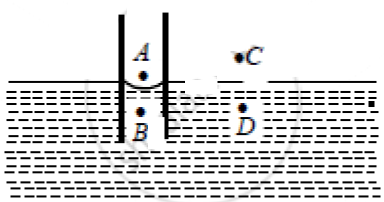
Physics

Academic Year: 2013-2014 Marks: 70
Date: March 2014

Question 1 | Attempt any SIX [12]

Question 1.1: Explain the rise of liquid in the capillary on the basis of pressure difference. [2]

Solution: Explanation of capillary action : Suppose that a capillary tube is dipped in a liquid like water which wets the capillary. Let us consider the situation before the movement of water inside the capillary. The shape of the surface in the capillary is concave. Let us consider four points A, B, C, D such that (i) A be just above the curved surface inside the capillary. (ii) B is just be low inside the capillary. (iii) C is just above the plane surface outside the capillary. (iv) D is just below the plane surface outside the capillary P_A, P_B, P_C, P_D be the pressures at these points.



As the pressure on the concave side of the liquid surface is greater than convex sides $P_A > P_B$ ....(1)

As the pressure is same on the both side of a plane surface $P_C = P_D$ ......(2)

Now $P_A = P_C$ = atmospheric pressure ......(3)

From relation (1), (2) and (3) $P_D > P_B$

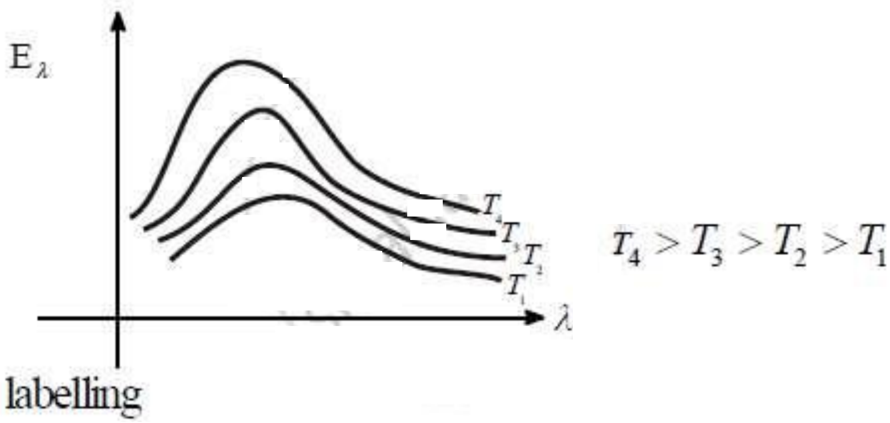
But B and D are same horizontal level in liquid, where pressure at D is greater than pressure at B. Therefore liquid cannot remain in equilibrium and it flows in to the capillary and rises above B till the pressure at B and D becomes equal. This is the reason why where is rise of liquid inside the capillary tube.

Question 1.2: Show graphical representation of energy distribution spectrum of perfectly black body. [2]

Solution: E_λ be emissive power of black body for wavelength λ.

$E_\lambda d\lambda$ be energy density between wavelength λ and λ + dλ

The graph of $E_\lambda d\lambda$ vs λ is called black body spectrum.



Question 1.3: The escape velocity of a body from the surface of the earth is 11.2 km/s. If a satellite were to orbit close to the surface, what would be its critical velocity? **[2]**

Solution: Escape velocity of body from the surface of the earth = 11.2 km/s

$$v_e = \sqrt{2}v_0$$

$$v_0 = \frac{v_e}{\sqrt{2}}$$

$$v_0 = \frac{11.2 \times 10^3}{1.414}$$

$v_0 = 7.92 \times 10^3$ m/s or 7.92 km/s

Question 1.4: A pipe which is open at both ends is 47 cm long and has an inner diameter 5 cm. If the speed of sound in air is 348 m/s, calculate the fundamental frequency of air column in that pipe. **[2]**

Solution: For open pipe, given
l = 47cm, inner diameter = 5 cm and v = 348 m/s
Fundamental frequency n =?

As,

$$n = \frac{V}{2L} = \frac{V}{2(l + 0.6d)}$$

$$n = \frac{348}{2(0.47 + 0.6 \times 0.05)}$$

$$n = \frac{348}{2(0.47 + 0.03)}$$

$$n = \frac{348}{2(0.05)}$$

$$n = 348Hz$$

Question 1.5: Show that R.M.S. velocity of gas molecules is directly proportional to square root of its absolute temperature. **[2]**

Solution:

$$PV = \frac{1}{3}mnv_{rms}^2 = \frac{1}{3}Mv_{rms}^2$$

$$V_{rms} = \frac{\sqrt{3PV}}{M}$$

$$V_{rms}\frac{\sqrt{3RT}}{M} \qquad \{\because PV=RT\}$$

$$V_{rms} \propto \sqrt{T}$$

Question 1.6: For a particle performing uniform circular motion $\vec{v} = \vec{\omega} \times \vec{r}$ obtain an expression for linear acceleration of the particle performing non-uniform circular motion. **[2]**

Solution:

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

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

where

$$\frac{d\vec{\omega}}{dt} = \vec{\alpha},$$

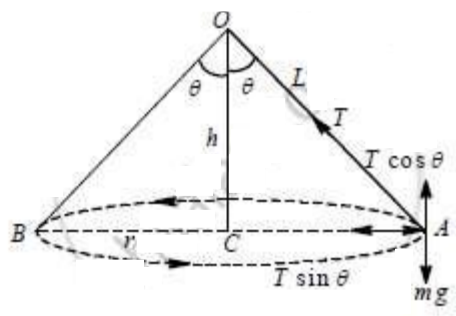
$$\frac{dr}{dt} = \vec{v}$$

$$\frac{d\vec{v}}{dt} = \vec{a}$$

$$\therefore \vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}$$

Question 1.7: A stone of mass 1 kg is whirled in horizontal circle attached at the end of a 1 m long string. If the string makes an angle of 30° with vertical, calculate the centripetal force acting on the stone. ($g=9.8 m/s^2$). **[2]**

