PRACTICE PAPER – 5

SOLUTIONS

SECTION – A

1. Distinguish between transverse and longitudinal waves.

Ans.

Transverse waves	Longitudinal waves
1. The particles of the medium vibrate perpendicular to the direction of wave propagation.	1. The particles of the medium vibrate parallel to the direction of wave propagation.
2. Crests and troughs are formed alternatively.	2. Crests and troughs are formed alternatively.

2. Explain Brewster's law.

Ans. Brewster's law : The tangent of the polarising angle is equal to the refractive index of the medium.

$\mu = \tan i_B$, where i_B = polarising angle and μ = refractive index.

Note : $r + i_B = 90°$

3. Repulsion is the sure test of charging than attraction. Why ?

Ans. A charged body may attract a neutral body and also an opposite charged body. But it always repels a like charged body. Hence repulsion is the sure test of electrification.

4. What happens to the capacitance of a parallel plate capacitor if the area of its plates is doubled ?

Ans. $\frac{C_2}{C_1} = \frac{A_2}{A_1}\left[\because C = \frac{\varepsilon_0 A}{d}\right]$

Given $A_2 = 2A_1$ $\frac{C_2}{C_1} = \frac{2A_1}{A_1}$ $\therefore C_2 = 2C_1$

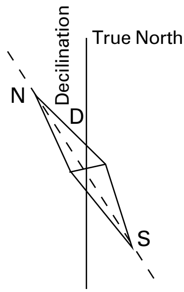
Therefore capacity increases by twice.

5. Why is manganin used for making standard resistors ?

Ans. Due to high resistivity and low temperature coefficient of resistance, manganin wire (Cu–84% + Mn – 12% + Ni – 4%) is used in the preparation of standard resistances.

6. Define magnetic declination.

Ans. Magnetic Declinatin (D) : The angle between the true geographic north and the north shown by a compass needle is called magnetic declination or simply declination (D).



7. State Faraday's law of electromagnetic induction.

Ans. "Magnitude of induced e.m.f is directly proportional to the rate of change of magnetic flux"

$$\varepsilon \propto \frac{d\phi}{dt}$$

8. A transformer converts 200 V ac into 2000 V ac. Calculate the number of turns in the secondary if the primary has 10 turns.

Ans. $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

$V_p = 200V, V_s = 2000V, N_p = 10$

$N_s = \frac{V_s}{V_p} \times N_p = \frac{2000}{200} \times 10$; $N_s = 100.$

9. Give two uses of infrared rays.

Ans. i) Infrared rays are used for producing dehydrated fruits.

ii) They are used in the secret writings on the ancient walls.

iii) They are used in green houses to keep the plants warm.

10. What is "World Wide Web" (WWW) ?

Ans. Tern Berners -Lee invented the World Wide Web.

It is an encyclopedia of knowledge accessible to every one round the clock through out the year.

SECTION – B

11. Define critical angle. Explain total internal reflection using a neat diagram.

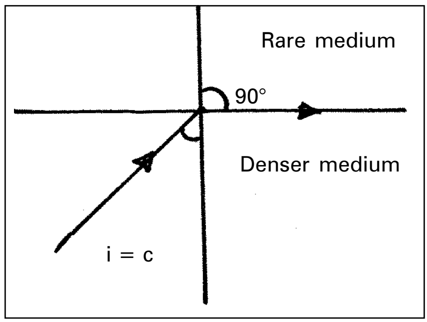
Ans. Critical angle :

When light ray travelling from denser medium to rarer medium, then the angle of incidence for which angle of refraction in air is 90° is called critical angle.

