LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNMENT PAPER 13**

Section A

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

Section A

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

1.

➥ Electric potential energy of electric dipole in uniform electric field,

$U = -\vec{p} \cdot \vec{E}$

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

(Where, θ is the angle between electric dipole moment $\vec{p}$ and electric field $\vec{E}$.)

➥ Special cases :

(i) Electric dipole is parallel to the electric field

$\therefore \theta = 0$

$\therefore U = -pE \cos 0$

$\therefore U = -pE$ (minimum)

➥ Which shows the stable equilibrium position of dipole.

(ii) If dipole is arranged anti parallel to the electric field, θ will be equal to 180°. (π rad).

$\therefore \theta = \pi$

$\therefore U = -pE \cos \pi$

$\therefore U = pE$ (maximum) ($\because \cos \pi = -1$)

➥ Which shows the unstable equilibrium position of dipole.

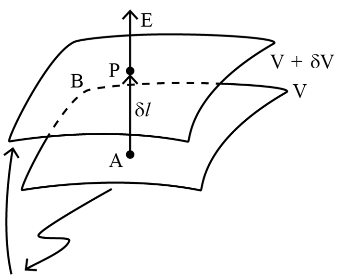
(iii) If dipole is arranged perpendicular to the electric field then, $\theta = \frac{\pi}{2}$ (90°)

$\therefore U = -pE \cos \frac{\pi}{2}$

$\therefore U = 0$ ($\because \cos \frac{\pi}{2} = 0$)

➥ Which shows the position of maximum non-equilibrium.

2.

➥ 

Equipotential surfaces

➥ As shown in the fig., two equipotential surfaces A and B are very close to each other. Magnitudes of electric potentials on them are V and V + δV respectively.

➥ Here, δV is change in electric potential in the direction of electric field $\vec{E}$.

➥ Point P is present on surface B. And the perpendicular distance from surface A to point P is δl.

➥ The amount of work done in taking a unit positive charge on the perpendicular line from surface B to surface A is equal to $|\vec{E}|$

δl. This work is equal to the electric potential difference between surfaces A and B, which is $V_A - V_B$.

$$\therefore |\vec{E}|\, \delta l = \Delta V = V_A - V_B$$

$$\therefore |\vec{E}| \cdot \delta l = V - (V + \delta V)$$

$$= -\,\delta V$$

$$\therefore |\vec{E}| = -\frac{\delta V}{\delta l}$$

➥ Here, δV is negative, so taking $-\,\delta V$ in place of δV,

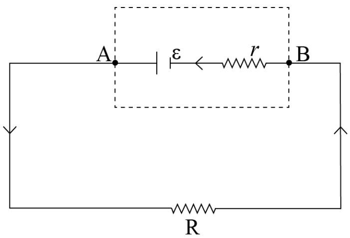
$$|\vec{E}| = \frac{\delta V}{\delta l}$$

3.

➥ $\varepsilon = 10$ V I = 0.5 A V = ?

$r = 3\ \Omega$ R = ?

➥ The resistance of the resistor (R)



$$\therefore I = \frac{\varepsilon}{r + R}$$

$$\therefore 0.5 = \frac{10}{3 + R}$$

$$\therefore 3 + R = \frac{10}{0.5} = 20$$

$$\therefore R = 20 - 3$$

$$\therefore R = 17\ \Omega$$

➥ The terminal voltage of the battery,

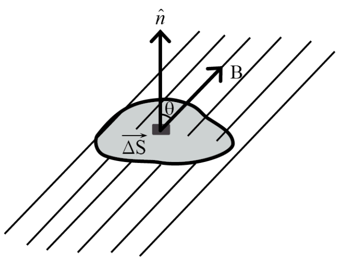
$$V_{AB} = V = \varepsilon - Ir$$

$$\therefore V = 10 - (0.5)\,(3)$$

$$\therefore V = 10 - 1.5$$

$$\therefore V = 8.5\ V$$

4.

➥ 

➥ As shown in the Fig., consider a surface ‘S’ in a uniform magnetic field.

➥ To calculate the magnetic flux associated with the surface, imagine the surface ‘S’ to be divided into many small area elements.

➥ Consider a small vector area element $\overrightarrow{\Delta S}$ from all such area elements.

➥ Magnetic flux passing through this area element.

$\Delta\varphi_B = \vec{B} \cdot \overrightarrow{\Delta S}$

➥ Total magnetic flux associated with the surface S,

$$\varphi = \sum_{all} \Delta\phi_B = \sum_{all} \vec{B} \cdot \overrightarrow{\Delta S} = 0 \; ... (1)$$

[That is because, for any enclosed surface, number of magnetic field lines leaving the surface is same as the number of field lines entering the surface. This means that the total positive flux is same as total negative flux and hence the net magnetic flux is zero.]

In the eq. (1) ‘all’ stands for ‘all area elements $\overrightarrow{\Delta S}$’. This can be compared with the Gauss’s law of electrostatics.

$$\sum \vec{E} \cdot \overrightarrow{\Delta S} = \frac{q}{\varepsilon_0}$$

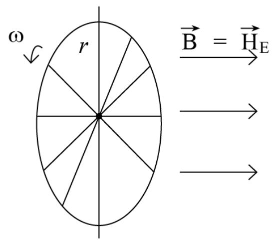
➥ From eq. (1), the Gauss’s law for magnetism can be written as follows :

“The net magnetic flux through any closed surface is zero.”

➥ Magnetic flux is a scalar quantity. SI unit of magnetic flux is :

W*b* (weber) = T m^2

5.

