Maharashtra State Board
Class XII Physics
Board Paper – 2015 Solution

SECTION - I

1.

(i) **(c)**

The time period of a conical pendulum is

$$T = 4\pi\sqrt{\frac{l\cos\theta}{4g}} = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

(ii) **(b)**

Kinetic energy of a rotating body is

$$K.E. = \frac{1}{2}I\omega^2$$

(iii) **(b)**

The time period of a simple pendulum is

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l = length of the pendulum

g = acceleration due to gravity

Therefore, from the given equation, we know that the periodic time of the pendulum does not depend on the mass of the bob, and so, it does not matter of what material the bob is made of, and hence, its time period remains the same.

(iv) **(a)**

Stress is directly proportional to strain and the elastic limit is

$$\frac{F}{A} \propto \frac{\Delta L}{L}$$

Since, A and L are constants.

$$\therefore F \propto \Delta L$$

Thus, the graph between applied force and change in length is a straight line with a positive slope.

(v) **(a)**

A compression is reflected as a compression at the boundary of a denser medium, but it is reflected as a rarefaction at the boundary of a rarer medium.

(vi) **(d)**

$$G = \frac{Fr^2}{Mm}$$

$$\therefore [G] = \frac{[L^1M^1T^{-2}][L^2]}{[M^2]} = [L^3M^{-1}T^{-2}]$$

(vii) **(b)**

$r_1 = 6$ cm

$r_2 = 12$ cm

$T_1 = T_2 = 15°C$

Ratio of loss of heat is

$$\frac{R_1}{R_2} = \frac{A_1}{A_2} \times \frac{T_1^4}{T_2^4}$$

$$\frac{R_1}{R_2} = \frac{4\pi r_1^2}{4\pi r_2^2} = \frac{6^2}{12^2} = \frac{1}{4}$$

2.

(i) Given that:

$$\vec{v} = \vec{\omega} \times \vec{r}$$

Differentiating the above equation,

$$\frac{\overrightarrow{dv}}{dt} = \frac{d}{dt}(\vec{\omega} \times \vec{r})$$

$$= \frac{d\omega}{dt} \times \vec{r} + \vec{\omega} \times \frac{dr}{dt}$$

By definition,

$$\frac{\overrightarrow{dv}}{dt} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}$$

$$\vec{a} = \overrightarrow{a_T} + \overrightarrow{a_r}$$

Where, a = Linear acceleration

a_T = Tangential component of linear acceleration

a_r = Radial component of linear acceleration

(ii) When an astronaut is in an orbiting satellite, the astronaut and satellite are attracted towards the centre of the Earth and both will fall towards the Earth with the same acceleration. This acceleration is the same as 'g' at the satellite. Thus, the astronaut is unable to exert weight on the floor of the satellite. Because of this, the satellite does not provide a normal reaction on the astronaut, and hence, the astronaut feels weightlessness.

(iii) **Theorem of parallel axes:** The moment of inertia of a body about any axis is equal to the sum of its moment of inertia about a parallel axis passing through its centre of mass and the product of its mass and the square of the perpendicular distance between the two parallel axes.

Theorem of perpendicular axes: The moment of inertia of a plane lamina about an axis perpendicular to its plane is equal to the sum of its moment of inertia about two mutually perpendicular axes concurrent with the perpendicular axis and lying in the plane of the laminar body.

(iv) (a) **Wien's displacement law:** The wavelength for which the emissive power of a black body is maximum is inversely proportional to the absolute temperature of the black body.

(b) **First law of thermodynamics:** Energy (ΔQ) supplied to the system goes in partly to increase the internal energy of the system (ΔU) and the rest in work on the environment (ΔW).

$$\Delta Q = \Delta U + \Delta W$$

(v) A particle in SHM has a period of 2 seconds and an amplitude of 10 cm. When it is at 4 cm from its positive extreme position, the displacement (x) of the particle is 10 − 4 = 6 cm.

Acceleration = $\omega^2.x$ (in magnitude)

$$= \left(\frac{2\pi}{T}\right)^2 x$$

$$= \frac{4\pi^2}{(2)^2} \times 6$$

$$= 59.16 \text{ m s}^{-2}$$

Thus, the acceleration of the particle at 4 cm from its positive extreme position is 59.16 m/s^2.

(vi) We have

$$T = T_o\ (1 - \alpha\theta)$$

$$= 75.5\ (1 - 2.7 \times 10^{-3} \times 25)$$

$$= 75.5\ (1 - 67.5 \times 10^{-3})$$

$$= 70.4 \text{ dyne/cm}$$

The surface of water at 25°C is 70.4 dyne/cm.

(vii) Given that

$\omega = 5$ r.p.s. $= 5 \times 2\pi$ rad/s $= 10\pi$ rad/s

$\omega_0 = 15$ r.p.s. $= 15 \times 2\pi$ rad/s $= 30\pi$ rad/s

$\theta = 50$ revolutions $= 50 \times 2\pi$ rad $= 100\pi$ rad

$$\omega^2 = \omega_o^2 + 2\alpha\theta$$

$$(10\pi)^2 = (30\pi)^2 + 2 \times \alpha \times (100\pi)^2$$

$$\alpha = -4\pi \text{ rad/s}^2$$

Or, $\alpha = -12.56 \text{ rad/s}^2$

The negative sign indicates that the angular acceleration is directed in a direction opposite to the angular velocity.

