Physics

Academic Year: 2016-2017 Marks: 70
Date & Time: 4th March 2017, 11:00 am
Duration: 3h

Question 1 | Select and write the most appropriate answer from the given alternatives for each sub-question: [7]

Question 1.1: Choose the correct option. [1]

If the pressure of an ideal gas decreases by 10% isothermally, then its volume will ______.

decrease by 9%
increase by 9%
decrease by 10%
increase by 11.11%

Solution: increase by 11.11%

Explanation:

[Use the formula $P_1V_1 = P_2 V_2$ ......(given)

$$\frac{V_2}{V_1} = \frac{1}{0.9} = 1.111$$

$$\therefore \frac{V_2 - V_1}{V_1} = 0.1111,$$

i.e. 11.11%

Question 1.2: Stretching of a rubber band results in ______. [1]

(A) no change in potential energy.
(B) zero value of potential energy.
(C) increase in potential energy.
(D) decrease in potential energy.

Solution: (C) increase in potential energy.

Question 1.3: When the angular acceleration of a rotating body is zero, which physical quantity will be equal to zero? [1]

(A) Angular momentum
(B) Moment of inertia
(C) Torque
(D) Radius of gyration

Solution: (C) Torque

Question 1.4: In a damped harmonic oscillator, periodic oscillations have ______ amplitude. **[1]**

(A) gradually increasing
(B) suddenly increasing
(C) suddenly decreasing
(D) gradually decreasing

Solution: (D) gradually decreasing

Question 1.5: A sine wave of wavelength λ is travelling in a medium. What is the minimum distance between two particles of the medium which always have the same speed? **[1]**

(A) λ
(B) $\frac{\lambda}{2}$
(C) $\frac{\lambda}{3}$
(D) $\frac{\lambda}{4}$

Solution:
(B) $\frac{\lambda}{2}$

Question 1.6: Velocity of transverse wave along a stretched string is proportional to ______. (T = tension in the string) **[1]**

(A) $\sqrt{T}$
(B) T
(C) $\frac{1}{\sqrt{T}}$
(D) $\frac{1}{T}$

Solution: (A) $\sqrt{T}$

Question 1.7: Find the wavelength at which a black body radiates maximum energy, if its temperature is 427°C. (Wein's constant b = 2.898×10^{-3} mK) **[1]**

(A) 0.0414×10^{-6}m
(B) 4.14×10^{-6}m
(C) 41.4×10^{-6}m
(D) 414×10^{-6}m

Solution: 4.14×10^{-6}m

Question 2 | Attempt any six [12]

Question 2.1: Explain the concept of centripetal force. [2]

Solution: a. Force acting on a particle performing circular motion along the radius of circle and directed towards the centre of the circle is called centripetal force.

It is given by FCP = $m\frac{V^2}{r}$

Where, r = radius of circular path.
b. Example: Electron revolves around the nucleus of an atom. The necessary centripetal force is provided by electrostatic force of attraction between positively charged nucleus and negatively charged electron.
c. Unit: N in SI system and dyne in CGS system.
d. Dimensions: $[M^1L^1T^{-2}]$

Question 2.2: Prove that root mean square velocity of gas molecule is directly proportional to the square root of its absolute temperature. [2]

Solution: Expression for r.m.s velocity:

a. Let, P = pressure exerted by one mole of an ideal gas
V = volume of one mole of the gas
T = absolute temperature
b. Pressure exerted by gas is given by,

$$P = \frac{1}{3}\frac{Mc^2}{V}$$

where M = mass of one mole (molecular weight) of the gas.

$$PV = \frac{1}{3}(Mc^2) \text{ ....(1)}$$

c. But for one mole of an ideal gas, PV = RT

$\therefore RT = \frac{1}{3}MC^2$ [From Equation 1]

$\therefore c^2 = \frac{3RT}{M}$

$\therefore c = \sqrt{\frac{3RT}{M}}$ ....(2)

Equation (2) represents expression for r.m.s velocity of gas molecules.

d. As R and M in equation (2) are constant,

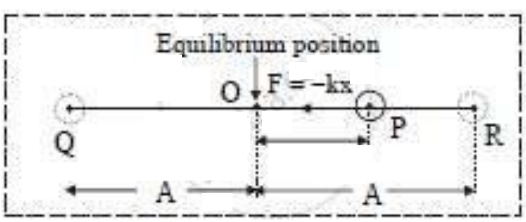
$\therefore c \propto \sqrt{T}$

$\therefore \frac{c_1}{c_2} = \sqrt{\frac{T_1}{T_2}}$

Question 2.3: Obtain the differential equation of linear simple harmonic motion. **[2]**

Solution: Differential equation of linear S.H.M:

a. Let a particle of mass 'm' undergo S.H.M about its mean position O. At any instant 't', displacement of particle be 'x' as shown in the following figure.



b. By definition, F = - kx ....(1)
where, k is force constant

c. The acceleration of the particle is given by,

$$a=\frac{dv}{dt}=\frac{d\left(\frac{dx}{dt}\right)}{dt}=\frac{d^2x}{dt^2}$$

d. According to Newton's second law of motion,

F = ma

$$\therefore F=m\left(\frac{d^2x}{dt^2}\right) \text{..................(2)}$$

e. From equations (1) and (2),

$$m\left(\frac{d^2x}{dt^2}\right)=-kx$$

$$\therefore \frac{d^2x}{dt^2}=-\frac{k}{m}x$$

$$\therefore \frac{d^2x}{dt^2}+\frac{k}{m}x=0\text{....................(3)}$$

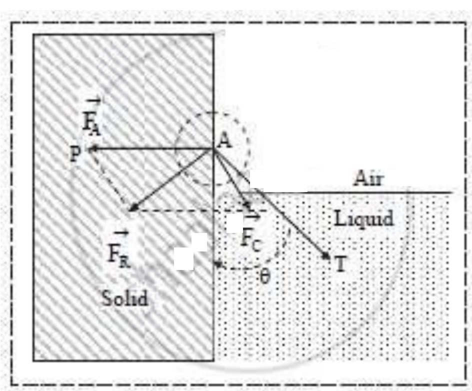
where, $\frac{k}{m}=\omega^2=contsant$

$$\therefore \frac{d^2x}{dt^2}+\omega^2x=0\text{...................(4)}$$

f. Equations (3) and (4) represent differential equation of linear S.H.M.

