Inter (Part-II) 2019

Physics	Group-II	PAPER: II
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) What is electric intensity? What is its SI unit?

Ans Electric field intensity at any point is defined as "The force acting on a unit +ve charge placed at that point."

SI unit of electric intensity is Newton per Coulomb (NC^{-1}).

(ii) Show that $\frac{1\text{ volt}}{1\text{ meter}} = \frac{1\text{ Newton}}{1\text{ Coulomb}}$.

Ans SI unit of electric intensity from equation $E = \frac{v\Delta}{\Delta r}$ is $\frac{\text{volt}}{\text{meter}}$.

$$1\frac{\text{volt}}{\text{meter}} = 1\frac{\text{Joul / coulomb}}{\text{meter}}$$

$$= 1\frac{\text{Newton} \times \text{meter}}{\text{meter} \times \text{coulomb}} = 1\frac{\text{Newton}}{\text{Coulomb}}$$

Hence $1\frac{\text{volt}}{\text{meter}} = \frac{\text{Newton}}{\text{Coulomb}}$

(iii) Describe the force or forces on a positive point charge when placed between parallel plates with similar and equal charges.

Ans When a positive point charge is placed between parallel plates with similar and equal charges, then the net force on the charge will be zero. Thus the value of resultant electric intensity "E" is zero because the electric intensity "E_1" due to one plate is equal in magnitude but opposite in direction of electric intensity "E_2" due to the other plate

$$E = E_1 - E_2 = 0$$

Hence the net force on the positive charge is zero. Thus, it will remain at rest.

(iv) Do electrons tend to go to region of high potential or of low potential?

Ans Since, a positive charge would move from high potential to low potential and a current is defined as a direction that positive charge would flow, an electron does the opposite. So, electrons tend to go from low potential to high potential.

(v) **Describe the change in the magnetic field inside a solenoid carrying a steady current I, if the length of the solenoid is doubled but the number of turns remains the same.**

Ans The strength of magnetic field B produced inside the solenoid when it has 'n' number of turns per unit length and carries current I is given by

$$B = \mu_o n I$$

The value of 'n' can be expressed as $n = \frac{N}{l}$ where N is total turns in the length 'l' of solenoid.

$$B = \mu_o \frac{N}{l} I$$

When $l = 2l$

$$B' = \mu_o \frac{N}{2l} I$$

or

$$B' = \frac{B}{2}$$

Thus on doubling the length of solenoid keeping its turns same, the number of turns per unit length decreases and hence the value of field also decreases.

(vi) **What is CRO? What is the function of grid in CRO?**

Ans Cathode Ray Oscilloscope (CRO) is basically a high speed graph-plotting device. It is a very versatile electronic instrument.

Function of grid in CRO:

The grid G is at a negative potential with respect to the cathode. It controls the number of electrons which are accelerated by anodes and thus, it controls the brightness of the spot formed on the screen.

(vii) Define ammeter. How can we increase the range of an ammeter?

Ans Ammeter is an instrument used for the measurement of electric current in amperes. It is basically galvanometer. Ordinary galvanometer cannot be used for measuring large currents without proper modification.

If we want to measure a maximum current-I, it is necessary to connect a low value bypass resistor called shunt.

(viii) Suppose that a charge q is moving in a uniform magnetic field with a velocity V. Why is there no work done by the magnetic force that acts on the charge q?

Ans The magnetic force on the charged particle moving in magnetic field is given by

$$\vec{F}_m = q(\vec{V} \times \vec{B})$$

The force $\vec{F}$ is normal to the motion of charged particle, so the work done by this force is given by

$$W = \vec{F}_m \cdot \vec{d}$$

where $\vec{d}$ is the displacement of charged particle and is at right angle to the force $\vec{F}_m$, so

$$W = F_m d \cos 90^\circ$$

$$W = 0 \qquad \because (\cos 90^\circ = 0)$$

Thus we can say that magnetic force is only deflecting force and it cannot do any work.

(ix) State Faraday's law of electromagnetic induction and also write expression for it.

Ans It states that the emf induced in around any loop is equal to the negative rate of change of outward magnetic flux through the surface bounded by the loop.

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

This is known as Faraday's law of electromagnetic induction. The minus sign indicates that the direction of the induced emf is such that to oppose the change in flux.