(viii) Given that $\dfrac{r_J}{r_E} = 5$

$$\frac{T_J^2}{T_E^2} = \frac{r_J^3}{r_E^3}$$

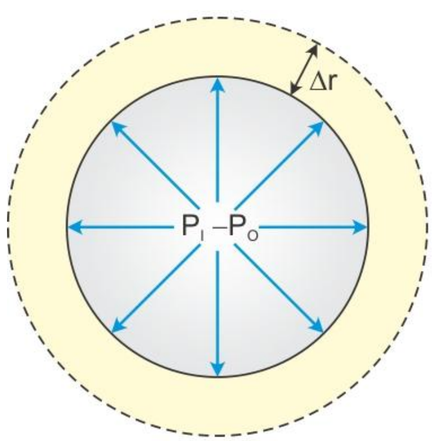
Or, $\dfrac{T_J}{T_E} = \left(\dfrac{r_J}{r_E}\right)^{3/2}$

$$\frac{T_J}{1} = (5)^{3/2} = 11.18 \text{ years}$$

Thus, the period of revolution of Jupiter is 11.18 years.

3.

(i) Consider a liquid drop of radius R. Due to the surface tension, the molecules lying on the surface of the liquid drop will experience a resultant force inwards, perpendicular to the surface. The pressure inside the liquid drop must be greater than the pressure outside as the size of the drop cannot be reduced to zero. This excess pressure inside the drop provides a force outwards, perpendicular to the surface to counter balance the resultant force due to the surface tension.



Let the pressure outside the liquid drop be P_o and the inside pressure be P_i.
The excess pressure inside the drop = $(P_i - P_o)$.
Let T be the surface tension of the liquid.
Let the radius of the drop increase from r to $(r + \Delta r)$ due to excess pressure.
The work done by the excess pressure is given by

$$dW = \text{Force} \times \text{Displacement}$$
$$= (\text{Excess pressure} \times \text{Area}) \times (\text{Increase in radius})$$
$$= \left[(P_i - P_o) \times 4\pi r^2\right] \times \Delta r \qquad \text{......(1)}$$

Let the initial surface area of the drop be $A_1 = 4\pi r^2$.
The final surface area of the drop is $A_2 = 4\pi(r+\Delta r)^2$.

$$A_2 = 4\pi\left(r^2 + 2r\Delta r + \Delta r^2\right)$$
$$= 4\pi r^2 + 8\pi r\Delta r + 4\pi\Delta r^2$$

As Δr is very small, Δr^2 can be neglected, i.e. $4\pi\Delta r^2 \cong 0$
Therefore,

$$A_2 = 4\pi r^2 + 8\pi r\Delta r$$

Therefore, increase in the surface area of the drop $dA = A_2 - A_1$

$$= 4\pi r^2 + 8\pi r\Delta r - 4\pi r^2$$
$$= 8\pi r\Delta r$$

Work done to increase the surface area by $8\pi r\Delta r$ is the extra surface energy.

$$dW = T \times dA$$

where T is the surface energy

$$dW = T \times 8\pi r\Delta r \qquad \text{...... (2)}$$

Comparing (1) and (2), we get

$$\left[(P_i - P_o) \times 4\pi r^2\right] \times \Delta r = T \times 8\pi r\Delta r$$
$$P_i - P_o = \frac{2T}{r}$$

The above equation gives the excess pressure inside a liquid drop.

(ii) The apparent change in the frequency of sound emitted by a source as heard by the observer when there is a relative motion between the source of sound and an observer is called **Doppler Effect**.
Applications of Doppler Effect:

a. In colour Doppler sonography – To provide information about the rate of flow of various fluids, including blood.
b. For the determination of the speed of rotation of the Sun and the speed of stars
c. In RADAR
d. For speed detection on highways

(iii) Given that

Temperature = 27°C = (273 + 27) K = 300 K

(a) Average kinetic energy per kilo mole = $\frac{3}{2}RT$

$$= \frac{3}{2} \times 8320 \text{ J/K mole} \times 300 \text{ K}$$

$$= 3.744 \times 10^6 \text{ J}$$

(b) Kinetic energy per kilogram = $\frac{\text{Kinetic energy per kilo mole}}{\text{Molecular weight}}$

Molecular weight of oxygen= 32

Kinetic energy per kilogram = $\frac{3.744 \times 10^6 \text{ J}}{32} = 0.117 \times 10^6 \text{ J}$

(iv) Given that $\alpha_{steel} = 12 \times 10^{-6}/°C$, $Y_{steel} = 20 \times 10^{10} \text{ N/m}^2$

