LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNTMENT PAPER 7**

Section A

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

Section A

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

1.

➥ (i) Electric field lines are imaginary curves drawn in such a way that the tangent to it of each point shows the direction of electric field at that point.

(ii) Field lines start from positive charges and end at negative charges. If there is a single charge, they may start or end at infinity.

(iii) In a charge-free region, electric field lines can be taken to be continuous curves without any breaks.

(iv) Two field lines never cross each other.

(v) Electrostatic field lines do not form any closed loops.

(vi) Distribution of electric field lines gives an idea of electric field intensity in that region.

(vii) Field lines of a uniform electric field are mutually parallel and equidistant.

2.

➥ $\varphi = 8.0 \cdot 10^3 \frac{Nm^2}{C}$

(a) Net charge inside the black box :

➥ Total charge (q) enclosed by the box,

From, $\varphi = \frac{q}{\varepsilon_0}$

$\therefore q = \varphi\, \varepsilon_0$

$\therefore q = 8 \cdot 10^3 \cdot 8.85 \cdot 10^{-12}$

$\therefore q = 70.8 \cdot 10^{-9}$ C

$\therefore q = 0.07 \propto$C

(b) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box? Why or why not?

➥ No. Because if there are equal positive and negative charges in box, then total electric charge in the box will be zero. This will result in electric flux associated with box to be zero.

3.

➥ The statements of Kirchhoff"s laws are as follows :

(1) Junction rule : *"At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction."*

(2) Loop rule : *"The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero."*

➥ Kirchhoff's junction rule works on the law of conservation of charge and loop rule works on the law of conservation of energy.

4.

➥ $\mu = 400$

I = 2A

$n = 1000 \frac{turns}{metre}$

(a) Magnetic intensity (H)

$H = nI$

$H = 1000 \times 2$

H = 2000 A/m

(b) Total magnetic field of the solenoid,

$B = \mu_r H$

but $\mu_r = \frac{\mu}{\mu_0}$ $\therefore \mu = \mu_r \mu_0$

$\therefore B = \mu_r \mu_0 H$

$\therefore B = 400 \times 4\pi \times 10^{-7} \times 2000$

$\therefore B = 4 \times 4\pi \times 2 \times 10^{-2}$

$\therefore B = 100.48 \times 10^{-2}$

$\therefore B = 1\ T$

(c) Magnetisation (M)

$B = \mu_0 (H + M)$

$\therefore \frac{B}{\mu_0} = H + M$

$\therefore M = \frac{B}{\mu_0} - H$

$\therefore M = \frac{1}{4\pi \times 10^{-7}} - 2000$

$\therefore M = \frac{100 \times 10^5}{4 \times 3.14} - 2000$

$\therefore M = 7.9618 \times 10^5 - 2000$

$\therefore M = 796180 - 2000$

$\therefore M = 794180\ A/m$

$\therefore M = 7.94 \times 10^5\ A/m$

$M \approx 8 \times 10^5\ A/m$

(d) Megnetising Current (I_m)

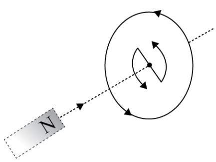
$M = n I_m$

$\therefore I_m = \frac{M}{n}$

$= \frac{7.94 \times 10^5}{1000}$

$= 794\ A$

5.

➥ 

➥ As shown in figures when N-pole of magnet is moved towards coil, according to Lenz's law, end of coil towards magnet behaves as N-pole and induced current flows in anti-clockwise direction.

➥ Suppose, here induced current flows in clockwise direction. In that case, end of coil towards magnet will behave as S-pole and so, attractive force arises between coil and magnet when coil approaches N-pole of magnet.

➥ Due to attractive force, magnet does accelerated motion towards coil.

➥ As a result, electrical energy arises in coil and magnet gains kinetic energy continuously.

➥ Thus, in the process starting with a gentle push on magnet, without spending any extra energy, we get kinetic energy and electrical energy. But this violates law of conservation of energy. Thus, our assumption is not correct.

➥ Thus, direction of induced current is possible only as per situation shown in figure. As a result, repulsive force arises between coil and magnet and energy spent (work done) gets transformed into kinetic energy and electrical energy.

➥ Thus, it can be said that Lenz's law is a specific statement of law of conservation of energy.

6.

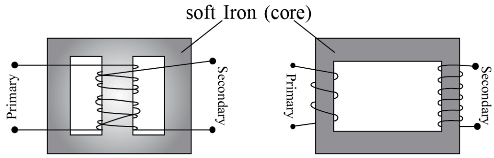
➥ The device using which alternating voltage can be changed from one to another of greater or smaller value, is called a transformer.

➥ Principle :

➠ Electro magnetic induction (Mutual induction)

➥ Construction :

➠ A transformer consists of two sets of coils, insulated from each other. They are wound on a soft iron core, either on top of the other as in fig. (a) or on separate limbs of the core as shown in (b).



(a) (b)

➥ One of the coils is called the primary coil and the other is called the secondary coil.

➥ Number of turns in the coils are N_P and N_S respectively.

➥ Often, the primary coil is the input coil and the secondary coil is the output coil of the transformer.

➥ When an alternating voltage is increased using a transformer, it is called step up transformer, and if the voltage is decreased, the transformer is known as step down transformer.

