Physics

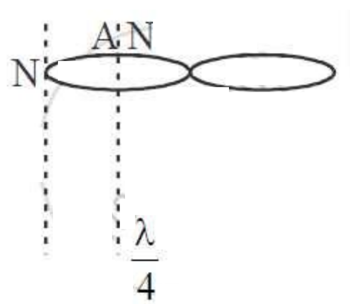
Academic Year: 2017-2018 Marks: 70
Date & Time: 26th February 2018, 11:00 am
Duration: 3h

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

Question 1.1: In the stationary wave, the distance between a node and its adjacent antinode is _______. [1]

(a) λ
(b) $\frac{\lambda}{4}$
(c) $\frac{\lambda}{2}$
(d) 2λ

Solution:
$\frac{\lambda}{4}$



Question 1.2: If the source is moving away from the observer, then the apparent frequency _____. [1]

(a) will increase
(b) will remain the same
(c) will be zero
(d) will decrease

Solution: Decrease, Doppler's effect

Question 1.3: A particle of mass m performs the vertical motion in a circle of radius r. Its potential energy at the highest point is _______. (g is acceleration due to gravity) [1]

2 mgr

mgr
0
3 mgr

Solution: 2 mgr
PE = mgh

Question 1.4: The compressibility of a substance is the reciprocal of ________. [1]

(a) Young's modulus
(b) Bulk modulus
(c) Modulus of rigidity
(d) Poisson's ratio

Solution: Bulk modulus

Comp = 1/K

Question 1.5: If the particle starts its motion from mean position, the phase difference between displacement and acceleration is ______. [1]

2π rad
$\frac{\pi}{2} rad$
$\pi\ rad$
$\frac{\pi}{4} rad$

Solution: π rad.
Hence phase difference between displacement and velocity is 90 degrees or π/2 radians. ... Hence phase difference between velocity and acceleration is also π/2. Phase difference between displacement and acceleration is pi radians or 180 degrees.

Question 1.6: The kinetic energy per molecule of a gs at temperature T is ________. [1]

(a) $\left(\frac{3}{2}\right) RT$
(b) $\left(\frac{3}{2}\right) K_B T$
(c) $\left(\frac{2}{3}\right) RT$
(d) $\left(\frac{3}{2}\right)\left(\frac{\mathrm{RT}}{M}\right)$

Solution:

$\left(\frac{3}{2}\right)K_BT$

ICE of 1 module = $\frac{3}{2}K_BT$

Question 1.7: A thin ring has mass 0.25 kg and radius 0.5 m. Its moment of inertia about an axis passing through its centre and perpendicular to its plane is _______. [1]

0. 0625 kg m^2
0.625 kg m^2
6. 25 kg m^2
62. 5 kg m^2

Solution: 0.0625 kg m^2

$I = mr^2$
where m is the mass of ring and r is the minimum Seperation between axis of rotation and point of observation {e.g., radius of ring}
here, m = 0.25 Kg
r = 0.5 m
now, $I = 0.25 \times (0.5)^2 = 0.25 \times 0.25 = 0.0625$ Kg.m^2

Question 2 | Attempt Any Six [12]

Question 2.1: State Kepler's law of orbit and law of equal areas. [2]

Solution 1: Ist law (Law of orbit) : The orbital path in the solar system is an ellipse with sun as one focus.

2nd law (Law of equal area) : The radius vector joining the centre of the planet to the centre of sun traces out equal area in equal intervals of time.

i.e. The area velocity of the planet is constant

Solution 2: All planet revolves around the sun in the elliptical orbit, the sun as one of its focus.

The line joining sun and planet sweeps the equal area in equal time interval i.e. A real velocity is constant.

Question 2.2: State any four assumptions of kinetic theory of gases. [2]

Solution: a) A gas consists of very large number of extremely small particles known as molecules.

b) The intermolecular force of attraction between gas molecules are negligible.

c) Molecules are always in the state of random motion, i.e., they are moving in all possible directions with all possible velocities. This state is called molecular chaos

d) Between any two successive collisions, a molecule travels in a straight line with constant velocity. It is called free path.

Notes:

1. A gas consists of a large number of tiny particles called molecules.
2. The molecules are rigid, perfectly elastic spheres of very small diameters.
3. All the molecules of the same gas are identical in shape, size and mass.
4. Actual volume occupied by gas molecules is very small compared to the total volume occupied by the gas.

Question 2.3: Define moment of inertia. State its SI unit and dimensions. [2]

Solution: It is the sum of the product of each point mass and square of its distance from the axis of rotations.

S.I unit kg. m^2

Dim $[M^1 L^2 T^0]$

Question 2.4: Distinguish between centripetal and centrifugal force. [2]

Solution:

Centripetal force	Centrifugal force
It is the real force	It is the pseudo force
It acts from particle towards the centre	it acts from centre to particle
e.g. Gravitation force, frictional force, Electrostatic force	e.g force experienced on the person in merry go round (outwards), the person pushed backwards in accelerating train.

Question 2.5: In Melde's experiment, when the tension in the string is 10 g wt then three loops are obtained. Determine the tension in the string required to obtain four loops, if all other conditions are constant. [2]

Solution: Let us assume that the Fork is in perpendicular position for our convenience.

For this experiment , $N = \frac{P}{2l} \times \sqrt{\frac{T}{m}}$

Here N is the frequency, p is the number of loops, ll is length, T is tension and m is linear density of string.

