LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNMENT PAPER 9**

Section A

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

Section A

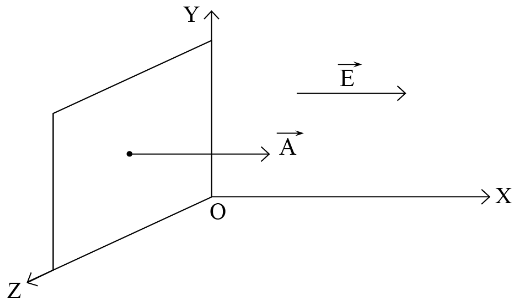
➢ **Write the answer of the following questions : (Each carries 2 Mark)**

1.

➥ $\vec{E} = 3 \cdot 10^3 \, \hat{i} \, \frac{N}{C}$

$l = 10$ cm $= 0.1$ m

$A = l^2 = 0.01 \, m^2$



➥ Flux associated with square,

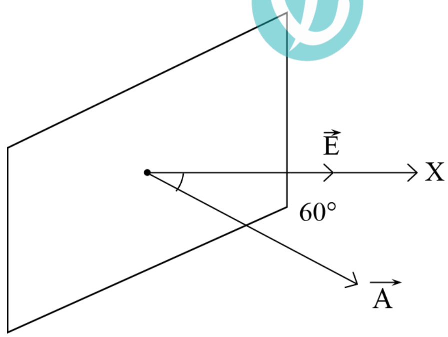
$\varphi = EA \cos \theta$

$\therefore \varphi = 3 \cdot 10^3 \cdot 0.01 \cdot \cos 0$

$\therefore \varphi = 30 \, \frac{Nm^2}{C}$

➥ $\vec{E} = 3 \cdot 10^3 \, \hat{i} \, \frac{N}{C}$

➥ Flux when angel θ between $\vec{E}$ and $\vec{A}$ is 60° :



➥ $\varphi = EA \cos \theta$

$\therefore \varphi = 3 \cdot 10^3 \cdot 0.01 \cdot \cos 60$

$\therefore \varphi = 30 \cdot \frac{1}{2}$

$\therefore \varphi = 15 \, \frac{Nm^2}{C}$

2. ➥

Electro Statics		Magnetism	
1	Permittivity of free space (vaccum) - ε_0	1	Permeability of free space (vacuum) - $\propto_0$
2	Constant $\frac{1}{4\pi\varepsilon_0}$	2	Constant $\frac{\mu_0}{4\pi}$
3	Electric Charge q	3	Pole Strength q_m
4	Electric dipole moment $p = 2aq$ Direction : $-q$ to $+q$	4	Magnetic dipole moment $m = 2l\,q_m$ Direction : S to N
5	Electric Field ($\vec{E}$)	5	Magnetic Field ($\vec{B}$)
6	Force acting between two stationary point charges $F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$	6	Magnetic force acting between two stationary magnetic poles, $F = \frac{\mu_0}{4\pi} \cdot \frac{q_{m_1} \cdot q_{m_2}}{r^2}$
7	Electric field on the axis of an electric dipole $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}$	7	Magnetic field on the axis of a magnetic dipole $B = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$
8	Electric field on the equatorial axis of electric dipole $E = \frac{-1}{4\pi\varepsilon_0} \cdot \frac{p}{r^3}$	8	Magnetic field on the equatorial axis of a magnetic dipole $B = \frac{-\mu_0}{4\pi} \cdot \frac{m}{r^3}$
9	Torque acting on an electric dipole in uniform electric field $\vec{\tau} = \vec{p} \times \vec{E}$	9	Torque acting on a magnetic dipole in uniform magnetic field $\vec{\tau} = \vec{m} \times \vec{B}$
10	Potential energy of an electric dipole in uniform electric field $U = -\vec{p} \cdot \vec{E}$ $= -pE \cos\theta$	10	Potential energy of a magnetic dipole in uniform magnetic field $U = -\vec{m} \cdot \vec{B}$ $= -mB \cos\theta$
11	Work required to be done in moving an electric dipole from angle θ_1 to θ_2 in uniform electric field, $W = pE(\cos\theta_1 - \cos\theta_2)$	11	Work required to be done in moving a magnetic dipole from angle θ_1 to θ_2 in uniform magnetic field, $W = mB(\cos\theta_1 - \cos\theta_2)$

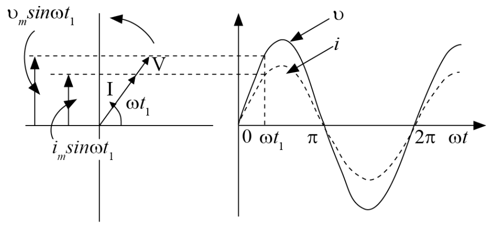
3.

