Inter (Part-II) 2021

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) Is E necessarily zero inside a charged rubber balloon if balloon is spherical? Assume that charge is distributed uniformly over the surface.

Ans The Gaussian surface considered inside a charged balloon does not contain any charge, so, from Gauss's law

$$\phi = \frac{1 \times 0}{\varepsilon_o} = \frac{1}{\varepsilon_o} \times 0 = 0$$

But $\phi = EA$ or $0 = EA$ As $A \neq 0$, So $E = 0$. It follows that electric field inside spherical charged balloon is zero.

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

Ans Since, electrons are negatively charged, so they tend to go to region of high potential, towards positive charge.

(iii) How a sensitive electric apparatus is shielded from electric fields?

Ans To eliminate stray electric field interference, circuits of sensitive electronics devices such as T.V and computers are often enclosed within metal boxes.

(iv) Give a comparison of electric and gravitational forces.

Ans

Electric Force	Gravitational Force
1. The electric force between two charges is written as:	1. The gravitational force between two point masses is written as:

	$F = \frac{q_1 q_2}{4\pi\varepsilon_o r^2}$		$F = G\frac{m_1 m_2}{4\pi\varepsilon_o r^2}$
2.	It varies inversely with the square of distance between two charges.	2.	It varies inversely with the square of distance between two masses.
3.	The value of electrical constant $\frac{1}{4\pi\varepsilon_o}$ is large.	3.	The value of gravitational constant G is small.
4.	The electric force can be attractive or repulsive.	4.	The gravitational force is only attractive.

(v) Describe the right hand rule to find the direction of magnetic field inside a current carrying solenoid.

Ans The direction of the lines of force can be found by a rule below:

If the wire is grasped in fist of right hand with the thumb pointing in the direction of the current, the fingers of the hand will circle the wire in the direction of the mag field.

This is known as right hand rule.

(vi) Electric force does work, while no work is do by the magnetic force. Why?

Ans When a charge particle q is moving with velocity v a region where there is an electric field E and magne field B, the total force F is the vector sum of the elec force qE and magnetic force q(v × B), that is,

$$F = F_e + F_B$$

$$F = qE + q(v \times B).$$

This force F is known as the Lorentz force. It is pointed out that only the electric force does work, w work is done by the magnetic force which is deflecting force.

(vii) A plane conducting loop is located in a uniform magnetic field that is directed along the x-axis. For what orientation of the loop is the flux a maximum? For what orientation is the flux a minimum?

Ans When the plane of the loop is held perpendicular to the direction of the magnetic field (*i.e.,* along x-axis), the maximum flux will pass through it. As we know

$$\phi_e = \vec{B}.\Delta\vec{A} = B\Delta A \cos 0^0 = B\Delta A \quad (1)$$

Because the field is directed along the normal to the surface area, so $\theta = 0$ and $\cos 0^0 = 1$. Thus, the flux will be maximum. (By Eq. 1)

When the plane of the loop is parallel to the direction of magnetic field, the minimum flux will pass through it.

As, $\phi_e = \vec{B}.\Delta\vec{A}$

$= B\,\Delta\,A \cos 90^o$

or $\phi_e = B\,\Delta\,A \times 0 = 0$

$$\phi_e = 0 \quad (2)$$

Because the angle between the field and normal to the surface area is 90^o, *i.e.,* $\theta = 90^o$ and $\cos 90^o = 0$. So, the flux through the loop will be minimum. (By Eq. 2)

(viii) How can a current loop be used to determine the presence of a magnetic field in a given region of space?

Ans When a current carrying loop is placed in a uniform magnetic field at different orientations, a torque is produced in a loop. If the loop is deflected in that region, then we can say that magnetic field is present due to torque, otherwise not.

(ix) How an emf is induced in a coil of wire using a bar magnet?

Ans A bar magnet and a coil of wire are connected with a galvanometer. When there is no relative motion between the magnet and the coil, the galvanometer indicates no current in the circuit. As soon as the bar magnet is moved towards the coil, a current appears in it. As the magnet is moved, the magnetic flux through the coil changes and this changing flux produces the induced emf and hence induced current in the coil. When the magnet moves away from the coil, a current is again induced but now in opposite direction. The current would also be induced if the magnet is held stationary and the coil is moved.

(x) Why the self-induced emf is sometimes called as back emf?

