XIIth 2023-24

Date : 06/11/2023

Physics Theory Round-02

Max.Marks :- 35

Time 90 Mins.

General Instructions : The question paper is divided into four sections.

(1) Section A : Q.No.1 contains Five Multiple choice type of question carrying **One** mark each.
Q.No.2 contains Five very short answer type of questions carrying **One** mark each.

(2) Section B : Q.No.3 to Q.9 are short answer type of question carrying **Two** marks each.

(3) Section C : Q.No.10 to Q. No.14 are short answer type of questions carrying **Three** marks each

(4) Section D: Q.No.15 to Q.No.18 are long answer type of questions carrying **Four** marks each.

(5) Figures to the right indicate full marks

MODEL ANSWER KEY

Section -A [05]

Q.1 Select and write the correct answer.

(i) A liquid rises in glass capillary tube upto a height of 2.5 cm at room temperature. If another glass capillary tube having radius half that of the earlier tube is immersed in the same liquid, the rise of liquid in it will be :

(a) 1.25 cm (b) 2.5 cm

(c) 5 cm (d) 10 cm

(ii) The angle at which maximum torque is exerted by the external uniform electric field on the electric dipole is ....

(a) 0° (b) 30°

(c) 45° **(d) 90°**

(iii) Which one of the following is not a characteristics of SHM?

(a) Its acceleration is maximum in the extreme position.

(b) It is the projection of a uniform circular motion on a diameter.

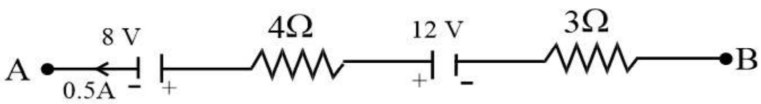
(c) Its velocity is maximum at the mean position.

(d) Its velocity time graph is a straight line.

(iv) The figure shows part of an electric circuit. The potential difference $V_A - V_B$ is .....

(a) 9.0 V **(b) 7.5 V**

(c) 6.0 V (d) 4.5 V



(v) Which of the following statement is correct for diamagnetic materials?

(a) Susceptibility is negative and law.

(b) Susceptibility is does not depend on temperature.

(c) $\mu_r < 1$

(d) All of above.

Q.2. Answer the following questions. **[05]**

(i) What is the value of resistance for an ideal voltmeter?

Ans : The value of resistance for an ideal voltmeter is infinite (i.e. $r = \infty$)

(ii) What is the value of force on a closed circuit in a magnetic field?

Ans : The value of force on a closed circuit in a magnetic is zero.

(iii) Calculate the velocity of particle performing S.H.M. after 1 second, if its displacement is given by

$$x = 5 \sin\left(\frac{\pi t}{3}\right) m.$$

Ans : Given : Displacement of particle

$$x = 5\sin\left(\frac{\pi t}{3}\right) m; \text{ time } t = 1 \text{ sec.}$$

To find : Velocity $v = ?$

$$v = \frac{dx}{dt} = 5\cos\left(\frac{\pi t}{3}\right) \times \frac{d}{dt}\left(\frac{\pi t}{3}\right)$$

$$= 5\cos\left(\frac{\pi t}{3}\right) \times \frac{\pi}{3}$$

Putting t = 1

$$v = \frac{5\pi}{3}\cos\left(\frac{\pi}{3}\right) = \frac{5\pi}{3} \times \frac{1}{2}$$

$$= \frac{5\pi}{6} \qquad = \frac{5 \times 3.14}{6} = 2.618 \text{ m/s}$$

(iv) State the formula for critical velocity in terms of Reynold's number for a flow of liquid.

Ans : Critical velocity of the fluid is,

$$v_c = \frac{R_n \eta}{\rho d} \text{ where,}$$

d = Diameter of tube

R_n = Reynold's number

η = Coefficient of viscosity

ρ = Density of fluid

(v) State the formula for magnetic potential energy.

Ans : Magnetic potential energy,

$U_m = -mB \cos\theta$

where, m is magnetic moment

B is magnetic field

Section -B : Attempt any 4 (Q.3 to 9) [08]

Answer the following questions :

Q.3. Define coefficient of viscosity. State its formula and S.I. units.