➥ In an AC circuit in order to show the phase relationship between voltage and current the notion of phasor is used.

➥ A phasor is a vector, which is used to represent periodically changing quantities in the form of vectors.

➥ For example to draw a phasor representing voltage $V = \upsilon_m \sin \omega t$, draw a vector of magnitude equal to υ_m and in the direction making an angle ωt with the horizontal axis.

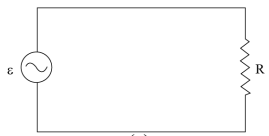
➥ As time increases, value of ωt goes on increasing and the phasor (vector) rotates in anticlockwise direction accordingly. And its instantaneous value also keeps changing.



(a) (b)

➥ The voltage and current phasor shown in the fig. rotates about the origin with angular speed ω.

➥ The vertical components of $\vec{V}$ and $\vec{I}$ represent the sinusoidally varying quantities υ and i. The magnitudes of phasors $\vec{V}$ and $\vec{I}$ represent the amplitudes (/peak values υ_m and i_m) of these oscillating quantities.



(c)

➥ Fig. (a) shows the voltage and current phasors and their relationship at time t_1 for the case of an AC source connected to a resistor. (fig. c)

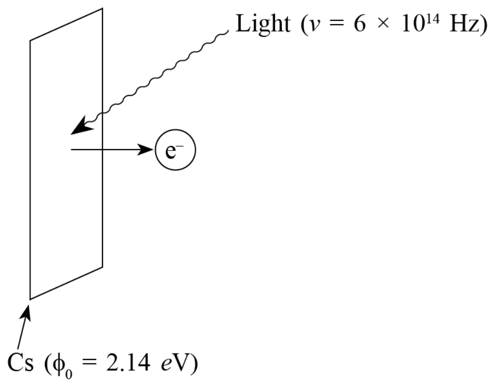
➥ The projection of voltage and current phasors on vertical axis, i.e. $\upsilon_m \sin \omega t_1$, and $i_m \sin \omega t_1$ respectively represent the value of voltage and current at that instant.

➥ As shown in fig. (a), phasors $\vec{V}$ and $\vec{I}$ for the case of a resistor are in the same direction. This means that phase angle(/phase difference) between the voltage and current is zero.

4.

➥ Work function $\varphi_0 = 2.14$ eV

frequency of radiation $v = 6 \times 10^{14}$ Hz



➥ (a) Maximum kinetic energy of the emitted electrons

$K_{max} = hv - \varphi_0$ (Einstein's equation)

$$K_{max} = \left(\frac{6.625 \times 10^{-34} \times 6 \times 10^{14}}{1.6 \times 10^{-19}}\right) eV - 2.14\ eV$$

$\therefore K_{max} = 2.484\ eV - 2.14\ eV$

$K_{max} = 0.344\ eV$

$K_{max} = 0.344 \times 1.6 \times 10^{-19}$ J

$K_{max} = 5.504 \times 10^{-20}$ J

➥ (b) Stopping potential

$K_{max} = eV_0$

➥ $0.344\ eV = eV_0$

$V_0 = 0.344$ V

➥ (c) Maximum speed of the emitted electrons

$$K_{max} = \frac{1}{2} mv^2_{max}$$

$$\therefore v^2_{max} = \frac{2K_{max}}{m}$$

$$\therefore v^2_{max} = \frac{2 \times 0.5504 \times 10^{-19}}{9.1 \times 10^{-31}}$$

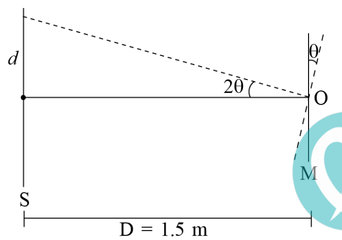
$v^2_{max} = 0.121 \times 10^{12}$

$v_{max} = 0.347 \times 10^{6}$ m/s

$v_{max} = 347$ km/s

5.

➥



➥ When mirror is rotated by θ = 3.5°, then reflected ray will be rotated by 2θ.

