Class- XII
Physics

TIME ALLOWED: 3 hours **MAX MARKS:70**

General Instructions:

(i) All questions are compulsory. There are 26 questions in all

(ii) The question paper has five sections. Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.

(iv) There is no overall choice. However, an internal choice has been provided for one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary.

$c = 3\times10^{8}\,\text{m s}^{-1}$

$h = 6.63\times10^{-34}$ J s

$e = 1.6\times10^{-19}\,\text{C}$

$\mu_0 = 4\pi\times10^{-7}\,\text{T m A}^{-1}$

$\varepsilon_0 = 8.854\times10^{-12}\,\text{C}^2\text{N}^{-1}\text{m}^{-2}$

$\dfrac{1}{4\pi\varepsilon_0} = 9\times10^{9}\,\text{Nm}^2\text{C}^{-2}$

$m_e = 9.1\times10^{-31}\,\text{kg}$

mass of neutron = 1.675×10^{-27}kg

mass of proton = 1.673×10^{-27}kg

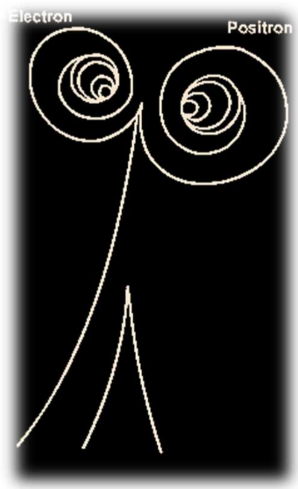
Avogadro number = 6.023×10^{23} per gram mole

Boltzmann constant = $1.38\times10^{-23}\,\text{JK}^{-1}$

SECTION A

1. A charge of 5μC is placed at the centre of a sphere *A* of radius 10.0 cm. The sphere *A* is then replaced by a sphere *B* of radius 25.0 cm. Find the ratio of the flux through the spheres *A* and *B*.

2. The following figure shows the phenomenon of pair production and the subsequent tracks made by the respective particles in a magnetic field. What is the direction of the magnetic field applied in the experiment?



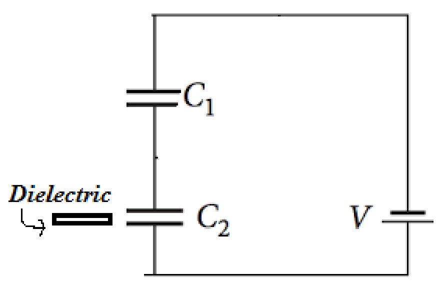
3. Find the ratio of the de Broglie wavelength of an electron in the third orbit of Hydrogen atom to its angular momentum.

4. What is the significance of disintegration energy of a nuclear reaction?

5. Why is amplification essential for effective transmission of signals?

SECTION B

6. Two identical capacitors C_1 and C_2 each of capacitance C are connected to a battery providing a potential difference V as shown.



A dielectric slab of constant K is slipped between the plates of the capacitor C_2 with the battery remaining connected. What happens to the values of (i) charge (ii) capacitance (iii) potential difference (iv) energy of each of the capacitors.

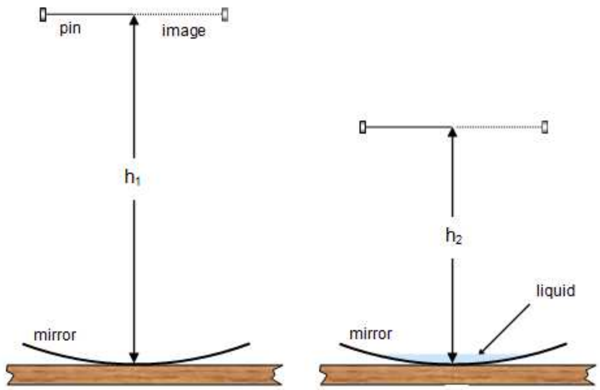
7. What is mutual inductance? List the factors on which the coefficient of mutual induction between the given pair of coils depends.

8. A bulb is connected to an ac supply of frequency 50 Hz. Discuss what happens to the glow of the bulb when (i) a coil of inductance L is connected to it and (ii) a capacitor of capacitance C is introduced in the circuit along with the coil.

OR

Deduce the amount of instantaneous power supplied to a capacitor of capacitance C by an ac supply of voltage defined by $v = v_m \sin \omega t$. What is the value of the average power?

9. A concave mirror is placed as shown below, on a flat surface. A pin is moved along the principal axis of the mirror such that it coincides with its real and inverted image. The height h_1 is measured as 20.0 cm.



A few drops of a liquid are added on the concave portion of the mirror and the pin is moved again for coincidence. The height h_2 is measured to be 15.0 cm. Find the refractive index of the liquid.

10. Explain the process of 'minority *charge injection'* in a forward biased junction diode.

SECTION C

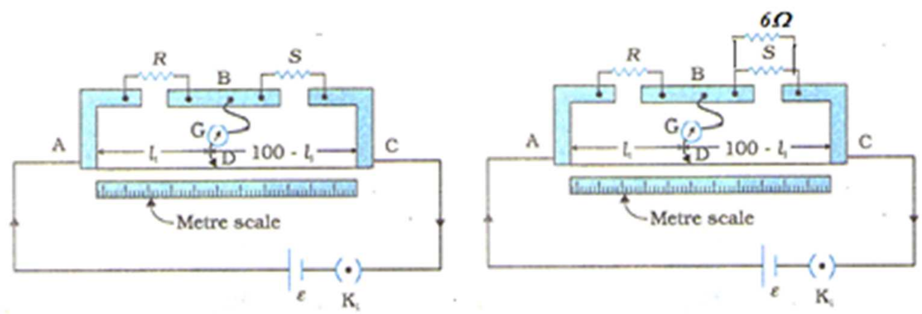
11. (a)Write the expression for the electric field at a point due to an infinitely long charged wire of uniform linear charge density λ.

(b) An electron revolves around a line of charge of charge density 5μC/m, at a distance of 2 cm from the wire. Find its time period of revolution.

12. Two charged metallic spheres of capacitances C_1 and C_2 are given charges Q_1 and Q_2 respectively. They are then connected by a wire. Find the ratio of the final energy to the initial energy of the system of capacitors.

13. Two wires each of resistance 10Ω is taken. One of them is stretched to three times its length and cut into three equal pieces. The other wire is melted an d recast into a wire half its original length. All the four wires are connected in parallel. Find the equivalent resistance of the network of resistances.

14. In the meter bridge circuit shown, the null point is obtained at a distance of 45 cm from A. When a resistance of 6Ω is connected in parallel to *S*, the null point is obtained at 55 cm from *A*. Find the values of *R* and *S*. If the 6Ω resistance be connected in series to *S*, where will the null point shift?