Ans : Coefficient of viscosity (η) : The coefficient of viscosity is defined as the viscous force per unit area per unit velocity gradient.

$$\eta = \frac{F}{A\left(\frac{dv}{dx}\right)}$$

where, F $\rightarrow$ Viscous force

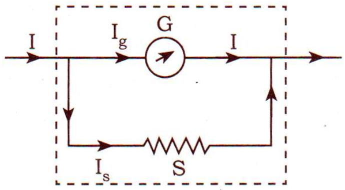
A $\rightarrow$ Area of the layer parallel to the direction of the flow.

$\frac{dv}{dx}$ $\rightarrow$ Velocity gradient.

SI unit : SI unit of η is Ns/m^2.

Q.4. How will you convert a moving coil galvanometer into an ammeter?

Ans :



A galvanometer is used to measure current but its range is limited. To increase its range we have to convert it into ammeter.

By connecting low value resistance in parallel with galvanometer, we can convert it into an ammeter,

Let,

G be the resistance of galvanometer,

S be the low value resistance (shunt),

I_g be the current flowing through galvanometer

I_s be the current flowing through shunt.

I be the total current.

$\therefore$ $I = I_g = I_n$ ....(i)

Since S and G are parallel, the potential difference (P.D.) across them is same.

$\therefore$ $I_g.\ G = I_S.S$

From equation (i), $I_s = I - I_g$

$\therefore$ $I_g.G = (I - I_g)\ .\ S$

$$\therefore \quad S = \frac{I_g}{(I - I_g)}.G$$

Thus, by connecting a small resistance or shunt resistance parallel to the galvanometer it can be converted into an ammeter.

Q.5. A bar magnet of mass 120 gm in the form rectangular parallelopiped, has dimensions $l = 40$ mm, $b = 10mm$ and $h = 80\ mm$, with its dimensions 'h' vertical, the magnet performs angular oscillations in the plane of the magnetic field with period π seconds. If the magnetic moment is 3.4 Am^2 determine the influencing magnetic field.

Ans : Given :

Mass $(m) = 120$ g $= 120 \times 10^{-3}$ kg

Length $(l) = 40$ mm $= 40 \times 10^{-3}$ m

Breadth $(b) = 10$ mm $= 10 \times 10^{-3}$ m

Height $(h) = 80$ mm $= 80 \times 10^{-3}$ m

Period (T) = π sec

Magnetic momentum (μ) = 3.4 Am^2

To find : Magnetic field (B) = ?

$$B = \frac{4m}{\mu}\left(\frac{l^2+b^2}{12}\right)$$

$$= \frac{4\times120\times10^{-3}}{3.4}\left(\frac{1600+100}{12}\right)\times10^{-6}$$

$$= \frac{48}{3.4}\left(\frac{1700}{12}\right)\times10^{-8}$$

$$= \frac{4}{3.4}\times17\times10^{-6}$$

$$= \frac{4}{3.4}\times17\times10^{-5}$$

$\therefore$ B = 2 × 10^{-5} Wb/m^2.

Q.6. Distinguish between potentiometer and voltmeter.

NO.	Potentiometer	No.	Voltmeter
(i)	A potentiometer is used to determine the emf of a cell, potential difference and internal resistance	(i)	A voltmeter can be used to measure the potential difference and thermal voltage of a cell. But it can not be used to measure the emf of a cell.
(ii)	Its accuracy and sensitivity are very high	(ii)	Its accuracy and sensitivity are less as compared to a potentiometer.
(iii)	It is not a portable instrument.	(iii)	It is a portable instrument.
(iv)	It does not give a direct reading.	(iv)	It gives a direct reading.

Q.7. An electron in an atom is revolving round the nucleus in a circular orbit of radius 5.3 × 10^{-11} m with a speed of 3 × 10^6 m/s. Find the angular momentum of electron.

Ans : m = 9.1 × 10^{-31} kg, v = 3 × 10^6 m/s

r = 5.3 × 10^{-11} m, L = ?

$\because$ L = mvr

$\therefore$ L = 9.1 × 10^{-31} × 3 × 10^6 × 5.3 × 10^{-11}

= 144.7 × 10^{-36}

= 1.447 × 10^{-34} kg m^2/s

Q.8. The wires which connect the battery of an automobile to its starting motor carry a current of 300 A (For a short time). What is the force per unit length between the wires if they are 70 cm long and 1.5 cm apart?