(x) Define mutual inductance of the coils and also define its unit henry.

Ans The phenomenon in which a changing current in one coil induces an emf in another coil is called mutual inductance. Mutual inductance depends upon the number of turns of coil, their area of cross-section, their closeness together and nature of core.

One henry is the mutual inductance of pair of coils in which the rate of change of current of one ampere per second in the primary coil causes an induced emf of one volt in the secondary coil.

(xi) Does the induced emf in a circuit depend on the resistance of the circuit? Does the induced current depend on the resistance of the circuit?

Ans An expression for induced emf is given by

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

This relation shows that the induced emf in a coil only depends upon the rate of change of magnetic flux and number of turns but does not depend upon the resistance of the coil or the circuit.

As the induced current flowing through a coil is given by

$$I = \frac{\varepsilon}{R}$$

This relation shows that the value of current depends upon the resistance of the coil. The smaller the value of the resistance of the coil, greater will be the value of current.

(xii) In a transformer, there is no transfer of charge from the primary to secondary. How is, then the power transferred?

Ans The two coils of the transformer are magnetically linked *i.e.,* the change of flux through one coil is linked with other coil and induced emf is produced. Power is transferred due to magnetic flux linkage.

3. Write short answers to any EIGHT (8) questions: (16)

(i) Define temperature coefficient of resistance and write its formula.

Ans "The fractional change in resistance per kelvin is known as the temperature coefficient of resistance."

Unit:

The SI unit of α (temperature coefficient) is K^{-1}.

The formula of temperature coefficient of resistance is:

$$\alpha = \frac{R_t - R_o}{R_{ot}}$$

(ii) A potential difference is applied across the ends of a copper wire. What is the effect on the drift velocity of free electrons by decreasing the length and the temperature of the wire?

Ans We know that

$$v_d = \frac{1}{n\,Ae}$$

where $I = \frac{\Delta V}{R}$ and $R = \rho \frac{L}{A}$

Therefore, eq. becomes as

$$v_d = \frac{\dfrac{\Delta V}{\rho \frac{L}{A}}}{n\,Ae}$$

$$v_d = \frac{\Delta V}{ne\rho L}$$

From this equation, it is clear that decreasing the length and temperature of the wire, drift velocity will also increase.

(iii) Is the filament resistance lower or higher in a 500 W, 220 V light bulb than in a 100 W, 220 V?

Ans We know that

$$P = \frac{V^2}{R} \quad \text{or} \quad R = \frac{V^2}{P}$$

The resistance of filament of bulb of 500 W, 220 V is

$$R_1 = \frac{(220)^2}{500} = 98.6\ \Omega$$

On the other hand, the resistance of filament of bulb of 100 W, 220 V is

$$R_2 = \frac{(220)^2}{100} = 484\ \Omega$$

It is clear that filament resistance is lower in a 500 W, 220 V light bulb than that in 100 W, 220 V bulb.

(iv) What is impedance? Write its formula.

Ans The combined effect of resistance and reactances in a circuit is known as impedance and is denoted by Z. It is measured by the ratio of the rms value of the applied voltage to the rms value of resulting A.C. Thus,

$$Z = \frac{V_{rms}}{I_{rms}}$$

Its S.I unit is ohm.

(v) A sinusoidal current has rms value of 10 A. What is the maximum or peak value?

Ans rms (effective) values of current = I_{rms} = 10 A

Peak values = Maximum value = I_o = ?

Using the formula

$$I_{rms} = \frac{I_o}{\sqrt{2}}$$

or $$I_o = \sqrt{2}\, I_{rms}$$

$$= 1.414 \times 10 \qquad (\because \sqrt{2} = 1.414)$$

$$I_o = 14.14 \text{ A}$$

Thus, maximum or peak value of current is 14.14 A.

(vi) What is meant by A.M. and F.M.?

Ans **A.M:**

The term A.M stands for amplitude modulus. A type of modulation in which amplitude of carrier wave is increased or decreased as amplitude of superposing modulating signal increases or decreases.

F.M:

The term F.M stands for frequency modulation. A type of modulation in which frequency of carrier wave is increased or decreased as modulating signal amplitude increases or decreases.

(vii) Differentiate between ductile and brittle substances.

Ans Ductile substances are such substances which undergo plastic deformation until they break.

Brittle substances are such substances which break just after the elastic limit is reached.

