

SOLUTIONS

SELF ASSESSMENT PAPER-1

Time : 1 Hours]

[Maximum Marks : 25

SECTION - A

1. (i) The approximate shape of the equipotential surface at a great distance from a collection of charges is a sphere.. 1
- (ii) As the electric field lines are parallel to the surface of the square, so there will not be any field lines crossing the surface. Hence, the electric flux through the surface will be zero. 1

Commonly Made Error

- Most of the candidates are unable to Gauss's law correctly. They cannot use the expression to know the value of angle for the formula.

Answering Tip

- The given figure should be carefully observed to know that the electric field lines are parallel to the surface and no lines will cross the surface.

- (iii) The electric potential at any point due to a charge Q is given by,

$$V = \frac{W}{Q} = \frac{2J}{20C} = 0.1V \quad 1$$

- (iv) Electric field = $E = -\frac{dV}{dx}$

When V is constant, then $\frac{dV}{dx} = 0$

$\therefore$ Electric field = $E = 0$.

2. (i) (a) Both A and R are true and R is the correct explanation of A 1

Detailed Answer :

$$\vec{E} = -\vec{\nabla} V$$

So, The electric field is always perpendicular to equipotential surface.

Negative gradient of electric potential is electric field. So, direction of electric field must have in the direction of the decreasing order of electric potential.

- (ii) (a) Both A and R are true and R is the correct explanation of A 1

Detailed Answer :

When an electric dipole placed in a uniform electric field at an angle θ with the field, The dipole experiences a torque.

The torque produced by two parallel forces qE acting as couple = τ

$$\tau = qE2l \sin\theta$$

In case of non-uniform field, force acting on both the ends of the dipole will not be equal. So, there will be a combination of couple and a net force. In this way, dipole will have both rotational as well as linear motion.

So, both assertion and reason are true. Reason also explains the assertion.

3. (i) Correct option: (c)

Explanation : Super capacitor is a high capacity capacitor with a capacitance value much higher than normal capacitors but with lower voltage limits. 1

- (ii) Correct option: (a)

Explanation : Such capacitors bridges the gap between electrolytic capacitors and rechargeable batteries. 1

- (iii) Correct option: (d)

Explanation: Super capacitors can be charged and discharged innumerable number of times without ever wearing out. 1

- (iv) Correct option: (a)

Explanation: The disadvantage is that super capacitors aren't well-suited for long-term energy storage. The discharge rate of super capacitors is significantly higher than lithium-ion batteries; they can lose as much as 10-20 percent of their charge per day due to self-discharge. 1

- (v) Correct option: (b)

Explanation: In auto mobile, bus, train, crane, elevator such capacitors are used for regenerative braking, short term energy storage or burst-mode power delivery. 1

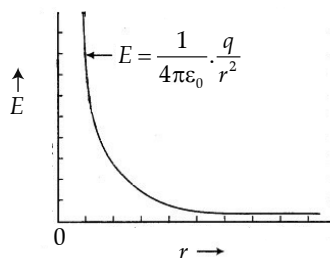
SECTION - B

4. Due to point charge :

Electric field, $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r^2}$

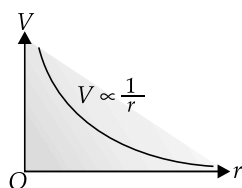
$$E \propto \frac{1}{r^2} \quad \frac{1}{2}$$

$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$



Electric potential, $V = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r}$

$$V \propto \frac{1}{r} \quad \frac{1}{2}$$



5.

(i) $\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$ along OA 1

(ii) $\frac{1}{4\pi\epsilon_0} \cdot \frac{2q}{r^2}$ along OA 1

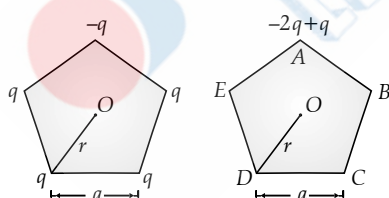
[CBSE Marking Scheme, 2017]

Detailed Answer :

- (i) If a charge q is removed from point A, a negative charge is developed at A where electric field will be

$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \text{ which is along OA.}$$

- (ii) If a charge q is replaced by charge $-q$ at point A, this generates a net electric field at point O as a result of $-2q$ change, so



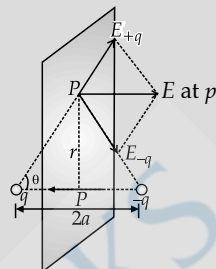
$$\vec{E}_{-q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \text{ along OA.}$$

Hence net electric field at the centre

$$\begin{aligned} \vec{E}_{\text{net}} &= \vec{E}_{-q} + \vec{E}_{\text{four changes}} \\ &= \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} + \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \\ \vec{E}_{\text{net}} &= \frac{1}{4\pi\epsilon_0} \cdot \frac{2q}{r^2} \text{ along OA.} \end{aligned}$$

SECTION - C

6. Derivation of expression of electric field on equatorial line of electric dipole 2
Depiction of orientation for stable and unstable equilibrium in electric field $\frac{1}{2} + \frac{1}{2}$



- (i) Let the point 'P' be at a distance ' r ' from the mid point of the dipole.

$$|E_{+q}| = \frac{q}{4\pi\epsilon_0(r^2 + a^2)} \quad \frac{1}{2}$$

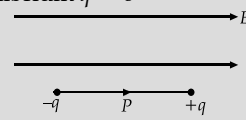
$$|E_{-q}| = \frac{q}{4\pi\epsilon_0(r^2 + a^2)} \quad \frac{1}{2}$$

Both are equal and their directions are as shown in the figure, hence net electric field

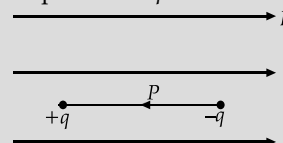
$$\vec{E} = [-(E_{+q} + E_{-q})\cos\theta] \hat{p} \quad \frac{1}{2}$$

$$p = -\frac{2qa}{4\pi\epsilon_0(r^2 + a^2)^{3/2}} \hat{p} \quad \frac{1}{2}$$

- (ii) Stable equilibrium $q = 0^\circ$ $\frac{1}{2}$



- Unstable equilibrium $q = 180^\circ$ $\frac{1}{2}$



[CBSE Marking Scheme, 2017]

7. When a battery remains connected,

- (i) potential difference V remains constant $\frac{1}{2}$
(ii) capacity C increases $\frac{1}{2}$
(iii) electric field will remain same $\frac{1}{2}$
(iv) energy stored $\frac{1}{2} CV^2$ increases as C increases

[CBSE Marking Scheme 2017] $\frac{1}{2}$ **Detailed Answer :**

When a battery remains connected to a parallel plate capacitor and if a dielectric slab is inserted between the plates of capacitor, then

- (i) there will be no change in the potential difference as the capacitor remained connected with the battery. $\frac{1}{2}$

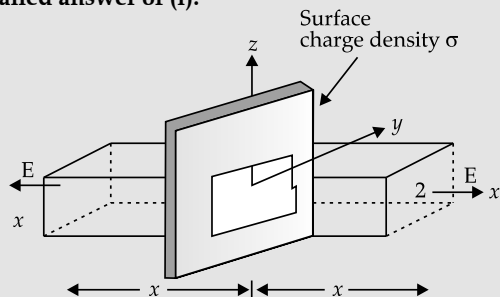
- (iii) Electric field will remain same as there will be no change in potential difference and distance between the plates. $\frac{1}{2}$
- (iv) Energy stored will be increased since from the expression $U = \frac{1}{2} CV^2$, potential difference V remains same while C increases which finally increases the energy of capacitor. $\frac{1}{2}$

SECTION - D

8.

Please write the following:

Detailed answer of (i):



In the figure, if σ is uniform surface charge density of an infinite plane sheet with x -axis to be normal to the plane then, by symmetry, electric field will not depend on y and z co-ordinate and their directions. Considering Gaussian rectangular parallelepiped surface with crosssectional area A , two faces 1 and 2 will contribute to flux.

It is analysed that the unit vector which is normal to first surface will be in negative x direction. Unit

vector normal to second surface will be in positive x direction. So, flux $E \cdot \Delta S$ by the surfaces will result equal and will add up.

Net flux through Gaussian surface = $2EA$

Charge enclosed by closed surface = σA

As per Gauss's law

$$\oint \vec{E} \cdot d\vec{s} = \frac{q}{\epsilon_0}$$

$$\text{or, } 2EA = \frac{\sigma A}{\epsilon_0}$$

$$\therefore E = \frac{\sigma}{2\epsilon_0}$$

This shows that the electric field around a infinite plane of charge does not vary with the distance from the plane.

In terms of vector,

$$\vec{E} = \frac{\sigma}{2\epsilon_0} \hat{n}$$

(ii) Amount of work done :

$$W = q \int_{\infty}^r \vec{E} \cdot d\vec{r} \quad \frac{1}{2}$$

$$W = q \int_{\infty}^r (-E \cdot dr) \quad \frac{1}{2}$$

$$W = -q \int_{\infty}^r \left(\frac{\sigma}{2\epsilon_0} \right) dr \quad \frac{1}{2}$$

$$W = \frac{q\sigma}{2\epsilon_0} | \infty - r | = \infty \quad \frac{1}{2}$$

[CBSE Marking Scheme, 2017]

SOLUTIONS

SELF ASSESSMENT PAPER-2

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) No. Since the charge resides only on the surface of a conductor.
- (ii) To work as voltmeter, the resistance of galvanometer should be high. A voltmeter indeed is a modified form of a pivoted coil galvanometer. Since, the resistance of coil of galvanometer of its own is low, hence to convert a galvanometer into a voltmeter, its resistance is to be increased. For this an appropriate high resistance is joined in series with the galvanometer. 1
- (iii) The meter bridge is more sensitive when all the resistances are same order, or their ratio is unity. 1

(iv) $v_d = \frac{-eV}{ml} \tau$ 1

[CBSE Marking Scheme, 2014]

Detailed Answer :

Since drift velocity, $v_d = \frac{-eE}{m} \tau$... (i)

But, $E = \frac{V}{l}$... (ii)

Now, from equation (i) and (ii),

Drift velocity, $v_d = \frac{-eV}{ml} \tau$ 1

2. (i) Correct option : (a)

Explanation: Power of 200 W lamp is more than the power of 100 W lamp.

