LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNTMENT PAPER 5**

Section A

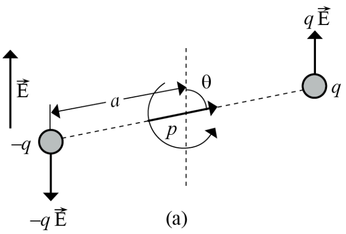
1. (D) **2.** (A) **3.** (C) **4.** (D) **5.** (A) **6.** (B) **7.** (C) **8.** (D) **9.** (A) **10.** (C) **11.** (C) **12.** (D) **13.** (A) **14.** (B) **15.** (C) **16.** (B) **17.** (A) **18.** (D) **19.** (D) **20.** (D) **21.** (D) **22.** (A) **23.** (D) **24.** (D) **25.** (A) **26.** (B) **27.**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

Section A

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

1.

➥



➥ As shown in figure, the electric dipole is placed in uniform electric field at θ angle.

➥ The force exerted on $+q$ electric charge in electric field $\vec{E}$ is,

$\vec{F}_+ = q\vec{E}$

➥ The force exerted on - q electric charge

$\vec{F}_- = -q\vec{E}$

➥ The net force on the dipole is zero, since E is uniform.

➥ However, the charges are separated, so the forces act at different points, resulting in a torque on the dipole.

➥ When the net force is zero, the torque (couple) is independent of the origin. Its magnitude equals the magnitude of each force multiplied by the arm of the couple (perpendicular distance between the two antiparallel forces).

➥ Magnitude of torque = $q E \times 2 a \sin\theta$

$= (2 q a) E \sin\theta = pE \sin\theta$

$\vec{\tau} = \vec{p} \cdot \vec{E}$

➥ The magnitude of $\vec{p} \times \vec{E}$ is also $p E \sin\theta$ and its direction is normal to the paper, coming out of it.

➥ Special cases :

(i) If electric dipole moment and electric field both are in one direction.

$\therefore \theta = 0$

$\therefore \tau = 0$

This condition is called stable equilibrium.

(ii) Both electric dipole moment and electric field are perpendicular.

$\therefore \theta = \frac{\pi}{2}$

$\therefore \tau = pE \sin\frac{\pi}{2}$

$\therefore \tau = pE \rightarrow$ Which is maximum

(iii) Electric dipole moment and electric field are arranged anti parallel direction.

$\therefore \tau = pE \sin\pi$

$\therefore \tau = 0 \rightarrow$ Unstable equilibrium

2.

➥ $q_1 = 0.4 \propto C = 0.4 \cdot 10^{-6} = 4 \cdot 10^{-7}$ C

$q_2 = 0.8 \propto C = 0.8 \cdot 10^{-6} = 8 \cdot 10^{-7}\ C_{(-ve)}$

F = 0.2 N

(a) Distance (r) between two electric charges :

From, $F = \frac{kq_1 q_2}{r^2}$

$r^2 = \frac{kq_1 q_2}{F}$

$$r^2 = \frac{9 \times 10^9 \times 4 \times 10^{-7} \times 8 \times 10^{-7}}{(0.2)^2}$$

$\therefore r^2 = 144 \cdot 10^{-4}$

$\therefore r = 12 \cdot 10^{-2}$ m

$\therefore r = 12$ cm

(b) Force on sphere-2 due to charge on sphere-1 :

➥ As per Newton's 3rd law, both the spheres exert equal but opposite forces.

Hence, the force on sphere-2 by sphere-1 will be 0.2 N. (attraction).

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.

➥ Total energy of the electron in hydrogen atom is -13.6 eV.

E = -13.6 eV

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

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

➥ But the total energy

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

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

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

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

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

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

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

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

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

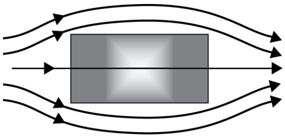
$$\therefore \upsilon = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}}$$

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

$\therefore \upsilon = 2.2 \times 10^6$ m/s

5.

- Simple explanation of dia-magnetism :
- Electrons in an atom orbiting around nucleus possess orbital angular momentum. These orbiting electrons are equivalent to current carrying loop and thus possess orbital magnetic moment.
- Diamagnetic substances are the ones in which the resultant magnetic moment in an atom is zero. When magnetic field is applied, those electrons having orbital magnetic moment in the same direction slow down and those in the opposite direction speed up.
- This happens due to induced current in accordance with Lenz's law.
- Thus, the substance develops a net magnetic moment in direction opposite to that of applied field and hence repulsion.
- This is a simple explanation of diamagnetism.



- Fig. shows a bar of diamagnetic material placed in an external magnetic field. The field lines in it are repelled and field inside the material is reduced.
- In most cases, this reduction is slight, being one part in 10^5.
- When placed in a non-uniform magnetic field, a diamagnetic substance experiences net force from stronger to weaker field and tends to move from high to low field. Which means they experience repulsion.
- Some diamagnetic materials are bismuth, copper, lead, silicon, nitrogen (at STP), water and sodium chloride.
- Value of χ (magnetic susceptibility) is negative ($-1 \leq \chi < 0$) for diamagnetic materials.

6. Explain in brief the phenomenon of self-induction. Derive the formula for self-induced emf.

- When electric current through an isolated conducting coil is changed, magnetic flux linked with it changes. As a result, induced *emf* is produced in the coil. This phenomenon is called self induction.
- Here, induced *emf* is called self induced *emf*.
- Suppose, electric current passing through an isolated coil having N turns is I.
- Total magnetic flux linked with coil,

  $N\varphi_B \propto I$

  $\therefore N\varphi_B = L I$ ... (1)
- Proportionality constant L in equation (1) is called self inductance.
- On changing current with time, magnetic flux linked changes. As a result, induced *emf* is produced.