(viii) Define stress and strain. What are their SI units?

Ans **Stress:**

It is defined as "The force applied on unit area to produce any change in shape, volume or length of a body."

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

Its unit is Nm^{-2}.

Strain:

"The change in the dimension of a body, produced by the action of the deforming force is called strain."

It has not unit.

(ix) What is meant by hysteresis loss?

Ans Hysterises loss is the energy expended to magnetize and demagnetize the core material in each cycle of the A.C.

(x) What is depletion region?

Ans Just after the formation of the p-n-junction, the free electrons in the n-region, because of their random motion, diffuse into the p-region. As a result of this diffusion, a region is formed around the junction in which charge carriers are not present. This region is known as depletion region the positive and negative ions which constitute the depletion region. Due to charge on these ions a potential difference develops across the depletion region.

(xi) How does the motion of an electron in a n-type substance differ from the motion of holes in a p-type substance?

Ans The motion of electrons in n-type semi-conductor is more fast than motion of holes in p-type semi-conductor.

(xii) What is the principle of virtual ground?

Ans Since, the open loop gain of operational amplifier is very high of the order of 10^5.

$$A_{OL} = \frac{V_o}{V_+ - V_-} = 10^5.$$

This is possible only when $V_+ - V_-$ is very small *i.e.*, $V+ - V- \approx 0 \Rightarrow V+ \approx V-$, *i.e.*, both inputs of op-amp are virtually at same potential. Thus if one input is grounded, the other is virtual grounded *i.e.*, if $V_+ = 0 \Rightarrow V_- = 0$. This is known as principle of virtual ground.

4. Write short answers to any SIX (6) questions: (12)

(i) Define Compton effect. At what angle Compton shift becomes equal to the Compton wavelength?

Ans The phenomenon in which the wavelength of the scattered X-rays is larger than the incident X-rays is known as Compton effect.

$$\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)$$

where m_o is the rest mass of the electron. The factor $\frac{h}{m_o c}$ has dimensions of length and is called Compton wavelength and has numerical value

$$\frac{h}{m_o c} = \frac{6.63 \times 10^{-34}\ \text{Js}}{9.1 \times 10^{-31}\ \text{kg} \times 3 \times 10^{8}\ \text{ms}^{-1}}$$

$$= 2.43 \times 10^{-12}\ \text{m}$$

If the scattered X-ray photons are observed at $\theta = 90^o$, the Compton shift $\Delta\lambda$ equals the Compton wavelength.

(ii) As a solid is heated and begins to glow, why does it first appear red?

Ans When a solid is heated, then at the start of its glow, it appears red because it emits wavelength of red light radiation.

(iii) What happens to radiation energy from a blackbody if its temperature is doubled?

Ans According to Stefen's law,

Total radiation intensity $\propto$ 4th power of its temperature.

When the temperature is increased to double of its value, then

$$E = 2^4 = 16$$

Thus, if the absolute temperature is doubled, the total radiation emitted by black body increases 16 times.

(iv) Define excitation energy and ionization energy.

Ans **Excitation Energy:**

The amount of energy to lift an electron from ground state to any higher energy state is called excitation energy.

Excitation energy = Energy of excited state – Energy of ground state

Ionization Energy:

The amount of energy required to remove the electron from the atom is called ionization energy. For hydrogen atom, the ionization energy is 13.6 eV.

(v) How can spectrum of hydrogen contain so many lines when hydrogen contains one electron? Explain.

Ans When the energy is supplied to the atom of hydrogen, it will be excited. Then, its single electron will jump from its ground state to some higher energy level. Now, when it de-excites from higher level to ground level by several jumps, spectral lines of different wavelength are emitted. That is why, the spectrum of hydrogen contains many lines.

(vi) Can X-rays be reflected, refracted and polarized just like any other waves? Explain.

Ans X-rays are similar in nature to ordinary light with the difference of frequency and wavelength and as a part of electromagnetic spectrum, it can be reflected, refracted diffracted and polarized.

(vii) Write down two advantages of solid state detector.

Ans Two advantages of solid state detector are as follow:

1. It is very small in size than any other detector and operates at low voltage.
2. The solid state detectors are more useful for detecting α and β particles whereas a specially designed detector and an amplifier can also be used for high energy γ-rays.

(viii) Why are heavy nuclei unstable?

