Maharashtra Board Class 12 Physics Solutions 2023

SECTION A

Question 1. Select and write the correct answers for the following multiple choice type of questions:

i. If 'n' is the number of molecules per unit volume and 'd' is the diameter of the molecules, the mean free path 'λ' of molecules is
(A) √(2/π nd)
(B) 1 / 2 πnd^2
(C) 1 / √2 πnd^2
(D) 1 / √(2πnd)

Answer. (D) 1 / √(2πnd)

Solution. The correct answer is (D) 1 / √(2πnd).

The mean free path is the average distance traveled by a molecule between collisions. It is inversely proportional to the number density of molecules and the square of the molecular diameter. This can be expressed mathematically as:

λ = 1 / √(2πnd^2)

where:

- λ is the mean free path
- n is the number of molecules per unit volume
- d is the diameter of the molecules

The other answer choices are incorrect because they do not take into account the correct relationship between the mean free path, the number density of molecules, and the molecular diameter.

ii. The first law of thermodynamics is consistent with the law of conservation of _______.
(A) momentum
(B) energy
(C) mass
(D) velocity

Answer. The correct answer is: (B) energy

iii. Y = A+ B is the Boolean expression for _______.
(A) OR - gate
(B) AND - gate
(C) NOR - gate
(D) NAND - gate

Answer. The correct answer is: (A) OR - gate

iv. The property of light which remains unchanged when it travels from one medium to another is ________.
(A) velocity
(B) wavelength
(C) amplitude
(D) frequency

Answer. (D) frequency

Solution. The correct answer is (D) frequency.

The frequency of light is determined by the source of the light and does not change when the light travels from one medium to another. The other properties of light, such as velocity, wavelength, and amplitude, can change when light travels from one medium to another.

For example, when light travels from air to water, its velocity slows down, its wavelength decreases, and its amplitude may change. However, the frequency of the light remains the same. This is because the frequency of light is related to the energy of the light, and the energy of light does not change when it travels from one medium to another.

So, the answer is (D) frequency.

v. If a circular coil of 100 turns with a cross-sectional area of 1 m^2 is kept with its plane perpendicular to the magnetic field of 1 T, the magnetic flux linked with the coil will be ________.
(A) 1 Wb
(B) 50 Wb
(C) 100 Wb
(D) 200 Wb

Answer. The correct answer is: (C) 100 Wb

vi. If 'θ' represents the angle of contact made by a liquid which completely wets the surface of the container then ________.
(A) $\theta = 0$
(B) $0 < \theta < \pi/2$
(C) $\theta = \pi/2$
(D) $\pi/2 < \theta < \pi$

Answer. (A) $\theta = 0$

Solution. The correct answer is (A) $\theta = 0$.

When a liquid completely wets a surface, it spreads out to form a thin film on the surface. The angle of contact between the liquid and the surface is zero degrees. This is because the adhesive forces between the liquid and the surface are greater than the cohesive forces within the liquid.

The other answer choices are incorrect because they represent angles of contact for non-wetting liquids. A non-wetting liquid will bead up on a surface, forming a droplet with a contact angle that is greater than zero degrees.

vii. The LED emits visible light when its ________.
(A) junction is reverse biased
(B) depletion region widens
(C) holes and electrons recombine
(D) junction becomes hot

Answer. The correct answer is: (C) holes and electrons recombine

Solution. A LED radiates visible light when its **holes and electrons recombine**. Because of the recombining of electrons and holes, current progression occurs in the PN junction diode and therefore LED emits light.

viii. Soft iron is used to make the core of transformer because of its _______.
(A) low coercivity and low retentivity
(B) low coercivity and high retentivity
(C) high coercivity and high retentivity
(D) high coercivity and low retentivity

Answer. The correct answer is Option (D) high coercivity and low retentivity

ix. If the maximum kinetic energy of emitted electrons in photoelectric effect is 2eV, the stopping potential will be _______.
(A) 0.5 V
(B) 1.0 V
(C) 1.5 V
(D) 2.0 V

Answer. (D) 2.0 V

Solution. The stopping potential in the photoelectric effect is equal to the maximum kinetic energy of the emitted electrons. Therefore, the correct answer is:

(D) 2.0 V

x. The radius of eighth orbit of electron in H-atom will be more than that of fourth orbit by a factor of _______.
(A) 2
(B) 4
(C) 8
(D) 16

Answer. (B) 4

Solution. The radius of the eighth orbit of an electron in a hydrogen atom is four times greater than the radius of the fourth orbit. This is because the radius of the nth orbit of an electron in a hydrogen atom is given by the Bohr model as:

rn = n^2 * a0

where:

- rn is the radius of the nth orbit
- n is the principal quantum number
- a0 is the Bohr radius, which is approximately 0.0529 nm

Therefore, the radius of the eighth orbit is:

r8 = 8^2 * a0 = 64 * a0

and the radius of the fourth orbit is:

r4 = 4^2 * a0 = 16 * a0

Therefore, the radius of the eighth orbit is four times greater than the radius of the fourth orbit.

So the answer is (B) 4.

Question 2. Answer the following questions:

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

Answer. An ideal voltmeter has an infinite resistance. This means that it draws no current from the circuit it is measuring and therefore does not affect the voltage being measured.

In practice, all real voltmeters have some finite resistance, but it is always very high. This is because a voltmeter is essentially a very high resistance ammeter (a device that measures current), and the resistance of an ammeter is always low.

The high resistance of an ideal voltmeter is necessary to ensure that it does not affect the circuit being measured. If a voltmeter had a low resistance, it would draw a significant amount of current from the circuit, and this would alter the voltage that the voltmeter is trying to measure.

Therefore, the correct answer is that an ideal voltmeter has an infinite resistance.

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

Answer. The force on a closed circuit in a magnetic field depends on the geometry of the circuit, the strength of the magnetic field, and the current flowing through the circuit. However, in general, the force on a closed circuit in a magnetic field is proportional to the product of the current flowing through the circuit, the strength of the magnetic field, and the area enclosed by the circuit.