It is mentioned that all conditions except the tension are constant.
Hence N will be equal for both.

$$\therefore \frac{P_1}{2l} \times \sqrt{\frac{T_1}{m}} = \frac{P_2}{2l} \times \sqrt{\frac{T_2}{m}}$$

$$\frac{P_1}{P_2} = \sqrt{\frac{T_2}{T_1}}$$

$$\therefore T_2 = \frac{P_1^2 \times T_1}{P_2^2} = \frac{3^2 \times 10}{4^2} = 5.625$$

5.625 g wt

Question 2.6: Whenever a liquid film is expanded, the work done gets stored as energy in the film. Hence the increase in energy of the film is equal to the work done. **[2]**

The soap bubble expands hence the surface area increases.
The increment in the surface area × the surface tension T is the extra energy and hence equal to the work done.

Note that the bubble has two areas, inner and outer. Since the thickness of the film is negligible, both the radii can be assumed as equal.

Work done = (increase in the surface areas of bubble) x Surface Tension

Given : r1 = 1 cm, r2 = 2cm, T = 30 dynes/cm
To find : Work (W)
Formula : W = TΔA

Calculation : $A_1 = 4\pi\, r_1^2 = 4\pi \times 1^2 = 4\pi cm^2$

$$A_2 = 4\pi\, r_2^2 = 4\pi \times 2^2 = 16\pi\ cm^2$$

$$\Delta A = A_2 - A_1 = (16\pi - 4\pi) = 12\pi\ cm^2$$

Since soap bubble has two surfaces

From formula,

W = 2T x ΔA

= 2 x 30 x 12π

= 2 x 30 x 12 x 3.14

W = 2.26×10^3 erg

∴ The work done in increasing the radius of the soap bubble is 2.26 x 10^3 erg

Question 2.7: A falt curve on a highways has a radius of curvature 400 m. A car goes around a curve at a speed of 32 m/s. What is the minimum value of the coefficient of friction that will prevent the car from sliding? (g = 9.8 m/ s^2) **[2]**

Solution:

$\frac{v^2}{R} = \mu g$

$\mu = \frac{v^2}{Rg} = \frac{(32)^2}{400 \times 9.8}$

$= \frac{1024}{3920}$

= 0.261

Question 2.8: A particle performing linear S.H.M. has the maximum velocity of 25 cm/s and maximum acceleration of 100 cm/ m^2. Find the amplitude and period of oscillation. (π = 3.142) **[2]**

Solution: In S.H.M the velocity is given as

Velocity, $v = A\, w \cos wt,$ where w is angular frequency and A is amplitude

Maximum velocity $vm = A\, w \quad [\therefore \cos wt = 1]$

Acceleration $= -Aw^2 \sin wt$

Maximum acceleration $a_m = \left|-Aw^2\right| = Aw^2 \;\left(\therefore \sin w^2 t = 1\right)$

$a_m = 100cm/s^2, v_m = 25cm/s$

$Aw = 25$ ....(i)

$Aw^2 = 100$ .....(ii)

Dividing (ii) by (i) $\frac{Aw^2}{Aw} = \frac{100}{25}$

w = 4

Time period, T = $\frac{2 \neq}{w}$

$= \frac{2 \times 3.14}{4}$

$T = 1.57\,\text{sec}$

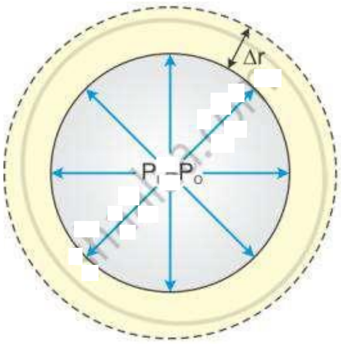
from 1 wa = 25

a = $\frac{25}{4} = 6.25$cm

Question 3 | Attempt Any Three **[9]**

Question 3.1: Derive Laplace's law for spherical membrane of bubble due to surface tension. **[3]**

Solution 1: Consider a spherical liquid drop and let the outside pressure be P_o and inside pressure be P_i, such that the excess pressure is $P_i - P_o$.



Let the radius of the drop increase from r Δto r, where Δr is very small, so that the pressure inside the drop remains almost constant.

Initial surface area $(A_1) = 4\Pi r^2$

Final surface area $(A_2) = 4\Pi(r + \Delta r)^2$

$= 4\pi(r^2 + 2r\Delta r + \Delta r^2)$

$= 4\Pi r^2 + 8\Pi r\Delta r + 4\Pi\Delta r^2$

As Δr is very small, Δr2 is neglected (i.e. $4\pi\Delta r^2 \cong 0$)

Increase in surface area (dA) $= A_2 - A_1 = 4\Pi r^2 + 8\Pi r\Delta r - 4\Pi r^2$

Increase in surface area (dA) $= 8\Pi\Delta r$

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

$\therefore dW = TdA$

$\therefore dW = T*8\pi r\Delta r$ ....(Equ.1)

This work done is equal to the product of the force and the distance Δr.

$dF = (P_1 - P_0)4\pi r^2$

The increase in the radius of the bubble is Δr.

$dW = dF\Delta r = (P_1 - P_0)4\Pi r^2*\Delta r$ ....(Equ.2)

Comparing Equations 1 and 2, we get

$(P_1 - P_0)4\pi r^2*\Delta r = T*8\pi r\Delta r$

$$\therefore (P_1 - P_0) = \frac{2T}{R}$$

This is called the Laplace's law of spherical membrane.