Solution:



m = 1kg

$$T\cos 30^{\circ} = mg$$

$$T = \frac{mg}{\cos 30^{\circ}}$$

$$F_c = T\sin 30^{\circ}$$

$$F_c = \frac{mg}{\cos 30^{\circ}} \times \sin 30^{\circ}$$

$= mg \times \tan 30^{\circ}$

$= 1 \times 9.8 \times 1/\sqrt{3}$

$= 9.8/1.732$

$= 5.658N$

the centripetal force acting on the stone is 5.658N

Question 1.8: A solid cylinder of uniform density of radius 2 cm has mass of 50 g. If its length is 12 cm, calculate its moment of inertia about an axis passing through its centre and perpendicular to its length. **[2]**

Solution:

m=50gm , L=12cm

R=2cm

$$I=\left(\frac{ml^2}{12}+\frac{mR^2}{4}\right)=m\left(\frac{l^2}{12}+\frac{R^2}{4}\right)$$

$$\therefore I=50\left[\frac{12\times 12}{12}+\frac{4}{4}\right]$$

= 50 x 13

=650 dyne-cm^2

Question 2 | Attempt any THREE: [9]

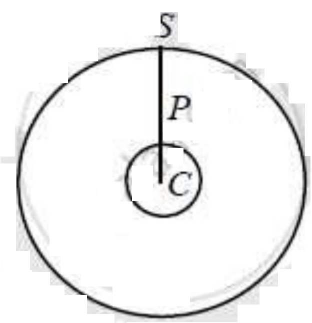
Question 2.1: Derive an expression for acceleration due to gravity at depth 'd' below the earth's surface. [3]

Solution: Let M be mass of the earth, R be the radius of the earth

g_d be gravitational acceleration at depth 'd ' from the earth surface

g be gravitational acceleration on the earth surfaces.

ρ be the density of the earth.



'P' be the point inside the earth at depth 'd ' from earth surfaces.

∴ CS-CP=d, ∴ CP=R-d ....(1) (since CS=R)

$$g=\frac{GM}{R^2},$$

$$\therefore g=\frac{G\frac{4}{3}\pi R^3\rho}{R^2}$$

$$\therefore g=\frac{4G\pi R\rho}{3} \quad \text{....(2)}$$

g_d = acceleration due to gravity at depth 'd '

$$g_d=\frac{G\times \text{Mass of the sphere with radius CP}}{CP^2}$$

$$\therefore g_d = \frac{G\frac{4}{3}\pi CP^3\rho}{CP^2}$$

$$\therefore g_d = \frac{4G\pi CP\rho}{3} \quad .... (3)$$

Dividing eq. (3) by eq. (2)

$$\frac{g_d}{g} = \frac{CP}{R} = \frac{R-d}{R}$$

$$\therefore g_d = g\left(1 - \frac{d}{R}\right)$$

Question 2.2: A copper metal cube has each side of length 1 m. The bottom edge of the cube is fixed and tangential force 4.2×10^8 N is applied to a top surface. Calculate the lateral displacement of the top surface if modulus of rigidity of copper is 14×10^{10} N/m^2. **[3]**

Solution: Given

$\eta = 14 \times 10^{10}$ N/m

$F = 4.2 \times 10^8$ N

$A = 1 \times 1 = 1 m^2$

$$\eta = \frac{Fh}{Ax}$$

$$x = \frac{Fh}{A\eta}$$

$$= \frac{4.2 \times 10^8 \times 1m}{1 \times 14 \times 10^{10}}$$

$$= \frac{4.2 \times 10^8}{14 \times 10^{10}}$$

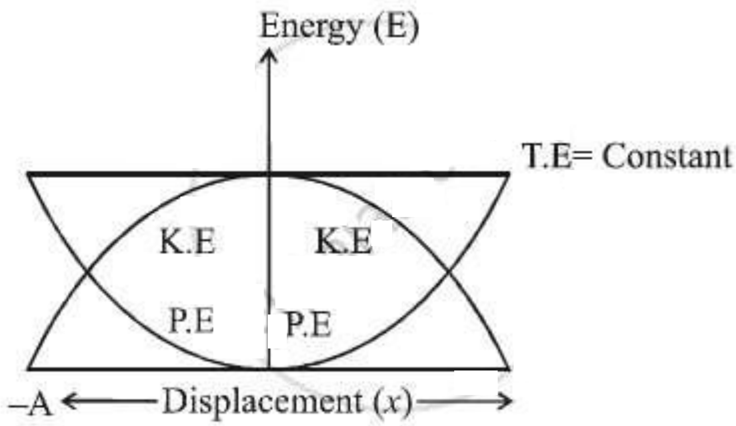
$= 0.3 \times 10^{-2} m = 3mm$

Question 2.3: State an expression for K. E. (kinetic energy) and P. E. (potential energy) at displacement 'x' for a particle performing linear S.H. M. Represent them graphically. Find the displacement at which K. E. is equal to P. E. **[3]**

Solution:

$$\therefore K.E. = \frac{1}{2}mw^2(A^2 - X^2)$$

$$P.E. = \frac{1}{2}mw^2X^2$$



K.E. = P.E.

$$\frac{1}{2}K(A^2 - X^2) = \frac{1}{2}KX^2$$

$\therefore A^2=2X^2$

$$\therefore X^2 = \frac{A^2}{2}$$

$$\therefore X = \frac{A}{\sqrt{2}}$$

Question 2.4: The equation of simple harmonic progressive wave is given by $y = 0.05 \sin \pi \left[20t - \frac{x}{6}\right]$ where all quantities are in S. I. units. Calculate the displacement of a particle at 5 m from origin and at the instant 0.1 second. **[3]**

Solution:

$$y = 0.05 \sin \pi \left[20t - \frac{x}{6}\right]$$
$$= 0.05 \sin \pi \left[20 \times 0.1 - \frac{5}{6}\right]$$
$$= 0.005 \sin \pi \left[2 - \frac{5}{6}\right]$$
$$= 0.05 \sin \left(2\pi - \frac{5\pi}{6}\right)$$
$$= 0.05 \sin \left(\frac{7\pi}{6}\right)$$

$$= 0.005 \sin \left(\pi + \frac{\pi}{6}\right)$$
$$= 0.05 \sin \left(\pi + \frac{\pi}{6}\right)$$
$$= -0.05 \times \frac{1}{2} = -0.025m$$

Question 3: Attempt Any One [7]

Question 3.1.1: State the theorem of parallel axes about moment of inertia. [4]

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.