7.

➥ Mass of Fe nucleus

$m_{Fe} = 55.85\ u$

$\therefore m_{Fe} = 55.85 \cdot 1.66 \cdot 10^{-27}$ kg

$m_{Fe} = 9.27 \cdot 10^{-26}$ kg

➥ Radius of nucleus

$R = R_0\ A^{\frac{1}{3}}$

$\therefore R = (1.2 \cdot 10^{-15})\ (56)^{\frac{1}{3}}$

$\therefore R = 4.59 \cdot 10^{-15}$ m

➥ Volume of nucleus

$V = \frac{4}{3}\pi R^3$

$\therefore V = \frac{4}{3} \cdot 3.14 \cdot (4.59 \cdot 10^{-15})^3$

$\therefore V = 4.05 \cdot 10^{-43}\ m^3$

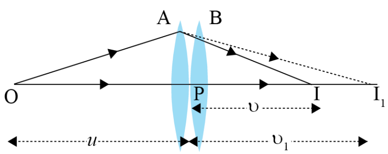
➥ Nuclear density

$\rho = \frac{\text{mass}}{\text{volume}}$

$\therefore \rho = \frac{9.27 \times 10^{-26}}{4.05 \times 10^{-43}}$

$\therefore \rho = 2.29 \cdot 10^{17}\ \text{kg m}^{-3}$

8.

➥ 

➥ As shown in figure two lenses A and B are arranges so that their principal axis is the same. The focal lengths of these are f_1 and f_2 respectively. Here we will assume that since both the lenses are thin, their optical centre converge on each other. Let the centre be the point P.

➥ Let the object be placed at point O beyond the focus of the first lens A. The first lens produces an image at I_1. This image I_1 serves as a virtual object for the second lens. B producing the final image at I.

➥ For the image formed by the first lens A,

$$\frac{1}{\upsilon_1} - \frac{1}{u} = \frac{1}{f_1} \quad \text{... (1)}$$

➥ For the image formed by the second lens B,

$$\frac{1}{\upsilon} - \frac{1}{\upsilon_1} = \frac{1}{f_2} \quad \text{... (2)}$$

➥ Adding equations (1) and (2),

$$\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad \text{... (3)}$$

➥ If the two lens-system is regarded as equivalent to a single lens of focal length f.

$$\therefore \frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f} \quad \text{... (4)}$$

➥ Comparing equations (3) and (4),

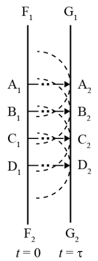
$$\therefore \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

➥ The derivation is valid for any number of thin lenses, in contact. If several thin lenses of focal length f_1, f_2, f_3, ... are in contact, the effective focal length of their combination is given by $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$

9.

➥ 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 $t = \tau$.

10.

➥ Voltage $V = 30 \text{ kV} = 30 \times 10^3 V$

➥ (a) The maximum frequency $(\nu_{max}) = ?$

$$qV = E_{max}$$

$$qV = h\nu_{max}$$

$$\therefore \nu_{max} = \frac{qV}{h}$$

$$= \frac{1.6 \times 10^{-19} \times 30 \times 10^{3}}{6.625 \times 10^{-34}}$$

$$\therefore \nu_{max} = 7.24 \times 10^{18} \text{ Hz}$$

➥ (b) The minimum wavelenth of X-rays.

$\lambda_{min} = ?$

$\lambda_{min} = \frac{c}{v_{\max}}$

$\lambda_{min} = \frac{3 \times 10^8}{7.24 \times 10^{18}}$

$\lambda_{min} = 0.414 \times 10^{-10}\ m$

$= 0.0414\ nm$

11.

➥ Bohr combined classical and early quantum concepts and gave his theory in the form of three postulates. These are :

➥ (i) Bohr's first postulate : An electron in an atom could revolve in certain stable orbits without the emission of radiant energy.

- According to this postulate, each atom has certain definite stable states in which it can exist, and each possible state has definite total energy. These are called the stationary states of the atom.
- This contrary to the predictions of electromagnetic theory.

➥ (ii) Bohr's second postulate : The electron revolves around the nucleus only in those orbits for which the angular momentum is in integral multiple of $\frac{h}{2\pi}$.

- Where, h is Planck's constant

$h = 6.625 \times 10^{-34}$ J s.

$L = \frac{nh}{2\pi}$ Where, $n = 1, 2, 3....$

➥ (iii) Bohr's third postulate : An electron makes a transition from one of its specified non-radiating orbits to another of lower energy. When it does so, a photon is emitted having energy equal to the energy difference between the initial and final states.

- The frequency of the emitted photon is then given by

$hv = E_i - E_f$

Where E_i and E_f are the energies of the initial and final states and $E_i > E_f$.

12.

➥ number of atoms in pure $Si = 5 \times 10^{28}\ m^{-3}$

➥ Concentration of As = 1 ppm

Impurity proportion is kept as 1 in 10^6 pure atoms.

