Physics

Model Set - 3

Academic Year: 2020-2021 Marks: 70
Date: April 2021
Duration: 3h

1. The question paper is divided into four sections.
2. **Section A**: Q. No. 1 contains Ten multiple-choice type of questions carrying One mark each.
3. **Section A**: Q. No. 2 contains Eight very short answer type of questions carrying One mark each.
4. **Section B**: Q. No. 3 to Q. No. 14 contains Twelve short answer type of questions carrying Two marks each. **(Attempt any Eight)**.
5. **Section C**: Q. No.15 to Q. No. 26 contains Twelve short answer type of questions carrying Three marks each. **(Attempt any Eight)**.
6. **Section D**: Q.No. 27 to Q. No. 31 contains Five long answer type of questions carrying Four marks each. **(Attempt any Three)**.
7. Use of log table is allowed. Use of calculator is not allowed.
8. Figures to the right indicate full marks.
9. For each MCQ, correct answer must be written along with its alphabet.
   e.g., (a) ..... / (b) .... / (c) .... / (d) ..... Only first attempt will be considered for evaluation.
10. **Physical constants:**
    a. Latent heat of vaporisation, L_{vap} = 2256 kJ/kg
    b. Acceleration due to gravity, g = 9.8 m/s^2

Q. 1 | Select and write the correct answer:

1.i Acceleration of a particle executing S.H.M. at its mean position.

1. Is infinity
2. Varies
3. Is maximum
4. Is zero

1.ii Which of the following cannot produce two coherent sources?

1. Lloyd's mirror
2. Fresnel biprism
3. Young's double-slit
4. Prism

1.iii Light follows wave nature because ______

1. Light rays travel in a straight line
2. Light exhibits the phenomenon of reflection and refraction
3. Light exhibits the phenomenon of interference
4. Light causes the phenomenon of the photoelectric effect

1.iv If an electron is brought towards another electron, the electric potential energy of the system _____

1. decreases
2. increases
3. Becomes zero
4. Remains same

1.v Relative permeability of iron 5500, then its magnetic susceptibility will be _____

1. 5500×10^{7}
2. 5501
3. 5499
4. 5500×10^{-7}

1.vi According to the right-hand rule, the direction of magnetic induction if the current is directed in an anticlockwise direction is _____

1. perpendicular and inwards
2. perpendicular and outwards
3. same as current
4. opposite to that of current

1.vii Choose the correct option.

Solar cell operates on the principle of:

1. diffusion
2. recombination
3. photovoltaic action
4. carrier flow

1.viii In a common base configuration, the transistor has an emitter current of 10 mA and a collector current of 9.8 mA. The value of base current is _____

1. 0.1 mA
2. 0.2 mA
3. 0.3 mA
4. 0.4 mA

1.ix An electric bulb operates 10 V d.c. If this bulb is connected to an a.c. source and gives normal brightness, then the peak value of the source is _____

1. 141.4 V
2. 14.14 V

3. 1.414 V
4. 0.1414 V

1.x In the expression e = –dΦ/dt, the -ve sign signifies ______

1. The induced emf is produced only when magnetic flux decreases
2. The induced emf opposes the change in the magnetic flux.
3. The induced emf is opposite to the direction of the flux.
4. The induced emf is independent of change in magnetic flux.

Q. 2 | Answer the following:

2.i What is the surface film?

Ans. A layer of the surface of a liquid whose thickness is equal to the range of an intermolecular force is called surface film.

2.ii Why wave motion is doubly periodic?

Ans. Wave motion is doubly periodic because it repeats itself after an equal interval of time and space.

2.iii What are harmonics?

Ans. The frequencies of a particular overtone which are the integral multiples of the fundamental frequency are known as harmonics.

2.iv A group of objects that can form a unit which may have the ability to exchange energy with its surrounding is called what?

Ans. A group of objects that can form a unit which may have the ability to exchange energy with its surrounding is called as a thermodynamic system.

2.v In Young's double-slit experiment, if there is no initial phase difference between the light from the two slits, a point on the screen corresponds to the 5th minimum. What is the path difference?

Ans.

$$\text{Path difference } \Delta l = (2n - 1)\frac{\lambda}{2} = (2 \times 5 - 1)\frac{\lambda}{2} = \frac{9\lambda}{2}$$

2.vi Which physical quantity has its unit as J/C? Is it a scalar or vector?

Ans. The electrostatic potential has its unit as J/C and it is a scalar quantity.

2.vii The relative velocity between two parallel layers of water is 8 cm/s and the perpendicular distance between them is 0.1 cm. Calculate the velocity gradient.

Ans.

$$\text{Velocity gradient, } V_g = \frac{dv}{dx} = \frac{8}{0.1} = 80/s$$

2.viii The radius of the smallest orbit of the electron(a_0) in a hydrogen atom is 0.053 nm. What is the radius of the 4th orbit of the electron in a hydrogen atom?

Ans. Radius of the 4th orbit of the electron in hydrogen atom, $r_4 = a_0 n^2 = 0.053 \times (4)^2 =$ 0.848 nm

Q. 3 | Attempt Any Eight:

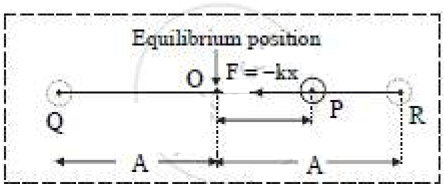
State the assumptions made for thermodynamic processes.

Ans. Assumptions made for studying various thermodynamic processes:

i. The majority of the thermodynamic processes are reversible. That is, they are quasi-static in nature. They are extremely slow and the system undergoes an infinitesimal change at every stage except the adiabatic processes. The system is, therefore, in thermodynamic equilibrium during all the changes.
ii. The system involved in all the processes is an ideal gas enclosed in a cylinder having a movable, frictionless, and massless piston.
iii. The ideal gas equation is applicable to the system.

