Physics
Model Set-1

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 Which of the following is correct, when the energy is transferred to a system from its environment?

1. System gains energy
2. System loses energy
3. System releases energy
4. the system does not exchange energy

1.ii For work done to be reversible, the process should be ______

1. cyclic
2. isobaric
3. isochoric
4. adiabatic

1.iii A particle is performing simple harmonic motion with amplitude A and angular velocity ω. the ratio of maximum velocity to maximum acceleration is _____

1. ω
2. I/ω
3. ω^2
4. A/ω

1.iv In the law of tension, the fundamental frequency of the vibrating string is, _____

1. inversely proportional to the square root of tension
2. directly proportional to the square of tension
3. directly proportional to the square root of tension
4. inversely proportional to the density

1.v The integral multiple of fundamental frequencies are _____

1. beats
2. resonance
3. overtones
4. harmonics

1.vi A LED emits visible white light when its _____

1. junction is reversed biased
2. depletion layer widens
3. holes and electrons recombine
4. junction becomes hot

1.vii Insect moves over the surface of water because of _____

1. Elasticity
2. Surface tension
3. Friction
4. Viscosity

1.viii Two capillary tubes of radii 0.6 cm and 0.3 cm are dipped in the same liquid. The ratio of heights through which the liquid will rise in the tubes is _____

1. 2:1
2. 1:2
3. 4:1
4. 1:4

1.ix Light of wavelength 5000 A.U. falls on a plane reflecting surface. The frequency of reflected light is _____

1. 6×10^{14}Hz
2. 5×10^{14}Hz
3. 2×10^{14}Hz
4. 1.666×10^{14}Hz

1.x You are given a number of capacitors labelled as 8μF - 250V. Find the number of capacitors needed to get an arrangement equivalent to 16μF - 1000V.

1. 4
2. 16
3. 32
4. 64

Q.2 | Answer the following:

2.i What are cohesive forces?

Ans. The force of attraction between the molecules of the same substance is called cohesive force.

2.ii Under which condition laws of Boyle, Charles, and Gay-Lussac are valid?

Ans. The laws of Boyle, Charles, and Gay-Lussac are strictly valid for real gases, only if the pressure of the gas is not too high and the temperature is not close to the liquefaction temperature of the gas.

2.iii When two objects are said to be in thermal equilibrium?

Ans. When two objects are at the same temperature, they are in thermal equilibrium.

2.iv A simple pendulum moves from one end to the other in ¼ second. What is its frequency?

Ans.

Time taken by simple pendulum to move from one end to the other is $\frac{T}{2}$ second.

Given: $\frac{T}{2} = \frac{1}{4}$ second

$\therefore$ T = $\frac{1}{2}$ second

$\therefore$ Frequency, n = $\frac{1}{T} = 2$ Hz

2.v What is the basis of Kirchhoff's current law and voltage law?

Ans.

i. Kirchhoff's current law is based on the law of conservation of charge.
ii. Kirchhoff's voltage law is based on the law of conservation of energy.

2.vi What does the ratio of magnetization to magnetic intensity indicate?

Ans. The ratio of magnetization to magnetic intensity indicates magnetic susceptibility (χ).

2.vii A square metal plate of area 100 cm^2 moves parallel to another plate with a velocity of 10 cm/s, both plates immersed in water. If the viscous force is 200 dyne and the viscosity of water is 0.01 poise, what is the distance between them?

Ans.

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

$$\therefore dx = \eta A \frac{dv}{F} = 0.01 \times 100 \times \frac{10}{200} = 0.05 \text{ cm}$$

2.viii What do you mean by dielectric polarization?

Ans. Dielectric polarization is the term given to describe the behavior of a material when an external electric field is applied to it. It occurs when a dipole moment is formed in an insulating material because of an externally applied electric field.

Q. 3 | Attempt Any Eight:

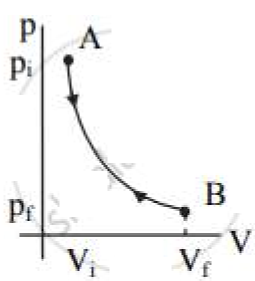
A flywheel is revolving with a constant angular velocity. A chip of its rim breaks and flies away. What will be the effect on its angular velocity?

Ans.

i. When the chip of the rim of a flywheel revolving with a constant angular velocity breaks away, its mass will decrease.
ii. Due to the decrease in its mass, the moment of inertia of the flywheel will decrease.
iii. In order to conserve angular momentum, the angular velocity of the flywheel will increase.

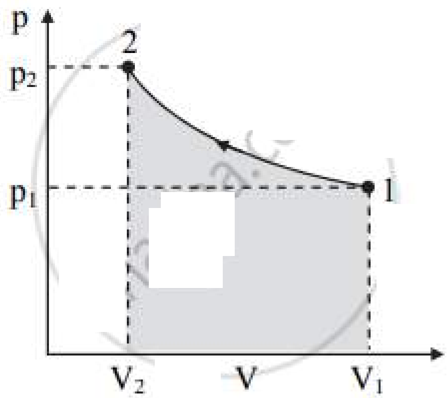
Q. 4 Draw a p-V diagram of the reversible process.

Ans. p-V diagram of the reversible process:



Q. 5 Draw a p-V diagram showing negative work with varying pressure.

Ans. p-V diagram showing negative work with varying pressure:



Q. 6 Distinguish between an overtone and harmonic.

Ans.

Sr. No.	Overtone	Harmonic
i.	The first harmonic is the natural frequency of vibration.	The first overtone is the next higher frequency of vibration.
ii.	Harmonics are simply integral multiples of the fundamental frequency.	Overtones are not necessarily integral multiples of the fundamental frequency. They are frequencies other than the fundamental frequency.
iii.	All harmonics may or may not be present in vibration	All overtones are always present in the vibration.

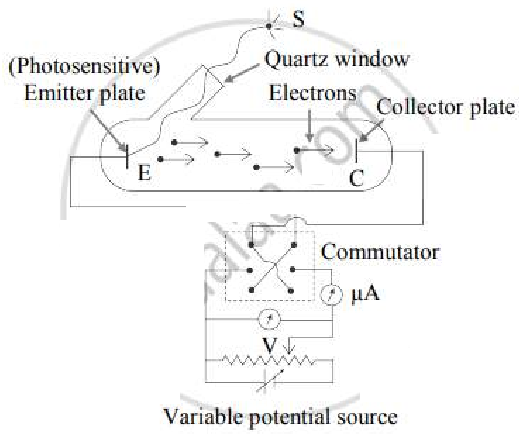
Q. 7 What are stationary waves? Why are they called stationary waves?

Ans.

i. When two identical waves traveling along the same path in opposite directions interfere with each other, the resultant wave is called a stationary wave.
ii. Stationary waves are called so because the resultant harmonic disturbance of the particles does not travel in any direction and there is no transport of energy.