➥ from figure, $\tan 2\theta = \frac{d}{D}$

$\therefore d = D \times \tan 2\theta$

$\therefore d = 1.5 \times \tan (2 \times 3.5)$

$\therefore d = 1.5 \times \tan 7°$

$\therefore d = 1.5 \times 0.1228$

$\therefore d = 0.1842$ m

$\therefore d = 18.42$ cm

6.

➥ Consider a plane wave AB incident at an angle *i* on a reflecting surface MN.

➥ If υ is the speed of wave in the given medium, τ represents the time taken by the wavefront to advance from point B to C, then the distance BC = υτ.

➥ In order to construct the reflected wavefront we draw a sphere of radius υτ from the point A as shown in fig.

➥ Let CE represent the tangent plane drawn from the point C to this sphere.

➥ Obviously,

$AE = BC = \upsilon\tau$

➥ From fig., incident and reflected wave fronts make angle *i* and *r* with reflecting surface, MN respectively.

➥ From fig.,

AC is the common side between ΔAEC and ΔABC.

Also, $\angle AEC = \angle ABC = \frac{\pi}{2}$

and $AE = BC = \upsilon\tau$

➥ So ΔAEC and ΔABC are congruent.

➥ And therfore, $\angle i = \angle r$,

which is law of reflection.

7.

➥ When two light nuclei fuse to form a larger nucleus, energy is released, because binding energy increases during the process.

➥ Some examples of such energy liberating nuclear fusion reactions are :

$${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + e^+ + \nu + 0.42\ MeV$$

$${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + n + 3.27\ MeV$$

$${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + {}_1H^1 + 4.03\ MeV$$

➥ In the first reaction, two protons combine to form a deuteron and a positron with a release of 0.42 MeV energy.

➥ In the second reaction, two deuterons combine to form the isotope of helium ${}_2He^3$.

➥ In third reaction two deuterons combine to form a tritium and a proton. 4.03 MeV energy is released during this process.

➥ For a fusion to take place, the two nuclei must come close enough so that nuclear force is able to affect them.

➥ This force must be strong enough to overcome the repulsive barrier between two positively charged nuclei.

➥ The height of the barrier depends on the charges and radii of the two interacting nuclei.

➥ For example :

The barrier height for two protons is ~ 400 *keV*.

The temperature required for a proton to overcome this barrier is T.

$$\therefore \frac{3}{2} kT = 400\ keV$$

$$T = \frac{2 \times 400 \times 10^3 \times 1.6 \times 10^{-19}}{3 \times 1.38 \times 10^{-23}}$$

$$T = 3 \cdot 10^9\ K$$

➥ When fusion is achieved by raising the temperature of the system so that particles have enough kinetic energy to overcome the Coulomb repulsive barrier, it is called thermo - nuclear fusion.

8.

➥ $R = 10$ cm

$r = 20$ cm

$E = -1.5 \cdot 10^3$ N/C

➥ Suppose, the electric charge on the sphere is q.

From,

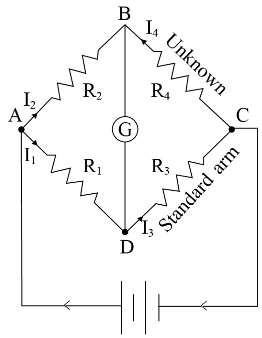
$$E = \frac{kq}{r^2}$$

$$\therefore q = \frac{Er^2}{k}$$

$$\therefore q = \frac{(-1.5 \times 10^3)(0.2)^2}{9 \times 10^9}$$

$$\therefore q = -6.67\ nC$$

9.

➥ 

➥ 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

$$-I_1R_1 + 0 + I_2R_2 = 0$$

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

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

$$I_4R_4 + 0 - I_3R_3 = 0$$

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

➥ 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 $I_2 = I_4$

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

➥ 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

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

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

10.

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

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

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

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

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

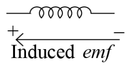
➥ Total work done to establish current I

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

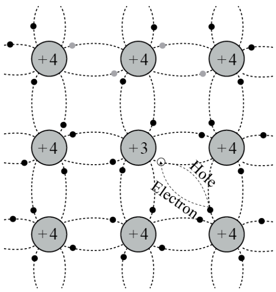
$$\therefore W = \frac{1}{2} L I^2 \ldots (2)$$

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

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

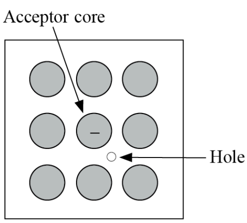
➥ Note : The coil possessing self inductance is called Inductor (L) It's symbol is : 

11.