Q. 4 Obtain the differential equation of linear simple harmonic motion.

Ans. (A) Differential equation of linear S.H.M:
a. Let a particle of mass 'm' undergo S.H.M about its mean position O. At any instant 't', displacement of the particle be 'x' as shown in the following figure.



b. By definition, F = - kx ....(1)

where k is force constant

c. The acceleration of the particle is given by,

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

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

F = ma

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

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

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

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

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

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

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

Ans. (B)

i. In a linear S.H.M., the force is directed towards the mean position and its magnitude is directly proportional to the displacement of the body from the mean position.
$\therefore f \propto -x$
$\therefore f = -kx$ ....(1)
where k is force constant and x is the displacement from the mean position.

ii. According to Newton's second law of motion,
f = ma ....(2)
From equations (1) and (2),
ma = −kx ....(3)

iii. The velocity of the particle is given by, $v = \frac{dx}{dt}$

$\therefore$ Acceleration, $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$.(4)

Substituting equation (4) in equation (3),

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

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

iv. Substituting $\frac{k}{m} = \omega^2$, where ω is the angular frequency,

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

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

Q. 5 State any two laws of the simple pendulum.

Ans. Laws of the simple pendulum:

i. The period of a simple pendulum is directly proportional to the square root of its length.

$\therefore T \propto \sqrt{L}$ ....(when g = constant)

The period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

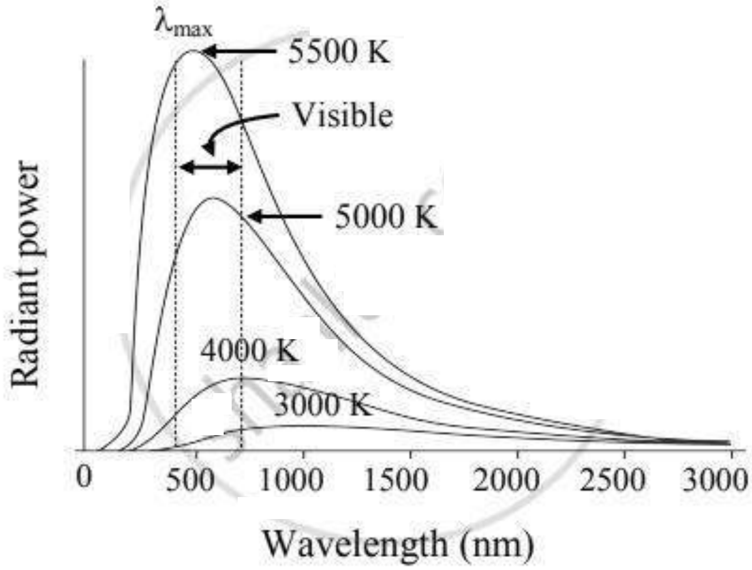
$\therefore T \propto \frac{1}{\sqrt{g}}$ ....(when L = constant)

i. The period of a simple pendulum does not depend on its mass.

ii. The period of a simple pendulum does not depend on its amplitude (for small amplitude).

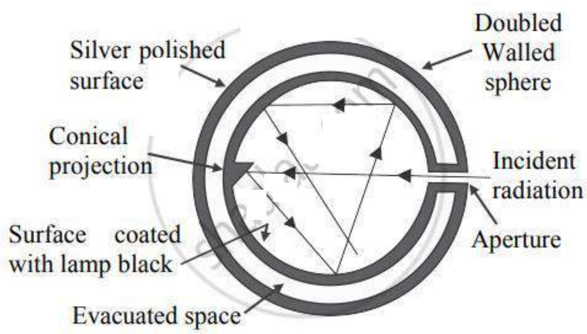
Q. 6 Show the graphical representation of radiant power of a black body per unit range of wavelength as a function of wavelength.

Ans.



Q. 7 Draw a neat labeled diagram of Ferry's black body.

Ans.



Q. 8 State any four applications of beats.

Ans.

i. The phenomenon of beats is used for matching the frequencies of different musical instruments by artists.

ii. The speed of an airplane can be determined by using Doppler RADAR. The phenomenon of beats, arising due to the difference in frequencies produced by the source and received at the source after reflection from the airplane, allows us to calculate the velocity of the airplane.

iii. Doppler ultrasonography and echocardiogram works on the principle of the phenomenon of beats.

iv. The unknown frequency of a sound note can be determined by using the phenomenon of beats.

Q. 9 Define: Ionization energy.

Ans. The ionization energy of an atom is the minimum amount of energy required to be given to an electron in the ground state of that atom to set the electron free.

Q. 10 A raindrop of radius 0.3 mm falls through the air with a terminal velocity of 1 m/s. The viscosity of air is 18 x 10^{-6} N-s /m^2. Find the viscous force on the raindrop.

Ans. Given:

r = 0.3 mm = 3×10^{-4} m,

v = 1 m/s,

$\eta = 18 \times 10^{-6}$ Ns/m^2

To find: Viscous force (F)

Formula: $F = 6\pi\eta rv$

Calculation: From formula,

$F = 6 \times 3.142 \times 18 \times 10^{-6} \times 3 \times 10^{-4} \times 1$

$= 324 \times 3.142 \times 10^{-10}$

= antilog {log 324 + log 3.142} × 10^{-10}

= antilog {2.5105 + 0.4972} × 10^{-10}

= antilog {3.0077} × 10^{-10}

$= 1.017 \times 10^{3} \times 10^{-10}$

$= 1.017 \times 10^{-7}$ N

The viscous force is 1.017 × 10^{-7} N

Q. 11 The optical path of a ray of light of a given wavelength travelling a distance of 3 cm in flint glass having refractive index 1.6 is the same as that on travelling a distance x cm through a medium having a refractive index 1.25. Determine the value of x.

Ans. (A) Let d_{fg} and d_m m be the distances by the ray of light in the flint glass and the medium respectively. Also, let n_{fg} and n_m be the refractive indices of the flint glass and the medium respectively.

Data: d_{fg} = 3 cm, n_{fg} = 1.6, n_m = 1.25,

$$\text{Optical path} = n_m \times d_m = n_{fg} \times d_{fg}$$

$$\therefore d_m = \frac{n_{fg} \times d_{fg}}{n_m} = \frac{1.6 \times 3}{1.25} = 3.84 \text{ cm}$$

Thus, x cm = 3.84 cm

$\therefore x = 3.84$

Ans. (B) Given:

d_1 = 3 cm, n_1 = 1.6, n_2 = 1.25

To find: Optical path in medium 2 (d_2)

Formula: $n_1 d_1 = n_2 d_2$

Calculation:

From formula,

$1.6 \times 3 = 1.25 \times d_2$

$$\therefore d_2 = \frac{1.6 \times 3}{1.25} = \mathbf{3.84\ cm}$$

The value of x is 3.84 cm.

