Physics

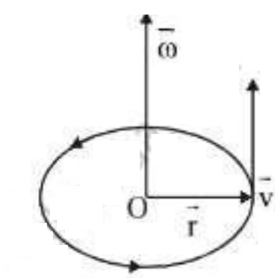
Academic Year: 2015-2016 Marks: 70
Date & Time: 24th February 2016, 11:00 am
Duration: 3h

Section I

Question 1 | Attempt any six [12]

Question 1.1: In U. C. M (Uniform Circular Motion), prove the relation $\vec{v} = \vec{w} \times \vec{r}$, where symbols have their usual meanings. [2]

Solution: Analytical method :
Consider a particle revolving in the anticlockwise sense along the circumference of a circle of radius r with centre O as shown.



Let

$\vec{\omega}$ = angular velocity of the particle

$\vec{v}$ = linear velocity of the particle

$\vec{r}$ = radius of the particle

In the vector form, the linear dispalcement is

$$\vec{\delta s} = \vec{\delta \theta} \times \vec{r}$$

Dividing both sides by δt we get

$$\frac{\vec{\delta s}}{\delta t} = \frac{\vec{\delta \theta}}{\delta t} \times \vec{r}$$

$$\lim_{\delta t \to 0} \frac{\vec{\delta s}}{\delta t} = \lim_{\delta t \to 0} \frac{\vec{\delta \theta}}{\delta t} \times \vec{r}$$

$$\therefore \frac{\vec{dS}}{dt} = \frac{\vec{d\theta}}{\delta t} \times \vec{r}$$

but

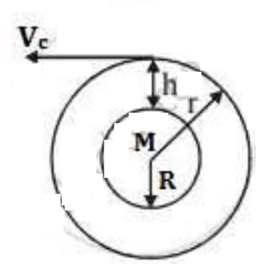
$\frac{\vec{dS}}{dt} = \vec{v}$ = Linear velocity

$\frac{\vec{d\theta}}{\delta t} = \vec{\omega}$ = angular velocity

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

Question 1.2: Derive an expression for critical velocity of a satellite revolving around the earth in a circular orbit. **[2]**

Solution 1:



Consider a satellite of mass m revolving round the Earth at a height 'h' above the surface of the Earth.
Let M be the mass and R be the radius of the Earth.
The satellite is moving with velocity Vc and the radius of the circular orbit is r = R + h.

Centripetal force = Gravitational force

$$\therefore \frac{mV_c^2}{r} = \frac{GMm}{r^2}$$

$$\therefore V_c^2 = G\frac{M}{r}$$

$$\therefore V_c = \sqrt{\frac{GM}{R+h}} \text{...............} (Equ. 1)$$

This is the expression for critical velocity of a satellite moving in a circular orbit around the Earth.

We know that,

$$g_h = \frac{GM}{(R+h)^2}$$

$$\therefore GM = g_h(R+h)^2$$

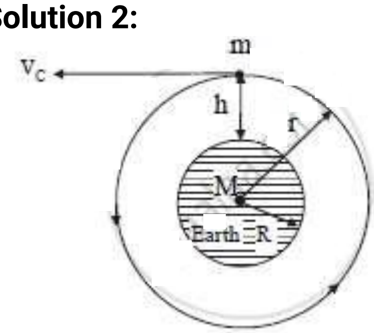
Substituting in equation 1, we get

$$\therefore V_c = \sqrt{\frac{g_h(R+h)^2}{R+h}}$$

$$\therefore V_c = \sqrt{g_h(R+h)}$$

Where g_h is the acceleration due to gravity at a height h above the surface of the Earth.

Solution 2:



Let,
M = mass of the earth
R = radius of the earth
h = height of the satellite from the earth’s surface
m = mass of the satellite
vc
= critical velocity of the satellite in the given orbit
r = (R + h) = radius of the circular orbit

For the circular motion of the satellite, the necessary centripetal force is given as

$$F_C P = \frac{mv_c^2}{r} \qquad 1$$

Gravitational force provides the centripetal force necessary for the circular motion of the satellite

$\therefore F_{CP} = F_G$

$$\therefore \quad \frac{mv_c^2}{r} = \frac{GMm}{r^2} \qquad \text{....[From equations (1) and (2)]}$$

$$\therefore \quad v_c^2 = \frac{GM}{r}$$

$$\therefore \quad v_c = \sqrt{\frac{GM}{r}} \qquad \text{....(3)}$$

e. But, $r = R + h$

$$\therefore \quad v_c = \sqrt{\frac{GM}{(R+h)}} \qquad \text{....(4)}$$

Equation (4) represents the expression for critical velocity.

Question 1.3: Obtain an expression for total kinetic energy of a rolling body in the form

$$\frac{1}{2}(MV^2)\left[1 + \frac{K^2}{R^2}\right]$$

[2]

Solution: Let M and R be the mass and radius of the body, V is the translation speed, ω is the angular speed and I is the moment of inertia of the body about an axis passing through the centre of mass.

Kinetic energy of rotation, $E_R = \frac{1}{2}MV^2$

Kinetic energy of translation, $E_r = \frac{1}{2}I\omega^2$

Thus, the total kinetic energy 'E' of the rolling body is

$E = E_R + E_r$

$$= \frac{1}{2}MV^2 + \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}MV^2 + \frac{1}{2}MK^2\omega^2 ......(I = MK^2 \text{ and K is the radius of gyration})$$

$$= \frac{1}{2}MR^2\omega^2 + \frac{1}{2}MK^2\omega^2 .... (V = R\omega)$$

$$\therefore E = \frac{1}{2}M\omega^2(R^2 + K^2)$$

$$\therefore E = \frac{1}{2}M\frac{V^2}{R^2}(R^2 + K^2)$$

$$E = \frac{1}{2}MV^2\left(1 + \frac{K^2}{R^2}\right)$$

Hence proved.

Question 1.4: Define emissive power and coefficient of emission of a body. **[2]**

Solution: Emissive power of a body at a given temperature is the quantity of radiant energy emitted by the body per unit time per unit surface area of the body at that temperature.
If 'Q' is the amount of radiant energy emitted, 'A' is the surface area of the body and 't' is the time for which body radiates energy, then the emissive power is

$$E = \frac{Q}{at}$$

Coefficient of emission of a body is the ratio of the emissive power of the body at given temperature to the emissive power of a perfectly black body at the same temperature.