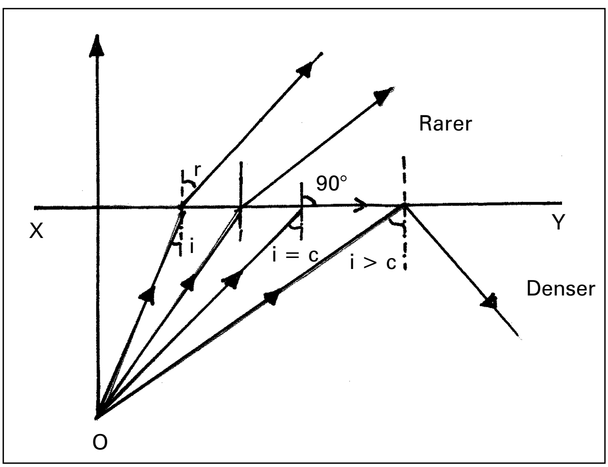
$$C = \sin^{-1}\left(\frac{1}{\mu}\right)$$

Total internal reflection :

When a light ray travels from denser to rarer medium, the angle of incidence is greater than the critical angle, then it reflects into the same medium is called total internal reflection.



Explanation : Consider an object in the denser medium. A ray OA incident on XY bends away from the normal. As the angle of incidence is increased, the angle of refraction goes on increasing. For certain angle of incidence, the refracted ray parallel to XY surface (r = 90°)



When the angle of incidence is further increased, the ray is not refracted but is totally reflected back in the denser medium. This phenomenon is called total internal reflection.

12. State Gauss's law in electrostatics and explain its importance.

Ans. Gauss's law : The total electric flux through any closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the surface.

Total electric flux, $\phi = \oint_S \vec{E} . d\vec{s} = \frac{q}{\varepsilon_0}$

Here q is the total charge enclosed by the surface 'S', $\oint$ represents surface integral of the closed surface.

Importance :

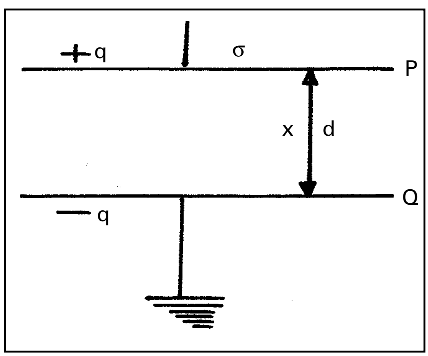
1) Gauss's law is very useful in calculating the electric field in case of problems where it is possible to construct a closed surface. Such surface is called Gaussian surface.
2) Gauss's law is true for any closed surface, no matter what its shape or size.
3) Symmetric considerations in many problems make the application of Gauss's law much easier.

13. Derive an expression for the capacitance of a parallel plate capacitor.

Ans. Expression for the capacitance of a parallel plate capacitor :

1) P and Q are two parallel plates of a capacitor separated by a distance of d.
2) The area of each plate is A. The plate p is charged and Q is earth connected.
3) The charge on P is + q and surface charge density of charge = σ

   $\therefore q = A\sigma$



4) The electric intensity at point x , $E = \frac{|\sigma|}{\varepsilon_0}$

5) Potential difference between the plates P and Q,

$$V = \int dV = \int_d^0 -E\,dx = \int_d^0 \frac{-\sigma}{\varepsilon_0} dx = \frac{\sigma d}{\varepsilon_0}$$

6) Capacitance of the capacitor $C = \frac{Q}{V} = \frac{A\sigma}{\frac{\sigma d}{\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$ Farads (In air)

Note : Capacity of a capacitor for with dielectric medium is C $= \frac{\varepsilon_0 A}{\left[d - t + \frac{t}{k}\right]}$ Farads.

14. State Kirchoff's law for an electrical network. Using these laws deduce the condition for balance in a Wheatstone bridge.

Ans. 1) Kirchhoff's first law (Junction rule or KCL) : The algebraic sum of the currents at any junction is zero. $\therefore \Sigma I = 0$

(or)

The sum of the currents flowing towards a junction is equal to the sum of currents away from the junction.

2) Kirchhoff's second law (Loop rule or KVL) : The algebraic sum of potential around any closed loop is zero.