  $\therefore N \dfrac{d\phi_B}{dt} = L \dfrac{dI}{dt}$ ... (2)
- According to Faraday's law,

  $\varepsilon = -N \dfrac{d\phi_B}{dt}$ ... (3)

  From equation (2) and (3),

  $\varepsilon = -L \dfrac{dI}{dt}$ ... (4)

  Equation (4) is expression for self induced *emf*.

7.

- $V = 220$ V

  $\nu = 50$ Hz

  $L = 44$ mH

  $= 44 \times 10^{-3}$ H
- rms value of current in the circuit,

  $I = \dfrac{V}{X_L} = \dfrac{V}{\omega L} = \dfrac{V}{2\pi\nu L}$

$$\therefore I = \frac{220}{2 \times 3.14 \times 50 \times 44 \times 10^{-3}}$$

$\therefore I = 15.92$ A

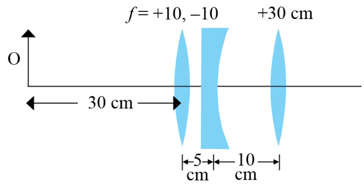
8.

➥ For first lens,

$u_1 = -30$ cm

$f = 10$ cm

$\upsilon_1 = ?$



➥ From lens formula,

➥ For the image formed by the first lens,

$$\frac{1}{\upsilon_1} - \frac{1}{u_1} = \frac{1}{f}$$

$$\therefore \frac{1}{\upsilon_1} = \frac{1}{f} + \frac{1}{u_1}$$

$$\therefore \frac{1}{\upsilon_1} = \frac{1}{10} - \frac{1}{30}$$

$$\therefore \frac{1}{\upsilon_1} = \frac{3-1}{30}$$

$\therefore \upsilon_1 = 15$ cm

➥ Image formed by first lens acts as a virtual object for the second lens.

➥ Object distance for second lens = 15 – 5

$u_2 = 10$ cm

(u_2 is positive, means it is in the direction of the incident ray)

➥ From lens formula,

$$\frac{1}{\upsilon_2} - \frac{1}{u_2} = \frac{1}{f_2}$$

$$\therefore \frac{1}{\upsilon_2} - \frac{1}{10} = -\frac{1}{10}$$

$$\therefore \frac{1}{\upsilon_2} = 0$$

$\therefore \upsilon_2 = \infty$ (infinite)

➥ This image acts as a virtual object for the third lens. So the object distance for the third lens is infinite.

➥ For the third lens $u_3 = \infty$

➥ From lens formula,

$$\frac{1}{\upsilon_3} - \frac{1}{u_3} = \frac{1}{f_3}$$

$$\therefore \frac{1}{\upsilon_3} - \frac{1}{\infty} = \frac{1}{30}$$

$$\therefore \frac{1}{\upsilon_3} = \frac{1}{30} \left(\because \frac{1}{\infty} = 0\right)$$

$\therefore \upsilon_3 = 30$ cm

➥ Thus, final image is formed at 30 cm distance on the right side of the third lens.

9.

	Interference pattern	Diffraction pattern
(1)	In an interference pattern, there are many bright and dark bands at equal distance from each other.	In a diffraction pattern, the central maximum has width double the width of other secondary maxima.
(2)	Intensity of all the bright fringes is same.	Intensity of the central maximum is the highest and intensity gradually keeps reducing for successive secondary maxima.
(3)	An interference pattern is seen because of super position of two waves created from two narrow slits.	A difference pattern is seen because of super position of continuous wave fronts created from each point of the single slit.
(4)	For constructive interference phase difference is $\pm 2n\pi$ (where $n = 0, 1, 2, ...$) For destructive interference phase diff. is $\pm (2n + 1)\pi$ (where $n = 0, 1, 2, 3 ...$)	For central maxima $\theta \approx 0$ secondary maxima phase diff. is $\left(n + \frac{1}{2}\right)\frac{\lambda}{a}$ (where $n = \pm 1, \pm 2, \pm 3 ....$) Secondary minima phase diff. is $\frac{n\lambda}{a}$ (where $n = \pm 1, \pm 2, \pm 3 ...$)

10.

➥ (i) For a given photosensitive material and frequency of incident radiation (above the threshold frequency), the photoelectric current is directly proportional to the intensity of incident light.

(ii) For a given photosensitive material and frequency of incident radiation, saturation current is proportional to the intensity of incident radiation but the stopping potential is independent of the intensity.

(iii) For a given photosensitive material, incident radiation has a certain minimum cut-off frequency, called the threshold frequency, below which no photoelectrons are emitted no matter how high the intensity of light is.

Above the threshold frequency, the stopping potential or maximum kinetic energy of the emitted photoelectrons increases linearly with the frequency of the incident radiation, but it does not depend on the intensity.

(iv) The photoelectric emission is an instantaneous process without any apparent time lag ($\sim 10^{-9}$ s or less), even when the incident radiation is made exceedingly dim.

11.

➥ Rutherford was the pioneer to visualize the nucleus of an atom. For this he studied the emission of α-particle by thin gold foil.

➥ The experiment revealed that the distance of closest approach to a gold nucleus of an α-particle of kinetic energy 5.5 MeV is about 4.0×10^{-14} m.

➥ From this, Rutherford suggested that the actual size of the nucleus has to be less than 4.0×10^{-14} m.

➥ If we use α-particles of higher energies than 5.5 MeV, the distance of closest approach to the gold nucleus will be smaller.