Q. 8 Draw a neat labelled diagram of a schematic of the experimental setup for the photoelectric effect.

Ans. Schematic of experimental set-up for photoelectric effect:



Q. 9 State any two advantages and disadvantages of a photodiode.

Ans. Advantages of photodiode:

i. Quick response when exposed to light.
ii. The reverse current is linearly proportional to the intensity of incident light. (Linear response)
iii. High speed of operations.
iv. Lightweight and compact size.
v. Wide spectral response. E.g., photodiodes made from silicon respond to radiation of wavelengths from 190 nm (UV) to 1100 nm (IR).
vi. Relatively low cost.

Disadvantages of photodiode:

i. Its properties are temperature-dependent, similar to many other semiconductor devices.
ii. Low reverse current for low illumination levels.

Q. 10 The moment of inertia of a body about a given axis is 1.2 kgm^2. initially, the body is at rest. For what duration on the angular acceleration of 25 $radian/sec^2$ must be applied about that axis in order to produce rotational kinetic energy of 1500 joule?

Ans.

Given:

I = 1.2 kgm^2, α = 25 $radian/sec^2$, ω_0 = 0 rad/s, $(K.E.)_{rot}$ = 1500 J

To find: Time (t)

Formulae:

i. $\alpha = \frac{\omega - \omega_0}{t}$

ii. K.E. = $\frac{1}{2} I\omega^2$

Calculation:

From formula (i),

$25 = \frac{\omega - 0}{t}$

$\therefore \omega = 25t$

From formula (ii),

$1500 = \frac{1}{2} \times 1.2 \times (25t)^2$

$\therefore t = \sqrt{\frac{2 \times 1500}{1.2 \times 2.5^2}} = \sqrt{4}$

∴ t = 2 sec.

An angular acceleration must be applied for 2 sec.

Q. 11 1000 calories of radiant heat are incident on a body. If the body absorbs 400 calories of heat, find the coefficient of emission of the body.

Ans.

Given: Q = 1000 cal, Q_a = 400 cal

To find: Coefficient of emission (e)

Formula:

i. a = $\frac{Q_a}{Q}$

ii. a = e

Calculation:

From formula (i),

a = $\frac{400}{1000} = 0.4$

From Formula (ii),

e = a = **0.4**

The coefficient of emission of the body is **0.4.**

Q. 12 Four resistances 6Ω, 6Ω, 6Ω and 18Ω form a Wheatstone bridge. Find the resistance which connected across the 18Ω resistance will balance the network.

Ans.

Given: P = Q = R = 6 Ω

To find: Resistance (X)

Formula: $\frac{\text{P}}{\text{Q}} = \frac{\text{R}}{\text{S}}$

Calculation:

Let resistance connected across 18 Ω be X.

Equivalent resistance for 18 Ω and X in parallel is given by,

X' = S = $\frac{18\text{X}}{18 + \text{X}}$

From formula,

$$\frac{6}{6} = \frac{6}{\frac{18X}{18+X}}$$

$$\therefore 1 = \frac{6(18+X)}{18X}$$

$\therefore$ 18X = 108 + 6X

$\therefore$ 12X = 108

$\therefore$ X = **9 Ω**

The resistance connected across 18 Ω resistance to balance the network is 9 Ω.

Q. 13 The magnetic flux through a loop varies according to the relation $\Phi = 8t^2 + 6t + 2$, Φ is in milliweber and t is in second. What is the magnitude of the induced emf in the loop at t = 2 seconds?

Ans.

Given:

$\Phi = 8t^2 + 6t + 2$ (in milliweber)

t = 2 s

To find: Magnitude of induced e.m.f. (e)

Formula: $e = \frac{d\phi}{dt}$ (in magnitude)

Calculation:

Using formula,

$e = \frac{d}{dt}\left(8t^2 + 6t + 2\right)$

$= 8 \times 2t + 6$

$= 16t + 6$

At t = 2s

$|e| = 16 \times 2 + 6$

= 38 mV

The magnitude of induced e.m.f. is 38 mV.

Q. 14 Define current amplification factor α_{DC} and β_{DC} Obtain the relation between them.

Ans.

i. In the case of common emitter configuration, common base current gain or the current amplification factor (α_{DC}) is the ratio of the collector current to the emitter current.

$\alpha_{DC} = \frac{I_c}{I_E}$ ....(1)

ii. Similarly, the common-emitter current gain of the current amplification factor (β_{DC}) is defined as the ratio of the collector current to the base current.

$\beta_{DC} = \frac{I_c}{I_B}$ ....(2)

iii. Since, $I_E = I_B + I_C$

Dividing throughout by I_C,

$$\frac{I_E}{I_c} = \frac{I_B}{I_c} + 1$$

$$\therefore \frac{1}{\alpha_{DC}} = \frac{1}{\beta_{DC}} + 1 \text{ ....[From (1) and (2)]}$$

$$\therefore \alpha_{DC} = \frac{\beta_{DC}}{1 + \beta_{DC}}$$

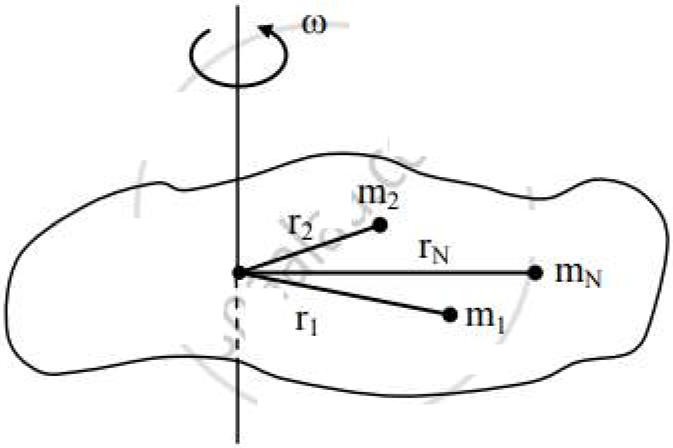
$$\therefore \beta_{DC} = \frac{\alpha_{DC}}{1 - \alpha_{DC}}$$

Q. 15 | Attempt Any Eight:

Derive an expression for the kinetic energy of a rotating body with uniform angular velocity.

Ans.

i. Consider a rigid object rotating with a constant angular speed ω about an axis perpendicular to the plane of the paper.



A body of N particles

ii. For theoretical simplification, let us consider the object to be consisting of N particles of masses m_1, m_2, ...m_N at respective perpendicular distances r_1, r_2, ...r_N from the axis of rotation.

iii. As the object rotates, all these particles perform UCM with the same angular speed ω, but with different linear speeds,

$v_1 = r_1\omega$, $v_2 = r_2\omega$,...., $v_N = r_N\omega$

iv. Translational K.E. of the first particle is

$(K.E.)_1 = \frac{1}{2}m_1v_1^2 = \frac{1}{2}m_1r_1^2\omega^2$

Similar will be the case of all the other particles.

v. The rotational K.E. of the object is the sum of individual translational kinetic energies.