➥ 

(a)

➥ As shown in Fig., to prepare this type of semiconductors, in pure Si or Ge, trivalent impurity like Al, B, In 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 Si and Ge atoms, and therefore, this atom can form covalent bonds with neighbouring three Si atoms but does not have any electron to offer to the fourth Si 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 Si 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.

$$n_h >> n_e.$$

12.

- From Bohr's second postulate, the formula for the radius of n^{th} orbit for hydrogen atom is.

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

- The total energy of the electron in the stationary states of the hydrogen atom is

$$E_n = -\frac{1}{8\pi\varepsilon_0} \frac{e^2}{r_n} \quad ... (2)$$

- Using equation (1) and equation (2)

$$E_n = -\frac{1}{8\pi\varepsilon_0} \frac{e^2}{\left(\frac{n^2 h^2 \varepsilon_0}{\pi m e^2}\right)}$$

$$\therefore E_n = -\frac{m e^4}{8 \varepsilon_0^2 n^2 h^2}$$

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

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$h = 6.625 \times 10^{-34} \text{ Js}$$

- Simplifying equation,

$$E_n = -\frac{2.18 \times 10^{-18}}{n^2} \text{ J}$$

- Atomic energies are often expressed in electron volts (*e*V).

$$\therefore E_n = -\frac{2.18 \times 10^{-18}}{n^2 \times 1.6 \times 10^{-19}} \text{ eV}$$

$$\therefore E_n = -\frac{13.6}{n^2} \text{ eV}$$

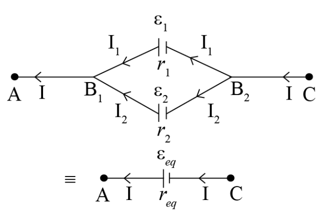
- The negative sign of the total energy of an electron moving in an orbit means that the electron is bound with the nucleus.
- Thus, energy will be required to remove the electron from the hydrogen atom to a distance infinitely far away from its nucleus.

Section B

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

13.

- If the positive (or negative) terminal of two cells are connected to one point and their negative (or positive) terminal to another point, such connection of cells is called the parallel connection.



- The figure shows a parallel combination of two cells, the *emf* of cells are ε_1 and ε_2 respectively and the internal resistances are r_1 and r_2 respectively.
- The currents leaving the positive terminals of the cells are I_1 and I_2 respectively. These currents meet near point B_1 so the total current at point B_1 is $I = I_1 + I_2$
- Let $V(B_1)$ and $V(B_2)$ be the potentials at B_1 and B_2. The potential diference across terminals of the first cell is

$$V = V(B_1) - V(B_2) = \varepsilon_1 - I_1 r_1$$

$$\therefore I_1 r_1 = \varepsilon_1 - V$$

$$\therefore I_1 = \frac{\varepsilon_1 - V}{r_1} \quad ... (1)$$

- The potential difference across terminals of the second cell is

$$V = V(B_1) - V(B_2) = \varepsilon_2 - I_2 r_2$$

$$\therefore I_2 r_2 = \varepsilon_2 - V$$

$$\therefore I_2 = \frac{\varepsilon_2 - V}{r_2} \quad ... (2)$$

- But the total current is $I = I_1 + I_2$
- Putting the values from equation (1) and (2) in above equation :

$$\therefore I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2}$$

$$\therefore I = \frac{\varepsilon_1}{r_1} - \frac{V}{r_1} + \frac{\varepsilon_2}{r_2} - \frac{V}{r_2}$$

$$\therefore I = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$\therefore V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} - I$$

$$\therefore V\left(\frac{r_1 + r_2}{r_1 r_2}\right) = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1 - I\, r_1 r_2}{r_1 r_2}$$

$$\therefore V(r_1 + r_2) = \varepsilon_1 r_2 + \varepsilon_2 r_1 - I\, r_1 r_2$$

$$\therefore V = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \quad ... (3)$$

- Let the equivalent *emf* ε_{eq} and equivalent internal resistance r_{eq} for this combination.

$$\therefore V = \varepsilon_{eq} - I r_{eq} \quad ... (4)$$

by comparing equation (3) and (4)

$$\therefore \varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} \quad \text{and } r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}}{\frac{r_1 r_2}{r_1 + r_2}} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 r_2} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}$$