➥ 

➥ $l = R = 0.5$ m

Number of turns = 10

$\omega = 120$ rev/min

$= \frac{120 \times 2\pi}{60} \frac{\text{rad}}{\text{sec}}$

$= 4\pi \frac{\text{rad}}{\text{sec}}$

$H_E = B = 0.4 \text{ G} = 0.4 \times 10^{-4}$ T

$\varepsilon = (?)$

➥ Here, induced *emf*

$$\varepsilon = \frac{B\omega R^2}{2}$$

$$= \frac{0.4 \times 10^{-4} \times 4\pi \times (0.5)^2}{2}$$

$= 0.628 \times 10^{-4}$

$= 6.28 \times 10^{-5}$ V

➥ Here the spoke are in parallel connection with each other so the total induced *emf* between the axle and the rim of the wheel is 6.28×10^{-5} V.

6.

➥ (1) $\oint \vec{E} \cdot \overrightarrow{dA} = \frac{Q}{\varepsilon_o}$ (Gauss’s Law for electricity)

(2) $\oint \vec{B} \cdot \overrightarrow{dA} = 0$ (Gauss’s Law for magnetism)

(3) $\oint \vec{E} \cdot \vec{dl} = \frac{-d\phi_B}{dt}$ (Faraday's Law)

(4) $\oint \vec{B} \cdot \vec{dl} = \propto_0 i_c + \propto_0 \varepsilon_0 \frac{d\phi_E}{dt}$

(Ampere – Maxwell Law)

7.

- $f_1 = 30$ cm (focal length of convex lens, positive)

  $f_2 = -20$ cm (focal length of concave lens, negative)
- Equivalent focal length of combination

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

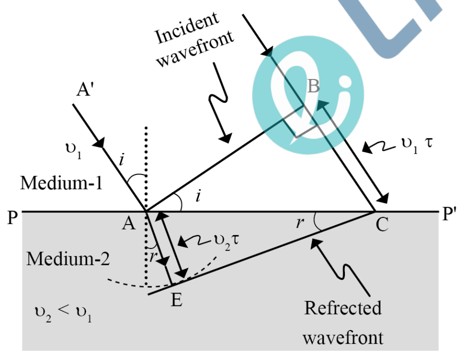
  $\therefore \frac{1}{f} = \frac{1}{30} - \frac{1}{20}$

  $\therefore \frac{1}{f} = \frac{2-3}{60}$

  $\therefore f = -60$ cm
- This is focal length of combination.
- Focal length of combination is negative, which indicates that combination acts as a concave lens.

8.

- As shown in fig. PP' represents the surface separating medium 1 and medium 2.
- Let υ_1 and υ_2 represent the speed of light in medium 1 and medium 2, respectively. Also, the refractive indices of medium 1 and 2 are n_1 and n_2 respectively.
- As shown in fig. a plane wave front AB is incident on the interface at an angle i.



- Let τ be the time taken by the wavefront to travel the distance BC.

  Thus, $BC = \upsilon_1 \tau$ ... (1)
- In order to determine the shape of the refracted wavefront, we draw a sphere of radius $\upsilon_2\tau$ from the point A in the second medium. A tangent (tangent plane) CE is drawn from the point C on the sphere.
- Let CE represent the refracted wavefront at the end of time τ.

  $AE = \upsilon_2 \tau$

  and r is the angle formed at point C which is angle of refraction.
- From Fig., From ΔABC

  $\sin i = \frac{BC}{AC} = \frac{\upsilon_1 \tau}{AC}$ ... (1)
- From, ΔAEC

$$\sin r = \frac{AE}{AC} = \frac{\upsilon_2 \tau}{AC} \quad \dots (2)$$

- Taking the ratio of eq. (1) and (2),

$$\frac{\sin i}{\sin r} = \frac{\upsilon_1 \tau}{AC} \times \frac{AC}{\upsilon_2 \tau}$$

$$\frac{\sin i}{\sin r} = \frac{\upsilon_1}{\upsilon_2} \quad \dots (3)$$

- Refractive index of medium 1, $n_1 = \frac{c}{\upsilon_1}$
- Refractive index of medium 2, $n_2 = \frac{c}{\upsilon_2}$

$$\therefore \frac{n_2}{n_1} = \frac{\upsilon_1}{\upsilon_2} \quad \dots (4)$$

- From eq. (3) and (4),

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$\therefore n_1 \sin i = n_2 \sin r$$

- which is Snell's law of refraction.
- Thus, the refraction of given plane wave front can be explained using Huygen's principle.

9.

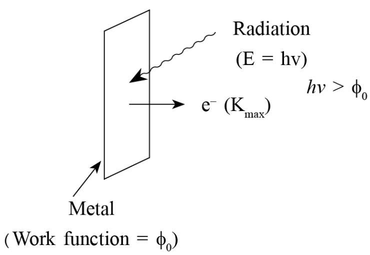
- In 1905, Einstien gave a historical explanation of the photoelectric effect. For which he was awarded the Nobel prize in physics in 1921.
- Einstein accepted Max Planck's concept of radiation.
- According to this concept, the energy of radiation is not continuous. Radiation is composed of discrete units of energy, (Bundles of energy) These units of energy are called quanta or photons.

  Each quantum (photon) has energy $E = h\nu$.

  Where, h = Planck's constant

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

  ν = Frequency of radiation
- When radiation is incident on a metal surface, the electrons in the metal interact with the quanta of the radiation. If the energy of quantum ($h\nu$) is greater than the work function (φ_0) of a given metal, the electron absorbs this quantum. i.e. the full energy of the quantum ($h\nu$) is absorbed and is emitted from the metal with a maximum kinetic energy K_{max}.
- Thus, $K_{max} = h\nu - \varphi_0$
- This equation is called Einstein's equation of photoelectric effect.