Q. 12 A Plane Wavefront of light of wavelength 5500 A.U. is incident on two slits in a screen perpendicular to the direction of light rays. If the total separation of 10 bright fringes on a screen 2 m away is 2 cm. Find the distance between the slits.

Ans. Given:

λ = 5500 A.U.= 5500×10^{-10} m, D = 2 m

Distance between 10 fringes = 2 cm = 0.02 m.

Fringe width W = 0.02/10 = 0.002 m = 2×10^{-3} m

To find: Distance between slits (d)

Formula: $W = \frac{\lambda D}{d}$

Calculation:

From formula,

$$2 \times 10^{-3} = \frac{5500 \times 10^{-10} \times 2}{d}$$

$$\therefore d = \frac{5.5 \times 10^{-7} \times 2}{2 \times 10^{-3}} = 5.5 \times 10^{-4} m$$

The distance between two slits is **5.5×10^{-4} m.**

Q. 13 Explain De Broglie's Hypothesis.

Ans.

i. De Broglie proposed that a moving material particle of total energy E and momentum p has a wave associated with it (analogous to a photon).
ii. He suggested a relation between properties of the wave, like frequency and wavelength, with that of a particle, like energy and momentum.

$$p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$

Thus, the frequency and wavelength of a wave associated with a material particle, of mass m moving with a velocity v, are given as

$$\nu = \frac{E}{h} \text{ and } \lambda = \frac{h}{p} = \frac{h}{mv} \quad ....(1)$$

i. De Broglie referred to these waves associated with material particles as matter waves. The wavelength of the matter waves, given by equation (1), is now known as de Broglie wavelength and the equation is known as de Broglie relation.

Q. 14 A sonometer wire of length 1 m is stretched by a weight of 10 kg. The fundamental frequency of vibration is 100 Hz. Determine the linear density of the material of the wire.

Ans. Given:

L = 1 m, M = 10 kg, n_0 = 100 Hz

To find: Linear density of wire (m)

Formulae:

i. $T = Mg$

ii. $n_0 = \frac{1}{2L}\sqrt{\frac{T}{m}}$

Calculation:

From formula (i),

T = 10 × 9.8 = 98 N

From formula (ii),

$$100 = \frac{1}{2 \times 1}\sqrt{\frac{98}{m}}$$

Squaring both sides, we get

$$10^4 = \frac{98}{4m}$$

$$\therefore m = \frac{98}{4 \times 10^4}$$

$$= \mathbf{2.45 \times 10^{-3}\ kg/m}$$

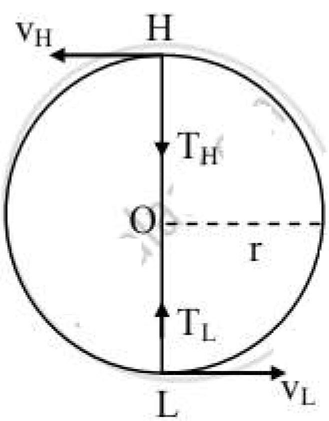
The linear density of the wire is 2.45×10^{-3} kg/m.

Q. 15 | Attempt Any Eight:

Derive an expression for the difference in tensions at the highest and lowest point for a particle performing the vertical circular motion.

Ans.

i. Suppose a body of mass 'm' performs V.C.M on a circle of radius r as shown in the figure.



ii. Let,
T_L = tension at the lowest point
T_H = tension at the highest point
v_L = velocity at the lowest point
v_H = velocity at the highest point

iii. At lowest point L,

$$T_L = \frac{mv_L^2}{r} + mg \text{ ....(1)}$$

At highest point H,

$$T_H = \frac{mv_H^2}{r} - mg \text{ ....(2)}$$

Subtracting (1) by (2),

$$T_L - T_H = \frac{mv_L^2}{r} + mg - \left(\frac{mv_H^2}{r} - mg\right)$$

$$= \frac{m}{r}\left(v_L^2 - v_H^2\right) + 2mg$$

$$\therefore T_L - T_H = \frac{m}{r}\left(v_L^2 - v_H^2\right) + 2mg \text{ ....(3)}$$

v. By law of conservation of energy,

(P.E + K.E) at L = (P.E + K.E) at H

$$\therefore 0 + \frac{1}{2}mv_L^2 = mg.2r + \frac{1}{2}mv_H^2$$

$$\therefore \frac{1}{2}m\left(v_L^2 - v_H^2\right) = mg.2r$$

$$\therefore v_L^2 - v_H^2 = 4gr \text{ ....(4)}$$

vi. From equation (3) and (4),

$$T_L - T_H = \frac{m}{r}(4gr) + 2mg = 4mg + 2mg$$

$$\therefore T_L - T_H = 6mg$$

Q. 16 Obtain an expression for the capillary rise or fall using the forces method.

Ans.

i. When a glass capillary tube is dipped into a liquid, then the liquid rises in the capillary against gravity.
Hence, the weight of the liquid column must be equal and opposite to the component of force due to surface tension at the point of contact.

ii. The length of liquid in contact inside the capillary is the circumference $2\pi r$.
Let, r = radius of the capillary tube
h = height of liquid level in the tube
T = surface tension of the liquid
r = density of liquid
g = acceleration due to gravity

iii. The force of magnitude f_T acts tangentially on a unit length of liquid surface which is in contact with the wall of the capillary tube and is given as $f_T = T \times 2\pi r$
This force can be resolved into two components:
a. $f_T \cos\theta$-vertically upward and
b. $f_T \sin\theta$-along horizontal

iv. The vertical component is effective. The horizontal component is not responsible for the capillary rise.

v. The vertical component of force acting on the liquid column
$(f_T)_v$ = force per unit length × circumference
= T cosθ × 2πr