Coefficient of emission, $e = \frac{E}{E_b}$

Question 1.5: A coin kept at a distance of 5cm from the centre of a turntable of radius 1.5m just begins to slip when the turntable rotates at a speed of 90 r.p.m. Calculate the coefficient of static friction between the coin and the turntable. **[2]**
[g = 9.8 m/s^2]

Solution: Given that r = 5 cm = 0.05 m,
n = 90 r.p.m. = 1.5 Hz
Limiting force of static friction = Centrifugal force

$$\mu_s mg = mr\omega^2$$

$$\therefore \mu_s = r\frac{\omega^2}{g} = r\frac{(2\pi n)^2}{g}$$

$$\therefore \mu_s = \frac{4r\pi^2 n^2}{g}$$

$$\therefore \mu_s = \frac{4 \cdot 0.05 \cdot (3.14)^2 \cdot (1.5)^2}{9.8}$$

$$\therefore \mu = 0.4527$$

Question 1.6: The fundamental frequency of an air column in a pipe closed at one end is in unison with the third overtone of an open pipe. Calculate the ratio of lengths of their air columns **[2]**

Solution: Given that $n_3 = n_o$

Where n_3 = frequency of the third overtone of the open pipe
n_o = fundamental frequency of the closed pipe

Third overtone of open pipe is

$$n_3 = 4\left(\frac{V}{2L_3}\right)$$

Fundamental frequency of closed pipe at one end is

$$n_o = \frac{V}{4L_o}$$

$$\frac{V}{4L_o} = 4\left(\frac{V}{2L_3}\right) \text{..........}(\because n_o = n_3)$$

$$\therefore \frac{L_o}{L_3} = \frac{1}{8}$$

$$\therefore L_0 : L_3 = 1 : 8$$

Question 1.7: A particle performing linear S.H.M. has a period of 6.28 seconds and a path length of 20 cm. What is the velocity when its displacement is 6 cm from mean position? **[2]**

Solution: Given:

T = 6.28s

Path length 20cm

∴ a =10 cm = 10×10^{-2}m

x = 6 $\times10^{-2}$m

To find:

Velocity, v = ?

Solution:

$$\omega = \frac{2\pi}{t}$$

$$\omega = \frac{2\times3.14}{6.28}$$

$$\omega = 1\mathrm{rad/s}$$

$$\mathrm{V = W\sqrt{A^2 - x^2}}$$

$$= 1\sqrt{(10^2 - 6^2)\times10^{-4}}$$

$$v = \sqrt{(100 - 36)\times10^{-4}}$$

$$v = 1\times8\times10^{-2}$$

$$v = 8\times10^{-2}\mathrm{m/s}$$

Question 1.8: The energy of the free surface of a liquid drop is 5π times the surface tension of the liquid. Find the diameter of the drop in C.G.S. system. **[2]**

Solution: Given that E = 5πT

Surface energy E = T × dA -------- (Equation 1)

dA = 4πr2 -------- (where r is the radius of the liquid drop)
Substituting in Equation 1, we get

E = T * 4πr2
5πT = T* 4πr2 -------- (since E = 5πT)

$$\therefore r^2 = \frac{5}{4}$$

$$\therefore r = \frac{\sqrt{5}}{2}$$

Diameter, $d = 2r = 2 \cdot \frac{\sqrt{5}}{2}$

$$\therefore d = \sqrt{5} = 2.23cm$$

Question 2: Select and write the most appropriate answer from the given alternatives for each sub-question : [7]

Question 2.1:

A particle rotates in U.C.M. with tangential velocity V along a horizontal circle of diameter ‘D'. Total angular displacement of the particle in time 't' is.......... [1]
vt
(v/D)-t
vt/2D
2vt/D

Solution:

$$\frac{2(\text{vt})}{D}$$

Velocity= v ; Diameter= D →Radius= $\frac{D}{2}$

$$\omega = \frac{\theta}{t} \text{ and } v = r \cdot \omega$$

$$\therefore v = \frac{D}{2} \cdot \frac{\theta}{t}$$

$$\therefore \theta = \frac{2vt}{D}$$

Question 2.2: Two springs of force constants K_1 and K_2 ($K_1 > K_2$) are stretched by same force. If W_1 and W_2 be the work done stretching the springs then...... [1]

$W_1=W_2$
$W_1<W_2$
$W_1>W_2$
$W_1=W_2=0$

Solution: $W_1<W_2$

$F_1 = K_1x1$ and $F_2 = K_2x2$

Force is same

$\therefore K_1x1=K_2x2$

$\therefore x_1<x_2$ ....$(K_1>K_2)$

Work done, $W_1 = \frac{1}{2}K_1x_1^2$ and $W_2 = \frac{1}{2}K_2x_1^2$

$\therefore W_1<W_2$ ....$(K_1>K_2$ and $x_1<x_2)$

Question 2.3: A and B are two steel wires and the radius of A is twice that of B. If they are stretched by the same load, then the stress on B is ..... **[1]**

four times that of A.
two times that of A.
three times that of A.
same as that of A.

Solution: Four times that of A.

$(r_A=2r_B)$ ....(1)

$$\therefore stress = \frac{F}{A}$$

$$stress \propto \frac{1}{r^2}$$

$$\therefore \frac{stress_A}{stress_b} = \frac{r_B^2}{r_A^2}$$

$$\text{Stress of B} = \frac{r_A^2}{r_B^2} \times \quad \text{stress of} \quad A$$

$$\text{Stress of B} = \frac{(2r_B)^2}{r_B^2} \times \quad \text{stress of} \quad A \text{ .... from equation 1}$$

$$\text{Stress of B} = \frac{4r_B^2}{r_B^2} \times \quad \text{stress of} \quad A$$

$$\text{Stress on B} = 4 \cdot \text{Stress on A}$$

Question 2.4: If sound waves are reflected from surface of denser medium, there is phase change of....... **[1]**

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

Solution: π rad
There is a phase change of 180°, i.e. the phase of the wave changes by π radians a.

Question 2.5: A sonometer wire vibrates with frequency n_1 in air under suitable load of specific gravity of. When the load is immersed in water, the frequency of vibration of wire n_2 will be .... **[1]**

$n_1\sqrt{\frac{\sigma+1}{\sigma}}$
$n_1\sqrt{\frac{\sigma-1}{\sigma}}$
$n_1\sqrt{\frac{\sigma}{\sigma+1}}$
$n_1\sqrt{\frac{\sigma}{\sigma-1}}$

Solution:

$$n_1\sqrt{\frac{\sigma-1}{\sigma}}$$

Frequency of vibration of wire n_2

$$\frac{n_2}{n_1}=\sqrt{\frac{\sigma-1}{\sigma}} \text{ as}$$

$$\frac{T_1}{T_2}=\frac{\sigma}{\sigma-1} \text{ and}$$

$$\frac{n_2}{n_1}=\sqrt{\frac{T_2}{T_1}}$$

Question 2.6: For polyatomic molecules having 'f' vibrational modes, the ratio of two specific heats, Cp/Cv is.......... **[1]**

$\frac{1+f}{2+f}$
$\frac{2+f}{3+f}$
$\frac{4+f}{3+f}$
$\frac{5+f}{4+f}$

Solution:

$$\frac{4+f}{3+f}$$

By the law of equipartition of energy, for one mole of polyatomic gas

$$C_p = (4+f)R \text{ and } C_v = (3+f)R$$

$$\therefore \frac{C_p}{C_V} = \frac{(4+f)R}{(3+f)R} = \frac{4+f}{3+f}$$

Question 2.7: A body of moment of inertia 5 kgm^2 rotating with an angular velocity 6 rad/s has the same kinetic energy as a mass of 20 kg moving with a velocity of ...... **[1]**

5 m/s
4 m/s
3 m/s
2 m/s

Solution:

3 m/s

Given that $\frac{1}{2}I\omega^2 = \frac{1}{2}mv^2$

$$\therefore \frac{1}{2} \cdot 5kgm^2 \cdot 6^2\frac{rad}{s} = \frac{1}{2} \cdot 20kg \cdot v^2$$