Area of cross-section of the rod, A = 5 mm^2 = 5×10^{-6} m

Change in temperature (ΔT), ($T_2 - T_1$) = 25°C

Force exerted by the rod due to heating = Thermal stress × Area

$$\text{Thermal stress} = Y \times \text{Strain}$$

$$= Y_{steel} \times \alpha_{steel} \times \Delta T$$

Therefore, the force exerted by the rod due to heating is

$$= Y_{steel} \times \alpha_{steel} \times \Delta T \times A$$

$$= 20 \times 10^{10} \times 12 \times 10^{-6} \times 25 \times 5 \times 10^{-6}$$

$$= 300 \text{ N}$$

$$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}} = \alpha \Delta T$$

$$\text{Strain} = \alpha_{steel} \Delta T$$

$$= 12 \times 10^{-6} \times 25$$

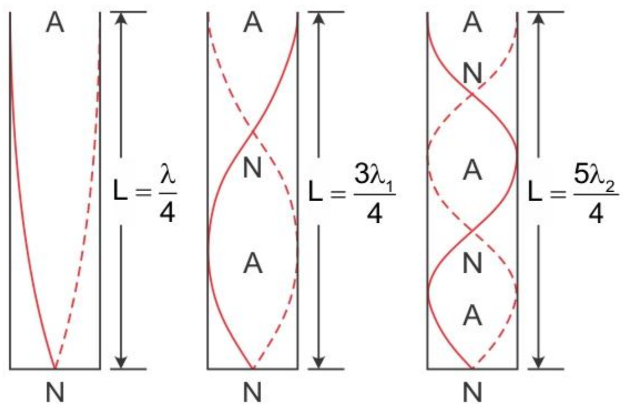
$$= 3 \times 10^{-4}$$

4. The vibrations of a body under the action of an external periodic force in which the body vibrates with a frequency equal to the frequency of the external periodic force, other than its natural frequency, are called **forced vibrations**.

Resonance is the phenomenon in which the body vibrates under the action of an external periodic force whose frequency is equal to the natural frequency of the driven body, so that its amplitude becomes maximum. Resonance is a special case of forced vibrations.

Consider the different modes of vibration of an air column within a pipe closed at one end. Let L be the length of the pipe.

Stationary waves are formed within the air column when the time taken by the sound waves to produce a compression and rarefaction becomes equal to the time taken by the wave to travel twice the length of the tube. The standing waves are formed only for certain discrete frequencies.



In the **first mode of vibration** of the air column, there is one node and one antinode as shown in the figure above.

If λ is the length of the wave in the fundamental mode of vibration,

$$\text{Then, Length of the air column, } L = \frac{\lambda}{4}$$

$$\Rightarrow \lambda = 4L \text{ ----------(1)}$$

As velocity of the wave, $v = n\lambda$

$$n = \frac{v}{\lambda}$$

substituting (1) we get:

$$n = \frac{v}{4L}; \text{ Frequency of the fundamental mode}$$

In the **second mode of vibration** of the air column, two nodes and two antinodes are formed.

In this case:

$$\text{The length of the air column, } L = \frac{3\lambda_1}{4}$$

where λ_1 is the wavelength of the wave in the second mode of vibration,

$$\Rightarrow \lambda_1 = \frac{4L}{3} \quad \text{-------(1)}$$

$$v = n_1\lambda_1$$

$$n_1 = \frac{v}{\lambda_1}$$

substituting (1), we get

$$n_1 = \frac{v}{\frac{4L}{3}} = \frac{3v}{4L} = 3n$$

This frequency is called the third harmonics or first overtone

Similarly, during the third mode of vibration of the air column, three nodes and three antinodes are formed.

Here,

The length of the air column, $L = \frac{5\lambda_2}{4}$

where λ_2 is the wavelength of the wave in third mode of vibration,

$$\Rightarrow \lambda_2 = \frac{4L}{5} \quad -------(1)$$

$$v = n_2\lambda_2$$

$$n_2 = \frac{v}{\lambda_2}$$

substituting (1), we get

$$n_2 = \frac{v}{\frac{4L}{5}} = \frac{5v}{4L} = 5n$$

This frequency is called the fifth harmonic or second overtone.

Thus, we see that the frequencies of the modes of vibrations are in the ratio **$n:n_1:n_2$ = 1:3:5**. This shows that only odd harmonics are present in the modes of vibrations of the air column closed at one end.

Let 'l' be the length of the wire which emits a fundamental note of frequency 256 Hz.

When length = (l − 10) cm, fundamental frequency n = 320 Hz.

We know that the fundamental frequency n of a stretched string is given by

$$n = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

where 'T' is the tension and 'm' the linear density of the string.