$\therefore \Sigma(IR) + \Sigma E = 0$

Wheatstone bridge : Wheatstone's bridge circuit consists of four resistances R_1, R_2, R_3 and R_4 are connected to form a closed path. A cell of emf ε is connected between the point A and C and a galvanometer is connected between the points B and D as shown in fig. The current through the various branches are indicated in the figure. The current through the galvanometer is I_g and the resistance of the galvanometer is G.

Applying Kirchhoff's first law

at the junction D, $I_1 - I_3 - I_g = 0$ ..... (1)

at the junction B, $I_2 + I_g - I_4 = 0$ ..... (2)

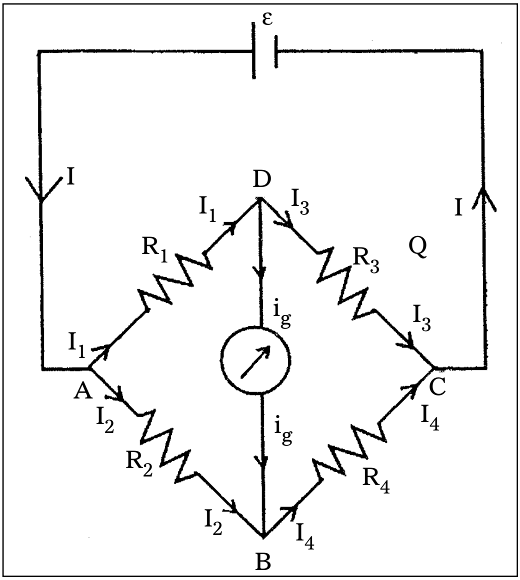
$\Rightarrow$ Applying Kirchhoff's second law to the closed path ADBA

$-I_1R_1 - I_gG + I_2R_2 = 0$

or

$\Rightarrow I_1R_1 + I_gG = I_2R_2$

$\Rightarrow$ to the closed path DCBD



$-I_3R_3 + I_4R_4 + I_gG = 0$

$\Rightarrow I_3R_3 - I_gG = I_4R_4$

$\Rightarrow$ When the galvanometer shows zero deflection the points D and B are at the same potential so $I_g = 0$.

Substituting this value in (1), (2), (3) and (4).

$I_1 = I_3$ – (5)

$I_2 = I_4$ – (6)

$I_1R_1 = I_2R_2$ – (7)

$I_3R_3 = I_4R_4$ – (8)

$\Rightarrow$ Dividing (7) by (8) $\frac{I_1R_1}{I_3R_3} = \frac{I_2R_2}{I_4R_4} \Rightarrow \frac{R_1}{R_3} = \frac{R_2}{R_1}$ [$\because I_1 = I_3$ & $I_2 = I_4$]

$\therefore$ Wheatstone's Bridge principle : $R_4 = R_3 \times \frac{R_2}{R_1}$

15. Describe the ways in which Eddy currents are used to advantage.

Ans. Eddy currents are used to advantage in

i) Magnetic braking in trains : A strong magnetic field is applied across the metallic drum rotating with the axle of the electric train. Thus large eddy currents are produced in the metallic drum. These currents oppose the motion of the drum and hence the axle of the train which ultimately makes the train come to rest.

ii) Induction Motor : Eddy currents are used to rotate the short circuited rotor of an induction motor. Ceiling fans are also induction motors which run on single phase alternating current.

iii) Electromagnetic damping : Certain galvanometers have a fixed core made of non magnetic metallic material. When the coil oscillates, the eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

iv) Induction furnace : Induction furnace can be used to produce high temperatures and can be utilised to prepare alloys, by melting the constituent metals. A high frequency alternating current is passed through a coil. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

v) Analogue energy meters : Concept of eddy currents is used in energy meters to record the consumption of electricity. Aluminium disc used in these meters get induced due to varying magnetic field. It rotates due to eddy currents produced in it.