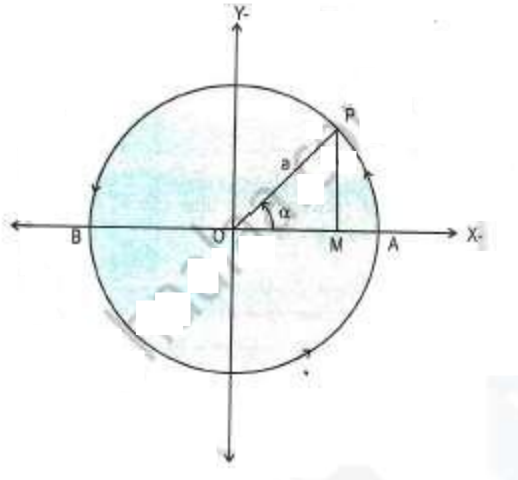
$\therefore v^2=9$

$\therefore V=3$ m/s

Question 3 | Attempt any one of following : [7]

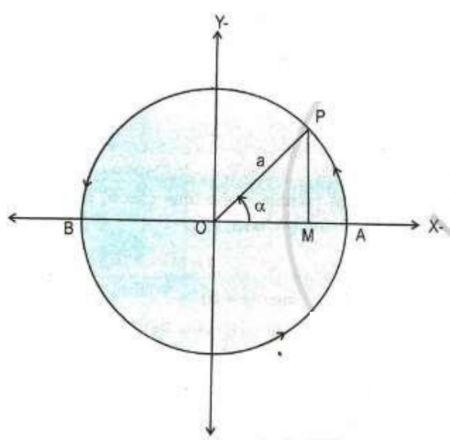
Question 3.1: Define linear S.H.M. **[7]**

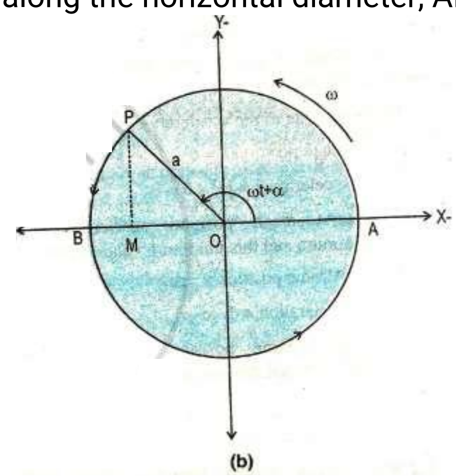
Solution: Linear S.H.M. is defined as the linear periodic motion of a body in which the restoring force (or acceleration) is always directed towards its mean position and its magnitude is directly proportional to the displacement from the mean position.
Consider a particle 'P' moving along the circumference of a circle of radius 'a' and centre O, with uniform angular speed of 'ω' in anticlockwise direction as shown.
Particle P along circumference of the circle has its projection particle on diameter AB at point M.



Question 3.1: Show that S.H.M. is a projection of U.C.M. on any diameter

Solution: Linear S.H.M. is defined as the linear periodic motion of a body, in which the restoring force (or acceleration) is always directed towards the mean position and its magnitude is directly proportional to the displacement from the mean position.
There is basic relation between S.H.M. and U.C.M. that is very useful in understanding S.H.M. For an object performing U.C.M. the projection of its motion along any diameter of its path executes S.H.M.
Consider particle 'P' is moving along the circumference of circle of radius 'a' with constant angular speed of ω in anticlockwise direction as shown in figure.
Particle P along circumference of circle has its projection particle on diameter AB at point M. Particle P is called reference particle and the circle on which it moves, its projection moves back and forth along the horizontal diameter, AB.





The x–component of the displacement of P is always same as displacement of M, the x–component of the velocity of P is always same as velocity of M and the x–component of the acceleration of M.
Suppose that particle P starts from initial position with initial phase α (angle between radius OP and the x – axis at the time t = 0) In time t the angle between OP and x - axis is (ωt + α) as particle P moving with constant angular velocity (ω) as shown in figure.

cos(ωt + α) = $\frac{x}{a}$

$\therefore x = a\cos(\omega t + \alpha)$ ......(1)

This is the expression for displacement of particle M at time t.

As velocity of the particle is the time rate of change of displacement then we have

$$v = \frac{dx}{dt} = \frac{d}{dt}[a\cos(\omega t + \alpha)]$$

$\therefore v = -a\omega\sin(\omega t + \alpha)$ ......(2)

As acceleration of particle is the time rate of change of velocity, we have

$$a = \frac{dv}{dt} = \frac{d}{dt}[-a\omega\sin(\omega t + \alpha)]$$

$$\therefore a = -a\omega^2\cos(\omega t + \alpha)$$

$$\therefore a = \omega^2 x$$

It shows that acceleration of particle M is directly proportional to its displacement and its direction is opposite to that of displacement. Thus particle M performs simple harmonic motion but M is projection of particle performing U.C.M. hence S.H.M. is projection of U.C.M. along a diameter, of circle.

Question 3.1: A metal sphere cools at the rate of 4°C / min. when its temperature is 50°C. Find its rate of cooling at 45°C if the temperature of surroundings is 25°C.

Solution: Given that for the metal sphere

$$\left(\frac{d\theta}{dt}\right)_1 = 4^{\circ}\text{C/min.}$$

$$\theta_1 = 50^{\circ}C, \theta_2 = 45^{\circ} \text{ and } \theta_0 = 25^{C}$$

By Newton's law of cooling,

$$\left(\frac{d\theta}{dt}\right) = k(\theta - \theta_0)$$

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

$$\therefore \frac{\left(\frac{d\theta}{dt}\right)_1}{\left(\frac{d\theta}{dt}\right)_2} = \frac{(50^{\circ} - 25^{0})}{(45^{\circ} - 25^{\circ})}$$

$$\therefore \left(\frac{d\theta}{dt}\right)_2 = \frac{20^{\circ}}{25^{\circ}} \cdot \left(\frac{d\theta}{dt}\right)_1 = \frac{20^{\circ}}{25^{\circ}} \cdot 4 = 3.2$$

$$\therefore \left(\frac{d\theta}{dt}\right)_2 = 3.2^{\circ}\text{C/min}$$

OR

Question 3.2: 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 $R = 2A\cos\left(\frac{2\pi x}{\lambda}\right)$

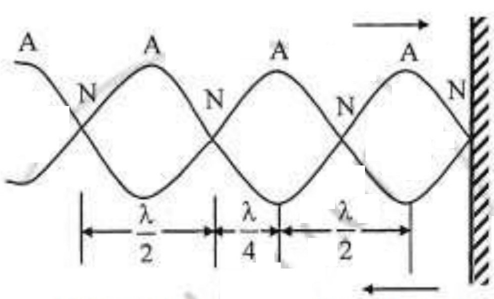
$\therefore y = R\sin(2\pi nt)$ ......(4)

But, $\omega = 2\pi n$

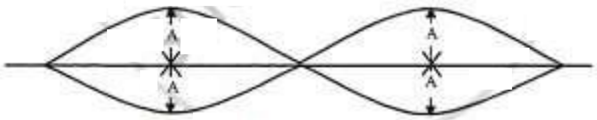
$\therefore y = R\sin\omega t$.........(5)

Question 3.2: Hence show that the distance between node and adjacent antinode is λ/4

Solution:



Position of nodes and antinodes on staionary wave



Position of antinodes

Amplitude of antipodes is maximum, A=±2a

A=2acos$\frac{2\pi x}{\lambda}$

∴±2a=2acos$\frac{2\pi x}{\lambda}$

∴cos$\frac{2\pi x}{\lambda}$=±1

∴$\frac{2\pi x}{\lambda} = 0, \pi, 2\pi.....$

or$\frac{2\pi x}{\lambda} = P\pi$

$\therefore x = \frac{P\pi}{2} = P\left(\frac{\lambda}{2}\right).......(where P = 0, 1, 2......)$

For x=

$0, \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}$, ...antinodes are produced.

