LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNTMENT PAPER 6**

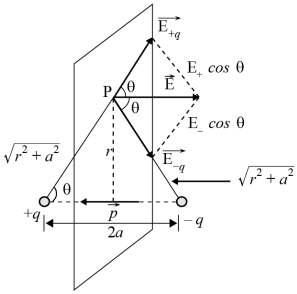
Section A

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

Section A

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

1.

➥ 

➥ The perpendicular bisector of dipole is often called the equator.

➥ As shown in figure a point P is located at equator of dipole at distance r.

➥ The distance between point P from $+q$ electric charge and -q electric charge is $\sqrt{r^2+a^2}$

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

$$E_{+q} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2} \quad \dots (1)$$

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

$$E_{-q} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2} \quad \dots (2)$$

➥ At point P, their components $E_{+q} \sin\theta$ and $E_{-q} \sin\theta$ normal to the axis of the dipole cancel each other because their magnitudes are equal and directions are opposite.

➥ And components $E_+ \cos\theta$ and $E_- \cos\theta$ along the axis add with each other because they are in the same direction which is opposite to $\hat{p}$

➥ Resultant electric field at point P

$$\vec{E} = -(E_{+q} \cos\theta + E_{-q} \cos\theta)\ \hat{p}$$

$$\vec{E} = -(E_{+q} + E_{-q}) \cos\theta\ \hat{p}$$

$$\therefore \vec{E} = -\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r^2+a^2)} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r^2+a^2)}\right) \cdot \frac{a}{(r^2+a^2)^{\frac{1}{2}}} \cdot \hat{p}$$

$$\therefore \vec{E} = -\left[\frac{1}{4\pi\varepsilon_0} \cdot \frac{2q}{(r^2+a^2)}\right] \cdot \frac{a}{(r^2+a^2)^{\frac{1}{2}}} \cdot \hat{p}$$

$$\therefore \vec{E} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{(r^2+a^2)^{\frac{3}{2}}} \cdot \hat{p} \quad (\because p = 2aq \text{ electric dipole moment})$$

➥ Suppose, the point P is very far on the equator so $r >> a$ so neglecting a^2 compare to r^2,

$$\therefore \vec{E} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{r^3} \cdot \hat{p}$$

2.

➥ $q_1 = 2 \cdot 10^{-7}$ C

$q_2 = 3 \cdot 10^{-7}$ C

$r = 30$ cm $= 0.3$ m

➥ Electric force acting between two charges at distance r, from Coulomb's Law,

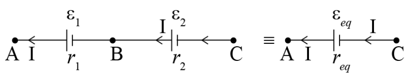
$$F = \frac{kq_1 q_2}{r^2}$$

$$\therefore F = \frac{9 \times 10^9 \times 2 \times 10^{-7} \times 3 \times 10^{-7}}{(0.3)^2}$$

$$\therefore F = \frac{9 \times 2 \times 3 \times 10^{-5}}{9 \times 10^{-2}}$$

$\therefore F = 6 \cdot 10^{-3}$ N (Repulsive Force)

3.

➥ 

➥ The figure shows the series connection of two cells. The emf of two cells are ε_1 and ε_2 respectively and their internal resistences are r_1 and r_2 respectively. The current I is passing through this combination.

Remember

As shown in the figure, consider two cells connected in such a way that one terminal of the two cells is joined together leaving the other terminal in both the cells free. Such connection is called series connection of cell. Similarly, more than two cells are also connected in series.

➥ Let the potentials at points A, B and C are V(A), V(B) and V(C) respectively as shown in the figure.

➥ The potential difference between the positive and negative terminal of the first cell is

$V_{AB} = V(A) - V(B) = \varepsilon_1 - Ir_1$ ... (1)

➥ Similarly, for the second cell

$V_{BC} = V(B) - V(C) = \varepsilon_2 - Ir_2$ ... (2)

➥ The potential difference between the terminals A and C of the combination is

$V_{AC} = V(A) - V(C)$

$V_{AC} = V(A) - V(B) + V(B) - V(C)$

$= \varepsilon_1 - Ir_1 + \varepsilon_2 - Ir_2$ ($\because$ from equations (1) and (2))

$\therefore V_{AC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$ ... (3)

➥ Suppose, the equivalent *emf* is ε_{eq} and equivalent internal resistance is r_{eq} between points A and C then.

$\therefore V_{AC} = \varepsilon_{eq} - I\, r_{eq}$ ... (4)

➥ Comparing equation (3) and (4)

$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ ... (5)

$r_{eq} = r_1 + r_2$ ... (6)

➥ Similarly, if n celll of *emf* $\varepsilon_1, \varepsilon_2, \varepsilon_3$ ..... ε_n are connected in series then the equivalent *emf* $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \ldots\ldots + \varepsilon_n$ and the equivalent internal resistance $r_{eq} = r_1 + r_2 + r_3 + \ldots\ldots + r_n$.

➥ If instead of the arrangement shown in the figure, a series connection is made by connecting two negative terminals then potential difference between points B and C is

$V_{BC} = -\varepsilon_2 - Ir_2$

➥ And the equivalent *emf*

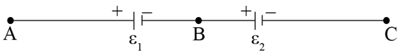
$\varepsilon_{eq} = \varepsilon_1 - \varepsilon_2$ $(\varepsilon_1 > \varepsilon_2)$ and

equivalent internal resistance is

$r_{eq} = r_1 + r_2$.

Remember

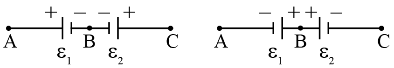
Constructive combination of cells



If the positive or negative terminal of one cell is connected to the negative or positive terminal of another cell respectivelly, then this combination of cells is called constructive combination (or connection).

In this type of connection, the equivalent *emf* is equal to the sum of the *emfs* of both the cells.

Destructive (or opposite) combination of cells



If both negative or both positive terminals of two cells are connected together, then this combination of cells is called the destructive (or opposite) combination.