Ans : $I_1 = I_2$ = 300 A

$l_1 = l_2$ = L = 70 cm = 0.7 m

d = 1.5 cm = 1.5 × 10^{-2} m

Since $d << l_1$ and l_2, each wire may be considered to have infinite length.

Force per unit length = $\frac{F}{L}$ = ?

$$\frac{F}{L} = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2}{d}$$

$$\therefore \frac{F}{L} = \frac{4\pi \times 10^{-7} \times 300 \times 300}{2\pi \times 1.5 \times 10^{-2}}$$

$$= 1.2 \times 10^5 \times 10^{-5}$$

$\therefore$ The force per unit length is 1.2 N/m

Q.9. State and explain Newton's law of viscosity.

Ans : Statement : For streamline flow, the viscous force acting on any layer is directly proportional to the area (A) and the velocity gradient $\left(\frac{dv}{dx}\right)$.

Explanation :

Let A be the area of layer. $\frac{dv}{dx}$ be the velocity gradient.

F be the viscous force.

$\therefore$ By Newton's law of viscosity,

$$F \propto A\left(\frac{dv}{dx}\right)$$

$$F = \eta A \frac{dv}{dx}$$

where η is constant called coefficient of viscosity of the liquid.

$$\therefore \eta = \frac{F}{A\left(\frac{dv}{dx}\right)}$$

$$\eta = F, \text{ if } A = 1 \text{ m}^2 \text{ and } \frac{dv}{dx} = 1 \text{ ms}^{-1}$$

Section -C : Attempt any 3 (Q.10 to 14) [09]

Q.10. (a) Define and state unit and dimensions of magnetization.

(b) Explain magnetic susceptibility.

Ans : (a) Magnetization : The ratio of magnetic moment to the volume of the material is called magnetization (M_z)

$$= \frac{\text{Dimension of Magnetic moment}}{\text{Dimension of Volume}}$$

$$= \frac{[L^2 I^1]}{[L^3]} = [M^0 L^{-1} T^0 I^1]$$

(b) Magnetic susceptibility : the ratio of magnitude of intensity of magnetization to that of magnetic intensity is called as magnetic susceptibility.

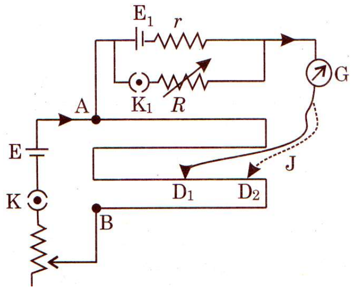
$\therefore$ Magnetic susceptibility (χ)

$$= \frac{\text{Intensity of magnetization}}{\text{Magnetic intensity}} = \frac{M_z}{H}$$

It is a measure of magnetic behaviour of the material in the external applied magnetic field. Since it is the ratio of two quantities with same unit ($A\,m^{-1}$), it is a dimensionless quantity.

Q.11. Explain the use of potentiometer to determine internal resistance of the cell.

Ans :



The experimental circuit diagram to determine the internal resistance of a cell by using potentiometer is as shown in the figure.

Take cell (E_1) whose internal resistance is to be determined and is connected as shown in the figure.

Initially, close key K and open key K_1 and find out null point (D_1) such that galvanometer shows zero deflection and measure balancing length AD_1.

Let $AD_1 = l_1$.

By Principle of potentiometer,

$E_1 = l_1$

$E_1 = (Constant)$ ....(i)

Now, close both keys K and K_1.

Remove suitable resistance from the resistance box again find null point (D_2) Measure length AD_2.

Measure length AD_2

Let $AD_2 = l_2$

By principle of potentiometer,

$V \propto l_2$

$V = (constant)\, l_2$ ...(ii)

Dividing equation (i) by (ii), we get

$$\frac{E_1}{V} = \frac{l_1}{l_2} \quad ...(iii)$$

By Ohm's law, V = IR and $E_1 = 1(R + r)$

$\therefore$ Equation (iii) becomes

$$\frac{I(R+r)}{IR} = \frac{l_1}{l_2}$$

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

$$\therefore 1 + \frac{r}{R} = \frac{l_1}{l_2}$$

$$\therefore \frac{r}{R} = \frac{l_1}{l_2} - 1$$

$$\therefore r = \left(\frac{l_1}{l_2} - 1\right) \quad ....(iv)$$

By using above equation (iv) we can determine the internal resistance (r) of the cell.