Total atoms of As = $\frac{5 \times 10^{28}}{10^6} = 5 \times 10^{22}\ m^{-3}$

➥ As is pentavalent impurity. Thus As is donating one extra electron. So electron number density due to As atom,

$n_e = n_D = 5 \times 10^{22}\ m^{-3}$

➥ Now $n_i^2 = n_e n_h$

$\therefore n_h = \frac{n_i^2}{n_e}$

$\therefore n_h = \frac{(1.5 \times 10^{16})^2}{5 \times 10^{22}}$

$\therefore n_h = \frac{2.25 \times 10^{32}}{5 \times 10^{22}}$

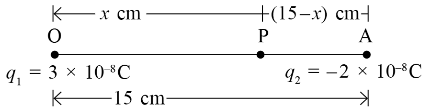
$\therefore n_h = 4.5 \times 10^9\ m^{-3}$

Section B

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

13.

➥



(a)

➠ Suppose, here the positive charge is at the origin and the negative charge is towords right side of the origin, on the x-axis.

➠ Suppose, electric potential at point P is zero.

$$\therefore \frac{k q_1}{x \times 10^{-2}} + \frac{k q_2}{(15-x) \times 10^{-2}} = 0$$

$$\therefore \frac{q_1}{x \times 10^{-2}} + \frac{q_2}{(15-x) \times 10^{-2}} = 0$$

$$\therefore \frac{3 \times 10^{-8}}{x \times 10^{-2}} - \frac{2 \times 10^{-8}}{(15-x) \times 10^{-2}} = 0$$

$$\therefore \frac{3 \times 10^{-8}}{x \times 10^{-2}} = \frac{2 \times 10^{-8}}{(15-x) \times 10^{-2}}$$

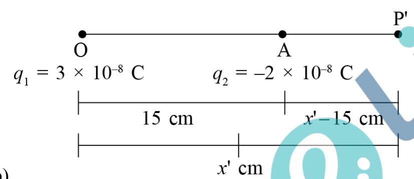
$$\therefore \frac{3}{x} = \frac{2}{(15-x)}$$

$\therefore 45 - 3x = 2x$

$\therefore 45 = 5x$

$\therefore x = 9$ cm

➥



(b)

➠ As shown in fig., suppose, electric potential at point P' is zero.

$$\therefore \frac{k q_1}{x' \times 10^{-2}} + \frac{k q_2}{(x'-15) \times 10^{-2}} = 0$$

$$\therefore \frac{3 \times 10^{-8}}{x' \times 10^{-2}} - \frac{2 \times 10^{-8}}{(x'-15) \times 10^{-2}} = 0$$

$$\therefore \frac{3 \times 10^{-8}}{x' \times 10^{-2}} = \frac{2 \times 10^{-8}}{(x'-15) \times 10^{-2}}$$

$$\therefore \frac{3}{x'} = \frac{2}{x'-15}$$

$\therefore 3x' - 45 = 2x'$

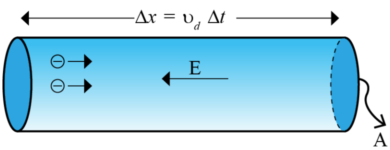
$\therefore 3x' - 2x' = 45$

$\therefore x' = 45$ cm

➠ Like this, the electric potential will be zero at distances 9 cm and 45 cm from positive charge.

14.

➥



- A conductor of cross- sectional area $\vec{A}$ is shown in the figure. The electric field inside the conductor is $\vec{E}$.
- Due to this electric field, there will be net flow of charges across any area of the conductor.
- Because of the drift, distance travelled by electron in time Δt is $|\vec{\upsilon}_d|\ \Delta t$.
- Suppose the number of free electrons per unit volume in metal is n, then the number of electrons passing through the area A is N $= nA|\vec{\upsilon}_d|\Delta t$.
- The total charge flowing through the cross - sectional area in time Δt is $-neA|\vec{\upsilon}_d|\Delta t$ ... (1)
- Here, electric field $\vec{E}$ is directed towards the left as a result the total electric charge passing through the surface in the direction of $\vec{E}$, will be equal to the negative value of above equation (1).

$$\therefore q = -(-ne\,A|\vec{\upsilon}_d|\Delta t) \ldots (2)$$

$$\therefore q = ne\,A|\vec{\upsilon}_d|\ \Delta t$$

- The amount of charge crossing the area $\vec{A}$ in time Δt is by definition I Δt (where I is the magnitude of the current).
- Hence,

$$\therefore I\,\Delta t = ne\,A|\vec{\upsilon}_d|\ \Delta t$$

$$\therefore I = ne\,A|\vec{\upsilon}_d| \ldots (3)$$

- but current density $j = \frac{I}{A}$

$$I = jA$$

$$\therefore jA = ne\,A|\vec{\upsilon}_d| \ (\because \text{ from } eq^n\ (3))$$

$$\therefore j = ne\ |\vec{\upsilon}_d| \ldots (4)$$

$$\therefore j = ne\left(\frac{eE}{m}\right)\cdot\tau\ (\because\ |\vec{\upsilon}_d| = \frac{eE}{m}\tau)$$

$$\therefore j = \frac{ne^2E}{m}\tau \ldots (5)$$

- Writing above equation (5) in vector form

$$\vec{j} = \frac{ne^2\tau}{m}\cdot\vec{E}$$

- Now comparing above equation with $\vec{j} = \sigma\vec{E}$

we get

$$\therefore \sigma\vec{E} = \frac{ne^2\tau}{m}\cdot\vec{E}$$

$$\therefore \sigma = \frac{ne^2\tau}{m} \ldots (6)$$

- Resistivity of conductor is reciprocal of conductivity

$$\varrho = \frac{1}{\sigma}$$

$$\therefore \varrho = \frac{m}{ne^2\tau} \ldots (7)$$

15.