When length = l, n = 256 Hz

i.e.

$$256 = \frac{1}{2l}\sqrt{\frac{T}{m}} --------(1)$$

When length = (l − 10) cm, n = 320 Hz

$$320 = \frac{1}{2(l-10)}\sqrt{\frac{T}{m}} --------(2)$$

Dividing (1) by (2) gives

$$\frac{256}{320} = \frac{2(l-10)}{2l}$$

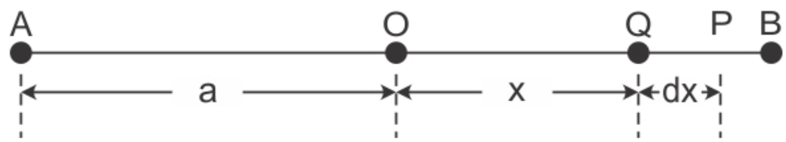
$$\frac{4}{5} = \frac{(l-10)}{l}$$

$l = 50$ cm = 0.5 m

Therefore, the original length of the wire is 50 cm.

OR

Consider a particle of mass 'm' performing simple harmonic motion along the path AB about its mean position O as shown.



If the particle is at a distance x (Q) from its mean position O, then the restoring force F on the particle is

$F = -k\,x$ (k = Force constant)

If the particle undergoes a further infinitesimal displacement dx against F, the work done is

$$dW = -Fdx$$
$$= -(-kx)dx$$
$$= kxdx$$

The total work done from O (x = 0) to Q (x = x) is

$$\int dW = \int_0^x kx\,dx = k\int_0^x x\,dx$$

On integrating we get:

$$W = \frac{1}{2}kx^2$$

$$W = \frac{1}{2}m\omega^2x^2 \qquad (\because\ k = m\omega^2)$$

This gives the potential energy of a particle executing simple harmonic motion.

i.e

$$\text{Potential energy} = \frac{1}{2}kx^2 = \frac{1}{2}m\omega^2x^2$$

At the mean position O: The velocity of the particle performing simple harmonic motion is maximum and the displacement is minimum (x = 0).

As x = 0

$$\text{Potential energy} = \frac{1}{2}kx^2 = 0$$

At the extreme position A/B: The velocity of the particle performing simple harmonic motion is minimum and the displacement is maximum (x = ±a).

$$\therefore \text{Potential energy} = \frac{1}{2}kx^2 = \frac{1}{2}ka^2 = \frac{1}{2}m\omega^2a^2$$

To calculate new frequency of rotation of disc:
It is given that
n_1 = 100 r.p.m
The moment of inertia of the disc about transverse axis is $I_1 = 2 \times 10^{-4}$ kg m^2
The mass of the wax is $m = 20$ g $= 20 \times 10^{-3}$ kg
The distance from the centre where wax falls = $r = 5$ cm $= 5 \times 10^{-2}$ m
To find n_2 = ?

Now, the moment of inertia of the disc with wax on it is $I_2 = I_1 + I_{wax}$ (according to parallel axes theorem)
So, we have $I_2 = I_1 + mr^2$

Now, we know that the angular momentum is conserved. So, we get

$$I_1\omega_1 = I_2\omega_2$$

$$I_1(2\pi n_1) = (I_1 + mr^2)(2\pi n_2)$$

$$I_1 n_1 = (I_1 + mr^2) n_2$$

$$\therefore n_2 = \frac{I_1 n_1}{I_1 + mr^2} = \frac{2\times10^{-4}\times100}{2\times10^{-4} + \left[20\times10^{-3}\times(5\times10^{-2})^2\right]}$$

$$\therefore n_2 = \frac{0.02}{2\times10^{-4} + 0.5\times10^{-4}} = \frac{0.02}{2.5\times10^{-4}} = 80 \text{ r.p.m}$$

Hence, the new frequency of rotation of disc is 80 revolutions per minute.

SECTION – II

5.

(i) **(a)**

Electric field intensity in the free space outside the charged conducting sphere in terms of surface charged density is given as

$$E = \frac{\sigma}{\varepsilon}\left(\frac{R}{r}\right)^2$$

(ii) **(c)**

A potentiometer is an instrument used to compare the e.m.f. of two cells or any two sources of e.m.f. If the e.m.f. of one of the sources is known, then the absolute value of the other source can be determined. The potentiometer can also be used to determine the internal resistance of a cell, to measure current, to calibrate an ammeter or voltmeter, to compare resistances and for measurement of thermoelectric e.m.f.

(iii) **(c)**

Since the frequency is double, the value of E is also double.

$$\text{K.E.} = E - \phi$$

$$\therefore \text{K.E.}_1 = E - \phi \qquad \text{......(i)}$$

$$\text{K.E.}_2 = 2E - \phi \qquad \text{......(ii)}$$

From (i) and (ii), we get

$$\text{K.E.}_2 > \text{K.E.}_1$$

(iv) **(b)**

Linear momentum, p = mv

Velocity of electron in Bohr's orbit is given as

$$v = \frac{e^2}{2\varepsilon_0 nh}$$

$$\therefore mv = \frac{e^2}{2\varepsilon_0 nh}$$

$$\Rightarrow p = \frac{me^2}{2\varepsilon_0 nh}$$

$$\Rightarrow p \propto \frac{1}{n}$$

(v) **(b)**

Indium is an acceptor impurity, whereas antimony, phosphorus and arsenic are donor impurities.

(vi) **(d)**

Effective power radiated by the antenna would be too small, because the power radiated by a linear antenna of length 'l' into space is $(l/\lambda)^2$.