Question 2.4: Draw a neat, labelled diagram for a liquid surface in contact with a solid, when the angle of contact is acute. **[2]**

Solution:



Question 2.5: A hole is drilled half way to the centre of the Earth. A body is dropped into the hole. How much will it weigh at the bottom of the hole if the weight of the body on the Earth's surface is 350 N? **[2]**

Solution: Acceleration due to gravity at a depth x from the earth surface $g' = g_s(1 - x/R)$ where R is the radius of the earth.

So, acceleration due to gravity at earth centre (x = R)

$$g_c' = g_s(1 - \frac{R}{R}) = 0.$$

Weight of body at earth's centre W' = mg'

$\Longrightarrow$ W'= 0 N

Question 2.6: A solid sphere of mass 1 kg rolls on a table with linear speed 2 m/s, find its total kinetic energy. **[2]**

Solution: Given: m = 1kg, v = 2 m/s

To find: Total K.E

$$E = \frac{1}{2}mv^2\left[1 + \frac{k^2}{R^2}\right]$$

for a solid sphere, $k^2 = \left(\frac{2}{5}\right)R^2$

$$\therefore E = \frac{1}{2}mv^2\left[1 + \frac{\frac{2}{5}R^2}{R^2}\right]$$

$$\therefore E = \frac{1}{2} \times \frac{7}{5} \times mv^2$$

$$\therefore E = \frac{1}{2} \times \frac{7}{5} \times 1 \times 2^2$$

$$\therefore E = \frac{14}{5}$$

$$\therefore E = 2.8J$$

The total kinetic energy of the solid sphere is $2.8J$

Question 2.7: A transverse wave is produced on a stretched string 0.9 m long and fixed at its ends. Find the speed of the transverse wave, when the string vibrates while emitting the second overtone of frequency 324 Hz. **[2]**

Solution: Length of the string L = 0.9 m

For second overtone frequency (or third harmonic mode of vibration) n = 3.

Frequency of nth mode of vibration when the string is fixed at both ends v = nv/2L

$$\therefore 324 = \frac{3v}{2 \times 0.9}$$

$$\Rightarrow v = \frac{324 \times 0.9 \times 2}{3} = 194.4 \text{ m/s}$$

We get speed of transverse wave, v = 194.4 m/s.

Question 2.8: A body cools at the rate of 0.5°C / minute when it is 25° C above the surroundings. Calculate the rate of cooling when it is 15°C above the same surroundings. **[2]**

Solution:

Given: $\theta_1 = 25^\circ C, \theta_2 = 15^\circ C$

$$\left[\frac{d\theta}{dt}\right] = 0.5^\circ \frac{C}{\min}$$

To Find: Rate of cooling at $\theta_2 \left(\frac{d\theta}{dt}\right)_2$

$$\frac{d\theta}{dt} = K(\theta - \theta_0)$$

Using formulae for $\theta_2 = 15^\circ C$

$$\frac{\left(\frac{d\theta}{dt}\right)_2}{\left(\frac{d\theta}{dt}\right)_1} = \frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$$

$$\frac{\left(\frac{d\theta}{dt}\right)_2}{0.5} = 15/25$$

$$= 0.3^\circ \frac{C}{\min}$$

The rate of cooling when it is 15°C above same surroundings is 0.3°C/min.

Question 3 | Attempt any THREE **[9]**

Question 3.1: Show that period of a satellite revolving around the Earth depends upon mass of the Earth. **[3]**

Solution: a. Let,

M = mass of earth

m = mass of satellite

R = radius of earth

vc = critical velocity

b. In one revolution, distance covered by satellite is equal to circumference of its circular orbit.

c. If T is the time period of satellite, then

$$T = \frac{\text{Circumference of the orbit}}{\text{Critical Velocity}}$$

$$\therefore T = \frac{2\pi r}{v_c} \text{ ....(1)}$$

But $v_c = \sqrt{\frac{GM}{r}}$ ....(2)

d. Substituting equation (2) in (1),

$$T = \frac{2\pi r}{\sqrt{\frac{GM}{r}}}$$

$$= 2\pi\sqrt{r^2 \times \frac{r}{GM}}$$

$$T = 2\pi\sqrt{\frac{r^3}{GM}} \text{ ....(3)}$$

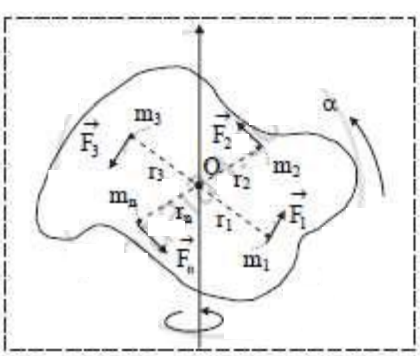
Thus, period of a satellite revolving around the Earth depends upon mass of the Earth.

Question 3.2: Obtain an expression for torque acting on a rotating body with constant angular acceleration. Hence state the dimensions and SI unit of torque. **[3]**

Solution: a. Suppose a rigid body consists of n particles of masses m_1, m_2, m_3, ..., m_n which are situated at distances r_1, r_2, r_3, …, rn respectively, from the axis of rotation as shown in the figure.
b. Each particle revolves with angular acceleration α.

c. Let F_1, F_2, F_3, …., F_n be the tangential force acting on particles of masses, m_1, m_2, m_3, …, m_n respectively.

d. Linear acceleration of particles of masses m1, m2,…, mn are given by, $a_1 = r_1\alpha$, a2 = $r_2\alpha$, $a_3 = r_3\alpha$, …, a_n = rnα



e. Magnitude of force acting on particle of mass m1 is given by,

$$F_1 = m_1 a_1 = m_1 r_1 \alpha \qquad [\because a = r\alpha]$$

Magnitude of torque on particle of mass m1 is given by,

$$\tau_1 = F_1 r_1 \sin\theta$$

But, $\theta = 90^\circ$ [$\because$ Radius vector is $\perp$ar to tangential force

$$\tau_1 = F_1 r_1 \sin 90^\circ$$

$$= F_1 r_1$$

$$= m_1 a_1 r_1$$

$$\tau_1 = m_1 r_1^2 \alpha$$

similarly

$$\tau_2 = m_2 r_2^2 \alpha$$

$$\tau_3 = m_3 r_3^2 \alpha$$

$$\tau_n = m_n r_n^2 \alpha$$

Total torque acting on the body,

f. $\tau = \tau_1 + \tau_2 + \tau_3 + ... + \tau_n$

$$\tau = m_1 r_1^2 \alpha + m_2^2 \alpha + m_2 r_3^2 \alpha + ... + m_n r_n^2 \alpha$$

$$\therefore \tau = \left[\sum_{i=1}^{n} m_i r_t^2\right] \alpha$$

But $\sum_{i=1}^{n} m_i r_i^2 = I$

$$\therefore \tau = I\alpha$$

g. Unit: Nm in SI system.