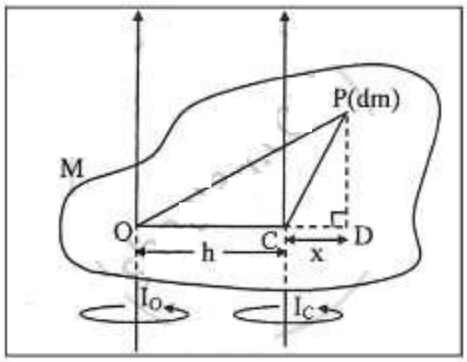
I_c = M. I of the body about parallel axis passing through centre of mass.

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,

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

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

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

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

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

$$\therefore I_o = I_c + h^2 \int dm + 2h \int x\ dm \qquad \text{.......(4)}$$

viii) Since ∫ dm = M and ∫ 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.

∴ Equation (4) becomes

$I_o = I_c + Mh^2$

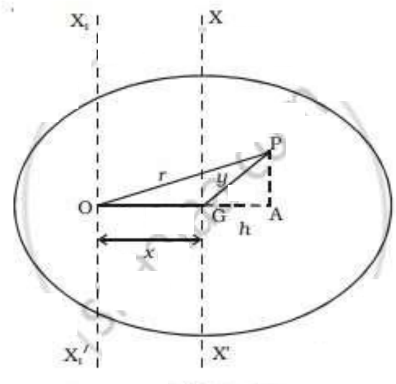
Hence proved.

Question 3.1.1: Prove the theorem of parallel axes about moment of inertia

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,

$I = \Sigma\ mr^2$???(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.

$\Sigma\ (mg)\ (h) = 0$ (or) $\Sigma\ mh = 0$ [since g is a constant]

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

Thus the parallel axes theorem is proved.

Question 3.1.2: Calculate the density of paraffin oil, if glass capillary of diameter 0.25 mm dipped in paraffin oil of surface tension 0.0245 N/m rises to a height of 4 cm. (Angle of contact of paraffin with glass = 28° and acceleration due to gravity = 9.8 m/s^2.) **[4]**

Solution:

Given $r = \frac{0.25}{2} = 0.125mm$

=0.125□10^{-3}m

T = 0.0245N /m

h=4x10^{-2}m

θ=28^{o}, g=9.8

$$T = \frac{hr\rho g}{2\cos\theta}$$

$$\rho = \frac{2T\cos\theta}{hrg}$$

$$= \frac{2 \times 0.0245\cos 28^o}{0.125 \times 10^{-3} \times 4 \times 10^{-2} \times 9.8}$$

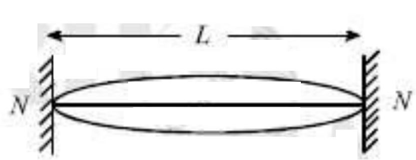
=882.9kg/m^3

Question 3.2.1: A wire of density 'ρ' and Young's modulus 'Y' is stretched between two rigid supports separated by a distance 'L' under tension 'T'. Derive an expression for its frequency in fundamental mode. Hence show that $n = \frac{1}{2L}\sqrt{\frac{Yl}{\rho L}}$ where symbols have their usual meanings **[5]**

Solution: Consider a string of lenght 'L'. Let 'm' be the mass per unit length of the string 'T' be tension in the string.

If transverse wave is produced in the string, the velocity of the wave is given by

$$v = \frac{\sqrt{T}}{m} .... (1)$$



If the string is plucked in middle, two incident and reflected wave will produce stationary wave. The string will vibrate in different mode which is called mode of vibrations.

The simplest mode of vibration is as shown in figure, which is called fundamental mode of vibration. Here two nodes and one antinode is formed. Let λ and n be corresponding wavelength and frequency

$\therefore L=\lambda/2 \quad \therefore \lambda=2L \quad \therefore v=n\lambda=n2L$

$$\therefore \text{From equation (i)} n(2L)=\sqrt{\frac{T}{m}}$$

$$\therefore n=\frac{1}{2L}\sqrt{\frac{T}{m}} \quad ....(2)$$

This is called fundamental frequency

Young's modulus

$$Y=\frac{TL}{Al}$$

$$T=\frac{YAl}{L}, m=\frac{M}{L}=\frac{V\rho}{L}$$

$$=\frac{AL\rho}{L}=A\rho$$

$$\therefore \text{from equation (2)} \quad n=\frac{1}{2L}\sqrt{\frac{\frac{YAl}{L}}{A\rho}}$$

$$n=\frac{1}{2L}\sqrt{\frac{Yl}{AL}}$$

Question 3.2.2: When the length of a simple pendulum is decreased by 20 cm, the period changes by 10%. Find the original length of the pendulum. **[2]**

Solution: $L_2 = L_1 - 0.20$
$T_2 = T_1 - 10\%T_1$

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

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

$$\therefore \frac{T_1}{T_2} = \sqrt{\frac{L_1}{L_2}}$$

$$\frac{T_1}{0.9T_1} = \sqrt{\frac{L_1}{L_1 - 0.2}}$$

Squaring both side

$$\frac{1}{0.81} = \frac{L_1}{L_1 - 0.2}$$

L_1-0.2=0.81L_1

$\therefore L_1$-0.81L_1=0.2

0.19L_1 = 0.2

$$L_1 = \frac{0.20}{0.19}$$

L_1 = 1.053m

Question 4 | Select and write the most appropriate answer from the given alternatives for each sub-question **[7]**