15. (a)Define (i) relative permeability and (ii) susceptibility of a magnetic material. Write the relation between these two quantities. What information does the value of susceptibility provide regarding the nature of the magnetic material?

(b) A magnetic material has a susceptibility of -0.0002. Plot graphically, its variation of susceptibility with increase of temperature.

16. Show that in the free oscillations of an LC circuit, the sum of energies stored in the capacitor and the inductor is constant in time.

OR

Derive an expression for power in an ac circuit containing an inductance *L*, a capacitor *C* and a resistor *R* in series. The voltage across the combination is expressed by $v = v_m \sin \omega t$. What is the importance of power factor? Hence define the term *wattless current*.

17. (a) Prove that the energy density of the electric field is equal to the energy density of the magnetic field of an electromagnetic wave.

(b) Light from a 100 W bulb falls on a metal plate of area 10 cm^2 placed at a distance of 3.0 cm from the bulb. Calculate the average force exerted on the plate, if light is allowed to fall for half an hour.

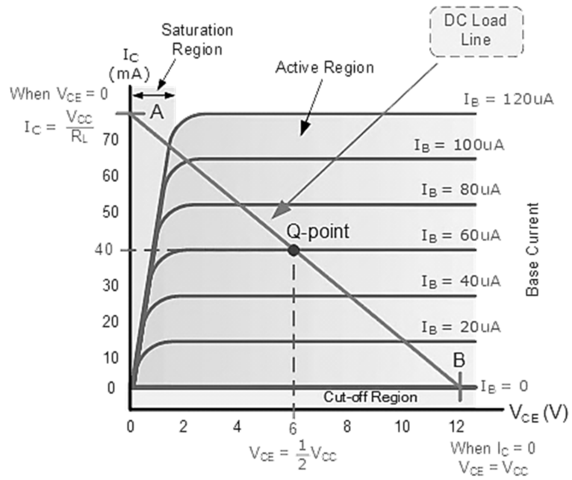
18. Compare and contrast interference pattern with diffraction pattern.

19. (a) Explain the proton- proton cycle by virtue of which Sun produces energy.

(b) What are the challenges the scientists face today in achieving controlled thermonuclear fusion?

20. Explain the action of a PNP transistor with a neat diagram.

21. (a) From the given output characteristic curve, calculate the values of β_{ac} and β_{dc} of the transistor for V_{CE} = 6V, I_C = 40 mA.



(b) Plot a graph between the base current and the collector current from the output graph. What is the relationship between the two quantities?

22. With a neat block diagram, explain the production of a AM wave.

SECTION D

23. Avinash and his family had shifted to a new locality and his father was in search of a good internet service provider. One company offered a regular cable service at a lower rate, while the other offered fibre optic cable at a higher rate. Avinash's father wanted to go for the regular cable connection since he thought it would be cost effective. Avinash convinced his father that the fibre optic connection was better in terms of both quality and speed.

(a) Do you agree with Avinash?

(b) On what principle do you think he has based his opinion?

(c) Does fibre optic cable minimize signal loss? If yes, then how? Draw a neat diagram to illustrate your answer.

(d) What are the values you find worth appreciating in Avinash?

SECTION E

24. (a) With a neat diagram, explain the construction and theory of a moving coil galvanometer.

(b) What is the importance of radial magnetic field? How is it achieved in the galvanometer?

(c) How can current sensitivity of a galvanometer be increased?

OR

(a) State Ampere's circuital law and express it in integral form.

(b) Use the law to obtain the expression for the magnetic field inside the core of a toroid.

(c) Show that the magnetic field in the empty space (i)inside the toroid and (ii) outside the toroid is zero.

(d) A toroid has a ferromagnetic core of inner radius 24 cm and outer radius 26 cm around which 400 turns of wire are wound. If the current in the wire is 10A, find the magnetic field inside the core of a toroid.

25. (a) With the help of a ray diagram, explain the formation of the image of an object placed before the objective of a compound microscope. Find the expression for magnification when the image is formed at (i) infinity (ii) near point.

(b) When viewing through a compound microscope, our eyes should be positioned at a short distance away from the eye piece for best viewing. Explain why.

OR

(a) Explain the phenomenon of polarisation by reflection. Deduce an expression for the polarising angle.

(b) When monochromatic light is incident on a prism, can total transmission of light be achieved with no reflection occurring at all? Explain how.

26. (a) How was the wave nature of electrons verified experimentally? Describe with a neat sketch the experimental arrangement. Also describe how the experiment was performed. What are the important conclusions of the experiment?

(b) Light of wavelength 488 nm produced by an Argon laser is incident on a emitter of a photocell. The stopping potential of the photoelectrons is 0.38V. Find the work function of the material from which the emitter is made.

OR

(a) Describe the Geiger- Marsden experiment and discuss the results of the experiment.

(b) Find the closest distance a 7.7 MeV alpha particle can approach a gold nucleus (Z = 79), before momentarily coming to rest and retracing its path.

(Solution)
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1. Ratio of the flux is 1:1. The flux through any surface is independent of the parameters of the surface. It is dependent only on the charge enclosed.

2. Applying Lorentz force $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$, the magnetic field is directed outwards from the plane of the paper.

3. The de Broglie wavelength and angular momentum of an electron in the nth orbit is

$$\lambda = \frac{2\pi r_n}{n}; l = \frac{nh}{2\pi}; \frac{\lambda}{l} = \frac{4\pi^2 r_n}{n^2 h}$$

Since $r_n = n^2 r_0$ where r_0 is the Bohr radius,

$$\frac{\lambda}{l} = \frac{4\pi^2 n^2 r_0}{n^2 h} = \boxed{\frac{4\pi^2 r_0}{h}}$$

4. If the disintegration energy or the Q value of a nuclear reaction is positive, the reaction is possible and if it is negative, the nuclear reaction is not possible.

5. Signals while passing through space are attenuated. Amplification is essential to compensate for the attenuation.

SECTION B

6. For C_1
Capacitance is constant; Charge increases; Potential difference increases and Stored energy increases.
For C_2
Capacitance increases; Charge increases; Potential difference decreases and Stored energy decreases.
[Explanation: The initial capacitance of the combination is

$$\frac{1}{C_i} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{C} + \frac{1}{C} = \frac{2}{C}; C_i = \frac{C}{2}$$

Both have equal charge Q and the potential difference across each of the capacitors is $\frac{V}{2}$.

If the dielectric is slipped between the plates of the capacitor C_2, with the battery still connected, **its capacitance increases.** $C_{2f} = kC$

The capacitance of the capacitor C_1 remains unchanged. $C_{1f} = C$.