Solution 2: Let us consider a liquid drop which is spherical in shape with surface area A_1

We know that due surface tension, liquids try to expose the minimum surface area to the air. Hence they have a tendency to contract.
Due to this contracting force, the inside pressure is greater than the outside pressure. Let us assume that due to this excess pressure from inside, the drop is expanding and the bigger surface area becomes A_2.

Increase in area = $\triangle A = A_2 - A_1 = 4\pi(r + \triangle r)^2 - 4\pi r^2$

$\therefore \triangle A = 4\pi \times \left[(r + \triangle r)^2 - r^2\right]$

$\therefore \triangle A = 4\pi \times 2r \triangle r$ ...($\because \Delta r$ is very small Δr^2 is still smaller and hence ignored and considered as zero)

$\Delta A = 8 \pi r \Delta r$

Work done in expanding the drop = gain in energy $\Delta W = T \Delta A = T 8 \pi r \Delta r$ ....(i)

Here T is surface tension.

Excess pressure = $P_i - P_0$

Excess force = excess pressure times × area

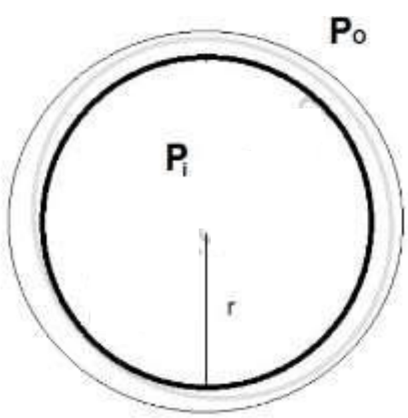
$\Delta F = (P_i - P_0) 4 \pi r^2$

Work done = $\Delta F \times \Delta r = (P_i - P_0) 4 \pi r^2 \Delta r$ ....(ii)

From 1 and 2 we get, $T 8 \pi r \Delta r = (P_i - P_0) 4 \pi r^2 \Delta r$

$\therefore \frac{2T}{r} = P_i - P_0$ ...... Lapalce's Law

For a bubble, there are 2 surface areas, internal and external, the Laplace's Law gets changed as $\frac{4T}{r} = P_i - P_0$



Question 3.2: State and prove : Law of conservation of angular momentum. **[3]**

Solution: Statement:-
The angular momentum of a body remains constant, if resultant external torque acting on the body is zero.

Proof:-
a. Consider a particle of mass m, rotating about an axis with torque 'τ'.

Let $\vec{p}$ be the linear momentum of the particle and $\vec{r}$ be its position vector.

b. By definition, angular momentum is given by, $\vec{L} = \vec{r} \times \vec{p}$ ....(1)

c. Differentiating equation (1) with respect to time t, we get,

$$\frac{d\vec{L}}{dt} = \frac{d}{dt}\left(\vec{r} \times \vec{p}\right)$$

$$\therefore \frac{d\vec{L}}{dt} = \vec{r} \times \frac{d\vec{p}}{dt} + \vec{p} \times \frac{d\vec{r}}{dt} \quad ....(2)$$

d.

$$\text{But,} \frac{d\vec{r}}{dt} = \vec{v}, \frac{d\vec{p}}{dt} = \vec{F} \quad \text{and} \quad \vec{p} = m\vec{v}$$

∴ Equation (2) becomes,

$$\frac{d\vec{L}}{dt} = \vec{r} \times \vec{F} + 0 \qquad [\because \vec{v} \times \vec{v} = v^2 \sin 0^\circ = 0]$$

e. Also, $\vec{\tau} = \vec{r} \times \vec{F}$

$$\therefore \frac{d\vec{L}}{dt} = \vec{\tau}$$

f. If resultant external torque (τ) acting on the particle is zero, then $\frac{d\vec{L}}{dt} = 0.$

$$\therefore \vec{L} = \text{constant}$$

Hence, angular momentum remains conserved.

Question 3.3: Calculate the strain energy per unit volume is a brass wire of length 3 m and area of cross - section 0.6 mm^2 when it is stretched by 3 mm and a force of 6 kgwt is applied to its free end. **[3]**

Solution: Data : L = 3m

A = 0.6 mm^2 = 0.6 × 10-6 m^2

l = 3 mm = 3 × 10^{-3} m

F = 6 kg-wt = 6 × 9.8 N

Formula:

$$\frac{\text{Strain Enegry}}{\text{Volume}} = \frac{1}{2}\left(\frac{F}{A}\right) \times \left(\frac{1}{L}\right)$$

$$= \frac{1}{2}\left(\frac{6 \times 9.8}{0.6 \times 10^{-6}}\right) \times \left(\frac{3 \times 10^{-3}}{3}\right)$$

$$= 4.9 \times 10^{4}\ \text{J/m}^3$$

Question 3.4: m = 500 kg **[3]**
d = 1000 km
R = 6400 km
g = 9.8 m/s^2

Formula:

$$\text{Wd} = \text{m} \times \text{gd} = \text{mg}\frac{(\text{R} - \text{d})}{\text{R}}$$

$$\text{gd} = \text{g}\frac{(\text{R} - \text{d})}{\text{d}}$$

$$= \frac{9.8(6400 - 1000)}{6400}$$

= 9.8 × 0.843

gd = 8.268 m/s

Wd = m × gd

= 500 × 8.268

Wd = 4134.3 N

Question 4: Attempt Any One **[7]**

Question 4.1.i: State the differential equation of linear simple harmonic motion. **[7]**

Solution: State the differential equation of linear S.H.M.