Thus,

Rotational K.E. = $\frac{1}{2}m_1r_1^2\omega^2 + \frac{1}{2}m_2r_2^2\omega^2 ..... + \frac{1}{2}m_Nr_N^2\omega^2$

$\therefore$ Rotational K.E. = $\frac{1}{2}(m_1r_1^2 + m_2r_2^2 ..... + m_Nr_N^2)\omega^2$

vi. But I = $\Sigma_{i=1}^{N} m_ir_i^2 = m_1r_1^2 + m_2r_2^2 ...... + m_Nr_N^2$

$\therefore$ Rotational K.E. = $\frac{1}{2}I\omega^2$

Q. 16 Explain the phenomena of surface tension on the basis of molecular theory.

Ans. Molecular theory of surface tension:

i. Let PQRS = Surface film of liquid in a container containing liquid. PS is the free surface of the liquid and QR is the inner layer parallel to PS at distance equal to the range of molecular force.

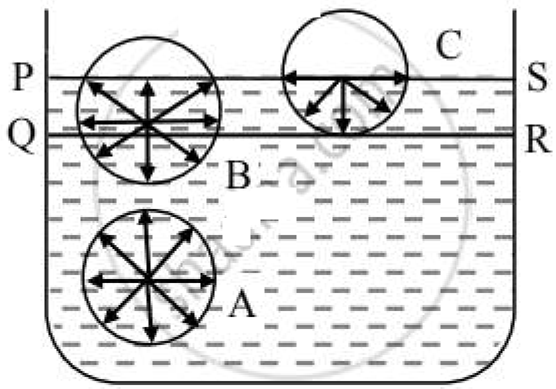
ii. Now consider three molecules A, B, and C in a liquid in a vessel such that molecule A is well inside the liquid, molecule B within the surface film, and molecule C is on the surface of the liquid as shown in the figure.

iii. The sphere of influence of molecule A is entirely inside the liquid. As a result, molecule A is acted upon by equal cohesive forces in all directions. Thus, the net cohesive force acting on molecule A is zero.

iv. For molecule B, a large part of its sphere of influence is inside the liquid and a smaller part is outside the surface (in the air). The adhesive force acting on molecule B due to air molecules above it and within its sphere of influence is weak compared to the strong downward cohesive force acting on the molecule. As a result, molecule B gets attracted inside the liquid.

v. For molecule C, half of the sphere of influence is in air and half is in liquid. As the density of air is much less than that of liquid, the number of air molecules within the sphere of influence of molecule C above the free surface of the liquid is much less than the numbers of liquid molecules within the sphere of influence that lies within the liquid. Thus, the adhesive force due to the air molecules acting on molecule C is weak compared to the cohesive force acting on the molecule. As a result, molecule C also gets attracted inside the liquid.

vi. Thus, all molecules in the surface film are acted upon by an unbalanced net cohesive force directed into the liquid. Therefore, the molecules in the surface film are pulled inside the liquid. This minimizes the total number of molecules in the surface film. As a result, the surface film remains under tension. The surface film of a liquid behaves like a stretched elastic membrane. This tension is known as surface tension and the force due to it acts tangential to the free surface of a liquid.



Q. 17 Obtain an expression for the resultant amplitude of, the composition of two S.H.M.'s having the same period along the same path.

Ans.

i. Consider a particle simultaneously subjected to two S.H.M.s having the same period and along the same path (let it be along the x-axis) but of different amplitudes and initial phases. The resultant displacement at any instant is equal to the vector sum of its displacements due to both the S.H.M.s at that instant.

ii. Let the two linear S.H.M's be given by equations,
$x_1 = A_1 \sin(\omega t + \Phi_1)$ ....(1)
$x_2 = A_2 \sin(\omega t + \Phi_2)$ ....(2)
where A_1, A_2 are amplitudes; Φ_1, Φ_2 are initial phase angles, and x_1, x_2 are the displacement of two S.H.M's in time 't'. ω is the same for both S.H.M's.

iii. The resultant displacement of the two S.H.M's is given by,
$x = x_1 + x_2$ ....(3)
Using equations (1) and (2) , equation (3) can be written as,
$x = A_1 \sin(\omega t + \Phi_1) + A_2 \sin(\omega t + \Phi_2)$
$= A_1 [\sin \omega t \cos \Phi_1 + \cos \omega t \sin \Phi_1] + A_2 [\sin \omega t \cos \Phi_2 + \cos \omega t \sin \Phi_2]$
$= A_1 \sin \omega t \cos \Phi_1 + A_1 \cos \omega t \sin \Phi_1 + A_2 \sin \omega t \cos \Phi_2 + A_2 \cos \omega t \sin \Phi_2$
$= [A_1 \sin \omega t \cos \Phi_1 + A_2 \sin \omega t \cos \Phi_2] + [A_1 \cos\omega t \sin \Phi_1 + A_2 \cos \omega t \sin\Phi_2]$
$\therefore x = \sin \omega t [A_1 \cos \Phi_1 + A_2 \cos \Phi_2] + \cos \omega t [A_1 \sin \Phi_1 + A_2 \sin \Phi_2]$ ....(4)

iv. As A_1, A_2, Φ_1 and Φ_2 are constants, we can combine them in terms of another convenient constants R and δ as
$A_1 \cos \Phi_1 + A_2 \cos \Phi_2 = R \cos\delta$ ....(5)
and $A_1 \sin \Phi_1 + A_2 \sin \Phi_2 = R \sin \delta$ ....(6)

v. Using equations (5) and (6), equation (4) can be written as,
$x = \sin \omega t.\ R \cos \delta + \cos \omega t.R \sin \delta = R [\sin \omega t \cos \delta + \cos \omega t \sin \delta]$
$\therefore x = R \sin(\omega t + \delta)$ ....(7)
Equation (7) is the equation of an S.H.M. of the same angular frequency (hence, the same period) but of amplitude R and initial phase δ. It shows that the combination

(superposition) of two linear S.H.M.s of the same period and occurring along the same path is also an S.H.M.

vi. Resultant amplitude is,

R = $\sqrt{(R\sin\delta)^2 + (R\cos\delta)^2}$

Squaring and adding equations (5) and (6) we get, $(A_1 \cos \Phi_1 + A_2 \cos \Phi_2)^2 + (A_1 \sin \Phi_1 + A_2 \sin \Phi_2)^2 = R^2 \cos^2 \delta + R^2 \sin^2 \delta$

∴

$$A_1^2\cos^2\Phi_1 + A_2^2\cos^2\Phi_2 + 2A_1A_2\cos\Phi_1\cos\Phi_2 + A_1^2\sin^2\Phi_1 + A_2^2\sin^2\Phi_2 + 2A_1A_2\sin\Phi_1\sin\Phi_2 = R^2(\cos^2\delta + \sin^2\delta)$$

$\therefore A_1^2(\cos^2\Phi_1 + \sin^2\Phi_1) + A_2^2(\cos^2\Phi_2 + \sin^2\Phi_2) + 2A_1A_2(\cos\Phi_1\cos\Phi_2 + \sin\Phi_1\sin\Phi_2) = R^2$

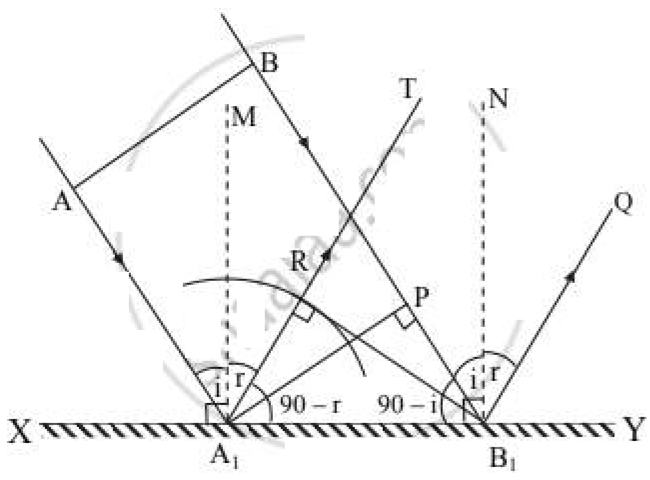
$\therefore A_1^2 + A_2^2 + 2A_1A_2\cos(\Phi_1 - \Phi_2) = R^2$

$\therefore R = \pm\sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\Phi_1 - \Phi_2)}$ ....(8)

Equation (8) represents resultant amplitude of two S.H.M's.