Question 4.1: The bulging of earth at the equator and flattening at the poles is due to _______. **[1]**

Centripetal Force
Centrifugal Force
Gravitational Force
Electrostatic Force

Solution: The bulging of equator and flattening at poles is due to rotation of earth. The rotation of earth creates a centrifugal force which is pseudo effect counter balancing the inward acting centripetal force. This pseudo effect pushes the earth outward, bugling from earth, and flattening at poles. Hence correct answer is **Centrifugal Force.**

Question 4.2: Young’s modulus of material of wire is ‘Y’ and strain energy per unit volume is ‘E’, then the strain is **[1]**

(A) $\frac{\sqrt{Y}}{2E}$
(B) $\sqrt{\frac{E}{Y}}$
(C) $\sqrt{\frac{2E}{Y}}$
(D) $\sqrt{2EY}$

Solution:

(c) $\sqrt{\frac{2E}{Y}}$

Question 4.3: The wavelength range of thermal radiation is **[1]**

(A) from 4000 Å to 7000 Å
(B) from 7700 Å to 4 x 10^6 Å
(C) from 106 Å to 10^8 Å
(D) from 4 x 10^{-12} Å to 4 x 108 Å

Solution: (b) from 7700 Å to 4 x 10^6 Å

Question 4.4: A pipe open at both ends resonates to a frequency 'n_1' and a pipe closed at one end resonates to a frequency 'n_2'. If they are joined to form a pipe closed at one end, then the fundamental frequency will be ______. **[1]**

(A) $\frac{n_1 n_2}{2n_2 + n_1}$
(B) $\frac{2n_2 n_1}{2n_2 + n_1}$
(C) $\frac{2n_2 n_1}{n_1 + n_2}$
(D) $\frac{n_2 + 2n_1}{n_1 n_2}$

Solution:

(a) $\frac{n_1 n_2}{2n_2 + n_1}$

Question 4.5: The phase difference between displacement and acceleration of a particle performing S.H.M. is _______. **[1]**

(A) $\frac{\pi}{2} rad$
(B) π rad
(C) 2π rad
(D) $\frac{3\pi}{2} rad$

Solution: π rad

Question 4.6: Let n_1 and n_2 be the two slightly different frequencies of two sound waves. The time interval between waxing and immediate next waning is ______. **[1]**

(A) $\frac{1}{n_1 - n_2}$

(B) $\frac{2}{n_1 - n_2}$

(C) $\frac{n_1 - n_2}{2}$

(D) $\frac{1}{2(n_1 - n_2)}$

Solution:

(d) $\frac{1}{2(n_1 - n_2)}$

Question 4.7: A metal ball cools from 64 ˚C to 50 ˚C in 10 minutes and to 42 ˚C in next 10 minutes. The ratio of rates of fall of temperature during the two intervals is _______. **[1]**

$\frac{4}{7}$

$\frac{7}{4}$

2

2.5

Solution:

$\frac{7}{4}$

Rate of fall of temperature in first 10 minutes = $R_1 = \frac{64 - 50}{10}$.°C/min = 1.4°C/min

Rate of fall of temperature in next 10 minutes = $R_2 = \frac{50 - 42}{10}$.°C/min = 0.8°C/min

$\Rightarrow \frac{R_1}{R_2} = \frac{7}{4}$

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

Question 5.1: Show that the orbital magnetic dipole moment of a revolving electron is $\frac{eVr}{2}$ **[2]**

Solution: In an atom, electron revolves around the nucleus in circular motion. 'e' be the charge on electron. The T be the time required to complete one revolution.

$$\therefore \text{Period of revolution} = \frac{\text{Circumference}}{\text{velocity}} \qquad \therefore T = \frac{2\pi r}{v}$$

Circulating current $I = \frac{e}{T} \qquad \therefore I = \frac{ev}{2\pi r}$

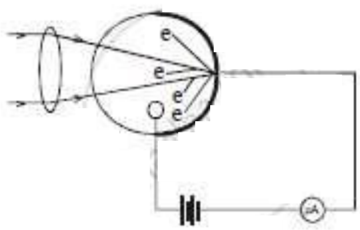
Magnetic moment associated with electron circular loop = M = IA $\therefore M = \frac{ev}{2\pi r} \times \pi r^2$

$$\therefore M = \frac{evr}{2}$$

The direction of this magnetic moment is in to the plane of paper. Negatively charge electron is moving in anticlockwise direction leading current in clockwise direction.

Question 5.2: Describe the construction of photoelectric cell. **[2]**

Solution 1: A photoelectric cell is device which converts light energy into electrical energy. It works on the principle of photoelectric effect.



Construction: A photoelectric cell consist a small evacuated bulb. A thin layer of an alkali metal is deposited on inner surface of the bulb. The bulb is made of quartz, if cell is used with ultraviolet light. If the cell is to be used with visible light only. the bulb is made of ordinary glass. A small portion of the surface of bulb is left uncoated and serves as a window for incoming light. The coated surface of the bulb acts as cathode. The anode is in shape of sphere.

Solution 2: Construction —

1. Photocell consists of evacuated glass tube containing two electrodes emitter (K) and collector (A).
2. The emitter is shaped in the form of a semi hollow cylinder. It is always kept at a negative potential.
3. The collector is in the form of a metal rod and fixed at the axis of the semi-cylinderical emitter. The collector is always kept as a positive potential.
4. The glass tube is fitted on non-metallic base and pins are provided at the base for external connection.

Working —

1. The emitter is connected to negative terminal and collector is connected to positive terminal of a battery.

2. A radiation of frequency more than threshold frequency of material of emitter is made incident on the emitter. Photo-emissions take place. The photoelectrons are attracted towards the collector which is positive w.r.t the emitter. Thus, current flows in the circuit.
3. If the intensity of incident radiation is increased, the photoelectric current increases.