Thus, distance between any two successive antinodes is $\frac{\lambda}{2}$

Amplitude of nodes is zero, A=0

∴A=2acos$\frac{2\pi x}{\lambda}$

∴0=2acos$\frac{2\pi x}{\lambda}$

∴cos$\frac{2\pi x}{\lambda}$=0

∴$\frac{2\pi x}{\lambda} = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}........$

∴x=(2P-1)$\frac{\lambda}{4}$...........(where P=1,2......)

For x=

$\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$......

Thus, distance between any two successive nodes is $\frac{\lambda}{2}$.

The distance between node and adjacent anitnodes is $\frac{\lambda}{4}$

Question 3.2: A set of 48 tuning forks is arranged in a series of descending frequencies such that each fork gives 4 beats per second with preceding one. The frequency of first fork is 1.5 times the frequency of the last fork, find the frequency of the first and 42^{nd} tuning fork

Solution: Given that :

$n_1=1.5\ n_{48}$,

beat frequency =4Hz

The set of tuning forks are arranged in decreasing order of frequencies.

$\therefore n_2=n_1-4$

$n_3=n_2-4=n_1-2 \times 4$

$n_{48}=n_{47}-4=n_1-47 \times 4$

$\therefore n_{48}=n_1-188$

$\therefore n_{48}=1.5n_{48}-188$ ....($n_1=1.5n_{48}$)

$\therefore 0.5n48=188$

$\therefore n_{48}=376$

$\rightarrow n_1=1.5n_{48}=1.5 \times 376=564$

$n_{42}=n_{41}-4=n1$

Given that $n_1=1.5\ n_{48}$ and beat frequency =5Hz

The set of tuning forks are arranged in decreasing order of frequencies.

$\therefore n_2=n_1-4$

$n_3=n_2-4=n_1-2 \times 4$

$n_{48}=n_{47}-4=n_1-47 \times 4$

$\therefore n_{48}=n_1-188$

$\therefore n_{48}=1.5n_{48}-188$ ....($n_1=1.5n_{48}$)

$\therefore 0.5n48=188$

$\therefore n_{48}=376$

$\rightarrow n_1 = 1.5 n_{48} = 1.5 \times 376 = 564$

$n_{42} = n_{41} - 4 = n_1 - 4 \times 41$

$\therefore n_{42} = n_1 - 160 = 564 - 164$

$\therefore n_{42} = 400\text{Hz}$

Question 4: Attempt any THREE [9]

Question 4.1: What is the decrease in weight of a body of mass 600kg when it is taken in a mine of depth 5000m? [Radius of earth = 6400km, g = 9.8 m/s^2] [3]

Solution: Given that m = 600 kg, d = 5000 m,
R = 6400 km = 6.4×10^6m
Weight of the body on the surface of the Earth = 600 × 9.8 = 5880 N
At depth d, gravitation acceleration is

$$g_d = g\left[1 - \frac{d}{R}\right]$$

$$\therefore g_d = g\left[1 - \frac{5}{6400}\right] = 9.8x0.999$$

$$\therefore g_d = 9.7902 \text{m/s}^2$$

Weight on surface = mg

=600 x 9.8

∴Weight on surface= 5880N

Weight of the body at depth = mg_d

= 600 x 9.7902

= 5874N

∴ Decrease in weight = mg $- mg_d$

=5880 N - 5874 N

∴ Decrease in weight = 6N

Question 4.2.1: State the theorem of parallel axes about moment of inertia. [1]

Solution: Definition of moment of inertia:

A measure of the resistance of a body to angular acceleration about a given axis that is equal to the sum of the products of each element of mass in the body and the square of the element's distance from the axis.

Theorem of parallel axes:-

The moment of inertia of a body about any axis is equal to the sums 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.

Mathematically, $I_o = I_c + Mh^2$

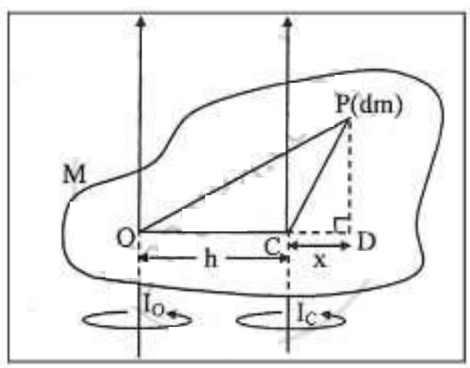
Where I_o = M. I of the body about any axis passing through centre O.

I_c = M. I of the body about parallel axis passing through centre of mass.

h = distance between two parallel axes.

Proof:

i) Consider a rigid body of mass M rotating about an axis passing through a point O as shown in the following
figure.
Let C be the centre of mass of the body, situated at distance h from the axis of rotation.



ii) Consider a small element of mass dm of the body, situated at a point P.

iii) Join PO and PC and draw PD perpendicular to OC when produced.

iv) M.I of the element dm about the axis through O is $(OP)^2$ dm

∴ M.I of the body about the axis thorugh O is given by

$I_o = \int (OP)^2\, dm$ ......(1)

v) M.I of the element dm about the axis through c is CP^2
dm

∴ M.I of the body about the axis through C

$I_c = \int (CP)^2\, dm$ .....(2)

vi) From the figure,

$OP^2 = OD^2 + PD^2$

$= (OC + CD)^2 + PD^2$

$= OC^2 + 2OC \cdot CD + CD^2 + PD^2$

$\because CP^2 = CD^2 + PD^2$

$\therefore OP^2 = OC^2 + 2\,OC\,.\,CD + CP^2$ .....(3)

vii) From equation (1)

$I_o = \int (OP)^2\,dm$

From equation (3)

$$I_o = \int (OC^2 + 2OC.\,CD + CP^2)dm$$

$$\therefore I_o = \int (h^2 + 2hx + CP^2)dm$$

$$= \int h^2 dm + \int 2h.x\,dm + \int CP^2\,dm$$

$$= h^2 \int dm + 2h \int x\,dm + \int CP^2 dm$$

$$I_o = h^2 \int dm + 2h \int x\,dm$$

[From equation (2)]

$$\therefore I_o = I_c + h^2 \int dm + 2h \int x\,dm \quad ....(4)$$

viii) Since $\int dm = M$ and $\int x\,dm = 0$ and

Algebraic sum of the moments of the masses of its individual particles about the centre of mass is zero
for body in equilibrium.

$\therefore$ Equation (4) becomes

$I_o = I_c + Mh^2$

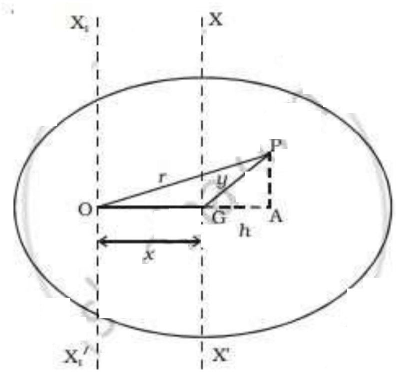
Hence proved.