When a particle performs linear SHM. The force acting on the particle is always directed towards the mean position. The magnitude of the force is directly proportional to the magnitude of the displacement of the particle from the mean position. Thus, if $\vec{F}$ is the force acting on the particle when its displacement from the mean position is $\vec{x}$

$\therefore \vec{F} = -k\vec{x}$ ....(1)

Where the constant k, the force per unit displacement, is called the force constant. The minus sign indicates that the force and the displacement are oppositely directed.

The velocity of the particle is $\frac{d\vec{x}}{dt}$ and its acceleration is $\frac{d^2\vec{x}}{dt^2}$

Let m be the mass of the particle

Force = mass x acceleration

$\therefore$ vecF = m $\frac{d^2\vec{x}}{dt^2}$

Hence from Eq. (1), m $\frac{d^2\vec{x}}{dt^2} = -k\vec{x}$

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

This is the differential equation of linear S.H.M.

Question 4.1.ii: Hence obtain the expression for acceleration, velocity and displacement of a particle performing linear S.H.M.

Solution: Hence obtain the expression for acceleration, velocity and displacement of a particle performing linear S.H.M.

The differential equation of linear SHM is $\frac{d^2\vec{x}}{dt^2} + \frac{k}{m}\vec{x} = 0$ where m = mass of the particle performing SHM.

(d^2vecx)/(dt)^2 = acceleration of the particle when its displacement from the mean position is $\vec{x}$ and k = force constant. For linear motion, we can write the differential equation in scalar form:

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$

Let $\frac{k}{m} = \omega^2$, a constant

$$\therefore \frac{d^2x}{dt^2} + \omega^2 x = 0$$

$\therefore$ Acceleration, a = $\frac{d^2x}{dt^2} = -\omega^2 x$ ....(1).

The minus sign shows that the acceleration and the displacement have opposite directions. Writing

v = $\frac{dx}{dt}$ as the velocity of the particle.

$$a = \frac{d^2x}{dt^2} = \frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt} = \frac{dv}{dx} = v = v\frac{dv}{dx}$$

Hence, Eq. (1) can be written as

$$v\frac{dv}{dx} = -\omega^2 x$$

$$\therefore vdv = -\omega^2 x$$

Integrating this expression, we get

$$\frac{v^2}{2} = \frac{-\omega^2 x^2}{2} + C$$

where the constant of integration C is found from a boundary condition.

At an extreme position (a turning point of the motion), the velocity of the particle is zero. Thus, v = 0 when x = ±A, where A is the amplitude.

$$\therefore 0 = \frac{-\omega^2 A^2}{2} + C \therefore C = \frac{\omega^2 A^2}{2}$$

$$\therefore \frac{v^2}{2} = \frac{-\omega^2 x^2}{2} + \frac{\omega^2 A^2}{2}$$

$$\therefore v^2 = \omega^2 (A^2 - x^2)$$

$$\therefore v = \pm\omega\sqrt{A^2 - X^2} \text{ ......(2)}$$

This equation gives the velocity of the particle in terms of the displacement, x. The velocity towards right is taken to be positive and towards left as negative.

Since v = dx/dt we can write Eq. 2 as follows:

$$\frac{dx}{dt} = \omega\sqrt{A^2 - x^2} \text{(considering only the plus sign)}$$

$$\therefore \frac{dx}{\sqrt{A^2 - x^2}} = \omega dt$$

Integrating the expression, we get,

$$\sin^{-1}\left(\frac{x}{A}\right) = \omega t + x \quad ....(3)$$

Where the constant of integration, x, is found from the initial conditions, i.e., the displacement and the
velocity of the particle at time t = 0.

From Eq (3), we have

$$\frac{x}{A} = \sin(\omega t + x)$$

∴ Displacement as a function of time is, x = Asin (ωt + x).

Question 4.1.iii:

A body cools from 80° C to 70° C in 5 minutes and to 62° C in the next 5 minutes. Calculate the temperature of the surroundings.

Solution: Average Temperature,
T_1 = 80 +70/2 = 75°C
Average Temperature,
T_2 = 70 + 62/2 = 66°C

We know, that $\frac{dT}{dt} = -k(T - T_0)$

Where, T is a average temperature

T_0 is surrounding temperature

$$\frac{10}{5} = -k(75 - T_0) \quad ....(1)$$

$$\frac{8}{5} = -k(66 - T_0) \quad ....(2)$$

Dividing (1) and (2)

$$\frac{10}{8} = \frac{75 - T_0}{66 - T_0}$$

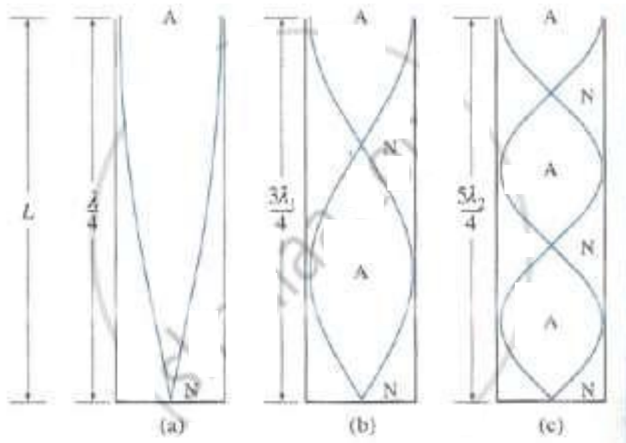
T_0 = 30°C

Question 4.2.i: What is meant by harmonics? **[7]**

Solution: The lowest allowed frequency of vibration (fundamental) of a bounded medium and all its integral multiples are called harmonics.