Question 5.3: For a glass plate as a polariser with refractive index 1.633, calculate the angle of incidence at which light is polarised. **[2]**

Solution: M = 1.633

$\because M = \tan i_p$

$\therefore i_p = \tan^{-1} M$

$= \tan^{-1}(1.633)$

$= 58^{\circ}31^{1}$

Question 5.4: The susceptibility of magnesium at 300 K is 2.4×10^{-5}. At what temperature will the susceptibility increase to 3.6×10^{-5}? **[2]**

Solution: T_1=300K

$x_1 = 2.4\text{x}10^{-5}$

$x_2 = 3.6\text{x}10^{-5}$

T_2=?

xT= costant

$\therefore x_1T_1 = x_2T_2$

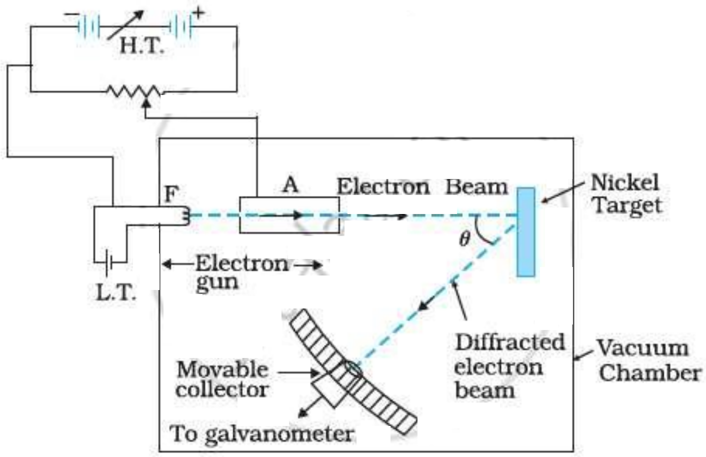
$$\therefore T_2 = \frac{x_1T_1}{x_2}$$

$$= \frac{2.4 \times 10^{-5} \times 300}{3.6 \times 10^{-5}}$$

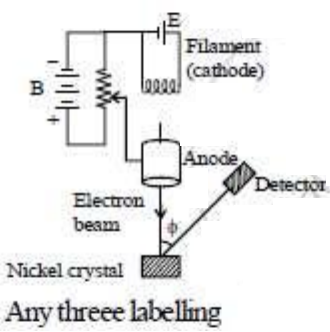
T_2 = 200K

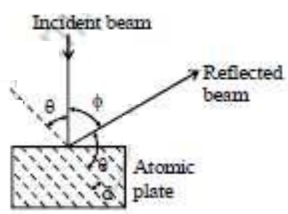
Question 5.5: Draw a neat labelled diagram for Davisson and Germer experiment, for diffraction of electron wave. **[2]**

Solution 1:



Solution 2:





Question 5.6: Write the functions of the following in communication systems: **[2]**

Transmitter

Solution 1: Transmitter: A transmitter converts the message signal from the source of information into a form suitable for transmission through a channel.

Solution 2: Transmitter: A transmitter converts a signal produced by the source of information into a form suitable for transmission through a channel and subsequent reception

Question 5.6: Write the functions of the following in communication systems:
Receiver **[2]**

Solution 1: Receiver is important components of communication systems. Its functions are as follows:

Receiver: The receiver operates on the received signal picked up from transmitted signal at the channel output and processes it to reproduce the recognisable form of the original message signal for delivering.

Solution 2: Receiver : A receiver extracts the desired message signals from the received signals at the channel output. It consists of a pickup antenna to pick up signal, demodulator, an amplifier and transducer the receiver reconstruct a recognizable from of the original message signal for delivering it to the user of information.

Question 5.7: A metal rod $1/\sqrt{\pi}$ m long rotates about one of its ends perpendicular to a plane whose magnetic induction is 4×10^{-3} T. Calculate the number of revolutions made by the rod per second if the e.m.f. induced between the ends of the rod is 16 mV. **[2]**

Solution:

$$L = \frac{1}{\sqrt{\pi}} m = \text{radius}$$

$B = 4x10^{-3}T$

$e = 16mv$

$=16x10^{-3}v$

Area covered in one revolution

$A = \pi L^2$

$$= \pi \left(\frac{1}{\sqrt{\pi}} \right)^2$$

$= 1m^2$

$e = BfA$

$$\therefore f = \frac{e}{BA}$$

$$= \frac{16 \times 10^{-3}}{4 \times 10^{-3} \times 1}$$

$f = 4Hz$

Question 5.8: Find the wave number of a photon having energy of 2.072 eV **[2]**

Given : Charge on electron = 1.6×10^{-19} C,
Velocity of light in air = 3×10^{8} m/s,
Planck's constant = 6.63×10^{-34} J-s.

Solution:

E = hv

$$\therefore v = \frac{E}{h}$$

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

∴ Wave number

$$\frac{1}{\lambda} = \frac{v}{c}$$

$$= \frac{E}{hc}$$

$$= \frac{2.072 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34} \times 3 \times 10^{8}}$$

$$= \frac{1}{\lambda} = 1.667 \times 10^{6} m^{-1}$$

Question 6: Attempt any THREE [9]

Question 6.1: State Ampere's circuital law. [3]

Solution 1:

Statement: The line integral of the magnetic field $\left(\vec{B}\right)$ around any closed path is equal to μ_0 times the total current (I) passing through that closed path.

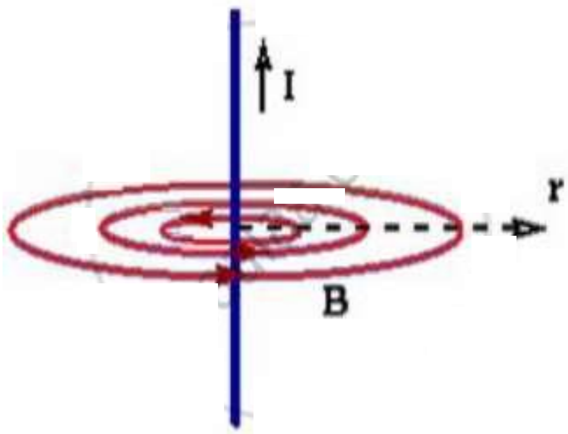
$$\therefore \oint \vec{B} . \vec{dl} = \mu_0 I$$

Solution 2: Ampere's law states that the path integral or line integral over a closed loop of the magnetic field produced by a current distribution is given by $\oint \vec{B} . \vec{dl} = \mu_0 I$

Where I refers to the current enclosed by the loop.