➥ Using fast electrons as projectiles instead of α-particles, the sizes of the nuclei of various elements can be accurately measured in scattering experiments.

➥ The relation between radius of nucleus and mass number A

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

Where, $R_0 = 1.2 \cdot 10^{-15}$ m ... (1)

($= 1.2\ fm$; $1\ fm = 10^{-15}$ m)

➥ This means the volume of the nucleus which is proportional to R^3 is proportional to A. Thus density of nucleus is constant, independent of A, for all nuclei.

➥ Different nuclei are like a drops of liquid of constant density.

- The density of nuclear matter is approximately 2.3×10^{17} kg m^{-3}. This density is very large compared to water which is 10^3 kg/m^3.
- Since the density of nucleus is very large, the entire mass is concentrated in the nucleus. As a result, the atom is largely hollow.

12.

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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 *m*A.	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.

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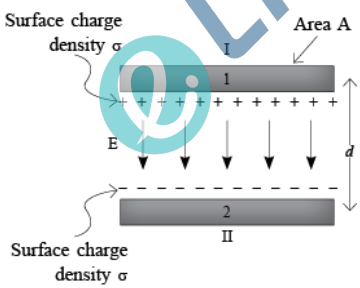


- A capacitor made up of two large parallel conducting plates kept at a small distance is called parallel plate capacitor.
- Two parallel conducting plates are arranged parallel to each other as shown in figure. Area of each plate is A and perpendicular distance between the two plates is *d*. Charge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

  $\sigma \left(= \frac{Q}{A}\right)$ and $-\sigma$ 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.
- Now, for uniform electric field, p.d. between two plates,

  $V = Ed$

  Substituting value of E from eg. (1),

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

- Now, capacitance,

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

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

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

- 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.

14.

- Resistance at room temperature

$R_1 = \frac{V}{I_1}$	$V = 230$ V
$= \frac{230}{4.6}$	$I_1 = 4.6$ A
$= 50\ \Omega$	$I_2 = 2.3$ A
	$T_1 = 27\ ^\circ C$
	$T_2 = ?$
	$\alpha = 1.70 \times 10^{-4}\ ^\circ C^{-1}$

- Resistance at stedy temperature

$$R_2 = \frac{V}{I_2} = \frac{230}{2.3} = 100\ \Omega$$

- Relation between resistance and temperature

$$R_2 = R_1[1 + \alpha(T_2 - T_1)]$$

$$\therefore \ 100 = 50\ [1 + 1.70 \times 10^{-4}(T_2 - 27)]$$

$$\therefore \ \frac{100}{50} = 1 + 1.70 \times 10^{-4}(T_2 - 27)$$

$$\therefore \ 2 - 1 = 1.70 \times 10^{-4}(T_2 - 27)$$

$$\therefore \ \frac{1}{1.70 \times 10^{-4}} = T_2 - 27$$

$\therefore \dfrac{5882}{1.70} = T_2 - 27$

$\therefore 5882 = T_2 - 27$

$\therefore T_2 = 5882 + 27$

$\therefore T_2 = 5909\ °C$

15.

➥ $d = 4 \times 10^{-2}$ m

$l = 10$ cm

$= 0.1$ m

$I_A = 8.0$ A

$I_B = 5.0$ A

➥ Force exerted by wire B on a wire A, of

$\therefore F = \dfrac{\mu_0 I_A I_B l}{2\pi d}$

$\therefore F = \dfrac{4\pi \times 10^{-7} \times 8 \times 5 \times 0.1}{2\pi \times 4 \times 10^{-2}}$

$\therefore F = 2 \times 10^{-5}$ N

16.

➥ $r = 8$ cm

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

$N = 20$

$B = 3 \times 10^{-2}$ T

$W = 50$ rad/s

$R = 10\ \Omega$

➥ Induced electric current em$f$

$\therefore V_m = NAWB = N(\pi r^2)\ WB$

$= 20\ (3.14 \times 64 \times 10^{-4})\ 50 \times 3 \times 10^{-2}$

$\therefore V_m = 0.6$ V

➥ Average induced em$f$ for the circuit.

$\langle V \rangle = \langle V_m \sin wt \rangle$

$\therefore \langle V \rangle = V_m \langle \sin wt \rangle$

but $\langle \sin wt \rangle = 0$

$\therefore \langle V \rangle = 0$

➥ Maximum value of current in the coil.

$I_m = \dfrac{V_m}{R} = \dfrac{0.6}{10}$

$= 0.06$ A

17.

➥ (i) $f = 0.5$ m

$\Rightarrow$ Power of lens $P = \dfrac{1}{f}$

$\therefore P = \dfrac{1}{0.5}$

$\therefore P = 2$ D

➥ (ii) $R_1 = 10$ cm $R_2 = -15$ cm

$f = 12$ cm $n_1 = 1$ (air)

$n_2 = (?)$

⇒ From lens maker's formula,

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

$$\therefore \frac{1}{12} = \frac{(n_2 - 1)}{1}\left(\frac{1}{10} + \frac{1}{15}\right)$$

$$\therefore \frac{1}{12} = (n_2 - 1)\left(\frac{3 + 2}{30}\right)$$

$$\therefore \frac{1}{12} = (n_2 - 1)\left(\frac{5}{30}\right)$$

$$\therefore \frac{1}{12} = (n_2 - 1)\left(\frac{1}{6}\right)$$

$$\therefore \frac{1}{2} = n_2 - 1$$

$$\therefore n_2 = 1 + \frac{1}{2} = \frac{3}{2}\ (1.5)$$

➠ The refractive index of material of lens is 1.5.