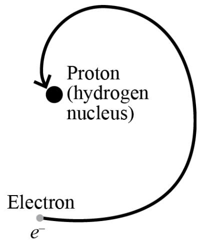


- If a photon interacts with an strongly bound electron than electron requires more energy to be ejected. So it is emitted with less energy than K_{max}.

10.

- Rutherford suggested that negatively charged electron revolves around the central nucleus just like the planets revolve around the sun.

- In a planetary system, the planets are held together by the gravitational force, while in an atom the electrons around the nucleus are held together by the Coulomb force.
- Limitations :
- An object which moves in a circular path is being constantly accelerated. This acceleration is called centripetal acceleration.
- According to classical electromagnetic theory, an accelerating charged particle emits radiation in the form of electromagnetic waves. Therefore the energy of an accelerating electron should continuously decrease.
- The electron would spiral inward and eventually fall into the nucleus. Thus, such an atom can not be stable.
- According to the classical electromagnetic theory, the frequency of the electromagnetic waves emitted by the revolving electrons is equal to the frequency of revolution.

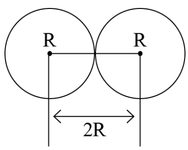


- As the electrons spiral inwards, their angular velocities and their frequencies would change continuously, so the frequency of the light emitted also changes. Thus, they would emit a continuous spectrum, opposite to the line spectrum actually observed.

11.

- Radius of deuteron R = 2.0 f m

  $= 2 \cdot 10^{-15}$ m
- When two deuterons collide head on the distance between their centres is given as = 2R
- Charge on a deuteron nucleus $q = 1.6 \cdot 10^{-19}$ C



(Head on collision)

- Potential energy for a head on collision

$$U = \frac{kq_1 q_2}{2R} = \frac{kq^2}{2R}$$

$$U = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{2 \times 2 \times 10^{-15}} = \frac{9 \times 10^9 \times 2.56 \times 10^{-38}}{4 \times 10^{-15}}$$

$$U = 5.76 \cdot 10^{-14} \text{ J}$$

$$U = \frac{5.76 \times 10^{-14}}{1.6 \times 10^{-19}} \; eV$$

$$U = 3.6 \cdot 10^5 \; eV$$

$$U = 360 \; keV$$

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	p - type semiconductor of p - n junction is connected to negative terminal and n - type is connected with

negative terminal of battery. Such a biasing is called forward biasing.	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 ∝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.

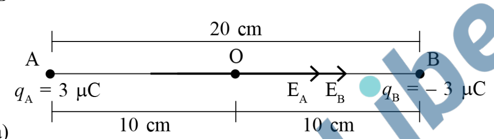
Section B

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

13.

➥ $q_A = 3\mu C$

$q_B = -3\mu C$



(a)

➥ Electric field at point ‘O’,

$E = E_A + E_B$

$E = \frac{kq_A}{r^2} + \frac{kq_B}{r^2}$

$\therefore E = \frac{9 \times 10^9 \times 3 \times 10^{-6}}{(0.1)^2} + \frac{9 \times 10^9 \times 3 \times 10^{-6}}{(0.1)^2}$

$\therefore E = \frac{27 \times 10^3}{10^{-2}} + \frac{27 \times 10^3}{10^{-2}}$

$\therefore E = 2.7 \cdot 10^{+6} + 2.7 \cdot 10^6$

$\therefore E = 5.4 \cdot 10^6$ N/C (Form A to B direction)

(b) Force acting on charge $q = 1.5 \cdot 10^{-9}$ C placed on ‘O’,

$F = qE$

$\therefore F = 1.5 \cdot 10^{-9} \cdot 5.4 \cdot 10^6$

$\therefore F = 8.1 \cdot 10^{-3}$ N (Form O to A direction)

➥ Thus, the force on the negative charge is in the opposite direction to the electric field.

14.

➥ When extremely small current passes through nichrome, its temperature is nearly equal to the room temperature

➥ so, $T_1 = 27\ ^{o}C$ and $R_1 = 75.3\ \Omega$

➥ Now, when the toaster is connected to supply, the steady current established is $I = 2.68$ A

➥ The resistance R_2 at the steady temperature T_2 is

$$\therefore R_2 = \frac{V}{I} = \frac{230}{2.68} = 85.8\ \Omega$$

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

$$\therefore R_2 = R_1 + R_1\ \alpha\ (T_2 - T_1)$$

$$\therefore R_2 - R_1 = R_1\ \alpha\ (T_2 - T_1)$$

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

➥ Putting the values in above equation

$$R_1 = 75.3\ \Omega,\ R_2 = 85.8\ \Omega$$

$$\alpha = 1.70 \times 10^{-4}\ °C^{-1}\ T_1 = 27\ °C$$

$$\therefore T_2 - 27 = \frac{85.8 - 75.3}{75.3 \times 1.70 \times 10^{-4}}$$

$$\therefore T_2 - 27 = \frac{10.5 \times 10^{4}}{128.01}$$

$$\therefore T_2 - 27 = \frac{105000}{128.01}$$

$$\therefore T_2 - 27 = 820$$

$$\therefore T_2 = 820 + 27$$

$$\therefore T_2 = 847\ °C$$

➥ **Note ...**

If the value of α is in K^{-1} then convert temperature in K before using in calculation

15.