16. What is the (a)momentum (b) speed (c) de Broglie wave length of an electron with kinetic energy of 120 eV.

Sol. Given, KE = 120 eV; m = 9.1×10^{-3} kg; e = 1.6×10^{-19} c

a) $P = \sqrt{2m(KE)} = \sqrt{2 \times 9.1 \times 10^{-31} \times (120 \times 1.6 \times 10^{-19})}$

$\therefore P = 5.91 \times 10^{-24}$ kg – m/s

b) $\upsilon = \frac{p}{m} = \frac{5.91 \times 10^{-24}}{9.1 \times 10^{-31}} = 6.5 \times 10^{6}$ m/s

c) $\lambda = \frac{12.27}{\sqrt{V}} \text{Å} = \frac{12.27}{\sqrt{120}} \text{Å} = 0.112 \times 10^{-9}$ m $\therefore \lambda = 0.112$ nm.

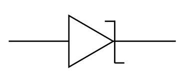
17. Distinguish between nuclear fission and nuclear fusion.

Ans.

Nuclear fission	Nuclear fusion
1. In this process heavy nucleus is divided into two fragments along with few neutrons.	1. In this process lighter nuclei will join together to produce heavy nucleus.
2. These reactions will takes place even at room temperature.	2. These reactions will takes place at very high temperature such as 10^6 °C.
3. To start fission atleast one thermal neutron from out side is compulsory.	3. No necessary of external neutrons.
4. Energy released per unit mass of participants is less.	4. Energy released per unit mass of participants is high. Nearly seven time more than fission reaction.
5. In this process neutrons are liberated.	5. In this process positrons are liberated.
6. This reaction can be controlled. **Ex :** Nuclear reactor.	6. There is no control on fusion reaction.
7. Atom bomb works on principle of fission reaction.	7. Hydrogen bomb works on the principle of fusion reaction.
8. The energy released in fission can be used for peaceful pur–pose. **Ex :** Nuclear reactor and Atomic power stations.	8. The energy released in fusion cannot be used for peaceful purpose.

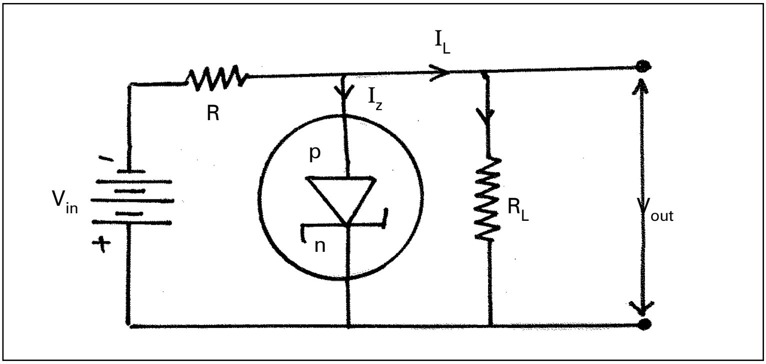
18. What is Zener diode ? Explain how it is used as voltage regulator.

Ans. Zener diode : Zener diode is a heavily doped germanium (or) silicon p-n junction diode. It works on reverse bias break down region.



The circuit symbol of zener diode is shown in figure.

Zener diode can be used as a voltage regulator. In general zener diode is connected in reverse bias in the circuits.



i) The zener diode is connected to a battery, through a resistance R. The battery reverse biases the zener diode.

ii) The load resistance R_L is connected across the terminals of the zener diode.

iii) The value of R is selected in such away that in the absence of load R_L maximum safe current flows in the diode.

iv) Now consider that load is connected across the diode. The load draws a current.

v) The current through the diode falls by the same amount but the voltage drops across the load remains constant.

vi) The series resistance R absorbs the output voltage fluctuations, so as to maintain constant voltage across the load.

vii) The voltage across the zener diode remains constant even if the load R_L varies.

Thus, zener diode works as voltage regulator.

viii) If I is the input current, I_Z and I_L are zener and load currents.

$$I = I_Z + I_L; \; V_{in} = IR + V_Z$$

$$\text{But } V_{out} = V_Z$$

$$\therefore V_{out} = V_{in} - IR$$

SECTION – C

19. Explain the formation of stationary waves in stretched strings and hence deduce the laws of transverse wave in stretched strings.