Ans Heavy nuclei are unstable because their binding energy per nucleon is less than the lighter nuclei. Also, neutrons are not so rigidly bound with each other. As they are unstable, so less energy is required to split heavy nuclei.

(ix) A particle which produces more ionization is less penetrating. Why?

Ans A particle which produces more ionization loses a part of its energy during each collision with an atom. The process of ionization continues till the particle losses all its energy and comes to rest. Therefore, it has less penetrating power. As α-particle is highly ionizing, therefore, its penetrating power is less.

SECTION-II

NOTE: Attempt any THREE (3) questions.

Q.5.(a) What is Gauss's law? Applying Gauss's law to find the electric intensity between two oppositely charged parallel plates. (5)

Ans Gauss's law states that "The flux through any closed surface is $\frac{1}{\varepsilon_o}$ times the total charge enclosed in it."

Mathematically, expression of Gauss's law is

$$\phi_e = \frac{1}{\varepsilon_o} \times Q$$

Electric intensity between two oppositely charged parallel plates:

Consider two oppositely charged parallel metal plates of infinite extent. Due to electric attraction, the changes appear on the inner surfaces of the plates. Let the surface charge density on each plate is σ, *i.e.,*

$$\sigma = \frac{q}{A}$$

In order to find out electric intensity E between the plates, we imagine a closed Gaussian surface in the form of a hollow box with its top inside the upper plate and its bottom in the space between plates as shown in fig. below. Since the field lines are parallel to the sides of box, so there is no flux through them.

i.e., $\phi_1 = 0$

As, there is no change inside the upper plate, so flux through the top is also zero

i.e., $\phi_2 = 0$

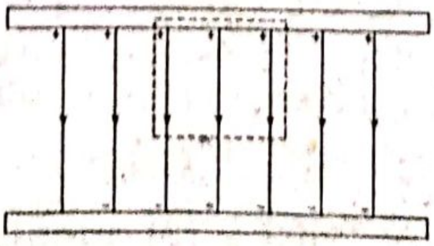
If A is the area of bottom, then flux through it is given by

$$\phi_3 = EA$$

Now total flux through box is

$$\phi_e = \phi_1 + \phi_2 + \phi_3 = 0 + 0 + EA$$

$$\phi_e = EA$$



According to Gauss's law, we have

$$\phi_e = \frac{q}{\varepsilon_o} \quad (1)$$

As $\sigma = \frac{q}{A}$ $\Rightarrow$ $q = \sigma A$

Now putting $\phi_e = EA$ and $q = \sigma A$ in eq. (1)

$$EA = \frac{\sigma A}{\varepsilon_o}$$

$$E = \frac{\sigma}{\varepsilon_o}$$

In vector form,

$$\vec{E} = \frac{\sigma}{\varepsilon_o}\hat{r}$$

where $\hat{r}$ is the unit-vector directed from positive to negative plate.

(b) A rectangular bar of iron is 2.0 cm by 2.0 cm in cross-section and 40 cm long. Calculate the resistance if the resistivity of iron is $11 \times 10^{-8}\ \Omega m$. (3)

Ans $R = ?$

$L = 40\text{ cm} = 40 \times 10^{-2}\text{ m}$

$A = 2 \times 2 \times 10^{-4}\text{ m}^2$

$$R = \rho\frac{L}{A}$$

$$R = 11 \times 10^{-8} \times \frac{40 \times 10^{-2}}{4 \times 10^{-4}}$$

$$R = 11 \times 10^{-5}\ \Omega$$

$$R = 1.1 \times 10^{-4}\ \Omega$$

Q.6.(a) Derive an expression for torque acting on current carrying coil placed in uniform magnetic field. (5)

Ans Let us place a rectangular coil of wire in a uniform magnetic field that starts from the north pole of the magnet and enters the south pole of the magnet. A current "I" is set up the coil. Any segment of the coil now represents a current carrying wire in an external magnetic field and thus experiences a force on it given by

$$F = I\,L\,B \sin\theta \qquad (1)$$

where 'θ' is the angle between conductor and the field.