As high powers are needed for good transmission, so higher frequency is required which can be achieved by modulation.

(vii) **(c)**

The minimum resolvable linear distance between two nearby objects is given by $x = \dfrac{\lambda}{2\,NA} = \dfrac{6000\times10^{-10}}{2\times0.12} = 2.5\times10^{-6}\,m = 25\times10^{-7}\,m$.

6.

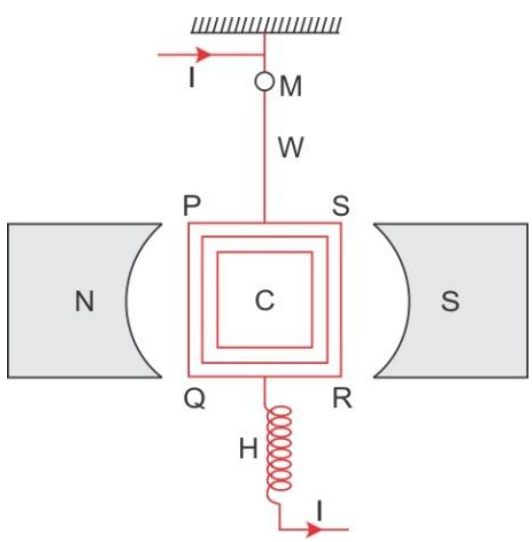
(i) Polaroid is a large sheet of synthetic material packed with tiny crystals of a substance oriented parallel to one another so that it transmits light in one direction of the electric vector.

Uses of Polaroid:

(1) In motor car head lights – To remove headlight glare

(2) To improve colour contrast in old oil paintings

(ii) Suspended type of moving coil galvanometer:



PQRS = Rectangular coil

W = Thin phosphor bronze wire suspension

M = Plane mirror

H = Helical spring

C = Soft iron cylinder

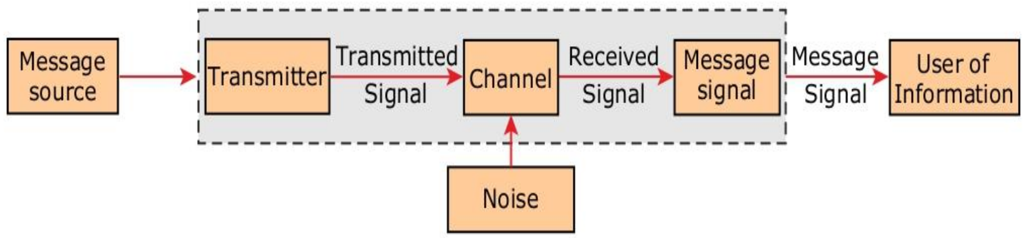
I = Current through the coil

(iii) Magnetization: The net magnetic dipole moment per unit volume is magnetizationof the sample.

$$\text{Magnetization} = \frac{\text{Net magnetic moment}}{\text{Volume}}$$

Magnetic intensity: Magnetic intensity is a quantity used in describing magnetic phenomenon in terms of the magnetic field. The strength of the magnetic field at a point can be given in terms of a vector quantity called magnetic intensity (H).

(iv) Block diagram of generalization of the communication system:



(v) Given that

Length of solenoid, l = 3.142 m

Diameter, d = 5.0 cm = 0.05 m

No. of turns, N = 500

Current, I = 5 A

Magnetic Induction, B =?

To calculate the magnetic induction at its centre along the axis,

Formula: $B = \mu_o nI$

$$B = \mu_o \left(\frac{N}{l}\right) I$$

$$\therefore B = \frac{4\pi \times 10^{-7} \times 500 \times 5}{3.142}$$

$\therefore B = 10 \times 10^{-7}$ T

Hence, the magnetic induction at the centre of the circular loop along its axis is 10×10^{-7} T.

(vi) No. of turns, n = 300

$A = 5 \times 10^{-3}\,m^2$

I = 15 A

For n turns, M = nIA

$M = 300 \times 15 \times 5 \times 10^{-3}$

$M = 22.5\ Am^2$

Hence, the magnitude of magnetic induction associated with the coil is $22.5\ Am^2$.

(vii) Magnetic flux through the coil is given by relation

$\phi = 8t^2 + 6t + c$ (where c is constant) (i)

To find the magnitude of the induced e.m.f. 'e' in the loop at t = 2 seconds, we know that $e = \left|\frac{d\phi}{dt}\right|$

Differentiating equation (i) w.r.t. t we get,

$e = 16t + 6$

$e = 16 \times (2) + 6$

$e = 38$ millivolt = 0.038 volt

Hence, the magnitude of induced e.m.f. is 0.038 volt.

(viii) Ground state energy $E_1 = -13.6$ eV

$E_5 = ?$

Energy of electron in Bohr's orbit is inversely proportional to the square of the principal quantum number.