h. Dimensions: $[M^1 L^2 T^{-2}]$

Question 3.3: The total energy of free surface of a liquid drop is 2π times the surface tension of the liquid. What is the diameter of the drop? (Assume all terms in SI unit). **[3]**

Solution: Given: E = 2πT

To find: Diameter of drop (d)

Formula: E = TΔA

Calculation: From formula,

$$\Delta A = \frac{E}{T}$$

$$\Delta A = \frac{2\pi T}{T}$$

$$\Delta A = 2\pi$$

we know ,$\Delta A = 4\pi r^2$

Substituting in equation (1)

$$2\pi = 4\pi r^2$$

$$4r^2 = 2$$

$$r^2 = \frac{2}{4} = \frac{1}{2}$$

$$r^2 = 0.5$$

$$r = \sqrt{0.5} = 0.71m$$

$$d = 2r$$

=2(0.71)

d=1.414 m

The diameter of the drop is 1.414 m.

Question 3.4: A vehicle is moving on a circular track whose surface is inclined towards the horizon at an angle of 10°. The maximum velocity with which it can move safely is 36 km / hr. Calculate the length of the circular track. [π = 3.142] **[3]**

Solution: Given, angle of banking, θ = 10°

Optimum speed, V_0 = 36 km/hr = 36 x $\frac{5}{18}$ m/s.

Or, V_0 = 10 m/s

Let R be the radius of the circular track

We have,

$V_0 = \sqrt{gR\tan\theta}$

$\Rightarrow V_0^2 = gR\tan\theta$

$\Rightarrow R = \frac{V_0^2}{g\tan\theta}$

$= \frac{\left(10\frac{m}{s}\right)^2}{\left(9.8\frac{m}{s^2}\right)\times\tan 10^0}$

$= \frac{100m}{9.8\times 0.1763}$

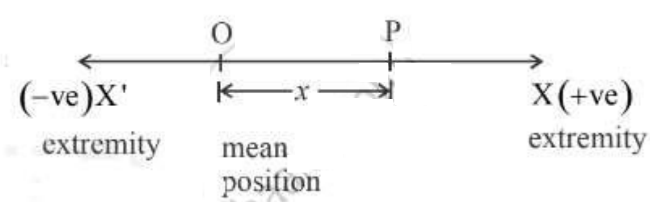
⇒ R = 57.88 m

∴ Length of the circular track = 2πR = 2 x 3.142 x 57.88 = 363.72m.

Question 4 | Attempt any one of the following [7]

Question 4.1: Prove the law of conservation of energy for a particle performing simple harmonic motion. Hence graphically show the variation of kinetic energy and potential energy w. r. t. instantaneous displacement. [7]

Solution: i. Suppose a particle of mass m performing linear S.H.M. is at point P which is at a distance x from the mean position O as shown in figure.



ii. Kinetic energy of particle at point P is given by,

$$K.E = \frac{1}{2}m\omega^2(A^2 - x^2)$$

iii. Potential energy at point P is given by,

$$P.E = \frac{1}{2}m\omega^2 x^2$$

iv. Total energy at point P is given by,

T.E. = K.E. + P.E

$$= \frac{1}{2}m\omega^2(A^2 - x^2) + \frac{1}{2}m\omega^2 x^2$$

$$= \frac{1}{2}m\omega^2(A^2 - x^2 + x^2)$$

$$T.E = \frac{1}{2}m\omega^2 A^2 \text{..........(1)}$$

v. If particle is at mean position:

x = 0

$$\therefore K.E = \frac{1}{2}m\omega^2 A^2$$

$$P.E = \frac{1}{2}m\omega^2 \times 0 = 0$$

$$\therefore T.E = K.E + P.E = \frac{1}{2}m\omega^2 A^2 \text{..............(2)}$$

vi. If particle is at extreme position:

x = A

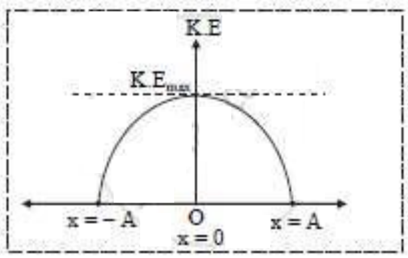
$$K.E = \frac{1}{2}m\omega^2(A^2 - A^2) = 0$$

$$P.E = \frac{1}{2}m\omega^2 A^2$$

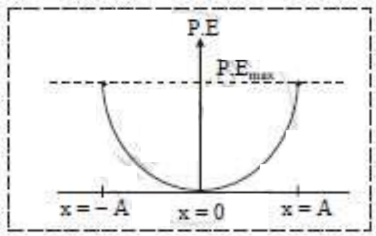
$$\therefore T.E = P.E + K.E = \frac{1}{2}m\omega^2 A^2 \text{..............(3)}$$

vii. From equations (1), (2) and (3), it is observed that total energy of a particle performing linear S.H.M. at any point in its path is constant. Hence, total energy of linear S.H.M. remains conserved.

viii. a. Graph of variation of kinetic energy w. r. t. instantaneous displacement.



b. Graph of variation of potential energy w.r.t. instantaneous displacement



Question 4.1: Two sound notes have wavelengths 83/170 m and 83/172 m in the air. These notes when sounded together produce 8 beats per second. Calculate the velocity of sound in the air and frequencies of the two notes.

Solution:

Given: $\lambda_1 = \frac{83}{170} m, \lambda_2 = \frac{83}{172} m$

no .of beats=8

find: Velocity (v) , frequency(n1, n2)

$v = n\lambda$

$n_1 = \frac{v}{\lambda_1}$ and $n_2 = \frac{v}{\lambda_2}$

But $\lambda_1 > \lambda_2$

$n_2 > n_1$

$n_2 - n_1 = 8$

$v\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = 8$or $v = \left(\frac{172}{83} - \frac{170}{83}\right) = 8$

$v = \frac{8 \times 83}{2} = 332 \frac{m}{s}$

$n_1 = 332 \times \frac{170}{83} = 680 Hz$ and

$n_2 = \frac{332 \times 172}{83} = 688 Hz$

i. The velocity of sound in air is 332 m/s.

ii. The frequencies of the two notes are 680 Hz and 688 Hz.

Question 4.2: Explain analytically how the stationary waves are formed **[7]**

Solution: Consider two simple harmonic progressive waves of equal amplitude and frequency propagating on a long uniform string in opposite directions.

