = \sqrt{\frac{2md}{qE}} \quad \ldots (1)$$

➥ The time taken by the electron (t_e) from eq. (1),

$$t_e = \sqrt{\frac{2m_e d}{eE}}$$

$$\therefore t_e = \sqrt{\frac{2 \times 9.1 \times 10^{-31} \times 1.5 \times 10^{-2}}{1.6 \times 10^{-19} \times 2 \times 10^{4}}}$$

$\therefore t_e = 2.92 \cdot 10^{-9}$ s

$\therefore t_e = 2.92$ ns

➥ The time taken by the proton (t_p) from eq. (1),

$$t_p = \sqrt{\frac{2m_p d}{eE}}$$

$$\therefore t_p = \sqrt{\frac{2 \times 1.67 \times 10^{-27} \times 1.5 \times 10^{-2}}{1.6 \times 10^{-19} \times 2 \times 10^{4}}}$$

$$\therefore t_p = 1.26 \cdot 10^{-7} \text{ s}$$

$$\therefore t_p = 126 \ ns$$

Hence, the time taken by the proton will be more.

$$a_p = \frac{eE}{m_p}$$

$$\therefore a_p = \frac{1.6 \times 10^{-19} \times 2 \times 10^{4}}{1.67 \times 10^{-27}}$$

$$\therefore a_p \approx 1.9 \cdot 10^{12} \text{ m/s}^2$$

➥ The acceleration generated in electron,

➥ $\therefore a_e = \frac{eE}{m_e}$

(b) The acceleration generated in proton,

$$\therefore a_e = \frac{1.6 \times 10^{-19} \times 2 \times 10^{4}}{9.1 \times 10^{-31}}$$

$$\therefore a_e = 0.35 \cdot 10^{16} \text{ m/s}^2$$

$$\therefore a_e = 3.5 \cdot 10^{15} \text{ m/s}^2$$

➥ Here, the magnitude of the acceleration generated in electron and proton, is enormous compared to the gravitational acceleration.

➥ Hence, the effect due to gravitational acceleration can be neglected.

20.

➥ As shown in the fig., an AC source is connected to a capacitor.

➥ Voltage of the AC source,

$\upsilon = \upsilon_m \sin \omega t$ ... (1)

Remember : A capacitor connected to an AC source, limits or regulates the current, but does not completely prevent the flow of charge.

The capacitor is alternatively charged and discharged as the current reverses each half cycle.

➥ Let q be the charge on the capacitor at any time t.

➥ The instantaneous voltage v across the capacitor is,

$$\upsilon = \frac{q}{C}$$

$$\therefore \upsilon_m \sin \omega t = \frac{q}{C}$$

$$\therefore q = \upsilon_m \cdot C \sin \omega t$$

➥ To find the current, we use the relation,

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

$$\therefore \frac{dq}{dt} = \upsilon_m C \frac{d}{dt} (\sin \omega t)$$

$$\therefore i = \upsilon_m \omega C \cos \omega t$$

$$\therefore i = \upsilon_m \omega C \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$\therefore i = \frac{\upsilon_m}{\frac{1}{\omega C}} \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$\therefore i = i_m \sin\left(\omega t + \frac{\pi}{2}\right) \quad ... (2)$$

Where $i_m = \frac{\upsilon_m}{\frac{1}{\omega C}}$ (Amplitude of current)

- This equation is similar to the equation

  $i_m = \frac{\upsilon_m}{R}$ for a purely resistive circuit.

- Thus, the term $\frac{1}{\omega C}$ is similar (or analogus) to resistor in D.C. circuit.
- It is called capacitive reactance and is denoted by X_C.

  $\therefore X_C = \frac{1}{\omega C}$ (Unit : ohm (Ω))

- Therefore, the amplitude of electirc current

  $i_m = \frac{\upsilon_m}{X_C}$

- From eq. (1) and (2), it can be said that current is $\frac{\pi}{2}$ rad ahead of voltage in phase.

21.

- $f = -21$ cm (focal length of concave lens is negative)

  $u = -14$ cm

  $h = 3$ cm

- from lens formula,

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

  $\therefore \frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$

  $\therefore \frac{1}{\upsilon} = \frac{-1}{21} - \frac{1}{14}$

  $\therefore \frac{1}{\upsilon} = \frac{-2-3}{42}$

  $\therefore \upsilon = -\frac{42}{5} = -8.4$ cm

- Here υ is negative which indicates that image is virtual and erect towards the object.
- magnification $m = \frac{\upsilon}{u}$

  $\therefore m = \frac{-8.4}{-14}$

  $\therefore m = 0.6$

- As $|m| < 1$ image obtained is smaller than object.