The final capacitance of the circuit,

$$\frac{1}{C_f} = \frac{1}{C_{1f}} + \frac{1}{C_{2f}} = \frac{1}{C} + \frac{1}{kC}; C_f = C\left(\frac{k}{k+1}\right)$$

$$\frac{C}{2} < C\left(\frac{k}{k+1}\right) < C$$

The total capacitance of the circuit increases.

Since V is constant, **charge increases in both capacitors**.

$$Q_f = C\left(\frac{k}{k+1}\right)V$$

Since the capacitance of C_1 remains as C and the charge increases, **the potential difference across C_1 increases.**

Since $V = V_1 + V_2$ is a constant, as V_1 increases, V_2 decreases.

The potential difference across C_2 decreases

$$V_1 = \left(\frac{k}{k+1}\right)V = \left(\frac{2k}{k+1}\right)\frac{V}{2}; V_2 = \frac{V}{k+1} = \left(\frac{2}{k+1}\right)\frac{V}{2}.$$

The energy of C_1 is $U_1 = \frac{1}{2}CV_1^2$.

$$U_1 = \frac{1}{2}CV_1^2 = \frac{1}{2}C\left(\frac{k}{k+1}\right)^2 V^2$$

The energy increases since V_1 increases.

The energy of C_2 is

$$U_2 = \frac{1}{2}(kC)\left(\frac{V}{k+1}\right)^2 = \frac{1}{2}\left(\frac{k}{(k+1)^2}\right)CV^2$$

The energy of C_2 decreases.]

7. Mutual inductance is numerically equal to the value of induced e m fin a coil when the rate of change of current in the neighbouring coil is unity.

Mutual inductance of a pair of coils depends on

(i) The number of turns in both the coils

(ii) Radius of the inner coil

(iii) Length of the coils

(iv) Medium between the coils

(v) Orientation of the coils.

8. When a bulb of resistance R is connected across an a c supply, the glow depends on the heat dissipated and is proportional to R.

When a inductance coil is introduced the impedance increases. The glow reduces.

$$Z_1 = \sqrt{R^2 + (L\omega)^2} > R$$

When a capacitor is introduced along with the inductor,

$$Z_2 = \sqrt{R^2 + \left[(L\omega)^2 - \left(\frac{1}{C\omega}\right)^2\right]}$$

The glow is more when compared to the inductor circuit but less than the circuit since $Z_1 > Z_2 > R$

OR

The instantaneous power supplied to the capacitor is

$$p_C = iv = (i_m \cos \omega t)(v_m \sin \omega t) = \frac{1}{2} i_m v_m \sin 2\omega t$$

The average power supplied to the capacitor is

$$P_C = \left\langle \frac{1}{2} i_m v_m \sin 2\omega t \right\rangle = \frac{1}{2} i_m v_m \langle \sin 2\omega t \rangle = 0$$

Since, $\langle \sin 2\omega t \rangle = 0$, over a complete cycle.

9. The refractive index of the liquid is given by

$$n = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{h_1}{h_2} = \frac{30.0}{20.0} = 1.5$$

10. Under forward bias, the P end of the diode is connected to the positive end of the battery and the N end is connected to the negative. Due to this applied voltage the electrons from the n side cross over to the p side where they are minority charge carriers, while the holes from the p side cross over to the n side, where they are the minority charge carriers. This process is called minority charge injection.

SECTION C

11. (a) The electric field at a point distance r from an infinitely long charged wire of uniform linear charge density λ is

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

(b) The force experienced by the electron due to the electric field provides the centripetal force.

$$F = eE = \frac{mv^2}{r}$$

$$\frac{e\lambda}{2\pi\varepsilon_0 r} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{e\lambda}{2\pi\varepsilon_0 m}} = \sqrt{\frac{2e\lambda}{4\pi\varepsilon_0 m}} = \sqrt{\frac{2\left(1.6\times10^{-19}\right)\left(5\times10^{-6}\right)\left(9\times10^{9}\right)}{9.1\times10^{-31}}}$$

$$= 1.25\times10^{8}\,\text{m/s}$$

$$T = \frac{2\pi r}{v} = \frac{2\times3.14\times2\times10^{-2}}{1.25\times10^{8}} = \boxed{1.00\times10^{-11}\ \text{s}}$$

12. The initial energies of the capacitors are

$$U_i = U_1 + U_2 = \frac{Q_1^2}{2C_1} + \frac{Q_2^2}{2C_2}$$

When they are joined charges flow from one conductor to another till both reach a common potential V.

$$V = \frac{Q_1 + Q_2}{C_1 + C_2}$$

The final energy of the capacitors is

$$U_f = \frac{1}{2}\left(C_1 + C_2\right)V^2 = \frac{1}{2}\left(C_1 + C_2\right)\left(\frac{Q_1 + Q_2}{C_1 + C_2}\right)^2$$

$$= \frac{1}{2}\frac{\left(Q_1 + Q_2\right)^2}{C_1 + C_2}$$

The ratio

$$\frac{U_f}{U_i} = \frac{\frac{1}{2}\frac{\left(Q_1 + Q_2\right)^2}{C_1 + C_2}}{\frac{Q_1^2}{2C_1} + \frac{Q_2^2}{2C_2}} = \frac{\left(Q_1 + Q_2\right)^2}{\left(C_1 + C_2\right)\left(\frac{Q_1^2}{C_1} + \frac{Q_2^2}{C_2}\right)}$$

13. For the first wire:

$$V = A_1 l_1 = A_2 l_2 ; \frac{A_1}{A_2} = \frac{l_2}{l_1} = 3$$

$$R = \frac{\rho l_1}{A_1} = 10\Omega$$

After stretching, the new resistance

$$R_1 = \frac{\rho l_2}{A_2}$$

$$\frac{R_1}{R} = \frac{l_2}{l_1} \times \frac{A_1}{A_2} = (3)^2 = 9$$

$$R_1 = 9R = 90\Omega$$

When cut into three equal parts each will have equal resistance *r,*

$$r = \frac{R_1}{3} = 30\Omega$$

For the second wire, which is melted and recast,

$$V = A_1 l_1 = A_2 l_2 ; \frac{A_1}{A_2} = \frac{l_2}{l_1} = \frac{1}{2}$$

The new resistance is

$$R_2 = \frac{\rho l_2}{A_2}$$

$$\frac{R_2}{R} = \frac{l_2}{l_1} \times \frac{A_1}{A_2} = \left(\frac{1}{2}\right)^2$$

$$R_2 = \frac{R}{4} = \frac{10}{4} = \frac{5}{2}\Omega$$

When all the four wires are connected in parallel, the equivalent resistance is

$$\frac{1}{R_{eq}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \frac{1}{R_2} = \frac{1}{30} + \frac{1}{30} + \frac{1}{30} + \frac{2}{5} = \frac{1}{2}$$

$$\boxed{R_{eq} = 2\Omega}$$

14. In the meter bridge for the first case,

$$\frac{R}{S} = \frac{45}{55} \qquad \text{......(1)}$$

When 6Ω is connected in parallel to *S*, the equivalent resistance in that arm is *X*.