Heat generated = $H = P \times t$

So, heat generated is more is 200 W lamp. So, it will glow more brightly.

So, assertion is true.

Resistance is inversely proportional to power. So, resistance of 100 W lamp will be more than the resistance of 200 W lamp. So, the reason is also true $H = P \times t = (V^2/R)t$

As R increases, less heat is produced and brightness become less.

So, reason properly explains the assertion.

(ii) **Correct option : (d)**

Explanation: Power rating describes the heat dissipation capability of the resistor. If the heat generated is more than the power rating of the resistor it will burn. So assertion is false.

Resistance value is temperature dependant. So, the reason is true, But reason does not explain the assertion. 1

3. (i) (c) Copper

Detailed Answer :

A Faraday cage or Faraday shield is an enclosure made of a conducting material.

Since copper is the only metal given in the list of options, copper is the correct answer.

(ii) (a) car

Detailed Answer :

Cars are examples of Faraday Cages in the real world. Cars can help keep ourselves safe from lightning. Its metal body acts as a Faraday Cage.

(iii) (c) zero

Detailed Answer :

The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero.

(iv) (c) – q

Detailed Answer :

If a charge is placed inside an ungrounded Faraday shield without touching the walls of the internal face of the shield becomes charged with – q, and +q accumulates on the outer face of the shield. If the cage is grounded, the excess charges will be neutralized by the ground connection.

(v) (c) $2.0 \times 10^5 \text{ Nm}^2/\text{C}$ leaving the surface

(any 4 parts to be attempted)

Detailed Answer :

The number of electric field lines passing through the cube normally and leaving the surface = Q/ϵ_0

$$Q = 2\mu\text{C} = 2 \times 10^{-6}\text{C}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

$$\therefore Q/\epsilon_0 = 2.2 \times 10^5 \text{ C}^2/\text{Nm}^2$$

SECTION - B

4. Power of bulb 1 = P_1

$$\text{Voltage rating} = V$$

$$\text{Resistance} = \frac{V^2}{P_1} = R_1 \left(\because P_1 = \frac{V^2}{R} \right)$$

Power of bulb 2 P_2

$$\text{Voltage rating} = V$$

$$\text{Resistance} = \frac{V^2}{P_2} = R_2$$

(i) When connected in series,

$$\text{Total Resistance, } R_s = R_1 + R_2 = V^2 \left[\frac{P_1 + P_2}{P_1 P_2} \right]$$

$$\text{Total current flowing through the circuit} = \frac{V}{R_s}$$

($\because$ they are connected to a supply of voltage V)

$$I_T = \frac{V}{V \left[\frac{P_1 + P_2}{P_1 P_2} \right]} = \frac{1}{V} \frac{P_1 P_2}{P_1 + P_2}$$

$$\text{Total power drawn} = VI_T = V$$

$$\frac{1}{V} \left[\frac{P_1 P_2}{P_1 + P_2} \right] = \frac{P_1 P_2}{P_1 + P_2}$$

(ii) Now, when both the bulbs are connected in parallel to the voltage supply V

$$\text{Power drawn by bulb I} = \frac{V^2}{R_1}$$

($\because$ in parallel voltage drop across all components is same)

$$= \frac{V^2}{V^2/P_1} P_1 = P_1 \quad \dots(i)$$

$$\text{Power drawn by bulb 2} = \frac{V^2}{R_2} = \frac{V^2}{V^2/P_2} = P_2 \quad \dots(ii)$$

Total power drawn from the source = $P_1 + P_2$ (from (i) & (ii))

5. Kirchhoff's first law is known as junction rule which states that for a given junction or node in a circuit, sum of the currents entering will be equal to sum of currents leaving. $\frac{1}{2}$

Kirchhoff's second law is also known as loop rule which shows that around any closed loop in a circuit, sum of the potential differences across all elements will be zero. $\frac{1}{2}$

Justification : The junction rule is in accordance with the conservation of charge that serves as basis of current rule while loop rule is based on law of conservation of energy.

[CBSE Marking Scheme, 2014] 1

Detailed Answer :

Kirchhoff's first law : The sum of the currents flowing towards a junction or node is equal to the sum of currents leaving the junction or node.

If I_1, I_2 and I_3 are the currents towards a node. I_4 and I_5 are the currents leaving the node.

According to Kirchhoff's 1st law :

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

i.e. $\sum I = 0$

Kirchhoff's second Law : The algebraic sum of all potential drops and e.m.f.s in a closed path or loop is zero i.e. $\sum E = \sum IR$

Kirchhoff's 1st law is in accordance with the conservation of charge.

Kirchhoff's 2nd law is in accordance with the conservation of energy. 1 + 1

SECTION - C

6. Derivation of current density 2
 explain with reason, the change in mobility of electrons 1
 Using Ohm's law,

$$V = IR = \frac{Ipl}{A} \quad \frac{1}{2}$$

Potential difference (V), across the ends of a conductor of length 'l', where field 'E' is applied is given by

$$\therefore \quad E = \frac{V}{l} = \frac{Ipl}{Al} \quad \frac{1}{2}$$

But current density,

$$J = \frac{I}{A}$$

$$El = Jpl = \frac{Jl}{\sigma} \quad \left[\because \frac{1}{\rho} = \sigma \right] \quad \frac{1}{2}$$

$$\Rightarrow \quad J = \sigma E \quad \frac{1}{2}$$

No change

$$\text{Mobility, } \mu = \frac{v_d}{E}$$

$$\text{and } v_d = \frac{eV\tau}{ml} \quad \frac{1}{2}$$

As potential is doubled, drift velocity also gets doubled, therefore, no change in mobility. 1/2

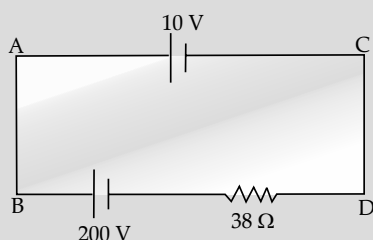
[CBSE Marking Scheme, 2017]

7. Writing the equation 1
 Finding the current 1
 By Kirchhoff's law, we have, for the loop ACDBA,
 $+ 200 - 38i - 10 = 0$ 1
 $\therefore \quad i = \frac{190}{38} \text{ A} = 5 \text{ A}$ 1

Alternatively :

Finding the Net emf 1

Stating that $I = \frac{V}{R}$ 1/2



Calculating I

1/2

The two cells being in 'opposition',

$$\therefore \quad \text{net E.M.F.} = 200 - 10 \text{ V} = 190 \text{ V}$$

$$\text{Now } I = \frac{V}{R}$$

$$\therefore \quad I = \frac{190 \text{ V}}{38 \Omega} = 5 \text{ A}$$

[Note : Some students may use the formulae

$$\frac{E}{r} = \frac{E_1}{r_1} + \frac{E_2}{r_2},$$

and

$$r = \frac{(r_1 r_2)}{(r_1 + r_2)}$$

For two cells connected in parallel

Then we can say that $r = 0$;

E is indeterminate and hence I is also indeterminate Award full marks (2)

to students giving this line of reasoning.]

[CBSE Marking Scheme, 2018] 2

SECTION - D

8. (i) Derivation of the expression for drift velocity 2
 Deduction of Ohm's law 2
 (ii) Name of quantity and justification 1/2 + 1/2
 (i) Let an electric field E be applied to the conductor. Acceleration of each electron is

$$a = -\frac{eE}{m} \quad \frac{1}{2}$$

Velocity gained by the electron

$$v = -\frac{eE}{m} t \quad \frac{1}{2}$$

Let the conductor contain n electrons per unit volume. The average value of time 't', between their successive collisions, is the relaxation time, 'τ'. 1/2

$$\text{Hence average drift velocity, } v_d = \frac{-eE}{m} \tau \quad \frac{1}{2}$$

The amount of charge, crossing area A, in time Δt, is $= neAv_d \Delta t = I \Delta t$ 1/2

Substituting the value of v_d , we get

$$I \Delta t = neA \left(\frac{eE\tau}{m} \right) \Delta t$$

$$\therefore \quad I = \left(\frac{e^2 A \tau n}{m} \right) E$$

$$\therefore \quad \frac{I}{A} = \left(\frac{e^2 \tau n}{m} \right) E$$

$$= \sigma E \quad \left(\sigma = \frac{e^2 \tau n}{m} \text{ is the conductivity} \right)$$

But $I = JA$, where, J is the current density, $\frac{1}{2}$

$$\Rightarrow J = \left(\frac{e^2 \tau n}{m} \right) E \quad \frac{1}{2}$$

$$\Rightarrow J = \sigma E \quad \frac{1}{2}$$

This is Ohm's law

[Note : Credit should be given if the student derives the alternative form of Ohm's law by substituting $E = \frac{V}{l}$]

- (ii) (b) Current density will remain constant in the wire. $\frac{1}{2}$

All other quantities, depend on the cross sectional area of the wire. $\frac{1}{2}$

[CBSE Marking Scheme, 2017]

Detailed Answer :

- (ii) Out of these, current density remains constant in a wire whose cross-sectional area increases linearly from its one end to other as current density is :

$$J = \frac{I}{A} \text{ and } I = \frac{V}{R}$$

$$\therefore J = \frac{V}{RA} \text{ and } R = \rho \frac{l}{A}$$

$$\therefore = \frac{VA}{\rho l A} = \frac{V}{\rho l} = \text{constant}$$

It is current per unit area that depends on area of cross-section. $\frac{1}{2}$

Drift speed is given as:

$$v_d = \frac{I}{Ane}$$

$$\text{Electric field} = \frac{J}{\sigma}; \text{ where } \sigma \text{ is electrical conductivity} \quad \frac{1}{2}$$