➥ (iii) $f_a = 20$ cm , $f_w = ?$

$n_a = 1$ $n_w = 1.33$ $n_g = 1.5$

➠ for lens in air,

$$\frac{1}{f_a} = \left(\frac{n_g - n_a}{n_a}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{... (1)}$$

➠ for lens in water,

$$\frac{1}{f_w} = \left(\frac{n_g - n_w}{n_w}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{... (2)}$$

➠ By taking ratio of equation (1) & (2),

$$\frac{f_w}{f_a} = \left(\frac{n_g - n_a}{n_a}\right)\left(\frac{n_w}{n_g - n_w}\right)$$

$$\therefore \frac{f_w}{20} = \left(\frac{1.5 - 1}{1}\right)\left(\frac{1.33}{1.5 - 1.33}\right)$$

$$\therefore \frac{f_w}{20} = (0.5)\left(\frac{1.33}{0.17}\right)$$

$$\therefore f_w = 78.23 \text{ cm}$$

18.

➥ $d = 0.1$ mm

D = 100 cm = 1m

(a) $\lambda = 6000\ \text{Å}$

n = 3 (dark fringe)

➥ Destructive interference for path difference $= (n + \frac{1}{2})\lambda$

but path difference $= \frac{xd}{D}$

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

$\therefore \frac{x \times 0.1 \times 10^{-3}}{1} = \left(3 + \frac{1}{2}\right) 6000 \times 10^{-10}$

$\therefore x = \frac{7 \times 6000 \times 10^{-10}}{2 \times 0.1 \times 10^{-3}}$

$\therefore x = 21000 \times 10^{-6}$

$\therefore x = 2.1 \times 10^{-2}$ m

$x = 2.1$ cm

(b) $\lambda_1 = 6000 \ \mathring{A}$

$\lambda_2 = 4000 \ \mathring{A}$

➡ Suppose, at some minimum distance x on the screen, from its central bright fringe n_1th order bright fringe of light with wave lenght $\lambda_1 = 6000$ nm superposes on the n_2th order bright fringe of light with wave length $\lambda_2 = 4000$ nm

➡ Hence, the path difference for both is same.

$n_1 \lambda_1 = n_2 \lambda_2$

$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1}$

$\therefore \frac{n_1}{n_2} = \frac{4000 \times 10^{-10}}{6000 \times 10^{-10}}$

$\therefore \frac{n_1}{n_2} = \frac{2}{3}$

➡ $n_1 = 2$ and $n_2 = 3$

➡ Suppose, these two fringe intersect at distance x from the central maxima.

$\therefore \frac{xd}{D} = n_1 \lambda_1$

$\therefore x = \frac{n_1 \lambda_1 D}{d}$

$\therefore x = \frac{2 \times 6000 \times 10^{-10} \times 1}{0.1 \times 10^{-3}}$

$\therefore x = 12000 \times 10^{-6}$

$\therefore x = 1.2 \times 10^{-2}$ m

$= 1.2$ cm

19.

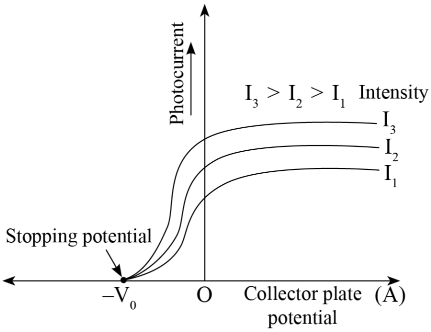
➡ Initially, plate C is illuminated with light keeping plate A at positive potential with respect to plate C and keeping the frequency (v) and intensity (I) of incident light constant. Due to the positive potential of A, some of the emitted photo electrons are attracted towards, plate A and form a photocurrent.

➡ Now if the magnitude (value) of the positive potential of A is increased then more and more emitted electrons are attracted to A and form more photocurrent. Thus, photocurrent increases with voltage.

➡ After some time, all the electrons emitted from plate C are collected by plate A and form the maximum photocurrent in the circuit. This value of current is saturated (maximum), meaning that on increasing the potential no longer increase the photocurrent. This maximum value of the photocurrent is called saturation current.

➡ Stopping Potential :

- Now apply a negative potential to the plate A with respect to the plate C.
- By doing this the electrons emitted from C will be repelled by A, so the electrons that have enough energy to overcome the repulsion of A will reach A and form a current in the circuit, so the photocurrent will decrease.
- Now if the negative potential of A is increased i.e. made more negative, more and more electrons will be repelled and the number of electrons falling on A will decrease, so the photocurrent will also decrease rapidly.
- For some minimum value of the negative potential of A, all electrons arriving at A will be stopped. i.e. the photocurrent in the circuit will be zero. This minimum value of negative potential of A is called the stopping potential or cut-off voltage.

- Each electron emitted from C has a different energy (kinetic energy), so if the electron with the maximum kinetic energy is stopped by the repulsion of the plate A, all the electrons are stopped and the photocurrent in the circuit is stopped.
- Suppose, maximum kinetic energy of electron is K_{max}.
- The energy provided by the repulsion of A to stop this electron = eV_0
- Thus, photocurrent stops if $K_{max} = eV_0$.
- Here the voltage V_0 will be the stopping potential or cut-off voltage.
- 

- Now keeping the frequency of the incident light constant and increasing its intensity (i.e. intensity I_2 then I_3, where $I_3 > I_2 > I_1$) a graph of photocurrent versus collector plate can be drawn.
- It is clear from this graph that by increasing the intensity of light the value of the maximum saturated photocurrent increases, So $I = \frac{q}{t} = \frac{ne}{t}$ as the number of electrons emitted in 1 sec increases by $\left(\frac{n}{t}\right)$, but the value of the stopping potential does not change, so it can be said from $K_{max} = eV_0$, the maximum kinetic energy of emitted photoelectrons does not depend on the intensity of incident light.
- K_{max} does not depend on the intensity of incident radiation.