Ans "The emf that causes an induced emf in the coil when magnetic flux through the coil changes, is called self-induced emf." The self-induced emf must oppose the change that produced it. That is why the self-induced emf is sometimes called as back emf. This is exactly in accord with the Lenz's law. If the current is increased, the induced emf will be opposite to that of battery and if the current is decreased the induced emf will aid, rather than opposing the battery.

(xi) Does the induced emf always act to decrease the magnetic flux through a circuit?

Ans **Lenz's law:**

The direction of the induced current is always so as to oppose the change which causes the current.

Henry:

One Henry is the mutual inductance of the 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.

(xii) Show that ε and $\frac{\Delta\phi}{\Delta t}$ have the same units.

Ans As we know that

$$\varepsilon = \frac{W}{q} = \frac{\text{unit of work}}{\text{unit of charge}} = \frac{J}{C}$$

$\therefore$ Unit of ε = J/C = volt

Hence, unit of $\boxed{\varepsilon = \text{volt}}$ .... (1)

$$\text{Unit of } \frac{\Delta\phi}{\Delta t} = \frac{B\Delta A}{\Delta t} = \frac{NA^{-1}\,m^{-1}m^2}{s}$$

$$= \frac{NA^{-1}m}{s} = \frac{N \times m}{A \times s}$$

But, $N \times m = \text{Joule} = J$

$A \times s = \text{coulomb} = C$

$$\therefore \quad \text{unit of } \frac{\Delta\phi}{\Delta t} = \frac{J}{C} = \text{volt}$$

$$\therefore \quad \boxed{\text{unit of } \frac{\Delta\phi}{\Delta t} = \text{volt}} \quad ..... (2)$$

Hence, it clear from eq. (1) and (2), both ε and $\Delta\phi / \Delta t$ have the same units.

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

(i) Does bends in a wire affect its electrical resistance? Explain.

Ans The resistance of the conductor of length 'L' and area of cross-section 'A' is given as $R = \rho \frac{L}{A}$, where 'ρ' is the resistivity whose value depends upon the nature of the conductor. The formula shows that resistance of conductor depends upon geometry and nature of the conductor. It is clear that bends in conducting wire do not affect its resistance.

(ii) Why does the resistance of a conductor rise with temperature?

Ans As we know that resistance offered by a conductor to the flow of current is due to collisions of free electrons with atoms of lattice. As temperature of the conductor rises, the amplitude of vibration of atoms in lattice increases and probability their collision also increases. Hence resistance of conductor rises with temperature.

(iii) What is temperature co-efficient of resistance?

Ans The change in resistance of a metallic conductor with temperature is found to be nearly linear over a considerable range of temperature above and below 0°C. Over such a range, the fractional change in resistance per kelvin is known as the temperature coefficient of resistance *i.e.*,

$$\alpha = \frac{R_t - R_o}{R_o t}$$

where R_o and R_t are resistances at temperature 0°C and t°C.

(iv) 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 $I_o = \sqrt{2}\, I_{rms}$

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

$I_o = 14.14$ A

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

(v) How many times per second will an incandescent lamp reach maximum brilliance when connected to a 50 Hz source?

Ans The lamp will reach maximum brilliance 100 times per second, because current becomes maximum twice in a cycle. As frequency of AC is 50 Hz *i.e.*, 50 cps.

Maximum Brilliance = 2 × 50 = 100 times per second

(vi) What are the electromagnetic waves?

Ans Each field generates the other and the whole package of electric and magnetic fields will move along propelling itself through space. Such moving electric and magnetic fields are known as electromagnetic waves. The electric field, magnetic field and the direction of their propagation are mutually perpendicular. The electromagnetic waves are periodic, hence they have a wavelength λ which is given by the relation $c = f\lambda$ where f is the frequency and c is the speed of the wave. In free space, the speed of electromagnetic waves is same as speed of light.

Depending upon the values of wavelength and frequency, the electromagnetic waves have been classified into different types of waves as radiowaves, microwaves, infrared rays, visible light, etc.

(vii) Write a note on superconductors.

Ans There are some materials whose resistivity becomes zero below a certain temperature T_c called critical temperature. Below this temperature, such materials are called superconductors. They offer no resistance to electric current and are, therefore, perfect conductors.

(viii) What is meant by hysteresis loss? How is it used in the construction of a transformer?

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

In order to improve the efficiency, care should be exercised to minimize all the power losses. For example, core should be assembled from the laminated sheets of a material whose hysteresis loop area is very small. The insulation between lamination sheets should be perfect so as to stop the flow of eddy currents. The resistance of the primary and secondary coils should be kept to a minimum.