Q.12. State the differential equation of linear S.H.M. Hence, obtain expression for
(a) acceleration (b) velocity

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

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

where,

$\omega^2 = \frac{k}{m}$ is the angular frequency.

(a) Expression for acceleration :

From the differential equation, we can write $\frac{d^2x}{dt^2} = -\omega^2 x$

By definition of linear acceleration, $a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$

$\therefore a = -\omega^2 x$ .....(i)

Equation (i) gives acceleration in linear S.H.M.

(b) Expression for velocity :

From the differential equation, we can write

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

$$\therefore \quad \frac{d}{dt}\left(\frac{dx}{dt}\right) = -\omega^2 x$$

$$\therefore \quad \frac{dv}{dt} = -\omega^2 x \qquad \left(\text{As } v = \frac{dx}{dt}\right)$$

$$\therefore \quad \frac{dv}{dx}\cdot\frac{dx}{dt} = -\omega^2 x \qquad \therefore \quad \frac{dv}{dx}\cdot v = -\omega^2 x$$

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

$$v\,dv = -\omega^2 x\, dx \qquad \text{...(ii)}$$

Integrating equation (ii),

$$\int v\, dx = \int (-\omega^2 x)\, dx = -\omega^2 \int x\, dx$$

$$\frac{v^2}{2} = \frac{-\omega^2 x^2}{2} + c \qquad \text{...(iii)}$$

where c is the constant of integration.

At extreme position, $x = \pm A$ and $v = 0$

$\therefore$ Equation (iii) becomes

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

$$\therefore \quad v^2 = \omega^2 A^2 - \omega^2 x^2$$

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

$$\therefore \quad v = \pm\omega\sqrt{A^2 - x^2} \qquad \text{....(iv)}$$

This is equation for velocity in linear S.H.M.

Q.13. Calculate the current flowing through two long parallel wires carrying equal currents and separated by a distance of 1.35 cm experiencing a force per unit length of 4.76×10^{-2} N/m.

Ans : Given : $I_1 = I_2 = 1$

$$a = 1.35 \text{ cm} = 1.35 \times 10^{-2} \text{ m}$$

$$\frac{f}{l} = 4.76 \times 10^{-2} \text{ N/m}$$

To find : I = ?

Formula : $\frac{f}{l} = \frac{\mu_0 I_1 I_2}{2\pi a}$

But $I_1 = I_2 = I$

$$\therefore \quad \frac{f}{l} = \frac{\mu_0 I^2}{2\pi a}$$

$$\therefore \quad 4.76 \times 10^{-2} = \frac{4\pi \times 10^{-7} \times I^2}{2\pi \times 1.35 \times 10^{-2}}$$

$$\therefore \quad I^2 = \frac{4.67 \times 10^{-2} \times 1.35 \times 10^{-2}}{2 \times 10^{-7}}$$

$$\therefore \quad I^2 = \frac{2.38 \times 1.35 \times 10^{-4}}{10^{-7}}$$

$$\therefore \quad I^2 = 2.38 \times 1.35 \times 10^3$$

$$\therefore \quad I^2 = 32.13 \times 10^2$$

$$\therefore I^2 = 3213$$

$$\therefore \quad I = \sqrt{3213}$$

$$\therefore \quad I = 56.68 \text{ A}$$

Q.14. Derive an expression for terminal velocity of a spherical object falling under gravity through a viscous medium.

Ans : Consider a spherical object falling through a viscous fluid-forces experienced by it during its downward motion are -

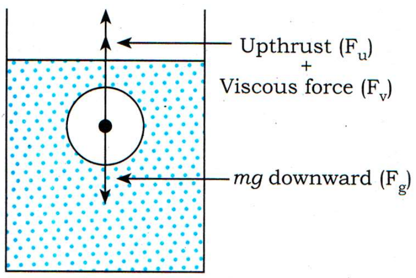
(i) Viscous force (F_v) directed upwards, its magnitude goes on increasing with increase in its velocity.