20.

- (a) Here, the work done depends only on the final arrangement of the charges.
- Here, suppose first the charge $+q$ is brought to point A, and then the charges $-q$. $+q$ and $-q$ are brought to points B, C and D respectively.

(i) work done to bring charge $+q$ on A is zero because there is no other charge present.

$\therefore W_1 = 0$

(ii) work needed to bring $-q$ to B, when $+q$ is at A,

$W_2 = \begin{pmatrix} Charge\ on \\ \text{B} \end{pmatrix} \times$ (Electric potential at B due to charge $+q$ at A)

$\therefore W_2 = -q\left(\frac{q}{4\pi\varepsilon_0 d}\right)$

$\therefore W_2 = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{d}$

(iii) Work needed to bring charge $+q$ to C when $+q$ is at A, and $-q$ is at B,

W_3 = (charge at point C) × (Electric potential at C due to charges at A and B)

$\therefore W_3 = q\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{\sqrt{2}d} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-q)}{d}\right)$

$\therefore W_3 = \frac{q^2}{4\pi\varepsilon_0 d}\left(\frac{1}{\sqrt{2}} - 1\right)$

(iv) Work needed to bring $-q$ to D when $+q$ at A, $-q$ at B and $+q$ at C, is given by :

$$W_4 = -q\left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{d} - \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{\sqrt{2}d} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{d}\right)$$

$$\therefore W_4 = -\frac{q^2}{4\pi\varepsilon_0 d}\left(1 - \frac{1}{\sqrt{2}} + 1\right)$$

$$\therefore W_4 = -\frac{q^2}{4\pi\varepsilon_0 d}\left(2 - \frac{1}{\sqrt{2}}\right)$$

$\therefore$ Total work

$W = W_1 + W_2 + W_3 + W_4$

$$\therefore W = 0 - \frac{q^2}{4\pi\varepsilon_0 d} + \frac{q^2}{4\pi\varepsilon_0 d}\left(\frac{1}{\sqrt{2}} - 1\right) - \frac{q^2}{4\pi\varepsilon_0 d}\left(2 - \frac{1}{\sqrt{2}}\right)$$

$$\therefore W = \frac{q^2}{4\pi\varepsilon_0 d}\left(-1 + \frac{1}{\sqrt{2}} - 1 - 2 + \frac{1}{\sqrt{2}}\right)$$

$$\therefore W = \frac{q^2}{4\pi\varepsilon_0 d}\left(\frac{2}{\sqrt{2}} - 4\right)$$

$$\therefore W = \frac{q^2}{4\pi\varepsilon_0 d}(\sqrt{2} - 4)$$

$$\therefore W = -\frac{q^2}{4\pi\varepsilon_0 d}(4 - \sqrt{2})$$

This work depends only on the arrangement of charges, and not on how they are assembled.

➥ (b) The extra work necessasary to bring charge q_0 to point E (centre of the square) when the four charges are at A, B, C and D, is ;

$W_E = q_0 \cdot V_E$

(where V_E is the total electric potential at E)

$V_E = V_{EA} + V_{EB} + V_{EC} + V_{ED}$

$$\therefore V_E = \frac{kq}{r} - \frac{kq}{r} + \frac{kq}{r} - \frac{kq}{r}$$

$\therefore V_E = 0$

➠ Electric potential at the centre of the square

$V_E = 0$

$\therefore W_E = q_0 V_E$

$\therefore W_E = 0$

➠ Hence, no work is required to bring any charge to point E.

OR

➥ (a) As shown in figure, the total work done in bringing the given four charges on the four vertices of ABCD will be equal to the total P.E. of the given system.

$W = U_{AB} + U_{AC} + U_{AD} + U_{BC} + U_{BD} + U_{CD}$

$$\therefore W = \frac{1}{4\pi\varepsilon_0}\cdot\frac{(q)(-q)}{d} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{(q)(q)}{\sqrt{2}d} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{(q)(-q)}{d}$$

➥ $$+ \frac{1}{4\pi\varepsilon_0}\cdot\frac{(-q)(q)}{d} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{(-q)(-q)}{\sqrt{2}d} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{(q)(-q)}{d}$$

$$\therefore W = \frac{q^2}{4\pi\varepsilon_0 d}\left[-1 + \frac{1}{\sqrt{2}} - 1 - 1 + \frac{1}{\sqrt{2}} - 1\right]$$

$$\therefore W = \frac{q^2}{4\pi\varepsilon_0 d}\left(-4 + \frac{2}{\sqrt{2}}\right)$$

$$\therefore W = -\frac{q^2}{4\pi\varepsilon_0 d}(4 - \sqrt{2})$$

➥ (b) as above

21.

➥ Total energy of electron in ground state of

H-atom = –13.6 eV

➥ Total energy after bombarding electron beam of

12.5 eV on H-atom = –13.6 + 12.5

= –1.1 eV

➥ So, $E_n = -1.1\ eV$

But $E_n = \dfrac{-13.6}{n^2}\ eV$

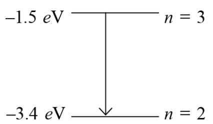
$n^2 = \dfrac{-13.6}{E_n}\ eV$

$n^2 = \dfrac{-13.6}{-1.1}$

$n^2 = 12.36$

$n = 3.51$

➥ An integer value of n is given as $n = 3$, which means that the electron is excited to level $n = 3$.