For meter M_1	For meter - M_2
$R_1 = 10\ \Omega$	$R_2 = 14\ \Omega$
$N_1 = 30$ Turns	$N_2 = 42$ Turns
$A_1 = 3.6 \times 10^{-3}\ m^2$	$A_2 = 1.8 \times 10^{-3}\ m^2$
$B_1 = 0.25$ T	$B_2 = 0.50$ T

➡ For both meters spring constant are same

$\therefore k_1 = k_2 = k$

(a) Current sensitivity of meter M_1

$$\left(\frac{\phi}{I}\right)_1 = \frac{N_1 B_1 A_1}{k} \quad \dots (1)$$

Current sensitivity of meter M_2

$$\left(\frac{\phi}{I}\right)_2 = \frac{N_2 B_2 A_2}{k} \quad \dots (2)$$

➡ taking ratio of equation (2) and equation (1)

$$\frac{\left(\frac{\phi}{I}\right)_2}{\left(\frac{\phi}{I}\right)_1} = \frac{\frac{N_2 B_2 A_2}{k}}{\frac{N_1 B_1 A_1}{k}} = \frac{N_2 B_2 A_2}{N_1 B_1 A_1}$$

$$\therefore \frac{\left(\frac{\phi}{I}\right)_2}{\left(\frac{\phi}{I}\right)_1} = \frac{42 \times 0.50 \times 1.8 \times 10^{-3}}{30 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$\therefore \frac{\left(\frac{\phi}{I}\right)_2}{\left(\frac{\phi}{I}\right)_1} = \frac{42}{30} = \frac{7}{5} = 1.4$$

(b) Voltage sensitivity of meter M_1

$$\left(\frac{\phi}{V}\right)_1 = \frac{N_1 B_1 A_1}{k R_1} \quad \dots (3)$$

Voltage sensitivity of meter M_2

$$\left(\frac{\phi}{V}\right)_2 = \frac{N_2 B_2 A_2}{k R_2} \quad \dots (4)$$

➡ Taking ratio of equation (4) and equation (3), we have

$$\frac{\left(\frac{\phi}{V}\right)_2}{\left(\frac{\phi}{V}\right)_1} = \frac{\frac{N_2 B_2 A_2}{k R_2}}{\frac{N_1 B_1 A_1}{k R_1}} = \frac{N_2 B_2 A_2 R_1}{N_1 B_1 A_1 R_2}$$

$$\therefore \frac{\left(\frac{\phi}{V}\right)_2}{\left(\frac{\phi}{V}\right)_1} = \frac{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10}{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}$$

$$\therefore \frac{\left(\frac{\phi}{V}\right)_2}{\left(\frac{\phi}{V}\right)_1} = \frac{42}{30} \times \frac{10}{14} = 1$$

Self Practice

A rectangular coil of 120 turns and an area of 10×10^{-4} m² suspended in a radial magnetic field of 45×10^{-4} T. If a current of 0.2 mA through the coil gives it a deflection of 36°, find the effective torsional constant for the spring system holding the coil.

Ans : $K = 17.2 \times 10^{-8} \frac{Nm}{rad}$

16.

➡ $\nu_{min} = 7.5 \text{ MHz} = 7.5 \times 10^6$ Hz

$\nu_{max} = 12 \text{ MHz} = 12 \times 10^6$ Hz

From $\lambda = \frac{c}{\nu}$,

➥ Minimum wavelength (λ_{min})

$$\lambda_{min} = \frac{c}{\nu_{max}}$$

$$\therefore \lambda_{min} = \frac{3 \times 10^8}{12 \times 10^6}$$

$$\therefore \lambda_{min} = 25 \text{ m}$$

➥ Maximum wavelength (λ_{max})

$$\lambda_{max} = \frac{c}{\nu_{min}}$$

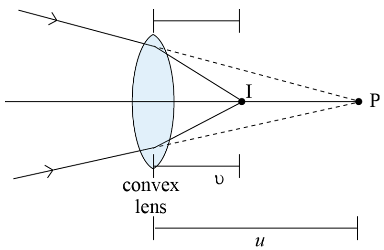
$$\therefore \lambda_{max} = \frac{3 \times 10^8}{7.5 \times 10^6}$$

$$\therefore \lambda_{max} = 40 \text{ m}$$

➥ Therefore, the range of wavelengths will be from 25 m to 40 m.

17.

➥ (a) for convex lens,



➠ As shown in the figure, placing a convex lens in the path of a beam of light, it concentrates at point I. (∵ it is converging lens.)

➠ Here the point P behaves as a virtual object.

∴ object-distance u = 12 cm

image-distance υ = ?

focal length f = 20 cm

➠ from lens formula,

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

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

$$\therefore \frac{1}{\upsilon} = \frac{1}{20} + \frac{1}{12}$$

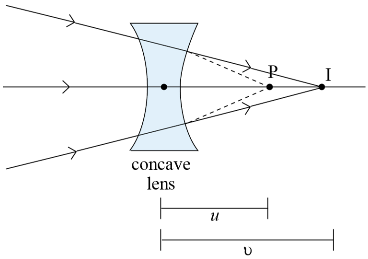
$$\therefore \frac{1}{\upsilon} = \frac{3+5}{60}$$

$$\therefore \upsilon = \frac{60}{8}$$

= 7.5 cm

➠ This beam of light is concentrated near point I at a distance of 7.5 cm as shown in figure.