$$X = \frac{6S}{S+6}$$

The condition for balance is

$$\frac{R}{X} = \frac{R(S+6)}{6S} = \frac{55}{45} \qquad \text{......(2)}$$

Dividing equation (2) by (1),

$$\frac{\frac{R(S+6)}{6S}}{\frac{R}{S}} = \frac{S+6}{6} = \left(\frac{55}{45}\right)^2 = 1.49$$

$$\boxed{S = 2.96\Omega}$$

Therefore,

$$R = \frac{45}{55}S = \boxed{2.42\Omega}$$

If the resistance of 6Ω is connected in series with *R*, then the balance point is obtained at a distance *x* from *A*.

$$\frac{R+6}{S} = \frac{x}{100-x}; \frac{x}{100-x} = \frac{8.42}{2.96};$$

$$\boxed{x = 74 \text{ cm}}$$

15. (a) (i) Relative permeability μ_r is defined as the ratio of the permeability μ in a medium to that in vacuum μ_0.

$$\mu_r = \frac{\mu}{\mu_0}$$

(ii) Susceptibility χ is the ratio of magnetisation M of the material to the magnetic intensity H.

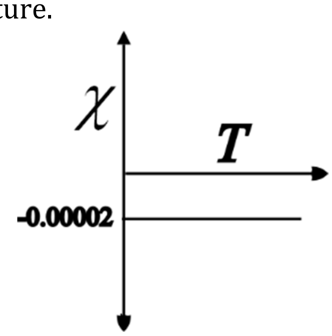
$$\chi = \frac{M}{H}$$

The relative permeability is related to the susceptibility as,

$$\mu_r = 1 + \chi$$

Susceptibility is a measure of how a magnetic material responds to an external field. For paramagnetic substance it is small and positive and for diamagnetic substances it is small and negative.

(b) The susceptibility of the given substance is negative, therefore it is a diamagnetic substance. The susceptibility of a diamagnetic substance is independent of temperature.



16. Let the capacitor of a capacitance *C*, be initially charged with a charge q_0. The initial energy stored in the capacitor is

$$U_i = \frac{q_0^2}{2C}$$

When it is connected to an inductor of inductance *L*, oscillations are set in the circuit and the frequency of oscillations is given by

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

At any instant, the electrostatic energy stored in the capacitor is $U_E = \frac{1}{2}\frac{q^2}{C}$ and that in the inductor due to a current I flowing in it is $U_B = \frac{1}{2}LI^2$.

The total energy at any instant is

$$U = U_E + U_B = \frac{1}{2}\frac{q^2}{C} + \frac{1}{2}LI^2$$

The oscillations of the charge is $q = q_0 \cos\omega_0 t;$ and the current

$$I = \frac{dq}{dt} = q_0\omega_0 \sin\omega_0 t$$

Therefore,

$$U = \frac{1}{2C}q_0^2\cos^2\omega_0 t + \frac{1}{2}Lq_0^2\omega_0^2\sin^2\omega_0 t$$

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

$$U = \frac{1}{2C}q_0^2\cos^2\omega_0 t + \frac{1}{2}Lq_0^2\left(\frac{1}{LC}\right)\sin^2\omega_0 t$$

$$= \frac{1}{2C}q_0^2\left(\cos^2\omega_0 t + \sin^2\omega_0 t\right)$$

$$= \frac{q_0^2}{2C} = U_i$$

OR

When a voltage $v = v_m \sin\omega t$ is applied to a circuit containing an inductor, resistor and a capacitor in series, the current in the circuit is defined as $i = i_m \sin(\omega t + \phi)$.

The instantaneous power supplied to the circuit is

$$p = vi = (v_m \sin\omega t)\left[i_m \sin(\omega t + \phi)\right]$$

$$= \frac{v_m i_m}{2}\left[\cos\phi - \cos(2\omega t + \phi)\right]$$

The average power is

$$P = \langle p \rangle = \left\langle \frac{v_m i_m}{2}\left[\cos\phi - \cos(2\omega t + \phi)\right]\right\rangle$$

Since over a complete cycle of a c, $\langle \cos(2\omega t + \phi)\rangle = 0$

Therefore,

$$P=\frac{v_m i_m}{2}\cos\phi=\frac{v_m}{\sqrt{2}}\frac{i_m}{\sqrt{2}}\cos\phi$$
$$=VI\cos\phi$$

The term $\cos\phi$ is the cosine of phase angle between the voltage and current and is called the power factor.

The average power dissipated in a circuit depends on the rms values of voltage and current and also the power factor.

In a purely inductive or a purely capacitive circuit the phase difference between the voltage and current is $\phi=\frac{\pi}{2}$.

The power factor for such circuits is $\cos\phi=\cos\frac{\pi}{2}=0$. Therefore, the power supplied to such circuits is $P=VI\cos\phi=0$.

No power is dissipated in the circuit even though a current flows in them. This current is called *wattless current.*

17. (a) The energy density of a static electric field is $u_E=\frac{1}{2}\varepsilon_0 E^2$ and that of a stationary magnetic field is $u_B=\frac{B^2}{2\mu_0}$. Since the fields vary sinusoidally in space and time, the values of the fields can be assumed to have their r m s value.

$$E=\frac{E_0}{\sqrt{2}};B=\frac{B_0}{\sqrt{2}}$$

Therefore $u_E=\frac{1}{4}\varepsilon_0 E_0^2;u_B=\frac{1}{4\mu_0}B_0^2$

since $E_0=cB_0;c^2=\frac{1}{\mu_0\varepsilon_0}$,

$$u_E=\frac{1}{4}\varepsilon_0 c^2 B_0^2=\frac{1}{4}\varepsilon_0\frac{1}{\mu_0\varepsilon_0}B_0^2=\frac{1}{4\mu_0}B_0^2=u_B$$

The average density of the electric field is equal to the average energy density of the magnetic field.

(b) The bulb radiates energy uniformly in all directions. At the distance of the plate, the energy is radiated over a surface area *A*.