(ix) Differentiate between N-type and P-type substances.

Ans Difference between P-type and N-type substances:

p-type substance	n-type substances
When a silicon crystal is doped with a trivalent	When a silicon crystal doped with a pentavalent

atom *e.g.*, aluminium, boron etc., three valence e^-s of the impurity atom form covalent bond with the three neighbouring Si atoms while the one missing e^- in the bond with fourth Si atom is called a hole which is a vacancy where an electron can be accommodated. Such a substance is called p-type substance.	atom *e.g.*, antimony, four e^-s of antimony will form covalent bonds with four silicon atoms. The fifth electron of antimony is free to move which makes Si a good conduct. This type of material is called n-type substance.

(x) Why ordinary silicon diodes do not emit light?

Ans Ordinary silicon diode does not emit light because of opaque nature of silicon. Wavelength of photon emitted by silicon diode is greater than wavelength of visible light (lies in infrared region) which is not visible.

(xi) Why a photodiode is operated in reverse biased state?

Ans When no light is incident on the junction, the reverse current 'I' is almost negligible but when its p-n junction is exposed to light, the reverse current increases with the intensity of light.

(xii) What is the working principle of a light emitting diode?

Ans Light emitting diodes (LED) are made from special semi-conductors such as gallium arsenide and gallium arsenide phosphide in which the potential barrier between p and n sides is such that when an electron combines with a hole during forward bias conduction, a photon of visible light is emitted. These diodes are commonly used as small light sources. A specially formed array of seven LED's is used for dispalying digits etc., in electronic appliances.

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

(i) If an electron and proton have the same de Broglie wavelength, which particle has greater speed?

Ans The wavelength associated with the particle of mass m when moving with velocity v is given by:

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda}$$

Since both electron and proton have the same de Broglie wavelength. Also 'h' is constant.

$$\therefore \quad v \propto \frac{1}{m}$$

This shows that, if wavelength is same, speed is inversely proportional to mass, therefore, electron will have greater speed as its mass is less than that of proton.

(ii) Which photon red, green or blue carries the most energy and momentum?

Ans **(a) Energy:**

According to the relation E = hf, the photons of blue light having larger frequency must have the largest value of energy as compared with photons of red colour light.

(b) Momentum

Since, $p = \frac{h}{\lambda}$ (Momentum is inversely proportional to wavelength)

and $\lambda = \frac{1}{f}$ (wavelength is inversely proportional to frequency)

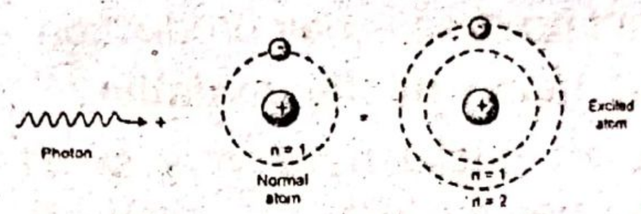
These relations show that if frequency is small, λ is large and hence, 'p' is small. This proves that red light photons have smaller value of momentum than blue light.

(iii) What are black body radiations?

Ans A non-reflecting object such as a solid that has a hollow cavity within it. It has a small hole and the radiation can enter or escape only through this hole. The inside is blackened with soot to make it as good an absorber and as bad a reflector as possible. The small hole appears black because the radiation that enters is reflected from the inside walls many times and is partly absorbed at each reflection until none remains. Such a body is termed as black body and has the property to absorb all the radiation entering it. A black body is both an ideal absorber and an ideal radiator.

(iv) What do we mean when we say that the atom is excited?

Ans



When electron of a normal atom absorbs photon, it is said to be excited atom.

(v) Is energy conserved when an atom emits a photon of light?

Ans Yes, the law of conservation of energy holds when a photon of light emits from the excited room, because the energy absorbed by the atom during its excitation is exactly balanced by the energy emitted during its de-excitation.

(vi) Describe a brief account of interaction of various types of radiations with matter.

Ans An α-particle travels a well-defined distance in a medium before coming to rest. α-particle continues producing intense ionization along its straight path till it loses all its energy and comes almost to rest. It, then, captures two electrons from the medium and becomes a neutral helium atom. β-particles also lose energy by producing ionization. However, its ionizing ability is about 100 times less than that of α-particles. As a result, its range is about 100 times more than α-particles. β-particles are more easily deflected by collisions than heavy α-particles.