If wave of frequency 'n' and wavelength 'l' is travelling along the positive X axis, then

$$y_1 = A\sin\left(\frac{2\pi}{\lambda}\right)(vt - x) \text{ ....(1)}$$

If wave of frequency 'n' and wavelength 'l' is travelling along the negative X-axis, then

$$y_2 = A\sin\left(\frac{2\pi}{\lambda}\right)(vt + x) \text{............ (2)}$$

These waves interfere to produce stationary waves. The resultant displacement of stationary waves is given by the principle of superposition of waves.

$y=y_1+y_2$ .....(3)

$$y = A\sin\left(\frac{2\pi}{\lambda}\right)(vt - x) + A\sin\left(\frac{2\pi}{\lambda}\right)(vt + x)$$

By Using

$$\sin C + \sin D = 2\sin\left[\frac{C+D}{2}\right]\cos\left[\frac{C-D}{2}\right]$$

We get

$$\therefore y = 2A\sin\left[\left(\frac{2\pi}{\lambda}\right)\left(\frac{vt - x + vt + x}{2}\right)\right]\cos\left[\left(\frac{2\pi}{\lambda}\right)\left(\frac{vt - x - vt - x}{2}\right)\right]$$

$$\therefore y = 2A\sin\left(\frac{2\pi vt}{\lambda}\right)\cos\left(\frac{2\pi}{\lambda}(-x)\right)$$

$$\therefore y = 2A\sin(2\pi nt)\cos\left(\frac{2\pi x}{\lambda}\right) \quad \left(\because n = \frac{v}{\lambda}\right)[\because \cos(-\theta) = \cos\theta]$$

$$\therefore y = 2A\cos\left(\frac{2\pi x}{\lambda}\right)\sin 2\pi nt$$

Let Equetion of stationary wave

$$y = 2A\cos\left(\frac{2\pi x}{\lambda}\right)\sin 2\pi nt$$

Let $R = 2A\cos\left(\frac{2\pi x}{\lambda}\right)$

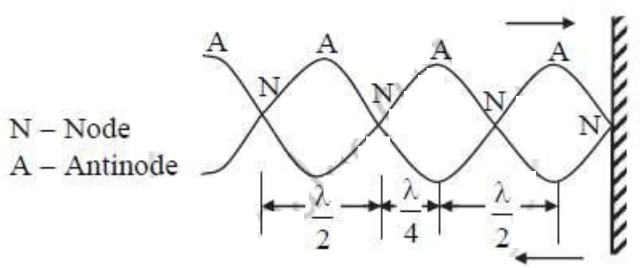
$\therefore y = R\sin(2\pi nt)$ ......(4)

But, $\omega = 2\pi n$

$\therefore y = R\sin\omega t$........(5)

Question 4.2: Show the formation of stationary waves diagrammatically

Solution:



Position and displacement of nodes and antinodes in a stationary wave

Question 4.2: A mass of 1 kg is hung from a steel wire if radius 0.5 mm and length 4 m. Calculate the extension produced. What should be the area of cross-section of the wire so that elastic limit is not exceeded? Change in radius is negligible
(Given : g = 9.8 $m/s^{2;}$ Elastic limit of steel is 2.4 x 10^8 N/m^2;Y for steel (Ysteel) = 20 x 10^{10} N/m^2; π = 3.142)

Solution: Given : g = 9.8 $m/s^{2;}$ Elastic limit of steel is 2.4 x 10^8 N/m^2;Y for steel (Ysteel) = 20 x 10^{10} N/m^2; π = 3.142

To find: Extension in length (l)
Area of cross section (A)
Formulae:

i. Y = FL/Al
ii. Elastic limit = F/A

$$l = \frac{FL}{AY} = \frac{MgL}{\pi r^2 Y}$$

$$l = \frac{1 \times 9.8 \times 4}{3.14 \times \left(0.5 \times 10^{-3}\right)^2 \times 20 \times 10^{10}}$$

$l = 2.495 \times 10^{-4}$ m

From formula (ii),

$$A = \frac{Mg}{\text{Elastic limit}}$$

$$= \frac{1 \times 9.8}{2.4 \times 10^{8}}$$

$$A = 4.o83 \times 10^{-8} m^2$$

The extension produced in length is 2.495x 10^{-4} m and the area of cross section of the wire should be 4.083 x 10^{-8} m^2.

Question 5 | Select and write the most appropriate answer from the given alternatives for each sub-question: [1]

Question 5.1: If A.C. voltage is applied to a pure capacitor, then voltage across the capacitor ____________. [1]

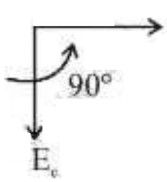
leads the current by phase angle (π/2) rad.

leads the current by phase angle π rad.

lags behind the current by phase angle (π/2) rad.

lags behind the current by phase angle π rad.

Solution: lags behind the current by phase angle (π/2) rad.



Question 5.2: In Doppler effect of light, the term "red shift" is used for ______. [1]

(A) frequency increase

(B) frequency decrease

(C) wavelength decrease

(D) frequency and wavelength increase

Solution: (B) frequency decrease

Question 5.3: If a watch-glass containing a small quantity of water is placed on two dissimilar magnetic poles, then water ______. [1]

shows a depression in the middle.
shows an elevation in the middle.
surface remains horizontal.
evaporates immediately.

Solution: Shows a depression in the middle.

Question 5.4: Any device that converts one form of energy into another is termed as _____. **[1]**
(A) amplifier
(B) transducer
(C) receiver
(D) demodulator

Solution: Transducer

Question 5.5: When a p-n-p transistor is operated in saturation region, then its _____. **[1]**

(A) base-emitter junction is forward biased and base-collector junction is reverse biased.
(B) both base-emitter and base-collector junctions are reverse biased.
(C) both base-emitter and base-collector junctions are forward biased.
(D) base-emitter junction is reverse biased and base-collector junction is forward biased

Solution: (C) both base-emitter and base-collector junctions are forward biased.

Question 5.6: In a photon-electron collision _____. **[1]**
(A) only total energy is conserved.
(B) only total momentum is conserved.
(C) both total energy and total momentum are conserved.
(D) both total momentum and total energy are not conserved

Solution: (C) both total energy and total momentum are conserved.