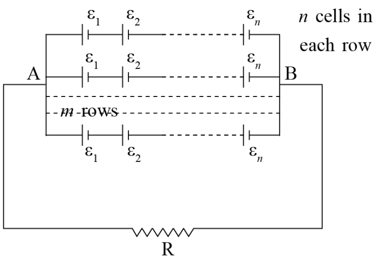
- If there are n cells of *emf* $\varepsilon_1, \varepsilon_2, \varepsilon_3$ ..... ε_n and internal resistances r_1, r_2, r_3 ..... r_n respectively are connected in parallel, the combination is equivalent to a single cell of *emf* ε_{eq} and internal resistance r_{eq}.

$$\therefore \frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + ... + \frac{1}{r_n}$$

$$\therefore \frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \frac{\varepsilon_3}{r_3} + ... + \frac{\varepsilon_n}{r_n}$$

Remember

Mixed Combination



Mixed combination of cells is shown in the figure. If n cells of *emf* $\varepsilon_1, \varepsilon_2, \varepsilon_3 \ldots \varepsilon_n$ and internal resistances $r_1, r_1, r_3 \ldots r_n$ are connected in series to make a row and m such rows are connected in parallel, then it is called mixed connection of cells. The current in mixed connection,

$$I = \frac{\sum_{i=1}^{n} \varepsilon_i}{R + \frac{1}{m}\sum_{i=1}^{n} r_i}$$

where, R - external resistance connected in circuit

m - number of rows

n - number of cells in a row

If *emfs* and internal resistances of all the cells are equal then

$$\therefore \quad I = \frac{n\varepsilon}{R + \frac{nr}{m}} = \frac{nm\varepsilon}{mR + nr}$$

14.

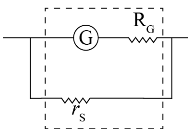
(a) $R_G = 60\ \Omega$ $R = 3\ \Omega$, $E = 3V$, $r_S = 0.02\ \Omega$

The current in the circuit $I = \frac{E}{R + R_G}$

$= \frac{3}{3+60} = \frac{3}{63}$

$I = 0.048$ A

(b) When the galvanometer is shunted with resistance r_S, the effective resistance



$R_P = \frac{R_G \cdot r_S}{R_G + r_S}$

$R_P = \frac{60 \times 0.02}{60 + 0.02}$

In denominator 0.02 is neglected compared to 60.

$R_P = 0.0199 \approx 0.02\ \Omega$

Current in the circuit

$I = \frac{E}{R + R_P}$

$= \frac{3}{3 + 0.02}$

$= \frac{3}{3.02}$

$\therefore I = 0.99$ A

(c) For the ideal ammeter with zero resistance,

current in the circuit

$I = \frac{E}{R + 0}$

$= \frac{3}{3}$

$= 1$ A

15.

➥ (a) Magnetic energy stored in solenoid

$U_B = \frac{1}{2} LI^2$

$= \frac{1}{2} L \left(\frac{B}{\mu_0 n}\right)^2$

($\because$ for solenoid, $B = \propto_0 nI \Rightarrow I = \frac{B}{\mu_0 n}$)

$= \frac{1}{2} (\propto_0 n^2 Al) \left(\frac{B}{\mu_0 n}\right)^2$

($\because$ Self inductance of solenoid $L = \propto_0 n^2 Al$)

$= \frac{1}{2} \propto_0 n^2 Al \times \frac{B^2}{\mu_0^2 n^2}$

$U_B = \frac{1}{2\mu_0} (B^2 Al)$... (1)

(b) Magnetic energy per unit volume

$\rho_B = \frac{U_B}{V}$ ($\because$ V = Volume)

$= \frac{U_B}{Al}$ ($\because$ Volume $V = Al$)

$= \frac{1}{2\mu_0} \frac{B^2 Al}{Al}$ (from eq. 1)

$\rho_B = \frac{B^2}{2\mu_0}$ ... (2)

➠ Electrostatic energy stored per unit volume in parallel plate capacitor.

$\rho_E = \frac{1}{2} \varepsilon_0 E^2$... (3)

➠ From equation (2) & (3), energy is directly proportional to square of field intensity in both cases.

16.

➥ As shown in the fig., two polaroids P_1 and P_3 are arranged such that their pass axis are perpendicular to each other.

➥ Polaroid P_2 is rotated between two crossed polaroids.

➥ Suppose, during some position of P_2, the angle between the pass axis of P_1 and P_2 is θ, since P_1 and P_3 are crossed, the angle between the pass axis of P_2 and P_3 will be $\frac{\pi}{2} - \theta$.