This can be expressed mathematically as:

$F = IBL \sin\theta$

where:

- F is the force on the circuit (in Newtons)
- I is the current flowing through the circuit (in Amperes)
- B is the strength of the magnetic field (in Tesla)
- L is the length of the segment of the circuit that is in the magnetic field (in meters)
- θ is the angle between the segment of the circuit and the magnetic field (in radians)

If the circuit is completely enclosed by the magnetic field, then the angle θ is zero, and the force on the circuit is zero. This is because the forces on each segment of the circuit cancel each other out.

However, if the circuit is not completely enclosed by the magnetic field, then the angle θ is not zero, and the force on the circuit is not zero. In this case, the force on the circuit will tend to move the circuit in a direction that will minimize the angle between the circuit and the magnetic field.

Therefore, the force on a closed circuit in a magnetic field can be zero or non-zero, depending on the geometry of the circuit, the strength of the magnetic field, and the current flowing through the circuit.

iii. What is the average value of alternating current over a complete cycle?

Answer. The average value of alternating current (AC) over a complete cycle is zero. This is because AC is a periodic waveform that oscillates back and forth between positive and negative values. The positive and negative half-cycles of the waveform cancel each other out, so the average value is zero.

To see this mathematically, let's consider the sine wave, which is a common type of AC waveform:

$I(t) = I_{max} \sin(2\pi ft)$

where:

- $I(t)$ is the current at time t
- I_{max} is the maximum amplitude of the current
- f is the frequency of the AC
- t is time

The average value of $I(t)$ over a complete cycle is given by:

$I_{avg} = \int_0^T I(t)\, dt / T$

where:

- T is the period of the AC waveform (i.e., the time it takes for one complete cycle)

Substituting the sine wave expression for $I(t)$, we get:

$I_{avg} = \int_0^T I_{max} \sin(2\pi ft)\, dt / T$

Using the trigonometric identity $\sin(-\theta) = -\sin(\theta)$, we can simplify this expression to:

$I_{avg} = 2\int_0^T I_{max} \sin^2(\pi ft)\, dt / T$

Using the trigonometric identity $\sin^2(\theta) = (1 - \cos(2\theta))/2$, we can further simplify this expression to:

$I_{avg} = I_{max} / \pi \int_0^T (1 - \cos(2\pi ft))\, dt / T$

Evaluating this integral, we get:

$I_{avg} = I_{max} (1 - 0) / \pi = I_{max} / \pi$

Therefore, the average value of AC over a complete cycle is zero.

iv. An electron is accelerated through a potential difference of 100 volt. Calculate de-Broglie wavelength in nm.

Answer. The de-Broglie wavelength of an electron accelerated through a potential difference of 100 volts is approximately 0.123 nanometers.

To calculate this, we can use the following equation:

$\lambda = h / (p * \sqrt{(2m * e * V)})$

where:

- λ is the de-Broglie wavelength in meters
- h is Planck's constant, equal to 6.626×10^{-34} joule-seconds
- p is the momentum of the electron in kilograms meters per second
- m is the mass of the electron, equal to 9.109×10^{-31} kilograms
- e is the charge of the electron, equal to 1.602×10^{-19} coulombs
- V is the potential difference in volts

First, we need to calculate the momentum of the electron. We can do this using the following equation:

$p = \sqrt{(2m * e * V)}$

Plugging in the values for m, e, and V, we get:

$p = \sqrt{(2 * 9.109 \times 10^{-31} \text{ kilograms} * 1.602 \times 10^{-19} \text{ coulombs} * 100 \text{ volts})}$

$p \approx 2.22 \times 10^{-24}$ kilograms meters per second

Now we can calculate the de-Broglie wavelength using the first equation:

$\lambda = 6.626 \times 10^{-34}$ joule-seconds / (2.22×10^{-24} kilograms meters per second * $\sqrt{(2 * 9.109 \times 10^{-31} \text{ kilograms} * 1.602 \times 10^{-19} \text{ coulombs} * 100 \text{ volts})}$)

$\lambda \approx 1.226 \times 10^{-10}$ meters

Converting this to nanometers, we get:

$\lambda \approx 0.1226$ nanometers

Therefore, the de-Broglie wavelength of an electron accelerated through a potential difference of 100 volts is approximately 0.123 nanometers.

v. If friction is made zero for a road, can a vehicle move safely on this road?

Answer. No, a vehicle cannot move safely on a road with zero friction. Friction is necessary for several reasons, including:

- Grip: Friction provides the grip between the tires of the vehicle and the road, which is essential for accelerating, braking, and turning. Without friction, the tires would simply spin and the vehicle would not be able to move.
- Stopping: Friction is also necessary for stopping a vehicle. When the brakes are applied, the brake pads rub against the wheels and create friction, which slows the vehicle down. Without friction, the vehicle would not be able to stop.
- Cornering: When a vehicle turns, the tires must generate friction against the road in order to change direction. Without friction, the vehicle would simply slide straight ahead.

In addition to these practical considerations, friction is also important for the safety of the vehicle's occupants. In the event of a collision, friction helps to absorb some of the impact and reduce the risk of injury.

Therefore, while friction can make driving more challenging in some conditions, it is an essential safety feature that cannot be eliminated.

vi. State the formula giving relation between electric field intensity and potential gradient.

Answer. The electric field intensity and the potential gradient are related by the following formula:

$E = -\nabla V$

where:

- E is the electric field intensity in volts per meter (V/m)
- ∇V is the gradient of the electric potential in volts per meter (V/m)

The gradient of a scalar field is a vector that points in the direction of the greatest rate of change of the scalar field and has a magnitude equal to the rate of change. In the case of the electric potential, the gradient points in the direction of the greatest rate of decrease of the electric potential.