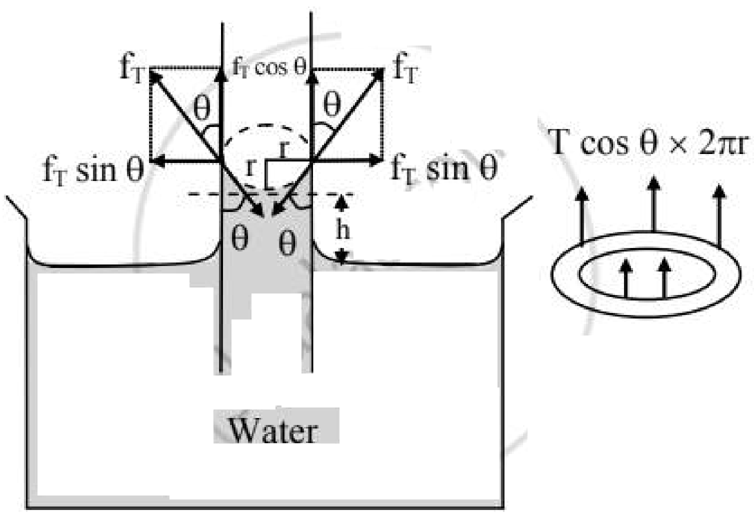
vi. Upward force balances the weight of the liquid in the capillary.
$W = mg = Vrg = \pi r^2 h\rho g$
where V = volume of liquid rise in the tube (ignoring the liquid in the concave meniscus.)
m = mass of the liquid in the capillary rise. This must be equal and opposite to the vertical component of the force due to surface tension.

vii. If the liquid in the meniscus is neglected, then for equilibrium.,

$$2\pi r\, T \cos\theta = \pi r^2\, h\, \rho g$$

$$\therefore h = \frac{2T\cos\theta}{r\rho g} \qquad ....(1)$$

This is the required expression for the rising or fall of liquid in a capillary tube.



Rise of liquid in a capillary tube

Q. 17 Calculate the ratio of two specific heats of polyatomic gas molecules.

Ans.

i. Gases that have molecules containing more than two atoms are termed polyatomic gases.

ii. Each molecule of the polyatomic gas has 3 translational degrees of freedom. Only linear molecules have 2 degrees of freedom for rotation. All other polyatomic molecules have 3 degrees of freedom for rotation.

iii. The number of degrees of freedom (f), for the vibrational motion of a polyatomic molecule, depends on the geometric structure of the molecule i.e., the arrangement of atoms in a molecule.

iv. Each such degree of freedom contributes average energy $2 \times \frac{1}{2} k_B T$ from kinetic energy and potential energy terms.

v. Therefore for 1 mole of a polyatomic gas, the internal energy is $E = \frac{3}{2} N_A k_B T + \frac{3}{2} N_A k_B T + f \times \frac{2}{2} N_A k_B T$

$= (3 + f) N_A k_B T$

vi. The molar specific heats at constant volume and constant pressure are given as

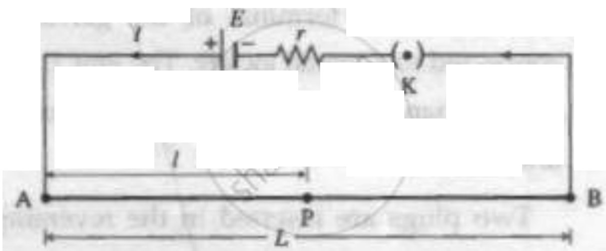
$C_V = (3 + f) R$ and $C_p = (4 + f) R$

$\therefore \gamma = \frac{C_p}{C_V} = \frac{4+f}{3+f}$

Q. 18 What is a potential gradient? How is it measured? Explain.

Ans. (A) The potential gradient is defined as the fall of potential per unit length of potentiometer wire. The gradient of potential energy is a force (measured in newtons).

Consider a potentiometer consisting of a long uniform wire AB of length L and resistance R, stretched on a wooden board and connected in series with a cell of stable emf E and internal resistance rand a plug key K as shown in the following figure.



Let I be the current flowing through the wire when the circuit is closed.

Current through AB, $I = \frac{E}{R + r}$

Potential difference across AB. $V_{AB} = IR$

$$\therefore V_{AB} = \frac{ER}{R + r}$$

The potential difference (the fall of potential from the high potential end) per unit length of the wire,

$$\frac{V_{AB}}{L} = \frac{ER}{(R + r)L}$$

As long as E and r remain constant, $\frac{V_{AB}}{L}$ will remain constant. $\frac{V_{AB}}{L}$ is known as a potential

is denoted by K. Thus the potential gradient is calculated by measuring the potential difference between ends of the potentiometer wire and dividing it by the length of the wire.

Let P be any point on the wire between A and B and AP= l =length of the wire between A and P.

Then $V_{AP} = Kl$

$\therefore V_{AP} \propto l$ as K is constant in a particular case. Thus, the potential difference across any length of the potentiometer wire is directly proportional to that length. This is the principle of the potentiometer.

Ans. (B)

i. Potential gradient (K) is defined as a potential difference per unit length of wire.

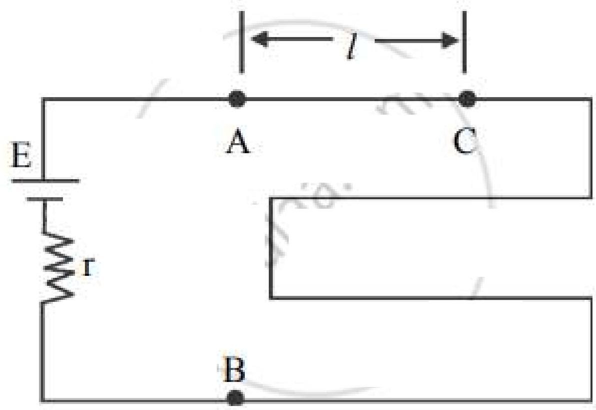
ii. It is measured as, $\frac{V}{L} = \frac{ER}{L(R+r)}$

where V = Potential difference between two points
L = Length (distance) between two points

Explanation:

a. A potentiometer consists of a long wire AB of length L and resistance R having uniform cross-sectional area A.

b. A cell of emf E having internal resistance r is connected across AB as shown in the figure.



c. When the circuit is switched on, the current I pass through the wire. Current through AB, $I = \frac{E}{R+r}$ ....(1)

d. Potential difference across AB,

$V_{AB} = IR$

$V_{AB} = \frac{ER}{(R+r)}$ ....[From equation (1)]

e. Therefore, the potential difference per unit length of the wire is,

$$\frac{V_{AB}}{L} = \frac{ER}{L(R+r)}$$

As long as E remains constant, $\frac{V_{AB}}{L}$ will remain constant.