In this type of connection, the equivalent *emf* is equal to the subtraction of the *emfs* of both the cells.

4.

- According to the third postulate of Bohr's model, when an atom makes a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number n_f ($n_f < n_i$), the difference of energy is carried away by a photon of frequency ν_{if} such that

  $h\,\nu_{if} = E_{ni} - E_{nf}$
- Since both n_f and n_i are integers, this shows that in transitions between different atomic levels, light is radiated in various discrete frequencies.
- The various lines in the atomic spectra are produced when electrons jump from higher energy state to a lower energy state and photons are emitted. These spectral lines are called emission lines.
- On the other hand, when an atom absorbs a photon that has the same energy needed by the electron in a lower energy state to make transitions to a higher energy state, the process is called absorption.
- Thus, if photons with a continuous range of frequencies pass through a rarefied gas and then are analysed with a spectrometer, a series of dark spectral absorption lines appear in the continuous spectrum. The dark lines indicate the frequencies that have been absorbed by the atoms of the gas.

5.

- Magnetisation : *"The net magnetic dipole moment per unit volume in a substance is called magnetisation."*
- Magnetisation $\vec{M} = \dfrac{\vec{m}_{net}}{V}$
- Magnetisation is a vector quantity and its direction is taken in the direction of magnetic dipole moment.
- Its unit is $\dfrac{A}{m}$ (or $A.m^{-1}$) and dimensional formula is $L^{-1} A^{1}$.
- Consider a long solenoid of n turns per unit length and carrying current I.
- The magnetic field in the interior of the solenoid,

  $B_0 = \propto_0 n I$ ... (1)
- If the interior of the solenoid is filled with a material having non-zero magnetisation, magnetic field (B_m) is generated due to this core material inside the solenoid.

  Therefore, the net field in the interior of the solenoid is equal to the vector addition of both the magnetic fields.

  $\therefore \vec{B} = \vec{B}_0 + \vec{B}_m$ ... (2)

  Where $\vec{B}_m$ is the field contributed by magnetic core.
- This additional field $\vec{B}_m$ is proportional to the magnetisation ($\vec{M}$) of the material.

$\therefore \vec{B}_m \,\alpha\, \vec{M}$

$\therefore \vec{B}_m = \propto_0 \vec{M}$ ... (3)

➥ Substituting the value of $\vec{B}_m$ from eq. (3) into eq. (2),

$\therefore \vec{B} = \vec{B}_0 + \propto_0 \vec{M}$

➥ dividing the equation by $\propto_0$,

$\therefore \frac{\vec{B}}{\mu_0} = \frac{\vec{B}_0}{\mu_0} + \vec{M}$

but $\frac{\vec{B}_0}{\mu_0} = \vec{H}$ – Which is a vector quantity called magnetic intensity.

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

$\therefore \vec{B} = \propto_0(\vec{H} + \vec{M})$

➥ Magnetic intensity ($\vec{H}$) has same dimensions as $\vec{M}$ and its unit is $\frac{A}{m}$ (or $A.m^{-1}$).

6.

➥ Self induced *emf* in a coil having self inductance L is

$\varepsilon = -L \frac{dI}{dt}$ ... (1)

This self induced *emf* opposes the change in current taking place in coil. Hence it is also called Back *emf*.

➥ Physically, self inductance plays the role of inertia in electricity.

➥ Work is required to be done against back *emf* to establish electric current in coil. This energy spent gets stored in form of magnetic energy U_B in the coil.

➥ Suppose, time rate of work done to establish current I in coil at any instant is $\frac{dW}{dt}$ then

$\frac{dW}{dt} = |\varepsilon|\, I$ (neglecting ohmic loss.)

$\therefore \frac{dW}{dt} = L I \frac{dI}{dt}$ (from equation (1))

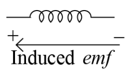
➥ Total work done to establish current I

$W = \int_0^I dW = \int_0^I L I \, dI = L \int_0^I I \, dI$

$\therefore W = \frac{1}{2} L I^2$ ... (2)

➥ Energy spent in doing this work gets stored in form of magnetic energy in the coil.

$\therefore$ Magnetic potential energy $U_B = \frac{1}{2} L I^2$ ... (3)

➥ Note : The coil possessing self inductance is called Inductor (L) It's symbol is :


7.

➥ Electric current for LCR series AC circuit,

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

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

$X_C = \frac{1}{\omega C}$ and $X_L = \omega L$

➥ From this equation, it can be said that when the value of ω is varied, the current also changes.

➥ Then at a particular frequency $\omega = \omega_0$, $X_C = X_L$. Then the impendence becomes miniumum. ($Z = \sqrt{R^2 + (X_C - X_L)^2} = R$)

➥ This frequency is called resonant frequency.

Here, $X_C = X_L$

$\therefore \frac{1}{\omega_0 C} = \omega_0 L$

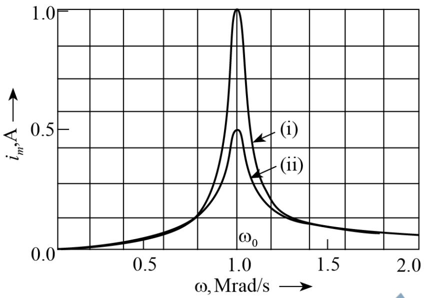
$\therefore \omega_0^2 = \frac{1}{LC}$

$\therefore \omega_0 = \frac{1}{\sqrt{LC}}$

➥ At resonant freq. the current amplitude is maximum.

$\therefore i_m^{max} = \frac{\upsilon_m}{R}$ $(\because Z = R)$

➥ The phenomenon of maximum current is called series resonance



➥ Figure shows the variation of i_m with ω in an RLC series circuit with

L = 1.00 mH, C = 1.00 *n*F for two values of

R : (i) R = 100 Ω and (ii) R = 200 Ω for the source applied υ_m = 100 V

➥ ω_0 for this case is :

$\omega_0 = \frac{1}{\sqrt{LC}} = 1.00 \times 10^6$ rad/s (substituting values)

➥ We can see that current amplitude becomes maximum at the resonance frequencey.