Photons of γ-rays, being uncharged, cause very little ionization. Photons are removed from a beam by either scattering or absorption in the medium. They interact with matter in three distinct ways, depending mainly on their energy:

1. At low energies (less than about 0.5 MeV), the dominant process that removes photons from a beam is the photoelectric effect.
2. At intermediate energies, the dominant process is Compton scattering.
3. At higher energies (more than 1.02 MeV), the dominant process is pair production.

(vii) Why are heavy nuclei unstable?

Ans The heavy nuclei have very small value of their binding energy per nucleon. So, they are unstable, and less energy is required to split heavy nuclei.

(viii) What do we mean by term critical mass?

Ans Such a mass of uranium in which one neutron, out of all the neutrons produced in one fission reaction, produces further fission is called critical mass. The volume of this mass of uranium is called critical volume.

(ix) Differentiate between Baryons and Mesons.

Ans Differences between baryons and mesons:

Baryons	Mesons
The particles equal in mass or greater than protons are called baryons.	The particles lighter than protons are called mesons.

SECTION-II

NOTE: Attempt any THREE (3) questions.

Q.5.(a) Define capacitance. Derive an expression for the capacitance of a parallel plate capacitor when dielectric is inserted between the plates. (5)

Ans "The capacitance of a capacitor is one farad if a charge of one coulomb, given to one of the plates of a parallel plate capacitor, produces a potential difference of one volt between them."

Consider a parallel plate capacitor consisting of two plane metal plates, each of area A, separated by a distance d. The distance d is small so that the electric field E between the plates is uniform and confined almost entirely in the region between the plates. Let initially the medium between the plates be air or vacuum.

$$C_{vac} = \frac{Q}{V} \quad (1)$$

where Q is the charge on the capacitor and V is the potential difference between the parallel plates. The magnitude E of electric intensity is related with the distance d.

$$E = \frac{V}{d} \quad (2)$$

As Q is the charge on either of the plates of area A, the surface density of charge on the plates is as

$$\sigma_1 = \frac{Q}{A}$$

The electric intensity between two oppositely charged plates is given by $E = \frac{\sigma}{\varepsilon_o}$. Substituting the value of σ, we have

$$\frac{V}{d} = \frac{Q}{A\varepsilon_o} \quad (3)$$

It gives $C_{vac} = \frac{Q}{V} = \frac{A\varepsilon_o}{d}$ (4)

If an insulating material, called dielectric, of relative permittivity ε_r is introduced between the plates, the capacitance of capacitor is enhanced by the factor ε_r. Capacitors commonly have some dielectric medium, thereby ε_r is also called as dielectric constant.

Following experiment gives the effect of insertion of dielectric between the plates of a capacitor.

Consider a charged capacitor whose plates are connected to a voltmeter. The deflection of the meter is a measure of the potential difference between the plates. When a dielectric material is inserted between the plates, reading drops indicating a decrease in the potential difference between the plates. From the definition, $C = \frac{Q}{V}$, since V decreases while Q remains constant, the value of C increases. Then

$$C_{med} = \frac{A\varepsilon_o\varepsilon_r}{d} \qquad (5)$$

This eq. shows the dependence of a capacitor upon the area of plates, the separation between the plates and medium between them.

Dividing eq. (5) by eq. (4), we get expression for dielectric constant as,

$$\varepsilon_r = \frac{C_{med}}{C_{vac}}$$

Dielectric coefficient or dielectric constant is defined as:

"The ratio of the capacitance of a parallel plate capacitor with an insulating substance as medium between the plates to its capacitance with vacuum (or air) as medium between them."

(b) A rectangular bar of iron is 2 cm by 2 cm in cross-sectional area and 40 cm long. Calculate its resistance if the resistivity is 11×10^{-8} Ωm. (3)

Ans For Answer see Paper 2019 (Group-II), Q.5.(b).

Q.6.(a) Discuss the principle, construction and working of alternating current generator. Also find expression for induced emf and current. (5)

Ans A current generator is a device that converts mechanical energy into electrical energy.

The principle of an electric generator is based on Faraday's law of electromagnetic induction. When a coil is rotated in a magnetic field by some mechanical means, magnetic flux through the coil changes, and consequently an emf is induced in the coil.

If the generator is connected to an external circuit, an electric current is the output of the generator.