  $m = \frac{h'}{h}$

  $\therefore 0.6 = \frac{h'}{3}$

  $\therefore h' = 1.8$ cm

- Height of image is 1.8 cm.

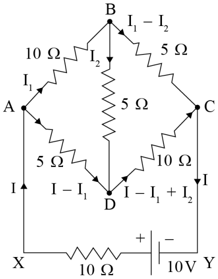
- As the object goes away from the lens, the image moves away from the lens towards the principal focus.
- When the object reaches infinity, image is obtained at the principal focus of the lens.

Section C

➢ **Write the answer of the following questions : (Each carries 4 Mark)**

22.

➥ The circuit shows the direction of currents and the currents in different branches.



➥ Applying Kirchhoff's loop rule to closed loop A – B – D – A

$- 10\, I_1 - 5\, I_2 + 5(I - I_1) = 0$

$\therefore - 2\, I_1 - I_2 + I - I_1 = 0$

$\therefore I - 3\, I_1 - I_2 = 0 \; ... \; (1)$

➥ Applying Kirchoff's loop rule to closed loop

B – C – D – B

$-5\, (I_1 - I_2) + 10(I - I_1 + I_2) + 5\, I_2 = 0$

$\therefore - (I_1 - I_2) + 2(I - I_1 + I_2) + I_2 = 0$

$\therefore - I_1 + I_2 + 2I - 2I_1 + 2I_2 + I_2 = 0$

$\therefore 2I - 3I_1 + 4I_2 = 0 \; ... \; (2)$

➥ Now, applying Kirchhoff's loop rule to closed loop

A – B – C – Y – X – A

$-10\, I_1 - 5(I_1 - I_2) + 10 - 10\, I = 0$

$\therefore - 2\, I_1 - (I_1 - I_2) + 2 - 2\, I = 0$

$\therefore - 2\, I_1 - I_1 + I_2 + 2 - 2\, I = 0$

$\therefore - 2\, I - 3\, I_1 + I_2 = -2$

$\therefore 2\, I + 3\, I_1 - I_2 = 2 \; ... \; (3)$

➥ Subtracting equation (2) from equation (1) we get,

$I - 3\, I_1 - I_2 = 0$

$2I - 3\, I_1 + 4I_2 = 0$

$- \;\; + \;\; -$

➥ $\therefore - I - 5I_2 = 0$

$\therefore I + 5I_2 = 0 \; ... \; (4)$

➥ By adding equations (2) and (3) we get

$\therefore 2I - 3\, I_1 + 4\, I_2 = 0$

$2I + 3\, I_1 - I_2 = 2$

➥ $\therefore 4I + 3\, I_2 = 2 \; ... \; (5)$

➥ By multipying equation (4) by 4 and subtracting equation (5), we have

$4I + 20\, I_2 = 0$

$4I + 3\, I_2 = 2$

➥ $- \;\; - \;\; -$

$17\, I^2 = -2$

$\therefore I_2 = - \dfrac{2}{17}\, A$

➥ Putting the value of I_2 in equation (4)

$$\therefore I + 5\left(-\frac{2}{17}\right) = 0$$

$$\therefore I = \frac{10}{17} \text{ A}$$

$$I = \frac{10}{17} \text{ A and } I_2 = -\frac{2}{17} \text{ A}$$

➥ Putting the value of I and I_2 in equation (1)

$$\therefore \frac{10}{17} - 3(I_1) - \left(-\frac{2}{17}\right) = 0$$

$$\therefore \frac{10}{17} + \frac{2}{17} = 3 I_1$$

$$\therefore \frac{12}{17} = 3 I_1$$

$$\therefore I_1 = \frac{4}{17} \text{ A}$$

Current flowing in the branch AB,

$$I_1 = \frac{4}{17} \text{ A}$$

Current flowing in the branch BD,

$$I_2 = -\frac{2}{17} \text{ A}$$

➥ Here the negative sign indicates that the current actually flows in the opposite direction to the journey we have considered. i.e. from D to B.

Current flowing in the branch BC,

$$I_1 - I_2 = \frac{4}{17} - \left(-\frac{2}{17}\right)$$

$$\therefore I_1 - I_2 = \frac{4+2}{17}$$

$$\therefore = \frac{6}{17} \text{ A}$$

➥ Current flowing in the branch DC,

$$I - I_1 + I_2 = \frac{10}{17} - \frac{4}{17} + \left(-\frac{2}{17}\right)$$

$$= \frac{10-4-2}{17}$$

$$= \frac{4}{17} \text{ A}$$

➥ Current flowing in the branch AD

$$I - I_1 = \frac{10}{17} - \frac{4}{17}$$

$$= \frac{6}{17} \text{ A}$$

$$\text{Total current} = \frac{4}{17} + \frac{6}{17} + \frac{-4}{17} + \frac{6}{17} + \frac{-2}{17}$$

$$= \frac{10}{17} \text{ A}$$

23.