A string has a length of 0.4 m and a mass of 0.16 g. If the tension in the string is 70 N. What are the three lowest frequencies it produces when plucked ?

Ans. A string is a metal wire whose length is large when compared to its thickness. A stretched string is fixed at both ends, when it is plucked at mid point, two reflected waves of same amplitude and frequency at the ends are travelling in opposite direction and overlap along the length. Then the resultant waves are known as the standing waves (or) stationary waves.

Let two transverse progressive waves of same amplitude a, wave length λ and frequency 'ν', travelling in opposite direction be given by

$y_1 = a \sin (kx - \omega t)$ and $y_2 = - a \sin (kx + \omega t)$

where $\omega = 2\pi\nu$ and $k = \dfrac{2\pi}{\lambda}$

The resultant wave is given by $y = y_1 + y_2$

$y = a \sin (kx - \omega t) - a \sin (kx + \omega t)$

$y = (2a \sin kx) \cos \omega t$

$2a \sin kx$ = Amplitude of resultant wave.

It depend on 'kx'. If $x = 0, \dfrac{\lambda}{2}, \dfrac{2\lambda}{2}, \dfrac{3\lambda}{2}$ ...... etc, the amplitude = zero

These positions are known as **"Nodes"**

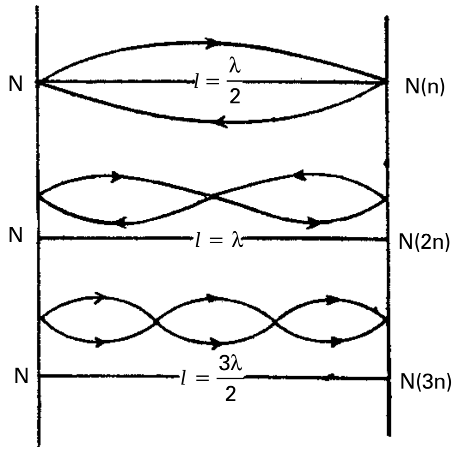
If $x = \dfrac{\lambda}{4}, \dfrac{3\lambda}{4}, \dfrac{5\lambda}{4}$ ...... etc, the amplitude = maximum (2a).

These positions are called "Antinodes"

Formation of stationary waves : A stretched string can be vibrate in different frequencies and form stationary wave. This mode of vibrations are known as Harmonics.

If it vibrates in one segment, which known as 'Fundamental Harmonic'. The Higher Harmonics are called the overtones.

It vibrates in two segments then the second Harmonic is called first overtone. Similarly the patterns of vibrations are as shown in figure.



Vibrating stretched strings

If the string vibrates in 'P' segments and 'l' is its length then length of each segment $= \frac{l}{p}$

Which is equal to $\frac{\lambda}{2}$

$$\therefore \frac{l}{p} = \frac{\lambda}{2} \Rightarrow \lambda = \frac{2l}{p}$$

Harmonic frequency $\nu = \frac{v}{\lambda} = \frac{vp}{2l}$

$$\nu = \frac{vp}{2l} \qquad \text{——— (1)}$$

If 'T' is tension (stretching force) in the string and 'μ' is linear density then velocity of transverse wave (v) in the string is

$$v = \sqrt{\frac{T}{\mu}} \qquad \text{—— (2)}$$

From the Eqs (1) and (2)

Harmonic frequency $\nu = \frac{p}{2l}\sqrt{\frac{T}{\mu}}$

If p = 1 then it is called fundamental frequency (or) first harmonic frequency

$\therefore$ Fundamental Frequency $\nu = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ —— (3)

If p = 2 then it is first overtone (or) second harmonic frequency.

$$\nu_1 = \frac{2}{2l}\sqrt{\frac{T}{\mu}} = 2\nu \qquad —— (4)$$

Similarly if p = 3 then second overtone (or) third harmonic frequency.

$$\nu_2 = \frac{3}{2l}\sqrt{\frac{T}{\mu}} = 3\nu \qquad —— (5)$$

from the Eqs (3), (4) and (5)

The ratio of the frequencies of harmonics are $\nu : \nu_1 : \nu_2 = \nu : 2\nu : 3\nu = 1 : 2 : 3$

$\therefore$ The frequencies of the overtones in a given vibrating length, are integral multiples of the fundamental in the same length.