(b) for concave lens,



As shown in figure, placing a concave lens in the path of a beam of light is concentrated near I.

∴ object distance $u = 12$ cm

image distance $\upsilon = ?$

focal length $f = -16$ cm

from lens formula,

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

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

$$\therefore \frac{1}{\upsilon} = \frac{-1}{16} + \frac{1}{12}$$

$$\therefore \frac{1}{\upsilon} = \frac{-3+4}{48}$$

$\therefore \upsilon = 48$ cm

This beam of light is concentrated near point I at a distance of 48 cm as shown in figure.

18.

The formula to find out the intensity of resultant wave generated due to super position of waves emanated from two coherent sources is,

$I = 4 I_0 \cos^2\left(\frac{\phi}{2}\right)$ (where, φ - phase difference)

Constructive Interference :

If the phase difference at the point of super position is

$\varphi = 0, \pm 2\pi, \pm 4\pi$ ... we will have constructive interference leading to maximum intensity.

Condition : phase difference $= \pm 2n\pi$

$(n = 0, 1, 2, 3 ...)$

Destructive Interference :

If the phase difference at the point of super position is

$\varphi = \pm \pi, \pm 3\pi, \pm 5\pi$ ... we will have destructive interference leading to zero intensity.

Condition : phase difference $= \pm (2n + 1)\pi$

$(n = 0, 1, 2, 3 ....)$

19.

Total energy of the electron in hydrogen atom is $-13.6\ e$V.

$E = -13.6\ e$V

$= -13.6 \times 1.6 \times 10^{-19}$

$= -2.2 \times 10^{-18}$ J

But the total energy

$$E = -\frac{e^2}{8\pi\varepsilon_0 r}$$

$$\therefore -2.2 \times 10^{-18} = -\frac{e^2}{8\pi\varepsilon_0 r}$$

$$\therefore 2.2 \times 10^{-18} = \frac{ke^2}{2r} \left(\because k = \frac{1}{4\pi\varepsilon_0}\right)$$

$$\therefore r = \frac{ke^2}{2 \times 2.2 \times 10^{-18}}$$

$$\therefore r = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{2 \times 2.2 \times 10^{-18}}$$

$$\therefore r = 5.3 \times 10^{-11} \text{ m} = 0.53 \text{ Å}$$

➥ The centripetal force on the electron in the hydrogen atom is balanced by the Coulombian force.

$$\frac{m\upsilon^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2}$$

$$\therefore \upsilon^2 = \frac{e^2}{4\pi\varepsilon_0 mr}$$

$$\therefore \upsilon = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}}$$

$$\therefore \upsilon = \frac{1.6 \times 10^{-19}}{\sqrt{4 \times 3.14 \times 8.85 \times 10^{-12} \times 9.1 \times 10^{-31} \times 5.3 \times 10^{-11}}}$$

$$\therefore \upsilon = 2.2 \times 1$$

20.

➥ $\nu = 6 \times 10^{14}$ Hz E = ?

$P = 2 \times 10^{-3}$ W N = ?

➥ (a) Each photon has an energy .

$$E = h\nu$$

$$E = 6.625 \times 10^{-34} \times 6 \times 10^{14}$$

$$E = 39.75 \times 10^{-20} \text{ J}$$

$$E = 3.98 \times 10^{-19} \text{ J}$$

$$E = \frac{3.98 \times 10^{-19}}{1.6 \times 10^{-19}} \, eV$$

$$E = 2.49 \, eV$$

➥ (b) If N is the number of photons emitted by the source per second,

➠ Then, P = NE

$$N = \frac{P}{E}$$

$$= \frac{2 \times 10^{-3}}{3.98 \times 10^{-19}}$$

$$= 5.0 \times 10^{15}$$

➥ Second Method :

➥ $$\text{Power (P)} = \frac{\text{Energy of radiation } (E_n)}{\text{time } (t)}$$

$$\therefore P = \frac{nh\nu}{t} \quad (\because E_n - nh\upsilon)$$

$$\therefore \frac{n}{t} = \frac{P}{h\nu}$$

$$\frac{n}{t} = \frac{2 \times 10^{-3}}{6.625 \times 10^{-34} \times 6 \times 10^{14}}$$

$$\frac{n}{t} = 0.05031 \times 10^{17}$$

$$\frac{n}{t} = 5.03 \times 10^{15} \frac{\text{photons}}{\text{second}}$$

21.