Since, $i_m^{max} = \frac{\upsilon_m}{R}$ at resonance,

the current amplitude for case (i) is twice to that for case (ii).

8.

➥ $n_1 = 1$ (air) $f = 20$ cm

$n_2 = 1.55$ (glass)

$R_1 = R$

$R_2 = -R$

➥ From lens maker's formula,

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

$\therefore \frac{1}{20} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R} + \frac{1}{R}\right)$

$\therefore \frac{1}{20} = (1.55 - 1)\left(\frac{2}{R}\right)$

$\therefore \frac{1}{20} = 0.55 \times \frac{2}{R}$

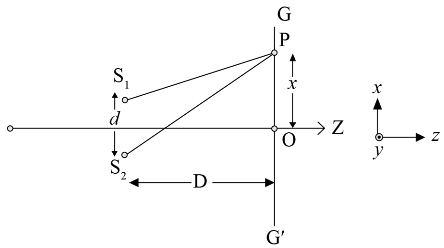
$\therefore R = 1.1 \times 20$

$\therefore R = 22$ cm

- Thus radius of curvature of both sides should be 22 cm.

9.

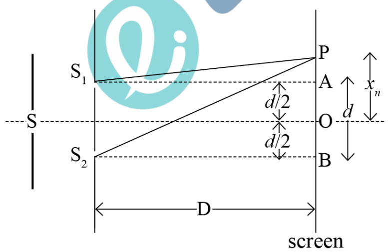
- The British physicist Thomas Young used an ingenious technique to “lock” the phases of the waves emanating from S_1 and S_2.
- He made two pinholes S_1 and S_2 (very close to each other) on an opaque screen. (fig. (a))
- These were illuminated by another pinholes that was in turn, lit by a bright source.



(b)

- Light waves spread out from S and fall on both S_1 and S_2.
- S_1 and S_2 then behave like two Coherent Sources because light waves coming out from S_1 and S_2 are derived out from same original source and any abrupt phase change in S will manifest in exactly similar phase changes in the light coming out from S_1 and S_2.
- Thus, the two sources S_1 and S_2 will be locked in phase; i.e. they will be coherent
- Thus spherical waves emanating from S_1 and S_2 will produce interference fringes on the screen GG ‘; as shown in fig. (b)

Formula derivation for fringe width and distance of n^{th} bright fringe



The dark and bright bands appear on the screen are called fringes.

The distance between two consecutive bright fringes or two consecutive dark fringes is called the fringe width.

From the triangle S_1AP

$$S_1P^2 - S_1A^2 + AP^2$$

That is

$$S_1P^2 = D^2 + [x_n - d/2]^2 \quad ...(1)$$

From triangle S_2BP

$$S_2P^2 = S_2B^2 + BP^2$$

That is $S_2P^2 = D^2 + [x_n - d/2]^2$ ...(2)

Subtracting equation 1 from 2, we get

$$S_2P^2 - S_1P^2 = \left[x_n + \frac{d}{2}\right]^2 - \left[x_n - \frac{d}{2}\right]^2$$

$$= \left[x_n^2 + 2x_n\frac{d}{2} + d^2/4\right] - \left[x_n^2 + 2x_n\frac{d}{2} - d^2/4\right]$$

Thus, $S_2P^2 - S_1P^2 = 2dx_n$

Or

$$[S_2P - S_1P]\,[S_2P + S_1P] - 2dx_n \qquad ...(3)$$

If the point P is near to O, then

$$S_2P \approx S_1P \approx D$$

Therefore, $[S_2P - S_1P]2D = 2dx_n$

Or

$$S_2P - S_1P = \frac{dx_n}{D}$$

Thus, Path Difference $= \dfrac{x_n d}{D}$

For the point P to be bright, the path difference $= n\lambda$, thus

$$\frac{x_n d}{D} = n\lambda$$

Therefore, the distance to n^{th} band (fringe) is

$$x_n = \frac{n\lambda D}{d};\ n = 0, \pm 1, \pm 2, ...$$

Thus, distance to $(n + 1)^{th}$ band is

$$x_{n+1} = \frac{(n+1)\lambda D}{d}$$

The band width is given by

$$\beta = x_{(n+1)} - x_n$$

Thus, $\beta = \dfrac{\lambda D}{d}$

This is the combined width of a dark band and a bright band.

The dark and bright bands are equally spaced.

If P is dark then,

$$x_n = \left(n + \tfrac{1}{2}\right)\frac{\lambda D}{d};\ n = 0, \pm 1, \pm 2$$

10.

- *"When electron in a metal possessing sufficient energy, the phenomenon of electrons leaving the metal is called electron emission."*
- Types of Electron Emission :
  - The energy required to eject an electron from a metal can be given in different ways. There are three types of electron emission based on it.
- (i) Thermionic emission :
  - Properly heating the metal gives thermal energy to the electrons in it. By absorbing this energy, electrons can escape from the metal.
- (ii) Field emission :
  - Applying a very strong electric field (of the order of 10^8 Vm^{-1}) to the metal can pull electrons out of the metal.
- (iii) Photo electric emission :
  - When light of sufficient frequency is incident on a metal surface, electrons are emitted from the metal. This phenomenon is called photoelectric effect and the emitted electrons are called photo-electrons.

- Threshold frequency : Hallwach and Lenard observed that electrons are emitted from a metal plate only if the frequency of ultraviolet light is above a certain frequency.
  - This specific frequency is called the threshold frequency of a given metal.
  - The threshold frequency depends on the type of metal, meaning its value is different for each metal.
  - Thus, to obtain photoelectric effect (emission of electrons) the frequency of ultraviolet light (v) should be greater than (or equal to) the threshold frequency of metal (v_0). $v \geq v_0$.