➥ Let I_0 be the intensity of polarised light after passing through the first polariser P_1 ($I_1 = I_0$).

➥ Then the intensity of light after passing through second polariser P_2 will be

$I_2 = I_0 \cos^2 \theta$ (from Malus law) ... (1)

➥ This light is incident on polariser P_3 at an angle $\frac{\pi}{2} - \theta$. Hence the intensity of light energing from P_3 will be :

$I_3 = I_2 \cos^2 \left(\frac{\pi}{2} - \theta\right)$

➥ Substituting the value from equation (1),

$I_3 = I_0 \cos^2\theta \cos^2 \left(\frac{\pi}{2} - \theta\right)$

$I_3 = I_0 \cos^2\theta \sin^2 \theta$

$I_3 = \frac{I_0}{4} (4 \sin^2\theta \cos^2\theta)$

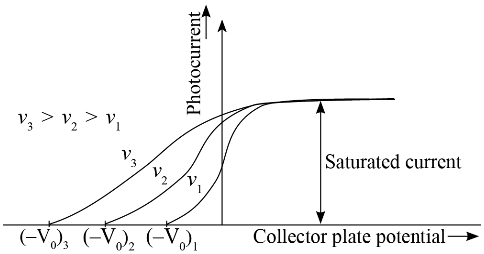
$\therefore I_3 = \frac{I_0}{4} (\sin^2 2\theta)$

➥ When $\theta = 0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}$ or 2π, $I_3 = 0$ (Minimum intensity)

➥ When $\theta = \frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4}$, $I_3 = \frac{I_0}{4}$ (Maximum intensity)

17.

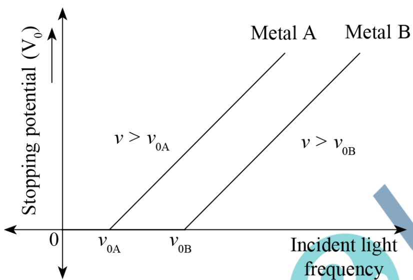
➥ The change in photocurrent with the collector plate potential (A) can be understood for various frequencies (v_1, v_2 and v_3 where $v_3 > v_2 > v_1$) keeping the constant intensity of incident light on the photosensitive plate C.



➥ As it is clear from the graph the value of maximum saturation current remains the same (constant) for the different frequencies, i.e. the maximum saturation current does not depend on the frequency of light.

➥ The value of the stopping potential varies with frequency. As the frequency is increased a higher stopping potential has to be applied to stop the electrons with maximum kinetic energy. Thus, the maximum kinetic energy of the emitted photoelectron depends on the frequency of the incident light.

➥



➥ Here is a graph of frequency versus stopping potential for two different metals A and B.

➥ It is clear from the graph, the value of the stopping potential varies linearly with the frequency of incident light.

➥ For a given metal a certain minimum cut-off frequency v_0 exists for which the stopping potential is zero, i.e. no electrons are emitted. This frequency is called the threshold frequency for a given metal.

➥ The value of the threshold frequency depends on the type of metal.

➥ Two points are clear from these observations.

➥ (i) The maximum kinetic energy of a photoelectron depends on the frequency of the incident radiation, but not on the intensity of the light.

➥ (ii) If the frequency of the incident light is less than the cut-off frequency (v_0) (Threshold frequency) of a given metal, electrons are not emitted no matter how intense the incident light is.

18.

➥ $n = 4$

$\lambda = ?$

$v = ?$

➥ Total energy of electron

$$E_n = -\frac{13.6}{n^2}\ eV \quad ... (1)$$

➥ For ground state, $n = 1$

$$E = -\frac{13.6}{1^2}\ eV$$

$= -13.6\ eV$

➥ Using $n = 4$ in equation (1)

$$E_4 = -\frac{-13.6}{(4)^2}\ eV$$

$$= \frac{-13.6}{16}\ eV$$

$$E_4 = -0.85\ eV$$

➥ Energy of incident photon

$$E_4 - E_1 = -0.85 - (-13.6)$$

$$E_4 - E_1 = 12.75\ eV$$

But, $E_i - E_f = hv$

$$hv = 12.75\ eV$$

$$\therefore v = \frac{12.75 \times 1.6 \times 10^{-19}}{6.625 \times 10^{-34}}$$