$\therefore \frac{E_5}{E_1} = \frac{n_1^2}{n_5^2}$

$\therefore \frac{E_5}{E_1} = \frac{1^2}{5^2}$

$\therefore E_5 = \frac{-13.6}{25} = -0.544$ eV

The ionization energy = $E_\infty - E_5 = 0 - (-0.544) = 0.544$ eV

Hence, the ionization energy in the 5th orbit is 0.544 eV.

7.

(i) Let us consider an electron revolving around the nucleus in a circular orbit of radius 'r'.

According to Bohr's first postulate, the centripetal force is equal to the electrostatic force of attraction. That is

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

$$\text{Or,}\ v^2 = \frac{e^2}{4\pi\varepsilon_o mr} \quad \text{---------}\ (1)$$

According to the Bohr's second postulate:

$$\text{Angular momentum} = n\frac{h}{2\pi}$$

$$mvr = n\frac{h}{2\pi}$$

$$\text{Or,}\quad v = \frac{nh}{2\pi mr} \quad \text{---------}\ (2)$$

Or, $$v^2 = \frac{n^2h^2}{4\pi^2m^2r^2} \text{ --------- (3)}$$

Comparing eqn (1) and eqn (3), we get

$$\frac{e^2}{4\pi\varepsilon_o mr} = \frac{n^2h^2}{4\pi^2m^2r^2}$$

$$\text{Or, } r = \left(\frac{h^2\varepsilon_o}{\pi me^2}\right)n^2 \text{ --------- (4)}$$

This equation gives the radius of the n^{th} Bohr orbit.

$$\text{For } n = 1,\ r_1 = \left(\frac{h^2\varepsilon_o}{\pi me^2}\right) = 0.537 \text{ --------- (5)}$$

$$\text{In general, } r_n = \left(\frac{h^2\varepsilon_o}{\pi me^2}\right)n^2$$

The above equation gives the radius of Bohr orbit.

(ii) Alpha (α_{dc}): It is defined as the ratio of collector current to emitter current.

$$\alpha_{dc} = \frac{I_c}{I_E} \text{ --------- (Equation 1)}$$

Beta (β_{dc}): It is the current gain defined as the ratio of collector current to the base current.

$$\beta_{dc} = \frac{I_c}{I_B} \text{ --------- (Equation 2)}$$

Relation between α_{dc} and β_{dc}:

For a transistor,

$I_E = I_B + I_C$ (with $I_c \cong I_E$) --------- (Equation 3)

Divinding both the side of eqn.(3) with I_c, we get :

$$\frac{I_E}{I_c} = \frac{I_B}{I_C} + 1$$

$$\frac{1}{\alpha_{dc}} = \frac{1}{\beta_{dc}} + 1$$

$$\alpha_{dc} = \frac{\beta_{dc}}{1 + \beta_{dc}} \text{ ---------(Equation 4)}$$

$$\text{Or, } \beta_{dc} = \frac{\alpha_{dc}}{1 - \alpha_{dc}} \text{ ---------(Equation 5)}$$

Equations (4) and (5) give the relation between α_{dc} and β_{dc} of a transistor.

(iii) $\sigma_1 = 5\ \mu C/m^2$

$\sigma_2 = -2\ \mu C/m^2$

$r_1 = 2$ mm

$r_2 = 1$ mm

$q_1 = \sigma_1 4\pi\, r_1^{\ 2}$

$q_2 = \sigma_2 4\pi\, r_2^{\ 2}$

T.N.E.I. = $q_1 + q_2$

$\therefore$T.N.E.I. = $4\pi(\sigma_1\, r_1^{\ 2} + \sigma_2\, r_2^{\ 2})$

$\therefore$T.N.E.I. = $4\pi(5 \times 10^{-6} \times 4 \times 10^{-6} + (-2) \times 10^{-6} \times 1 \times 10^{-6})$

$\therefore$T.N.E.I. = $72\pi \times 10^{-12}$ C

$\therefore$T.N.E.I. = 226.08×10^{-12} C

Hence, the total normal electric induction over the closed surface is 226.08×10^{-12} C.

(iv) Wavelength of silver, $\lambda_1 = 3800$ A°

Wavelength of ultraviolet light, $\lambda_2 = 2600$ A°

H = 6.63×10^{-34} Js

Velocity of light in air, c = 3×10^8 m/s

To calculate kinetic energy, K.E. = $h\upsilon - h\upsilon_o$

$$K.E. = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

$$K.E. = 19.89 \times 10^{-19}\left[\frac{1}{2.6} - \frac{1}{3.8}\right]$$

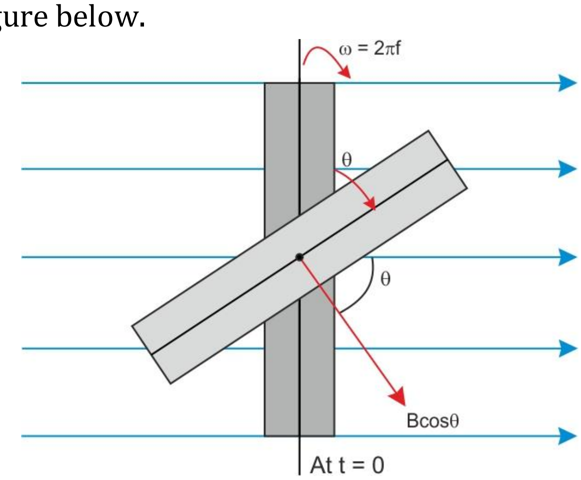
$$K.E. = \frac{2.416 \times 10^{-19}}{1.6 \times 10^{-19}}$$

K.E. = 1.51 eV

Hence, the maximum kinetic energy emitted by the photoelectron is 1.51 eV.