The negative sign in the formula above indicates that the electric field intensity is always directed in the direction of the greatest decrease of the electric potential. This is because the electric field is a force field, and a force always acts to move an object from an area of high potential to an area of low potential.

Therefore, the formula $E = -\nabla V$ states that the electric field intensity is always directed towards the negative gradient of the electric potential.

vii. Calculate the velocity of a particle performing S.H.M. after 1 second, if its displacement is given by x = 5 sin (πt/3) m.

Answer. The velocity of a particle performing simple harmonic motion (SHM) is given by the following equation:

v = ω√(A^2 - x^2)

where:

- v is the velocity of the particle in meters per second (m/s)
- ω is the angular frequency of the SHM in radians per second (rad/s)
- A is the amplitude of the SHM in meters (m)
- x is the displacement of the particle from its equilibrium position in meters (m)

In this case, we are given that the displacement of the particle is $x = 5 \sin(\pi t/3)$ m. The amplitude of the SHM is A = 5 m. To find the angular frequency ω, we can use the following equation:

$\omega = \sqrt{(k/m)}$

where:

- k is the spring constant of the system in Newtons per meter (N/m)
- m is the mass of the particle in kilograms (kg)

In this case, we are not given the values of k or m, so we cannot calculate the angular frequency ω directly. However, we can still calculate the velocity of the particle at a specific time t.

For example, if we want to calculate the velocity of the particle after 1 second (i.e., t = 1 s), we can substitute the values of A and x into the equation for v:

$v = \omega\sqrt{(A^2 - x^2)} = \omega\sqrt{(5^2 - (5 \sin(\pi/3))^2)}$

Since we do not know the value of ω, we cannot calculate the exact value of v. However, we can express v in terms of ω:

$v = \omega\sqrt{(25 - 25/4)} = \omega\sqrt{(100/4)} = \omega\sqrt{(25)} = 5\omega$ m/s

Therefore, the velocity of the particle after 1 second is 5ω m/s, where ω is the angular frequency of the SHM in radians per second.

viii. Write the mathematical formula for Bohr magneton for an electron revolving in nth orbit.

Answer. The mathematical formula for the Bohr magneton for an electron revolving in the nth orbit is:

$\mu_B = e\hbar/4\pi m$

where:

- μ_B is the Bohr magneton in joules per tesla (J/T)

- e is the elementary charge in coulombs (C)
- ħ is the reduced Planck constant in joule-seconds (J·s)
- m is the mass of the electron in kilograms (kg)

The Bohr magneton is a fundamental constant of nature that defines the magnetic moment of an electron in a hydrogen atom. The magnetic moment of an electron is a measure of its ability to generate a magnetic field. The Bohr magneton is a very small quantity, with a value of approximately 9.274 × 10^-24 J/T.

The formula for the Bohr magneton shows that the magnetic moment of an electron is proportional to its charge and angular momentum. The angular momentum of an electron in a hydrogen atom is quantized, meaning that it can only take on certain discrete values. The nth orbit of an electron in a hydrogen atom corresponds to a particular value of angular momentum. Therefore, the magnetic moment of an electron in the nth orbit is also quantized.

The Bohr magneton is an important concept in physics because it is used to explain the magnetic properties of materials. The magnetic properties of materials are determined by the magnetic moments of the individual atoms in the material. The Bohr magneton provides a way to calculate the magnetic moment of an individual atom, which can then be used to calculate the magnetic properties of the material as a whole.

SECTION B

Attempt any EIGHT questions of the following:

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

Answer. The coefficient of viscosity is a measure of a fluid's resistance to flow. It is defined as the tangential force per unit area required to maintain a constant unit velocity gradient between two parallel layers of fluid. The SI unit of viscosity is the pascal-second (Pa·s), which is equivalent to the newton-second per square meter (N·s/m^2).

The formula for the coefficient of viscosity is:

$\eta = F/Av$

where:

- η is the coefficient of viscosity in pascal-seconds (Pa·s)
- F is the tangential force in newtons (N)
- A is the area of the fluid layer in square meters (m^2)
- v is the velocity gradient in seconds per meter (s/m)

The velocity gradient is defined as the rate of change of velocity with respect to distance. In other words, it is the difference in velocity between two points separated by a small distance.

The coefficient of viscosity is a property of the fluid and depends on a number of factors, including the temperature, pressure, and composition of the fluid. In general, the viscosity of a fluid decreases with increasing temperature and increases with increasing pressure. The viscosity of a fluid is also affected by the presence of dissolved substances. For example, the viscosity of water is increased by the presence of salt.

The coefficient of viscosity is an important concept in fluid mechanics and is used in a wide variety of applications, including:

- The design of pumps and pipes
- The study of blood flow
- The development of lubricants
- The prediction of the behavior of fluids in various processes

Question 4. Obtain an expression for magnetic induction of a toroid of 'N' turns about an axis passing through its centre and perpendicular to its plane.

Answer. To calculate the magnetic induction inside a toroid of 'N' turns, we can apply Ampere's law, which states that the circulation of the magnetic field around a closed loop is equal to the permeability of the medium multiplied by the total electric current passing through the loop.

Consider a toroid with a mean radius 'r' and 'N' turns of wire carrying a current 'I'. Ampere's law for a closed loop can be written as:

$$\oint B \cdot dl = \mu_0 I$$

where:

B is the magnetic field strength at a point on the loop dl is an infinitesimal segment of the loop μ_0 is the permeability of free space ($4\pi \times 10^{-7}$ H/m) I is the total electric current passing through the loop

In the case of a toroid, the magnetic field lines inside the toroid are circular and concentric with the toroid. Therefore, the loop for Ampere's law can be chosen as a circle of radius 'r' inside the toroid. The magnetic field strength at all points on this circle is the same and is tangential to the circle.

For a toroid, the total electric current passing through the loop is 'NI', where N is the number of turns of wire.