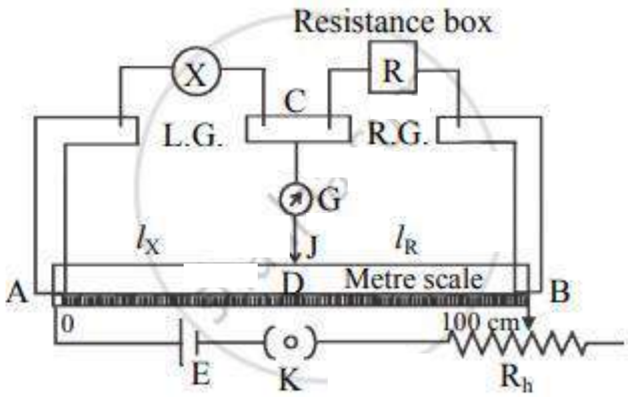
f. $\frac{V_{AB}}{L}$ is known as a potential gradient along with AB and is denoted by K.

The potential gradient can be defined as a potential difference per unit length of wire.

Q. 19 Explain with a neat circuit diagram. How you will determine the unknown resistances using a meter bridge.

Ans. Construction:

i. Metrebridge consists of a one-metre long wire of uniform cross-section, stretched on a metre scale which is fixed on a wooden table.
ii. The ends of the wire are fixed below two L shaped metallic strips. A single metallic stripe separates the two L-shaped strips leaving two gaps, left gap and right gap.
iii. iii. Usually, an unknown resistance X is connected in the left gap and a resistance box is connected in the other gap.
iv. One terminal of a galvanometer is connected to point C on the central strip, while the other terminal of the galvanometer carries the jockey (J). Temporary contact with the wire AB can be established with the help of the jockey.
v. A cell of emf E along with a key and a rheostat is connected between points A and B.



Working:

i. A suitable resistance R is selected from the resistance box.
ii. The jockey is brought in contact with AB at various points on the wire AB and the balance point (null point), D is obtained. The galvanometer shows no deflection when the jockey is at the balance point (point D).
iii. Let the respective lengths of the wire between A and D, and that between D and C be l_X and l_R.
iv. Then using the balancing conditions,

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

i. where R_{AD} and R_{DB} are a resistance of the parts AD and DB of the wire respectively.

ii. If l is the length of the wire, ρ is its specific resistance, and A is its area of cross-section then

$$R_{AD} = \frac{\rho l_x}{A} \quad ....(2)$$

$$R_{DB} = \frac{\rho l_R}{A} \quad ....(3)$$

From equations (1), (2) and (3),

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

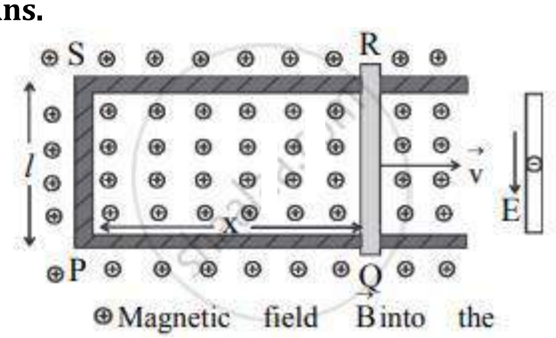
$$\therefore \frac{X}{R} = \frac{l_x}{l_R}$$

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

Thus, knowing R, l_x and l_R, the value of the unknown resistance can be determined.

Q. 20 Determine the motional emf induced in a straight conductor moving in a uniform magnetic field with constant velocity on the basis of Lorentz force.

Ans.



A frame of wire PQRS in the magnetic field $\vec{B}$ and wire BC is moving with velocity $\vec{v}$ along the x-axis

i. Consider a rectangular frame of wires PQRS of area (lx) situated in a constant magnetic field $\left(\vec{B}\right)$.

ii. As the wire QR of length l is moved out with velocity $\vec{v}$ to increase x, the area of the loop PQRS increases. Thus the flux of $\vec{B}$ through the loop increases with time.

iii. According to the flux rule, the induced emf will be equal to the rate at which the magnetic flux through a conducting circuit changes.

iv. The induced emf will cause a current in the loop. It is assumed that there is enough resistance in the wire so that the induced currents are very small producing a negligible magnetic field.

v. As the flux ϕ through the frame PQRS is Blx, the magnitude of the induced emf can be written as

$|e| = \frac{d\phi}{dt} = \frac{d}{dt}(Blx) = Bl\frac{dx}{dt} = Blv$ ....(1)

where v is the velocity of wire QR increasing the length x of wires PQ and SR.

vi. Now, a charge q which is carried along by the moving wire QR, experiences Lorentz force $\vec{F} = q(\vec{v} \times \vec{B})$; which is perpendicular to both $\vec{v}$ and $\vec{B}$ and hence is parallel to wire QR.

vii. The force $\vec{F}$ is constant along the length l of the wire QR (as v and B are constant) and zero elsewhere ($\because$ v = 0 for stationary part RSPQ of wireframe).

viii. When the charge q moves a distance l along the wire, the work done by the Lorentz force is W = F.l = qvBsinθ.l

where θ = angle between $\vec{B}$ and $\vec{v}$.

ix. The emf generated is, $e = \frac{\text{Work}}{\text{charge}} = \frac{W}{q} = qvB\sin\theta.l$

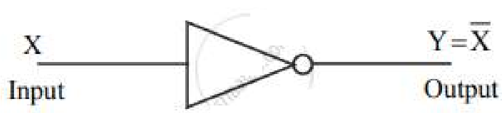
i. For maximum induced emf, sinθ = 1
$e_{max} = Blv$ ....(2)

ii. Thus, from equations (1) and (2), for any circuit whose parts move in a fixed magnetic field, the induced emf is the time derivative of flux (ϕ) regardless of the shape of the circuit.

Q. 21 What is a logic gate? Draw the symbol and give the truth table for NOT gate. Why NOT the gate is called an inverter?

Ans. Logic gate: A digital circuit with one or more input signals but only one output signal is called a logic gate. It is a switching circuit that follows a certain logical relationship between the input and output voltages.