➥ $B = 1.0$ T
$r = 8$ cm
$= 8 \times 10^{-2}$ m
$N = 30$ Turns
$I = 6$ A
$\theta = 60°$

Area of the coil

$A = \pi r^2$

$A = 3.14 \times (64 \times 10^{-4})$

$A = 200.96 \times 10^{-4}$

$A = 2 \times 10^{-2}\ m^2$

(a) The magnitude of the torque

$$\tau = BINA\ sin\ 60$$

$$\therefore \tau = (1)\ (6)\ (30)\ (2 \times 10^{-2}) \left(\frac{\sqrt{3}}{2}\right)$$

$$\therefore \tau = 180 \times \sqrt{3} \times 10^{-2}$$

$$\therefore \tau = 3.1\ \text{Nm}$$

(b) The magnitude of the torque acting on the coil does not depend on the shape, but it does depend on the area of the coil. So, the magnitude of the torque acting on the coil will not change

16.

➥ Suppose, electric current I_2 flows in outer circular coil.

➥ Magnetic field at centre of this coil

$$B_2 = \frac{\mu_0 I_2}{2 r_2} \quad ...(1)$$

Here, in comparision to coil of radius r_2, other coaxially placed coil has very small radius r_1 so, B_2 can be considered constant over its cross-section.

➥ Hence, flux linked with coil of radius r_1 is

$$\varphi_1 = B_2 A_1$$

$$= \frac{\mu_0 I_2}{2r_2} \cdot \pi r_1^2 \ (\because \text{ from equation (1)})$$

$$= \frac{\mu_0 \pi r_1^2}{2r_2} \cdot I_2$$

➥ But $\varphi_1 = M_{12} I_2$

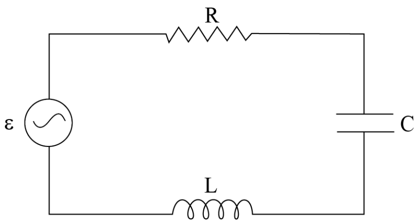
Thus, $M_{12} = \dfrac{\mu_0 \pi r_1^2}{2r_2}$

➥ From Reciprocity theorem,

$$M_{12} = M_{21}$$

➥ Thus $M_{12} = M_{21} = \dfrac{\mu_0 \pi r_1^2}{2r_2}$

17.

➥ 

➥ As shown in the fig., a resistor, an inductor and a capacitor are connected in series in an AC circuit.

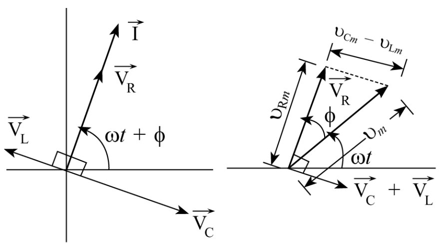
➥ Voltage of the AC source $\upsilon = \upsilon_m \sin \omega t$

➥ As the components are in series, ac current in each element is same, having the same amplitude and phase.

➥ Let current i be :

➥ $i = i_m \sin(\omega t + \varphi)$ ... (1)

➥ where, φ – is the phase difference between the voltage across the source and the current in the circuit.

➥ 

(a) (b)

➥ In the fig. (a), the phasor representing the current in the circuit as given by eq. (1), is shown by $\vec{I}$.

➥ Further, $\vec{V}_L$, $\vec{V}_R$, $\vec{V}_C$ and $\vec{V}$ represent the voltage across inductor L, resistor R, capacitor C and the source, respectively.

➥ All the phasors are shown in the fig. with their corresponding phase difference.

➥ The length of these phasors or the amplitudes of $\vec{V}_R$, $\vec{V}_C$ and $\vec{V}_L$ are :

➥ $\upsilon_{Rm} = i_m R$, $\upsilon_{Cm} = i_m X_C$, $\upsilon_{Lm} = i_m X_L$

➥ From the phasor diagram, the equation of resultant voltage is as follows :

$\vec{V}_L + \vec{V}_R + \vec{V}_C = \vec{V}$ ... (2)

(Note : voltage equation from the vertical components of above phasor relation can be written as : $\upsilon_L + \upsilon_R + \upsilon_C = \upsilon$)

➥ Since $\vec{V}_C$ and $\vec{V}_L$ are always along the same line and in opposite directions, they can be combined into a single phasor ($\vec{V}_C + \vec{V}_L$) which has a magnitude $|\upsilon_{Cm} - \upsilon_{Lm}|$.

➥ Since $\vec{V}$ is represented as the hypotenuse of a right-angle whose sides are $\vec{V}_R$ and $\vec{V}_C + \vec{V}_L$ the phythagorean theorem gives :

$$\upsilon_m^2 = \upsilon_{Rm}^2 + (\upsilon_{Cm} - \upsilon_{Lm})^2$$

➥ $\upsilon_m^2 = (i_m R)^2 + (i_m X_C - i_m X_L)^2$

$$\therefore \upsilon_m^2 = i_m{}^2 R^2 + i_m{}^2 (X_C - X_L)^2$$

$$\therefore \upsilon_m^2 = i_m{}^2 [R^2 + (X_C - X_L)^2]$$

$$\therefore i_m{}^2 = \frac{\upsilon_m^2}{R^2 + (X_C - X_L)^2}$$

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

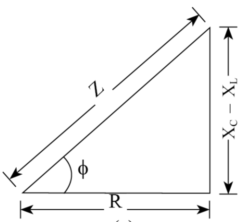
➥ The equation can also be written as follows :

$$\therefore i_m = \frac{\upsilon_m}{Z}$$

where, $Z = \sqrt{R^2 + (X_C - X_L)^2}$

➥ Z is known as impedence of the given AC circuit, which is analogous to resistance in a DC circuit. Its unit is ohm (Ω) (And it has the same dimension as resistance).