Substituting these values into Ampere's law, we get:

$$\oint B \cdot dl = \mu_0 N I$$

The integral on the left-hand side represents the circulation of the magnetic field around the circle. Since the magnetic field is tangential to the circle, the integral can be simplified to:

$2\pi rB = \mu_0 NI$

Solving for B, the magnetic induction inside the toroid, we get:

$B = \mu_0 NI/(2\pi r)$

Question 5. State and prove principle of conservation of angular momentum.

Answer. The principle of conservation of angular momentum states that the total angular momentum of an isolated system remains constant unless acted upon by an external torque. Angular momentum is a measure of an object's rotational motion, and it is defined as the product of an object's moment of inertia and its angular velocity.

Proof of the principle of conservation of angular momentum

The angular momentum of an object can be expressed as:

$L = I\omega$

where:

- L is the angular momentum of the object
- I is the object's moment of inertia
- ω is the object's angular velocity

The time rate of change of angular momentum is equal to the torque acting on the object:

$\tau = dL/dt$

where:

- τ is the torque acting on the object

Combining these two equations, we get:

$\tau = I\, d\omega/dt$

This equation states that the torque acting on an object is equal to the rate of change of its angular momentum.

If no external torque acts on an object, then the rate of change of its angular momentum is zero, and therefore its angular momentum is constant. This is the principle of conservation of angular momentum.

Examples of the principle of conservation of angular momentum

The principle of conservation of angular momentum has many applications in physics and engineering. Here are a few examples:

- Ice skaters spinning with their arms outstretched

If an ice skater spins with their arms outstretched and then pulls their arms in, they will spin faster. This is because the moment of inertia of the skater decreases when their arms are pulled in, and therefore their angular momentum must remain constant. As a result, their angular velocity must increase.

- A planet orbiting the sun

The angular momentum of a planet orbiting the sun remains constant as it orbits. This is because the gravitational force between the planet and the sun does not exert a torque on the planet.

- A spinning top

A spinning top will continue to spin for a long time if there is no friction. This is because the principle of conservation of angular momentum prevents the top from slowing down. However, if there is friction between the top and the ground, the torque from friction will eventually cause the top to slow down and stop spinning.

Question 6. Obtain an expression for equivalent capacitance of two capacitors C1 and C2 connected in series.

Answer. When two capacitors C1 and C2 are connected in series, the equivalent capacitance (Ceq) is given by the following formula:

$C_{eq} = C_1 * C_2 / (C_1 + C_2)$

This formula is derived from the fact that the total charge stored in the series combination of capacitors is equal to the charge stored in each capacitor individually. The total charge stored in a capacitor is given by:

$Q = CV$

where:

- Q is the charge stored in the capacitor
- C is the capacitance of the capacitor
- V is the voltage across the capacitor

In a series circuit, the voltage across each capacitor is the same. Therefore, we can write the following equations:

$Q_1 = C_1V$

$Q_2 = C_2V$

where:

- Q1 is the charge stored in capacitor C1
- Q2 is the charge stored in capacitor C2

Since the total charge is the same in each capacitor, we can equate these two equations:

$C_1V = C_2V$

This simplifies to:

$C_1 = C_2$

Since the voltage across each capacitor is the same, the equivalent capacitance is simply the sum of the individual capacitances:

Ceq = C1 + C2

Therefore, the equivalent capacitance of two capacitors C1 and C2 connected in series is given by the formula:

Ceq = C1 * C2 / (C1 + C2)

Question 7. Explain, why the equivalent inductance of two coils connected in parallel is less than the inductance of either of the coils.

Answer. The equivalent inductance of two coils connected in parallel is less than the inductance of either of the coils because the parallel connection provides multiple paths for the current to flow through, effectively reducing the overall inductance of the circuit.

Inductance is a property of an electrical conductor that opposes changes in current flow. It is caused by the magnetic field generated by the current flowing through the conductor. The larger the inductance, the greater the opposition to changes in current.

When two coils are connected in parallel, the current has two paths to follow, one through each coil. This means that the overall magnetic field generated by the current is reduced, and therefore the inductance of the circuit is also reduced.

The exact amount by which the equivalent inductance is reduced depends on the values of the individual inductances of the coils. However, in general, the equivalent inductance will always be less than the inductance of either of the coils.

Here's a more intuitive explanation:

Imagine two water pipes connected in parallel. Water flowing through the pipes encounters resistance due to the friction between the water and the pipe walls. The larger the pipe, the less resistance the water encounters.

Similarly, in an electrical circuit, current flowing through a coil encounters resistance due to the inductance of the coil. The larger the inductance, the greater the resistance to changes in current.

When two coils are connected in parallel, the current has two paths to follow, each with its own resistance. This effectively reduces the overall resistance of the circuit, similar to how two water pipes connected in parallel reduce the overall resistance to water flow.

As a result, the equivalent inductance of two coils connected in parallel is less than the inductance of either of the coils.

Question 8. How will you convert a moving coil galvanometer into an ammeter?

Answer. A moving coil galvanometer can be converted into an ammeter by connecting a shunt resistor in parallel with the galvanometer coil. The shunt resistor is a low-resistance resistor that diverts most of the current around the galvanometer coil, allowing only a small portion of the current to flow through it. This protects the galvanometer coil from damage and allows it to measure larger currents.

The value of the shunt resistor is chosen according to the desired range of the ammeter. For example, if you want to convert a galvanometer with a full-scale deflection of 10 mA into an ammeter with a full-scale deflection of 1 A, you would need to use a shunt resistor with a resistance of 0.01 Ω.

Here is a step-by-step guide on how to convert a moving coil galvanometer into an ammeter:

1. Identify the terminals of the galvanometer coil. These are usually labeled with the letters "G" and "P".
2. Connect the shunt resistor in parallel with the galvanometer coil. Make sure that the shunt resistor is connected to the correct terminals (G and P).

3. Calibrate the ammeter. To do this, you will need to connect the ammeter to a known current source and adjust the shunt resistor until the galvanometer needle deflects to the full-scale deflection.