Laws of Transverse Waves along Stretched String :

Fundamental frequency of the vibrating string $\nu = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

First Law : When the tension (T) and linear density (μ) are constant, the fundamental frequency (ν) of a vibrating string is inversely proportional to its length.

$$\therefore \nu \propto \frac{1}{l} \Rightarrow \nu l = \text{constant, when 'T' and '}\mu\text{' are constant.}$$

Second Law : When the length (l) and its, linear density (m) are constant the fundamental frequency of a vibrating string is directly proportional to the square root of the stretching force (T).

$$\therefore \nu \propto \sqrt{T} \Rightarrow \frac{\nu}{\sqrt{T}} = \text{constant, when '}l\text{' and 'm' are constant.}$$

Third Law : When the length (l) and the tension (T) are constant, the fundamental frequency of a vibrating string is inversely proportional to the square root of the linear density (m).

$$\nu \propto \frac{1}{\sqrt{\mu}} \Rightarrow \nu\sqrt{\mu} = \text{constant, when '}l\text{' and 'T' are constant.}$$

Problem : $l = 0.4$ m; M = 0.16g = 0.16×10^{-3} kg;

$$\mu = \frac{M}{l} = \frac{0.16 \times 10^{-3}}{0.4} = 0.4 \times 10^{-3} \text{ kg/m;}$$

$$T = 70 \text{ N; } \nu_n = \frac{P}{2l}\sqrt{\frac{T}{\mu}}$$

$$\nu_1 = \frac{1}{2l}\sqrt{\frac{T}{\mu}} = \frac{1}{2 \times 0.4}\sqrt{\frac{70}{0.4 \times 10^{-3}}} = 523\text{Hz}$$

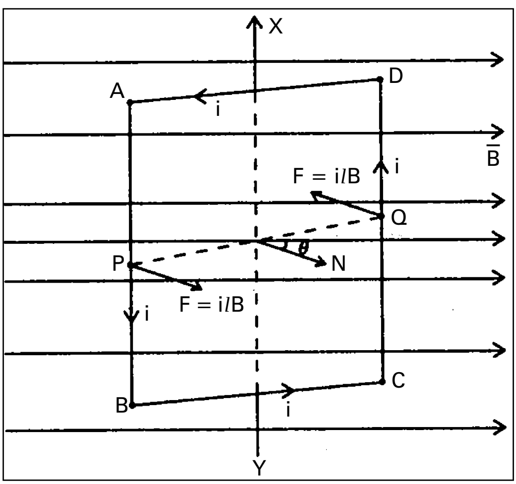
$$\nu_2 = 2\nu_1 = 2 \times 523 = 1046 \text{ Hz}$$

$$\nu_3 = 3\nu_1 = 3 \times 523 = 1569 \text{ Hz}$$

20. Obtain an expression for the torque on a current carrying loop placed in a uniform magnetic field. Describe the construction and working of a moving coil galvanometer.

Ans. Torque acting on a coil carrying a current kept in a uniform magnetic field : Let a rectangular current loop ABCD of length l = AB = CD and width b = AD = BC carrying a current "i" be suspended in a magnetic field of flux density B.

The normal ON drawn to the plane of the coil makes an angle 'θ' with the magnetic field B.