Let us divide the coil into four segments AB, CD, BC and DA. In case of segments AB and CD of the coil, the angle θ is zero or 180°, therefore, according to eq. (1), force on these segments will be zero, because sin 0° or sin 180° is equal to zero. But in case of segment BC and DA, the angle θ is 90° and force on these side will be

$$F_1 = F_2 = I\,L\,B \sin 90^\circ$$

$$F_1 = F_2 = I\,L\,B \times 1 \qquad (\because \sin 90^\circ = 1)$$

Therefore,

$$F_1 = F_2 = I\,L\,B$$

where,

L = Length of the sides BC and DA
F_1 = Force on the side DA
F_2 = Force on the side BC and cos α
I = Current flowing through the coil
B = Magnetic field in which the coil is placed

The direction of the force is given by the vector $\vec{IL} \times \vec{B}$. It can be seen from figure, that $\vec{F_1}$ is directed out of the plane of the paper and $\vec{F_2}$ into the plane of the paper.

Therefore, the forces $\vec{F}_1$ and $\vec{F}_2$ are equal and opposite, so they form a couple which tends to rotate the coil about the axis. The torque of this couple is given by

$$\tau = \text{Force} \times \text{Moment arm}$$

$$\tau = I\,L \times a$$

where 'a' is the moment arm of the couple and is equal to the length of the side AB and CD. La is the area "A" of the coil, so the above equation becomes as

$$\tau = I\,B\,A \qquad (2)$$

Eq. (2) gives the value of the torque when the field $\vec{B}$ is in the plane of the coil. However, if the field makes an angle α with the plane of the coil, as shown in fig. (2), the momentum now because is a cos α, so

$$\tau = \text{Force} \times \text{moment arm}$$

$$\tau = I\,L\,B \times a\cos\alpha \qquad (\because \ La = A)$$

or $$\tau = I\,B\,A\cos\alpha \qquad (3)$$

However, if the coil has "N" turns, then total torque on the coil is

$$\tau = B\,I\,N\,A\cos\alpha$$

(b) A circular coil has 15 turns of radius 2 cm each. The plane of the coil lies at 40° to a uniform magnetic field of 0.2 T. If the field is increased by 0.5 T in 0.2 s, find the magnitude of induced emf? (3)

Ans Given data:

No. of turns = N = 15

Radius = 2 cm = 2×10^{-2} m

Area of cross-section = A = πr^2

$= (3.14)(2 \times 10^{-2})^2$

$= 1.25 \times 10^{-3}\ m^2$

Angle between plane of coil and field = 40°

Angle between vector and the field = 90° − 40° = 50

Initial field strength = B_1 = 0.2 T

Final magnetic field = B_2 = 0.5 T

Change in field = $\Delta B = B_2 - B_1 = 0.5 - 0.2 = 0.3$ T

Time interval = Δt = 0.2 sec

To find: Induced emf = ε = ?

Calculation:

Using formula = $\varepsilon = N \frac{\Delta\phi}{\Delta t}$

As, $\Delta\phi = \Delta\vec{B} \cdot \vec{A}$

$= \Delta B.A \cos\theta$

$= \frac{N \Delta B A \cos\theta}{\Delta T}$

$= \frac{15 \times 0.3 \times 1.25 \times 10^{-3} \times \cos 50^\circ}{0.2}$

$\varepsilon = 1.8 \times 10^{-2}$ volt

Induced e.m.f = ε = 1.8×10^{-2} volt.

Q.7.(a) Define comparator. Describe, how it is used as a night switch? (1,1,3)

Ans **Comparator:**

A comparator is a circuit that accepts the voltage V_1 and V_2 and output is zero volt. If $V_1 > V_2$ or outputs a positive voltage level of $V_2 > V_1$, then comparator can be built from operational amplifier.

Used as a Night Switch:

It is observed that when an op-amp is used as a comparator, the street light at night can also be automatically switched on when intensity of light is below a certain limit.