Q. 18 Explain the reflection of light at a plane surface with the help of a neat ray diagram.

Ans.



Reflection of light

XY: Plane reflecting surface
AB: Plane wavefront
RB_1: Reflecting wavefront
A_1M, B_1N: Normal to the plane
$\angle AA_1M = \angle BB_1N = \angle i$ = Angle of incidence
$\angle TA_1M = \angle QB_1N = \angle r$ = Angle of reflection

Explanation:

i. A plane wavefront AB is advancing obliquely towards the plane reflecting surface XY. AA_1 and BB_1 are incident rays.

ii. When 'A' reaches XY at A_1, then the ray at 'B' reaches point 'P' and it has to cover distance PB_1 to reach the reflecting surface XY.

iii. Let 't' be the time required to cover distance PB_1. During this time interval, secondary wavelets are emitted from A_1 and will spread over a hemisphere of radius A_1R, in the same medium. Distance covered by secondary wavelets to reach from A_1 to R in time t is the same as the distance covered by primary waves to reach from P to B_1. Thus $A_1R = PB_1 = ct$.

iv. All other rays between AA_1 and BB_1 will reach XY after A_1 and before B_1. Hence, they will also emit secondary wavelets of decreasing radii.

v. The surface touching all such hemispheres is RB_1 which is reflected wavefront, bounded by reflected rays A_1R and B_1Q.

vi. Draw $A_1M \perp XY$ and $B_1N \perp XY$.
Thus, angle of incidence is $\angle AA_1M = \angle BB_1N = i$ and angle of reflection is $\angle MA_1R = \angle NB_1Q = r$.
$\therefore \angle RA_1B_1 = 90 - r$ and $\angle PB_1A_1 = 90 - i$

vii. In ΔA_1RB_1 and ΔA_1PB_1

$\angle A_1RB_1 \cong \angle A_1PB_1$

$A_1R = PB_1$ (Reflected waves travel equal distance in the same medium in equal time).

$A_1B_1 = A_1B_1$ ....(common side)

$\therefore \Delta A_1RB_1 \cong \Delta A_1PB_1$

$\therefore \angle RA_1B_1 = \angle PB_1A_1$

$\therefore 90 - r = 90 - i$

$\therefore i = r$

viii. Also, from the figure, it is clear that incident ray, reflected ray, and normal lie in the same plane.

ix. Assuming rays AA_1 and BB_1 to be coming from extremities of the object, A_1B_1 is the size of the object. Distance between corresponding reflected rays A_1T and B_1Q will be the same as A_1B_1 as they are corresponding parts of congruent triangles. This implies the size of the object in a reflected image is the same as the actual size of an object.

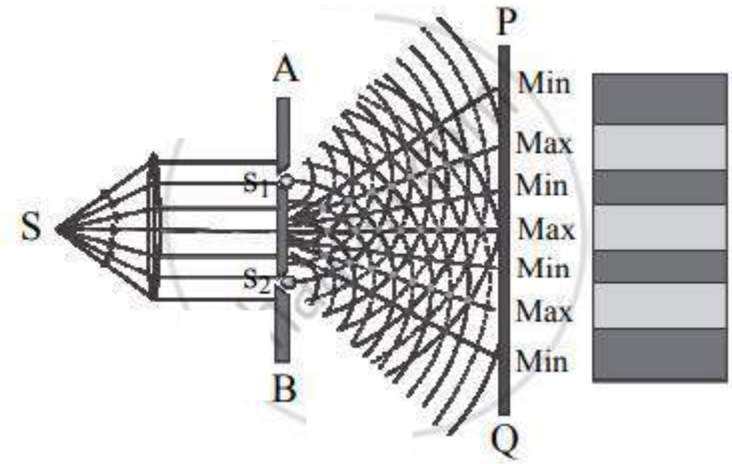
x. Also, taking A and B to be right and left sides of the object respectively, after reflection right side at A is seen at T and left side at B is seen at Q. This explains lateral inversion.

Q. 19 Describe Young's double-slit experiment with a neat diagram showing points of maximum and minimum intensity.

Ans.

i. In Young's double-slit interference experiment, a plane wavefront is made to fall on an opaque screen AB having two similar narrow slits S_1 and S_2.

ii. The figure below shows a cross-section of the experimental setup and the slits have their lengths perpendicular to the plane of the paper.



Young's double-slit experiment

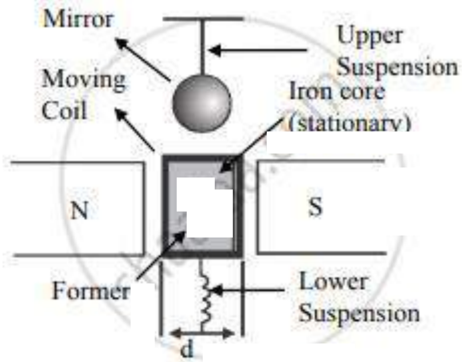
iii. The slits are about 2 - 4 mm apart from each other.
iv. An observing screen PQ is placed behind AB.
v. Assuming that the slits S_1 and S_2 are equidistant from the S, the wavefronts starting from S and reaching the S_1 and S_2 at every instant of time are in phase.
vi. When the rays fall on S_1 and S_2, the two slits act as secondary sources of light-emitting cylindrical wavelets (with axis along the slit length) to the right of AB.
vii. The two secondary sources emit waves in phase with each other.
viii. The crests/troughs of the secondary wavelets superpose as shown in the figure and interfere constructively high intensity giving rise to a bright band.
ix. When the crest of one wave coincides with the trough of the other causing zero intensity, dark images of the slits are produced on the screen PQ.
x. The dark and bright regions are called fringes and the whole pattern is called an interference pattern.

Q. 20 Explain the construction and working of the Moving coil Galvanometer.

Ans. Construction:

i. M.C.G. consists of a coil of several turns mounted (suspended or pivoted) in such a way that it can freely rotate about a fixed axis, in a radial uniform magnetic field.

ii. A soft iron cylindrical core makes the field radial and strong.