Question 4.2.2: Prove the theorem of parallel axes about moment of inertia **[3]**

Solution: The moment of inertia of a body about any axis is equal to the sum of its moment of inertia about a parallel axis through its centre of gravity and the product of the mass of the body and the square of the distance between the two axes.

Proof :

Let us consider a body having its centre of gravity at G as shown in Fig.. The axis XX' passes through the centre of gravity and is perpendicular to the plane of the body. The axis X_1X_1' passes through the point O and is parallel to the axis XX' . The distance between the two parallel axes is x.



Parallel axes theorem

Let the body be divided into large number of particles each of mass m . For a particle P at a distance r from O, its moment of inertia about the axis X_1OX_1' is equal to m r ^{2}.

The moment of inertia of the whole body about the axis X_1X_1' is given by,

I = Σ mr^2 ???(1)

From the point P, drop a perpendicular PA to the extended OG and join PG.

In the ΔOPA,

$OP^2 = OA^2 + AP^2$

$r^2 = x^2 + 2xh + h^2 + AP^2$???(2)

But from Δ GPA,

$GP^2 = GA^2 + AP^2$

$y^2 = h^2 + AP^2$ ..(3)

Substituting equation (3) in (2),

$r^2 = x^2 + 2xh + y^2$ ..(4)

Substituting equation (4) in (1),

$I_0 = \Sigma m (x^2 + 2xh + y^2)$

$= \Sigma mx^2 + \Sigma 2mxh + \Sigma my^2$

$= Mx^2 + My^2 + 2x\Sigma mh$

Here $My^2 = I_G$ is the moment of inertia of the body about the line passing through the centre of gravity. The sum of the turning moments of all the particles about the centre of gravity is zero, since the body is balanced about the centre of gravity G.

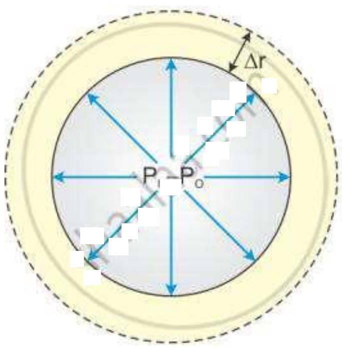
Σ (mg) (h) = 0 (or) Σ mh = 0 [since g is a constant]

Equation (5) becomes, $I_0 = Mx^2 + I_G$

Thus the parallel axes theorem is proved.

Question 4.3: 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 Δ to r, where Δ r 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 = $\triangle \mathbf{A} = \mathbf{A_2} - \mathbf{A_1} = 4\pi(\mathbf{r} + \triangle \mathbf{r})^2 - 4\pi \mathbf{r}^2$

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

$\therefore \triangle \mathbf{A} = 4\pi \times 2\mathbf{r} \triangle \mathbf{r}$ ...($\because$ Δ 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

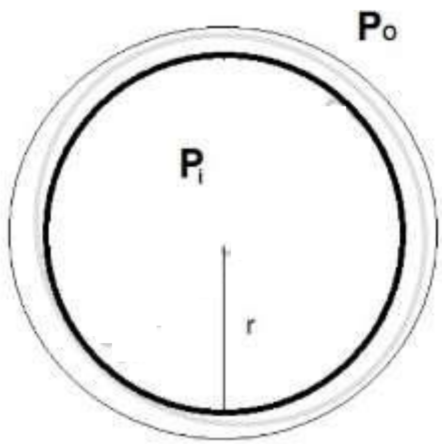
$\Delta F = (P_i - P_0)\, 4 \pi r^2$

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 4.4: A steel wire having cross sectional area 1.5 mm^2 when stretched by a load produces a lateral strain 1.5 x 10^{-5}. Calculate the mass attached to the wire. (Y_{steel} = 2 x 10^{11} N/m^2, Poisson's ratio σ = 0.291,g = 9.8 m/s^2) **[3]**

Solution: Given that A = 1.5 mm^2, lateral strain = 1.5 *10^{-5},

Y_{steel} = 2 * 10^{11} N/m^2, σ = 0.291 and g = 9.8 m/s^2

Poisson's ratio, $\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$

∴Longitudinal strain = $\frac{1.5 \cdot 10^{-5}}{0.291} = 5.14 \cdot 10^{-5}$

Longitudinal stress = Y * Longitudinal strain

$=2*10^{11}*5.14*10^{-5}$

∴Longitudinal stress $=10.28*10^{6}$

But longitudinal stress $= \frac{mg}{A}$

$\rightarrow 10.28*10^{6} = \frac{M \cdot 9.8}{1.5 \cdot 10^{-6}}$

$\therefore M = \frac{10.28 \cdot 10^{6} \cdot 1.5 \cdot 10^{-6}}{9.8} = \frac{15.42}{9.8}$

∴M = 1.58kg

Section II

Question 5: Attempt any SIX **[12]**

Question 5.1: What is 'diffraction of light' **[2]**

Solution: Bending of light near the edges of an obstacle or slit and spreading into the region of geometrical shadow is known as diffraction of light.

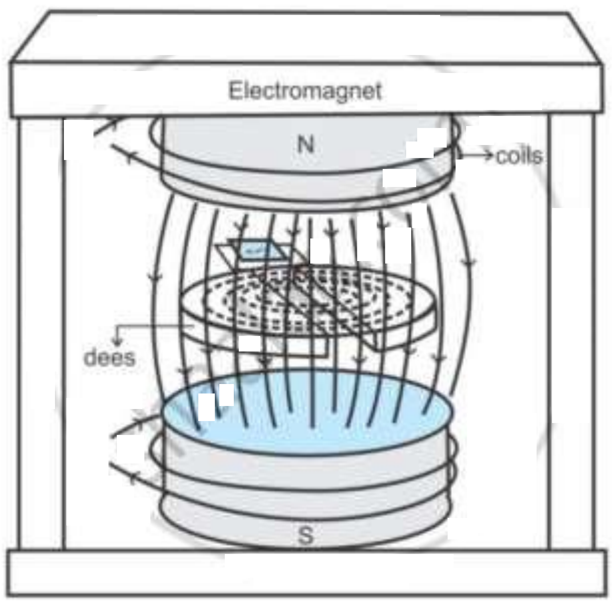
Question 5.1: Explain two types of diffraction of light.

Solution: The diffraction phenomenon is classified into two types:
1. Fraunhofer diffraction: The source of light and the screen on which the diffraction pattern is obtained are effectively at infinite distance from the diffracting system. In this case, we consider plane wave front. The diffraction pattern is obtained by using a convex lens.

2. Fresnel diffraction: The source of light and the screen are kept at finite distance from the diffracting system. In this case, we consider a cylindrical or spherical wave front.

Question 5.2: Draw a neat labelled diagram for the construction of 'cyclotron' **[2]**

Solution:



Question 5.3: Distinguish between 'paramagnetic' and 'ferromagnetic' substances. **[2]**

Solution:

Paramagnetic	**Ferromagnetic**
Substances which are weakly attracted by a magnet are called paramagnetic substances.	Substances which are strongly attracted by a magnet are called ferromagnetic substances.
Paramagnetic materials lose their magnetism on removal of the external field and hence cannot be used to make permanent magnets.	Ferromagnetic materials retain some magnetism on removal of external field and hence can be used to make permanent magnets.
The susceptibility is positive but small.	The susceptibility is positive but very high.