➥ $l = 10 \text{ cm} = 0.1 \text{ m}$

Area $A = l^2$

$= (0.1)^2$

$= 0.01 \text{ m}^2$

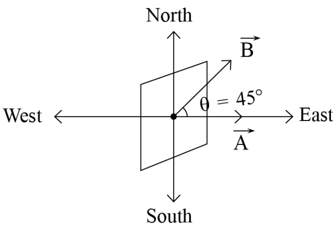
$R = 0.5\ \Omega$

$B_1 = 0.10 \text{ T}$

$B_2 = 0$

$\theta = 45°$

$\Delta t = 0.70 \text{ sec}$



➥ From Faraday's law, induced *emf* in loop

$$|\varepsilon| = \frac{|\Delta\phi_B|}{\Delta t}$$

$$\therefore |\varepsilon| = \frac{|\phi_2 - \phi_1|}{\Delta t}$$

$$\therefore |\varepsilon| = \frac{|B_2 A \cos\theta - B_1 A \cos\theta|}{\Delta t}$$

$$\therefore |\varepsilon| = \frac{|-B_1 A \cos\theta|}{\Delta t} \quad (\because B_2 = 0)$$

$$\therefore |\varepsilon| = \frac{0.1 \times 10^{-2} \times \cos 45}{0.7}$$

$$\therefore |\varepsilon| = 0.1 \times 10^{-2} \text{ V}$$

$$\therefore |\varepsilon| = 1 \text{ mV}$$

➥ Induced current in the loop

$$I = \frac{\varepsilon}{R}$$

$$\therefore I = \frac{1 \times 10^{-3}}{0.5}$$

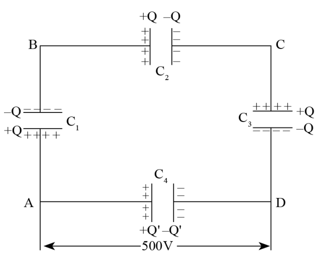
$$\therefore I = 2 \times 10^{-3} \text{ A}$$

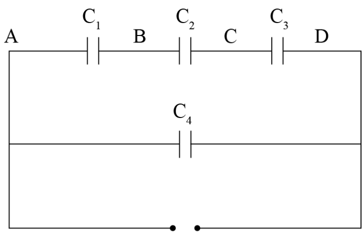
$$\therefore I = 2 \text{ mA}$$

Section C

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

22.





V = 500 V
equivalent network
(a)

(a) For the given network, (fig.a) all 3 capacitors C_1, C_2 and C_3 are in series connection, and their effective (/ equivalent) capacitance is C'.

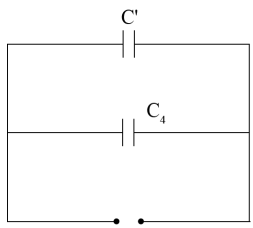
$\therefore \frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$\therefore \frac{1}{C'} = \frac{1}{10} + \frac{1}{10} + \frac{1}{10}$

$\therefore \frac{1}{C'} = \frac{3}{10}$

$\therefore C' = \frac{10}{3}\ \mu F$

➥ Now, C' and C_4 both are in parallel connection.



V = 500 V
equivalent network
(b)

➥ Suppose, its equivalent capacitance is C.

$\therefore C = C' + C_4$

$C = \frac{10}{3} + 10$

$C = \frac{40}{3}\ \mu F$

➥ The total charge of the circuit Q = CV

$Q = \frac{40}{3} \times 10^{-6} \times 500$

$Q = \frac{20}{3} \times 10^{-3}$

$Q = 6.67 \times 10^{-3}$ C

(b) Electric charge on capacitor C_4

$Q_4 = C_4 V = 10 \times 10^{-6} \times 500$

$Q_4 = 5 \times 10^{-3}$ C

➥ Between A and D ; C_1, C_2 and C_3 all 3 capacitors are in series connection, and therefore the charge on each will be same. Suppose, that equal charge is Q

➥ p.d. between AB, BC and CD are V_1, V_2 and V_3 respectively.

$V = V_1 + V_2 + V_3$

$$\therefore 500 = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\therefore 500 = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\therefore 500 = Q\left(\frac{1}{C'}\right)$$

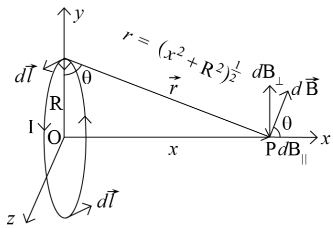
$$\therefore 500 = Q\left(\frac{1}{\frac{10}{3} \times 10^{-6}}\right)$$

$$\therefore Q = 500 \times \frac{10}{3} \times 10^{-6}$$

$$\therefore Q \approx 1.67 \times 10^{-3}\ C$$

23.

➥ As shown in the figure, a steady current I is flowing through a conducting loop of radius R.



➥ The loop is placed in such a way that it lies in the *y-z* plane and the X-axis passing through its axis.

➥ A point P lies at a distance x on the X-axis from its origin. We want to calculate the magnetic field at the point P.

➥ Consider a current element $I\,d\vec{l}$ from the loop shown in figure. The magnitude of the magnetic field due to this element is,

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{|I d\vec{l} \times \vec{r}\,|}{r^3} \quad \dots (1)$$

➥ But $I\,d\vec{l} \perp \vec{r}$ because $I\,d\vec{l}$ is in the *yz* plane and the position vector ($\vec{r}$) is in *xy* plane.

$$\therefore dB = \frac{\mu_0}{4\pi} \cdot \frac{I dl r \sin 90}{r^3}$$

$$\therefore dB = \frac{\mu_0}{4\pi} \cdot \frac{I dl}{r^2} \quad \dots (2)$$

➥ From the figure, $r^2 = R^2 + x^2$. Hence,

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{I dl}{(R^2 + x^2)} \quad \dots (3)$$

➥ The magnetic field has two components at point P

(i) Perpendicular component ($dB_\perp = dB \sin\theta$)

➠ When the perpendicular components are summed to get the net magnetic field, they cancel each other and the result is zero

(ii) Parallel component ($dB_{||} = dB \cos\theta$)

➠ The parallel components are summed up to get the net magnetic field, so it can be obtained by integrating $dB_x = dB \cos\theta$ over the loop.