SOLUTIONS

SELF ASSESSMENT PAPER-3

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) When charge/mass ratio of these two particles are same and charges on them are of opposite nature then the charged particles will traverse identical helical paths in a completely opposite sense.

$$\text{i.e., } \left(\frac{e}{m} \right)_1 + \left(\frac{e}{m} \right)_2 = 0$$

- (ii) According to the Curie's law of magnetization, the magnetic susceptibility for a substance is directly proportional to magnetic field induction (B) and inversely proportional to the absolute temperature (T).

$$I \propto \frac{B}{T}$$

$$\therefore \frac{I_2}{I_1} = \frac{B_2 T_1}{B_1 T_2}$$

$$\text{Given, } I_1 = 8 \text{ Am}^{-1}$$

$$B_1 = 0.6 \text{ T}$$

$$T_1 = 4 \text{ K}$$

$$B_2 = 0.2 \text{ T}$$

$$T_2 = 16 \text{ K}$$

Putting the values,

$$I_2 = \left(\frac{B_2 T_1}{B_1 T_2} \right) \times I_1$$

$$= \frac{0.2 \times 8 \times 4}{0.6 \times 16} = \frac{2}{3} \text{ Am}^{-1}.$$

1

- (iii) Due to high permeability of the ferromagnetic material, the magnetic field inside the magnet gets increased to a great extent.
- (iv) Magnetic field at the axis inside the solenoid $B = \mu n i$
Here $n = 10 \text{ turns/cm} = 1000 \text{ turns/m}$,
 $i = 5 \text{ A}$
 $\therefore B = 4\pi \times 10^{-7} \times 1000 \times 5 = 2\pi \times 10^{-3} \text{ T}$

2. (i) **Correct option (b)**

Magnetic poles exist in pairs. So assertion is true.

The bar magnet does not exert a torque on itself in its own magnetic field. Torque is proportional to cross product of $\vec{M}$ and $\vec{B}$. The angle between $\vec{M}$

and $\vec{B}$ being 0, the cross product is 0. So, there will be no torque. So reason is also true.

But R cannot explain A.

1

- (ii) **Correct option (b)**

Magnetic poles always exist in pairs even in atomic level. So assertion is true.

When a magnet is broken into two pieces, the pole strength remains same; only the length becomes half. So, the magnetic moment becomes half. So, the reason is also true.

But R is not the proper explanation of A.

1

3. (i) **Correct option : (c)**

Explanation: Magnetic effects are generally smaller than electric effects.

(ii) **Correct option : (a)**

Explanation: $10^{-3}\text{N} = \text{mass in kg} \times g \text{ in m/s}^2$

Or, $10^{-3} = \text{mass} \times 10$

$\therefore \text{Mass} = 10^{-4} \text{ kg} = 100 \text{ mg}$ 1

(iii) **Correct option : (b)**

Explanation: The spring shrinks due to force acting between two current carrying wires. 1

(iv) **Correct option : (c)**

Explanation: Mercury, DC voltage source, key are essential components for the Roget's spiral to work. 1

(v) **Correct option : (d)**

Explanation: Only mercury can be used in Roget's spiral since mercury is a liquid metal through which an electrical circuit, may be completed. 1

SECTION - B

4. Gauss law of magnetism describes that divergence of magnetic field will be zero while divergence of electric field is not zero which shows the non existence of magnetic monopole. As per Gauss law of magnetism,

$$\oint \vec{B} \cdot d\vec{s} = 0 \quad 1$$

If monopole exists, then the right side will be equal to the monopole which is multiplied by μ_0 . 1

[CBSE Marking Scheme 2017]

Detailed Answer :

According to Gauss law of magnetism,

$$\oint \vec{B} \cdot d\vec{s} = 0 \quad (\text{Integral form})$$

$$\Delta \cdot \vec{B} = 0 \quad (\text{Differential form})$$

If magnetic monopoles exist, then Gauss's law for magnetism would be modified as :

$$\oint \vec{B} \cdot d\vec{s} \quad (\text{Integral form})$$

$$\Delta \cdot \vec{B} = \mu_0 \rho_m \quad (\text{Differential form})$$

Where, ρ_m = magnetic charge density μ_0 = permeability of free space. 2

5. **Equivalent magnetic moment of the coil,**

$$\vec{M} = IA\hat{n}$$

$$\therefore \vec{M} = Ilb\hat{n} \quad \frac{1}{2}$$

($\hat{n}$ = unit vector $\perp$ to the plane of the coil)

$$\therefore \text{Torque} = \vec{M} \times \vec{B}$$

$$= Ilb\hat{n} \times \vec{B} \quad \frac{1}{2}$$

$$= 0 \quad \frac{1}{2}$$

(as $\hat{n}$ and $\vec{B}$ are parallel or antiparallel to each other) 1/2

[CBSE Marking Scheme 2014]

SECTION - C

6. Formula for magnetic field of torroid 1

Calculation of magnetic field 1 1/2

Effect of change of core 1/2

$$B = \mu_r \mu_0 n I \quad 1$$

$$= (800 \times 4\pi \times 10^{-7}) \times \left(\frac{4000}{2\pi \times 20 \times 10^{-2}} \right) \times 3 \quad \frac{1}{2}$$

$$= 9.6 \text{ T} \quad 1$$

Since Bismuth is diamagnetic, its $\mu_r < 1$ 1/2

$\therefore$ The magnetic field in the core will get very much reduced.

[CBSE Marking Scheme 2017]

Detailed Answer :

Given :

Mean radius of torroidal solenoid = 20 cm

Number of turns of wire wound = 4000

Relative permeability of ferromagnetic core = 800

Current passing through the coil = 3 A

Magnetic field in a torroid coil:

$$B = \frac{\mu_0 NI}{2\pi r} \quad 1$$

$$\text{Now, } B = \frac{(800 \times 4\pi \times 10^{-7} \times 4000 \times 3)}{(2\pi \times 20 \times 10^{-2})} \quad \frac{1}{2}$$

$$B = 9.6 \text{ T} \quad 1$$

It is observed that as Bismuth is diamagnetic substance with relative permeability less than 1, it will have a tendency to move away from the stronger to weak part of external magnetic field making the core field less as compared to empty core field. 1/2

7. (i) $|\epsilon| = Bvl$

P is positive end

Q is negative end 1

- (ii) Magnetic force gets cancelled by electric force that generates due to extra charge of opposite sign at rod ends. 1

- (iii) Induced emf is zero as motion of rod not cutting field lines 1

[CBSE Marking Scheme 2017]

SECTION - D

8. (a) The equivalent magnetic moment is given

by $\mu = NiA$ 1/2

The direction of m is perpendicular to the plane of current carrying loop. It is directed along the direction of advance of a right-handed screw rotated along the direction of flow of current. 1/2

Derivation of expression for μ of electron revolving around a nucleus 2

For 1 revolution of electron, $N = 1$

$$\text{Current} = i = \frac{eV}{2\pi R}$$

Putting in the expression,

$$\begin{aligned}\mu &= NiA \\ &= 1 \times \left(\frac{eV}{2\pi R} \right) \times \pi R^2 \\ &= \frac{eVR}{2}\end{aligned}$$

(b) for the loop,

$$\vec{\mu} = N(\pi r^2) i (\pm \hat{k}) \quad \frac{1}{2}$$

$$\text{Magnetic potential energy} = \vec{\mu} \cdot \vec{B} \quad \frac{1}{2}$$

$$= N(\pi r^2) i (\pm \hat{k}) \cdot (B_x \hat{i} + B_y \hat{j} + B_z \hat{k}) \quad \frac{1}{2}$$

$$= \pm \pi r^2 Ni B_z. \quad \frac{1}{2}$$

[CBSE Marking Scheme, 2018-19]

SOLUTIONS

SELF ASSESSMENT PAPER-4

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) Magnetic flux is defined as the total number of magnetic lines of force passing normally through an area placed in a magnetic field.

Square lies in x - y plane in $\vec{B}$.

So,

$$\begin{aligned}\vec{A} &= L^2 \hat{k} \\ \Phi &= \vec{B} \cdot \vec{A} \\ &= B_0 (2\hat{i} + 3\hat{j} + 4\hat{k}) \cdot L^2 \hat{k} \\ &= B_0 L^2 (2\hat{i} \cdot \hat{k} + 3\hat{j} \cdot \hat{k} + 4\hat{k} \cdot \hat{k}) \\ &= B_0 L^2 (0 + 0 + 4) \\ &= 4 B_0 L^2 \text{ Wb} \quad 1\end{aligned}$$

- (ii) The self inductance of coil or solenoid is given by

$$L = \mu_0 n^2 A l$$

where μ_0 is permeability of free space, n is number of turns per unit length of a coil, A is cross sectional area of coil and l is length of coil.

If A and l are constant terms then, inductance is directly proportional to square of number of turns. According to question, the number of turns in a coil is doubled without any change in inductance lending of the coil. So, inductance of coil becomes four times. 1

- (iii) Due to the heating effect of eddy currents set up in the metallic piece.

- (iv) Relative permeability

$$\begin{aligned}\mu_r &= \frac{L}{L_0} \\ \mu_r &= \frac{2.8}{2.0 \times 10^{-3}} \quad \frac{1}{2} \\ &= 1400 \quad \frac{1}{2}\end{aligned}$$

[CBSE Marking Scheme 2017]

2. (i) Correct option: (a)

Explanation: The filament of bulb is an inductor (coil). During switching on and off, the current changes from steady value to 0 or from 0 to a steady value within a very short time. So, from the relation $V = L di/dt$, it is evident that V will be high at that time. So, there remains a possibility of the bulb to fuse. So the assertion is true.

The surge is produced due to inductive effect at the time of switching ON and OFF. So, reason is also true.

The reason explains the assertion.

- (ii) Correct option : (c)

Explanation: Faraday's laws involves only transformation of energy into electrical energy.