Question 4.2.ii: Show that only odd harmonics are present as overtones in the case of an air column vibrating in a pipe closed at one end.

Solution: The stationary waves in the air column, in this case, are subject to two boundary conditions that there must be a node at the closed end and an antinode at the open end. In what follows, we shall ignore the end correction.



L = Length of the air column, N = node, A = antinode

Let v be the speed of sound in air. In the simplest mode of vibration, as shown in the figure, there is a node at the closed end and an antinode at the open end. The distance between a node and a constructive antinode is λ/4 where λ is the wavelength of sound. The corresponding wavelength λ and frequency n are

$$\lambda = 4L \text{ and } n = \frac{v}{\lambda} = \frac{v}{4L} \quad \text{....(1)}$$

This gives the fundamental frequency of vibration and the mode of vibration is called the fundamental mode or first harmonic.

In the next higher mode of vibration, the first overtune, two nodes and two antinodes are formed as shown in the figure. The corresponding wavelength λ_1 and frequency λ_1 are λ_2 are

$$\lambda_1 = \frac{4L}{3} \text{ and } n_1 = \frac{v}{\lambda_1} = \frac{3v}{4L} = 3n \quad \text{.....(2).}$$

Therefore, the frequency in the first overtone is three times the fundamental frequency, i.e., the first overtone is the third hamonic.

In the second overtone, three nodes and three antinodes are formed as shown in the figure. The corresponding wavelength λ_2 and frequency n_2 are

$$\lambda_2 = \frac{4L}{5} \text{ and } n_2 = \frac{v}{\lambda_2} = \frac{5v}{4L} = 5n \quad \text{...(3)}$$

Which is the fifth harmonic.

Therefore, in general, the frequency of the pth overtone (p = 1, 2, 3, ...) is

$n_p = (2p + 1)n$ ......(4)

i.e., the pth overtone is the (2p + 1) the harmonic

Equations (1), (2) and (3) show that allowed frequencies in an air column are a pipe closed at one end and n, 3n, 5n, ... That is, only odd harmonics are present as overtones.

Question 4.2.iii: The wavelengths of two sound waves in air are 81/173m and 81/170m. They produce 10 beats per second. Calculate the velocity of sound in air.

Solution:

Data: $\lambda_1 = \frac{81}{173}$ m = 0.468 m

$$\lambda_2 = \frac{81}{170} m = 0.476m$$

Δn = 10 beats

Formula:

$\Delta n = n_1 - n_2$

$$= \frac{V}{\lambda_1} - \frac{V}{\lambda_2}$$

$\Delta n = n_1 - n_2$

$$= V\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$$

$$10 = V\left[\frac{173}{81} - \frac{170}{81}\right]$$

$$10 = V\left[\frac{3}{81}\right]$$

$$10 = V\frac{10 \times 81}{3}$$

V = 270 m/s

Question 5: Select and write the most appropriate answer from the given alternatives for each sub-question : [7]

Question 5.1: The reflected waves from an ionosphere are _____. **[1]**
(a) Ground waves
(b) Sky waves
(c) Space waves
(d) Very high-frequency waves

Solution: Sky waves

Question 5.2: In interference pattern, using two coherent sources of light; the fringe width is _______ **[1]**
(a) Directly proportional to the wavelength
(b) Inversely proportional to the square of the wavelength
(c) Inversely proportional to wavelength.
(d) Directly proportional to the square of the wavelength.

Solution: Directly proportional to wavelength.

Question 5.3: Electric intensity outside a charged cylinder having the charge per unit length 'λ' at a distance from its axis is _______.

(a) E = $\frac{2\pi \in_0 \lambda}{Kr^2}$
(b) E = $\frac{\in_0 \lambda}{2\pi Kr^2}$
(c) E = $\frac{\lambda}{2\pi \in_0 Kr}$
(d) E = $\frac{4\pi \in_0 \lambda}{Kr^2}$

Solution:

E = $\frac{\lambda}{2\pi \in_0 Kr}$

Question 5.4: SI unit of potential gradient is ______. **[1]**

(a) V cm
(b) $\frac{V}{\text{cm}}$
(c) Vm
(d) $\frac{V}{m}$

Solution:
$\frac{V}{m}$

Question 5.5: The momentum associated with the photon is given by______. **[1]**

(a) hv
(b) $\frac{\text{hv}}{c}$
(c) hE
(d) hλ

Solution:
$\frac{\text{hv}}{c}$

Question 5.6: A pure semiconductor is _______. **[1]**

(a) an extrinsic semiconductor
(b) an intrinsic semiconductor
(c) p-type semiconductor
(d) n-type semiconductor

Solution: An intrinsic semiconductor

Question 5.7: The glass plate of refractive index 1.732 is to be used as a polarizer, its polarising angle is _______. **[1]**

30°
45°
60°
90°

Solution: 60°

Question 6 | Attempt Any Six **[12]**

Question 6.1: State the conditions to get constructive and destructive interference of light. **[2]**

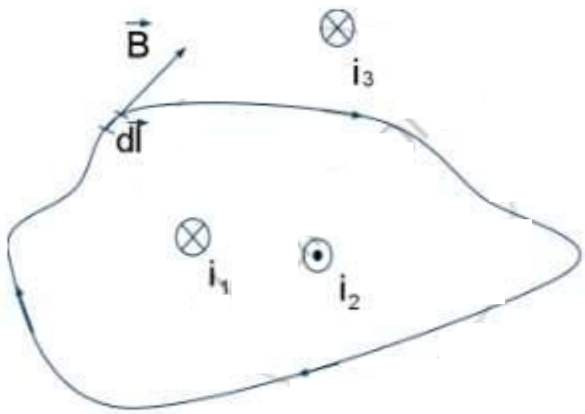
Solution: For constructive interference, the path difference should be even multiple of λ/2 or phase difference should be 2πn. Where n = 0, 1, 2....