(ii) Gravitational force, or its weight (F_a) directed upwards.

(iii) Buoyant force or upthrust (F_u) directed upwards.

Net downward force given by

$F = F_g - (F_v - F_u)$ is responsible for initial increase in the velocity.



Forces acting on object moving through a viscous medium.

Let the radius of the sphere be r, its mass m and density ρ. Let the density of the medium be σ and its coefficient of viscosity be η.

When the sphere attains the terminal velocity, the total downward force acting on the sphere is balanced by the total upward force acting on the sphere.

Total downward force = Total upward force

$$\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v + \frac{4}{3}\pi r^3 \sigma g$$

$$6\pi\eta r v = \left(\frac{4}{3}\pi r^3 \rho g\right) - \left(\frac{4}{3}\pi r^3 \sigma g\right)$$

$$6\pi\eta r v = \left(\frac{4}{3}\right)\pi r^3 g(\rho - \sigma)$$

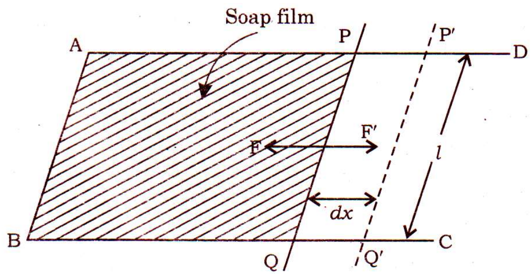
$$\therefore \quad v = \left(\frac{4}{3}\right)\pi r^3 g(\rho - \sigma) \times \frac{1}{6\pi\eta r}$$

$$\therefore \quad v = \frac{2}{9} \times \frac{r^2 g(\rho - \sigma)}{\eta}$$

Section -D : Attempt any 2 (Q.15 to 18) [08]

Q.15. Obtain the relation between surface energy and surface tension.
Calculate the work done in blowing a soap bubble to a radius of 1 cm. The surface tension of soap solution is 2.5×10^{-2} N/m.

Ans : Relation between surface tension and surface energy.



Consider a rectangular frame ABCD of wire fitted with a movable arm PQ as shown in figure.

The frame held in horizontal position is dipped into soap solution and taken out so that soap film ABQP is formed. Due to surface tension of soap solution, a force F will act on the arm of the frame. Due to this force, the arm PQ moves towards AB by a small distance dx.

By definition of surface tension.

$$T = \frac{F}{2l}$$

A factor 2 appears because soap film has two free surfaces in contact.

$\therefore$ F = T.2l

where l is length of wire PQ.

Now, the wire PQ displaces by distance dx.

The work done by force F' is

$\therefore \quad dw = F' \cdot dx$

$dw = 2T\, l dx$ [As F = F' $\therefore$ F' = 2T l]

$dw = T \times 2l \times dx$

$dw = T \times dA$

Where $dA = 2l\,dx$ = surface area

This work done in stretching the film is stored in the area dA in the form of potential energy (or surface energy)

$\therefore$ Surface energy = T × dA

Numerical :

Given : Radius $r = 1$ cm $= 1 \times 10^{-2}\ m$

Surface tension (T) $= 2 \times 10^{-2}$ N/m

To find : Work done, W = ?

$W = T(2dA)$

$= T \times 2\,(A_2 - A_1)$

$= T \times 2\,(4\pi r^2 - 0)$

$\therefore\ W = T \times 8\pi r^2$

$= 2.5 \times 10^{-2} \times 8 \times 3.142 \times (1 \times 10^{-2})^2$

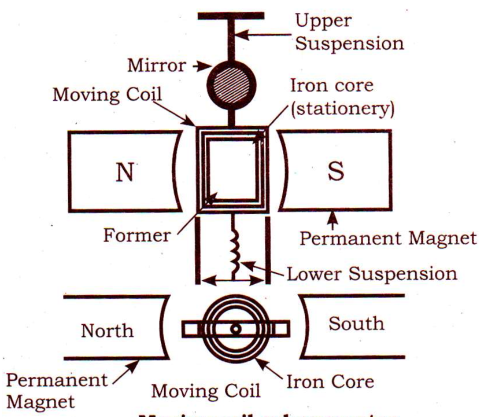
$= 2.5 \times 10^{-2} \times 25.136 \times 10^{-4}$

$\therefore\ W = 62.84 \times 10^{-6}$ J

Q.16. Draw a neat labelled diagram of suspended coil type moving coil galvanometer.