Once you have calibrated the ammeter, you can use it to measure currents up to its full-scale range.

Question 9. A 100 Ω resistor is connected to a 220 V, 50 Hz supply. Calculate:
i. r.m.s. value of current and
ii. net power consumed over the full cycle

Answer. Given:

- Voltage (V) = 220 V
- Frequency (f) = 50 Hz
- Resistance (R) = 100 Ω

i. Calculate the rms value of current (Irms)

The rms value of current is given by the formula:

Irms = V / (sqrt(2) * R)

Substituting the given values:

Irms = 220 V / (sqrt(2) * 100 Ω) ≈ 1.555 A

ii. Calculate the net power consumed over the full cycle (Pavg)

The net power consumed over the full cycle is given by the formula:

Pavg = (V^2) / (2 * R)

Substituting the given values:

Pavg = $(220\ V)^2 / (2 * 100\ \Omega) \approx 242\ W$

Therefore:

- The rms value of current is 1.555 A.
- The net power consumed over the full cycle is 242 W.

Question 10. A bar magnet of mass 120 g in the form of a rectangular parallelepiped, has dimensions l = 40 mm, b = 100 mm and h = 80 mm, with its dimension '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.

Answer. Given:

- Mass (m) = 120 g = 0.12 kg
- Length (l) = 40 mm = 0.04 m
- Breadth (b) = 100 mm = 0.1 m
- Height (h) = 80 mm = 0.08 m
- Period (T) = π seconds
- Magnetic moment (M) = 3.4 Am^2

Solution:

1. Calculate the moment of inertia (I) of the bar magnet.

For a rectangular parallelepiped, the moment of inertia about an axis passing through its center and perpendicular to its plane is given by:

$I = (1/12) * m * (b^2 + h^2)$

Substituting the given values:

$I = (1/12) * 0.12\ kg * ((0.1\ m)^2 + (0.08\ m)^2) \approx 8.333 \times 10^{(-4)}\ kg \cdot m^2$

2. Calculate the angular frequency (ω) of the oscillations.

The angular frequency is related to the period by the formula:

$\omega = 2\pi/T$

Substituting the given value of T:

$\omega = 2\pi/\pi \approx 2\ rad/s$

3. Calculate the influencing magnetic field (B).

The influencing magnetic field is the magnetic field that causes the bar magnet to oscillate. It is given by the formula:

$B = (2\pi * I * \omega) / (M * \sin(\omega T/2))$

Substituting the values of I, ω, and M:

$B = (2\pi * 8.333 \times 10^{(-4)}\ kg \cdot m^2 * 2\ rad/s) / (3.4\ Am^2 * \sin(\pi/2)) \approx 2.4 \times 10^{(-2)}\ T$

Therefore, the influencing magnetic field is $2.4 \times 10^{(-2)}$ T.

Question 11. Distinguish between free vibrations and forced vibrations (Two points).

Answer. Free vibrations and forced vibrations are two types of mechanical vibrations.

Free vibrations are vibrations that occur in a system after an initial disturbance, and then die out over time due to damping. For example, if you pluck a guitar string, the string will vibrate freely until the energy of the vibration is dissipated by damping.

Forced vibrations are vibrations that are maintained by an external periodic force. For example, if you pluck a guitar string and then hold your finger on the string, the string will vibrate with a frequency that is determined by the frequency of your finger plucking the string.

Here is a table that summarizes the key differences between free vibrations and forced vibrations:

Feature	Free vibrations	Forced vibrations
Cause	Initial disturbance	External periodic force
Damping	Damping is present	Damping may or may not be present
Frequency	Frequency is determined by the natural frequency of the system	Frequency is determined by the frequency of the external periodic force
Amplitude	Amplitude decays over time	Amplitude can be maintained by the external periodic force

In addition to the key differences listed in the table, there are a few other important points to note about free vibrations and forced vibrations:

- Free vibrations can occur in any system that has a natural frequency, while forced vibrations can only occur in systems that are subjected to an external periodic force.

- The amplitude of free vibrations decays over time, while the amplitude of forced vibrations can be maintained by the external periodic force.
- The frequency of free vibrations is determined by the natural frequency of the system, while the frequency of forced vibrations is determined by the frequency of the external periodic force.

Question 12. Compare the rate of loss of heat from a metal sphere at 827°C with rate of loss of heat from the same at 427°C, if the temperature of surrounding is 27°C.

Answer. The rate of heat loss from a body is directly proportional to the temperature difference between the body and its surroundings. Therefore, the rate of heat loss from a metal sphere at 827°C will be much greater than the rate of heat loss from the same sphere at 427°C, if the temperature of the surrounding is 27°C.

This is because the temperature difference between the sphere at 827°C and the surroundings is 800°C, while the temperature difference between the sphere at 427°C and the surroundings is 400°C.

The exact ratio of the rates of heat loss can be calculated using Newton's law of cooling, which states that:

$Q = kA\Delta T$

where:

- Q is the rate of heat loss
- k is the constant of proportionality (also known as the heat transfer coefficient)
- A is the surface area of the sphere
- ΔT is the temperature difference between the sphere and the surroundings

Since the sphere is the same in both cases, the surface area (A) will be the same. Additionally, the constant of proportionality (k) will also be the same for both cases. Therefore, the only variable that will affect the rate of heat loss is the temperature difference (ΔT).

As mentioned earlier, the temperature difference between the sphere at 827°C and the surroundings is 800°C, while the temperature difference between the sphere at 427°C and the surroundings is 400°C. Therefore, the rate of heat loss from the sphere at 827°C will be twice the rate of heat loss from the sphere at 427°C.

In other words, the ratio of the rates of heat loss is 2:1.

Question 13. An ideal mono-atomic gas is adiabatically compressed so that its final temperature is twice its initial temperature. Calculate the ratio of final pressure to its initial pressure.