Moving coil galvanometer

Working:

i. The coil rotates due to a torque acting on it as the current flows through it. The torque acting on the current-carrying coil is τ = NIAB sinθ.
Here $\theta = 90°$ as the field is radial.
$\therefore \tau$ = NIAB
where A is the area of the coil, B the strength of the magnetic field, N the number of turns of the coil, and I the current in the coil.

ii. This torque is counter balanced by a torque due to a spring fitted at the bottom so that a fixed steady current I in the coil produces a steady angular deflection Φ.

iii. The larger the current is, the larger is the deflection and the larger is the torque due to the spring. If the deflection is Φ, the restoring torque due to the spring is equal to $K\Phi$ where K is the torsional constant of the spring. Thus, $K\Phi$= NIAB, and the deflection $\Phi = \left(\frac{NAB}{K}\right)I$

This means the deflection Φ is proportional to the current I i.e., $\Phi \propto I$.

Q. 21 Explain the term inductive reactance. State its unit and dimensions.

Ans.

i. The opposing nature of an inductor to the flow of alternating current is called inductive reactance.

ii. In an inductive circuit,

$i_0 = \frac{e_0}{\omega L}$ ....(1)

iii. For a resistive ac circuit, according to Ohm's law,

$i = \frac{V}{R}$ ....(2)

where R = resistance in the circuit

iv. Comparing equations (1) and (2), we can conclude that ωL plays a similar role in an inductive ac circuit as a resistor in a pure resistor circuit.

v. Hence, the effective resistance X_L offered by the inductance L is called inductive reactance and is given as,

$X_L = \omega L = 2\pi fL$. ....($\because \omega = 2\pi/T = 2\pi f$)

where f = frequency of the AC supply.

vi. X_L is directly proportional to the inductance (L) and the frequency (f) of the alternating current.

vii. In DC circuits, f = 0

$\therefore X_L = 0$

It implies that a pure inductor offers zero resistance to DC, i.e., it cannot reduce DC.

Thus, it passes DC and blocks AC of very high frequency.

viii. In an inductive circuit, the self-induced emf opposes the growth as well as decay of current.

ix. The dimensions of inductive reactance are $[ML^2T^{-3}I^{-2}]$ and its SI unit is the ohm (Ω).

Q. 22 An alternating emf of 230V, 50Hz is connected across a pure ohmic resistance of 50Ω. Find (1) the current (2) equations for instantaneous values of current and voltage.

Ans.

Given:

$e_{rms} = 230$ V, f = 50 Hz, R = 50 Ω

i. R.M.S value of current, $i_{rms} = \frac{e_{rms}}{R} = \frac{230}{50} = \mathbf{4.6\ A}$

ii. a. Peak value of current,

$i_0 = i_{rms} \times \sqrt{2}$

$= 4.6 \times \sqrt{2}$

= 6.5 A

∴ Equation for instantaneous value of current,

$i = i_0 \sin 2\pi ft$

$= 6.5 \sin (2 \times \pi \times 50 \times t)$

$\therefore \mathbf{i = 6.5 \sin 100 \pi t}$

b. Peak value of voltage,

$e_0 = e_{rms} \times \sqrt{2} = 230 \times \sqrt{2} = 325.27V$

∴ Equation for instantaneous value of voltage,

$e = e_0 \sin 2\pi ft$

$= 325.27 \sin (2 \times \pi \times 50 \times t)$

∴ $e = 325.27 \sin 100\pi t$

i. R.M.S value of current is 4.6 A.

ii. Equations for instantaneous value of current and voltage are i = 6.5 sin 100 πt and e = 325.27 sin 100 πt respectively.

Q. 23 The work function of a surface is 3.1 eV. A photon of frequency 1×10^{15} Hz. Is an incident on it. Calculate the incident wavelength is photoelectric emission occurs or not.

Ans.

Using formula (ii),

$$\lambda = \frac{3 \times 10^8}{1 \times 10^{15}}$$

$= 3 \times 10^{-7}$ m = **3000 Å**

As $\lambda < \lambda_0$, **photoelectric mission will occur.**

i. **Incident wavelength is 3000 Å**

ii. **Photoelectric emission will occur.**

Calculation:

Using formula (i),

$$\lambda_0 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{3.1 \times 1.6 \times 10^{-19}}$$

$$= \frac{6.63 \times 3}{3.1 \times 1.6} \times 10^{-7}$$

= antilog {log 6.63 + log 3 − log 3.1 − log 1.6} × 10^{-7}

= antilog {0.8215 + 0.4771 − 0.4914 − 0.2041} × 10^{-7}

= antilog {0.6031} × 10^{-7}

= 4.010 × 10^{-7} m

= 4010 Å

Using formula (ii),

$$\lambda = \frac{3 \times 10^8}{1 \times 10^{15}}$$

= 3 × 10^{-7} m = **3000 Å**

As $\lambda < \lambda_0$, **photoelectric mission will occur.**

i. **Incident wavelength is 3000 Å**

ii. **Photoelectric emission will occur.**

Q. 24 The primary of a transformer has 40 turns and works on 100 V and 100 W. Find a number of turns in the secondary to step up the voltage to 400 V. Also calculate the current in the secondary and primary.

Ans.

Given:

$N_P = 40$, $e_P = 100$ V, $P_P = 100$ watt, $e_S = 400$ V

To find:

i. Number of turns in the secondary (N_S)

ii. Current in the secondary (I_S)

iii. Current in the primary (I_P)

Formulae:

i. $\frac{e_p}{e_s} = \frac{N_p}{N_s}$

ii. $P = Ie$

Calculation:

From formula (i),

$$N_s = N_p \times \frac{e_s}{e_p} = \frac{40 \times 400}{100}$$

$\therefore N_S =$ **160**

For an ideal transformer, $P_S = P_P$

From formula (ii),

$P_S = I_S e_S$

$\therefore I_P e_P = I_S e_S$

$$\therefore I_s = \frac{I_p e_p}{e_s}$$

$$= \frac{P_p}{e_s} = \frac{100}{400} = 0.25 \text{ A}$$

$$I_p = \frac{P_p}{e_p}$$

$$I_p = \frac{100}{100} = 1 \text{ A}$$

$\therefore I_p =$ **1 A**

i. **The number of turns in the secondary is 160.**
ii. **The current in the secondary is 0.25 A.**
iii. **The current in the primary is 1 A.**

Q. 25 A circular loop of radius 9.7 cm carries a current 2.3 A. Obtain the magnitude of the magnetic field
(a) at the centre of the loop
(b) at a distance of 9.7 cm from the centre of the loop but on the axis.