The initial pressure and volume of a gas enclosed in a cylinder are 2×10^5 N/m^2 and 6×10^{-3} m^3 respectively. If the work done in compressing the gas at constant pressure is 150 J. Find the final volume of the gas.

Ans :



Moving coil galvanometer

Numerical :

$P = 2 \times 10^5$ N/m^2, $V_i = 6 \times 10^{-3}$ m^3

$W = -150$ J (For compressing), $V_f = ?$

$W = P(V_f - V_i)$

$$\therefore\quad V_f = V_i + \frac{W}{P}$$

$$= 6\times10^{-3} + \left(\frac{-150}{2\times10^5}\right)$$

$$= 6\times10^{-3} - 75\times10^{-5}$$

$$= 6\times10^{-3} - 0.75\times10^{-3}$$

$$V_f = 5.25\times10^{-3}\ \text{m}^3$$

Q.17. Define seconds pendulum. Derive a formula for the lengths of second pendulum.
A particle performing linear S.H.M. has maximum velocity 25 cm/sec and maximum acceleration 100 cm/s^2. Find period of oscillations.

Ans : Second's pendulum : A simple pendulum whose time period is 2 seconds is called seconds pendulum.

We know, Period, T = $2\pi\sqrt{\frac{L}{g}}$

$\therefore$ For a seconds pendulum, 2 = $2\pi\sqrt{\frac{L_s}{g}}$

where L_S is the length of seconds pendulum having period T = 2 sec. $\therefore\ L_S = \frac{g}{\pi^2}$

Using this equation, we can find the length of a seconds pendulum at a place if we know the acceleration due to gravity at that place. Experimentally, if L_S is known, it can be used to determine acceleration due to gravity g at that place.

Numerical : $v_{max} = a\omega$

$a_{max} = a\omega^2$

$\therefore\ \omega = \frac{a_{max}}{v_{max}} = \frac{100}{25} = 4\text{rads}$ $\therefore\ T = \frac{2\pi}{\omega} = \frac{2\pi}{4} = \frac{\pi}{2} = 1.571\,\text{sec}$.

Q.18. An iron is subjected to a magnetising field of 1200 Am^{-1}. The susceptibility of iron is 599. Find the permeability and the magnetic field produced.
Draw the graph for variation of magnetic susceptibility (χ) of a material with temperature (T) and hence explain curie temperature.

Ans : Given : H = 1200 Am^{-1}, χ = 599

To find : μ = ? B = ?

Permeability, $\mu = \mu_0(1 + \chi)$

$= 4\pi \times 10^{-7} \times (1 + 599)$

$\mu = 7.536 \times 10^{-4}$ T mA^{-1}

Magnetic field, B = μH

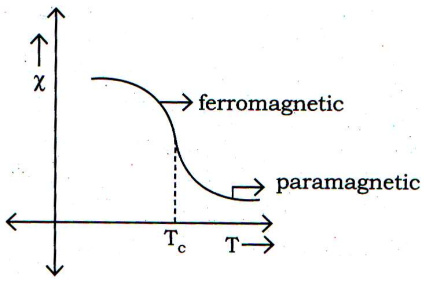
$= 7.536 \times 10^{-4} \times 1200$ $\therefore$ B = 0.904 T

Variation of magnetic susceptibility :

An increase in the temperature of a ferromagnetic material weakens the exchange coupling between neighbouring moments which results in the domain structure setting distorted. At a certain temperature, depending upon the material. The domain structure collapses totally and the material behaves like paramagnetic material. The temperature at which a ferromagnetic material behaves like paramagnetic material transforms into a paramagnetic substance is called Curie temperature (T_c) of that material. The relation between the magnetic susceptibility of a material when it has acquired paramagnetic property and the temperature T is given by

$\chi = \frac{C}{T - T_c}$ for $T > T_c$ .... (i)

Where C is a constant.



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