Let a rectangular loop of wire of area A be placed in a uniform magnetic field B. The loop is rotated about z-axis through its centre at constant angular velocity ω. One end of the loop is attached to a metal ring R and the other end to the ring R′. These rings, called the slip rings are concentric with the axis of the loop and rotate with it. Rings RR′ slide against stationary carbon brushes to which external circuit is connected.

To calculate the induced emf in the loop, consider its position while it is rotating anticlockwise. The figure shows the top view of the coil. The vertical side ab of the loop is moving with velocity v in the magnetic field B. If the angle between v and B be θ, the motional emf induced in the side ab has the magnitude,

$$\varepsilon_{ab} = vBL \sin\theta$$

The direction of induced current in the wire ab is the same as that of force F experienced by the charges in the wire, *i.e.*, from top to the bottom. The same amount of emf is induced in the side cd but the direction of current is from bottom to the top.

Therefore,

$$\varepsilon_{cd} = vBL \sin\theta$$

The net contribution to emf by sides bc and da is zero because the force acting on the charges inside bc and da is not along the wire.

Thus $\varepsilon_{bc} = \varepsilon_{da} = 0$

Since both the emfs in the sides ab and cd drive current in the same direction around the loop, the total emf in the loop is

$$\varepsilon = \varepsilon_{ab} + \varepsilon_{cd}$$
$$\varepsilon = vBL \sin\theta + vBL \sin\theta$$
$$\varepsilon = 2vBL \sin\theta$$

If the loop is replaced by a coil of N turns, the total emf in the coil will be,

$$\varepsilon = 2\,NvBL \sin\theta \qquad (1)$$

The linear speed v of the vertical wire is related to the angular speed ω by the relation

$$v = \omega r$$

where r is the distance of the vertical wires from the centre of the coil. Substituting ωr for v in eq. (1), we get

$$\varepsilon = 2\,N(\omega\, r)\, BL \sin\theta$$
$$\varepsilon = N\omega(2r\,L)\, B \sin\theta$$
$$\varepsilon = N\omega\, AB \sin\theta \qquad (2)$$

where $A = 2\,r\,L$ = area of the coil

As the angular displacement $\theta = \omega t$, so the eq. (2) becomes

$$\varepsilon = N\omega\, AB \sin(\omega t) \qquad (3)$$

Eq. (3) shows that the induced emf varies sinusoidally with time.

It has the maximum value ε_o when $\sin(\omega t)$ is equal to 1. Thus

$$\varepsilon_o = N\omega\, AB \qquad (4)$$

The eq. (3) can be written as,

$$\varepsilon = \varepsilon_o \sin(\omega t) \qquad (5)$$

If R is the resistance of the coil, then by Ohm's law, induced current in the coil will be

$$I = \frac{\varepsilon}{R} = \frac{\varepsilon_o \sin(\omega t)}{R} = \frac{\varepsilon_o}{R} \sin(\omega t)$$
$$I = I_o \sin(\omega t) \qquad (6)$$

where I_o is maximum current.

Angular speed ω of the coil is related to its frequency of rotation f as, $\omega = 2\pi f$

The eq. (5) and (6) can be written as

$$\varepsilon = \varepsilon_o \sin(2\pi f t) \qquad (7)$$

$$I = I_o \sin (2\pi f) \qquad (8)$$

Eq. (8) indicates the variation of current as a function of $\theta = 2\pi f t$.

When the angle between v & B is $\theta = 0°$, the plane of the loop is perpendicular to B, current is zero. As θ increases, current also increases and at $\theta = 90° = \pi/2$ rad, the loop is parallel to B, current is maximum, directed along abcda. On further increase in θ current decreases, and at $\theta = 180° = \pi$ rad the current becomes zero as the loop is again perpendicular to B. For $180° < \theta < 270°$ current increases but reverses its direction as is clear from the figure. Current is now directed along dcbad. At $\theta = 270° = 3\pi/2$ rad, current is maximum in the reverse direction as the loop is parallel to B. At $\theta = 360° = 2\pi$ rad, one rotation is completed, the loop is perpendicular to B and the current decreases to zero. After one rotation, the cycle repeats itself. The current alternates in direction once in one cycle. Therefore, such a current is called the alternating current. It reverses its direction f times per second.