Answer. For an ideal monatomic gas undergoing adiabatic compression, the relationship between the initial pressure (P1), initial temperature (T1), final pressure (P2), and final temperature (T2) is given by:

(P2/P1) = (T2/T1)^γ

where γ is the specific heat capacity ratio, which is 5/3 for monatomic gases.

Since the final temperature is twice the initial temperature (T2 = 2T1), we can substitute this into the equation to get:

(P2/P1) = (2T1/T1)^5/3

Simplifying the expression:

(P2/P1) = 2^(5/3)

Plugging in the value of 2^(5/3) ≈ 3.1498:

(P2/P1) ≈ 3.1498

Therefore, the ratio of final pressure to initial pressure is approximately 3.1498.

Question 14. Disintegration rate of a radio-active sample is 10^{10} per hour at 20 hours from the start. It reduces to 5 *10^9 per hour after 30 hours. Calculate the decay constant.

Answer. Given:

- Initial disintegration rate (R1) = 10^10 per hour
- Final disintegration rate (R2) = 5 × 10^9 per hour
- Time difference (t) = 30 hours - 20 hours = 10 hours

Solution:

The decay constant (λ) is a measure of the rate at which a radioactive sample decays. It is defined as the fraction of the original number of nuclei that decay per unit time.

The decay constant can be calculated using the formula:

λ = ln(R1/R2) / t

Substituting the given values:

λ = ln(10^10 / 5 × 10^9) / 10 hours ≈ 0.0693 hours^(-1)

Therefore, the decay constant is approximately 0.0693 hours^(-1).

SECTION C

Attempt any EIGHT questions of the following:

Question 15. Derive laws of reflection of light using Huygens' principle.

Answer. Huygens' principle is a fundamental concept in wave optics that states that every point on a wavefront acts as a secondary source of waves. These secondary waves spread out in all directions, and the new wavefront is the envelope of these secondary waves.

Huygens' principle can be used to derive the laws of reflection of light. The laws of reflection state that:

1. The incident ray, the reflected ray, and the normal to the reflecting surface at the point of incidence all lie in the same plane.

2. The angle of incidence (i) is equal to the angle of reflection (r).

To derive these laws, consider a plane wave incident on a reflecting surface. Let A be a point on the wavefront, and let B be the point of incidence on the reflecting surface. According to Huygens' principle, every point on the wavefront, including A, acts as a secondary source of waves. These secondary waves spread out in all directions, and the new wavefront is the envelope of these secondary waves.

Let C be a point on the reflected wavefront, and let D be the point of intersection of the normal to the reflecting surface at B with the reflected wavefront. Since the secondary waves from all points on the wavefront are in phase, the envelope of these waves will be a straight line. Therefore, the incident ray, the reflected ray, and the normal to the reflecting surface at the point of incidence all lie in the same plane.

To prove that the angle of incidence is equal to the angle of reflection, consider the triangles ABC and BCD. These triangles are congruent, since they are both right triangles with the same hypotenuse (AB) and the same angle at C (a right angle). Therefore, the corresponding angles in these triangles are equal. This means that the angle of incidence (i) is equal to the angle of reflection (r).

Huygens' principle provides a powerful tool for understanding the behavior of waves, including light waves. By applying Huygens' principle, we can derive the laws of reflection of light, which are essential for understanding how light behaves in optical systems.

Question 16. State postulates of Bohr's atomic model.

Answer. Here are the postulates of Bohr's atomic model:

1. Electrons in an atom revolve around the nucleus in fixed circular paths called orbits or shells.
2. Each orbit is associated with a specific energy level, and electrons can only move between orbits by absorbing or emitting energy in the form of photons.
3. The angular momentum of an electron in an orbit is quantized, meaning that it can only have certain discrete values.
4. Electrons in the lowest energy level (ground state) are stable and do not emit radiation.
5. When an electron absorbs energy, it moves to a higher energy level (excited state). When an electron returns to a lower energy level, it emits energy in the form of a photon, with the frequency of the photon being equal to the energy difference between the two levels.

These postulates provided a significant improvement over the earlier Rutherford model, which did not explain the stability of atoms or the emission of spectral lines. Bohr's model was able to explain these phenomena, and it laid the foundation for the development of quantum mechanics.

Here is a table summarizing the postulates of Bohr's atomic model:

Postulate	Description
1	Electrons revolve in fixed circular orbits.
2	Each orbit has a specific energy level.
3	Angular momentum is quantized.
4	Electrons in the ground state are stable.
5	Energy absorption leads to higher energy levels.

Question 17. Define and state unit and dimensions of :

i. Magnetization

Answer. Here is the definition, unit, and dimensions of magnetization:

Magnetization (M) is a measure of the strength and direction of the magnetic field within a material. It is defined as the net magnetic moment per unit volume of the material.

The SI unit of magnetization is the ampere per meter (A/m).

The dimensions of magnetization are [L^(-1)I].

Here is a table summarizing the definition, unit, and dimensions of magnetization:

Property	Definition	Unit	Dimensions
Magnetization (M)	Net magnetic moment per unit volume	A/m	L^(-1)I

ii. Magnetic susceptibility

Answer. Magnetic susceptibility is a measure of the extent to which a material can be magnetized. It is a dimensionless quantity that is defined as the ratio of the magnetization (M) of a material to the applied magnetic field (H). In other words, magnetic susceptibility is a measure of how easily a material can be magnetized.

The magnetic susceptibility of a material is typically denoted by the Greek letter χ (chi). In SI units, the magnetic susceptibility is measured in amperes per meter (A/m). However, it is often more convenient to use the dimensionless form of χ, which is simply a number.

The magnetic susceptibility of a material can be positive, negative, or zero. A material with a positive magnetic susceptibility is said to be paramagnetic, while a material with a negative magnetic susceptibility is said to be diamagnetic. A material with a magnetic susceptibility of zero is said to be non-magnetic.

Paramagnetic materials have a tendency to be magnetized in the same direction as the applied magnetic field. This is because the atoms in paramagnetic materials have unpaired electrons, which are small magnets. When an external magnetic field is applied, the unpaired electrons align themselves with the field, creating a net magnetic moment in the same direction as the field.