➥ 

(i)

➠ In transition from $n = 3$ to $n = 2$, wavelength of α-line emitted in Balmar Series

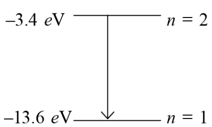
$E_3 - E_2 = \dfrac{hc}{\lambda_{32}}$

$\therefore \lambda_{32} = \dfrac{hc}{E_3 - E_2} = \dfrac{6.625 \times 10^{-34} \times 3 \times 10^8}{(-1.51) - (-3.4)\ eV}$

$= \dfrac{19.875 \times 10^{-26}}{1.89 \times 1.6 \times 10^{-19}}$

$= 6.575 \times 10^{-7}$ m

$\therefore \lambda_{32} = 657$ nm

➥ 

(ii)

➠ When electron transition from $n = 2$ to $n = 1$, the wavelength of α-line emitted in Lyman Series.

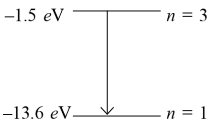
$E_2 - E_1 = \dfrac{hc}{\lambda_{21}}$

$\therefore \lambda_{21} = \dfrac{hc}{E_2 - E_1} = \dfrac{6.625 \times 10^{-34} \times 3 \times 10^8}{(-3.4) - (-13.6)\ eV}$

$= \dfrac{19.875 \times 10^{-26}}{10.2 \times 1.6 \times 10^{-19}}$

$= 1.22 \times 10^{-7}$ m

$\therefore \lambda_{21} = 122$ nm

➥ 

(iii)

➠ When electron transits from $n = 3$ to $n = 1$, the wavelength of β-line emitted in Lyman Series,

$$E_3 - E_1 = \frac{hc}{\lambda_{31}}$$

$$\therefore \lambda_{31} = \frac{hc}{E_3 - E_1}$$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{(-1.51) - (-13.6)\,eV}$$

$$= \frac{19.875 \times 10^{-26}}{12.09 \times 1.6 \times 10^{-19}}$$

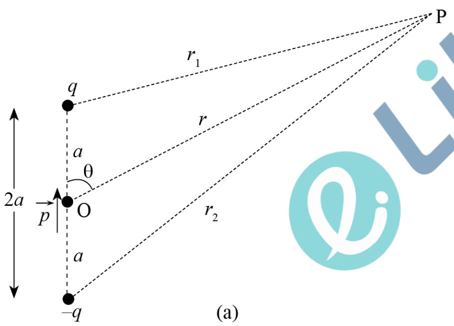
$$= 1.03 \times 10^{-7} \text{ m}$$

$$\therefore \lambda_{31} = 103 \text{ nm}$$

Section C

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

22.

➥ 

(a)

➥ As shown in fig. point P is given at a distance 'r' from the midpoint 'O' of electric dipole and at an angle θ (with the electric dipole moment $\vec{p}$).

We want to find electric potential at this point P.

➥ Electric potential at point P due to charge $+q$,

$$V_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_1}$$

➥ Electric potential at point P due to charge $-q$,

$$V_2 = \frac{1}{4\pi\varepsilon_0} \frac{(-q)}{r_2}$$

$$= -\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_2}$$

➥ Total electric potential at point P as per super position principle,

$$V = V_1 + V_2$$

$$\therefore V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r_2}$$

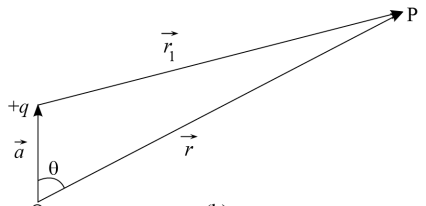
$$\therefore V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \text{... (1)}$$

➥ As shown in the figure (a), position vector of point P with respect to origin O is $\vec{r}$.

Position vector of point P with respect to $+q$ is $\vec{r}_1$.

Position vector of point P with respect to $-q$ is $\vec{r}_2$.

➥



(b)

➥ From figure (b),

$$\vec{r} = \vec{a} + \vec{r}_1$$

$$\therefore \vec{r}_1 = \vec{r} - \vec{a}$$

$\therefore r_1^2 = r^2 + a^2 - 2ra\cos\theta$ (θ is angle between $\vec{r}$ and $\vec{a}$)

$$\therefore r_1^2 = r^2\left(1 + \frac{a^2}{r^2} - \frac{2a\cos\theta}{r}\right)$$

➥ But value of $\frac{a^2}{r^2}$ is very less for $r >> a$,

so it can be neglected from equation.

$$\therefore r_1^2 = r^2\left(1 - \frac{2a\cos\theta}{r}\right)$$

$$\therefore r_1 = r\left(1 - \frac{2a\cos\theta}{r}\right)^{\frac{1}{2}}$$

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{2a\cos\theta}{r}\right)^{-\frac{1}{2}}$$

Note ...

Binomial Theorem :

$$(1 - x)^n = 1 - \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + ...(x^2 < 1)$$

$$(1 - x)^{-n} = 1 \; m \; \frac{nx}{1!} + \frac{n(n+1)x^2}{2!} + ...(x^2 < 1)$$

➥ Using the binomial theorem to expand the equation,

$$\frac{1}{r_1} = \frac{1}{r}[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r} + ... + \text{other higher order terms of } \frac{2a\cos\theta}{r})$$

➥ But the terms having more than 1 power will be very small and hence they can be neglected in the above equation,

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{1}{2}\cdot\frac{2a\cos\theta}{r}\right)$$

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{a\cos\theta}{r}\right) \quad \text{... (2)}$$

➥ Similarly,

$$\frac{1}{r_2} = \frac{1}{r}\left(1 - \frac{a\cos\theta}{r}\right) \quad \text{... (3)}$$

can be derived.