So, it is a consequence of conservation of energy. So the assertion is true.

In purely resistive circuit, current and voltage are in phase. So the reason is false.

3. (i) Correct option : (c)

Explanation : Phenomenon involved in tuning a radio set to a particular radio station is resonance.

The capacitor has to be tuned in tandem corresponding to the frequency of a station. So, that the LC combination of the radio set resonates at the frequency of the desired station. 1

- (ii) Correct option : (c)

Explanation: A simple radio receiver is a simple crystal set with a coil & capacitor combination. Desired frequency is tuned by tuning the coil - capacitor combination. Tuning means to make Capacitive reactance (X_C) equal to the inductive reactance (X_L), so that the resonance occurs. 1

- (iii) Correct option : (b)

Explanation: The resonant frequency is given by

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

(iv) **Correct option : (c)**

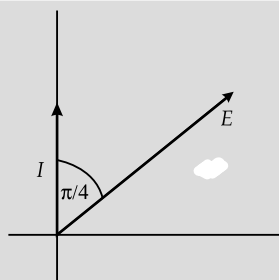
Explanation: At resonance, capacitive reactance (X_C) is equal to the inductive reactance (X_L). Circuit is totally resistive and the current amplitude becomes maximum. 1

(v) **Correct option : (a)**

Explanation: Capacitor used in old radio is parallel plate capacitor. It consists of two sets of parallel circular plates, one of which can rotate manually by means of a knob. The rotation causes overlapping areas of plates to change, thus changing its capacitance. 1

SECTION - B

4.



Equal length of phasors

Current leads voltage

phase difference is $\frac{\pi}{4}$

$\frac{1}{2}$

$\frac{1}{2}$

1

[CBSE Marking Scheme, 2018]

Detailed Answer :

The equation of voltage may be written as :

$$E(t) = E_0 \sin \omega t \quad \dots(i)$$

The equation of current may be written as :

$$I(t) = I_0 \sin (\omega t + \phi) \quad \dots(ii)$$

where ϕ is the phase difference.

At $t = \frac{T}{8}, I(t) = I_0$

So, $I_0 = I_0 \sin \left(\frac{\omega T}{8 + \phi} \right)$

$$\therefore \sin \left(\frac{\omega T}{8 + \phi} \right) = 1 \quad \dots(iii)$$

At $t = \frac{T}{4}, E(t) = E_0$

So, $E_0 = E_0 \sin \frac{\omega T}{4}$

Or, $\sin \frac{\omega T}{4} = 1$

Or, $\sin \frac{\omega T}{4} = \sin \frac{\pi}{2}$

Or, $\frac{\omega T}{4} = \frac{\pi}{2}$

$$\therefore \omega = \frac{2\pi}{T}$$

Putting in equ (iii),

$$\sin \left(\frac{\omega T}{8 + \phi} \right) = 1$$

Or, $\sin \left(\frac{\pi}{4} + \phi \right) = \sin \frac{\pi}{2}$

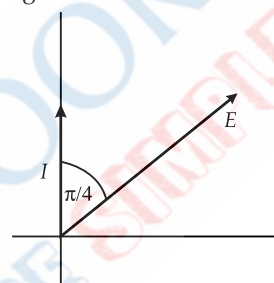
Or, $\frac{\pi}{4} + \phi = \frac{\pi}{2}$

$$\therefore \phi = \frac{\pi}{4}$$

So, phase difference = $\frac{\pi}{4}$

Current leads voltage by $\frac{\pi}{4}$

Phasor diagram :



5. A transformer is based on the principle of mutual induction which states that due to continuous change in the current in the primary coil, an emf gets induced across the secondary coil. 1

Electric power generated at the power station, is stepped-up to very high voltages by means of a step-up transformer and transmitted to a distant place. At receiving end, it is stepped down by a step-down transformer. 1

SECTION - C

6.

Statement of Lenz's Law 1

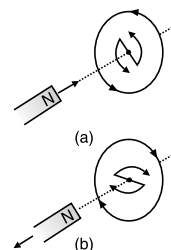
Explanation (with example) 2

[CBSE Marking Scheme 2017]

Detailed answer :

Statement : The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it. 1

Explanation :



1

When the north pole of a bar magnet is pushed towards the close coil, the magnetic flux through coil increases and the current is induced in the coil in such a direction that it opposes the increase in flux. This is possible when the induced current

in the coil is in the anti clockwise direction. The opposite will happen when the north pole is moved away from the coil. $\frac{1}{2}$

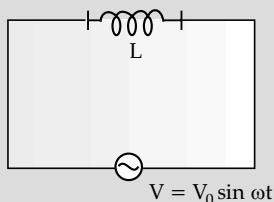
In either case, it is the work done against the force of magnetic repulsion/attraction that gets 'converted' into the induced emf. **2**

7. Derivation of instantaneous current **2**

Derivation of average power dissipated **1**

Given : $V = V_0 \sin \omega t$

$$V = L \frac{di}{dt} \Rightarrow di = \frac{V}{L} dt$$



$$\therefore di = \frac{V_0}{L} \sin \omega t dt \quad \frac{1}{2}$$

Integrating, $i = -\frac{V_0}{\omega L} \cos \omega t \quad \frac{1}{2}$

$$\therefore i = -\frac{V_0}{\omega L} \sin \left(\frac{\pi}{2} - \omega t \right) \\ = I_0 \sin \left(\frac{\pi}{2} - \omega t \right) \quad \frac{1}{2}$$

where, $I_0 = \frac{V_0}{\omega L}$

Average power,

$$P_{av} = \int_0^T V i dt \quad \frac{1}{2} \\ = \frac{-V_0^2}{\omega L} \int_0^T \sin \omega t \cos \omega t dt \\ = \frac{-V_0^2}{2\omega L} \int_0^T \sin(2\omega t) dt \\ = 0 \quad \mathbf{1}$$

[CBSE Marking Scheme, 2017]

SECTION - D

8. (i) Identification $\frac{1}{2}$
 (ii) Identifying the curves $\frac{1}{2}$
 Justification $\frac{1}{2}$

- (iii) Variation of Impedance with frequency $\frac{1}{2}$

Graph $\frac{1}{2}$

- (iv) Expression for current **2**

Phase relation $\frac{1}{2}$

- (i) The device X is a capacitor $\frac{1}{2}$

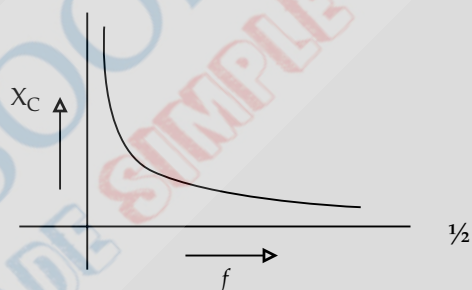
- (ii) Curve B $\rightarrow$ voltage

Curve C $\rightarrow$ current

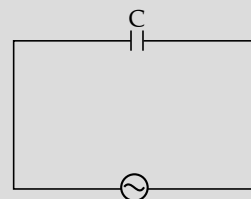
Curve A $\rightarrow$ power $\frac{1}{2}$

Reason : The current leads the voltage in phase, by $\frac{\pi}{2}$, for a capacitor. $\frac{1}{2}$

- (iii) $X_c = \frac{1}{\omega C}$ or $\left(X_c \propto \frac{1}{\omega} \right)$ $\frac{1}{2}$



- (iv) $V = V_0 \sin \omega t$
 $q = VC = CV_0 \sin \omega t \quad \frac{1}{2}$
 $I = \frac{dq}{dt} = \omega CV_0 \cos \omega t \quad \frac{1}{2}$



$$V = V_0 \sin \omega t \quad \frac{1}{2}$$

$$I = I_0 \sin \left(\omega t + \frac{\pi}{2} \right) \quad \frac{1}{2}$$

Current leads the voltage, in phase, by $\frac{\pi}{2}$ $\frac{1}{2}$

[Note : If the student identifies the device X as an Inductor but writes correct answer to parts (c) and (d) (in terms of an inductor), the student will be given full marks for (only) these two parts]

[CBSE Marking Scheme, 2017]

SOLUTIONS

SELF ASSESSMENT PAPER-5

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) Photoelectric effect and Compton effect 1
 - (ii) Consider a plane perpendicular to the direction of propagation of the wave. An electric charge on the plane will be set in motion by the electric and magnetic fields of the EM wave, incident on the plane. This illustrates that EM waves carry energy and momentum. 1
 - (iii) Microwaves are considered suitable for radar systems used in aircraft navigation because of their short wavelength range which makes them suitable for long-distance communication. 1
 - (iv) X rays/Gamma rays. 1
- [CBSE Marking Scheme, 2014]

2. (i) **Correct option : (a)**

Explanation : Velocity of all electromagnetic wave is 3×10^8 m/s which is the velocity of light.

X ray is an electromagnetic wave. So, it travels with the velocity 3×10^8 m/s which is the velocity of light.

So, assertion and reason both are correct and reason properly explains the assertion.

- (ii) **Correct option : (b)**

Explanation : Since $E = mc^2$ and

$$E = \frac{hc}{\lambda}$$

$$\therefore mc^2 = \frac{hc}{\lambda}$$

$$\therefore m \propto \frac{1}{\lambda}$$

So, the assertion is true.

According to Einstein's theory energy of a particle moving with velocity of light $= mc^2$

So, reason is also true.

But the reason does not explain the assertion.

3. (i) **Correct option: (b)**

Explanation : Microwaves have frequency and energy smaller than visible light and wavelength larger than it. 1

- (ii) **Correct option: (a)**

Explanation : When the energy of the random motion of atoms and molecules of a substance increases and the molecules travel or vibrate or rotate with higher energies then the substance becomes hot. 1

- (iii) **Correct option: (c)**

Explanation : The frequency of rotation of water molecules is about 2.45 gigahertz. 1

- (iv) **Correct option: (d)**

Explanation : One should use porcelain vessels and not metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get heated up. 1

- (v) **Correct option : (a)**

Explanation : In the conventional heating method, the vessel on the burner gets heated first, and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food. 1

SECTION - B

4. Type the following answer:

Electromagnetic waves carry energy and momentum. It also exerts pressure. This property of e.m. wave was exhibited by Prof. C.V. Raman s by suspending a tiny light ball freely in a transparent vacuum chamber by shining a laser beam on it.