➥ As shown in fig., an AC source is connected to pure inductor. (A pure inductor means an inductor having negligibly small resistance.)

➥ Let the voltage across the source be

$\upsilon = \upsilon_m \sin \omega t$... (1)

➥ Using the kirchhoff's loop rule for the AC circuit shown in the fig.,

$\upsilon - L\frac{di}{dt} = 0$ ... (2)

Remember : First term in the above equation shows the voltage of the AC source. The second term shows the self-induced emf in the inductor, and L is the self-inductance of the inductor. The negative sign follows from Lenz's law.

➥ From equation (2),

$\therefore \upsilon = L\frac{di}{dt}$

$\therefore \upsilon_m \sin \omega t = L\frac{di}{dt}$

$\therefore \frac{di}{dt} = \frac{\upsilon_m}{L} \sin \omega t$ ... (3)

Remember : The equation implies that the equation for $i(t)$, the current as a function of time, must be such that its slope $\frac{di}{dt}$ is a sinusoidally varying quantity, with the same phase as the source voltage and an amplitude given by $\frac{\upsilon_m}{L}$.

➥ To obtain the current, we integrate equation (3)

$\therefore \int \frac{di}{dt} dt = \int \frac{\upsilon_m}{L} \sin(\omega t)\, dt$

$\therefore i = -\frac{\upsilon_m}{\omega L} \cos(\omega t) + \text{constant}$

➥ The integration constant has the dimension of current and is time-independent. Since the source has an emf which oscillates symmetrically about zero, so that no constant or time-independent component of the current exists. Therefore, the integration constant is zero.

$\therefore i = -\frac{\upsilon_m}{\omega L} \cos \omega t$

$\therefore i = \frac{\upsilon_m}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)$

$\therefore i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)$ ... (4)

$i_m = \frac{\upsilon_m}{\omega L}$ Amplitude of the current

➥ The quantity ωL is analogous to the resistance and is called inductive reactance, denoted by X_L :

$\therefore X_L = \omega L$

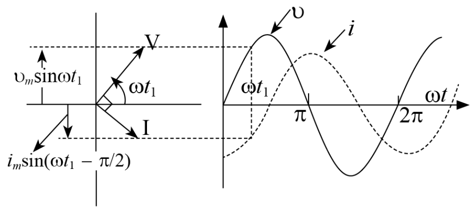
Unit of X_L is ohm (Ω).

➥ From eq. (1) and (4), it can be said that current lags the voltage by $\frac{\pi}{2}$ rad. [or one-quarter $\frac{1}{4}$ cycle].

➥ Voltage of the AC source, $\upsilon = \upsilon_m \sin \omega t$

➥ For an AC circuit which is purely inductive, electric current, $i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)$.

➥ Comparison of above two equations shows that current lags behind the voltage by $\frac{\pi}{2}$ rad (or one fourth of a time period $\frac{T}{4} = \frac{\frac{\pi}{2}}{\omega}$)



(a) (b)

- The fig. shows the voltage and the current phasors for some time t_1. Current phasor $\vec{I}$ is lagging behind voltage phasor $\vec{V}$ by $\frac{\pi}{2}$ radian.
- When rotated with angular frequency ω counter clockwise, they generate the voltage and current given by equations

  $\upsilon = \upsilon_m \sin \omega t$ and $i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)$, respectively as shown in the figure.
- Voltage of the AC source,

  $\upsilon = \upsilon_m \sin \omega t$
- Electric current in the circuit having only inductor,

  $$i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

  Where, $i_m = \frac{\upsilon_m}{\omega L}$ Amplitude of electric current
- The instantaneous power supplied to the inductor is.

  $$p = \upsilon i$$

  $$\therefore p = \upsilon_m i_m \sin \omega t \sin\left(\omega t - \frac{\pi}{2}\right)$$

  $$\therefore p = -\upsilon_m i_m \sin \omega t \cos \omega t$$

  $$\therefore p = -\frac{\upsilon_m i_m}{2}(2 \sin \omega t \cos \omega t)$$
- But $2 \sin \omega t \cos \omega t = \sin 2\omega t$

  $$\therefore p = -\frac{\upsilon_m i_m}{2} \sin 2\omega t$$
- The average power over a complete cycle is