The intensity at the distance is

$$I=\frac{P}{A}=\frac{100}{4\times3.14\times\left(3.0\times10^{-2}\right)^2}=8.8\times10^3\,\mathrm{W/m^2}$$

Total energy falling on the surface of area *a* is

$$U=I\times t\times a$$

The momentum transferred to the surface is

$$p = \frac{U}{c} = \frac{I \times t \times a}{c}$$

Average force on the surface is

$$F = \frac{p}{t} = \frac{I \times a}{c} = \frac{8.846 \times 10^3 \times \left(10 \times 10^{-4}\right)}{3 \times 10^8} = \boxed{2.93 \times 10^{-8}\,\mathrm{N}}$$

18. Interference and diffraction:

SN	Interference	Diffraction
1	Fringes are equally spaced	The central maxima is twice as wide as the other maxima
2	all the fringes are of equal brightness	The intensity falls as one moves away from the central maxima
3	The pattern is obtained by the superposition of two waves originating from two narrow slits	The pattern is a superposition of a continuous family of waves originating from each point on a single slit.
4	At an angle $\frac{\lambda}{a}$, the maximum is obtained for two narrow slits separated by a distance *a*.	The first null of the pattern occurs at an angle $\frac{\lambda}{a}$, where *a* is the width of the slit.

19. (a) The proton –proton cycle in sun:

$${}_1^1H + {}_1^1H \rightarrow {}_1^2H + e^+ + \nu + 0.42MeV \qquad \ldots\ldots(1)$$

$$e^+ + e^- \rightarrow \gamma + \gamma + 1.02MeV \qquad \ldots\ldots(2)$$

$${}_1^2H + {}_1^1H \rightarrow {}_2^3He + \gamma + 5.49MeV \qquad \ldots\ldots(3)$$

These three reactions occur twice in order for the following reaction to happen.

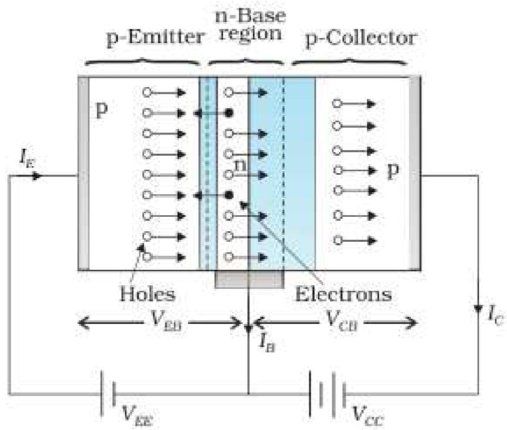
$${}_2^3He + {}_2^3He \rightarrow {}_2^4He + {}_1^1H + {}_1^1H + 12.86MeV \qquad \ldots\ldots(4)$$

The net effect is

$$4\,{}_1^1H + 2e^- \rightarrow {}_2^4He + 2\nu + 6\gamma + 26.7MeV$$

(b) Fusion occurs at very high temperatures of the order 10^8K. At these temperatures, the fuel exists as a mixture of positive and negative ions called plasma. The challenge lies in confining this plasma, as no vessel can withstand such high temperatures.

20. Action of a PNP transistor: A transistor works as an amplifier when its emitter-base junction is forward biased and the collector –base junction is reverse biased.



The biasing batteries are V_{EE} and V_{CC}. The heavily doped emitter has a high concentration of holes in a PNP transistor. These holes enter the base region in large numbers due to the forward bias applied to the junction. The base is lightly doped and has a very small number of electrons. A very small base current flows out due to recombination. The reverse bias applied to the collector base junction facilitates the entry of the holes into the collector. Since the base is very thin, majority of holes cross over to the collector.

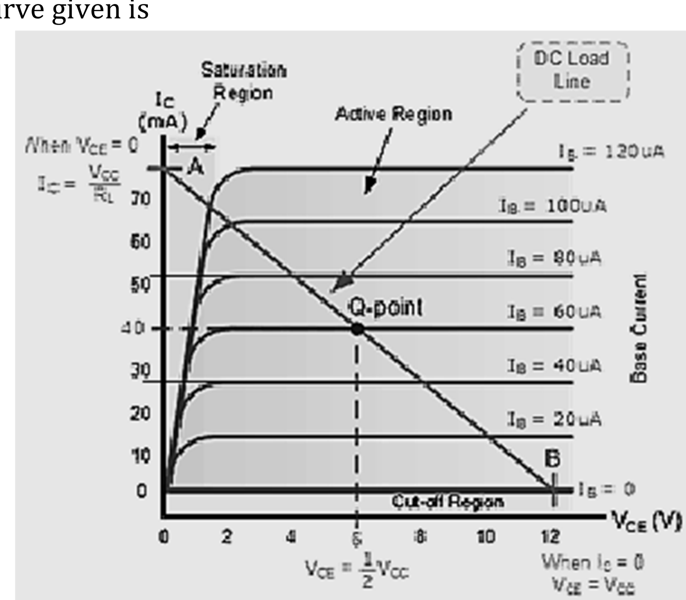
The current entering into the emitter from outside is equal to the emitter current I_E. The current emerging from the base terminal is the base current I_B and the current from the collector terminal is I_C.

By Kirchhoff's law,

$$I_E = I_B + I_C$$

Since the base current is negligible, $I_C \approx I_E$.

21. The output curve given is



$$\beta_{ac}=\left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}=\left[\frac{(50-30)\times10^{-3}}{(80-40)\times10^{-6}}\right]=500$$

$$\beta_{dc}=\frac{I_C}{I_B}$$

For the first point,

$$\beta_{dc1}=\frac{I_C}{I_B}=\frac{50\times10^{-3}}{80\times10^{-6}}=625$$

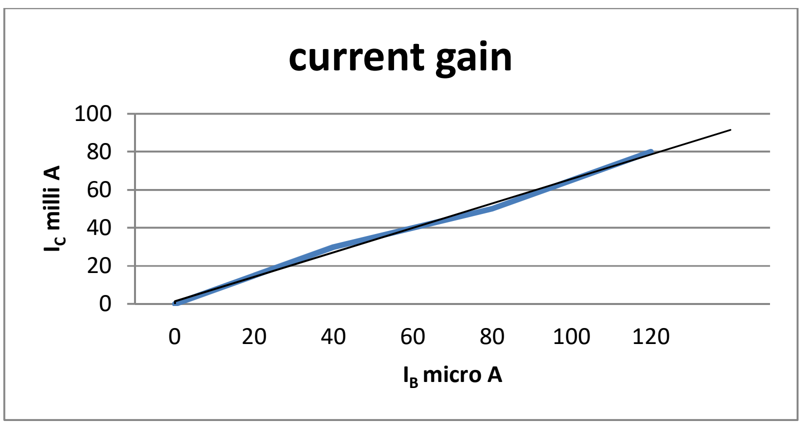
For the second point,

$$\beta_{dc2}=\frac{I_C}{I_B}=\frac{30\times10^{-3}}{40\times10^{-6}}=725$$

The dc current gain is

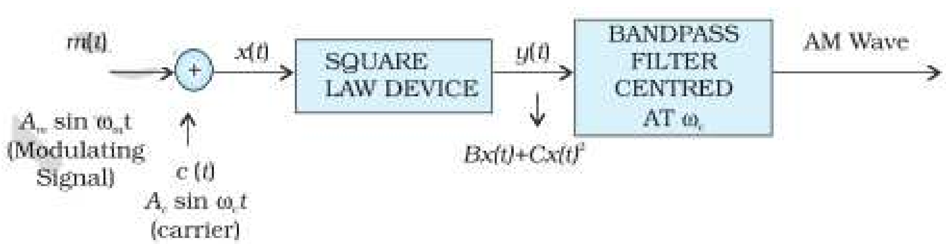
$$\beta_{dc}=\frac{625+725}{2}=675$$

(b) The relation between I_B and I_C is



There is a linear relationship between I_C and I_B.