Another example of such property is generation of tail of a comet due to solar radiation pressure.

5. Type the following answer:

(i) X-rays. Used for medical purpose.

(ii) Microwaves. Used for radar system.

SECTION - C

6. Type the following answer:

The name of the e.m. wave in the given wavelength range is Microwave.

It is generated by magnetron valve or mawser

Uses of microwave: (i) Used in radar, (ii) used in telemetry.

7. (a) **Microwaves :** Frequency range

$$(\sim 10^{10} \text{ to } 10^{12} \text{ Hz}) \quad \frac{1}{2} + \frac{1}{2}$$

Ultraviolet rays : Frequency range

$$(\sim 10^{15} \text{ to } 10^{17} \text{ Hz}) \quad \frac{1}{2} + \frac{1}{2}$$

[Note : Award $\left(\frac{1}{2} + \frac{1}{2}\right)$ marks for frequency ranges even if the student just writes the correct order of magnitude for them].

(b) Average energy density of the electric field

$$\begin{aligned}
 &= \frac{1}{2} \epsilon_0 E^2 \\
 &= \frac{1}{2} \epsilon_0 (cB)^2 \\
 &= \frac{1}{2} \epsilon_0 \frac{1}{\mu_0 \epsilon_0} B^2 \\
 &= \frac{1}{2} \frac{B^2}{\mu_0}
 \end{aligned}$$

1

= Average energy density of the magnetic field.

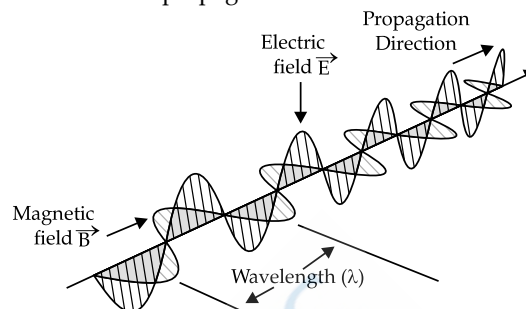
[Note : Award 1 mark for this part if the student just writes the expressions for the average energy density of the electric and magnetic fields].

[CBSE Marking Scheme, 2019]

SECTION - D

8. (i) An electromagnetic wave consists of both electric as well as magnetic field components. The energy of the EM wave is also distributed equally in the electric as well as magnetic field component. These are produced by oscillating charges and do not require any medium for the propagation. The maximum and minimum value of these waves is attained at the same time. The direction of electric field and magnetic field is perpendicular to each other and also to the direction of propagation of wave. So, the statement is incorrect which states

that the electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of the wave.



Electromagnetic wave

- (ii) For the EM wave, propagating along the z-axis, we have

$$E = E_0 \sin(kz \mp \omega t) \text{ and } B = B_0 \sin(kz \mp \omega t) \quad \frac{1}{2}$$

The two possible forms are :

$$E_x = E_0 \sin(kz - \omega t) \quad \frac{1}{2}$$

$$B_y = B_0 \sin(kz - \omega t)$$

$$\text{And } E_y = E_0 \sin(kz + \omega t) \quad \frac{1}{2}$$

$$B_x = B_0 \sin(kz + \omega t)$$

$$\text{We have, } E_0 = cB_0 \quad \frac{1}{2}$$

[Do not deduct any mark if the student uses any of the two signs (- or +) in the two sets of expression.] 2

SOLUTIONS

SELF ASSESSMENT PAPER-6

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) Decreases $\frac{1}{2}$

(ii) $\mu_{\text{violet}} > \mu_{\text{Red}}$ $\frac{1}{2}$

[CBSE Marking Scheme, 2017]

Detailed answer :

We know, $\delta_m = (n_{21} - 1) A$. Hence, larger the refractive index, larger will be the deviation. As refractive index of glass for violet is more than the refractive index of glass for red, the deviation will decrease if the incident violet light is replaced by red light. 1

(ii) Reflecting telescope is used to see erect image of distant object.

(iii) A passenger in an aeroplane may see primary and secondary rainbow as concentric circles due to the dispersion of sunlight. 1

(iv) As $\mu_2 > \mu_1$, the upper half of the lens will become converging. 1

As $\mu_1 > \mu_3$, the lower half of the lens will become converging. 1

2. (i) Correct option : (b)

Explanation: Stars are located at a distance of many light years. Light from stars while coming through atmospheric layers of varying refractive indices shifts its path again and again.

So, the position of the image changes again and again. Hence, stars seem to twinkle. The assertion is true.

Stars are bigger than the planets that they can form their own planetary system. So reason is also true.

But reason cannot explain the assertion properly that why stars twinkle. 1

(ii) Correct option : (a)

Explanation: Air bubbles shine in water due to total internal reflection. Total internal reflection is a special case of refraction when light passes from denser medium (water) to rarer medium (air inside the bubble) and angle of incidence is more than the critical angle. So, the reason is also true.

The reason also explains the assertion properly. 1

3. (i) **Correct option : (d)**

Explanation: In 1967 Soviet physicist Victor Veselago hypothesized that a material with a negative refractive index could exist without violating any of the laws of physics. 1

(ii) **Correct option : (a)**

Explanation : Snell's law is satisfied for the materials having a negative refractive index, but the direction of the refracted light ray is 'mirror-imaged' about the normal to the surface. 1

(iii) **Correct option : (c)**

Explanation : The magnitude of angle of refraction in normal "negative glass" will also be 45° , but the direction of the refracted light ray is 'mirror-imaged' about the normal to the surface. 1

(iv) **Correct option : (b)**

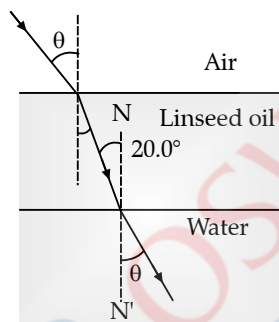
Explanation : Like normal refraction, for material having negative refraction index also when the angle of incidence is equal to 0° , then angle of refraction will be equal to angle of incidence *i.e.* 0° . 1

(v) **Correct option : (c)**

Explanation : Recently, meta material samples are being tested for negative refractive index. The experiments show significant losses, and this is the an intrinsic property of negative index materials. 1

SECTION - B

4.



Applying Snell's law at the air-oil interface,

$$n_{\text{air}} \sin \theta = n_{\text{oil}} \sin 20.0^\circ$$

yields $\theta = 30.4^\circ$.

Applying Snell's law at the oil-water interface

$$n_{\text{oil}} \sin 20.0^\circ = n_{\text{water}} \sin \theta'$$

yields $\theta' = 22.3^\circ$.

5. (i) Refractive index of a medium is the ratio of speed of light (c) in free space to the speed of light (v) in that medium. 1

(ii)

$$\mu = \frac{c}{v}$$

$$\mu = \frac{c}{v} = \frac{1}{\sin i_c} \quad \frac{1}{2}$$

$$= \frac{3 \times 10^8}{v} = \frac{1}{\frac{30}{50}}$$

$$v = \frac{30}{50} \times 3 \times 10^8$$

$$= 1.8 \times 10^8 \text{ m/s} \quad \frac{1}{2}$$

[CBSE Marking Scheme, 2017]

SECTION - C

6. (a) Any two points of difference

Interference	Diffraction
Fringes are equally spaced.	Fringes are not equally spaced.
Intensity is same for all maxima.	Intensity falls as we go to successive maxima away from the centre.
Superposition of two waves originating from two narrow slits.	Superposition of a continuous family of waves originating from each point on a single slit.
Maxima along an angle λ/a for two narrow slits separated by a distance a .	Minima at an angle of λ/a for a single slit of width a .

 $\frac{1}{2} + \frac{1}{2}$

(b) Let D be the distance of the screen from the plane of the slits.

We have

$$\text{Fringe width, } \beta = \frac{\lambda D}{d} \quad \frac{1}{2}$$

In the first case

$$\beta = \frac{\lambda D}{d} \text{ or } \beta d = \lambda D \quad \dots(i) \quad \frac{1}{2}$$

In the second case

$$(\beta - 30 \times 10^{-6}) = \frac{\lambda(D - 0.05)}{d}$$

$$\text{or } (\beta - 30 \times 10^{-6})d = \lambda(D - 0.05) \quad \dots(ii) \quad \frac{1}{2}$$

Subtracting (ii) from (i) we get

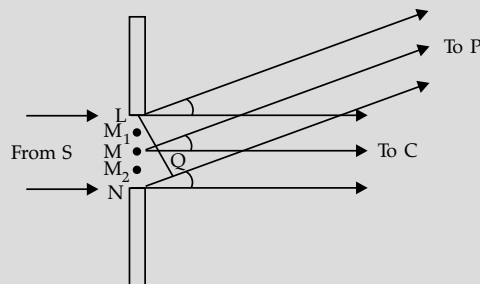
$$30 \times 10^{-6} \times d = \lambda \times 0.05$$

$$\therefore \lambda = \frac{30 \times 10^{-6} \times 10^{-3}}{5 \times 10^{-2}} \text{ m}$$

$$\therefore \lambda = 6 \times 10^{-7} \text{ m} = 600 \text{ nm} \quad \frac{1}{2}$$

[CBSE Marking Scheme, 2018]

7.