8. Coil rotating in uniform magnetic field:

Consider a coil of ‘N’ turns with effective area NA placed in uniform magnetic induction B as shown in the figure below.



The coil is rotated continuously with constant angular velocity ω. The axis of rotation is in the plane of the coil and normal to the magnetic induction B.

At t = 0, the plane of the coil is perpendicular to the magnetic induction B.
The magnetic flux passing through the coil is NAB.

After t seconds, the plane of the coil is at an angle θ.

Thus, the magnetic flux ϕ through the coil at time t is given by

$$\phi = NAB\cos\theta = NAB\cos\omega t$$

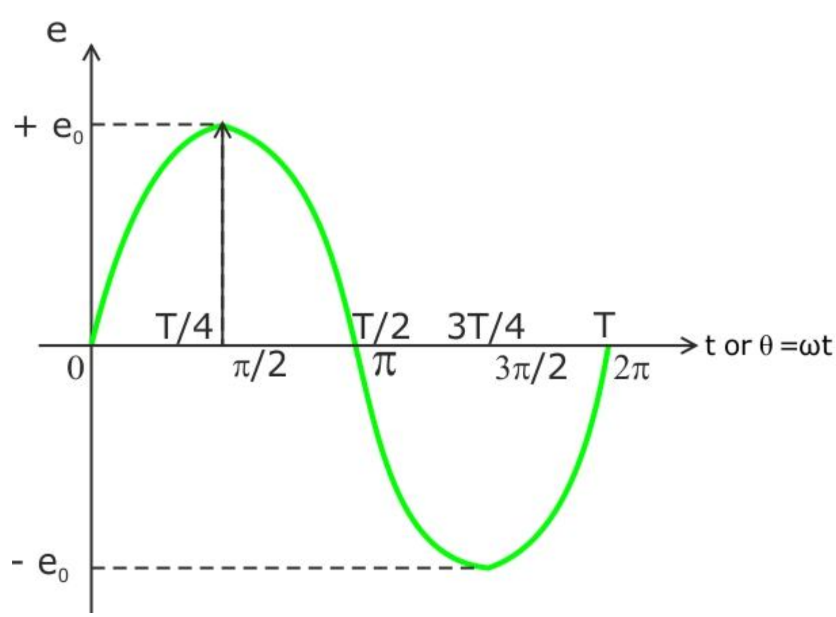
As time changes, the magnetic flux goes on changing. Hence, the e.m.f. generated in the coil is given by

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}\left(NAB\cos\omega t\right)$$

$$e = NAB\omega\sin\omega t$$

$$e = 2\pi fNAB\sin\omega t$$

This is the expression for induced e.m.f. generated in the coil at any instant t. It is known as instantaneous e.m.f.



Given that

$$\frac{R}{L} = \sigma = 0.1\ \Omega/\text{cm} = 0.1 \times 100 = 10\ \Omega/\text{m}$$

$l_1 = 300\ \text{cm} = 3\ \text{m},\ E_1 = 1.5\ \text{V},\ E_2 = 1.4\ \text{V}$

We know that

$$E_1 = iR_1 = i\sigma l_1$$

$$\therefore i = \frac{E_1}{\sigma l_1} = \frac{1.5}{10 \times 3} = 0.05\ \text{A}$$

Hence, the current for the other cell is 0.05 A.

For potentiometer, the balancing condition is

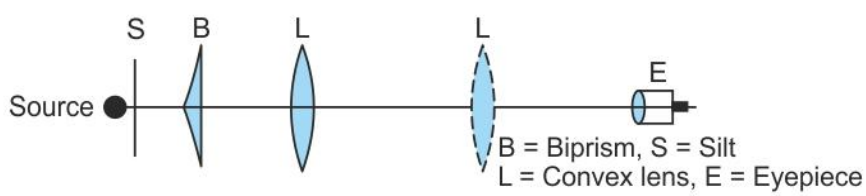
$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$\therefore l_2 = l_1 \frac{E_2}{E_1} = 3 \times \frac{1.4}{1.5} = 2.8\ \text{m}$$

So, the balancing length for the other cell is 2.8 m.

OR

To measure the wavelength of light, an optical bench is used. It is about one and a half metre long, and a scale is marked along its length. Four adjustable stands carrying the slit (S), biprism (B), lens (L) and micrometre eyepiece (E) are mounted on the optical bench.