Ans. A Data: R = z = 9.7 cm = 9.7 x 10^{-2} m, I = 2.3 A, N = l

(a) At the centre of the coil:

The magnitude of the magnetic induction,

Data: R = z = 9.7 cm = 9.7 x 10^{-2} m, I = 2.3 A, N = I

(a) At the centre of the coil:

The magnitude of the magnetic induction,

$$B = \frac{\mu_0 NI}{2R}$$

$$= \frac{(4\pi \times 10^{-7})(1)(2.3)}{2(9.7 \times 10^{-2})} = \frac{2 \times 3.142 \times 2.3}{9.7} \times 10^{-5}$$

$$= 1.49 \times 10^{-5}\ \mathrm{T}$$

(b) On the axis, at a distance z = 02 m from the coil:

$$B = \frac{\mu_0}{4\pi} \frac{2\pi IR^2}{\left(\left(R^2 + z^2\right)\right)^{\frac{3}{2}}}$$

$$\left(R^2 + z^2\right)^{\frac{3}{2}} = \left(2R^2\right)^{\frac{3}{2}} = 2\sqrt{2}R^3 \quad (\because R = z)$$

$$\therefore B = \frac{\mu_0}{4\pi} \frac{2\pi IR^2}{2\sqrt{2}R^3} = \frac{\mu_0}{4\pi} \frac{\pi I}{\sqrt{2}R}$$

$$= \left(10^{-7}\right) \frac{3.142 \times 2.3}{1.414 \times 9.7 \times 10^{-2}}$$

$$= \frac{7.227}{13.72} \times 10^{-5} = 5.267 \times 10^{-6}\mathrm{T} = 5.267\mu\mathrm{T}$$

Ans. B Given:

R = 9.7 cm = 9.7 × 10^{-2} m,

I = 2.3 A,

z = 9.7 cm = 9.7 × 10^{-2} m

To find:

Magnetic field

i. at the centre of the loop
ii. on the axis at a distance

Formulae:

$$\text{i. } B_c = \frac{\mu_0 I}{2R}$$

$$\text{ii. } B_a = \frac{\mu_0 I R^2}{2\left(z^2 + R^2\right)^{\frac{3}{2}}}$$

Calculation:

From formula (i),

$$B_c = \frac{4\pi \times 10^{-7} \times 2.3}{2 \times 9.7 \times 10^{-2}}$$

$$= \frac{2 \times 3.142 \times 2.3}{9.7} \times 10^{-7+2}$$

$$= \frac{4\pi \times 10^{-7} \times 2.3 \times \left(9.7 \times 10^{-2}\right)^2}{2 \times 2^{\frac{3}{2}} \times \left(9.7 \times 10^{-2}\right)^3}$$

$$= \frac{\pi \times 10^{-7} \times 2.3}{2^{\frac{1}{2}} \times \left(9.7 \times 10^{-2}\right)}$$

$= 5.268 \times 10^{-6}$T

= 5.268 μT

i. **The magnetic field at the centre of 14.9 μT.**

ii. **The magnetic field on the axis at a distance of 9.7 cm from the centre is 5.268 μT.**

Q. 26 A cell of e.m.f 1.5V and negligible internal resistance is connected in series with a potential meter of length 10 m and the total resistance of 20 Ω. What resistance should be introduced in the resistance box such that the potential drop across the potentiometer is one microvolt per cm of the wire?

Ans. Given:

$R = 20\ \Omega$, $L = 10$ m, $E = 1.5$ V,
$K = 1\ \mu V/cm = 1 \times (10^{-6} / 10^{-2})$ V/ m
$= 10^{-4}$ V/ m

To find: External resistance (R_E)

Formula: $K = \dfrac{V}{L}$

Calculation:

Since, $I = \dfrac{E}{R + R_E}$

Also, $V = IR = \dfrac{ER}{R + R_E}$

From formula,

$$K = \frac{ER}{(R + R_E)L}$$

$$R + R_E = \frac{ER}{KL}$$

$$\therefore R_E = \frac{1.5 \times 20}{10^{-4} \times 10} - 20 = 30000 - 20$$

$\therefore R_E =$ **29980 Ω**

The external resistance should be 29980 Ω.

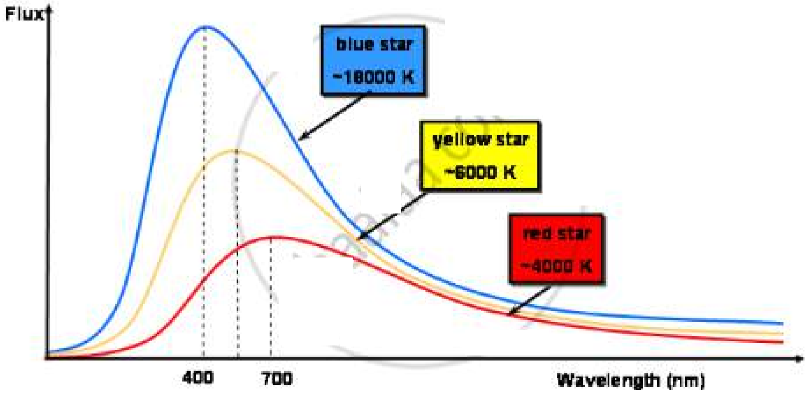
Q. 27 | Attempt Any Three:

Answer in brief: Explain the spectral distribution of blackbody radiation.

Ans. 1 All objects with a temperature above absolute zero (0 K, -273.15°C) emit energy in the form of electromagnetic radiation.

A blackbody is a theoretical or model body that absorbs all radiation falling on it, reflecting or transmitting none. It is a hypothetical object which is a "perfect" absorber and a "perfect" emitter of radiation over all wavelengths.

The spectral distribution of the thermal energy radiated by a blackbody (i.e. the pattern of the intensity of the radiation over a range of wavelengths or frequencies) depends only on its temperature.



The characteristics of blackbody radiation can be described in terms of several laws:

1. **Planck's Law** of blackbody radiation, a formula to determine the spectral energy density of the emission at each wavelength (E_λ) at a particular absolute temperature (T).

$$E_\lambda = \frac{8\pi h\,c}{\lambda^5\left(e^{hc/\lambda kT} - 1\right)}$$

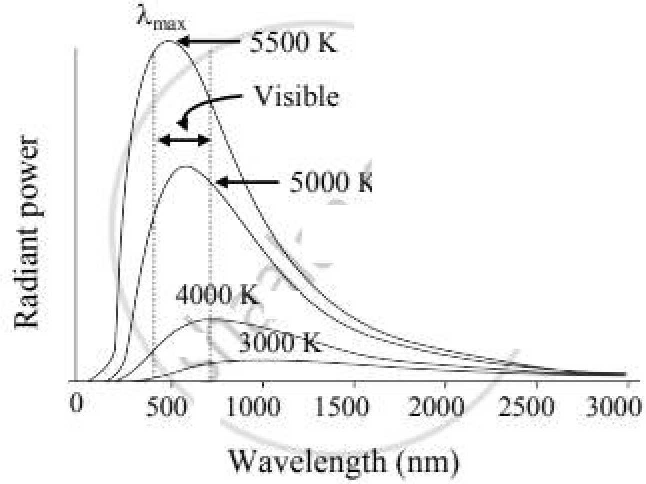
1. **Wien's Displacement Law,** which states that the frequency of the peak of the emission (f_{max}) increases linearly with absolute temperature (T). Conversely, as the temperature of the body increases, the wavelength at the emission peak decreases.
   $f_{max} \alpha T$
2. **Stefan–Boltzmann Law**, which relates the total energy emitted (E) to the absolute temperature (T).
   $E \alpha T^4$

In the image above, notice that:

- The blackbody radiation curves have quite a complex shape (described by Planck's Law).
- The spectral profile (or curve) at a specific temperature corresponds to a specific peak wavelength, and vice versa.
- As the temperature of the blackbody increases, the peak wavelength decreases (Wien's Law).
- The intensity (or flux) at all wavelengths increases as the temperature of the blackbody increases.
- The total energy being radiated (the area under the curve) increases rapidly as the temperature increases (Stefan–Boltzmann Law).
- Although the intensity may be very low at very short or long wavelengths, at any temperature above absolute zero energy is theoretically emitted at all wavelengths (the blackbody radiation curves never reach zero).