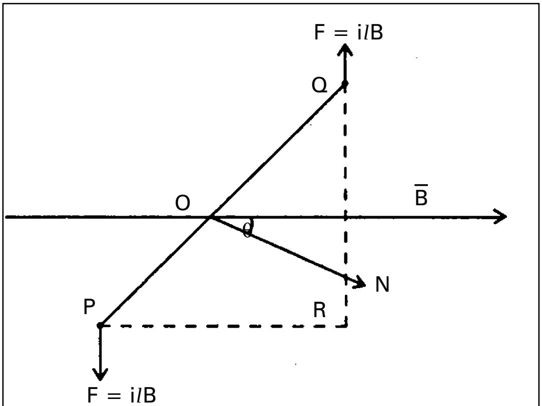


Torque on current loop

Force on arm AD = $i\bar{b} \times \bar{B}$ acting upwards along the axis of suspension

Force on arm BC = $i\bar{b} \times \bar{B}$ acting downwards along the axis of suspension

Hence these two forces cancel.



Couple on current loop

Force on arm AB = i*l*B acting perpendicular to the plane as shown.

Force on arm CD = i*l*B acting perpendicular to the plane as shown.

These two forces constitute a couple on the coil.

Moment of the couple = (Force) × (Perpendicular distance between the forces) = i*l*B (PQ sin θ)

Torque = i*l*B b sinθ

But $l \times b$ = Area of coil

∴ Torque = iAB sin θ

If the loop has 'n' turns the torque on the coil

$\tau = n\, i\, AB \sin\theta$

If 'ϕ' is the deflection of the coil, that is the angle between the plane of the coil and magnetic field B

$\tau = n\, i\, AB \cos\phi$

Moving coil galvanometer :

Principle : When a current carrying coil is placed in the uniform magnetic field, it experiences a torque.

Construction :

i) It consists of a coil wound on a non metallic frame.

ii) A rectangular coil is suspended between two concave shaped magnetic poles with the help of phosphor Bronze wire.

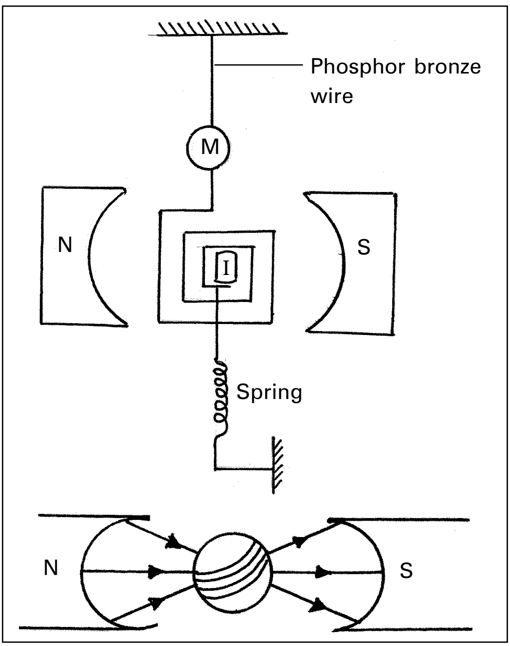
iii) The lower portion of the coil is connected to a spring.

iv) A small plane mirror M is fixed to the phosphor Bronze wire to measure the deflection of the coil.

v) A small soft iron cylinder is placed with in the coil without touching the coil. The soft iron cylinder increases the induction field strength.

vi) The concave shaped magnetic poles render the field radial. So maximum torque acting on it.

vii) The whole of the apparatus is kept inside a brass case provided with a glass window.



Theory :

Consider a rectangular coil of length l and breadth b and carrying current i suspended in the induction field strength B.

Deflecting torque $(\tau) = B\,i\,A\,N \longrightarrow (5)$

where A = Area of the coil

N = Total number of turns.

The restoring torque developed in the suspension $= C\,\theta \longrightarrow (2)$

Where C is the couple per unit twist and θ is the deflection made by the coil.

When the coil is in equilibrium position

Deflecting torque = Restoring torque

$$B\,i\,A\,N = C\theta$$

$$i = \left(\frac{C}{BAN}\right)$$

Where $K = \frac{C}{BAN}$ = Galvanometer constant.

$$i = K\,\theta \longrightarrow (3)$$

$$i \propto \theta$$

Thus deflection of the coil is directly proportional to the current flowing through it.