 $\frac{1}{2}$

The path difference

$$NP - LP = NQ$$

$$= a \sin \theta \approx a \theta$$

$$\text{or, } a \sin \theta = a \theta$$

$$\text{as } \theta \ll 1 \therefore \sin \theta \approx \theta \quad \frac{1}{2}$$

By dividing the slit into an appropriate number of parts, we find the point P for which

(i) $\theta = \frac{n\lambda}{a}$ are points of minima. $\frac{1}{2}$

(ii) $\theta = \left(n + \frac{1}{2}\right) \frac{\lambda}{a}$ are points of maxima $\frac{1}{2}$

Angular width of central maxima,

$$\theta = \theta_1 - \theta_{-1} = \frac{\lambda}{a} - \left(-\frac{\lambda}{a}\right)$$

$$\theta_2 = \frac{2\lambda}{a} \quad \frac{1}{2}$$

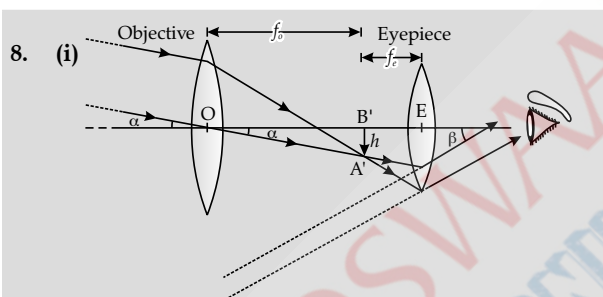
Angular width of secondary maxima = $\theta_2 - \theta_1$

$$= \frac{2\lambda}{a} - \frac{\lambda}{a} = \frac{\lambda}{a}$$

$$= \frac{1}{2} \times \text{Angular width of central maxima} \quad \frac{1}{2}$$

[CBSE Marking Scheme, 2017]

SECTION - D



[Note : deduct $\frac{1}{2}$ mark if not labelled] $1\frac{1}{2}$

Magnifying power,

$$m = \frac{\tan \beta}{\tan \alpha} \cong \frac{\beta}{\alpha} \quad \frac{1}{2}$$

($\because$ The angles are small)

Final image is formed at infinity when the image $A'B'$ is formed by the objective lens at the focus of the eyepiece,

$$m = \frac{h}{f_e} \times \frac{f_o}{h} \quad \frac{1}{2}$$

$$m = \frac{f_o}{f_e} \quad \frac{1}{2}$$

(ii) Given,

$$f_o + f_e = 105, f_o = 20 f_e \quad \frac{1}{2}$$

$$20 f_e + f_e = 105$$

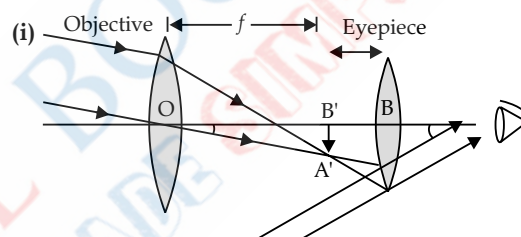
$$f_e = \frac{105}{21} = 5 \text{ cm} \quad \frac{1}{2}$$

$$f_o = 20 \times 5 = 100 \text{ cm} \quad \frac{1}{2}$$

$$\therefore \text{Magnification, } m = \frac{f_o}{f_e} = \frac{100}{5} = 20 \quad \frac{1}{2}$$

[CBSE Marking Scheme, 2014]

Detailed Answer :



Magnification

$$\frac{\text{angle subtended by image at observer's eye}}{\text{angle subtended by object at observer's eye}} = \frac{\beta}{\alpha}$$

$$\text{For small angle, } \beta = \tan \beta = \frac{-A'B'}{-f_e}$$

(as eye is very near to eyepiece)

$$\text{Angle } \alpha = \tan \alpha = \frac{-A'B'}{f_o}$$

$$m = \frac{\frac{-A'B'}{-f_e}}{\frac{-A'B'}{f_o}} = \frac{-f_o}{f_e}$$

$$= \frac{100}{5} = 20.$$

SOLUTIONS

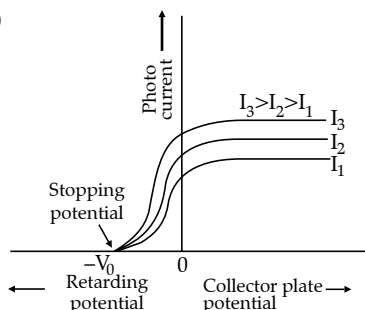
SELF ASSESSMENT PAPER-7

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i)



1

- (ii) Intensity of radiation is proportional to (// equal to) the number of energy quanta (photons) per unit area per unit time. 1

[CBSE Marking Scheme, 2019]

Detailed Answer :

Intensity : It the total energy falling (or going through) a surface/region per unit area, per unit time and is measured in $\text{J/m}^2\text{s}$.

For monochromatic radiator, total energy emitted is equal to the number of photons, n , times the energy of one photon, $h\nu$

$$I = \frac{h\nu n}{At}$$

$$\therefore$$

where, $A = \text{Area}$.

$t = \text{time}$.

- (iii) Each photon has an energy, $E = h\nu$ 1/2
 $= (6.63 \times 10^{-34} \text{ J-s})(6.0 \times 10^{14} \text{ Hz})$
 $= 3.98 \times 10^{-19} \text{ J}$ 1/2

[CBSE Marking Scheme, 2018]

(iv) Photoelectric effect (Raman / Compton effect)

2. (i) **Correct option : (b)**

Explanation: The minimum energy required to eject an electron from the surface is called the photoelectric work function. So, if work function is low then less energy is required to eject photoelectrons *i.e.* photosensitivity becomes high. So, assertion is true.

Work function = Planck's constant $\times$ threshold frequency

So, the reason is also true.

But the reason cannot explain the assertion properly.

as on does not explain the assertion.

(ii) **Correct option: (b)**

Explanation: The de-Broglie wavelength $= \lambda = \frac{h}{\sqrt{2mkT}}$

So,
$$\lambda \propto \frac{1}{\sqrt{T}}$$

So, the assertion is true.

$$V_{\text{RMS}} = \sqrt{\frac{3RT}{M}}$$

So,
$$V_{\text{RMS}} \propto \sqrt{T}$$

So, root mean square velocity of the molecule is temperature dependant.

So, the reason is also true.

But reason does not explain the assertion.

3. (i) **Correct option: (d)**

When sunlight falls on the light-mill, the vanes, of Crook's radiometer, turn with the black surfaces apparently being pushed away by the light. So, it is called "lightmill".

(ii) **Correct option: (b)**

Crookes at first believed this demonstrated that light radiation pressure on the black vanes was turning it around.

James Clerk Maxwell accepted the explanation Crookes gave. It seems that Maxwell was delighted to see a demonstration of the effect of radiation pressure as predicted by his theory of electromagnetism. 1

(iii) **Correct option: (c)**

Crookes' Radiometer consists of four vanes, each of which is blackened on one side and silvered on the other. 1

(iv) **Correct option: (a)**

The mechanism is encased inside a clear glass bulb that has been pumped out to a high vacuum, but not perfect vacuum. 1

(v) **Correct option : (a)**

Actually the black side of each vane absorb heat from infrared radiation more than the silver side. This causes the rarefied gas to be heated on the black side. In that case, the obvious explanation is that the pressure of the gas on the darker side increases with its temperature, creating a higher force on the dark side of the vane which thus pushes the rotor around. 1

SECTION - B

4. Calculating the energy of the incident photon **1**
 Identifying the metals $\frac{1}{2}$
 Reason $\frac{1}{2}$
 The energy of a photon of incident radiation is given by

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{(412.5 \times 10^{-9}) \times (1.6 \times 10^{-19})} \text{ eV} = 3.01 \text{ eV}$$

Hence, only Na and K will show photoelectric emission. $\frac{1}{2}$

[Note : Award this $\frac{1}{2}$ mark even if the student writes the name of only one of these metals]

Reason : The energy of the incident photon is more than the work function of only these two metals. $\frac{1}{2}$

[CBSE Marking Scheme, 2018]

Detailed Answer :

Energy of incident photon :

The energy of a photon of incident radiation is given by

$$E = \frac{hc}{\lambda}$$

Where h = Planck's constant = 6.63×10^{-34} Js

c = velocity of light = 3×10^8 ms $^{-1}$

λ = Wavelength = 412.5 nm = 412.5×10^{-9} m

Putting the values

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{(412.5 \times 10^{-9})} \text{ J}$$

$$\text{or, } E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{[(412.5 \times 10^{-9}) \times (1.6 \times 10^{-16})]} \text{ eV}$$

$$\therefore E = 3.01 \text{ eV}$$

Photoelectric emission will be shown by Na and K only.

Since the energy of incident Photon is greater than the work functions of Na and K, photoelectric emission will take place from those two metals only.

5. Finding the work function **1**
 Finding the frequency of incident light **1**
 We have

$$W = h\nu_0$$

$$= 6.63 \times 10^{-34} \times 8 \times 10^{14} \text{ J} \quad \frac{1}{2}$$

$$= \frac{6.63 \times 10^{-20} \times 8}{1.6 \times 10^{-19}}$$

$$= 3.315 \text{ eV} \quad \frac{1}{2}$$

$$\text{We have } h\nu = W + eV_s$$

$$= (3.315 + 3.3) \text{ eV} \quad \frac{1}{2}$$

$$\therefore \nu = \frac{6.615 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} \text{ Hz}$$

$$= 1.596 \times 10^{15} \text{ Hz} \quad \frac{1}{2}$$

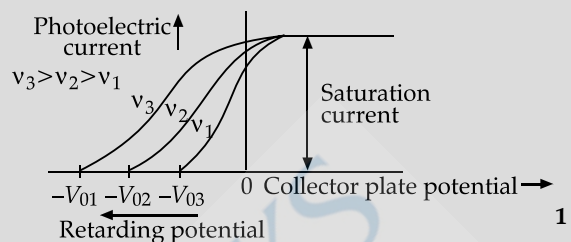
[CBSE Marking Scheme, 2018]