$$\therefore v = 3.08 \times 10^{15}\ Hz$$

➥ Wavelength of incident radiation

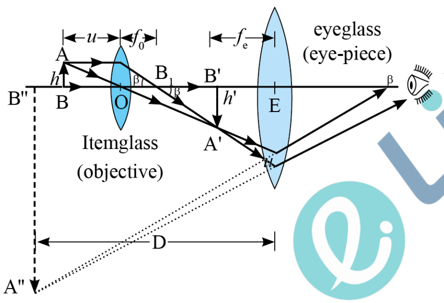
$$\lambda = \frac{c}{v} = \frac{3 \times 10^{8}}{3.08 \times 10^{15}}$$

$$\therefore \lambda = 0.974 \times 10^{-7}\ m$$

$$\therefore \lambda = 97.4\ nm$$

19.

➥



➥ D = 25 cm

$f_0 = 8\ mm = 0.8\ cm$

$f_e = 2.5\ cm$

➥ object distance for objective,

$u_0 = -9\ mm = -0.9\ cm$

➥ Applying lens formula for objective,

$$\frac{1}{\upsilon_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\therefore \frac{1}{\upsilon_0} = \frac{1}{f_0} + \frac{1}{u_0}$$

$$\therefore \frac{1}{\upsilon_0} = \frac{1}{0.8} - \frac{1}{0.9}$$

$$\therefore \frac{1}{\upsilon_0} = \frac{0.9 - 0.8}{0.72}$$

$$\therefore \frac{1}{\upsilon_0} = \frac{0.1}{0.72}$$

$\therefore \upsilon_0 = \frac{0.72}{0.1} = 7.2$ cm

➥ For eye-piece,

$f_e = 2.5$ cm $\upsilon_e = D = -25$ cm

➥ From lens formula,

$$\frac{1}{\upsilon_e} - \frac{1}{u_e} = \frac{1}{f_e}$$

$$\therefore \frac{1}{\upsilon_e} - \frac{1}{f_e} = \frac{1}{u_e}$$

$$\therefore \frac{1}{u_e} = \frac{-1}{25} - \frac{1}{2.5}$$

$$\therefore \frac{1}{u_e} = \frac{-1-10}{25}$$

$$\therefore u_e = -\frac{25}{11} = -2.27 \text{ cm}$$

➥ Distance between two lenses (from figure)

$= \upsilon_0 + |u_e|$

$= 7.2 + 2.27$

$= 9.47$ cm

➥ Magnification of a compound microscope,

$m = m_0 \times m_e$

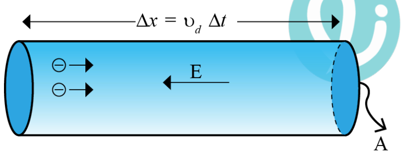
$$= \frac{\upsilon_0}{|u_0|} \times \left(1 + \frac{D}{f_e}\right)$$

$$\therefore m = \frac{7.2}{0.9} \times \left(1 + \frac{25}{2.5}\right)$$

$\therefore m = 8(1 + 10)$

$\therefore m = 88$

20.

➥ 

➥ A conductor of cross- sectional area $\vec{A}$ is shown in the figure. The electric field inside the conductor is $\vec{E}$.

➥ Due to this electric field, there will be net flow of charges across any area of the conductor.

➥ Because of the drift, distance travelled by electron in time Δt is $|\vec{\upsilon}_d| \Delta t$.

➥ Suppose the number of free electrons per unit volume in metal is n, then the number of electrons passing through the area A is N $= nA|\vec{\upsilon}_d|\Delta t$.

➥ The total charge flowing through the cross - sectional area in time Δt is $-neA|\vec{\upsilon}_d|\Delta t$ ... (1)

➥ Here, electric field $\vec{E}$ is directed towards the left as a result the total electric charge passing through the surface in the direction of $\vec{E}$, will be equal to the negative value of above equation (1).

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

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

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

➥ Hence,

$\therefore I\,\Delta t = neA\left|\vec{\upsilon_d}\right|\,\Delta t$

$\therefore I = neA\left|\vec{\upsilon_d}\right|$ ... (3)

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

$I = jA$

$\therefore jA = neA\left|\vec{\upsilon_d}\right|$ ($\because$ from eq^n (3))

$\therefore j = ne\left|\vec{\upsilon_d}\right|$ ... (4)

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

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

➥ Writing above equation (5) in vector form

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

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

we get

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

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

➥ Resistivity of conductor is reciprocal of conductivity

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

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

21.