➥ Substituting values of $\frac{1}{r_1}$ and $\frac{1}{r_2}$ from equation (2) and (3) in equation (1),

$$\therefore V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1+\frac{a\cos\theta}{r}\right)-\frac{1}{r}\left(1-\frac{a\cos\theta}{r}\right)\right]$$

$$\therefore V = \frac{q}{4\pi\varepsilon_0 r}\left(1+\frac{a\cos\theta}{r} - 1+\frac{a\cos\theta}{r}\right)$$

$$\therefore V = \frac{q}{4\pi\varepsilon_0 r}\cdot\frac{2a\cos\theta}{r}$$

$$\therefore V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p\cos\theta}{r^2} \quad \ldots (4)$$

($\because p = 2aq$ Electric dipole moment)

$$\therefore V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}\cdot\hat{r}}{r^2} \quad (r >> a) \ldots (5) \; (\because p\cos\theta = \vec{p}\cdot\hat{r})$$

Where, $\hat{r}$ is the unit vector along the position vector $\vec{r}$.

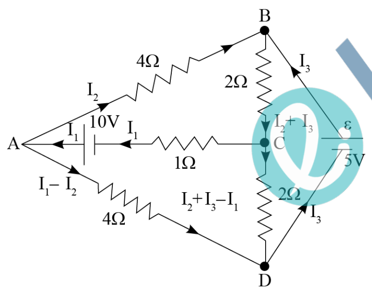
OR

$$V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}\cdot\vec{r}}{r^3} \quad \ldots (6)$$

➥ Equations (4), (5) and (6) show electric potential of dipole.

23.

➥ Here, each branch of network is assigned an unknown current. The distribution of currents is such that the number of these unknown currents is minimised.



➥ As shown in the figure, we consider three unknown currents I_1, I_2 and I_3.

➥ Applying kirchhoff's second rule for the closed loop ADCA,

$- 4 (I_1 - I_2) + 2 (I_2 + I_3 - I_1) - 1(I_1) + 10 = 0$

$\therefore - 4I_1 + 4I_2 + 2I_2 + 2I_3 - 2I_1 - I_1 = - 10$

$\therefore -7I_1 + 6I_2 + 2I_3 = -10$

$\therefore 7I_1 - 6I_2 - 2I_3 = 10 \ldots (1)$

➥ Applying Kirchhoff's second rule for the closed loop ABCA,

$- 4I_2 - 2(I_2 + I_3) - 1(I_1) + 10 = 0$

$\therefore - 4I_2 - 2I_2 - 2I_3 - I_1 = - 10$

$\therefore - I_1 - 6I_2 - 2I_3 = -10$

$\therefore I_1 + 6I_2 + 2I_3 = 10 \ldots (2)$

➥ Applying kirchhoff's second rule for the closed loop BCDεB,

$-2(I_2 + I_3) - 2(I_2 + I_3 - I_1) + 5 = 0$

$\therefore -2I_2 - 2I_3 - 2I_2 - 2I_3 + 2I_1 = -5$

$\therefore 2I_1 - 4I_2 - 4I_3 = -5$

$\therefore I_1 - 2I_2 - 2I_3 = -2.5$ ... (3)

➥ Adding equations (1) and (2) we get,

$$\begin{array}{l} \therefore\ 7I_1 - 6I_2 - 2I_3 = 10 \\ \quad\ I_1 + 6I_2 + 2I_3 = 10 \\ \hline \quad 8I_1 \qquad\qquad\quad = 20 \end{array}$$

$\therefore I_1 = \frac{20}{8} = 2.5$ A ... (4)

➥ Now, by adding equation (2) and (3),

$$\begin{array}{l} \therefore\ I_1 + 6I_2 + 2I_3 = 10 \\ \quad I_1 - 2I_2 - 2I_3 = -2.5 \\ \hline \quad 2I_1 + 4I_2 \qquad = 7.5 \end{array}$$

$\therefore 2(2.5) + 4I_2 = 7.5$

$\therefore 4I_2 = 7.5 - 5$

$\therefore I_2 = \frac{2.5}{4} = \frac{25}{40} = \frac{5}{8}$ A ... (5)

➥ Putting the value of I_1 and I_2 in equation (2)

➥ (we can use equation (1), (2) and (3) for similar calculations)

$\therefore 2.5 + 6\left(\frac{5}{8}\right) + 2I_3 = 10$

$\therefore 2I_3 = 10 - 2.5 - \frac{30}{8}$

$\therefore 2I_3 = 7.5 - \frac{30}{8}$

$\therefore 2I_3 = \frac{60 - 30}{8}$

$\therefore I_3 = \frac{30}{16} = \frac{15}{8}$ A

Current flowing through the Arm AB $I_2 = \frac{5}{8}$ A

Current flowing through the Arm AC $I_1 = 2.5$ A

Current flowing through the Arm AD

$I_1 - I_2 = \frac{5}{2} - \frac{5}{8}$

$= \frac{20 - 5}{8} = \frac{15}{8}$ A

➥ Current in the Arm B ε D

$I_3 = \frac{15}{8}$ A

➥ Current in the Arm BC is

$I_2 + I_3 = \frac{5}{8} + \frac{15}{8} = \frac{20}{8} = \frac{5}{2}$ A

➥ Current in the Arm CD is

$I_2 + I_3 - I_1 = \frac{5}{8} + \frac{15}{8} - \frac{5}{2} = \frac{5 + 15 - 20}{8} = 0$ A

24.