➠ $dB(x) = dB \cos\theta$

$$\therefore dB(x) = \frac{\mu_0}{4\pi} \cdot \frac{I dl}{R^2 + x^2} \cdot \cos\theta \quad \dots (4)\ (\because \text{ from equation (3)})$$

➠ From the figure,

$$\cos\theta = \frac{R}{(x^2 + R^2)^{\frac{1}{2}}}$$

$$\therefore dB(x) = \frac{\mu_0}{4\pi} \cdot \frac{Idl}{R^2 + x^2} \cdot \frac{R}{(R^2 + x^2)^{\frac{1}{2}}}$$

$$\therefore dB(x) = \frac{\mu_0}{4\pi} \cdot \frac{Idl \cdot R}{(R^2 + x^2)^{\frac{3}{2}}}$$

➥ The resultant magnetic field.

$$B = \oint dB(x) = \frac{\mu_0 IR}{4\pi(R^2 + x^2)^{\frac{3}{2}}} \oint dl$$

$$\therefore B = \frac{\mu_0 IR}{4\pi(R^2 + x^2)^{\frac{3}{2}}} (2\pi R) \quad (\because \oint dl = 2\pi R)$$

$$\therefore B = \frac{\mu_0 IR^2}{2(R^2 + x^2)^{\frac{3}{2}}}$$

➥ In vector form,

$$\vec{B} = \frac{\mu_0 IR^2}{2(R^2 + x^2)^{\frac{3}{2}}} \cdot \hat{i}$$

➥ To obtain the magnetic field at the centre of the loop $x = 0$

$$\therefore B = \frac{\mu_0 IR^2}{2R^3} = \frac{\mu_0 I}{2R}$$

➥ If there are N turns, then

$$\vec{B} = \frac{\mu_0 NIR^2}{2(R^2 + x^2)^{\frac{3}{2}}} \cdot \hat{i}$$

24.

➥ 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,

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

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

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

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

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

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

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.
- Here, the voltage applied to the capacitor is $\upsilon = \upsilon_m \sin \omega t$ And the current flowing through the circuit is $i = i_m \sin\left(\omega t + \frac{\pi}{2}\right)$
- A comparison of both the equations shows that the current is $\frac{\pi}{2}$ rad ahead of voltage.
- Fig. shows the phasor diagram at an instant time t_1. Here, the current phasor $\vec{I}$ is $\frac{\pi}{2}$ ahead of the voltage phasor $\vec{V}$ as they rotate counter clockwise.
- Voltage of AC source $\upsilon = \upsilon_m \sin \omega t$
- Current in a circuit containing only capacitors is

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

- Where,

  $i_m = \frac{\upsilon_m}{X_C} = \frac{\upsilon_m}{\frac{1}{\omega C}}$ Amplitude of electric current

- The instantaneous power supplied to the capacitor 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, $2 \sin \omega t \cos \omega t = \sin 2\omega t$

  $\therefore p = \frac{\upsilon_m i_m}{2} \sin 2\omega t$

- Average power (during one complete cycle)

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

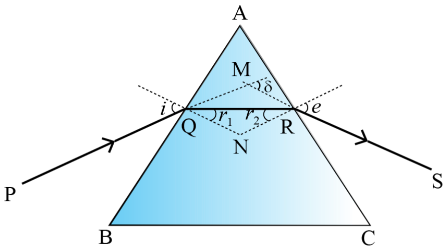
  $\therefore P = \frac{\upsilon_m i_m}{2} \langle \sin 2\omega t \rangle$

  But, $\langle \sin 2\omega t \rangle = 0$

  $\therefore P = 0$

- Thus, average power supplied to a capacitor during one complete cycle is zero.

25.

➥ 

➥ Figure shows the cross section of a prism.

➥ The path of a light passing through this prism is PQRS.

➥ The angle of incidence is i and the angle of refraction is r at the first side AB.

➥ The angle incidence is r_2 and the angle of emergence (angle of refraction) is e.

➥ Angle between the direction of emergent ray RS and incident ray PQ is called angle of deviation (δ).

➥ In □AQNR m∠AQN = m∠ARN = 90°.

➥ The sum of remaining two angles is 180°.

$\therefore \angle A + \angle QNR = 180° \; ... (1)$

➥ For ΔQNR,

$r_1 + r_2 + \angle QNR = 180° \; ... (2)$

➥ Comparing equation (1) and (2),

$\therefore \angle A + \angle QNR = r_1 + r_2 + \angle QNR$

$\therefore A = r_1 + r_2 \; ... (3)$

➥ For ΔQMR, δ is the exterior angle.

$\therefore \delta = \angle MQR + \angle MRQ \; ... (4)$

but $i = r_1 + \angle MQR$

$\therefore \angle MQR = i - r_1$

and same way $\angle MRQ = e - r_2$.