Question 5.7: If the charge on the condenser of 10°F is doubled, then the energy stored in it becomes _________ **[1]**
zero
twice that of initial energy
half the initial energy
four times the initial energy

Solution: If the charge on the condenser of 10°F is doubled, then the energy stored in it becomes **four times the initial energy**.

$$E = \frac{q^2}{2c}$$

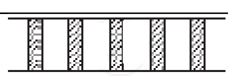
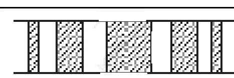
$$E\prime = \frac{(2q)^2}{2c} = 4\left(\frac{q^2}{2c}\right)$$

$$E\prime = 4E$$

Question 6 | Attempt any six of the following [12]

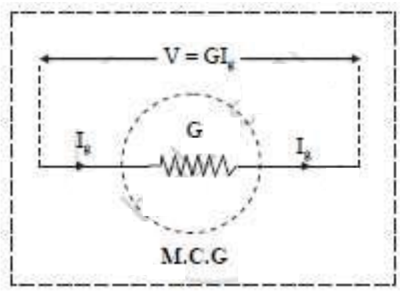
Question 6.1: Distinguish between the phenomenon of interference and diffraction of light. [2]

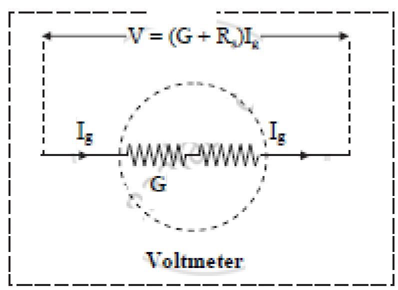
Solution:

No	Interference	Diffraction
1	Interference is due to superposition of waves from different wave fronts.	Diffraction is due to waves coming from different parts of the same wave front.
2	All bright fringes are of equal intensity	Intensity decreases with the order of bright band.
3	Minimum intensity may be zero.	Minimum intensity is not zero.
4	Width of the central maximum is same as that of other bright fringes i.e fringe width is same for all fringes including central maxima.	Width of central maximum is broader than other maxima and it is double the fringe width.
5	The waves emitted by two coherent sources travel in straight line.	The light waves are bend at the corners and displaced from their straight line path.
6	The resolving power of an optical instrument does not depend on the phenomenon of interference.	The resolving power of an optical instrument depends on the phenomenon of diffraction
7		

Question 6.2: Explain how moving coil galvanometer is converted into a voltmeter. Derive the necessary formula. [2]

Solution: a. To use a M.C.G as a voltmeter, its resistance should be increased to a desired value and an arrangement should be provided to measure large potential difference. This is achieved by connecting a high resistance in series with the M.C.G.





b. Let 'G' be the resistance of the galvanometer coil and 'Ig' be the maximum current which can be passed through the galvanometer coil for full-scale deflection.

c. Let 'V' be the potential difference to be measured.
Let 'Rs' be the resistance connected in series with the galvanometer coil.

d. From Ohm's law,
$V = I_g (G + R_s)$

$$G + R_s = \frac{V}{I_g}$$

$$R_s = \frac{V}{I_g} - G$$

Knowing V, I_g and G, value of R_s can be determined.

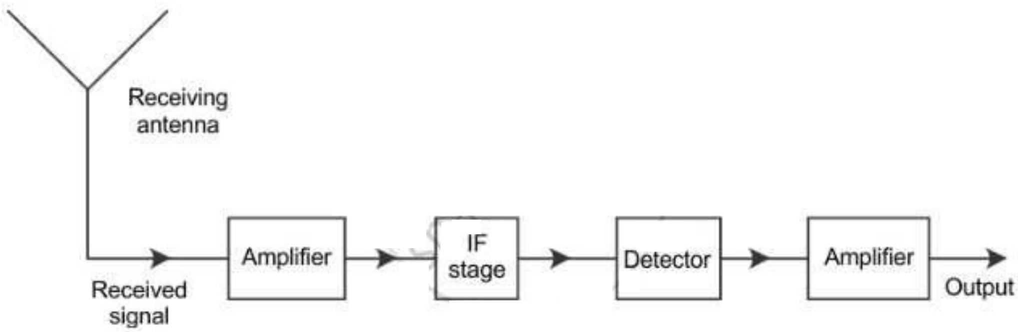
Question 6.3: State the advantages of potentiometer over voltmeter. **[2]**

Solution: Advantages of potentiometer over voltmeter:
a. The voltmeter is used to measure terminal P.D of cell while potentiometer is used to measure small terminal P.D as well as e.m.f of the cell.
b. The accuracy of potentiometer can be easily increased by increasing the length of wire.
c. A small P.D can be measured accurately with the help of potentiometer. The resistance of voltmeter is high but not infinity to work as an ideal voltmeter.

d. The internal resistance of a cell can be measured with the help of potentiometer.
e. Potential difference across the wire is greater than E_1 or E_2 or $E_1 + E_2$.

Question 6.4: Draw a neat, labelled block diagram of a receiver for the detection of amplitude modulated wave. **[2]**

Solution:



Question 6.5: A rectangular coil of a moving coil galvanometer contains 100 turns, each having area 15 cm^2. It is suspended in the radial magnetic field 0.03 T. The twist constant of suspension fibre is 15 x 10^{-10} N-m/degree. Calculate the sensitivity of the moving coil galvanometer. **[2]**

Solution:

Given: $N = 100, A = 15cm^2 = 15 \times 10^{-4}m^2,$

$B = 0.03\dfrac{Wb}{m^2},$

$C = 15 \times 10^{-10}\dfrac{\text{Nm}}{\text{degree}}$

To find: Sensitivity (Si)

Formulae: $S_i = \dfrac{NAB}{c}$

$$S_i = \frac{100 \times 15 \times 10^{-4} \times 0.03}{15 \times 10^{-10}}$$

$$S_i = 3 \times 10^6 \frac{\text{div}}{A}$$

The sensitivity of a moving coil galvanometer is $3 \times 10^6 \dfrac{\text{div}}{A}$.

Question 6.6: The magnetic flux through a loop is varying according to a relation $\phi = 6t^2 + 7t + 1$ where ϕ is in millimeter and t is in second. What is the e.m.f. induced in the loop at t = 2 second? **[2]**

Solution:

Given : $\phi = 6t^2 + 7t + 1$ (in milliweber),t=2s

find: Magnitude of induced e.m.f. (e)

formula: $e = \frac{d\phi}{dt}$ (in magnitude)

Calculation: Using formula

$$e = \frac{d}{dt}\left(6t^2 + 7t + 1\right)$$

$$= 12t + 7$$

At t=2s

$$|e| = 12 \times 2 + 7$$

$$= 31mV = 31 \times 10^{-3}V$$

Question 6.7: An unknown resistance is placed in the left gap and resistance of 50 ohm is placed in the right gap of a meter bridge. The null point is obtained at 40 cm from the left end. Determine the unknown resistance. **[2]**

Solution: Given:

$$R = 50\Omega$$

$$l_X = 40cm = 0.4m$$

$$l_R = 60cm = 0.6m$$

To find: Unknown resistance (X)

Formula: $X = R\frac{l_X}{l_R}$

Solution:

$$X = \frac{50 \times 40}{60}$$

$$X = \frac{100}{3}$$

$$X = 33.33\Omega$$

The value of unkown resistance is 33.33 Ω.