22. Production of AM wave:



The modulating signal $A_m \sin \omega_m t$ is added to the carrier signal $A_c \sin \omega_c t$ to produce the signal $x(t)$.

$x(t) = A_m \sin \omega_m t + A_c \sin \omega_c t$

This signal is passed through a square law device which produces an output

$y(t) = Bx(t) + Cx^2(t)$, where B and C are constants.

$$
\begin{aligned}
y(t) &= Bx(t) + Cx^2(t) \\
&= B\left(A_m \sin\omega_m t + A_c \sin\omega_c t\right) + C\left(A_m \sin\omega_m t + A_c \sin\omega_c t\right)^2 \\
&= BA_m \sin\omega_m t + BA_c \sin\omega_c t \\
&\quad + C\left(A_m^2 \sin^2\omega_m t + A_c^2 \sin^2\omega_c t + 2A_m A_c \sin\omega_m t \sin\omega_c t\right) \\
&= BA_m \sin\omega_m t + BA_c \sin\omega_c t \\
&\quad + \frac{C\left(A_m^2 + A_c^2\right)}{2} - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t \\
&\quad + CA_m A_c \cos\left(\omega_c - \omega_m\right)t - CA_m A_c \cos\left(\omega_c + \omega_m\right)t
\end{aligned}
$$

The signal contains a dc term $\frac{C\left(A_m^2 + A_c^2\right)}{2}$ and sinusoids of frequencies $\omega_m, \omega_c, 2\omega_m, 2\omega_c, \left(\omega_c - \omega_m\right)$ and $\left(\omega_c + \omega_m\right)$

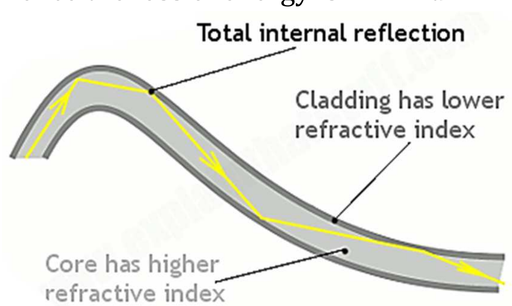
This signal is passed through a band pass filter which rejects the dc and the sinusoids of frequencies $\omega_m, 2\omega_m, 2\omega_c$ and retains $\omega_c, \left(\omega_c - \omega_m\right)$ and $\left(\omega_c + \omega_m\right)$. The output of the band pass filter is an AM wave.

SECTION D

23. (a) Yes, Avinash was correct.

(b) Optic fibre is based on the principle of total internal reflection.

(c) Total internal reflection is 100% reflection as there can be no refraction and hence the loss of energy is minimum.



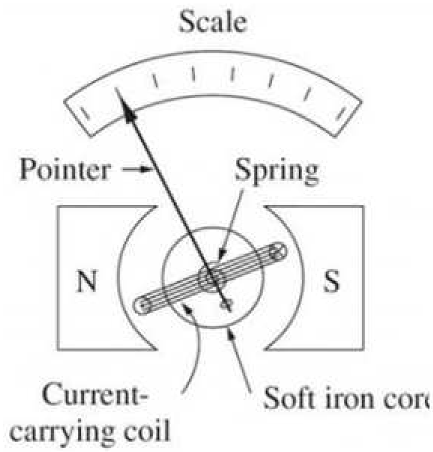
(d) Scientific enquiry, knowledge of physics, long term vision.

SECTION E

24. Moving coil galvanometer:

Principle: A current carrying coil experiences a torque when placed in a magnetic field.

Construction: It consists of a coil of area A and with N turns, which is free to rotate about a fixed axis in a uniform radial magnetic field B. A cylindrical soft iron core is inserted into the coil. This increases the magnetic flux through the coil and makes the field radial. The coil is pivoted on thin phosphor bronze springs which have a very low torsion constant. A pointer is attached to the coil by means of another similar spring and the pointer moves on a graduated scale.



Working: The field acts along the plane of the coil. When a current I is passed through the coil, the coil experiences a torque given by

$$\tau = NIAB$$

This torque tries to rotate the coil through an angle θ. A restoring torque is created in the spring, which tries to bring the coil to its original position.

This is given by

$$\tau = k\theta$$

At equilibrium,

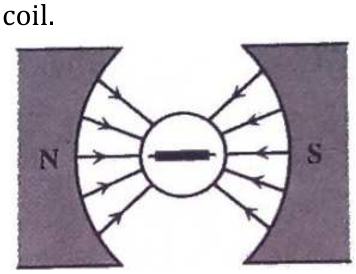
$$NIAB = k\theta$$

$$\theta = \left(\frac{NAB}{k}\right) I$$

Since $\frac{NAB}{k}$ is a constant,

$$\theta \propto I$$

(b) Radial field is a field which always acts along the plane of the coil, irrespective of the orientation of the coil.



Radial field is achieved by using hemispherical pole pieces and inserting a soft iron core into the coil.

(c) Current sensitivity is defined as the deflection per unit current.

$$\frac{\theta}{I} = \frac{NAB}{k}$$

It can be increased by increasing

(i)number of turns

(ii) area of the coil

(iii) magnetic field

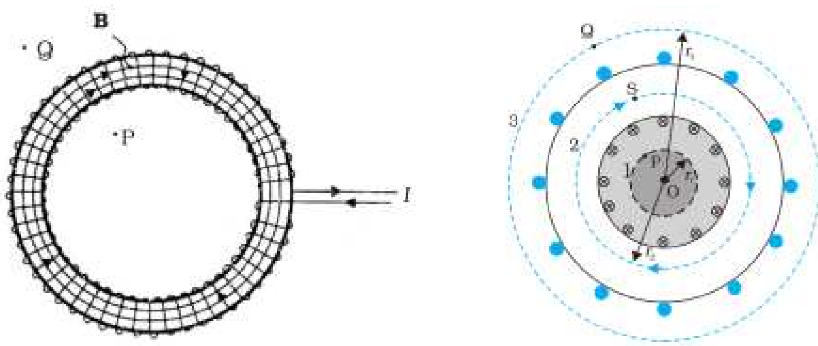
And by using a spring of low torsion constant.