The circuit for the operation of comparator as night switch is shown in figure. So, in this figure, resistances R_1 and R_2 form a potential divider. The potential drop across R_2 provides the reference voltage V_R to (+) input of the op-amp. Thus

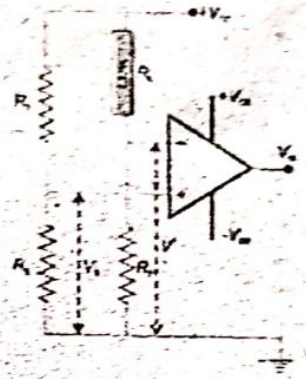
V_R = current in $(R_1 + R_2) \times R_2$

$$V_R = \frac{V_{cc}}{(R_1 + R_2)} \times R_2$$

or $$V_R = \frac{R_2}{(R_1 + R_2)} \times V_{cc} \qquad (1)$$

Light Dependent Resistance:

In the circuit diagram, LDR (R_1) is the light dependent resistance whose value depends upon the intensity of light falling upon it. R_2 and R_3 form another potential divider. The potential drop across R_3 is V′ which is given by



$$V' = \frac{R_3}{R_2 + R_3} \times V_{CC} \qquad (2)$$

V′ provides the voltage to (–) input of the op-amp. V′ will not be a constant voltage but it will vary with the intensity of light.

During Day Time:

When light is falling upon LDR, R_L is small. According to equation (2), V′ will be greater such that

$$V' > V_R \text{ so that } V_o = -V_{cc}$$

The output of the op-amp is connected with a relay system which gets energy (*i.e.*, power) only when $V_o = +V_{cc}$ and then it turns on the street lights. Thus, when $V_o = -V_{cc}$, the light will not be switched ON.

During Night:

After sunset as it gets darker, R_L becomes larger and V′ decreases. When V′ becomes just less than V_R, then the output of op-amp switches to $+V_{cc}$ (*i.e.*, $V_o = +V_{CC}$) which energizes the relay system and hence the street lights are switched or (turned) ON.

(b) A circuit has an inductance of $\frac{1}{\pi}$ H and resistance of 2000 Ω. A 50 Hz A.C is supplied to it. Calculate the reactance and impedance offered by the circuit. (3)

Ans Given data,

$$\text{Inductance} = L = \frac{1}{\pi}\text{ H}$$

$$\text{Resistance} = R = 2000\ \Omega$$

$$\text{Frequency} = f = 20\text{ Hz}$$

To Find:

(i) Reactance $= X_2 = ?$

(ii) Impedance $= Z = ?$

(i) Using formula,

$$X_L = 2\pi f_L$$

$$X_L = 2\pi \times 50 \times \frac{1}{\pi}$$

$$X_L = 100\ \Omega$$

(ii) Using formula,

$$Z = \sqrt{R^2 + XL^2}$$

$$= \sqrt{(2000)^2 + (100)^2}$$

$$= \sqrt{4010000}$$

$$Z = 2002.5\ \Omega$$

Reactance $= X_2 = 100\ \Omega$

Impedance $= Z = 2002.5\ \Omega$

Q.8.(a) Describe the formation of energy bands in solids. Explain the difference amongst electrical behaviour of conductors, insulators and semiconductors in terms of energy band theory. (4)

Ans Electrons of an isolated atom are bound to the nucleus, and can only have distinct energy levels. However, when a large number of atoms, say N, are brought close to one another to form a solid, each energy level of the isolated atom splits into N sub-levels, called states, under the action of the forces exerted by other atoms in the solid. These permissible energy states are discrete but so closely spaced that they appear to form a continuous energy band. There is a range of energy states which cannot be occupied by electrons. These are called forbidden energy states, and its range is termed as forbidden energy gap.

According to band theory, there are three types of energy bands:

(i) Valence band (ii) Conduction band
(iii) Filled band

(i) Valence band:

The energy band occupying the valence electrons is known as valence band. It is the highest occupied band. It may be completely filled or partially filled and can never be empty.

(ii) Conduction band:

The band above the valence band is called conduction band. It may be either empty or partially filled with electrons. In conduction band, the electrons move freely and conduct electric current through solids.

(iii) Filled band:

The band below the valence band is normally completely filled and is called filled band. Filled bands play no role in the conduction process.

Distinguish Between Conductor, Insulator and Semi-conductor

Conductor:

According to "Energy Band Theory", the conductors are those materials in which:

(i) Valence and conduction bands largely overlap each other.
(ii) There is no physical distinction between the valence and conduction bands.
(iii) A plenty of elements are available for conduction process.

Insulators:

In terms of energy bands, the insulators are those materials in which:

(i) Valence band is completely filled.
(ii) Conduction band is completely empty.
(iii) There are very large energy gaps between valence and conduction bands.

Semi-conductors:

In terms of energy bands, the semi-conductors are those materials in which:

(i) Valence band is partially filled.
(ii) Conduction band is also partially filled.
(iii) There is very small forbidden energy gap of the order of 1 eV between the conduction band and valence band.