Ampere's law is a useful relation that is analogous to Gauss's law of electrostatics. It is a relation between the tangential component of magnetic field at points on a closed curve and the net current through the area bounded by the curve.

To evaluate the expression for $\oint \vec{B} . \vec{dl}$ et us consider a long, straight conductor carrying a current I, passing through the centre of a circle of radius r in a plane perpendicular to the conductor.



According to Biot-Savart law of magnetism, the field has a magnitude $\frac{\mu_0 l}{2\pi r}$ at every point on the circle, and it is tangent to the circle at each point.

The line integral of $\vec{B}$ around the circle is

$$\oint \vec{B}.\vec{dl} = \oint \frac{\mu_0 I}{2\pi r} dl = \frac{\mu_0 l}{2\pi r} \oint dl$$

Since $\oint \vec{dI} = 2\pi r$ is the circumference of the circle,

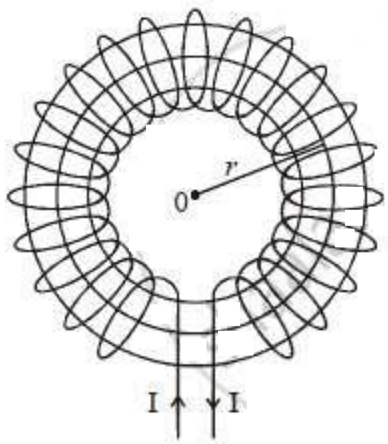
Therefore , $\oint \vec{B}.\vec{dl} = \mu_0 l$

Question 6.1: Obtain an expression for magnetic induction along the axis of the toroid.

Solution: Magnetic induction along the axis of toroid:

The toroid is a solenoid bent into a shape of the hollow doughnut.

Consider a toroidal solenoid of average radius ‘r’ having center carrying the current I. In order to find magnetic field produced at the center along the axis of toroid due to the current flowing through the coil, imagine an Imperial loop of radius ‘r’ and traverse it in the clockwise direction.



According to Ampere's circuital law,

$$\oint \vec{B} \cdot \vec{dL} = \mu_0 I$$

Here current I flow through the ring as many times time as there are the number of turns. Thus the total current flowing through toroid is N I, where N is the total number of turns.

$$\therefore \oint \vec{B} \cdot \vec{dL} = \mu_0 NI \text{ ---------(1)}$$

Now, and are in same direction $\therefore \oint \vec{B} \cdot \vec{dL} = B \oint dL$

$$\therefore \oint \vec{B} \cdot \vec{dL} = B(2\pi r) \text{ ------(2)}$$

Comparing equation (1) and equation (2)

$\mu_0 NI = B(2\pi r)$ $\therefore B = \dfrac{\mu_0 NI}{2\pi r}$ ....(3)

If 'n' is the number of turns per unit length of toroid then $n = \dfrac{N}{2\pi r}$

Substituting this value in equation No (3) we get $B = \mu_0 n I$

Question 6.2: Calculate the radius of second Bohr orbit in hydrogen atom from the given data. **[3]**

Mass of electron = 9.1×10^{-31}kg
Charge on the electron = 1.6×10^{-19} C
Planck's constant = 6.63×10^{-34} J-s.
Permittivity of free space = 8.85×10^{-12} C^2/Nm^2

Solution:

$$r_n = \left(\frac{h^2\varepsilon_0}{\pi m e^2}\right)n^2$$

$$\therefore r_2 = \left(\frac{h^2\varepsilon_0}{\pi m e^2}\right)(2)^2$$

$$r_2 = \frac{\left(6.63 \times 10^{-34}\right)^2 \times 8.85 \times 10^{-12} \times (2)^2}{3.14 \times 9.1 \times 10^{-31} \times \left(1.6 \times 10^{-19}\right)^2}$$

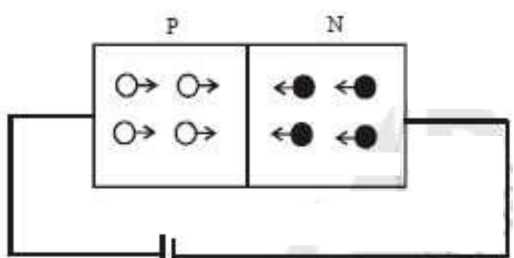
$$= \frac{43.96 \times 10^{-68} \times 8.85 \times 10^{-12} \times 4}{3.14 \times 9.1 \times 10^{-31} \times 2.56 \times 10^{-38}}$$

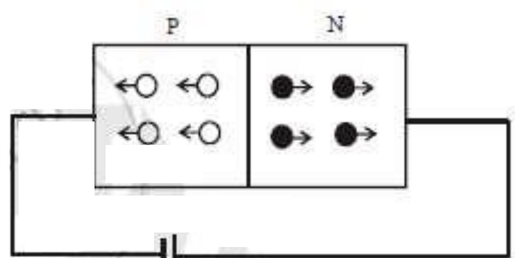
$=2.127 \times 10^{-10}$m

$=2.127$ Å

Question 6.3: Explain the working of P-N junction diode in forward and reverse biased mode. **[3]**

Solution: If a germanium crystal or silicon crystal is doped during manufacture in such a way that half of it is p-type and other half is n-type, we get p-n junction.