Question 6.8: Find the frequency of revolution of an electron in Bohr's 2nd orbit; if the radius and speed of electron in that orbit is 2.14×10^{-10} m and 1.09×10^{6} m/s respectively. [π= 3.142] **[2]**

Solution 1: Given

$r_2 = 2.14 \times 10^{-10}$ m

n = 2

$v_2 = 1.09 \times 10^{6}$ m/s

To find: Frequency of revolution (ν_2)

$$v = r\omega = r(2\pi\nu)$$

$$\nu = \frac{v}{2\pi r}$$

$$\nu_2 = \frac{v_2}{2\pi r_2} = \frac{1.09 \times 10^{6}}{2 \times 3.142 \times 2.14 \times 10^{-10}}$$

$$\nu_2 = 8.11 \times 10^{14} Hz$$

The frequency of revolution of electron in 2nd Bohr orbit is 8.11×10^{14} Hz.

Solution 2:

$$T = \frac{2\pi r}{V}$$

$$\because T = \frac{1}{f}$$

$$f = \frac{V}{2\pi r}$$

$$f = \frac{1.09 \times 10^{6}}{2 \times 3.14 \times 2.14 \times 10^{-10}}$$

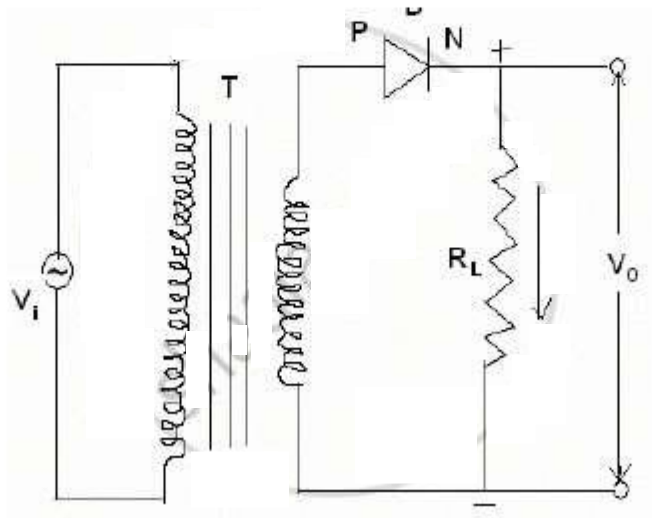
$$f = 8.11 \times 10^{14} Hz$$

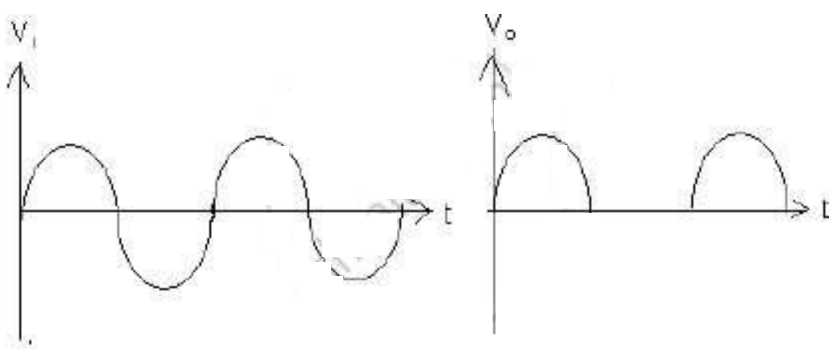
The frequency of revolution of electron in 2nd Bohr orbit is 8.11×10^{14} Hz.

Question 7 | Attempt any THREE: **[9]**

Question 7.1: With the help of neat labelled circuit diagram explain the working of half wave rectifier using semiconductor diode. Draw the input and output waveforms. **[3]**

Solution: A device which converts A.C. to D.C. is called rectifier. In this case output exists only for half cycle hence it is called half wave rectifier. Construction: The circuit diagram of a half wave rectifier using a junction diode is as shown in fig. The alternating voltage source is connected to the primary coil of a transformer. The secondary coil is connected to the diode in series with a resistance RL called the load resistance





T=Transformer

D=Diode

V0=output voltage

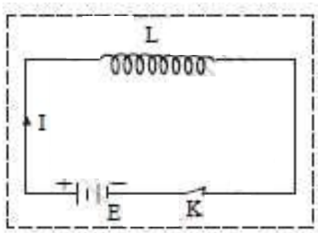
v1=input voltage

RL=load resistance

Working: In first cycle of input voltage, the anode of the diode is positive potential w.r.t. cathode. Hence the diode is in forward-biased. Hence it conduct current. The current flows through load resistance giving voltage drop iRL. This voltage drop is called output voltage. During next half cycle the anode of diode is in negative potential w.r.t. Hence it is in reversed-biased. Hence it does not conduct the current. Hence current does not flow through load resistance giving no P.D. across it. Hence output voltage is unidirectional. It is called as D.C.

Question 7.2: Explain self induction and mutual induction [3]

Solution: Derivation of induced e.m.f due to self induction:



a. Consider a coil connected with battery E, plug key K and inductor L carrying current of magnitude I as shown in figure.

b. Since magnetic flux linked with the coil is directly proportional to the current.

$\phi \propto I$

$\phi \propto LI$..................(1)

Where, L = constant called coefficient of self-induction or self-inductance of the coil, which depends upon the material of the core, number of turns, shape and area of the coil

c. Induced e.m.f in the coil is given by,

$$e = -\frac{d\phi}{dt}$$

$$e = -L\frac{dI}{dt}$$ ....(2)

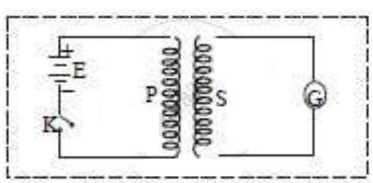
-ve sign in equation (ii) shows that self-induced e.m.f opposes the rate of change of current.

$$|e| = \left|-L\frac{dI}{dt}\right| = L\frac{dI}{dt}$$

Therefore Magnitude of self-induced e.m.f is given by, |e|=L(dI)/dt

This is required induced e.m.f.