The deflection in the coil is measured using lamp and scale arrangement.

21. State the basic postulates of Bohr's theory of atomic spectra. Hence obtain an expression for the radius of orbit and the energy of orbital electron in a hydrogen atom.

The radius of the first electron orbit of a hydrogen atom is 5.3×10^{-11} m. What is the radius of the second orbit ?

Ans. a) Basic postulates of Bohr's theory are

1) The electron revolves round a nucleus is an atom in various orbits known as stationary orbits. The electrons can not emit radiation when moving in their own stationary levels.

2) The electron can revolve round the nucleus only in allowed orbits whose angular momentum is the integral multiple of $\frac{h}{2\pi}$

i.e., $m\upsilon_n r_n = \frac{nh}{2\pi}$ $\longrightarrow$ (1)

where n = 1, 2, 3.....

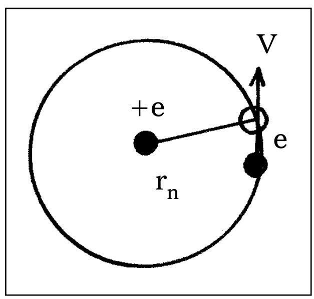
3) If an electron jumps from higher energy (E_2) orbit to the lower energy (E_1) orbit, the difference of energy is radiated in the form of radiation.

i.e., $E = h\nu = E_2 - E_1 \Rightarrow \nu = \frac{E_2 - E_1}{h}$ $\longrightarrow$ (2)

b) Energy of emitted radiation : In hydrogen atom, a single electron of charge $\bar{e}$, revolves around the nucleus of charge e in a circular orbit of radius r_n.

1) K.E. of electron : For the electron to be in circular orbit, centripetal force = The electrostatic force of attraction between the electron and nucleus.

From Coulomb's law,



$\frac{m\upsilon n^2}{r_n} = \frac{Ke^2}{r_n^{\ 2}}$ $\longrightarrow$ (3)

where $K = \frac{1}{4\pi\varepsilon_0}$ $\longrightarrow$ (4)

$m\upsilon^2 = \frac{Ke^2}{r_n}$ $\longrightarrow$ (5)

$m\upsilon^2 r_n = ke^2$ $\longrightarrow$ (6)

Dividing (5) by (1), $\upsilon_n = Ke^2 \times \frac{2\pi}{nh}$

From (3), kinetic energy $K = \frac{1}{2} m\upsilon_n^{\ 2} = \frac{Ke^2}{2r_n}$

2) Potential energy of electron :

P.E. of electron, $U = \frac{Ke}{r_n} \times -e = \frac{-Ke^2}{r_n} \quad \left[\because W = \frac{1}{4\pi\varepsilon_0}\frac{q}{d} \times -q\right]$

3) Radius of the oribit : Substituting the value of (6) in (2),

$$\frac{m}{r_n}\left(\frac{n^2h^2}{4\pi^2 r_n^2 \; m^2}\right) = \frac{Ke^2}{r_n{}^2}$$

$$r_n = \frac{n^2h^2}{4\pi^2 mke^2} \longrightarrow (1)$$

$\therefore r_n = 0.53n^2$

4) Total energy (E_n) : Revolving electron posses K.E. as well as P.E.

i.e., $E_n = K + U = \frac{Ke^2}{2r} - \frac{ke^2}{r} = \frac{-ke^2}{2r}$

$\Rightarrow E_n = \frac{-Ke^2}{2n^2h^2} \times 4\pi^2 mke^2 \quad [\therefore \text{ from } (7)]$

But $K = \frac{1}{4\pi\varepsilon_0}$

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

Problem : $r_n \propto n^2$

$\frac{r_2}{r_1} = \frac{2^2}{1^2} = \frac{4}{1} \Rightarrow r_2 = 4r_1$

$r_2 = 4 \times 5.3 \times 10^{-11} = 2.12 \times 10^{-10}$ m

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