➥ Since phasor $\vec{I}$ is always parallel to phasor $\vec{V}_R$, the phase angle φ is the angle between $\vec{V}_R$ and $\vec{V}$ and it is shown in fig. (c).



(c)

➥ $tan\ \phi = \frac{\upsilon_{Cm} - \upsilon_{Lm}}{v_{Rm}}$

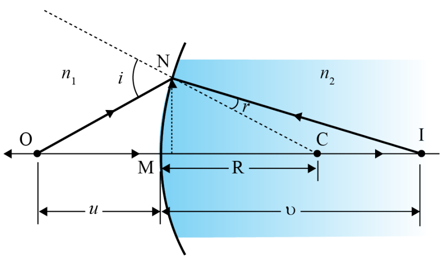
$$tan\ \phi = \frac{i_m X_C - i_m X_L}{i_{mR}}$$

$$\therefore tan\ \phi = \frac{X_C - X_L}{R}$$

➥ The diagram shown in fig. (c) is known as Impedence diagram, which is a right-triangle with Z as its hypotenuse.

18.

➥



- As shown in figure, a point like object O is placed on the principal axis of the spherical surface. A spherical surface has centre of curvature 'C' and radius of curvature R.
- Rays emerge from a medium having refractive index n_1. Here, OM and ON are the incident rays.
- They refract in a medium having refractive index n_2. Here NI and MI are the refractive rays. As a result, image I of the point object O is obtained.
- Assume that the aperture of the spherical surface is small compared to the object distance, image distance and radius of curvature, so that the angles can be taken small.
- Since the aperture of the surface is assumed to be small here, NM will be taken to be nearly equal to the length of the perpendicular from the point N on the principal axis.
- From figure,

$$\tan \angle NOM \approx \angle NOM = \frac{MN}{OM} \quad ... (1)$$

$$\tan \angle NCM \approx \angle NCM = \frac{MN}{MC} \quad ... (2)$$

$$\tan \angle NIM \approx \angle NIM = \frac{MN}{MI} \quad ... (3)$$

- For ΔNOC, i is the exterior angle.

  Therefore,

  $i = \angle NOM + \angle NCM$

  Substituting values from equation (1) and equation (2),

$$\therefore i = \frac{MN}{OM} + \frac{MN}{MC} \quad ... (4)$$

- From figure for ΔNIC, $\angle$NCM is the exterior angle.

  $\therefore \angle NCM = r + \angle NIM$

  $r = \angle NCM - \angle NIM$

$$\therefore r = \frac{MN}{MC} - \frac{MN}{MI} \quad ... (5)$$

- By applying Snell's law at point N,

  $n_1 \sin i = n_2 \sin r$

  But, $\sin i \approx i$

  $\sin r \approx r$

  $\therefore n_1 i = n_2 r$

- Substituting i and r from equation (4) and equation (5),

$$\therefore n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} - \frac{MN}{MI}\right)$$

$$\therefore \frac{n_1}{OM} + \frac{n_1}{MC} = \frac{n_2}{MC} - \frac{n_2}{MI}$$

$$\therefore \frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2}{MC} - \frac{n_1}{MC}$$

$$\therefore \frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

- But from figure, applying Cartesian sign convention,

  OM = $-u$, MI = υ and MC = R

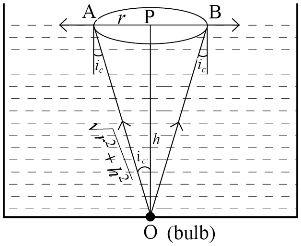
$$\therefore -\frac{n_1}{u} + \frac{n_2}{\upsilon} = \frac{n_2 - n_1}{R}$$

- Above equation gives us a relation between object and image distance in terms of refractive index of the medium and the radius of curvature of the curved spherical surface.

19.

- h = 80 cm (depth of bottom)

  $n_w = 1.33$



- O is a bulb as shown in figure which is placed at the bottom of a tank.
- The rays coming out of bulb are incident at point A and point B at an angle equal to the critical angle. Consequently, after point A and point B, the rays undergo total internal reflection, so the rays will not be able to come out of surface.
- Thus the ray can only pass through a circle of diameter AB, whose area is to be obtained.

From $\sin i_c = \frac{1}{n}$, (where, n = refractive index of water w.r.t. air)

$$\therefore \frac{r}{\sqrt{r^2+h^2}} = \frac{1}{n}$$

$$\therefore rn = \sqrt{r^2+h^2}$$

$$\therefore r^2n^2 = r^2 + h^2$$

$$\therefore r^2(n^2-1) = h^2$$

$$\therefore r^2 = \frac{h^2}{n^2-1}$$

$$\therefore r = \frac{h}{\sqrt{n^2-1}} \text{ (where, } r = \text{radius)}$$

- Area of circular path,

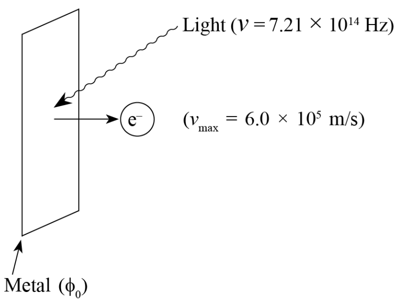
$$A = \pi r^2 = \frac{\pi h^2}{n^2-1}$$

$$\therefore A = \frac{3.14 \times (0.8)^2}{(1.33)^2 - 1} = \frac{2.0096}{0.7689}$$

$$\therefore A = 2.6 \text{ m}^2$$

- Thus, light will emerge out from a circular surface having an area of 2.6 m^2 of water.