In the absence of electric field, the net dipole moment is zero.	In the absence of electric field, the net dipole moment is non-zero.
Aluminium, manganese, chromium and platinum are some examples of paramagnetic substances.	Iron, nickel, cobalt, gadolinium, dysprosium and their alloys are some examples of ferromagnetic substances.

Question 5.4: Write a short note on surface wave propagation of electromagnetic waves. **[2]**

Solution: Definition :
When the electromagnetic waves (radio waves) from the transmitting antenna propagate along the surface of the earth so as to reach the receiving antenna, the wave propagation is called ground wave propagation (surface wave propagation). [1 mark]

Explanation :

(i) Ground waves are the radio waves which propagate along the surface of the earth.

(ii) There is loss of power in a signal during its propagation on the surface of the earth due to partial absorption of energy by ground. Hence ground wave propagation is suitable for low frequency and medium frequency. It is used for local broadcasting.

(iii) Ground wave propagation is possible only when the transmitting and receiving antenna are close to the earth's surface.

Question 5.5: The combined resistance of a galvanometer of resistance 500Ω and its shunt is 21Ω. Calculate the value of shunt. **[2]**

Solution:
Here, G = 500Ω and Req = 21Ω

$$\frac{1}{R_{eq}} = \frac{1}{G} + \frac{1}{S}$$

$$\therefore \frac{1}{S} = \frac{1}{R_{eq}} - \frac{1}{G} = \frac{G - R_{eq}}{G \times R_{eq}}$$

$$\therefore S = \frac{G \times R_{eq}}{G - R_{eq}}$$

$$\therefore S = \frac{500 \times 21}{500 - 21} = \frac{10500}{479}$$

$$\therefore S = 21.92\Omega$$

Question 5.6: The susceptibility of magnesium at 200 K is 1.8×10^{-5}. At what temperature will the susceptibility decrease by 6×10^{-6}? **[2]**

Solution: Given,

T = 200K,

$\chi_1 = 1.8 \times 10^{-5}$

$\chi_1 - \chi_2 = 6 \times 10^{-6}$

To Find: Required temperature (T_2)

Formula: χT = constant

Calculation:

$\chi_1 - \chi_2 = 6 \times 10^{-6}$

$\chi_2 = 1.8\times10^{-5} - 0.6\times10^{-5}$

$\chi_2 = 1.2 \times10^{-5}$

From formula,

$\therefore \chi T$ = constant

$\chi_1 T_1 = \chi_2 T_2$

$$T_2 = \frac{\chi_1 T_1}{\chi_2}$$

$$T_2 = \frac{1.8 \times 10^{-5} \times 200}{1.2 \times 10^{-5}}$$

$$T_2 = 300K$$

The required temperature is 300 K.

Question 5.7: The co-efficient of mutual induction between primary and secondary coil is 2H. Calculate induced e.m.f. if current of 4A is cut off in 2.5 x 10^{-4} seconds **[2]**

Solution: Here, the co-efficient of mutual induction, M = 2H

4A is cut-off in 2.5 × 10^{-4} seconds.

Induced e.m.f., E = $M\frac{di}{dt}$

$$\therefore E = 2H \times \frac{4A}{2.5 \times 10^{-4}}$$

$$\therefore E = 3.2 \times 10^4 V$$

Question 5.8: The decay constant of radioactive substance is 4.33 x 10^{-4} per year. Calculate its half-life period. **[2]**

Solution:

Here, $\lambda = 4.33 * 10^{-4}$ per year

$$t_{1/2} = \frac{0.6931}{\lambda}$$

$$\therefore t_{1/2} = \frac{0.6931}{\lambda} = \frac{0.6931}{4.33 \cdot 10^{-4}}$$

$\therefore t_{1/2}$ = 1600.69 years or

$t_{1/2} = 0.16 * 10^4 * 365$ days

$\therefore t_{1/2}$ = 584000days

Question 6: Select and write the most appropriate answer from the given alternatives for each sub-question : **[7]**

Question 6.1: If the polarising angle for a given medium is 60°, then the refractive index of the medium is................ **[7]**

$\frac{1}{\sqrt{3}}$

$\sqrt{\frac{3}{2}}$

1

$\sqrt{3}$

Solution: √3

Refractive index, $\mu = \tan i_P$

$\rightarrow \mu = \tan 60°$

$\therefore \mu = \sqrt{3}$

Question 6.2: The resolving power of a telescope depends upon the.............. **[1]**

length of the telescope
focal length of an objective
diameter of an objective
focal length of an eyepiece

Solution: Diameter of an objective

$$\text{R.P of telescope} = \frac{1}{d\theta} = \frac{a}{1.22\lambda}$$

Thus, it is clear that a telescope with a large diameter of the objective has higher resolving power. Thus, the resolving power of a telescope depends on the diameter of an objective.

Question 6.3: Electric intensity due to a charged sphere at a point outside the sphere decreases with.................. **[1]**

increase in charge on sphere.
increase in dielectric constant.
decrease in the distance from the centre of sphere.
decrease in square of distance from the centre of sphere.

Solution: increase in dielectric constant

Electric field intensity at a point outside a charged conducting sphere is given as

$$E = \frac{1}{4\pi}\cdot\frac{q}{r^2}$$

Question 6.4: In potentiometer experiment, if l_1 is the balancing length for e.m.f. of cell of internal resistance r and l_2 is the balancing length for its terminal potential difference when shunted with resistance R then : **[1]**

$$l_1 = l_2\left(\frac{R+r}{R}\right)$$
$$l_1 = l_2\left(\frac{R}{R+r}\right)$$
$$l_1 = l_2\left(\frac{R}{R-r}\right)$$
$$l_1 = l_2\left(\frac{R-r}{R}\right)$$

Solution:

$$l_1 = l_2\left(\frac{R+r}{R}\right)$$

The internal resistance of a cell is given as

$$r = \left(\frac{l_1 - l_2}{l_2}\right)R$$

$$\rightarrow \frac{r}{R} = \frac{l_1 - l_2}{l_2}$$

$$\therefore rl_2 = Rl_1 - Rl_2$$

$$\therefore l_2(R+r) = Rl_1$$

$$\therefore l_1 = l_2\frac{R+r}{R}$$

Question 6.5: The energy of photon of wavelength X is_____ . **[1]**
[h = Planck's constant, c = speed of light in vacuum]

hcλ
$\frac{h\lambda}{c}$
$\frac{\lambda}{hc}$
$\frac{hc}{\lambda}$

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

Energy of a photon E $= h\nu = \frac{hc}{\lambda}$

Question 6.6: Which logic gate corresponds to the truth table given below? **[1]**

A	B	Y
0	0	I
0	1	0
1	0	0
1	1	0

AND
NOR
OR
NAND

Solution: NOR

Question 6.7: The process of superimposing a low frequency signal on a high frequency wave is_______. **[1]**
detection
mixing
modulation
attenuation

Solution: modulation

The process of superimposing a low frequency signal on a high frequency wave is known as modulation.

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

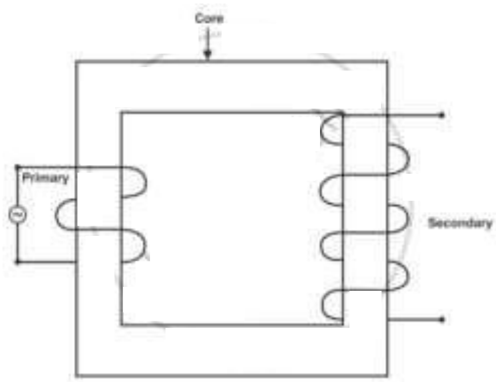
Question 7.1: State the principle on which transformer works. **[7]**

Solution: A transformer is a device with the help of which, a given alternating voltage can be increased or decreased to any desired value. The first type of transformer which delivers an output voltage smaller than the input voltage
is called a step down transformer. The second type of transformer which delivers an output voltage larger than the input voltage is called a step up transformer.