SECTION - C

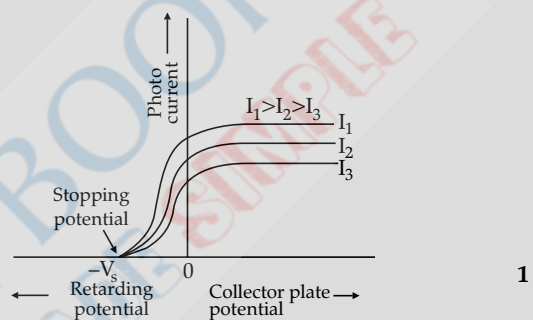
6. (i) X is collector plate potential. $\frac{1}{2}$

- (ii) A is stopping potential. $\frac{1}{2}$

- (iii) Graph for different frequencies :



- (iv) Graph for three different intensities :



[CBSE Marking Scheme, 2017]

7. (i) Q has higher threshold frequency $\frac{1}{2}$

- (ii) Work function, $\phi_0 = h\nu_0$ $\frac{1}{2}$

$$h\nu_0 = (6.6 \times 10^{-34}) \times \frac{6 \times 10^{14}}{1.6 \times 10^{-19}} \text{ eV} \quad \frac{1}{2}$$

$$= 2.475 \text{ eV}$$

- (iii) $K_{\max} = h(\nu - \nu_0)$ $\frac{1}{2}$

$$= \frac{6.6 \times 10^{-34} \times 2 \times 10^{14}}{1.6 \times 10^{-19}} \text{ eV}$$

$$K_{\max} = 0.825 \text{ eV} \quad \frac{1}{2} + \frac{1}{2}$$

[CBSE Marking Scheme, 2017]

Detailed Answer :

(ii) Work function of Q $\phi_0 = h\nu_0$

$$= \frac{6.6 \times 10^{-34} \times 6 \times 10^{14}}{1.6 \times 10^{-19}} \text{ eV}$$

$$= 2.475 \text{ eV}$$

(iii) $h\nu_0 = \frac{6.6 \times 10^{-34} \times 8 \times 10^{14}}{1.6 \times 10^{-19}} \text{ eV}$

$$= 3.3 \text{ eV}$$

$$KE_{\max} = h\nu - h\nu_0$$

$$= (3.3 - 2.475) \text{ eV}$$

$$= 0.825 \text{ eV} \quad 1$$

SECTION - D

8. (i) Energy of photon, $E_p = \frac{hc}{\lambda}$ 1/2

For proton, $\lambda = \frac{h}{mv}$

$mv = \frac{h}{\lambda}$ 1/2

Kinetic energy of proton,

$E_k = \frac{1}{2}mv^2$ 1/2

$E_k = \frac{1}{2} \frac{h^2}{m\lambda^2}$

$E_p = \left(\frac{2m\lambda c}{h} \right) E_k$ 1/2

- (ii) Maximum kinetic ($K_{\max}$), of emitted photoelectrons, depends linearly on frequency of incident radiations

$(K.E.)_{\max} = h\nu - h\nu_0$ 1/2 + 1/2

Existence of threshold frequency for the metal surface $\phi_0 = h\nu_0$ (Any other relevant feature)

- (iii) Since, no photoelectric emission takes place from P it means frequency of incident radiation (10^{15} Hz) is less than its threshold frequency (ν_0) 1/2

Photo emission takes place from Q but kinetic energy of photoelectrons is zero.

This implies that frequency of incident radiation is just equal to the threshold frequency of Q.

For Q, work function $\phi_0 = h\nu_0$
 $= \frac{6.6 \times 10^{-34} \times 10^{15}}{1.6 \times 10^{-19}} \text{ eV}$ 1/2
 $= 4.125 \text{ eV}$ 1/2 + 1/2
[CBSE Marking Scheme, 2017]

Detailed Answer :

(i) Energy of a photon, $E_p = \frac{hc}{\lambda}$

or $\lambda = \frac{hc}{E_p}$

$\frac{h}{\lambda} = \frac{E_p}{c}$...(i)

de-Broglie wavelength of proton,

$\lambda = \frac{h}{\sqrt{2mK}}$

where, K = Kinetic energy of proton

$K = \frac{h^2}{2m\lambda^2}$

$K = \frac{h}{2m\lambda} \times \frac{h}{\lambda}$...(ii)

Putting the value of $\frac{h}{\lambda}$ from eq (1)

$K = \frac{h}{2m\lambda} \times \frac{E_p}{c}$

$\Rightarrow E_p = \left(\frac{2mc\lambda}{h} \right) K$ **Hence Proved.**

SOLUTIONS

SELF ASSESSMENT PAPER-8

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) Energy of the photon must be equal to the binding energy of proton So, energy of photon = 1 MeV = $10^6 \times 1.6 \times 10^{-19} \text{ J}$

$$\begin{aligned} \lambda &= \frac{hc}{E} \\ &= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{13}} \\ &= 1.24 \times 10^{-3} \times 10^{-9} \\ &= 1.24 \times 10^{-3} \text{ nm} \end{aligned}$$

- (ii) Daughter nuclei will have higher binding energy per nucleon. The mass of heavier nucleus (daughter) is less than the sum of masses of combining nuclei. So, mass defect is more in daughter nuclei resulting into more binding energy per nucleon. 1

- (iii) If n is the quantum number of highest energy level, then the total number of possible spectral lines emitted is

$$N = \frac{n(n-1)}{2}$$

Here, third excited state means fourth energy level, i.e., $n = 4$

$\therefore N = \frac{4 \times (4-1)}{2} = 6$ 1

- (iv) The difference between the rest mass of a nucleus and the sum of the rest masses of its constituent nucleons is called its mass defect. It is given by

$$\Delta m = Zm_p + (A - Z)m_n - M$$
 1

2. (i) **Correct option : (b)**

Explanation: According to Bohr's postulate that electrons in stationary orbits around the nucleus do not radiate.

When electron jumps from one orbit to the next lower orbit then only it radiates.

So, both the assertion and reason are true.

But reason does not explain the assertion.

(ii) Correct option : (a)

Explanation: Average radius of a nucleus is given by $R = R_0 A^{1/3}$

The volume of the nucleus is directly proportional to the total number of nucleons.

This suggests that all nuclei have nearly the same density.

So, assertion and reason both are true and the reason properly explains the assertion.

3. (i) Correct option : (b)

The atomic energy programme in India was launched around the time of independence under the leadership of Homi J. Bhabha (1909-1966). **1**

(ii) Correct option : (a)

An early historic achievement was the design and construction of the first nuclear reactor in India named APSARA. **1**

(iii) Correct option : (d)

ARYABHATTA is an Indian artificial satellite. **1**

(iv) Correct option : (b)

The main objectives of the Indian Atomic Energy programme are to provide safe and reliable electric power for the country's social and economic progress and to be self-reliant in all aspects of nuclear technology. **1**

(v) Correct option : (d)

Exploration of atomic minerals in India undertaken since the early fifties has indicated that India has limited reserves of uranium, but fairly abundant reserves of thorium. **1**

SECTION - B

4. (i) According to Rutherford's model, electron orbiting around the nucleus, continuously radiates energy due to the acceleration; hence the atom will not remain stable. **1**

- (ii) As electron spirals inwards; its angular velocity and frequency change continuously; therefore it will emit a continuous spectrum. **1**

[CBSE Marking Scheme, 2017]

5. We have

$$R = R_0 A^{1/3} \quad \frac{1}{2}$$

$$\therefore \text{Density, } \rho = \frac{mA}{\frac{4}{3}\pi(R_0 A^{1/3})^3} \quad \frac{1}{2}$$

$$= \frac{m}{\frac{4}{3}\pi R_0^3} \quad \frac{1}{2}$$

Hence ρ is independent of A .

(Here m is the mass of the nucleus.) **1/2**

[CBSE Marking Scheme, 2013]

Detailed Answer :

Mass of nucleus $M = \text{volume of nucleus} \times \text{nucleus density}$

$$M = V \times \rho$$

$$M = \frac{4}{3}\pi R^3 \rho$$

($R = \text{radius of the nucleus}$)

$$R^3 = \frac{3M}{4\pi\rho}$$

$$R = \left(\frac{3}{4\pi\rho}\right)^{\frac{1}{3}} M^{\frac{1}{3}} \quad \dots(i) \frac{1}{2}$$

If $m = \text{mass of one nucleon}$

$M = mA$ where $A = \text{mass number } (Z + N)$

Putting the value of M in eq. (i)

$$R = \left(\frac{3}{4\pi\rho}\right)^{\frac{1}{3}} (mA)^{\frac{1}{3}}$$

We know that

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

Hence,

$$R_0 A^{\frac{1}{3}} = \left(\frac{3}{4\pi\rho}\right)^{\frac{1}{3}} (mA)^{\frac{1}{3}}$$

Cubing both sides

$$R_0^3 A = \frac{3}{4\pi\rho} mA$$

or

$$\rho = \frac{3m}{4\pi R_0^3}$$

Hence, the nuclear density ρ , over a wide range of nuclei is constant and independent of mass number A .

SECTION - C

6. Nuclear Fission is the breaking down of heavier nucleus into smaller fragments while nuclear fusion is combining of lighter nuclei to form heavier nucleus. We see that binding energy per nucleon of daughter nuclei in both fission and fusion processes is more than that of parent nuclei. Further, the difference in binding energy is released in form of energy while in both the processes certain masses get converted into energy. **1 + 1**

In both processes, some mass get converted into energy.