Schematic symbol:



NOT gate symbol

The truth table for NOT gate:

Input	Output
X	Y
0	1
1	0

Reason:

i. NOT gate has one input and one output.
ii. It produces a 'high' output or output '1' if the input is '0'. When the input is 'high' or '1', its output is 'low' or '0'.
iii. That is, it produces a negated version of the input at its output.
Hence, NOT gate is called an inverter.

Q. 22 The magnetic field at the centre of a circular loop of radius 12.3 cm is 6.4 x 10^{-6} T. What will be the magnetic moment of the loop?

Ans. Given:

B = 6.4 × 10^{-6} T,

R = 12.3 cm

= 12.3 × 10^{-2} m

To find: Magnetic moment (m)

Formula:

$$B = \frac{\mu_0 I R^2}{2\left(z^2 + R^2\right)^{\frac{3}{2}}}$$

Calculation:

From formula,

$$B = \frac{\mu_0 I \pi R^2}{2\pi\left(z^2 + R^2\right)^{\frac{3}{2}}}$$

$$= \frac{\mu_0 m}{2\pi\left(z^2 + R^2\right)^{\frac{3}{2}}} \quad ....[\because m = I(\pi R^2)]$$

$$B = \frac{\mu_0 m}{2\pi R^3} \quad ....(\because z = 0)$$

$$\therefore m = \frac{B \times 2\pi R^3}{\mu_0}$$

$$= \frac{6.4 \times 10^{-6} \times 2 \times \pi \times \left(12.3 \times 10^{-2}\right)^3}{4\pi \times 10^{-7}}$$

$$= 3.2 \times 10^{-6+7-6} \times (12.3)^3$$

$$= \{\text{antilog } (\log 3.2 + 3 \log 12.3)\} \times 10^{-5}$$

$$= \{\text{antilog } (0.5051 + 3.2697)\} \times 10^{-5}$$

$$= \{\text{antilog } (3.7748)\} \times 10^{-5}$$

= 5.954 × 10^{-2} Am^2

The magnetic moment of the loop is **5.954 × 10^{-2} Am^2.**

Q. 23 A plane of a coil of 10 turns is tightly wound around a solenoid of diameter 2 cm having 400 turns per centimeter. The relative permeability of the core is 800. Calculate the inductance of the solenoid.

Ans. Given:

N = 10, d = 2 cm = 0.02 m

N = 400 turns/cm = 4 × 10^4 turns/m

μ_r = 800

To find: Inductance of solenoid (L)

Formulae:

i. $\mu = \mu_r \mu_0$

ii. $N = nl$

iii. $L = \mu n^2 l \left(\frac{\pi d^2}{4}\right)$

Calculation:

From formula (i), (ii) and (iii),

$$L = \mu_r \mu_0 n N \left(\frac{\pi d^2}{4}\right)$$

$$= \frac{800 \times 4\pi \times 10^{-7} \times 4 \times 10^4 \times 10 \times \pi \times 0.02^2}{4}$$

= 0.1264 H

The inductance of the solenoid is 0.1264 H.

Q. 24 What is the capacitive reactance of a capacitor of 5μF at a frequency of (1) 50 Hz and (2) 20KHZ?

Ans. Given:

$C = 5\ \mu F = 5 \times 10^{-6}$ F
$f_1 = 50$ Hz, $f_2 = 20$ kHz

To find:

i. Capacitive reactance at 50 Hz ($X_{C\,1}$)

ii. Capacitive reactance at 20 kHz ($X_{C\,2}$)

Formula: $X_C = \frac{1}{2\pi f C}$

Calculation:

i. From formula,

$$X_{C\,1} = \frac{1}{2\pi f_1 C}$$

$$= \frac{1}{2 \times 3.142 \times 50 \times 5 \times 10^{-6}}$$

= 636.94 Ω

ii. From formula,

$$X_{C2} = \frac{1}{2\pi f_2 C}$$

$$= \frac{1}{2 \times 3.142 \times 20 \times 10^3 \times 5 \times 10^{-6}}$$

= 1.59 Ω

i. **When the frequency is 50 Hz, the capacitive reactance is 636.94 Ω.**
ii. **When the frequency is 20 kHz, the capacitive reactance is 1.59 Ω.**

Q. 24 What is the capacitive reactance of a capacitor of 5μF at a frequency of (1) 50 Hz and (2) 20KHZ?

Ans. Given:

$C = 5\ \mu F = 5 \times 10^{-6}$ F
$f_1 = 50$ Hz, $f_2 = 20$ kHz

To find:

i. Capacitive reactance at 50 Hz (X_{C1})

ii. Capacitive reactance at 20 kHz (X_{C2})

Formula: $X_C = \frac{1}{2\pi f C}$

Calculation:

i. From formula,

$$X_{C1} = \frac{1}{2\pi f_1 C}$$

$$= \frac{1}{2 \times 3.142 \times 50 \times 5 \times 10^{-6}}$$

= 636.94 Ω

ii. From formula,

$$X_{C2} = \frac{1}{2\pi f_2 C}$$

$$= \frac{1}{2 \times 3.142 \times 20 \times 10^3 \times 5 \times 10^{-6}}$$

i. **= 1.59 Ω**
i. **When the frequency is 50 Hz, the capacitive reactance is 636.94 Ω.**

ii. **When the frequency is 20 kHz, the capacitive reactance is 1.59 Ω.**

Q. 25 The energy of a photon is 2 eV. Find its frequency and wavelength.

Ans. Given:

$E = 2 \text{ eV} = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}$ J

To find:

i. Frequency (ν)
ii. Wavelength (λ)

Formulae:

i. $E = h\nu$

ii. $\lambda = \frac{c}{\nu}$

Calculation:

Using formula (i),

$$\nu = \frac{3.2 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$= \frac{3.2 \times 10^{15}}{6.63}$$

$= \text{antilog}\ \{\log(3.2) + \log(10^{15}) - \log(6.63)\}$

$= \text{antilog}\ \{0.5051 + 15 - 0.8215\}$

$= \text{antilog}\ \{14.6836\}$

$= 4.826 \times 10^{14}$ Hz

Using formula (ii),

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{4.826 \times 10^{14}}$$

$= \text{antilog}\ \{\log 3 - \log 4.826\} \times 10^{-6}$

$= \text{antilog}\ \{0.4771 - 0.6836\} \times 10^{-6}$

$= \text{antilog}\ \{\bar{1}.7935\} \times 10^{-6}$

$= 0.6216 \times 10^{-6} \text{m}$

$= 6216 \times 10^{-10}\ \text{m}$

= 6216 Å

= 6216 Å

i. **The frequency of photons is 4.826×10^{14} Hz.**
ii. **The wavelength of the photon is 6216 Å.**

Q. 26 A radioactive substance decays to $(1/10)^{th}$ of its original value in 56 days. Calculate its decay constant.

Ans.