11.

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

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

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

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

  Mass of 8 electrons = $8 \cdot 0.00055\ u$
- Therefore, the expected mass of $_8O^{16}$ nucleus

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

  $= 8(1.00866 + 1.00727)$

  $= 8 \cdot 2.01593\ u$

  $= 16.12744\ u$
- The atomic mass of $_8O^{16}$ found from mass spectroscopy experiments is seen to be $15.99493\ u$.
- Subtracting the mass of 8 electrons

  ($8 \cdot 0.00055\ u = 0.0044\ u$) from this we get the experimental mass of $_8O^{16}$ nucleus to be $15.99053\ u$.
- Thus, the mass of the $_8O^{16}$ nucleus is less than the total mass of its constituents by

  $(16.12744 - 15.99053) = 0.13691\ u$.
- *"The difference in mass of a nucleus and its constituents, ΔM is called the mass defect"* and is given by

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

  Where, Z = number of protons

  A – Z = N = neutron number

  m_p - mass of proton

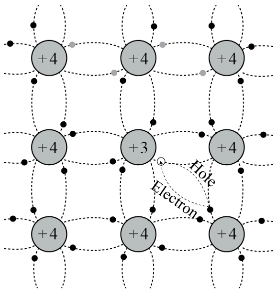
  m_n - mass of neutron

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

  $\therefore$ Binding energy $E_b = \Delta Mc^2$
- Binding energy per nucleon is the binding energy divided by the total number of nucleons.

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

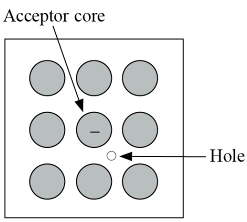
12.



(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.

  $n_h >> n_e$.

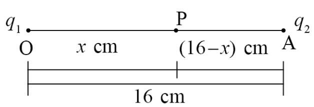
Section B

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

13.

- (a) $q_1 = 5 \times 10^{-8}$ C

  $q_2 = -3 \times 10^{-8}$ C



  - Suppose, here the positive charge 'q_1' is on the origin and negative charge 'q_2' is on the X-axis, towards the RHS of the origin.
  - Suppose, electric potential at point P is zero. Point P is x cm away from charge q_1.

$\therefore \frac{k\,q_1}{x \times 10^{-2}} + \frac{k\,q_2}{(16-x)\times 10^{-2}} = 0$

$\therefore \frac{k\,(5\times 10^{-8})}{x \times 10^{-2}} - \frac{k\,(3\times 10^{-8})}{(16-x)\times 10^{-2}} = 0$

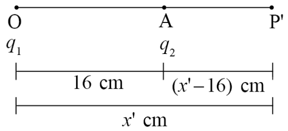
$\therefore \frac{k\,(5\times 10^{-8})}{x \times 10^{-2}} = \frac{k\,(3\times 10^{-8})}{(16-x)\times 10^{-2}}$

$\therefore \frac{5}{x} = \frac{3}{16-x}$

$\therefore 80 - 5x = 3x$

$\therefore 80 = 8x$

$\therefore x = 10$ cm

➥ 

(b)

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

$\therefore \frac{k\,q_1}{x' \times 10^{-2}} + \frac{k\,q_2}{(x'-16)\times 10^{-2}} = 0$

$\therefore \frac{k\,(5\times 10^{-8})}{x' \times 10^{-2}} - \frac{k\,(3\times 10^{-8})}{(x'-16)\times 10^{-2}} = 0$

$\therefore \frac{k\,(5\times 10^{-8})}{x' \times 10^{-2}} = \frac{k\,(3\times 10^{-8})}{(x'-16)\times 10^{-2}}$

$\therefore \frac{5}{x'} = \frac{3}{x'-16}$

$\therefore 5x' - 80 = 3x'$

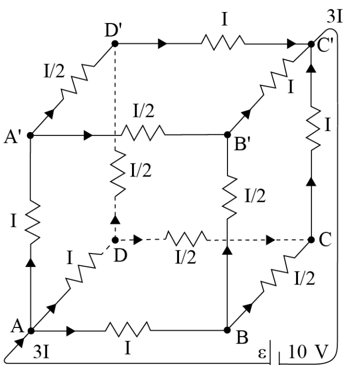
$\therefore 5x' - 3x' = 80$

$\therefore 2x' = 80$

$\therefore x' = 40$ cm

➠ Hence, electric potential will be zero at distance 10 cm from q_1 (positive charge) and at 40 cm from q_1.

14.

➥ 

➥ Here, the network is not simplified in terms of series and parallel connections. By using symmetry in the problem we can obtain the equivalent resistance of the network.

➥ As shown in fig., ε = 10 V battery is connected across point A and C'. Neglect the internal resistance of battery. Assume that 3I current is passing through the battery.

➥ As shown in the network the paths AA', AD and AB we symmetrically placed and the current in each this path is I.

- At each of the junction A', B and D, the incoming current I is split equally into two parts of $\frac{I}{2}$.
- In this similar manner the current in all the 12 edges of the cube are in terms of I.
- Applying Kirchhoff's second rule to loop

$A - B - C - C' - \varepsilon - A$,

$$-IR - \left(\frac{I}{2}\right)R - IR + \varepsilon = 0$$

$$\therefore \varepsilon = IR + \frac{IR}{2} + IR$$

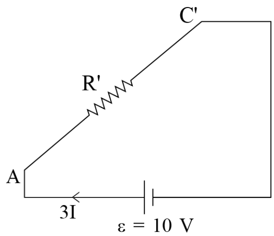
$$\therefore \varepsilon = \frac{2IR + IR + 2IR}{2}$$

$$\therefore \varepsilon = \frac{5}{2} IR \quad ... (1)$$

- Suppose, the equivalent resistance of the circuit is R_{eq}.

$$\therefore R_{eq} = \frac{\varepsilon}{3I}$$

$$\therefore \varepsilon = R_{eq}(3I) \quad ... (2)$$



(Equivalent circuit)

- Comparing equation (1) and (2),

$$\therefore R_{eq} = \frac{5}{6} R$$

but $R = 1\ \Omega$

$$R_{eq} = \frac{5}{6}\ \Omega$$

- from equation (1), we get

$$\varepsilon = \frac{5}{2} IR$$

$$\therefore 10 = \frac{5}{2} I(1)$$

$$\therefore I = 4\ A$$

- So from the figure the current in branches

AB, AD, AA', B'C', D'C', C'C is I = 4 A

- Similarly in branches A'D', A'B', DD', DC, BB' and BC is $\frac{I}{2} = \frac{4}{2} = 2\ A$

and the total current is $3I = 3 \times 4 = 12\ A$

15.