(b) An electron is to be confined to a box of the size of the nucleus (1.0×10^{-14} m). What would be the speed of the electron if it were so confined? (3)

Ans Maximum uncertainty in the location of electron is equal to the size of the box itself that is $\Delta x = 1.0 \times 10^{-14}$ m. The minimum uncertainty in the velocity of electron is found from Heisenberg's Uncertainty Principle.

$$\Delta p \approx \frac{h}{\Delta x}$$

$$m\,\Delta v \approx \frac{h}{\Delta x}$$

$$\Delta v = \frac{h}{m\,\Delta x} = \frac{1.05 \times 10^{-34}\ \text{Js}}{9.1 \times 10^{-31}\ \text{kg} \times 1.01 \times 10^{-14}\ \text{m}}$$

$$= 1.15 \times 10^{10}\ \text{ms}^{-1}$$

Q.9.(a) What are postulates of Bohr's model of the hydrogen atom? Show that energy of hydrogen atom is quantized. (5)

Ans **Bohr's Model of the Hydrogen Atom:**

In order to explain the empirical results obtained by Rydberg, Neils Bohr, in 1913, formulated a model of hydrogen atom utilizing classical physics and Planck's quantum theory. This semi-classical theory is based on the following three postulates:

Postulate I:

An electron, bound to the nucleus in an atom, can move around the nucleus in certain circular orbits without radiating. These orbits are called the discrete stationary states of the atom.

Postulate II:

Only those stationary orbits are allowed for which orbital angular momentum is equal to an integral multiple of $\frac{h}{2\pi}$ *i.e.,*

$$m\,vr = \frac{nh}{2\pi} \qquad \text{(i)}$$

where n = 1, 2, 3, ... and n is called the principal quantum number, m and v are the mass and velocity of the orbiting electron, respectively, and h is Planck's constant.

Postulate III:

Whenever an electron makes a transition, that is, jumps from high energy state E_n to a lower energy state E_p, a photon of energy hf is emitted so that

$$hf = E_n - E_p \qquad \text{(ii)}$$

Quantized Radii:

Consider a hydrogen atom in which electron moving with velocity v_n is in stationary circular orbit of radius r_n. From equation (i),

$$v_n = \frac{nh}{2\pi m r_n} \qquad \text{(iii)}$$

For this electron to stay in the circular orbit, shown in fig., the centripetal force $F_c = \frac{mv_n^2}{r_n}$ is provided by the Coulomb's force $F_e = \frac{ke^2}{r_n^2}$, where e is the magnitude of charge on electron as well as on the hydrogen nucleus consisting of a single proton. Thus,

$$\frac{m v_n^2}{r_n} = \frac{k e^2}{r_n^2} \qquad \text{(iv)}$$

where constant k is equal to $\frac{1}{4\pi\varepsilon_o}$.

After substituting for v_n from eq. (iii), we have,

$$r_n = \frac{n^2h^2}{4\pi^2 kme^2} = n^2 r_1 \qquad \text{(v)}$$

where $r_1 = \frac{h^2}{4\pi^2 kme^2} = 0.053 \text{ nm}$

This agrees with the experimentally measured values and is called the first Bohr orbit radius of the hydrogen atom. Thus, according to Bohr's theory, the radii of different stationary orbits of the electrons in the hydrogen atom are given by,

$$r_n = r_1, 4r_1, 9r_1, 16r_1, ...$$

Substituting the value of r_n from eq. (v) in eq. (iii), the speed of electron in the nth orbit is:

$$v_n = \frac{2\pi ke^2}{nh}$$

(b) How much energy is absorbed by a man of mass 80 kg who receives a lethal whole body equivalent dose of 400 rem in the form of low energy neutrons for which RBE factor is 10? (3)

Ans

RBE Factor = 10

$D_e = 400 \text{ rem} = 400 \times 0.01 \text{ Sv} = 4 \text{ Sv}$

$D = ?$

$$D = \frac{D_e}{RBE} = \frac{4 \text{ Sv}}{10} = 0.4 \text{ Gy}$$

Since 1 Gy is 1 J kg^{-1}, hence total energy absorbed by the whole body = mD = 80 × 0.4 Gy = 32 J.