Here, $\frac{N(t)}{N} = \frac{1}{10}$ and t = 56 days

We have, $\frac{N(t)}{N_0} = e^{-\lambda t}$

$$\therefore \frac{1}{10} = e^{-\lambda t}$$

$$\therefore e^{\lambda t} = 10$$

$$\therefore \lambda t = \log_e 10$$

$$\therefore \lambda = \frac{\log_e 10}{t}$$

$= \frac{2.303 \times \log 10}{56}$

$= \frac{2.303}{56}$

= antilog {log(2.303) − log (56)}

= antilog {0.3623 − 1.7481}

= antilog {$\bar{2}$ .6142}

= 4.113×10^{-2} per day

The decay constant is 4.113×10^{-2} per day.

Q. 27 | Attempt Any Three:
What is a conical pendulum? Obtain an expression for its time period

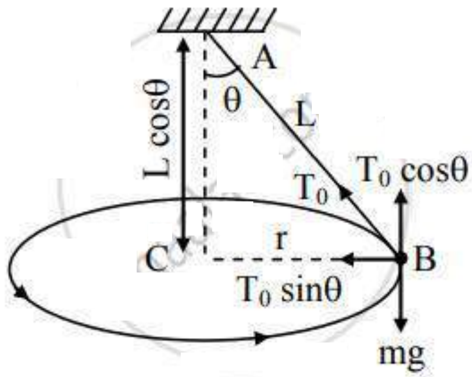
Ans. A tiny mass (assumed to be a point object and called a bob) connected to a long, flexible, massless, inextensible string, and suspended to rigid support revolves in such a way that the string moves along the surface of a right circular cone of the vertical axis and the point object performs a uniform horizontal circular motion. Such a system is called a **conical pendulum**.

Expression for its time period:

i. Consider the vertical section of a conical pendulum having bob (point mass) of mass m and string of length 'L'.
Here, θ is the angle made by the string with the vertical, at any position (semi-vertical angle of the cone)

ii. In a given position B, the forces acting on the bob are
a. its weight 'mg' directed vertically downwards

iii. b. the force 'T_0' due to the tension in the string, directed along the string, towards the support A.



In an inertial frame

iv. As the motion of the bob is a horizontal circular motion, the resultant force must be horizontal and directed towards the centre C of the circular motion.
For this, tension (T_0) in the string is resolved into
a. $T_0 \cos\theta$: vertical component
b. $T_0 \sin\theta$: horizontal component

v. The vertical component ($T_0 \cos\theta$) balances the weight 'mg'.
$\therefore mg = T_0 \cos\theta$ ....(1)

The horizontal component $T_0 \sin\theta$ then becomes the resultant force which is centripetal.
$mr\omega^2 = T_0 \sin\theta$ ....(2)
Dividing equation (2) by equation (1),

$$\omega^2 = \frac{g \sin\theta}{r \cos\theta} \quad ....(3)$$

v. From the figure,

$$\sin\theta = \frac{r}{L}$$

$\therefore r = L \sin\theta$ ....(4)

From equation (3) and (4),

$$\omega^2 = \frac{g \sin\theta}{L.\sin\theta.\cos\theta}$$

$$\omega = \sqrt{\frac{g}{L \cos\theta}}$$

vi. If T is the period of revolution of the bob, then

$$\omega = \frac{2\pi}{T} = \sqrt{\frac{g}{L \cos\theta}}$$

$$\therefore \text{Period, } T = 2\pi\sqrt{\frac{L \cos\theta}{g}}$$

Q. 28 Explain the thermodynamics of the isobaric process.

Ans.

i. A thermodynamic process that is carried out at constant pressure i.e., $\Delta p = 0$ is called the isobaric process.
ii. For an isobaric process, none of the quantities ΔU, Q, and W is zero.
iii. The temperature of the system changes, i.e., $\Delta T \neq 0$.
iv. The energy exchanged is used to do work as well as to change internal energy causing an increase in temperature. Thus, $Q = \Delta U + W$.
v. As work is done volume changes during the process.
vi. Heat exchanged in case of an isobaric process:
a. Consider an ideal gas undergoing volume expansion at constant pressure.
b. If V_i and T_i are its volume and temperature in the initial state of a system and V_f and T_f are its final volume and temperature respectively, the work done in the expansion is given by,

vii. $W = pdV = p(V_f - V_i) = nR(T_f - T_i)$ ....(1)

c. Also, the change in the internal energy of a system is given by, $\Delta U = nC_V\Delta T = nC_V(T_f - T_i)$ ....(2)

Where, C_V is the specific heat at constant volume, and $\Delta T = (T_f - T_i)$ is the change in its temperature during the isobaric process.

d. According to the first law of thermodynamics, the heat exchanged is given by, $Q = \Delta U + W$

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

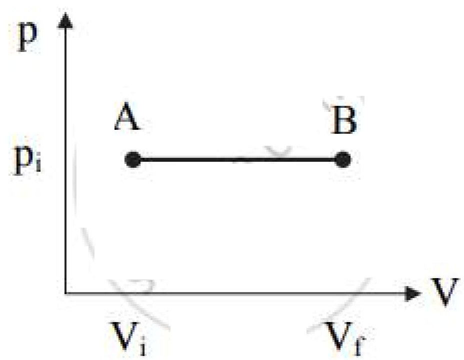
$Q = nC_V(T_f - T_i) + nR(T_f - T_i)$

$\therefore Q = (nC_V + nR)(T_f - T_i)$

$\therefore Q = nC_p(T_f - T_i)$ ....($\because C_p = C_V + R$)

Where, C_p is the specific heat at constant pressure.

viii. The p-V diagram for an isobaric process is called isobar. It is shown in the figure below.