Ans. 2

i. The rate of emission per unit area or power per unit area of a surface is defined as a function of the wavelength λ of the emitted radiation.
ii. Scientists studied the energy distribution of blackbody radiation as a function of wavelength.



iii. By keeping the source of radiation (such as a cavity radiator) at different temperatures they measured the radiant power corresponding to different wavelengths. The measurements were represented graphically in the form of curves showing the variation of radiant power per unit area as a function of wavelength λ at different constant temperatures as shown in the figure.

Q. 28 State the postulates of Bohr's atomic model. Hence show the energy of electrons varies inversely to the square of the principal quantum number.

Ans. Bohr's three postulates are:

i. In a hydrogen atom, the electron revolves around the nucleus in a fixed circular orbit with constant speed.
ii. The radius of the orbit of an electron can only take certain fixed values such that the angular momentum of the

electron in these orbits is an integral multiple of $\frac{h}{2\pi}$, h being the Planck's constant.

i. An electron can make a transition from one of its orbits to another orbit having lower energy. In doing so, it emits a photon of energy equal to the difference in its energies in the two orbits.

Expression for the energy of an electron in the n^{th} orbit of Bohr's hydrogen atom:

i. **Kinetic energy:**
Let, m_e = mass of the electron
r_n = radius of n^{th} orbit of Bohr's hydrogen atom
v_n = velocity of electron

−e = charge of the electron
+e = charge on the nucleus
Z = a number of electrons in an atom.
According to Bohr's first postulate,

According to Bohr's first postulate,

$$\frac{m_e V_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0} \times \frac{Ze^2}{r_n^2}$$

where, ε_0 is permittivity of free space.

$$\therefore m_e v_n^2 = \frac{Z}{4\pi\varepsilon_0} \times \frac{e^2}{r_n} \quad ....(1)$$

The revolving electron in the circular orbit has linear speed and hence it possesses kinetic energy.

It is given by, K.E = $\frac{1}{2} m_e v_n^2$

$$\therefore \text{K.E} = \frac{1}{2} \times \left(\frac{Z}{4\pi\varepsilon_0} \times \frac{e^2}{r_n}\right) \quad ....\text{[From equation (1)]}$$

$$\therefore \text{K.E} = \frac{Ze^2}{8\pi\varepsilon_0 r_n} \quad ....(2)$$

ii. **Potential energy:**

The potential energy of the electron is given by, P.E = V(−e)

where,

V = electric potential at any point due to charge on the nucleus

− e = charge on the electron.

In this case,

$$\therefore \text{P.E} = \frac{1}{4\pi\varepsilon_0} \times \frac{e}{r_n} \times (-Ze)$$

$$\therefore \text{P.E} = \frac{1}{4\pi\varepsilon_0} \times \frac{-Ze^2}{r_n}$$

$$\therefore \text{P.E} = -\frac{Ze^2}{4\pi\varepsilon_0 r_n} \quad ....(3)$$

iii. **Total energy:**

The total energy of the electron in any orbit is its sum of P.E and K.E.

$\therefore$ T.E = K.E + P.E

$$= \left(\frac{Ze^2}{8\pi\varepsilon_0 r_n}\right) + \left(-\frac{Ze^2}{4\pi\varepsilon_0 r_n}\right) \text{ ....[From equations (2) and (3)]}$$

$$\therefore \text{T.E} = -\frac{Ze^2}{8\pi\varepsilon_0 r_n} \quad ....(4)$$

iv. But, $r_n = \left(\frac{\varepsilon_0 h^2}{\pi m_e Ze^2}\right) \times n^2$

Substituting for r_n in equation (4),

$$\therefore \text{T.E} = -\frac{1}{8\pi\varepsilon_0} \times \frac{Ze^2}{\left(\frac{\varepsilon_0 h^2}{\pi m_e Ze^2}\right)n^2}$$

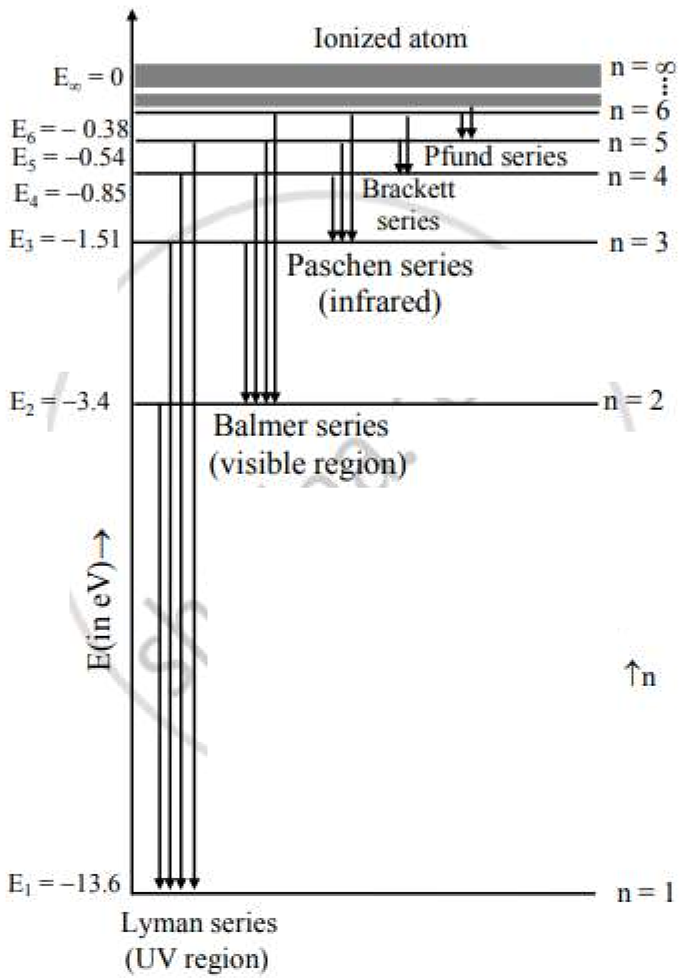
$$= -\frac{1}{8\pi\varepsilon_0} \times \frac{Z^2 e^2 \pi m_e e^2}{\varepsilon_0 h^2 n^2}$$

$$\therefore \text{T.E} = -\frac{m_e Z^2 e^4}{8\varepsilon_0^2 h^2} \times \frac{1}{n^2} \quad ....(5)$$

$$\Rightarrow \text{T.E.} \propto \frac{1}{n^2}$$

Q. 29. i Draw a neat labelled diagram showing energy levels and transition between them for the hydrogen atoms.

Ans. Energy levels and transition between them for hydrogen atom:



Q. 29.ii An electron in an atom is revolving around the nucleus in a circular orbit of a radius of 5.3×10^{-11} m, with a speed of 2×10^6 m/s. Find the resultant orbital magnetic moment and angular momentum of the electron. [$e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg]

Ans. A

i. **Data:** $r = 5.3 \times 10^{-11}$ m, $v = 2 \times 10^6$ m/s,

$e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg

The orbital magnetic moment of the electron is

$M_0 = \frac{1}{2}evr$

$= \frac{1}{2}(1.6 \times 10^{-19})(2 \times 10^{6})(5.3 \times 10^{-11})$

$= 8.48 \times 10^{-24}$ A.m^2

The angular momentum of the electron is

$L_0 = m_e vr$

$= (9.1 \times 10^{-31})(2 \times 10^{6})(5.3 \times 10^{-11})$

$= 96.46 \times 10^{-36} = 9.646 \times 10^{-35}$ kg.m^2/s

Ans. B

Given:

r = 5.3×10^{-11} m,

v = 2×10^{6} ms^{-1},

e = 1.6×10^{-19} C,

m_e = 9.1×10^{-31} kg

To find:

i. Orbital magnetic moment (m_{orb})

ii. Angular momentum of electron

Formulae:

i. $m_{orb} = \frac{evr}{2}$

ii. $L = mvr$

Calculation:

From formula (i),

$$m_{orb} = \frac{1.6 \times 10^{-19} \times 2 \times 10^{6} \times 5.3 \times 10^{-11}}{2}$$

$= 1.6 \times 5.3 \times 10^{-24}$

$= 8.48 \times 10^{-24}$ Am^2

From formula (ii),

$L = 9.1 \times 10^{-31} \times 2 \times 10^{6} \times 5.3 \times 10^{-11}$

$= 96.46 \times 10^{-36}$

$\therefore L \approx \underline{9.646 \times 10^{-35}}$ kgm^2/s

i. Orbital magnetic moment is 8.48×10^{-24} Am^2.

ii. Angular momentum of electron is 9.646×10^{-35} kgm^2/s.

Q. 30.i Define magnetization. State its SI unit and dimensions. Derive the relation between magnetic field intensity(H) and magnetization(M) for a magnetic material placed in a magnetic field.

Ans.

i. The ratio of magnetic moment to the volume of the material is called magnetization.

ii. **Unit:** Am^{-1} in SI system.

iii. **Dimensions:** $[M^0 L^{-1} T^0 I^1]$

iv. **Relation between magnetic field intensity(H) and magnetization(M):**

a. Consider a magnetic material (rod) placed in a magnetizing field (solenoid with n turns per unit length and carrying current I).

b. The magnetic field inside the solenoid is given by,

$B_0 = \mu_0 nI$ ....(1)

Where μ_0 = permeability of free space.

c. The magnetic field inside the rod is given as,

$B_m = \mu_0 M$ ....(2)

Where M = magnetization of the material

d. The net magnetic field inside the rod is expressed as,

$B = B_0 + B_m$ ....(3)

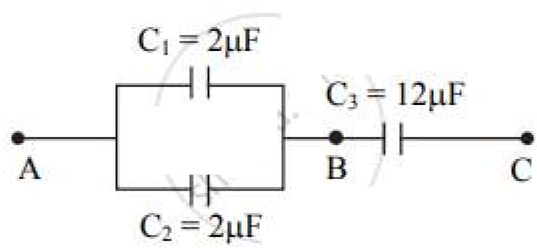
$\therefore B = \mu_0 nI + \mu_0 M$

$\therefore B = \mu_0 H + \mu_0 M$

e. Equation (4) shows that the magnetic field (B) induced in the material depends on magnetic field intensity (H) and magnetization (M).

Q. 30.ii Two capacitors each of capacity 2 μF are connected in parallel. This system is connected in series with the third capacitor of 12μF capacity. Find the equivalent capacity of the system.

Ans.



Here, C_1 and C_2 are in parallel.

$\therefore C_{AB} = C_1 + C_2 = 2\ \mu F + 2\ \mu F = 4\ \mu F$

Here, C_{AB} and C_3 are in series,

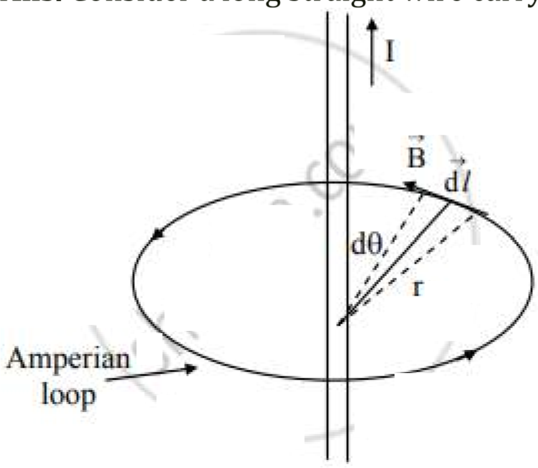
$$\therefore \frac{1}{C_{AC}} = \frac{1}{4\mu} + \frac{1}{12\mu}$$

$\therefore C_{AC}$ = **3μF**

The equivalent capacity of the system is 3μF.

Q. 31.i Using Ampere's law, obtain an expression for the magnetic induction near a current-carrying straight infinitely long wire.

Ans. Consider a long straight wire carrying a current I as shown in the figure below.



A long straight current-carrying wire

$\vec{B}$ and $\vec{dl}$ are tangential to the Amperian loop which in this case is a circle.

$\therefore \vec{B}.\vec{dl} = B\ dl$

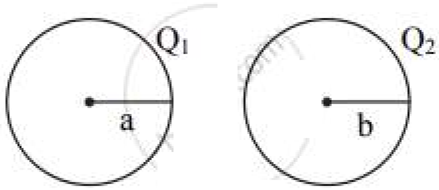
$= B\ r\ d\theta$

ii. The field $\vec{B}$ at a distance r from the wire is given by

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

$$\therefore \oint_c \vec{B}.\vec{dl} = \int_0^{2\pi} \frac{\mu_0 I}{2\pi r} r\ d\theta = \mu_0 I$$

Q. 31.ii Two spheres A and B of radius a and b respectively are at the same potential. Find the ratio of the surface charge densities of A and B.



Since the electric potential is the same, $\frac{1}{4\pi\varepsilon_0}\frac{Q_1}{a} = \frac{1}{4\pi\varepsilon_0}\frac{Q_2}{b}$

$$\therefore \frac{Q_1}{Q_2} = \frac{a}{b}$$

But $\sigma_1 = \frac{Q_1}{4\pi a^2}$ and $\sigma_2 = \frac{Q_2}{4\pi b^2}$

$$\therefore \frac{\sigma_1}{\sigma_2} = \frac{Q_1}{Q_2} \times \frac{b^2}{a^2} = \frac{a}{b} \times \frac{b^2}{a^2} = \frac{b}{a}$$

The ratio of the surface charge densities of A and B is b : a.