For destructive interference, the path difference should be the odd multiple of λ/2 or $(2n-1)\frac{\lambda}{2}$ or phase difference should be the odd multiple of π i.e., (2n - 1)π

Question 6.2.i: State Ampere's circuital law **[2]**

Solution 1: Ampere's circuital law states that the line integral of magnetic field induction $\vec{B}$ around a closed path in vacuum is equal to μ_0 times the total current *I* passing through the surface, i.e. $\oint \vec{B}\,.\,\vec{dl} = \mu_0 I$

Solution 2: Ampere's Circuital Law states that the circulation of the resultant magnetic field along a closed, plane curve is equal to μ_o times the total current crossing the area bounded by the closed curve, provided the electric field inside the loop remains constant.



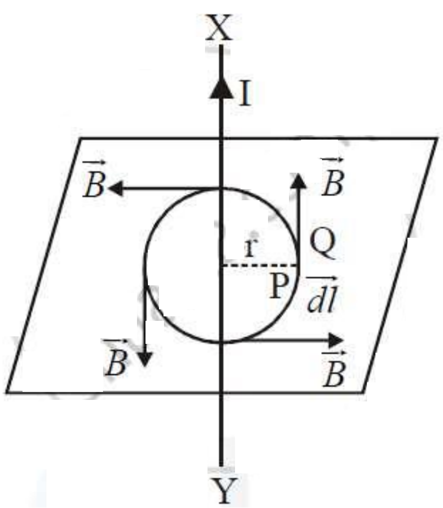
In the above illustration, the Ampere's Circuital Law can be written as follows:

$$\oint \vec{B}\,.\,\vec{dl} = \mu_0 i$$

where, $i = |i_1 - i_2|$

Question 6.2.ii: Explain Ampere's circuital law.

Ampere's law is the generalisation of Biot-Savart's law and is used to determine magnetic field at any point due to a distribution of current. Consider a long straight current carrying conductor XY, placed in the vacuum. A steady current 'I' flows through it from the end Y to X as shown in the figure

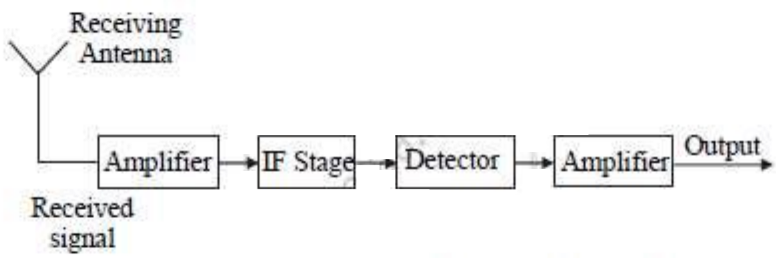


Imagine a closed curve (amperian loop) around the conductor having radius 'r'. The loop is assumed to be made of a large number of small elements each of length $\vec{dl}$. Its direction is along the direction of the traced loop.

Le $\vec{B}$ be the strength of magnetic field around the conductor. All the scalar products of $\vec{B}$ and $\vec{dl}$ given the product of μ_0 and I. It is given by $\oint \vec{B}\,.\,\vec{dl} = \oint Bl\cos\theta$ where, theta = angle between $\vec{B}$ and $\vec{dl}$

Question 6.3: Draw the block diagram of a receiver in communication system **[2]**

Solution:



Block diagram of a receiver

Question 6.4: Define magnetization. State its formula and S.I. unit. **[2]**

Solution: The net magnetic dipole moment per unit volume is called as the magnetization of the sample.

Magnetization = $\frac{\text{Net magneticmoment}}{\text{Volume}}$

It is vector quantity.

Unit A/m and Dimension $\left[M^0L^{-1}T^0I^1\right]$

$\therefore M_z = \frac{M_{\text{net}}}{\text{Volume}}$

Unit (A / m) and dimensions $\left[L^{-1}M^0T^0I^1\right]$

Question 6.5: The electron in the hydrogen atom is moving with a speed of 2.3x10^6 m/s in an orbit of radius 0.53 Å. Calculate the period of revolution of the electron. (Π = 3.142) **[2]**

Solution:

$v = 2.3 \times 10^6 m$

$r = 0.53\text{Å} = 0.53 \times 10^{-10} m$

$v = r\omega = r \times \frac{2\pi}{T}$

$T = \frac{2\pi r}{v} = \frac{2 \times 3.14 \times 0.53 \times 10^{-10}}{2.3 \times 10^6}$

$\therefore T = 1.44 \times 10^{-16}$ sec

$f = \frac{1}{T} = 6.9 \times 10^{15}$ Hz

Question 6.6: A capacitor of capacitance 0.5 μF is connected to a source of alternating e.m.f. of frequency 100 Hz. What is the capacitive reactance? (Π = 3.142) **[2]**

Solution:

C = 0.5×10^{-6}

f = 100 Hz

$$X_c = \frac{1}{\omega C}$$

$$= \frac{1}{2\pi f \times C}$$

$$= \frac{1}{2 \times 3.14 \times 100 \times 0.5 \times 10^{-6}}$$

$$= \frac{1}{2 \times 3.14 \times 0.5 \times 10^{-4}}$$

$$= \frac{10^{-4}}{3.142}$$

= 3182.68 Ω

Question 6.7: Calculate the de-Broglie wavelength of an electron moving with one-fifth of the speed of light. Neglect relativistic effects. (h = 6.63×10^{-34} J.s, c = 3×10^{8} m/s, mass of electron = 9×10^{-31} Kg) **[2]**

Solution:

v = $\frac{1}{5} \times 3 \times 10^{8}$ m/s

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

$$= \frac{6.63 \times 10^{-34}}{9 \times 10^{-31} \times \frac{3}{5} \times 10^{8}}$$

= 1.22×10^{-11} m

= 0.122 Å

Question 6.8: For proton acceleration, a cyclotron is used in which a magnetic field of 1.4 Wb/m^2 is applied. Find the time period for reversing the electric field between the two Ds. **[2]**

Solution:

Data: $B = 1.4\ Wb/m^2$, $m = 1.67 \times 10^{-27}$ kg,

$q = 1.6 \times 10^{-19}$ c

$$T = \frac{2\pi m}{qB}$$

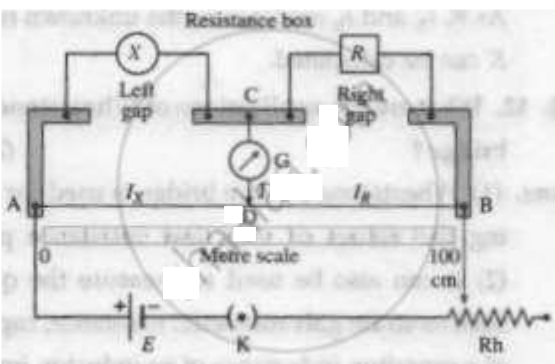
$$t = \frac{T}{2} = \frac{\pi m}{qB} = \frac{3.142(1.67 \times 10^{-27})}{(1.6 \times 10^{-19})(1.4)}$$

$= 2.342 \times 10^{-8}$ s

Question 7: Attempt Any Three [9]

Question 7.1: Explain with a neat circuit diagram how will you determine unknown resistance 'X' by using meter bridge [3]

Solution: A meter bridge consists of a rectangular wooden board with two L-shaped thick metallic strips fixed along its three edges. A single thick metallic strip separates two L-shaped strips. A wire of length one meter and uniform cross-section is stretched on a meter scale fixed on the wooden board. The ends of the wire are fixed to the L-shaped metallic strips.



An unknown resistance X is connected in the left gap and a resistance box R is connected in the right gap as shown above figure. One end of a center-zero galvanometer (G) is connected to terminal C and the other end is connected to a pencil jockey (J). A cell (E) of emf E, plug key (K) and rheostat (Rh) are connected in series between points A and B.

Working: Keeping a suitable resistance (R) in the resistance box, key K is closed to pass a current through the circuit. The jockey is tapped along the wire to locate the equipotential point D when the galvanometer shows zero deflection. The bridge is then balanced and point D is called the null point and the method is called a null deflection method. The distances l_X and l_R of the null point from the two ends of the wire are measured.

According to the principle of Wheatstone's network,

$$\frac{X}{R} = \frac{\text{resistance of the wire of length } l_X\ (R_{AD})}{\text{resistance of the wire of length } l_R\ (R_{DB})}$$

$$\therefore \frac{X}{R} = \frac{R_{AD}}{R_{DB}} \quad .....(1)$$

Now, R = $\rho\frac{1}{A}$ where l is the length of the wire, ρ is the resistivity of the material of the wire and A is the area of cross-section of the wire.

$\therefore R_{AD} = \rho\frac{l_x}{A}$ and $R_{DB} = \rho\frac{l_g}{A}$

$$\therefore \frac{X}{R} = \frac{R_{AD}}{R_{DC}} = \frac{\rho l_x/A}{\rho l_g/A}$$

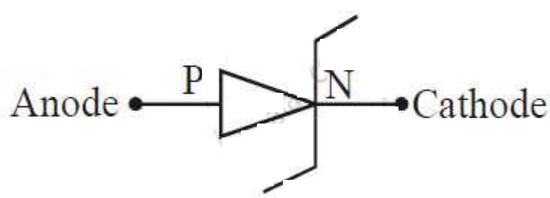
$$\therefore \frac{X}{R} = \frac{l_x}{l_g}$$

$$\therefore X = \frac{l_x}{l_R} \times R$$

As R, l_x and l_g are known, the unknown resistance X can be calculated.

Question 7.2: What is Zener diode? **[3]**

Solution: Zener diode: A Zener diode is a P-N junction diode intentionally manufactured to operate in breakdown region. It is symbolically represented as shown in the figure.



A breakdown for a given Zener diode depends upon doping level of P and N regions.