- $l = 10$ cm $= 0.1$ m
  $N = 20$ Turns
  $I = 12$ A
  $B = 0.8$ T
  $\theta = 30°$

  Area of coil
  $A = l^2 = (0.1)^2$
  $A = 0.01\ m^2$

- Torque acting on the coil

$$\tau = BINA \sin\theta$$

$$\therefore \tau = (0.8)(12)(20)(0.01) \sin 30$$

$\therefore \tau = 1.92 \times \frac{1}{2}$

$\therefore \tau = 0.96$ Nm

16.

➡ Characteristics of EM waves are as follows :

(1) In EM wave, the electric field, magnetic field and direction of wave propogation are mutually perpendicular.

(2) Relationship between the values / magnitudes of electric field and magnetic field in EM wave is :

$$\frac{E_0}{B_0} = c \text{ or } \frac{E_{rms}}{B_{rms}} = c$$

(3) EM waves are transverse and non-mechanical waves.

(4) Velocity of EM waves in vacuum,

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

where, $\propto_0$ - permeability of free space

ε_0 - permittivity of free space

➡ Velocity of EM waves in medium,

$$\upsilon = \frac{1}{\sqrt{\mu\varepsilon}}$$

where, $\propto$ - permeability of medium

ε - permittivity of medium

(5) As demonstrated by scientist Hertz, the EM waves experience diffraction, refraction and polarisation.

(6) EM waves are polarized.

(7) EM waves possess and carry energy, which is known as radiation energy.

(8) When an EM wave strikes (/ is incident) on a surface, it exerts pressure, which is called radiation pressure.

(9) Direction of $\vec{E} \times \vec{B}$ shows the direction of propogation of wave.

(10) In the region of space far from the source, the oscillations of electric field and magnetic field vectors are in phase.

(11) Energy density in EM wave,

$$\varrho = \varepsilon_0 E^2_{rms} \text{ and } \varrho = \frac{B^2_{rms}}{\mu_0}.$$

17.

➡ h_2 (Real depth) = 12.5 cm

h_1 (Apparent depth) = 9.4 cm

n_1 (for air) = 1

➡ Refractive index of water (n_2)

$$\frac{h_1}{h_2} = \frac{n_1}{n_2}$$

$$\therefore \frac{9.4}{12.5} = \frac{1}{n_2}$$

$\therefore n_2 = \frac{12.5}{9.4}$

$\therefore n_2 = 1.33$

This equation $\frac{h_1}{h_2} = \frac{n_{rarer}}{n_{denser}}$ can also be written in this form.

where, h_1 = Apparent depth

h_2 = Real depth

n_{rarer} = refractive index of air

n_{denser} = refractive index of water

➥ Now the tank is filled to the same height with liquid instead of water.

➥ h_2 (Real depth) = 12.5 cm

h'_1 (New Apparent depth) = ?

n_1 (refractive index of air) = 1

n_2 (refractive index of liquid) = 1.63

$\therefore \frac{h_1'}{h_2} = \frac{n_1}{n_2}$

$\therefore \frac{h_1'}{12.5} = \frac{1}{1.63}$

$\therefore h_1' = \frac{12.5}{1.63}$

$\therefore h_1' = 7.7$ cm

➥ A decrease in apparent depth of the needle,

$h_1 - h_1' = 9.4 - 7.7$

$= 1.7$ cm

➥ To focus the microscope on the needle, it has to be moved upward by 1.7 cm.

18.

➥ d = 0.1 mm = 10^{-4} m
D = 100 cm = 1m
$\lambda = 6000$ Å

➥ Path difference for constructive interference = $n\lambda$ where n = 0, 1, 2, 3.....

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

$\therefore \frac{xd}{D} = n\lambda$, $x = \frac{n\lambda D}{d}$

➥ for 3rd bright fringe n = 3

$x_3 = \frac{3\lambda D}{d}$ ....(1)

➥ Path difference for destructive interference = $(n + \frac{1}{2})\lambda$ where n = 0, 1, 2, 3, 4.....

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

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

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

➥ for 5th dark fringe n = 4

$\therefore x_5 = \left(4 + \frac{1}{2}\right)\frac{\lambda D}{d}$

$\therefore x_5 = \frac{9\lambda D}{2d}$ ....(2)

➥ distance between the 3rd bright fringe & 5th dark fringe

$\therefore x_5 - x_3 = \frac{9\lambda D}{2d} - \frac{3\lambda D}{d}$

$\therefore x_5 - x_3 = \frac{3}{2}\frac{\lambda D}{d}$

$$= \frac{3 \times 6000 \times 10^{-10} \times 1}{2 \times 10^{-4}}$$

$= 9000 \times 10^{-6}$

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

$= 9\ mm$

19.

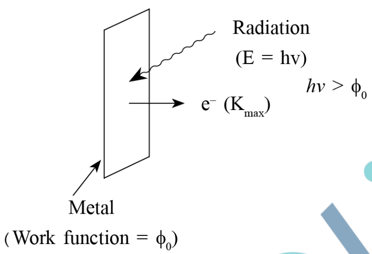
- In 1905, Einstien gave a historical explanation of the photoelectric effect. For which he was awarded the Nobel prize in physics in 1921.
- Einstein accepted Max Planck's concept of radiation.
- According to this concept, the energy of radiation is not continuous. Radiation is composed of discrete 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}.