(b) Find the radius of an orbit of an electron moving at a rate of 2.0×10^7 ms^{-1} in a uniform magnetic field of 2.0×10^{-3} T. (3)

Ans Speed of the electron = $v = 2.0 \times 10^7$ ms^{-1}

Magnetic field strength = $B = 2.0 \times 10^{-3}$ T

Mass of the electron = $m = 9.11 \times 10^{-31}$ kg

Charge on electron = $e = 1.61 \times 10^{-19}$ C

The radius of the orbit is

$$r = \frac{mv}{eB}$$

$$= \frac{9.11 \times 10^{-31} \text{ kg} \times 2.0 \times 10^7 \text{ ms}^{-1}}{1.61 \times 10^{-19} \text{ C} \times 2.0 \times 10^{-3} \text{ T}}$$

$$r = .566 \times 10^{-2} \text{ m}$$

Q.7.(a) What is the behaviour of A.C. current and voltage in inductor? Discuss power loss through an inductor over a period. (5)

Ans **A.C. Through An Inductor:**

An inductor is usually in the form of a coil or a solenoid wound from a thick wire so that it has a large value of self-inductance and has a negligible resistance. We have already seen how self-inductance opposes changes of current. So, when an alternating source of voltage is applied across an inductor, it must oppose the flow of A.C. which is continuously changing. Let us assume that the resistance of the coil is negligible. We can simplify the theory by considering first, the current and then finding the potential difference across the inductor which will cause this current. Suppose the current is $I = I_o \sin 2\pi f t$. If L is the inductance of the coil, the changing current sets up a back emf in the coil of magnitude

$$\varepsilon_L = L\frac{\Delta I}{\Delta t}$$

To maintain the current, the applied voltage must be equal to the back e.m.f. The applied voltage across the coil must, therefore, be equal to

$$V = L\frac{\Delta I}{\Delta t}$$

Since L is a constant, V is proportional to $\frac{\Delta I}{\Delta t}$. Fig. (1) shows how the current I varies with time. The value of $\frac{\Delta I}{\Delta t}$ is given by the slop of the I - t curve at the various instants of time.

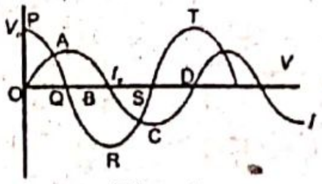


Fig. 1.

At O, the value of the slope is maximum, so the maximum value of V equal to V_o occurs at O and is represented by OP. From O to A, the slope of I - t graph decreases to zero. So, the voltage decreases from V_o to zero at Q. From A to B, the slope of the I - t graph is negative, so the voltage curve goes from Q to R. In this way, the voltage is represented by the curve PQRST corresponding to current curve OABCD. By comparing the phases of the pair of points (O, P), (A, Q), (B, R) (C, S) and (D, T), it can be seen that the phase of the current is always less than the phase of voltage by 90° or $\pi/2$ *i.e.*, current lags behind the applied voltage by 90° or $\pi/2$ or the applied voltage leads the current by 90° or $\pi/2$. This is vectorially shown in Fig (2). Inductive reactance is a

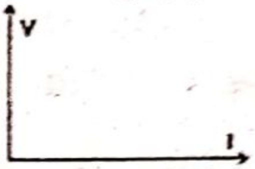


Fig. 2.

measure of the opposition offered by the inductance coil to the flow of A.C. It is usually denoted by X_L.

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

If V_{rms} is rms value of the alternating voltage across an inductance and I_{rms}, the rms value of the current passing through it, the value of X_L is given by

$$X_L = \frac{V_{rms}}{I_{rms}} = 2\pi f L = \omega L$$

The reactance of a coil, therefore, depends upon the frequency of the A.C. and the inductance L. It is directly proportional to both f and L. L is expressed in henry, f in hertz, and X_L in ohms. It is to be noted that inductance and capacitance behave oppositely as a function of frequency. If f is low X_L is small but X_C is large. For high f, X_L is large but X_C is small. The behaviour of resistance is independent of frequency.

Referring to Fig. 1, it can be seen that no power is dissipated in a pure inductor. In the first quarter of cycle, both V and I are positive, so the power is positive, which means energy is supplied to inductor. In the second quarter, V is positive but I is negative. Now power is negative which implies that energy is returned by the inductor. Again in third quarter, it receives energy but returns the same amount in the fourth quarter. Thus, there is no net change of energy in a complete cycle. Since an inductor coil does not consume energy, the coil is often employed for controlling A.C. without consumption of energy. Such an inductance coil is known as choke.

(b) The current flowing into the base of a transistor is 100 μA. Find its collector current I_C, its emitter current I_E and the ratio $\frac{I_C}{I_E}$. If the value of current gain β is 100. **(3)**

Ans For Answer see Paper 2018 (Group-I), Q.7.(b).