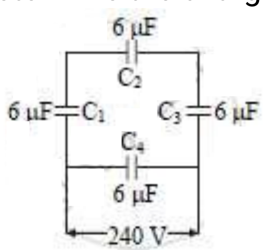




(a) Forward biased: A battery is connected across p-n junction diode such that, p-type is connected to positive terminal and n-type is connected to negative terminal, then it is called forward biased. The potential difference applied should be more than 0.3 V for germanium and more than 0.7 V for silicon. Then holes from p-type region and electrons from n-type region moves towards barrier and it decreases width and height of barrier. Hence an electric current flows through circuit. When applied potential is zero, then current also equal to zero. When P.D. Increases the current is also increases but very slowly. When applied P.D. is more than potential barrier, current increases rapidly. This voltage is called knee voltage. **The forward biased voltage at which the current through diode increases rapidly is called knee voltage**

b) Reversed biased : A battery is connected across p-n junction diode such that, p-type is connected to negative terminal and n-type is connected to positive terminal, then it is called reversed biased. The holes from p type region and electrons from n-type region moves away from junction and it increases width and height of barrier. Hence there is no flow of an electric current in ideal case. In actual case current is very small (inμA)) . The width of potential barrier increases and diode offer very high resistance. The very small current flows through circuit is called as reverse current. If reversed bias voltage increased then the kinetic energy of electrons increases. At certain reversed bias voltage the K.E. of electrons increases enough and they knock out the electrons from semiconductor atoms\ Therefore current suddenly increase. That certain reversed bias voltage is called as breakdown voltage. At breakdown voltage the current increases suddenly and destroy the junction permanently. **The reversed bas voltage at which P-N junction breaks and current suddenly increases is called as breakdown voltage.**

Question 6.4: A network of four capacitors of 6 μF each is connected to a 240 V supply. Determine the charge on each capacitor. **[3]**



Solution:

C_1,C_2 and C_3 are in series

$$\therefore \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$= \frac{1}{6 \times 10^{-6}} + \frac{1}{6 \times 10^{-6}} + \frac{1}{6 \times 10^{-6}}$$

$$\frac{1}{C_s} = \frac{3}{6 \times 10^{-6}}$$

∴ $C_s = 2\times10^{-6}$ F

C_s and C_4 are parallel

∴ equivalent resistance

$C = C_p = C_s + C_4$

$= 2\times10^{-6} + 6\times10^{-6}$

$C = 8\times10^{-6}$

∴$v = v1+ v2+ v3$

$240 = 3v_1$ $\{v_1=v_2=v_3\}$

$\therefore v_1 = 80$ volt

Also charge on C_1, C_2, C_3 are same.

$Q_1 = Q_2 = Q_3 = Q$

$Q = C_1 v_1$

$= 6 \times 10^{-6} \times 80$

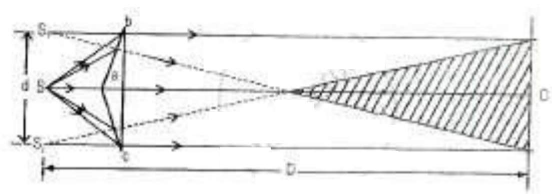
$Q = 480 \times 10^{-6}$C and $Q_4 = 6 \times 10^{-6} \times 240 = 144 \times 10^{-5}$

$Q_4 = 1.44 \times 10^{-3}$ C

Question 7: Attempt Any One [7]

Question 7.1.1: Describe biprism experiment to find the wavelength of monochromatic light. Draw the necessary ray diagram for magnified and diminished images of virtual sources. [5]

Solution: Fresnel's biprism experiment can be used to determine the wavelength of a monochromatic light. The fig. shows the experimental arrangement and ray diagram.



Apparatus: An optical bench is used in the biprism expeiment. It consists of a heavy metal platform about 2m in length and carrying four vertical stands to a slits, the biprism, the lens and eyepiece. The stands can be moved along the bench as well as perpendicular to the bench

Adjustment : The slit S is adjusted to be vertical and narrow. It is illuminated by light from a monochromatic source placed behind it. The light emerging from the slit is made incident on the biprism. The eyepiece stand is arranged at about 1 m from the slit. The refracting edge of the biprism and the vertical cross-wire of the eyepiece are arranged parallel to the slit and along a straight line. The sit is observed through the eyepiece and the biprism is slowly rotated aobut the horizontal axis. When its refracting edge becomes exactly parallel to the slit, the interference pattern consisting of alternate bright and dark bands is seen through the eyepiece. The slit must be sufficiently narrow so that the bands are sharp and clear.

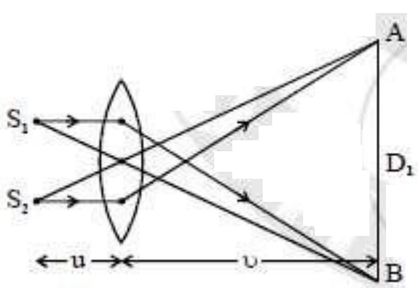
Measurement: The wavelength of a monochromatic light is given by $\lambda = \frac{\overline{X}d}{D}$, is the band width or the fringe width d is the distance between the coherent sources and D is the distance between the sources and the eyepiece. The distance D can be measured directly with the help of the scale marked on the optical bench. To measure the band width X , the micrometer screw fitted to the eyepiece is adjusted such that the vertical cross-wire is made coincide with one of the bright bands.

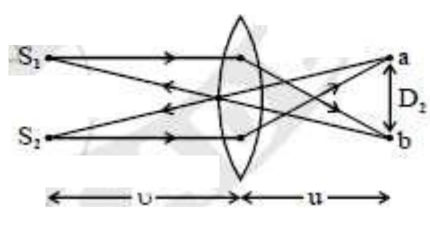
The micrometer reading X1 is noted By rotating the screw in the same sense, the vertical cross-wire is made coincide with successive bright bands and the corresponding reading X_2,X_3, X_4.....etc. are noted. The mean value of $(X_2-X_1),(X_3-X_2),(X_4-X_3)$... etc are noted. The mean value of $(X_2-X_1),(X_3-X_2),(X_4-X_3)$.... etc gives the mean band width X . To measured the distance between two coherent sources, a convex lens is mounted on the stand between the biprism and the eyepiece.