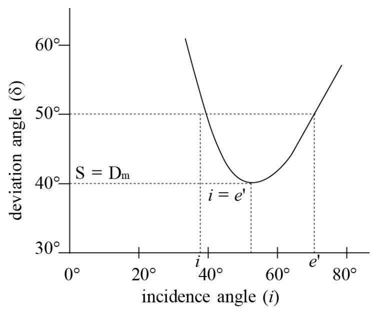
➥ Substituting these two values in equation (4),

$\therefore \delta = i - r_1 + e - r_2$

$\therefore \delta = i + e - (r_1 + r_2)$

➥ From equation (3),

$\therefore \delta = i + e - A$

➥ 

➥ The graph of deviation angle versus incidence angle is shown in figure.

➥ The graph shows that for a single value of deviation angle (δ) there are two values of incidence angle i and hence also of e.

➥ From the symmetry it can be said that angle of deviation δ remains the same if angle of incidence i and angle of emergent e are interchanged. Even if the path of ray can be traced back, resulting in the same angle of deviation.

➥ From the graph, for a particular value of $i = e$ the angle of incidence, a single value of deviation is obtained. At the minimum deviation, D_m, the refracted ray becomes parallel to its base.

➥ So when $\delta = D_m$ and $i = e$, then $r_1 = r_2$.

➥ For prism, $A = r_1 + r_2$

$$\therefore A = 2r_1$$

$$\therefore r_1 = \frac{A}{2} \quad ... (1)$$

➥ and from $\delta = i + e - A$,

$$D_m = 2i - A$$

$$2i = D_m + A$$

$$i = \frac{A + D_m}{2} \quad ... (2)$$

➥ Applying Snell's law at incident point Q,

$$n_1 \sin i = n_2 \sin r_1$$

➥ Substituting value of r_1 and i from equation (1) and (2),

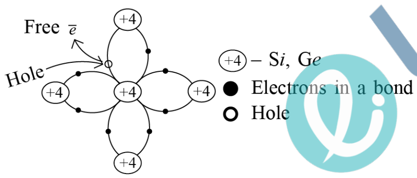
$$\therefore n_1 \sin \left(\frac{A + D_m}{2}\right) = n_2 \sin \left(\frac{A}{2}\right)$$

$$\therefore \frac{n_2}{n_1} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin \frac{A}{2}}$$

$$\therefore n_{21} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin \frac{A}{2}}$$

➥ which is the formula to find the refractive index of the material of the prism.

26.

➥ 

➥ At absolute zero temperature, each of the valence electrons of S*i* (and G*e*) is bound by the covalent bond. As a consequence S*i* (and G*e*) behave as insulators at absolute zero temperature.

➥ The atoms of the crystal perform thermal oscillations at the room temperature. This results in breaking of several covalent bonds and results in the electrons freeing from the covalent bond. These free electrons take part in electrical conduction.

➥ Deficiency of electron is created at the place from where the electron becomes free.

➥ This deficiency has the ability of attracting the electrons.

➥ An electron which has become free from any other covalent bond can get trapped in this place.

This deficiency of electron is known as hole.

➥ It behaves as if it has positive electric charge.

➥ Remember that hole is not a real particle and it neither has any positive electric charge. It is just deficiency (or an empty space) from where electron has become free.

➥ At room temperature in S*i* the required energy for electrons to escape from covalent bond is 1.1 *e*V and for G*e* it is 0.72 *e*V.

➥ In intrinsic (pure) Semiconductors, the number of free electrons, n_e is equal to the number of holes, n_h. That is $n_e = n_h = n_i$; where n_i is called the intrinsic carrier concentration.

➥ Here, electrons and holes are also known as intrinsic charge carriers.

27.

➥ Nucleus of copper contains 29 protons and number of neutrons N = A – Z

= 34

➥ Mass Defect $\Delta M = [Zm_p + Nm_n] - m({}^{63}_{29}Cu)$

$\therefore \Delta M = [29 \cdot 1.007825 + 34 \cdot 1.008665] - 62.92960$

$\therefore \Delta M = [29.226925 + 34.29461] - 62.92960$

$\therefore \Delta M = 0.591935\ u$

➥ Binding Energy

$E_b = \Delta M\, c^2$

$\therefore E_b = 0.591935 \times 931.5$

$\therefore E_b = 551.39$ MeV

➥ An energy of 551.39 MeV is required to separate protons and neutrons in a copper nucleus.

➥ Number of atoms in 3 g copper coin,

Mass of Cu Number of atoms in Cu

63 g $6.022 \cdot 10^{23}$

$\therefore$ 3 g (?)

➥ Number of atoms in coin,

$$N = \frac{3 \times 6.022 \times 10^{23}}{63} = 2.87 \cdot 10^{22}$$

➥ The energy required to separate all the neutrons and protons from the copper of 3 g.

$E = E_b \cdot N$

$\therefore E = 551.39 \cdot 2.87 \cdot 10^{22}$ MeV

$\therefore E = 1582.4893 \cdot 10^{22}$ MeV

$\therefore E = 1582.4893 \cdot 10^{22} \cdot 10^{6} \cdot 1.6 \cdot 10^{-19}$ J

$\therefore E = 2531.98 \cdot 10^{9}$ J

$\therefore E = 2.53 \cdot 10^{9}$ J