Diamagnetic materials have a tendency to be magnetized in the opposite direction as the applied magnetic field. This is because the atoms in diamagnetic materials have all of their electrons paired. When an external magnetic field is applied, the paired electrons create a small magnetic field that opposes the applied field.

Non-magnetic materials have no net magnetic moment, regardless of the applied magnetic field. This is because the atoms in non-magnetic materials have all of their electrons paired, and the paired electrons create a magnetic field that cancels out the magnetic field of the nucleus.

The magnetic susceptibility of a material is a temperature-dependent property. In general, the magnetic susceptibility of a material decreases as the temperature increases. This is because the thermal energy of the atoms increases with temperature, and this can cause the atoms to vibrate more freely. The increased vibration can disrupt the alignment of the atoms, which can reduce the magnetic susceptibility of the material.

Magnetic susceptibility is an important property in many applications. For example, it is used in the design of magnetic sensors, which are used to measure the strength of magnetic fields. It is also used in the development of magnetic materials, such as superconductors, which have a very high magnetic susceptibility.

Question 18. With neat labelled circuit diagram, describe an experiment to study the characteristics of photoelectric effect.

Question 19. Explain the use of potentiometer to determine internal resistance of a cell.

Answer. A potentiometer is a device that can be used to measure the internal resistance of a cell. It works by comparing the voltage drop across a known resistance to the voltage drop across the cell.

Principle of Operation

The principle of operation of a potentiometer is based on the fact that the voltage drop across a resistor is directly proportional to the current flowing through it. This can be expressed by Ohm's law:

$V = IR$

where:

- V is the voltage drop across the resistor (in volts)
- I is the current flowing through the resistor (in amps)
- R is the resistance of the resistor (in ohms)

When a potentiometer is used to measure the internal resistance of a cell, the known resistance is called the "rheostat." The rheostat is a variable resistor that can be adjusted to change the current flowing through the circuit.

Steps to Measure Internal Resistance

1. Connect the cell and the rheostat in a series circuit.
2. Connect the potentiometer in parallel with the cell and the rheostat.
3. Adjust the rheostat until the galvanometer needle in the potentiometer deflects to zero.
4. Measure the current flowing through the circuit.
5. Measure the voltage drop across the cell.
6. Calculate the internal resistance of the cell using the following formula:

$r = V / I$

where:

- r is the internal resistance of the cell (in ohms)
- V is the voltage drop across the cell (in volts)
- I is the current flowing through the circuit (in amps)

Advantages of Using a Potentiometer

There are several advantages to using a potentiometer to measure the internal resistance of a cell:

- It is a very accurate method of measurement.
- It is a non-destructive method of measurement, meaning that it does not damage the cell.
- It is a relatively simple method of measurement.

Applications of Measuring Internal Resistance

Measuring the internal resistance of a cell is important for a number of applications, including:

- Determining the efficiency of a cell
- Predicting the performance of a cell under load
- Monitoring the health of a cell

Question 20. Explain the working of n-p-n transistor in common base configuration.

Answer. Here is an explanation of the working of an n-p-n transistor in common base configuration:

Common Base Configuration

In the common base configuration of an n-p-n transistor, the base terminal is common to both the input and output signals. The emitter is forward biased, and the collector is reverse biased. This configuration is characterized by high input impedance and low output impedance.

Working Principle

When a small signal is applied to the emitter, it causes a large change in the collector current. This is because the emitter-base junction is forward biased, which allows electrons to flow easily from the emitter to the base. The base is very thin, so most of these electrons are able to drift across the base region and into the collector. This results in a large increase in the collector current.

Current Amplification

The current amplification factor of a transistor in common base configuration is denoted by the Greek letter alpha (α). Alpha is defined as the ratio of the collector current (IC) to the emitter current (IE). In other words, alpha tells us how much the transistor amplifies the current. For n-p-n transistors in common base configuration, alpha is typically between 0.9 and 0.99. This means that the transistor can amplify the current by a factor of 10 to 100.

Applications

Common base configuration is not as common as other transistor configurations, such as common emitter and common collector. However, it is still used in some applications where high input impedance and low output impedance are required. For example, common base transistors are sometimes used in voltage amplifiers and radio frequency amplifiers.

Summary

The common base configuration of an n-p-n transistor is characterized by high input impedance and low output impedance. The transistor amplifies the current by a factor of 10 to 100, and it is used in some applications where these characteristics are required.

Question 21. State the differential equation of linear S.H.M. Hence, obtain expression for :
i. Acceleration

Answer. Here is the differential equation of linear S.H.M. and the expressions for acceleration, velocity, and displacement:

Differential Equation of Linear S.H.M.

The differential equation of linear simple harmonic motion (S.H.M.) is given by:

$d^2x/dt^2 + (k/m)x = 0$

where:

- x is the displacement from equilibrium (in meters)
- t is time (in seconds)
- m is the mass of the object (in kilograms)
- k is the force constant (in Newtons per meter)

The force constant (k) is a measure of the stiffness of the spring or restoring force. The larger the force constant, the stiffer the spring and the faster the object will oscillate.

Expression for Acceleration

The acceleration of an object in S.H.M. is given by the second derivative of its displacement with respect to time:

$a = d^2x/dt^2$

Substituting the differential equation of S.H.M. into this expression, we get:

$a = -(k/m)x$

This means that the acceleration of an object in S.H.M. is always directed towards the equilibrium position and is proportional to the displacement from equilibrium.

Expression for Velocity

The velocity of an object in S.H.M. is given by the first derivative of its displacement with respect to time:

$v = dx/dt$

Substituting the differential equation of S.H.M. into this expression, we get:

$v = \pm\sqrt{(k/m)(x^2 - A^2)}$

where:

- A is the amplitude of the oscillation (in meters)

The ± sign in front of the square root indicates that the velocity can be positive or negative, depending on the direction of motion.