Question 7.3: In a biprism experiment, the light of wavelength 5200Å is used to get an interference pattern on the screen. The fringe width changes by 1.3 mm when the screen is moved towards biprism by 50 cm. Find the distance between two virtual images of the slit. **[3]**

Solution:

$\lambda = 5200Å = 5.2 \times 10^{-7}m$

$X_1 - X_2 = 1.3mm = 1.3 \times 10^{-3}m$

$D_1 - D_2 = 50cm = 0.5m$

$X_1 - X_2 = \frac{\lambda D_1}{d} - \frac{\lambda D_2}{d}$

$= \frac{\lambda}{d}(D_1 - D_2)$

$\therefore d = \frac{\lambda(D_1 - D_2)}{X_1 - X_2}$

$= \frac{5.2 \times 10^{-7} \times 0.5}{1.3 \times 10^{-3}}$

$= 2 \times 10^{-4}m$

= 0.2 mm

Question 7.4: The refractive indices of water and diamond are 4/3 and 2.42 respectively. Find the speed of light in water and diamond. (c = 3×10^8 m/s) **[3]**

Solution:

$^a\mu_w = \frac{4}{3}$

$^a\mu_d = 2.42$

$^a\mu_w = \frac{4}{3} = \frac{V_a}{V_w}$

$\therefore V_w = \frac{3 \times 10^8}{\frac{4}{3}} = 3 \times 10^8 \times \frac{3}{4} = 2.25 \times 10^8$ m/c

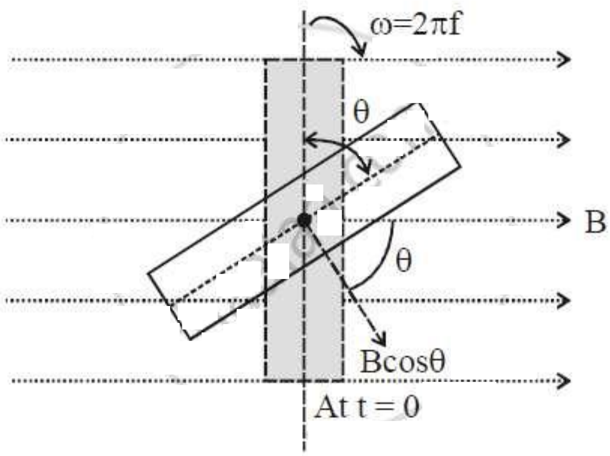
$^a\mu_d = 2.42 = \frac{V_a}{V_d} = \frac{3 \times 10^8}{V_d}$

$V_d = \frac{3 \times 10^8}{2.42} = 1.23 \times 10^8$ m/s

Question 8: Attempt Any One **[7]**

Question 8.1.i: Prove theoretically the relation between e.m.f. induced in a coil and rate of change of magnetic flux in electromagnetic induction. **[7]**

Solution: 1)



Magnetic flux Φ = NABcos ωt

N → No.s of turns

A → Area of a coil

B → Magnetic field {external}

ω → Angular speed of the coil

$\therefore \max \phi_0 = NAB, \omega t \to 0$

$\therefore \phi = \phi_0 \cos \omega t$

induce EMF(e)

e = $-\frac{d\phi}{dt} = +\omega NAB \sin \omega t$

$e_0 = \omega NAB, \omega t \to 90$

$\therefore e = e_0 \sin \omega t$

So there is phase difference of $\frac{\pi}{2}$ with ϕ and e

Question 8.1.ii:

A parallel plate air condenser has a capacity of 20μF. What will be a new capacity if:
1) The distance between the two plates is doubled?
2) A marble slab of dielectric constant 8 is introduced between the two plates?

Solution: Capacitance between the parallel plates of the capacitor, C = 20 pF

Initially, distance between the parallel plates was d and it was filled with air. Dielectric constant of air, k = 1

Capacitance C, is given by the formula,

C = $\dfrac{k \in_0 A}{d}$

= $\dfrac{\in_0 A}{d}$

C = $\dfrac{A \in_0}{d} = 20\mu F$

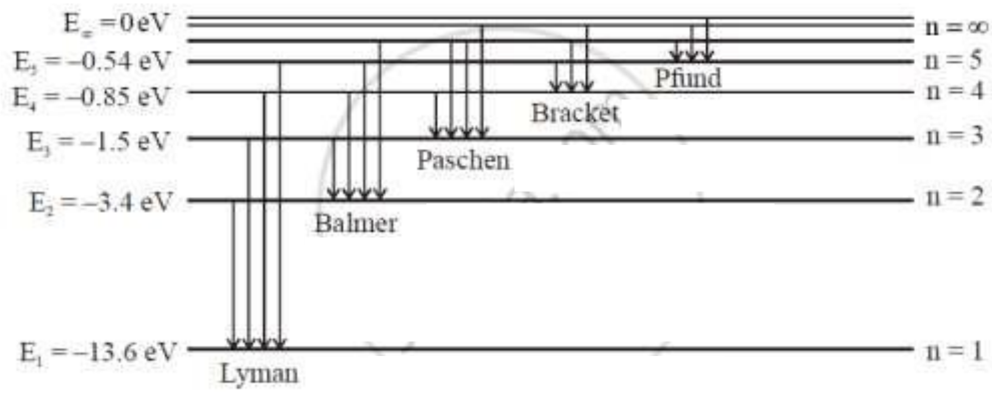
if $d\prime \rightarrow 2d \quad \therefore C\prime \rightarrow \dfrac{C}{2} = 10\mu F$

If k = 8 introduce

C" $= \dfrac{A \in_0}{d} \times k = 20 \times 8 = 160\mu F$

Question 8.2.i: Draw a neat and labelled energy level diagram and explain Balmer series and Brackett series of spectral lines for the hydrogen atom. **[7]**

Solution:



Energy level diagram for hydrogen atom

Balmer series: The spectral lines of this series corresponds to the transition of an electron from some higher energy state to 2nd orbit. For Balmer series, p = 2 and n = 3, 4, 5. The wave numbers and the wavelengths of spectral lines constituting the Balmer series are given by.

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

This series lies in the visible region.

This series lies in the visible region.

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

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

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

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

These series lie in the near infrared region of the spectrum.