Energy Released,

$$Q = \left[m(^2_1\text{H}) + m(^3_1\text{H}) - m(^4_2\text{He}) - m(n) \right] \times 931.5 \text{ MeV}$$

$$= [2.014102 + 3.016049 - 4.002603 - 1.008665] \times 931.5 \text{ MeV}$$

$$= 0.018883 \times 931.5 \text{ MeV}$$

$$= 17.59 \text{ MeV} \quad \mathbf{1}$$

[CBSE Marking Scheme, 2015]

7. $mvr = \frac{nh}{2\pi}$ Bohr postulate $\frac{1}{2}$

Also, $\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2}$ $\frac{1}{2}$

$\Rightarrow mv^2r = \frac{e^2}{4\pi\epsilon_0}$ $\frac{1}{2}$

$\Rightarrow v = \frac{e^2}{4\pi\epsilon_0} \times \frac{2\pi}{nh} = \frac{e^2}{2\epsilon_0 nh}$ 1

$T = \frac{2\pi r}{v} = \frac{2\pi mvr}{mv^2}$ $\frac{1}{2}$

$$= \frac{2\pi \left(\frac{nh}{2\pi} \right)}{m \left(\frac{e^2}{2\epsilon_0 nh} \right)^2}$$

$$= \frac{4n^3 h^3 \epsilon_0^2}{me^4}$$
 $\frac{1}{2}$

(Also accept if the student calculates T by obtaining expressions for both v and r .)
[CBSE Marking Scheme, 2017]

SECTION - D

8. (i) $mvr = \frac{nh}{2\pi}$ $\frac{1}{2}$

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2}$$

$$r = \frac{e^2}{4\pi\epsilon_0 mv^2}$$

$$r = \frac{e^2}{4\pi\epsilon_0 m \left(\frac{nh}{2\pi mr} \right)^2}$$
 $\frac{1}{2}$

$$\Rightarrow r = \frac{\epsilon_0 n^2 h^2}{\pi m e^2}$$
 $\frac{1}{2}$

Potential energy, $U = -\frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{r}$

$$= -\frac{me^4}{4\epsilon_0^2 n^2 h^2}$$
 $\frac{1}{2}$

$$\text{K.E.} = \frac{1}{2} mv^2 = \frac{1}{2} m \left(\frac{nh}{2\pi mr} \right)^2$$
 $\frac{1}{2}$

$$= \frac{n^2 h^2 \pi^2 m^2 e^4}{8\pi^2 m \epsilon_0^2 n^4 h^4}$$
 $\frac{1}{2}$

$$\text{K.E.} = \frac{me^4}{8\epsilon_0^2 n^2 h^2}$$
 $\frac{1}{2}$

T.E. = K.E. + P.E.

$$= -\frac{me^4}{8\epsilon_0^2 n^2 h^2}$$
 $\frac{1}{2}$

(ii) Rydberg's formula : For first member of Lyman series,

$$\frac{1}{\lambda} = R \left(\frac{1}{1^2} - \frac{1}{2^2} \right)$$

$$\lambda = \frac{4}{3R} = \frac{4}{3} \times 912 \text{ \AA}$$
 $\frac{1}{2}$

$$= 1216 \text{ \AA}$$

For first member of Balmer Series.

$$\frac{1}{\lambda} = R \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$\lambda = \frac{36}{5R}$$
 $\frac{1}{2}$

$$= \frac{36}{5} \times 912 \text{ \AA}$$

$$= 6566.4 \text{ \AA}$$

[CBSE Marking Scheme, 2014]

SOLUTIONS

SELF ASSESSMENT PAPER-9

Time : 1 Hours

Maximum Marks : 25

SECTION - A

1. (i) Holes are the minority carrier in n -type Silicon. 1
- (ii) The two processes that take place in the formation of a p - n junction are :
 - (i) Diffusion
 - (ii) Drift

1. When a p - n junction is being formed, holes diffuse from the p -side to the n -side and electrons diffuse from n -side to the p -side due to the concentration gradient of holes and electrons.
2. An electric field develops across the p - n junction, this electric field causes the movement of electrons from the p -side to the n -side and holes from the n -side to p -side. This motion of charged carrier due to the electric field is called drift. 1

(iii) The important requisites of an intermediate band is that it is not electronically coupled to the other bands, this means that one cannot have a single Fermi level. Instead, there should be the formation of three separated quasi-Fermi levels within the three bands *i.e.* conduction band, valence band and intermediate band.

(iv) In the three given elements, the energy band gap of carbon is the maximum and that of germanium is the least. The energy band gaps of these elements are related as :

$$(E_g)_C > (E_g)_{Si} > (E_g)_{Ge} \quad 1$$

2. (i) **Correct option : (d)**

Explanation: As temperature increases, the covalent bonds of semiconductor rupture and more number of carriers become available. So resistivity decreases and conductivity increases. So the question is false. Energy band gap for semiconductor is normally less than 1 eV. So, the reason is true. But reason does not explain the assertion.

(ii) **Correct option : (d)**

Explanation: Einstein demonstrated the particle nature of light by photoelectric effect. So, the assertion is false.

Also number of photons is not the measure of intensity. Hence the reason is also false.

3. (i) **Correct option : (b)**

LED is a heavily doped *p-n* junction diode. 1

(ii) **Correct option : (b)**

LED under forward bias emits spontaneous radiation. 1

(iii) **Correct option : (b)**

On recombination, the energy is released in the form of photons. Photons with energy equal to or slightly less than the band gap are emitted. 1

(iv) **Correct option : (b)**

The V-I characteristics of a LED is similar to that of a Si junction diode. But the threshold voltages are much higher and slightly different for each colour. 1

(v) **Correct option : (b)**

The reverse breakdown voltages of LED's are very low, typically around 5V. 1

SECTION - B

4. Any two differences

1 + 1

	Intrinsic	Extrinsic
(i)	Pure semiconductor	Doped with impurity
(ii)	$n_e = n_h$	$n_e = n_h$
(iii)	Low conductivity to room temperature.	Higher conductivity at room temperature.
(iv)	Conductivity depends on temperature	Conductivity does not depend significantly on temperature.

[CBSE Marking Scheme 2017]

5. No.

$$\begin{aligned} \text{Energy of photon } E &= \frac{hc}{\lambda} \\ &= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{6000 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{ eV} \\ &= 0.206 \text{ eV} \end{aligned}$$

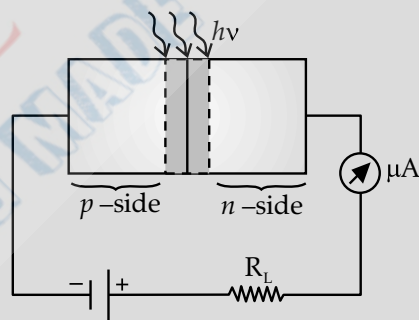
As $E < E_g$ (2.8 eV), so photodiode cannot detect this photon.

SECTION - C

6. It is fabricated with a transparent window to allow light to fall on diode. 1½

When the photodiode is illuminated with photons of energy ($h\nu > E_g$) greater than the energy gap of the semiconductor, electron hole pairs are generated. These get separated due to the junction electric field (before they recombine) which produce an emf. 1

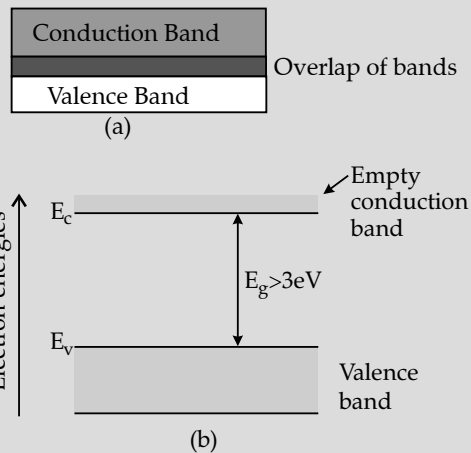
Reason : It is easier to observe the change in the current, with change in light intensity, if a reverse bias is applied.



Alternatively,

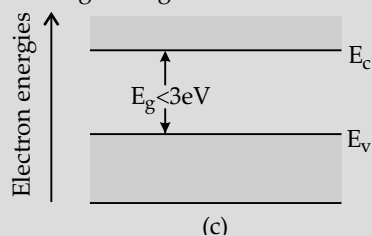
The fractional change in the minority carrier current, obtained under reverse bias, is much more than the corresponding fraction change in majority carrier current obtained under forward bias. [CBSE Marking Scheme, 2015] 1

7.



(a) metals, (b) insulators and (c) semiconductors**(½ each)**

Two distinguishing features :



(i) In conductors, the valence band and conduction band tend to overlap (or nearly overlap), while in insulators they are separated by a large energy gap and in semiconductors they are separated by a small energy gap. **1**

(ii) The conduction band of a conductor, has a large number of electrons available for electrical conduction. However, the conduction band of insulators is almost empty while that of the semiconductor has only a (very) small number of such electrons available for electrical conduction.

[CBSE Marking Scheme 2014] ½

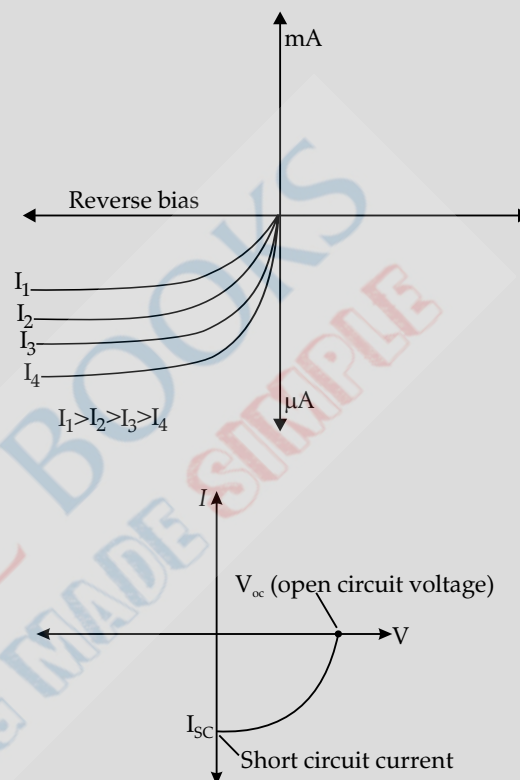
SECTION - D

8. (a) The fractional change in majority charge carriers is very less compared to the fractional change in minority charge carriers on illumination. **2**

(b) The difference in the working of two devices :

	Photodiode	Solar cell
(i) Biased	Used in reverse biasing	No external biasing is given

(ii) Junction Area	Small	Large for solar radiation to be incident on it.
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1**(iii) I-V characteristics****1**

[CBSE Marking Scheme, 2018]