20.

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

  Where, h is Planck's constant
- $h = 6.625 \times 10^{-34}$ Js
- Thus the angular momentum of the electron

  $L = \frac{nh}{2\pi}$ Where, $n = 1, 2, 3$ ......
- De - Broglie's explanation :
- According to de-Broglie's hypothesis even matter particles like electrons have wave nature. Its practical explanation was given by Davisson and Germer, from which de-Broglie argued that the electron in its circular orbit must be seen as a particle wave.
- When the tensioned wire is plucked tied to a rigid support on both ends, a vast number of wavelengths are excited. However only those wavelengths survive which have nodes at the ends and form the standing wave in the string. It means standing waves are formed when the total distance travelled by a wave down the string and back is one wavelength or any integral number of wavelength.
- Waves with other wavelengths interfere with themselves upon reflection and their amplitudes rapidly drop to zero.
- For an electron moving in n^{th} circular orbit of radius r_n, the total distance is the circumference of the orbit. Thus,

  $2\pi r_n = n\lambda$ ... (1)

  Where $n = 1, 2, 3,$ ....

➥ But the de-Broglie wavelength $\lambda = \frac{h}{p}$

Where p = momentum of electron. If the speed of the electron is much less than the speed of light, the momentum is = mv_n

$\therefore \lambda = \frac{h}{mv_n}$ ... (2)

➥ Form equation (1) and (2),

$\therefore 2\pi r_n = \frac{nh}{mv_n}$

$\therefore mv_n r_n = \frac{nh}{2\pi}$

➥ This is the quantum condition proposed by Bohr for the angular momentum of the electron.

➥ Thus, de-Broglie hypothesis provided an explanation for Bohr's second postulate for the quantisation of angular momentum of the orbiting electron.

21.

➥ As shown in fig., an AC source is connected with a (pure) resistor.

➥ Voltage of the AC source, $\upsilon = \upsilon_m \sin \omega t$... (1)

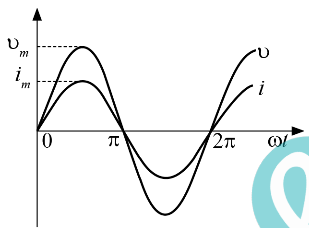
Where, υ_m is the amplitude of the oscillating potential difference and ω is the angular frequency.

➥ To find the value of current through the resistor, we apply Kirchhoff's loop rule $\sum \varepsilon(t) = 0$, to the closed loop shown in fig.,

$\therefore \upsilon_m \sin \omega t = i R$

$\therefore i = \frac{\upsilon_m}{R} \sin \omega t$ (Here, R is constant)

$\therefore i = i_m \sin \omega t$ ... (2)



(b)

Where, $i_m = \frac{\upsilon_m}{R}$ Amplitude of electric current ... (3)

➥ Equation (3) is Ohm's law which works equally well for both AC and DC voltages.

➥ From eq. (1) and (2), it can be said that voltage and current both are in phase with each other.

➥ [Which means both V and i reach zero, minimum and maximum values at the same time.]

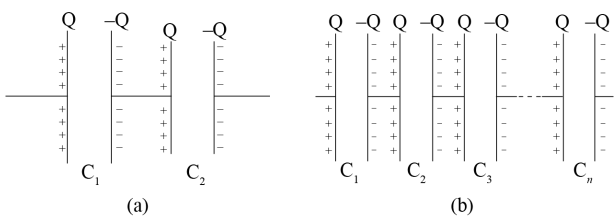
Section C

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

22.

➥ (a) series

➥



- As shown in fig. (a), two capacitors C_1 and C_2 are connected in series.
- The left plate of C_1 and the right plate of C_2 are connected to two terminals of a battery, and have charges Q and –Q on them, respectively.
- Consequently the right plate of C_1 has charge –Q and left plate of C_2 has charge Q induced on it.
- Like this, even though the capacitors may have different capacitance, the charge on them (the charge on each capacitor plate) is same.
- Suppose, the potential difference between two terminals of C_1 and C_2 is V_1 and V_2 respectively.
- The total potential drop V across the combination will be :

$$V = V_1 + V_2 \ ... (1)$$

but $C_1 = \frac{Q}{V_1}$

$$\therefore V_1 = \frac{Q}{C_1}$$

Similarly we get $V_2 = \frac{Q}{C_2}$

$\therefore$ From eq^n (1)

$$V = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\therefore \frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} \ ... (2)$$

- Suppose, the equivalent capacitance for the given combination of capacitors is C, then,

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

$$\therefore \frac{1}{C} = \frac{V}{Q} \ ... (3)$$

$\therefore$ From equation (2) and (3)

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

- As shown in fig. (b), n capacitors are connected in series.
- Their capacitance are C_1, C_2, C_3 .... C_n respectively. Electric charge on each of those, is Q.
- Suppose the p.d. across these capacitors, are $V_1, V_2, V_3 \ .... \ V_n$
- The total p.d. of the series combination will be :

$$V = V_1 + V_2 + V_3 + ... + V_n$$

$$\therefore V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + ... + \frac{Q}{C_n}$$

$$\therefore \frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n} \ ... (4)$$

- Suppose, the equivalent (/ effective) capacitance for the given series combination of capacitors is C.

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

$$\therefore \frac{1}{C} = \frac{V}{Q} \ ... (5)$$

- From equations (4) and (5),

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

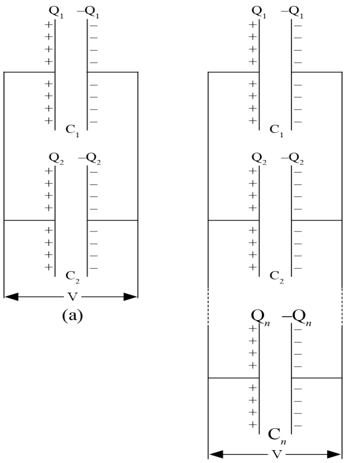
- Suppose, the capacitance of each capacitor is same.