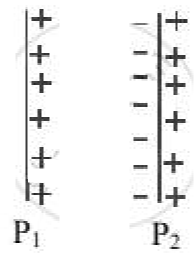
Q. 29

29.i Explain the principle of a capacitor.

Ans. Consider a metal plate P_1 having area A with some positive charge +Q be given to the plate. Let its potential be V.

Its capacity is given by, $C_1 = \frac{Q}{V}$

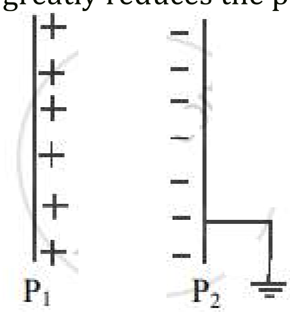
Now consider another insulated metal plate P_2 held near plate P_1. By induction, a negative charge is produced on the nearer face and an equal positive charge develops on the farther face of P_2 as shown in figure (a) below.

i. 

(a)

ii. The induced negative charge lowers the potential of plate P_1, while the induced positive charge raises its potential.

iii. As the induced negative charge is closer to P_1 it is more effective, and thus there is a net reduction in the potential of plate P_1. If the outer surface of P_2 is connected to the earth, the induced positive charges on P_2 being free, flows to earth. The induced negative charge on P_2 stays on it, as it is bound to the positive charge of P_1. This greatly reduces the potential of P_2 as shown in figure (b) below.



(b)

iv. If V_1 is the potential on plate P_2 due to charge (−Q) then the net potential of the system will now be $+V - V_1$.

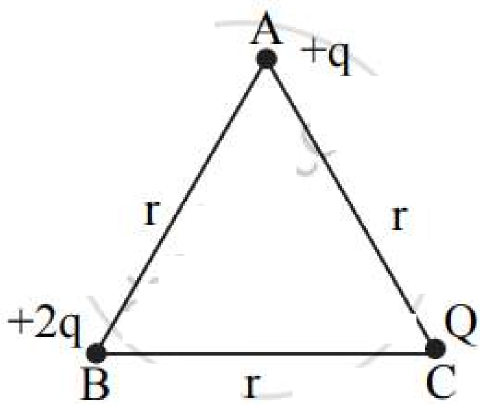
$$\text{Hence the capacity } C_2 = \frac{Q}{V - V_1}$$

$$\therefore C_2 > C_1$$

v. Thus, the capacity of metal plate P_1 is increased by placing an identical earth-connected metal plate P_2 near it.

29.ii Three-point charges +q, +2q and Q are placed at the three vertices of an equilateral triangle. Find the value of charge Q (in terms of q), so that the electric potential energy of the system is zero.

Ans.



Let ‘r’ be the side of the equilateral triangle,

$$(U)_{AB} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q.2q}{r}$$

$$(U)_{BC} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q.Q}{r}$$

$$(U)_{AC} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q.Q}{r}$$

Since the electric potential energy of the system is zero.

$$\therefore (U)_{AB} + (U)_{BC} + (U)_{AC} = 0$$

$$\therefore \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q^2}{r} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{2qQ}{r} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{r} = 0$$

$$\therefore 2q^2 + 2qQ + qQ = 0$$

$\therefore (U)_{AB} + (U)_{BC} + (U)_{AC} = 0$

$$\therefore \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q^2}{r} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{2qQ}{r} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{r} = 0$$

$\therefore 2q^2 + 2qQ + qQ = 0$

$\therefore 3qQ = -2q^2$

$\therefore Q = \frac{-2q}{3}$

$\therefore$ The value of charge Q (in terms of q) is $\frac{-2q}{3}$.

Q. 30

30.i A solenoid has a core of material with relative permeability 500 and its windings carry a current of 1 A. The number of turns of the solenoid is 500 per meter. Calculate the magnetization of the material.

Ans. Given: $\mu_r = 500$, I = 1 A, n = 500

To find: Magnetization (M)

Formula: $M = (\mu_r - 1)nI$

Calculation:

From formula,

M = (500 - 1) × 500 × 1

= 2.495 × 10^5 Am^{-1}

The magnetization of the material is 2.495 × 10^5 Am^{-1}.

30.ii A solenoid of length π m and 5 cm in diameter has a winding of 1000 turns and carries a current of 5 A. Calculate the magnetic field at its centre along the radius.

Ans. Given:

l = π m, diameter = 5 cm,
N = 1000 turns, i = 5 A
We know that, $\mu_0 = 4\pi \times 10^{-7}$ Tm/A

To find: Magnetic field (B)

Formulae:

i. $n = \frac{N}{l}$

ii. $B = \mu_0 n i$

Calculation:

From formula (i),

$n = \frac{1000}{\pi} \frac{\text{turns}}{\text{m}}$

From formula (ii),

$B = 4\pi \times 10^{-7} \times \frac{1000}{\pi} \times 5$

$= 20 \times 10^{-7+3}$

$= 2 \times 10^{-3}$ T

The magnetic field is 2×10^{-3} T.

Q. 31

Q. 31.i State any two characteristics of a series LCR AC resonance circuit.

Ans.

i. Resonance occurs when $X_L = X_C$.

ii. Resonant frequency $f_r = \frac{1}{2\pi\sqrt{LC}}$

i. Impedance is minimum and the circuit is purely resistive.
ii. Current has a maximum value.
iii. When a number of frequencies are fed to it, it accepts only one frequency (f_r) and rejects the other frequencies. The current is maximum for this frequency. Hence it is called the acceptor circuit.

31.ii A magnet of magnetic moment 3Am^2 weighs 75 g. The density of the material of the magnet is 7500 kg/m^3. what is magnetization?

Ans. Given:

$m_{net} = 3$ Am^2
mass = 75 g = 75×10^{-3} kg
Density, d = 7500 kg/m^3

To find: Magnetization (M)

Formulae:

i. $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

ii. $M = \frac{m_{net}}{V}$

Calculation:

From formula (i) and (ii),

$$M = m_{net} \times \frac{\text{density}}{\text{mass}}$$

$$= 3 \times \frac{7500}{75 \times 10^{-3}}$$

$= 3 \times 10^5$ A/m

The magnetization is 3×10^5 A/m.