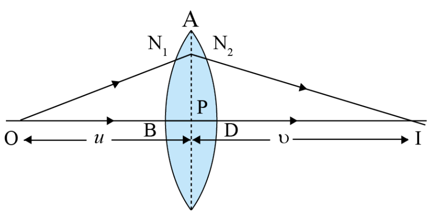
  $$P = \overline{p} = \left\langle -\frac{\upsilon_m i_m}{2} \sin 2\omega t \right\rangle$$

  $$P = -\frac{i_m \upsilon_m}{2} < \sin 2\omega t >$$

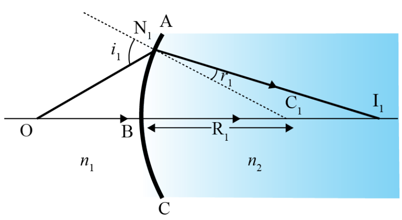
  But $< \sin 2\omega t > = 0$

  $\therefore P = 0$
- Thus, the average power supplied to an inductor over one complete cycle is zero.

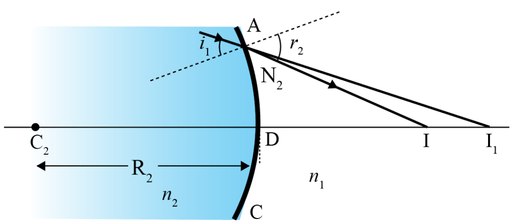
24.

- 

(a)



(b)



(c)

- Figure (a) shows the geometry of image formation by a convex lens.
- A point object O is placed at a distance u from the optical centre. On the other side of the lens there is image I. Here image distance is υ. The radii of curvature of both surfaces of the lens are R_1 and R_2 respectively and the focal length of the lens is f.
- The image formation can be seen in terms of two steps :

  (i) The first refracting surface forms the image I_1 of the object O. (figure b)

  (ii) The image I_1 acts as a virtual object for the second surface. (figure c) that forms image at I.
- For refraction at interface ABC,

$$\frac{n_1}{OB} + \frac{n_2}{BI_1} = \frac{n_2 - n_1}{BC_1} \quad \text{... (1)}$$

- A similar procedure applied to the interface ADC gives,

$$-\frac{n_2}{DI_1} + \frac{n_1}{DI} = \frac{n_2 - n_1}{DC_2}$$

- For a thin lens,

$$BI_1 = DI_1$$

$$\therefore -\frac{n_2}{BI_1} + \frac{n_1}{DI} = \frac{n_2 - n_1}{DC_2} \quad \text{... (2)}$$

- Adding equations (1) and (2),

$$\frac{n_1}{OB} + \frac{n_1}{DI} = \frac{n_2 - n_1}{BC_1} + \frac{n_2 - n_1}{DC_2} \quad \text{... (3)}$$

- Suppose the object is at infinity

  i.e. OB $\rightarrow \infty$ and DI $\rightarrow f$ (focal length)
- from equation (3),

$$0 + \frac{n_1}{f} = \frac{n_2 - n_1}{BC_1} + \frac{n_2 - n_1}{DC_2}$$

$$\therefore \frac{n_1}{f} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right)$$

- Now substituting $BC_1 = R_1$ and $DC_2 = -R_2$ in above equation.

  (Positive and negative signs are determined according to the sign convention).

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

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

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

$$\therefore \frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

- This equation is known as lensmaker's formula.
- Note that the formula is true for a concave lens also. For concave lens R_1 is negative, R_2 positive and therefore f is negative.

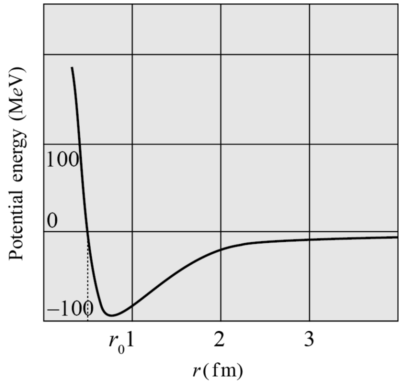
25.

- Nucleus contains protons and neutrons, in which there is a coulomb repulsion between protons and protons. However, the proton can not escape from the nucleus. Because to bind a nucleus together there must be a strong attractive force of a totally different kind. It must be strong enough to overcome the repulsion between (the positively charged) protons and to bind both protons and neutrons into the tiny nuclear volume.
- Many features of the nuclear binding force are summarised below :

  (i) The nuclear force is much stronger than the Coulomb force acting between charges or the gravitational forces between masses. That's why it holds protons and neutrons in the nucleus.