20.

- 

- $\nu = 7.21 \times 10^{14}$ Hz

$v_{max} = 6.0 \times 10^5$ m/s

$\nu_0 = ?$

$K_{max} = h\nu - \varphi_0$

$$\therefore \frac{1}{2} mv^2_{max} = h\nu - \varphi_0 \ (\because K_{max} = \frac{1}{2} mv^2_{max})$$

$$\therefore \varphi_0 = h\nu - \frac{1}{2} mv^2_{max}$$

$\therefore h\nu_0 = h\nu - \frac{1}{2} m\nu^2_{max}$ ($\because \varphi_0 = h\nu_0$)

$\therefore \nu_0 = \nu - \frac{m\upsilon^2_{max}}{2h}$

$\therefore \nu = (7.21 \times 10^{14}) - \left(\frac{9.1 \times 10^{-31} \times (6.0 \times 10^5)^2}{2 \times 6.625 \times 10^{-34}}\right)$

$\nu_0 = (7.21 \times 10^{14}) - (2.472 \times 10^{14})$

$\nu_0 = 4.738 \times 10^{14}$ Hz

21.

➥ (a) The radius of electron

$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}$ ... (1)

➠ We know $F_c = F_e$

(Centripetal force) = (Coulomb Force)

$\frac{m\upsilon_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r_n^2}$

$\therefore \upsilon_n^2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{m r_n}$

➠ Putting the value from equation (1)

$\therefore \upsilon_n^2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{m\left(\frac{n^2 h^2 \varepsilon_0}{\pi m e^2}\right)}$

$\therefore \upsilon_n^2 = \frac{e^4}{4h^2 \varepsilon_0^2 n^2}$

$\therefore \upsilon_n = \frac{e^2}{2 h \varepsilon_0 n}$

$\therefore \upsilon_n = \frac{(1.6 \times 10^{-19})^2}{2 \times 6.625 \times 10^{-34} \times 8.85 \times 10^{-12} \times n}$

$\therefore \upsilon_n = \frac{2.18 \times 10^6}{n}$ ... (2)

➠ Taking $n = 1$ in equation (2),

$\upsilon_1 = 2.18 \times 10^6$ m/s

➠ Taking $n = 2$ in equation (2),

$\upsilon_2 = \frac{2.18 \times 10^6}{2}$

$\therefore \upsilon_2 = 1.09 \times 10^6$ m/s

➠ Taking $n = 3$ in equation (2),

$\upsilon_3 = \frac{2.18 \times 10^6}{3}$

$= 0.727 \times 10^6$ m/s

➥ (b) Time period (T)

$T_n = \frac{2 \pi r_n}{\upsilon_n}$

➠ Using equation (1) and (2)

$$T_n = \frac{2\pi\left(\frac{n^2h^2\varepsilon_0}{\pi me^2}\right)}{\frac{2.18\times10^6}{n}}$$

$$T_n = \frac{2h^2\varepsilon_0 n^3}{2.18\times10^6\times me^2}$$

$$T_n = \frac{2\times(6.625\times10^{-34})^2\times(8.85\times10^{-12})\times n^3}{2.18\times10^6\times9.1\times10^{-31}\times(1.6\times10^{-19})^2}$$

$T_n = 1.529 \times 10^{-16}\, n^3$

$T_n = 1.53 \times 10^{-16}\, n^3$ ... (3)

- Taking $n = 1$ in equation (3)

$T_1 = 1.53 \times 10^{-16}$ sec

- Taking $n = 2$ in equation (3)

$T_2 = 1.53 \times 10^{-16} \times (2)^3$

$\therefore T_2 = 1.22 \times 10^{-15}$ sec

- Taking $n = 3$ in equation (3)

$T_3 = 1.53 \times 10^{-16} \times (3)^3$

$\therefore T_3 = 4.13 \times 10^{-15}$ sec

Section C

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

22.

- (i) Electric field at point A,
  - $\therefore E_A = E_{1A} + E_{2A}$

(Both the electric fields are in the same direction.)

$$\therefore E_A = \frac{kq}{r^2} + \frac{kq}{r^2}$$

$$\therefore E_A = \frac{9\times10^9\times10^{-8}}{(0.05)^2} + \frac{9\times10^9\times10^{-8}}{(0.05)^2}$$

$\therefore E_A = 3.6 \cdot 10^4 + 3.6 \cdot 10^4$

$= 7.2 \cdot 10^4 \dfrac{N}{C}$

- (ii) Electric field at point B,
  - The electric field at point B due to q_1 will be on left side and electric field due to q_2 will be on right side.

$\therefore$ Net electric field at point B,

$E_B = E_{1B} - E_{2B}$

$$E_B = \frac{9\times10^9\times10^8}{(0.05)^2} - \frac{9\times10^9\times10^8}{(0.15)^2}$$

$\therefore E_B = 3.2 \cdot 10^4 \dfrac{N}{C}$ (towards left)

- (iii) Electric field at point C,
  - The electric field at point C, due to charge q_1,

$$E_{1C} = \frac{kq}{r^2}$$

$$= \frac{9 \times 10^9 \times 10^{-8}}{0.01} = 9 \cdot 10^3 \ \frac{N}{C}$$

➥ The electric field at point C, due to charge q_2,

$$E_{2C} = \frac{kq}{r^2}$$

$$= \frac{9 \times 10^9 \times 10^{-8}}{0.01} = 9 \cdot 10^3 \ \frac{N}{C}$$

➥ $E_{1C} = E_{2C}$

➥ Net electric field at point C,

$$E_C = \sqrt{E_{1C}^2 + E_{2C}^2 + 2E_{1C}\, E_{2C} \cos 120°}$$

$$\therefore E_C = \sqrt{E_{1C}^2 + E_{1C}^2 + 2E_{1C}^2 \left(-\frac{1}{2}\right)}$$

$$\therefore E_C = \sqrt{E_{1C}^2 + E_{1C}^2 - E_{1C}^2} = E_{1C}$$

$$\therefore E \ = 9 \cdot 10^3 \ \frac{N}{C} \ \text{(Right side)}$$

23.