Q.8.(a) Describe the principle, construction and working of a Wilson Cloud Chamber. **(5)**

Ans **Wilson Cloud Chamber:**

Principle:

It is a device which shows the visible path of an ionizing particle. It makes use of the fact that supersaturated vapours condense preferentially on ions. If an ionizing particle passes through a region in which cloud droplets are about to form, the droplets will form first along the particle's path, showing the path as a trail of droplets.

Construction:

The apparatus consists of a cylindrical glass chamber closed at the upper end by a glass window and at the lower end by a movable piston.

Working:

A black felt pad soaked in alcohol is placed on a metal plate inside the chamber. The air soon becomes saturated with alcohol vapours. A rapid expansion is produced by pulling quickly the piston of the bicycle pump having the leather washer reversed so that it removes air. The sudden cooling resulted from adiabatic expansion helps to form supersaturated vapours. As radiation passes through the chamber, ions are produced along the path. The tiny droplets of moisture condense about these ions and form vapour tracks showing the path of the radiation. These are the atomic versions of the ice crystals left in the sky by a jet plane when suitable conditions exist. The fog tracks are illuminated with a lamp and may be seen or photographed through the glass window.

The α-particle leave thick, straight and continuous tracks due to intense ionization produced by them as shown in Fig. (a), β-particles form thin and discontinuous tracks extending in erratic manner showing frequent deflections (Fig. b) and γ-rays leave no definite tracks along their path (Fig. c). The length of the cloud tracks has been found proportional to the energy of the incident particle. A high potential difference of the order of 1 kV between the top and bottom of the chamber provides an electric field which clears away all the unwanted ions from the chamber to make it ready for use. The tracks seen are, therefore, those of rays that pass the chamber as the expansion occurs.

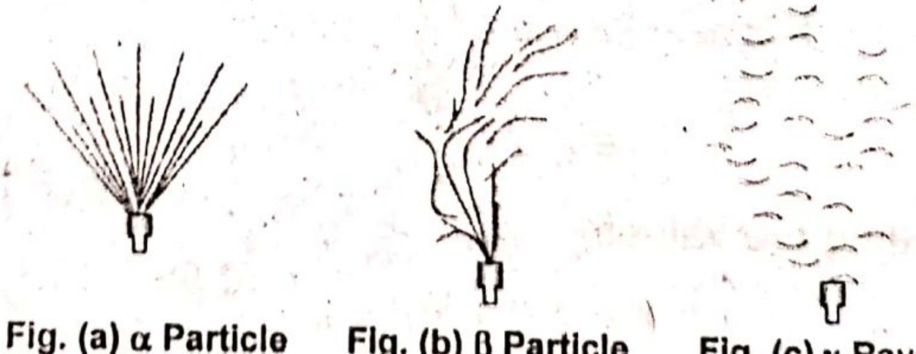


Fig. (a) α Particle **Fig. (b) β Particle** **Fig. (c) γ-Rays**

The chamber may be placed in a strong magnetic field which will bend the paths providing information about the charge, mass and energy of the radiating particle. In this way, it has helped in the discovery of many new particles.

(b) What stress should cause a wire to increase in length by 0.01%, if the Young's modulus of the wire is 12 × 10¹⁰ P.a? What force would produce this stress if the diameter of the wire is 0.56 mm? (3)

Ans

Stress = σ = ?

Percentage increase in length = 0.01 %

Young's modulus = $Y = 12 \times 10^{10}$ Pa

Diameter of wire = $d = 0.56$ mm $= 0.56 \times 10^{-3}$ m

Force = F = ?

Using Formula,

$$Y = \frac{\sigma \text{ (Stress)}}{\varepsilon \text{ (Strain)}}$$

$$\sigma = \varepsilon Y$$

$$\sigma = 12 \times 10^{10} \times \varepsilon$$

$$\text{Strain } (\varepsilon) = \frac{\Delta l}{l} = 0.01 \times \frac{1}{100} = 10^{-4}$$

$$\sigma = 12 \times 10^{10} \times 10^{-4}$$

$$= 1{,}20{,}00{,}000$$

$$\boxed{\text{Stress } \sigma = 1.2 \times 10^7 \text{ Pa}}$$

As $$\sigma = \frac{F}{A}$$

$$F = \sigma A$$

$$= \sigma \times \pi r^2$$

$$= \sigma = \pi \left(\frac{d}{2}\right)^2$$

$$= \sigma \times \pi \frac{d^2}{2}$$

Putting the values,

$$F = 1.2 \times 10^7 \times \pi \times \frac{(0.56 \times 10^{-3})^2}{4}$$

$$F = 1.2 \times 10^7 \times \pi \times \frac{3.136 \times 10^{-7}}{4}$$

$$F = 1.2 \times 10^7 \times \pi \times 7.84 \times 10^{-8}$$

$$F = 2.9556\ N$$

Force $\boxed{F = 2.96\ N}$

Q.9.(a) What is wave nature of particles? How Davisson and Germer experiment confirmed it? (5)