OR

(a) Ampere's circuital law: The loop integral $\oint \vec{B}\cdot d\vec{l}$ is equal to μ_0 times the total current passing through the surface.

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_e$$

(b) Toroid: A toroid is a hollow circular ring on which a large number of turns of wire are closely wound. Let the direction of current through the toroid be in the clockwise direction.



(a) (b)

Consider a loop 2 located in the interior of the toroid. The magnetic field at the point S is uniform and has a magnitude *B*.

Applying Ampere's circuital law,

$$\oint \vec{B}\cdot d\vec{l} = B(2\pi r_2)$$

$$I_e = NI$$

Since $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_e$

$$B(2\pi r_2) = \mu_0 NI$$

$$B = \frac{\mu_0 NI}{2\pi r_2}$$

For a toroid of average radius *r*, $B=\dfrac{\mu_0 NI}{2\pi r}$

If $n=\dfrac{N}{2\pi r}$ the number of turns per unit length of the toroid, then

$B=\mu_0 nI$

(c) (i) At a point P inside the toroid, in the ampere's circuital law, $\oint \vec{B}\cdot d\vec{l}=\mu_0 I_e$,

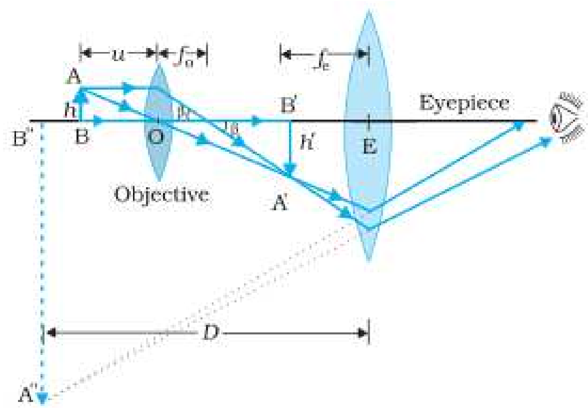
$I_e=0$ and therefore $B=0$

(ii) At a point Q outside the toroid, the current entering the amperean loop is equal to the current leaving the amperean loop. The algebraic sum of the currents is zero. In the ampere's circuital law, $\oint \vec{B}\cdot d\vec{l}=\mu_0 I_e$, $I_e=0$ and therefore $B=0$.

(d) The average radius of the toroid is $r=\dfrac{24+26}{2}=25\text{ cm}=25\times10^{-2}\,\text{m}$

$$B=\frac{\mu_0 NI}{2\pi r}=\frac{4\pi\times10^{-7}\times400\times10}{2\pi\times25\times10^{-2}}=3.2\times10^{-3}\,\text{T}$$

25. Compound microscope:



The schematic diagram of a compound microscope is shown. The lens near the object is called the objective lens and it forms a real, inverted and magnified image of the object. This image is formed near the focal plane of the eyepiece and it serves as the object for the eyepiece which forms a virtual magnified final image.

The linear magnification of the objective

$$m_0=\frac{h'}{h}=\frac{L}{f_0},$$

where $L=f_o+f_e$ is called the tube length of the microscope.

And $\tan\beta=\dfrac{h}{f_o}=\dfrac{h'}{L}$

If the final image is formed at the near point, the magnification of the eyepiece is

$$m_e = 1 + \frac{D}{f_e}$$

If the final image is formed at infinity,

$$m_e = \frac{D}{f_e}$$

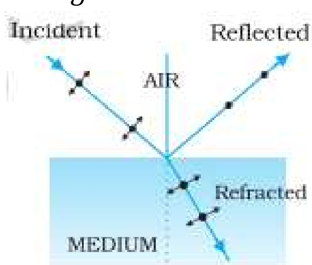
The total magnification

$$m = m_0 m_e = \frac{L}{f_0}\frac{D}{f_e}$$

(b) The image of the objective in the eyepiece is called the eye ring. The eye ring is located a little above the eyepiece. All the rays refracted by objective go through the eye ring. If we place our eyes very close to the eye piece, we may not be able to collect all the rays and the intensity will be less. But, if we place our eyes on the eye ring, the area of our pupil is greater than or equal to the area of the eye ring and our eyes will collect all the rays.

OR

(a) When unpolarised light is incident on the boundary between two transparent media, the light with its electric vector parallel to the boundary is transmitted while those rays with their electric vector perpendicular to the plane of the boundary are reflected. The reflected light is totally polarised with its electric vector perpendicular to the plane of incidence when refracted and the reflected waves make a right angle with each other. This angle of incidence is called the angle of polarisation or *Brewster's angle*.



Using Snell's law,

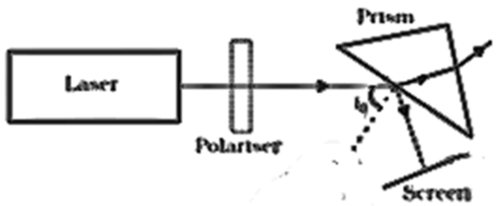
$$\frac{\sin i}{\sin r} = \mu$$

When light is incident at Brewster's angle, $i = i_B; r = \frac{\pi}{2} - i_B$, therefore,

$$\mu = \frac{\sin i_B}{\sin\left(\frac{\pi}{2} - i_B\right)} = \frac{\sin i_B}{\cos i_B} = \tan i_B$$

$\boxed{\mu = \tan i_B}$ is known as Brewster's law.

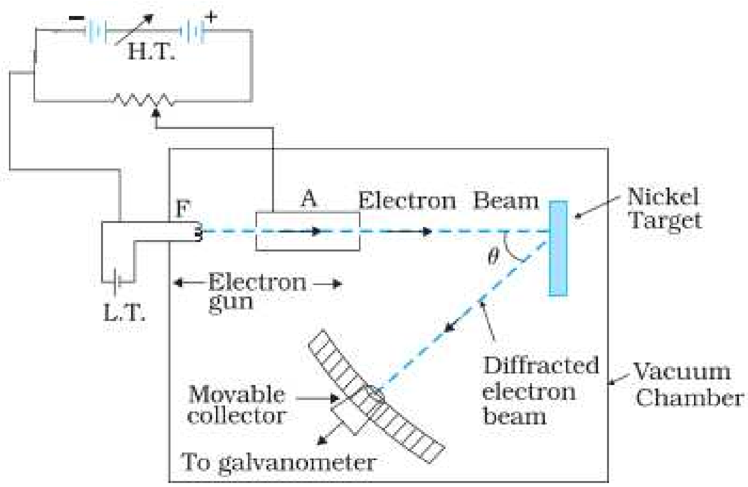
(b) It is possible to achieve total transmission using a polariser and a prism.