  Then we get the equivalent capacitance.

  $$C_{eq} = \frac{C}{n}$$

Remember

The effective capacitance of the series combination of capacitors will have value of capacitance smaller than the smallest valued capacitor.

- (b) parallel connections of capacitors.
- 

(a) (b)

- As shown in the fig. (a) two capacitors C_1 and C_2 are connected in parallel.
- For such connection, the p.d. across each capacitor is same, suppose its value is V.
- The charge on the plate of capacitor '1' is ($+Q_1$) and the charge on the plate of capacitor '2' is ($+Q_2$)
- $Q = CV$ for first capacitor $Q_1 = C_1V$ and for second capacitor $Q_2 = C_2V$
- Hence, the total charge (/ charge of the equivalent capacitor)

  $$Q = Q_1 + Q_2$$
  $$\therefore Q = C_1V + C_2V$$
  $$\therefore Q = V(C_1 + C_2)$$
  $$\therefore \frac{Q}{V} = C_1 + C_2 \text{ .....(1)}$$

- Suppose, the equivalent capacitance for the given parallel connection is C.

  $$\therefore C = \frac{Q}{V} \text{ ... (2)}$$
  $$\therefore C = C_1 + C_2 \text{ (From (1) and (2)}$$

- As shown in fig. (b), C_1, C_2, C_3 ..... C_n total n capacitors are connected in parallel. P.d. for each is V and the charge on each capacitor is Q_1, Q_2, Q_3 ..... Q_n
- Hence, the total charge,

  $$Q = Q_1 + Q_2 + Q_3 + ... + Q_n$$
  $$\therefore Q = C_1V + C_2V + C_3V + ... + C_nV$$
  $$\therefore \frac{Q}{V} = C_1 + C_2 + C_3 + ... + C_n \text{ ... (3)}$$

- Suppose, the equivalent capacitance for the given parallel connection is C.

Where $\therefore C = \frac{Q}{V}$ ... (4)

- So, from eq (3) and (4),
- $C = C_1 + C_2 + C_3 + ... + C_n$
- Suppose, the capacitance of each capacitor is same and it is 'C'

  ∴ Equivalent capacitance,

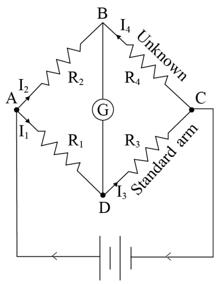
  $C_{eq} = C + C + C + ... + C$ (n times)

  $\therefore (C_{eq} = nC)$

Note ...

In parallel connection of capacitors, the value of equivalent capacitance is greater than the capacitance of anyone of (more than the parallely connected) capacitors.

23.

- 

- The circuit shown in the figure is called the wheatstone bridge. It uses four resistors R_1, R_2, R_3 and R_4 out of them three resistors are known and one is unknown, wheatstone bridge is used to find the value of unknown resistance.
- As shown in the figure, across one pair of diagonally opposite points (A and C in the figure) a source is connected hence AC is called the battery arm.
- Between the other two vertices, B and D, a galvanomenter G is connected hence BD is called the galvanometer arm.
- When battery is connected, the currents flowing through the resistors R_1, R_2, R_3 and R_4 are I_1, I_2, I_3 and I_4 respectively.
- Here, there resistors are chosen in such a way that current flowing through galvanometer is zero ($I_g = 0$).
- When the current flowing through the galvanometer becomes zero, the bridge is said to be in balanced condition.
- From the figure, in balanced condition

  $I_1 = I_3$ and $I_2 = I_4$

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

  $-I_1R_1 + 0 + I_2R_2 = 0$

  $\therefore I_1R_1 = I_2R_2$ ... (1)

- Applying similarly, for closed loop C – B – D – C

  $I_4R_4 + 0 - I_3R_3 = 0$

  $\therefore I_3R_3 = I_4R_4$ ... (2)

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

  $\therefore \frac{I_1R_1}{I_3R_3} = \frac{I_2R_2}{I_4R_4}$

  But $I_1 = I_3$ and $I_2 = I_4$

  $\therefore \frac{R_1}{R_3} = \frac{R_2}{R_4}$ OR $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ ... (3)

- which is a condition for the whetstone bridge to be in balanced condition.
- If three resistors R_1, R_2 and R_3 are known then unknown resistence of R_4 is given by

  $R_4 = R_3 \cdot \frac{R_2}{R_1}$ ... (4)

- A practical device using this principle is called the meter bridge.

24.

➥ When an AC voltage is applied to primary, the resulting current produces an alternating magnetic flux, which links the secondary and induces an emf in it. The value of this emf depends on number of turns in secondary.

➥ We consider an ideal transformer in which the primary has negligible resistance and all the flux in the core links both primary and secondary windings.

➥ Let φ be the flux in each turn in the core at time *t* due to current in the primary when a voltage (υ_p) is applied to it.

➥ Then the induced emf or voltage (E), in the secondary

$$\varepsilon_s = -N_s \frac{d\phi}{dt} \quad \text{... (1)}$$

where, N_s is no. of turns in secondary.

➥ The alternating flux, φ also induces an *emf* called the back emf in the primary. This is,

$$\varepsilon_p = -N_p \frac{d\phi}{dt} \quad \text{... (2)}$$

Where, N_p is no. of turns in the primary.