Derivation of induced e.m.f. due to mutual induction:



a. Consider primary coil P and secondary coil S fitted with galvanometer G are placed very close to each other as shown in figure. The coil P is connected in series with the source of e.m.f (battery) and key K.

b. When tap key K is pressed current IP passes through the coil P. Magnetic flux ϕS linked with secondary coil S at any instant is directly proportional to current IP through primary coil P at that instant.

$$\phi_s \propto I_p$$

$$\phi_s = MI_p \text{.......................(1)}$$

where M is constant called coefficient of mutual induction or mutual inductance of the coil.

e.m.f induced in S at any instant is given by, $e_s = -\frac{d\phi_s}{dt}$

$$= -\frac{d}{dt}(MI_p)$$

$$e_s = -M\frac{dI_p}{dt}$$

Magnitude of induced e.m.f is given by,

$$|e_s| = -\left|M\frac{dI_p}{dt}\right| = \frac{MdI_p}{dt}$$

$$M = \frac{e_s}{\frac{dI_p}{dt}}$$

Question 7.3: A cube of marble having each side 1 cm is kept in an electric field of intensity 300 V/m. Determine the energy contained in the cube of dielectric constant 8. [Given : ϵ_0 = 8.85 10^{-12} C^2/Nm^2] **[3]**

Solution:

Given: $l = 1cm = 10^{-2}m, E = 300Vm^{-11}, k = 8$

To find: Energy contained in the cube (U)

formula: $u = \frac{U}{V}$

volume of marble

$V = (i^3) = (10^{-2})3 = 10^{-6}m^3$

Energy Density, $u = \frac{1}{2} \in_0 kE^2$

$= \frac{1}{2} \times 8.85 \times 10^{-12} \times 8 \times (300)^2$

$= 3.185 \times 10^{-6} \frac{J}{m^3}$

From formula $U = u \times V = 3.185 \times 10^{-6} \times 10^{-6}$

$U = 3.185 \times 10^{-12} J$

Question 7.4: An electron in an atom revolves around the nucleus in an orbit of radius 0.53 Å. If the frequency of revolution of an electron is 9 x10^9 MHz, calculate the orbital angular momentum [Given: Charge on an electron = 1.6 x 10^{-19} C; Gyromagnetic ratio = 8.8 x 10^{10} C/kg; π = 3.142] **[3]**

Solution: Given : Charge on an electron = 1.6 x 10^{-19} C;
Gyromagnetic ratio = 8.8 x 10^{10} C/kg; π = 3.142

Formula: $L_0 = \frac{M_0}{\text{gyromagnetic ratio}}$

M=IA

Since $I = \frac{1}{T}e = fe$

From formula

$M = feA = fe\pi r^2$

$= 9 \times 10^{15} \times 1.6 \times 10^{-19} \times \pi \times (0.53 \times 10^{-10})^2$

$= 1.6 \times \pi \times 0.25 \times 10^{-23}$

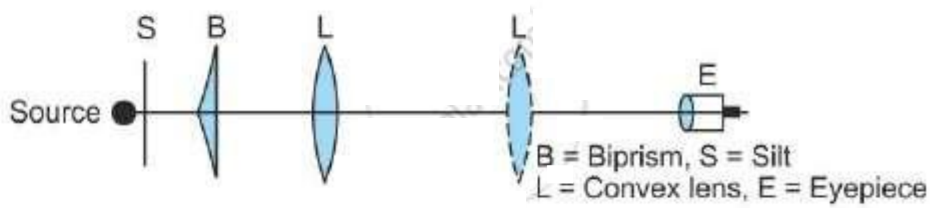
$M = 1.270 \times 10^{-23} Am^2$

Using formula $L_0 = \frac{1.270 \times 10^{-23}}{8.8 \times 10^{10}}$

$L_0 = 0.1443 \times 10^{-33} \frac{kgm^2}{s}$

Question 8.1: Describe biprism experiment to calculate the wavelength of a monochromatic light. Draw the necessary ray diagram. **[7]**

Solution: 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:

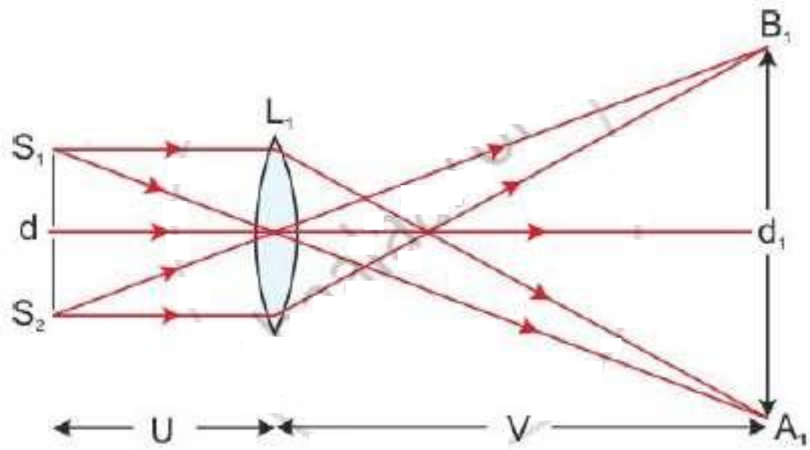
(1) The distance between the slit and the eyepiece D can be easily measured from the scale marked on the optical bench.

(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.



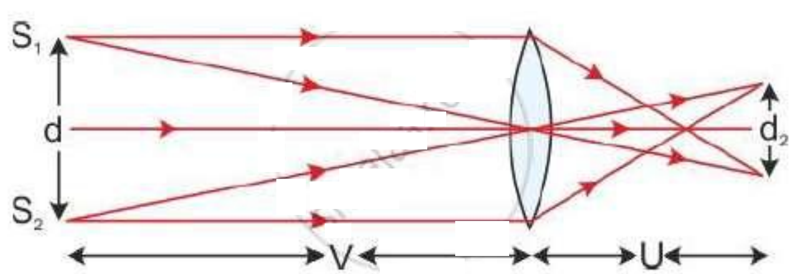
The convex lens of short focal length is introduced between the biprism and the eyepiece. Without disturbing the slit and biprism, the eyepiece is moved back so that its distance from the slit becomes greater than four times the focal length of the lens.

The lens is moved towards the slit and its position L1 is so adjusted that two magnified images A1 and B1 of S1 and S2 are formed in the focal plane of the eyepiece. The distance d1 between A1 and B1 is measured by the micrometer eyepiece.