Laser light from the source is allowed to fall on the face of a prism. Light is partially reflected and partially transmitted. A small spot can be seen on the screen due to the reflected light. If the angle of incidence is adjusted so that it becomes equal to the Brewster angle, the perpendicular component will be reflected while the component parallel to the plane of incidence will be transmitted. A polariser is introduced between the source and the prism and it is rotated so as to allow only the parallel component and cut off the perpendicular component. All the light falling on the prism will be transmitted and the spot on the screen disappears.

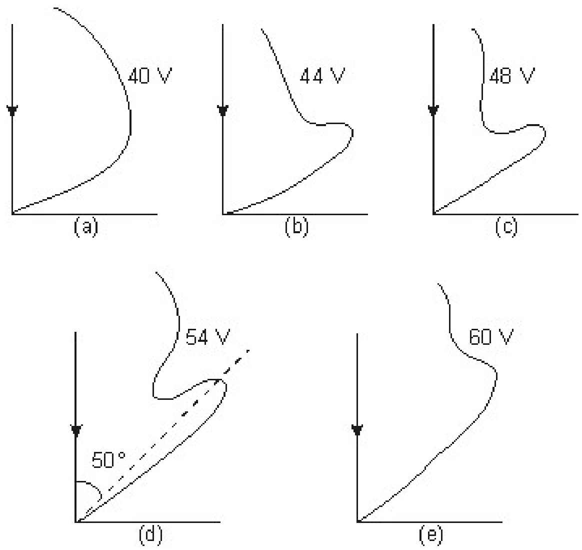
26. The experiment to verify the wave nature of electrons is the Davisson and Germer experiment.

The experimental arrangement is as shown below.



Experimental Arrangement and procedure: The tungsten filament coated with barium oxide in an electron gun with is heated using a low tension battery. The electrons emitted by the filament are accelerated by applying suitable potential using a HT battery. The beam is collimated by allowing it to pass through a cylinder with fine holes and allowed to fall on a Nickel crystal. The crystal scatters the electrons in all directions. The intensity of the scattered electrons in any particular direction is measured using a collector which can be moved on a circular scale. The collector is connected to a galvanometer. The whole apparatus is enclosed in an evacuated chamber.

By moving the detector on the circular scale, the values of intensities are calculated for various angles of scattering angles and the variation of intensity with the scattering angles were studied for different accelerating potentials.
The experiment was performed by varying accelerating potentials from 44 V to 68 V.



It was noticed that a sharp peak was obtained for an accelerating voltage of 54V at a scattering angle of 50^0.
Conclusions:(i) The appearance of the peak in a particular direction is due to the constructive interference of electrons scattered from different layers of the regularly spaced atoms of the crystals.
(ii) From the electron diffraction pattern the wavelength of matter waves was found to be 0.165nm.
(iii) the deBroglie wavelength of electrons for V = 54 V is,

$$\lambda = \frac{h}{p} = \frac{1.227}{\sqrt{V}} nm$$

$$= \frac{1.227}{\sqrt{54}} = 0.167 nm$$

This is in agreement with the experimental values and thus confirms the wave nature of electrons.
(b) From Einstein's photoelectric equation,

$$\frac{hc}{\lambda} = W + K$$

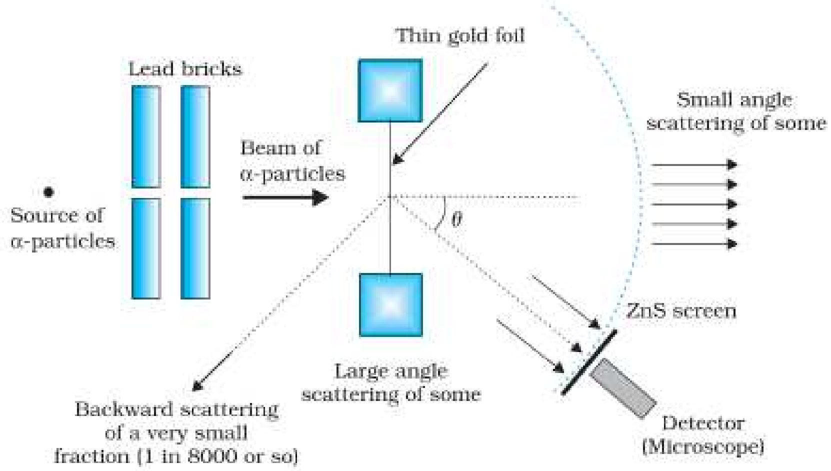
$$\frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.88\times10^{-7}\times1.6\times10^{-19}}\text{ eV=2.55 eV}$$

$$K = 0.38 \text{ eV}$$

$$W = \frac{hc}{\lambda} - K = 2.55 - 0.38 = \boxed{2.17\text{eV}}$$

OR

(a) Geiger- Marsden experiment was performed at the suggestion of Rutherford. The schematic arrangement of the experiment is as shown below.

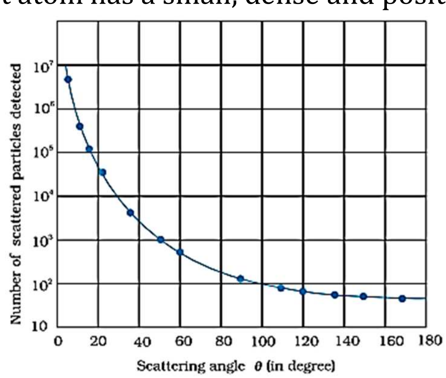


A beam of 5.5MeV α- particles emitted from $^{214}_{83}\text{Bi}$ source were collimated by passing them through lead bricks and directed on to a thin metal foil made of gold of thickness $2.1\times10^{-7}\,\text{m}$. The scattered α- particles were observed through a rotatable detector consisting of a zinc sulphide screen and a microscope. The scattered α- particles produced brief light flashes on striking the screen. These flashes were viewed through a microscope and the distribution of the number of scattered particles may be studied as a function of the angle of scattering.

A graph is plotted between the total number of particles scattered and the scattering angles.

Conclusions: (i) Many of the α- particles pass through the foil and are scattered through less than 1^0. This leads to the fact that most of the atom is an empty space.

(ii) A few of the α- particles were sharply deflected, indicating that the positive charge was concentrated at a very small space of about 10^{-14}m to 10^{-15}m.This proved that the target atom has a small, dense and positively charged nucleus.



(b) The α- particle retraces its path when its kinetic energy is converted into potential energy.

$$K = \frac{(Ze)(2e)}{4\pi\varepsilon_0 r_0}$$

The distance of closest approach is

$$r_0 = \frac{2Ze^2}{4\pi\varepsilon_0 K} = \frac{2(79)\left(1.6\times10^{-19}\right)^2\left(9\times10^{9}\right)}{7.7\times10^{6}\times1.6\times10^{-19}} = \boxed{2.95\times10^{-14}\,\mathrm{m}}$$