Initially, the slit, biprism and eyepiece are kept at the same height such that their centres are in the same line. The slit is made narrow and is illuminated by a sodium vapour lamp. The biprism is now rotated slowly about a horizontal axis so that its refracting edge becomes parallel to the slit.

When the refracting edge of the biprism becomes exactly parallel, the interference pattern consisting of alternate bright and dark bands appear in the field of view of the eyepiece.

The formula to be used is

$$\lambda = \frac{Xd}{D}$$

To determine the wavelength, the following steps are taken:

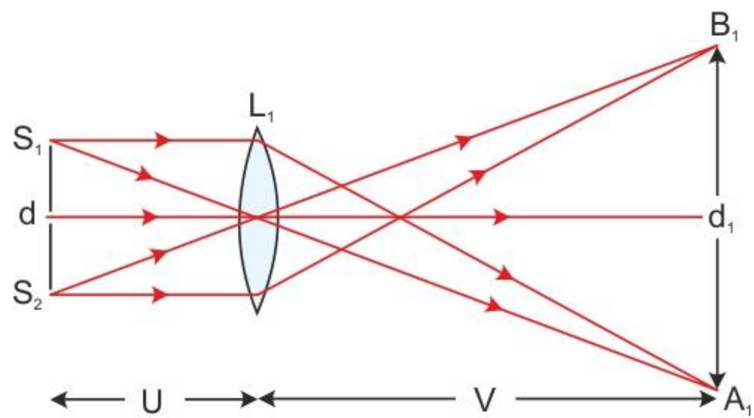
(1) The distance between the slit and the eyepiece D can be easily measured from the scale marked on the optical bench.

(2) The bandwidth X is measured with the help of the micrometre eyepiece. The vertical crosswire in the eyepiece is adjusted at the centre of the bright fringe. The micrometre eyepiece reading is noted.

Now, the eyepiece is moved horizontally until the crosswire has moved over a known number N of bright fringes. Again the reading of the micrometre eyepiece is noted. The difference between the two readings of the micrometre eyepiece gives the distance x through which the eyepiece is moved. Thus, the average distance between two adjacent bright fringes is

$$X = \frac{x}{N}$$

(3) The distance 'd' between two coherent sources cannot be measured directly because the sources are virtual. Hence, the method of conjugate foci is used. In this method, the object and image distances get interchanged in two adjustments.

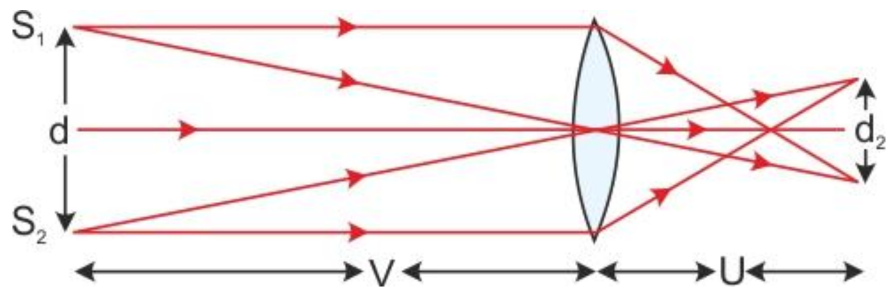


The convex lens of short focal length is introduced between the biprism and the eyepiece. Without disturbing the slit and biprism, the eyepiece is moved back so that its distance from the slit becomes greater than four times the focal length of the lens. The lens is moved towards the slit and its position L_1 is so adjusted that two magnified images A_1 and B_1 of S_1 and S_2 are formed in the focal plane of the eyepiece. The distance d_1 between A_1 and B_1 is measured by the micrometre eyepiece.

From the figure, we get

$$\frac{\text{Size of image}}{\text{Size of object}} = \frac{\text{Distance of image}}{\text{Distance of object}}$$

$$\therefore \frac{d_1}{d} = \frac{v}{u} \qquad \text{......(1)}$$



The lens is now moved towards the eyepiece to the position L_2 where two diminished images A_2 and B_2 of S_1 and S_2 are formed in the focal plane of the eyepiece.

The distance d_2 between A_2 and B_2 is measured by the micrometre eyepiece. Then by the principle of conjugate foci, we can write

$$\frac{d_2}{d} = \frac{u}{v} \qquad \text{......(2)}$$

Multiplying equations (1) and (2), we get

$$\frac{d_1 d_2}{d^2} = \frac{v}{u} \times \frac{u}{v} = 1$$

$$\therefore d^2 = d_1 d_2$$

$$\therefore d = \sqrt{d_1 d_2}$$

Thus, knowing D, X and d, we can calculate the wavelength λ of monochromatic light by using the equation $\lambda = \frac{Xd}{D}$.

The critical angle is given as

$$\sin\theta_C = \frac{1}{n}$$

It is given that

$$\theta_C = \sin^{-1}\frac{3}{5}$$

$$\therefore \frac{1}{n} = \frac{3}{5}$$

$$\therefore n = \frac{5}{3}$$

Now, the polarising angle is given as

$$\theta_P = \tan^{-1} n = \tan^{-1}\frac{5}{3}$$