From the figure, we get

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

$$\frac{d_1}{d} = \frac{v}{u} \text{ ------(1)}$$



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

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

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 $\lambda = Xd/D$

The critical angle is given as

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

It is given that

$$\theta_c = \sin^{-1}\left(\frac{3}{5}\right)$$

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

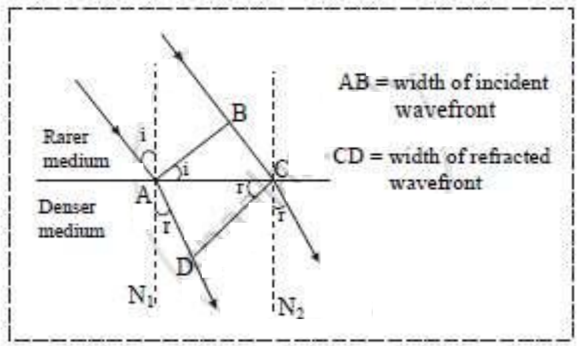
$$\therefore n = \frac{5}{3}$$

Now, the polarising angle is given as

$$\theta_p = \tan^{-1} n = \tan^{-1}\left(\frac{5}{3}\right)$$

Question 8.1: The width of plane incident wave front is found to be doubled on refraction in denser medium. If it makes an angle of 65° medium with the normal, calculate the refractive index for the denser medium.

Solution:



Given: i = 65°, CD = 2AB
To find: Refractive index (μ)

formulae:

$$\frac{\cos i}{\cos r} = \frac{AB}{CD} \text{ ....(1)}$$

$$\mu = \frac{\sin i}{\sin r} \text{ ....(2)}$$

From formula 1

$$\frac{\cos 65^\circ}{\cos r} = \frac{AB}{2AB}$$

$$\frac{0.4226}{\cos r} = \frac{1}{2}$$

$$\cos r = 32^\circ 16\prime$$

from formula 2

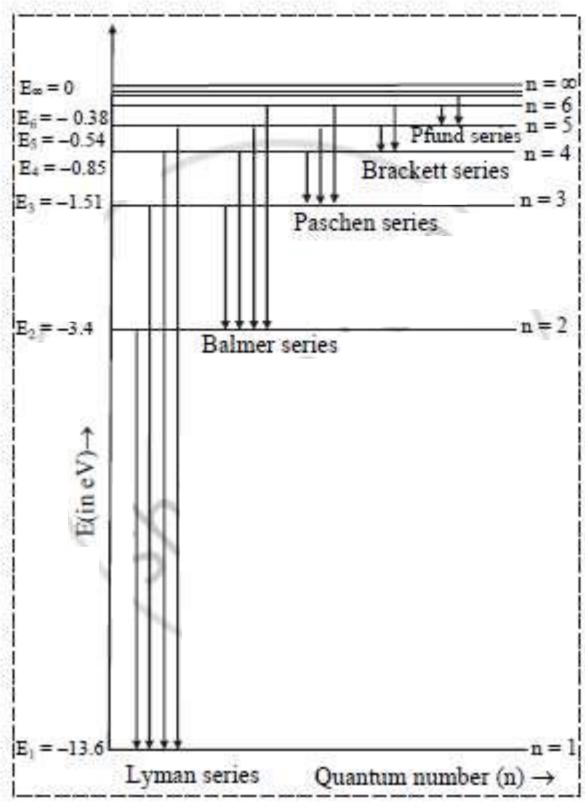
$$\mu = \frac{\sin 65^\circ}{\sin(32^\circ 16\prime)}$$

$$\mu = 1.697$$

The refractive index for the denser medium is 1.697.

Question 8.2: Draw a neat, labelled energy level diagram for H atom showing the transitions. Explain the series of spectral lines for H atom, whose fixed inner orbit numbers are 3 and 4 respectively. **[7]**

Solution:



Paschen series:

i. The spectral lines of this series correspond to the transition of an electron from some higher energy state to 3rd orbit.

ii. For paschen series, p = 3 and n = 4, 5,...

The wave numbers and the wavelengths of the spectral lines constituting the Paschen series are given by,

$$\bar{v} = \frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$$

iii. Paschen series lies in the infrared region of the spectrum which is invisible and contains infinite number of lines.

iv. Wavelengths for n = 4 and 5 are 18750 Å and 12820 Å respectively.

Brackett series:

i. The spectral lines of this series corresponds to the transition of an electron from a higher energy state to the 4th orbit.

ii. For this series, p = 4 and n = 5, 6, 7,...

The wave numbers and the wavelengths of the spectral lines constituting the Brackett series are given by,

$$\bar{v} = \frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$$

iii. This series lies in the ne ar infrared region of the spectrum and contains infinite number of lines. Wavelengths for n = 5 and 6, are 40518 Å and 26253 Å respectively.

Question 8.2: The work functions for potassium and caesium are 2.25 eV and 2.14 eV respectively. Is the photoelectric effect possible for either of them if the incident wavelength is 5180 Å?
[Given : Planck's constant = 6.63×10^{-34} J.s.;
Velocity of light = 3×10^{8} m/s; 1 eV = 1.6×10^{-19} J]

Solution: Given: $(W_0)_P = 2.25$ eV = $2.25 \times 1.6 \times 10^{-19}$ J = 3.6×10^{-19} J,
$(W_0)_C = 2.14$ eV = $2.14 \times 1.6 \times 10^{-19}$ J = 3.424×10^{-19} J,
λ = 5180 Å = 5.18×10^{-7} m

To find: Will the photoelectric effect occur for either of these elements with λ = 5180 Å

Formula: $W_0 = hv_0$

$$(W_0)_p = h(v_0)_p$$

$$(v_0)_p = \frac{(W_0)_p}{h} = \frac{3.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$(v_0)_p = 5.430 \times 10^{14} Hz$$

Similarly

$$(v_0)_c = \frac{(W_0)_c}{h} = \frac{3.424 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$(v_0)_c = 5.164 \times 10^{14} Hz$$

The corresponding frequency is given by,

$$v_2 = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{5.18 \times 10^{-7}} = \frac{3}{5.18} \times 10^{15}$$

$$v_2 = 5.792 \times 10^{14} Hz$$

for potassium

$$5.792 \times 10^{14} Hz > 5.430 \times 10^{14} Hz$$

$$i.e, v_2 > (v_o)_p$$

Photoelectric emission will take place when light of wavelength λ is incident on it. For caesium,

$$5.792 \times 10^{14} Hz > 5.16 \times 10^{14} Hz$$

$$i.e, v_2 > (v_o)_c$$

Photoelectric emission will take place when light of wavelength λ is incident on it. For λ= 5180Å wavelength, both potassium and caesium will exhibit photoelectric emission.