➥ 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 :

$\therefore X_L = \omega L$

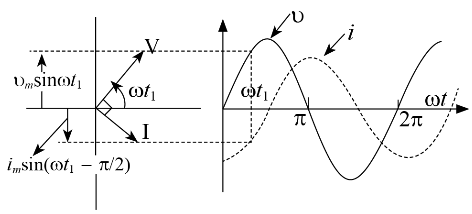
Unit of X_L is ohm (Ω).

➥ 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

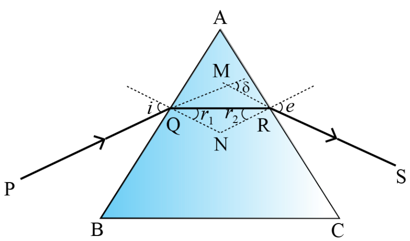
  $$P = \overline{p} = \left\langle -\frac{\upsilon_m i_m}{2} \sin 2\omega t \right\rangle$$

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

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

  $\therefore P = 0$
- Thus, the average power supplied to an inductor over 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 $\angle MRQ = e - r_2$.

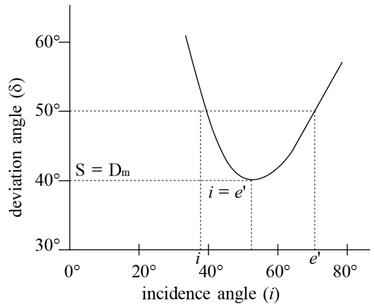
➥ Substituting these two values in equation (4),

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

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

➥ 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, $A = r_1 + r_2$

$\therefore A = 2r_1$

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

➥ and from $\delta = i + e - A$,

$D_m = 2i - A$

$2i = D_m + A$

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

➥ (a) In nucleus of ${}^{56}_{26}Fe$

number of protons Z = 26

and number of neutrons N = 56 – 26 = 30

➠ Mass Defect

$\Delta M = (Zm_p + Nm_n) - m({}^{56}_{26}Fe)$

$\therefore \Delta M = (26 \cdot 1.007825 + 30 \cdot 1.008665) - 55.934939$

$\therefore \Delta M = 26.20345 + 30.25995 - 55.934939$

$\therefore \Delta M = 0.528461\ u$

➠ Binding Energy

$E_b = \Delta Mc^2$

$\therefore E_b = 0.528461 \cdot 931.5$

$\therefore E_b = 492.26142\ MeV$

➠ Binding energy per nucleon

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

$\therefore E_{bn} = \frac{492.26142}{56}$

$\therefore E_{bn} \approx 8.79\ MeV$

(b) In nucleus of ${}^{209}_{83}Bi$

number of protons Z = 83

and number of neutrons N = 209 – 83 = 126

➠ Mass Defect

$\therefore \Delta M = [Zm_p + Nm_n] - m[{}^{209}_{83}Bi]$

$\therefore \Delta M = [83 \cdot 1.007825 + 126 \cdot 1.008665] - [208.980388]$

$\therefore \Delta M = [83.649475 + 127.091790] - [208.980388]$

$\therefore \Delta M = 1.760877\ u$

➠ Binding Energy

$E_b = \Delta Mc^2$

$\therefore E_b = 1.760877 \cdot 931.5$

$\therefore E_b = 1640.2569255\ MeV$

➠ Binding Energy per nucleon

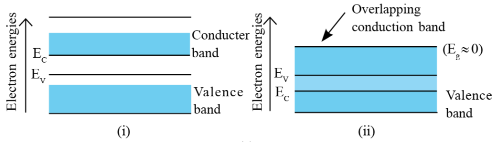
$E_{bn} = \frac{E_b}{A}$

$$\therefore E_b = \frac{1640.2569255}{209}$$

$$\therefore E_{bn} = 7.84 \frac{MeV}{nucleon}$$

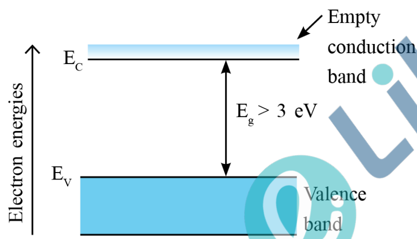
27.

- *"The gap between the top of the valence band and bottom of the conduction band is called the energy band gap (Energy gap E_g.)".*
- There isn't any energy-level present in this energy-gap. Hence, there is not even a single electron present in this gap.
- This energy gap can be large, small or zero depending upon the material.
- Material type wise different situations are shown in the fig. below.
- Case I : Conductors :



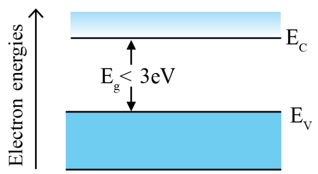
(a)

- As shown in fig. (i), in many metals the conduction band is partially filled and the valence band is partially empty or when the conduction and valence bands overlap. (which is shown in fig (ii))
- When there is overlap, electrons from valence band can easily move into the conduction band. This situation makes a large number of electrons available for electrical conduction. Therefore, the resistance of such materials is low or the conductivity is high.
- Case II : Insulators :



- In this case, as shown in fig., a large band gap E_g exists ($E_g > 3$ eV) between the two levels. (Valence band and conduction band)
- There are no electrons in the conduction band, and therefore no electrical conduction is possible.
- Note that the energy gap is so large that electrons can not be excited from the valence band to the conduction band by thermal excitation.

  This is the case of the insulators.
- Case III : Semi-conductors :



- As shown in Fig. here a finite but small band gap ($E_g < 3$ eV) exists.
- Because of the small band gap, at room temperature, some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction band.
- These electrons (though small in numbers) can move in the conduction band.
- Hence, the resistance of semiconductors is not as high as that of the insulators.