Principle of working of a transformer:
A transformer works on the principle that whenever the magnetic flux linked with a coil changes, an emf is induced in the neighbouring coil.

Question 7.1: Explain transformer working with construction.

Solution: Construction:
It consists of two coils, primary (P) and secondary (S), insulated from each other and wound on a soft iron core as shown in the figure below.



The primary coil is called the input coil and the secondary coil is called the output coil.

Working:
When an alternating voltage is applied to the primary coil, the current through the coil goes on changing. Hence, the magnetic flux through the core also changes. As this changing magnetic flux is linked with both coils, an emf is induced in each of them. The amount of magnetic flux linked with the coil depends on the number of turns of the coil.

Question 7.1: Derive an expression for ratio of e.m.f.s and currents in terms of number of turns in primary and secondary coil.

Solution: Derivation:

Let ‘Φ’ be the magnetic flux linked per turn with both coils at a certain instant of time ‘t’. Let the number of turns of the primary and secondary coils be ‘N_p’ and ‘N_s’, respectively. Therefore, the total magnetic flux linked with the primary coil at certain instant of time ‘t’ is $N_p\Phi$. Similarly, the total magnetic flux linked with the secondary coil at certain instant of time ‘t’ is $N_s\Phi$.

Now, the induced emf in a coil is

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

Therefore, the induced emf in the primary coil is

$$e_p = \frac{d\phi_p}{dt} = \frac{dN_p\phi}{dt} = -N_p\frac{d\phi}{dt} \qquad \text{.......(1)}$$

Similarly, the induced emf in the secondary coil is

$$e_s = \frac{d\phi_s}{dt} = \frac{dN_s\phi}{dt} = -N\frac{d\phi}{dt} \qquad \text{........(2)}$$

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

$$\frac{e_s}{e_p} = \frac{-N_s\frac{d\phi}{dt}}{-N_p\frac{d\phi}{dt}} = \frac{N_s}{N_p} \qquad \text{........(3)}$$

The above equation is called the equation of the transformer and the ratio N_s/N_p is known as the turns ratio of the transformer.
Now, for an ideal transformer, we know that the input power is equal to the output power.

$$\therefore P_p = P_s$$

$$\therefore e_p i_p = e_s i_s$$

$$\therefore \frac{e_s}{e_p} = \frac{i_p}{i_s}$$

From equation (3), we have

$$\frac{e_s}{e_p} = \frac{N_s}{N_P}$$

$$\therefore \frac{e_s}{e_p} = \frac{N_s}{N_p} = \frac{i_p}{i_s}$$

Question 7.1: A conductor of any shape, having area 40 cm^2 placed in air is uniformly charged with a charge 0* 2μC. Determine the electric intensity at a point just outside its surface. Also, find the mechanical force per unit area of the charged conductor. [ϵ_0=8.85x10^{-12} S.I. units]

Solution: Given: Q=0.2 μC=0.2*10^{-6}C

A = 40cm^2 = 40 * $10^{-4}m^2$

ε_0 = 8.85*10^{-12}SI units

The electric field intensity just outside the surface of a charged conductor of any shape is

$$E=\frac{\sigma}{\varepsilon_0}=\frac{Q}{A\varepsilon_0}$$

$$\therefore E=\frac{0.2\cdot 10^{-6}}{40\cdot 10^{-4}\cdot 8.85\cdot 10^{-12}}$$

$\therefore E=5.65\cdot 10^{6}$N/C

Now, the mechanical force per unit area of a conductor is

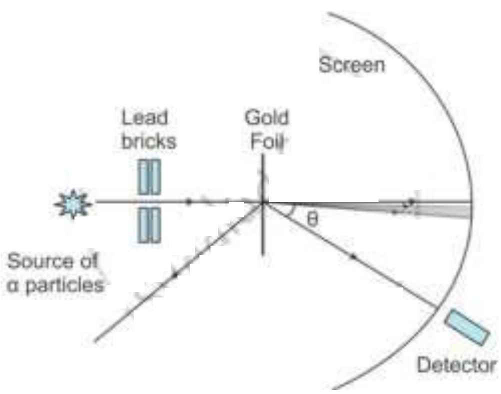
$$f=\frac{1}{2}\varepsilon_0 E^2=\frac{1}{2}\cdot 8.85\cdot 10^{-12}\cdot\left(5.65\cdot 10^{6}\right)^2$$

$\therefore$f=141.25N/m^2

OR

Question 7.2: With the help of a neat labelled diagram, describe the Geiger- Marsden experiment **[7]**

Solution: Geiger–Marsden experiment:
The setup of the Geiger–Marsden experiment is as shown below.



In this experiment, a narrow beam of α-particles from a radioactive source was incident on a gold foil. The scattered α-particles were detected by the detector fixed on a rotating stand. The detector used had a zinc sulphide screen and a microscope.

The α-particles produced scintillations on the screen which could be observed through a microscope. This entire setup is enclosed in an evacuated chamber.
They observed the number of α-particles as a function of scattering angle. Now, the scattering angle is the deviation (θ) of α-particles from its original direction.
They observed that most α-particles passed undedicated and only a few (~0.14%) scattered by more than 1°. Few were deflected slightly and only a few (1 in 8000) deflected by more than 90°. Some particles even bounced back with 180°.

Question 7.2: What is mass defect?

Solution: Mass defect:

It is observed that the mass of a nucleus is smaller than the sum of the masses of the constituent nucleons in the free state. The difference between the actual mass of the nucleus and the sum of the masses of constituent nucleons is called mass defect.

The mass defect is

$\Delta m = [Zm_p + (A - Z)m_n] - M$

where,

Z is the atomic number (number of protons),

A is the mass number,

(A - Z) is the number of neutrons,

m_p is the mass of a proton,

m_n is the mass of a neutron and

M is the measured mass of a nucleus.

Question 7.2: The photoelectric work function for a metal surface is 2.3 eV. If the light of wavelength 6800A is incident on the surface of metal, find threshold frequency and incident frequency. Will there be an emission of photoelectrons or not?
[Velocity of light $c = 3 \times 10^8$ m/s,
Planck's constant, $h = 6.63 * 10^{-34}$ Js]

Solution: Given:

$$\phi_0 = 2.3eV = 2.3 \cdot 1.6 \cdot 10^{-19}J = 3.68 \cdot 10^{-19}J$$

$\lambda = 6800$ Å $= 6800 * 10^{-10}$m, $c = 3 * 10^8$ m/s, $h = 6.63 * 10^{-34}$ Js

We know that the incident frequency is given as

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

$$\therefore v = \frac{3 \cdot 10^8}{6800 \cdot 10^{-10}} = 4.41 \cdot 10^{14}Hz$$

Now, if the incident frequency is greater than the threshold frequency, then photoelectrons will be emitted from the metal surface. The threshold frequency is given from work function as

$$v_0 = \frac{\phi_0}{h}$$

$$v_0 = \frac{3.68 \cdot 10^{-19}}{6.63 \cdot 10^{-34}} = 5.55 \cdot 10^{14} Hz$$

Since, photoelectrons $v < v_0$ will not be emitted.