➥ $V_m = 283$ V

$R = 3\ \Omega$

$C = 796\ \mu F$

$v = 50$ Hz

$L = 25.48$ mH

➥ (a) Impedence of the circuit (Z),

➠ Inductive reactance (X_L)

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

$\therefore X_L = 2 \times 3.14 \times 50 \times 25.48 \times 10^{-3}$

$\therefore X_L = 8000.72 \times 10^{-3}$

$\therefore X_L = 8\ \Omega$

➠ Capacitive reactance (X_C)

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi v C}$

$\therefore X_C = \frac{1}{2\times 3.14\times 50\times 796\times 10^{-6}}$

$\therefore X_C = \frac{1000000}{249944}$

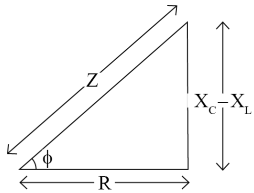
$\therefore X_C = 4\ \Omega$

➠ $Z = \sqrt{R^2 + (X_C - X_L)^2}$

$\therefore Z = \sqrt{3^2 + (4-8)^2}$

$\therefore Z = 5\ \Omega$

(b) Phase difference (φ)



(impedance diagram)

$tan\ \varphi = \frac{X_C - X_L}{R}$

$tan\ \varphi = \frac{4-8}{3}$

$tan\ \varphi = -\frac{4}{3}$

$tan\ \varphi = -1.3333$

$\varphi = -53.1°$

$(\because tan(-\theta) = -tan\theta)$

Note : Here φ is negative. So the current in the circuit is lagging behind the voltage between two terminals of the source.

(c) Power dissipated in the circuit :

$P = I^2 R$

But $I = \frac{I_m}{\sqrt{2}}$

$\therefore I = \frac{V_m}{Z\sqrt{2}}$

$\therefore P = \frac{V_m^2}{Z^2(2)} \cdot R$

$\therefore P = \frac{(283)^2 \times 3}{25 \times 2}$

$\therefore P = 4800\ W$

(d) Power factor,

$cos\ \varphi = cos\ (-53.1°)\ (\because cos(-\theta) = cos\theta)$

$= cos\ 53.1°$

$= 0.6$

Section C

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

22.

➥ (a) Given (actually it should be spherical shell) sphere is a conductor, so the electric charge is established only on the surface of the conductor. Hence the net charge inside the spherical conductor, will be zero hence the electric field inside shell will be zero.

➥ (b) on the surface of the sphere :

(/ Just outside the sphere)

$q = 1.6 \times 10^{-7}$ C

$R = 12 \times 10^{-2}$ m

Electric field $E = \frac{kq}{R^2}$

$$E = \frac{9 \times 10^9 \times 1.6 \times 10^{-7}}{(12 \times 10^{-2})^2}$$

$$\therefore E = \frac{14.4 \times 10^2}{144 \times 10^{-4}}$$

$$\therefore E = 1 \times 10^5 \frac{N}{C}$$

➥ (c) At a point 18 cm from the centre of the sphere : (E at distance $r > R$)

$$\therefore E = \frac{kq}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-7}}{(18 \times 10^{-2})^2}$$

$$\therefore E = 4.4 \times 10^4 \frac{N}{C}$$

23.

➥ $V = 230$ V

$L = 5$ H

$C = 80\ \mu F$

$R = 40\ \Omega$

➥ (a) Source angular frequency (ω_0) which drives the circuit in resonance :

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

$$\therefore \omega_0 = \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}}$$

$$\therefore \omega_0 = \frac{1}{20 \times 10^{-3}}$$

$$\therefore \omega_0 = \frac{1000}{20}$$

$$= 50 \frac{rad}{s}$$

(b) At the time of resonance in the circuit,

$X_C - X_L = 0$

So, impedence $Z = R$

$\therefore Z = 40\ \Omega$

➠ Amplitude of current means peak (max.) value of current (i_m)

$$i_m = \sqrt{2}\ I$$

$$= \sqrt{2} \frac{V}{Z}$$

$$\therefore i_m = \frac{1.414 \times 230}{40}$$

$$\therefore i_m = 8.13 \text{ A}$$

(c) (i) Potential difference between two terminals of a resistor,

$$V_R = I R$$

$$= \frac{V}{Z} \times R$$

$$V_R = \frac{230}{40} \times 40$$

$$= 230 \text{ V}$$

(ii) Potential difference between two terminals of an inductor,

$$V_L = I X_L$$