Without disturbing the slit and the biprism, the eyepiece stand is moved along the bench so that the distance the slit and the eyepiece is more than four times the focal length of the lens. The lens stand is moved towards the biprism and its position (L1) is so adjusted that the two magnified images of the slit are seen through the eyepiece by rotating the micrometer screw.

The vertical cross-wire in the eyepiece is made to coincide with each image and the corresponding reading is noted. The difference between these two reading gives the distance d1 between the two magnified images. The lens is moved towards the eyepiece and its position (L_2) is so adjusted that two diminished images of the slit are seen through the eyepiece. The distance d_2 between these images is measure as in case of d_1 Then the distance between the two coherent sources is given by $d = \sqrt{d_1 d_2}$

The wavelength of the monochromatic light is determined by formula i.e $\lambda = \frac{\overline{X} d}{D}$





Question 7.1.2: If the difference in velocities of light in glass and water is 2.7 x 10^7 m/s, find the velocity of light in air. (Refractive index of glass = 1.5, Refractive index of water = 1.333) **[4]**

Solution:

$$u = \frac{C}{v}$$

$$\therefore v_g = \frac{C}{\mu_g}$$

$$v_w = \frac{C}{\mu_w}$$

$$\therefore v_w - v_g = \frac{C}{\mu_w} - \frac{C}{\mu_g}$$

$$2.7 \times 10^7 = C\left(\frac{3}{4} - \frac{2}{3}\right)$$

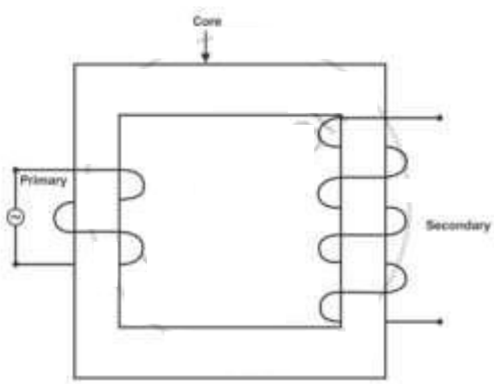
$$2.7 \times 10^7 = C\left(\frac{9-8}{12}\right)$$

$C = 2.7 \times 12 \times 10^7$

$= 3.24 \times 10^8 m/s$

Question 7.2.1: Explain transformer working with construction. **[4]**

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 7.2.1: State the principle on which transformer works.

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 7.2.1: 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 turn’s 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

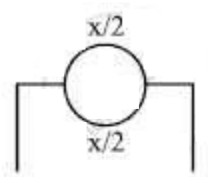
$$\frac{e_s}{e_p} = \frac{N_s}{N_P}$$

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

Question 7.2.2: Two diametrically opposite points of a metal ring are connected to two terminals of the left gap of Meter Bridge. The resistance of 11 Ω is connected in right gap. If null point is obtained at a distance of 45 cm from the left end, find the resistance of metal ring. **[3]**

Solution: R = 11Ω, lx = 45cm

$l_r = 100 - l_x = 55$cm



Let x be the resistance of metal ring

∴Equivalent resistance in left gap

$$\frac{1}{R_p} = \frac{1}{x}$$

$$\therefore R_p = \frac{x}{4}$$

From balancing condition

$$\therefore \frac{R_p}{R} = \frac{l_x}{100 - l_x}$$

$(x$

$$\therefore \frac{x}{4} = \frac{45}{55} \times 11$$

∴ x=9x4

∴x=36Ω

Question 8 | Select and write the most appropriate answer from the given alternatives for each sub-question **[7]**

Question 8.1: Intensity of electric field at a point close to and outside a charged conducting cylinder is proportional to ______. (r is the distance of a point from the axis of cylinder) **[1]**

(A) $\frac{1}{r}$
(B) $\frac{1}{r^2}$
(C) $\frac{1}{r^3}$
(D) r^3

Solution:

(a) $\frac{1}{r}$

Question 8.2: When a hole is produced in P-type semiconductor, there is _______. **[1]**

extra electron in valence band.
extra electron in conduction band.
missing electron in valence band.
missing electron in conduction band.

Solution: Missing electron in valence band

Question 8.3: The outermost layer of the earth's atmosphere is _______. **[1]**

(A) stratosphere
(B) mesospher
(C) troposphere
(D) ionosphere

Solution: (d) Ionosphere

Question 8.4: Accuracy of potentiometer can be easily increased by ______ **[1]**

(A) increasing resistance of wire
(B) decreasing resistance of wire
(C) increasing the length of wire
(D) decreasing the length of wire

Solution: (c) increasing the length of wire

Question 8.5: When electron in hydrogen atom jumps from second orbit to first orbit, the wavelength of radiation emitted is λ. When electron jumps from third orbit to first orbit, the wavelength of emitted radiation would be _______. **[1]**

(A) $\frac{27}{32}\lambda$
(B) $\frac{32}{27}\lambda$
(C) $\frac{2}{3}\lambda$
(D) $\frac{3}{2}\lambda$

Solution:
(a) $\frac{27}{32}\lambda$

Question 8.6: An ideal voltmeter has ______. [1]

(A) low resistance
(b) high resistance
(C) infinite resistance
(D) zero resistance

Solution: (c) Infinite resistance

Question 8.7:
The resolving power of telescope of aperture 100 cm for light of wavelength 5.5 x 10^{-7} m is ____________. [1]

0.149 x 10^7
1.49 x 10^7
14.9 x 10^7
149 x 10^7

Solution: The resolving power of telescope of aperture 100 cm for light of wavelength 5.5 x 10^{-7} m is **0.149 x 10^7.**

Aperture (diameter) of telescope D = 100cm = 1m
Wavelength of light λ = 5.5 x 10^{-7} m

Resolving power of telescope RP = $\frac{D}{1.22\lambda}$

$\Rightarrow$ RP = $\frac{1}{1.22 \times 5.5 \times 10^{-7}} = 0.149 \times 10^7$