Question 8 | Attempt any three : **[9]**

Question 8.1: Determine the change in wavelength of light during its passage from air to glass. If the refractive index of glass with respect to air is 1.5 and the frequency of light is 3.5 x 10^{14} Hz, find the wave number of light in glass. **[3]**
[Velocity of light in air c = 3 x 10^8 m/s]

Solution: Given: μ_g = 1.5, n=4 × 10^{14}Hz, c = 3 × 10^8m/s

The wavelength of light incident on glass from air is

Question 8.2: In biprism experiment, 10th dark band is observed at 2.09 mm from the central bright point on the screen with red light of wavelength 6400 A. By how much will fringe width change if blue light of wavelength 4800A is used with the same setting? **[3]**

Solution: In the biprism experiment, the 10^{th} dark band is observed.
The distance between the mth dark band with the central bright band is

$$x_m = (2m-1)\frac{\lambda D}{2d}$$

Therefore, the distance for the 10th dark band is

$$x_{10} = ((2 \cdot 10) - 1)\frac{\lambda D}{2d} = \frac{19\lambda D}{2d}$$

Now, when red light is used, we have

$$(x_{10}) = \frac{19\lambda_r D}{2d} \qquad \text{........(1)}$$

Similarly, for blue light, we have

$$(x_{10})_b = \frac{19\lambda_b D}{2d} \qquad \text{..........(2)}$$

Now, the fringe width is

$$X = \frac{\lambda D}{d}$$

$$\therefore X_r = \frac{\lambda_r D}{d} \qquad ....(3)$$

$$\therefore X_b = \frac{\lambda_b D}{d} \qquad ....(4)$$

From equations (1) and (3), we get

$$(x_{10})_r = \frac{19X_r}{2} = 2.09mm$$

$$\therefore X_r = \frac{2 \cdot 2.09}{19} = 0.22mm$$

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

$$\frac{(x_{10})_r}{(x_{10})_b} = \frac{\frac{19\lambda_r D}{2d}}{\frac{19\lambda_b D}{2d}} = \frac{\lambda_r}{\lambda_b}$$

$$\therefore (x_{10})_b = \lambda_b \cdot \frac{(x_{10})_r}{\lambda_r} = \frac{4800 \cdot 2.09}{6400} = 1.57mm$$

Now, from equations (2) and (4), we get

$$(x_{10})_b = \frac{19X_b}{2} = 1.57mm$$

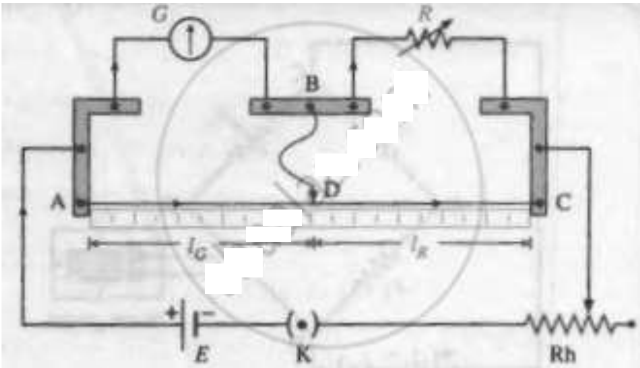
$$\therefore X\_b = \frac{2 \cdot 1.57}{19} = 0.165mm$$

Therefore, the change in fringe width when blue light is used instead of red is X_r-X_b = 0.22-0.165=0.055mm

Question 8.3: Describe Kelvin's method to determine the resistance of the galvanometer by using a meter bridge. **[3]**

Solution: Kelvin's method:

Circuit: The meter bridge circuit for Kelvin's method of determination of the resistance of a galvanometer is shown in the following figure. The galvanometer whose resistance G is to be determined is connected in one gap of the meter bridge. A resistance box providing a variable known resistance R is connected to the other gap.



Kelvin's meter bridge circuit for the measurement of galvanometer resistance

Where, G: Galvanometer, R: Resistance box, AC: Uniform resistance wire, D: Balance point, E: Cell, K: Plug key, Rh: Rheostat

The junction B of the galvanometer and the resistance box is connected directly to a pencil jockey. A cell of emf E, a key (K) and a rheostat (Rh) are connected across AC.

Working: Keeping a suitable resistance R in the resistance box and maximum resistance in the rheostat, key K is closed to pass the current. The rheostat resistance is slowly reduced such that the galvanometer shows about 2/3rd of the full-scale deflection.

On tapping the jockey at end-points A and C, the galvanometer deflection should change to opposite sides of the initial deflection. Only then will there be a point D on the wire which is equipotential with point B. The jockey is tapped along the wire to locate the equipotential point D when the galvanometer shows no change in deflection. Point D is now called the balance point and Kelvin's method is thus an equal deflection method. At this balanced condition,

$$\frac{G}{R} = \frac{\text{resistance of the wire of length } l_G}{\text{- resistance of the wire of length } l_g}$$

Where $l_G \equiv$ the length of the wire opposite to the galvanometer, $l_R \equiv$ the length of the wire opposite to the resistance box.

If $\lambda \equiv$ the resistance per unit length of the wire,

$$\frac{G}{R} = \frac{\lambda l_G}{\lambda l_R} = \frac{l_G}{l_R}$$

$$\therefore G = R\frac{l_G}{l_R}$$

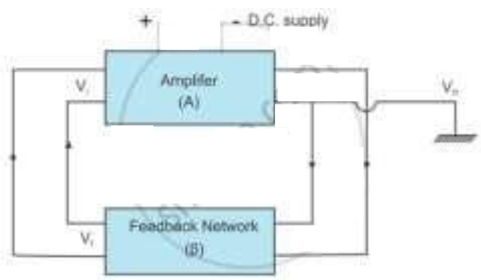
The quantities on the right hand side are known, so that G can be calculated.

Question 8.4: Explain the elementary idea of an oscillator with the help of block diagram **[3]**

Solution: Oscillator:

An oscillator is an electronic device which generates an AC signal from a DC source. Oscillators are used in radio/TV receiver sets, radio/TV transmitters, RADAR, smartphones and microwave ovens. No input is applied to the oscillator, yet an output is obtained from it.

An oscillator requires an amplifier and a feedback network with frequency-determining components. When a part of the output of an amplifier is coupled to the input of the amplifier, it is called feedback. When the feedback sample is out of phase with the input, it is called negative feedback. When the feedback sample is in phase with the input, it is called positive feedback. For an oscillator, a positive feedback is required. The block diagram of an oscillator is shown below.



The voltage gain of a complete system is given by

$$A_r = \frac{A}{1 - A\beta}$$

Where A_f is the voltage gain with feedback, A is voltage gain without feedback and β is the feedback factor.

If for some frequency Aβ= 1, then the system gain becomes ∞ and the circuit begins to oscillate at that frequency. This condition (Aβ = 1) is called the Burkhouse criterion for sustained oscillations.

The frequency of oscillations depends on the LC or RC combinations used in a feedback network. When the power supply connected to the oscillator is turned ON, electrical noise of a wide range of frequencies is generated in the circuit, but the condition Aβ = 1 is satisfied only for a particular frequency and the oscillator oscillates at that frequency.