(ii) The range of the nuclear force is of the order of femtometres. For distances greater than one femtometres this force rapidly decreases to zero.

- This leads to saturation of forces in a medium or a large sized nucleus.
- A plot of the potential energy between two nucleons as a function of distance as shown in figure.

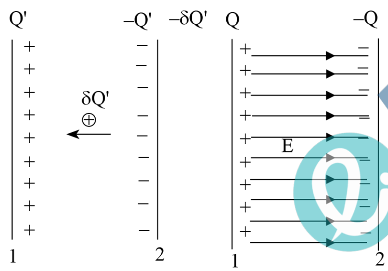


- The potential energy is minimum at a distance r_0 of about 0.8 fm. The force is attractive for distance larger than 0.8 fm.
- The force is repulsive for distance less than 0.8 fm.

(iii) The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

- Unlike Coulomb's law or the Newton's law of gravitation there is no simple mathematical form of the nuclear force.

26.



- To find the energy stored in capacitor, suppose the charge on the conductor is zero, initially.
- Suppose the positive charge is taken from conductor-2 to conductor 1, bit by bit. At the end of the process, suppose the conductor 1 gets charge Q and conductor 2 has charge –Q.
- To transfer the positive charge from conductor 2 to conductor 1, work needs to be done and the energy equivalent to this work is stored in the capacitor, which is known as the energy stored in the capacitor.
- Consider the intermediate situation when the conductors 1 and 2 have charges Q' and –Q' respectively. At this stage, the p.d. V' between the conductors 1 and 2 is $\frac{Q'}{C}$ where C is the capacitance of the system.
- Now, work done to transfer a small charge δQ' from conductor 2 to conductor 1,

$$\delta W = V'\,\delta Q' = \frac{Q'}{C}\,\delta Q' \quad ......(1)$$

- Total work required to be done in building (/ establishing) + Q charge on conductor 1,

$$W = \int_0^Q \frac{Q'}{C}\,\delta Q'$$

$$\therefore W = \frac{1}{C}\left(\frac{Q'^2}{2}\right)_0^Q \quad \left[\because \int x^n dx = \frac{x^{n+1}}{n+1}\right]$$

$$\therefore W = \frac{1}{C}\left(\frac{Q^2}{2} - 0\right)$$

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

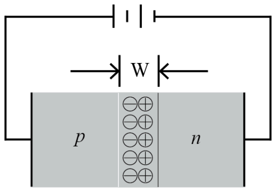
- Because this work is stored in capacitor in the form of energy which is called energy stored in capacitor.

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

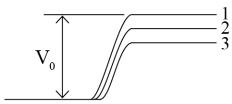
- Using Q = CV in above equation, we can easily get other alternate forms of above equation.
- $U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ$

27.

- When an external voltage V is applied across a semi-conductor diode such that *p*-side is connected to the positive terminal of the battery and the *n*-side to the negative terminal (fig. (a)), it is said to be forward biased.

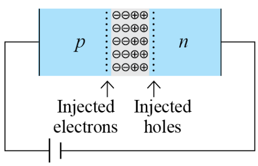


(a)



(b)

- Here, the voltage applied to the diode across the two terminals of the depletion region and the direction of the applied voltage (V) is opposite to the built-in potential (V).
- As a result, the depletion layer width decreases and the barrier height is reduced (Fig. (b)). The effective barrier height under forward bias is $(V_0 - V)$.
- If the applied voltage is small, the barrier potential will be reduced only slightly below the equilibrium value and only a small number of carriers in the material - those that happen to be in the uppermost energy levels - will possess enough energy to cross the junction. So the current will be small.
- If we increase the applied voltage significantly, the height of the barrier potential reduces, and more number of charge carriers gain enough energy to cross the depletion region, due to which the current also increases.
- *"Due to the applied voltage, electrons from the* n*-side cross the depletion region and reach* p*-side (Where they are minority carriers). Similarly, holes from the* p*-side cross the junction and reach the* n*-side. (Where they are minority carriers.) This process under forward bias is known as minority carrier injection."*
- At the junction boundary, on each side, the minority carrier concentration increases significantly compared to the locations far from the junction.
- Due to this concentration gradient, the injected electrons on *p*-side diffuse from the junction edge of *p*-side to the other end of *p*-side. Likewise, the injected holes on *n*-side diffuse from the junction edge of *n*-side to the other end of *n*-side. This is shown in fig. below.



- This motion of charged carriers on either side gives rise to current. The total diode forward current is sum of hole diffusion current and conventional current due to electron diffusion. The magnitude of this current is usually in *m*A.