➥ But $\varepsilon_p = \upsilon_p$ If this were not so, the primary current would be infinite due to zero resistance. (as assumed)

➥ If the secondary is an open circuit or the current taken from it is small, then to a good approximation, $\varepsilon_s = \upsilon_s$

➥ From eq. (1) and (2),

$$\upsilon_s = -N_s \frac{d\phi}{dt} \text{ ... (3) and } \upsilon_p = -N_p \frac{d\phi}{dt} \text{ ... (4)}$$

(where υ_s is the voltage a cross secondary)

➥ By taking the ratio of eq. (3) and (4),

$$\frac{\upsilon_s}{\upsilon_p} = \frac{N_s}{N_p} \quad \text{... (5)}$$

➥ Following three assumptions are used in obtaining the above relation :

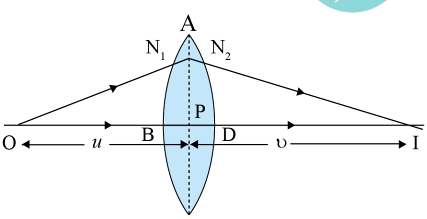
(1) The primary resistance and current are small;

(2) The same flux links both the primary as well as secondary (as very less flux escapes from the core)

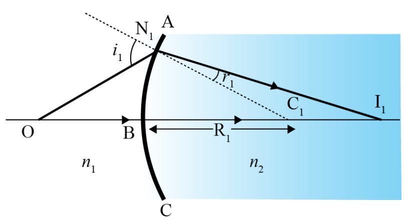
(3) The secondary current is small.

25.

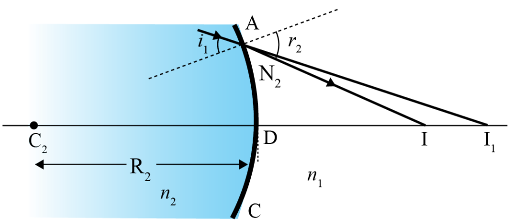
➥



(a)



(b)



(c)

➥ Figure (a) shows the geometry of image formation by a convex lens.

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

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

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

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

- A similar procedure applied to the interface ADC gives,

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

- For a thin lens,

  $BI_1 = DI_1$

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

- Adding equations (1) and (2),

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

- Suppose the object is at infinity

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

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

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

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

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

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

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

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

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

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

26.

- (i) The force is attractive and sufficiently strong to produce a binding energy of a few MeV per nucleon.

  (ii) The constancy of the binding energy in the range $30 < A < 170$ is a consequence of the fact that the nuclear force is short ranged.

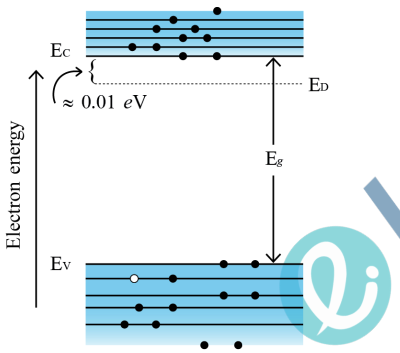
  - Consider a particular nucleon inside a sufficiently large nucleus. This nucleon can interact with another nucleon within a distance of the duration of the nuclear force.
  - If any other nucleon is at a distance more than the range of the nuclear force from the particular nucleon, so there is no interaction between these two nucleus. (There is no force between two nucleons)

- Suppose a nucleon can have a maximum of *p* neighbours within the range of the nuclear force. All these nucleons exert a force on the considered nucleon. Due to which the considered nucleon has binding energy. This binding energy would be proportional to *p*. Let the binding energy of the nucleus be *pk*, where *k* is a constant having the dimension of energy.
- If we increase A by adding nucleons they will not change the binding energy of a nucleon inside.
- Since most of the nucleons in a large nucleus reside inside it and not on the surface, the change in binding energy per nucleon would be small, which can be ignored. The binding energy per nucleon is constant and is approximately equal to *pk*.
- The property that a given nucleon influences only nucleons close to it is also referred to as saturation property of the nuclear force.

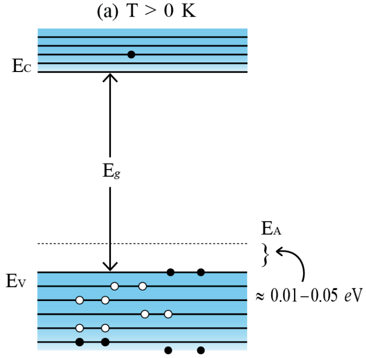
(iii) A very heavy nucleus say A = 240, has lower binding energy per nucleon compared to that of a nucleus with A = 120.

- Thus, if a nucleus A = 240 breaks into two A = 120 nuclei, so the value of E_{bn} increases. This implies energy would be released in the process. This process is called Nuclear Fission. This process takes place in a controlled manner in a nuclear reactor.
- *"Consider two very light nuclei (A ≤ 10) joining to form a heavier nucleus, the binding energy per nucleon increases. Energy is also released during this process. This process is called nuclear fusion"*. Energy is released from the sun due to the thermal nuclear fusion that takes place in the Sun.

27.

- The semiconductor's energy band structure is affected by doping. In the case of extrinsic semi-conductors, additional energy states due to donor impurities (E_D) and acceptor impurities (E_A) also exist.
- 

(a) T > 0 K



(b) T > 0 K

one thermally generated electron-hole pair +9 electrons from donor atoms

- In the energy band diagram of *n*-type S*i* semiconductor, the donor energy level E_D is slightly below the bottom E_C of conduction band and the electrons from this level move into the conduction band with very small supply of energy. At room temperature, most of the donor atoms get ionised but very few (~ 10^{-12}) atoms of S*i* get ionised. So the conduction band will have most electrons coming from the donor impurities as shown in fig. (a).

- Similarly for *p*-type semiconductor, the acceptor energy level E_A is slightly above the top of E_V the valence band as shown in fig (b).
- At room temperature, most of the acceptor atoms get ionised, which create holes in the valence band.
- Thus at room temperature, the density of holes in the valence band is pre-dominantly due to impurity in the extrinsic semiconductor. The electron and hole concentration in a semiconductor in thermal equilibrium is given by,

$$n_e \cdot n_h = n_i^2.$$