➥ The formula of electric potential of electric dipole is as follows :

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p \cos \theta}{r^2}$$

OR

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{p} \cdot \vec{r}}{r^3}$$

Where, p = Electric dipole moment

θ = angle between position vector $\vec{r}$ and dipole moment $\vec{p}$.

➥ Special cases :

(i) The point at which electric potential is to be derived, is on the axis of the dipole.

$\therefore \theta = 0$

OR

$\theta = \pi$

$$\therefore V = \pm \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{r^2}$$

($\because \cos \theta = 1$ or $\cos \theta = -1$)

(ii) The point at which electric potential is to be found (/derived) is on equatorial axis of dipole.

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

$$\therefore \cos \theta = \cos \frac{\pi}{2} = 0$$

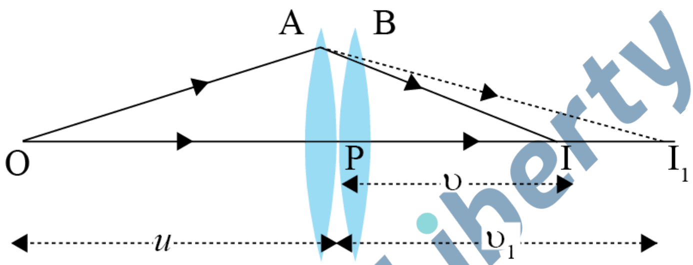
$\therefore V = 0$

So, potential on the equatorial axis of dipole is zero.

24.

- Resonant circuits have a variety of applications:
- In the tuning mechanism of a radio or a TV set, the antenna acccepts (/receives) signals from so many braodcasting stations.
- The signals picked up in the antenna act as a source in the tuning circuit of the radio (or TV), so the circuit can be driven by at many frequencies.
- But to hear one particular radio station, we tune the radio. (or TV).
- In tuning, we vary the capacitance of a capacitor in the tuning circuit such that the resonant frequency of the circuit becomes nearly equal to the frequency of the radio signal received.
- When this happens, the amplitude of the current with the frequency of the signal of the particular radio station in the circuit is maximum. And so we can listen to that radio/TV station properly.

25.

- 

- 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,

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

- For the image formed by the second lens B,

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

- Adding equations (1) and (2),

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

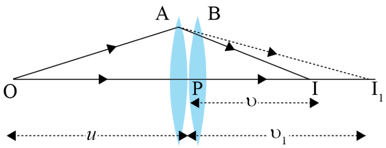
- If the two lens-system is regarded as equivalent to a single lens of focal length f.

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

- 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 $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$

➥ 

➥ Equivalent focal length of combination of two lenses A and B as shown in figure,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \quad ... (1)$$

Where, f_1 = focal length of lens A

f_2 = focal length of lens B

➥ Let the power of lenses A and B be P_1 and P_2 respectively.

$$\therefore P_1 = \frac{1}{f_1} \text{ and } P_2 = \frac{1}{f_2}$$

➥ Let the equivalent power of combination is P.

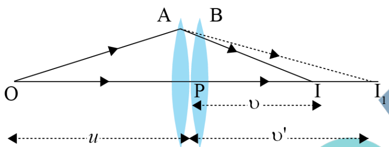
$$\therefore P = \frac{1}{f}$$

➥ from equation (1) we get $P = P_1 + P_2$.

➥ Equivalent power of several lens combinations,

$$P = P_1 + P_2 + P_3 + ...$$

➥ Equivalent power of combination is an algebraic sum of individual powers.

➥ 

➥ Figure shows combination of two lenses A and B. Let their magnification be m_1 and m_2.

➥ For lens A,

Object distance is u and image distance is υ'.

$$\text{magnification } m_1 = \frac{v'}{u} \quad ... (1)$$

➥ For lens B,

Object distance is v' and image distance is v.

$$\therefore \text{magnification } m_2 = \frac{v}{v'} \quad ... (2)$$

➥ Suppose magnification for the given lens combination is m.

$$\therefore \text{magnification } m = \frac{v}{u}$$

$$\therefore m = \frac{v'}{u} \times \frac{υ}{v'} \text{ (multiplying and dividing by υ')}$$

➥ Substituting values of equation (1) and (2),

$$\therefore m = m_1 \times m_2$$

➥ For combination of several lenses,

$$m = m_1 \times m_2 \times m_3 \times ....$$

➥ Thus, equivalent magnification of combination is an algebraic multiplication of individual magnifications.

26.