Ans **Wave Nature of Particles:**

It has been observed that light displays a dual nature, it acts as a wave and it acts as a particle. Assuming symmetry in nature, the French physicist, Louis de Broglie proposed in 1924 that particles should also possess wave-like properties. As momentum p of photon is given by equation

$$\frac{1}{2} mv^2_{max} = V_o e, \text{ which gives}$$

$$p = \frac{h}{\lambda}$$

de Broglie suggested that momentum of a material particle of mass m moving with velocity v should be given by the same expression. Thus,

$$p = \frac{h}{\lambda} = mv$$

or $$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Davisson and Germer Experiment:

A convincing evidence of the wave nature of electrons was provided by Clinton J. Davisson and Laster H. Germer. They showed that electrons are diffracted from metal crystals in exactly the same manner as X-rays or any other wave. The apparatus used by them is shown in figure in which electrons from heated filament are accelerated by an adjustable applied voltage V.

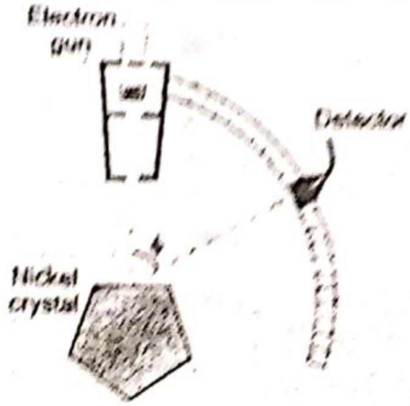


Fig. Experimental arrangement of Davisson and Germer for electron diffraction.

The electron beam of energy Ve is made incident on a nickel crystal. The beam diffracted from crystal surface enters a detector and is recorded as a current I. The gain in K.E. of the electron as it is accelerated by a potential V in the electron gun is

given by $\frac{1}{2}mv^2 = Ve$

or $mv^2 = 2\,Ve$; $m^2v^2 = 2\,mVe$

or $mv = \sqrt{2\,mVe}$

From de Broglie equation,

$$\lambda = \frac{h}{mv}$$

Thus, $$\lambda = \frac{h}{\sqrt{2\,mVe}} \qquad \text{(i)}$$

In one of the experiments, the accelerating voltage V was 54 volts, hence

$$\lambda = \frac{h}{\sqrt{2\,mVe}} = \frac{6.63 \times 10^{-34}\ \text{Js}}{\sqrt{2 \times 9.1 \times 10^{-31}\ \text{kg} \times 54\ \text{JC}^{-1} \times 1.6 \times 10^{-19}\ \text{C}}}$$

$$\lambda = 1.66 \times 10^{-10}\ \text{m}$$

This beam of electrons diffracted from crystal surface was obtained for a glancing angle of 65°. According to Bragg's equation,

$$2\,d \sin\theta = m\lambda$$

For 1st order diffraction m = 1

For nickel $d = 0.91 \times 10^{-10}$ m

Thus, $2 \times 0.91 \times 10^{-10}\ \text{m} \times \sin 65° = \lambda$

which gives, $\lambda = 1.65 \times 10^{-10}$ m

Thus, experimentally observed wavelength is in excellent agreement with theoretically predicted wavelength.

Diffraction patterns have also been observed with protons, neutrons, hydrogen atoms and helium atoms thereby giving substantial evidence for the wave nature of particles.

(b) Find the speed of the electron in the first Bohr orbit. (3)

Ans The speed found from Eq. $v_n = \frac{2\pi ke^2}{h}$, with n = 1, is

$$v_1 = \frac{2\pi ke^2}{h} = 2 \times 3.14 \times (9 \times 10^9\ Nm^2\ C^{-2}) \left(\frac{(1.6 \times 10^{-19}\ C)^2}{6.63 \times 10^{-34}\ Js}\right)$$

$$v_1 = 2.19 \times 10^6\ ms$$