- When a heavy nucleus is bombarded with a neutron, then first neutron is absorbed. This nucleus is in a highly excited state. As a result, it splits into two lighter nuclei of approximately equal mass to become stable.
- Neutron is chargeless so it does not have to face coulomb forces. So neutron is a best projectile.
- When a neutron is bombarded on the nucleus of uranium its nucleus breaks into two almost equal parts. Its nuclear reaction is as below :

$$ {}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{144}_{56}\mathrm{B}a + {}^{89}_{36}\mathrm{K}r + 3({}^{1}_{0}n) + \mathrm{Q} $$

$$ {}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{133}_{51}\mathrm{S}b + {}^{99}_{41}\mathrm{N}b + 4({}^{1}_{0}n) + \mathrm{Q} $$

$$ {}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{140}_{54}\mathrm{X}e + {}^{94}_{38}\mathrm{S}r + 2({}^{1}_{0}n) + \mathrm{Q} $$

- The fission fragments are radioactive and by successive emmision of β - particles results in the stable nuclei.
- During the fission process of uranium the energy released per fission is almost 200 MeV.
- Suppose a nucleus with mass number A = 240 breaks into two fragments each of A = 120.
- Binding energy per nucleon for a nucleus with A = 240 is 7.6 M*e*V and for a nucleus with A = 120 is 8.5 M*e*V.
- Gain in binding energy per nucleon

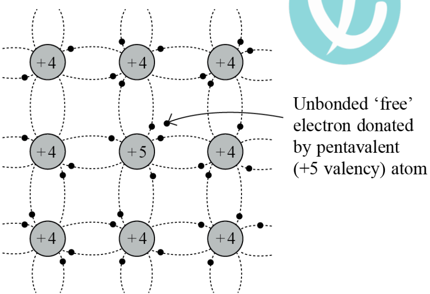
  = 8.5 – 7.6

  = 0.9 M*e*V
- Total gain in binding energy

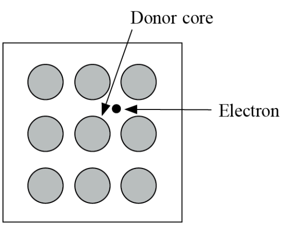
  = 0.9 × 240

  = 216 M*e*V.
- The disintegration energy in fission events first appears as the kinetic energy of the fragments and neutrons. Eventually it is transferred to the surrounding matter appearing as heat.
- In a nuclear reactor this process takes place in a controlled manner whereas in an atomic bomb this process takes place in an uncontrolled manner.

27.

- As shown in the Fig., to make this type of semi-conductor pure S*i* or G*e* is doped with a pentavalent element. (In the outer most orbit, there are 5 electrons in such atoms, So they are called pentavalent.)
- 

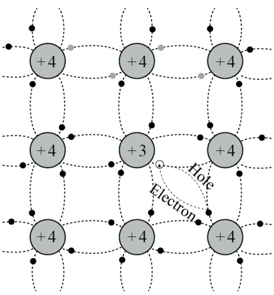
(a)



(b)

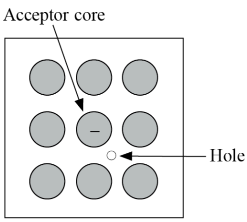
Example : Arsenic (A*s*), Antimony (S*b*), Phosphorous (P) etc.

- When an atom of +5 Valency element occupies the position of an atom in the crystal lattice of S*i*, four of its electrons bond with the four silicon neighbours while the fifth remains very weakly bound to its parent atom.
- As a result the ionisation energy required to set this electron free is very small and even at room temperature the electron gains energy sufficient to be free and to move in the lattice of the semiconductor.
- For example :
- the energy required to free this fifth electron is ~ 0.01 *e*V for germanium and 0.05 *e*V for silicon, to separate the electron from its atom.
- Thus the pentavalent dopant is donating one extra electron for conduction and hence it is known as donor impurity.
- The number of electrons made available for conduction by dopant atoms depends strongly upon the doping level and it's is independent of any increase in ambient temperature.
- In a doped semiconductor the total number of conduction electrons n_e is due to the electrons contributed by donors and those generated intrinsically, while the total number of holes n_h is only due to the holes from the intrinsic source.
- Thus, with proper level of doping the number of conduction electrons can be made much larger than the number of holes.
- Hence in an extrinsic semiconductor doped with pentavalent impurity, electrons become the majority carriers and the holes the minority carriers.
- Charge of electron is negative. Hence from the first letter of the word 'negative', '*n*', such semiconductors are known as *n*-type semiconductors.
- For *n*-type semiconductors.

  $n_e >> n_h$.
- 

  (a)
- As shown in Fig., to prepare this type of semiconductors, in pure S*i* or G*e*,

  trivalent impurity like A*l*, B, I*n* etc. are added. (In the outer most orbit, there are 3 electrons in such atoms, so they are called tri-valent.)

  (b)
- The dopant has one valence electron less than the S*i* and G*e* atoms, and therefore, this atom can form covalent bonds with neighbouring three S*i* atoms but does not have any electron to offer to the fourth S*i* atom.
- So, a vacancy (empty space) or hole is created in the bond between the fourth neighbour and the trivalent atom, as shown in the Fig.
- Since the neighbouring S*i* atom in the lattice wants an electron in place of a hole, an electron in the outer orbit of an atom in the neighbourhood may jump to fill this vacancy, leaving a vacancy or hole at its own site.
- Thus the hole is available for conduction. Hole has the tendency to attract/accept an electron. Hence, such impurities are called acceptor impurities.

- Apart from this, at room temperature, some covalent bonds break and pair of electron and a hole is created.
- Thus, for such a material, the holes are majority carriers and electrons are minority carriers.
- Since, the holes behave as a positive charge due to deficiency of negatively charged electrons, from the first letter of the word positive, such extrinsic semiconductors doped with trivalent impurity are called *p*-type semiconductors.
- For *p*-type semiconductors.

  $n_h >> n_e$.