Expression for Displacement

The displacement of an object in S.H.M. is given by:

$x = A\cos(\omega t + \varphi)$

where:

- ω is the angular frequency of the oscillation (in radians per second)
- φ is the phase angle (in radians)

The angular frequency (ω) is related to the force constant (k) and the mass (m) of the object by the following equation:

$\omega = \sqrt{(k/m)}$

The phase angle (φ) is a measure of the initial displacement of the object from equilibrium.

ii. Velocity

Answer. Here is the expression for velocity in linear simple harmonic motion (S.H.M.):

The velocity of an object in S.H.M. is given by the first derivative of its displacement with respect to time:

$v = dx/dt$

where:

- x is the displacement from equilibrium (in meters)
- t is time (in seconds)

Substituting the differential equation of S.H.M. into this expression, we get:

$v = \pm\sqrt{(k/m)(x^2 - A^2)}$

where:

- k is the force constant (in Newtons per meter)
- m is the mass of the object (in kilograms)
- A is the amplitude of the oscillation (in meters)

The ± sign in front of the square root indicates that the velocity can be positive or negative, depending on the direction of motion.

Additional Notes

- The velocity of an object in S.H.M. is maximum at its equilibrium position (x = 0) and zero at its extreme positions (x = ±A).
- The velocity of an object in S.H.M. is directly proportional to the square root of its amplitude (A) and inversely proportional to the square root of its mass (m).

Question 22. Two tuning forks of frequencies 320 Hz and 340 Hz are sounded together to produce sound wave. The velocity of sound in air is 326.4 m/s. Calculate the difference in wavelengths of these waves.

Answer. Here is the solution to the problem:

Given:

- Frequency of first tuning fork (f1) = 320 Hz
- Frequency of second tuning fork (f2) = 340 Hz

- Velocity of sound in air (v) = 326.4 m/s

Solution:

The wavelength of a sound wave is given by the formula:

$\lambda = v / f$

where:

- λ is the wavelength (in meters)
- v is the velocity (in meters per second)
- f is the frequency (in Hertz)

Substituting the given values for f1 and v, we get the wavelength of the first sound wave:

$\lambda_1 = 326.4$ m/s / 320 Hz ≈ 1.016875 meters

Substituting the given values for f2 and v, we get the wavelength of the second sound wave:

$\lambda_2 = 326.4$ m/s / 340 Hz ≈ 0.96 m

Finally, we can calculate the difference in wavelengths:

difference = $\lambda_1 - \lambda_2 \approx 0.056875$ meters ≈ 5.6875 cm

Therefore, the difference in wavelengths of the two sound waves is approximately 5.6875 cm.

Question 23. In a biprism experiment, the fringes are observed in the focal plane of the eye-piece at a distance of 1.2 m from the slit. The distance between the central bright band and the 20th bright band is 0.4 cm. When a convex lens is placed between the biprism and the eye-piece, 90 cm from the eye-piece, the distance between the two virtual magnified images is found to be 0.9 cm. Determine the wavelength of light used.

Answer. here is the solution to the problem:

Given:

- Distance between slit and eye-piece (d1) = 1.2 m
- Distance between central bright band and 20th bright band (y) = 0.4 cm
- Distance between convex lens and eye-piece (D) = 0.9 m
- Distance between two virtual magnified images (d2) = 0.9 cm

Solution:

1. Calculate the distance between two bright bands (x)

The distance between the central bright band and the 20th bright band is given by:

$x = 20y = 20 * 0.4 \text{ cm} = 8 \text{ cm}$

2. Calculate the focal length of the convex lens (f)

The focal length of the convex lens can be calculated using the formula:

$f = (d1 * d2) / (d1 + d2 - D)$

Substituting the given values, we get:

$f = (1.2 \text{ m} * 0.9 \text{ m}) / (1.2 \text{ m} + 0.9 \text{ m} - 0.9 \text{ m}) = 1.08 \text{ m}$

3. Calculate the wavelength of light (λ)

The wavelength of light can be calculated using the formula:

$\lambda = (x * f) / (d1 * d2)$

Substituting the given values, we get:

$\lambda = (8 \text{ cm} * 1.08 \text{ m}) / (1.2 \text{ m} * 0.9 \text{ m}) = 0.00072 \text{ m} = 720 \text{ nm}$

Therefore, the wavelength of light used is approximately 720 nm.

Question 24. 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.

Answer. Here is the solution to the problem:

Given:

- Force per unit length (f) = 4.76 × 10^(-2) N/m
- Distance between wires (d) = 1.35 cm = 0.135 m
- Current in each wire (I) = unknown

The force per unit length between two long parallel wires carrying equal currents is given by the formula:

f = μ_0/4π(I^2/d)

where:

- μ_0 is the permeability of free space (4π × 10^(-7) H/m)

Substituting the given values, we get:

4.76 × 10^(-2) N/m = μ_0/4π(I^2/0.135 m)

Solving for I, we get:

I = √(4πf * d * μ_0) = √(4π * 4.76 × 10^(-2) N/m * 0.135 m * 4π × 10^(-7) H/m)

Simplifying the expression:

I ≈ 56.68 A

Therefore, the current flowing through each wire is approximately 56.68 A.

Question 25. An alternating voltage given by e = 140 sin (314.2 t) is connected across a pure resistor of 50Ω . Calculate :
i. the frequency of the source

Answer. Here is the solution to the problem:

Given:

- Alternating voltage (e) = 140 sin (314.2t)
- Resistance (R) = 50 Ω

Solution:

1. Calculate the angular frequency (ω)

The angular frequency of a sinusoidal wave is given by the formula:

$\omega = 2\pi f$

where:

- f is the frequency (in Hz)

Substituting the given value of f, we get:

$\omega = 2\pi * 314.2 \text{ Hz} \approx 986.6 \text{ rad/s}$

2. Calculate the peak current (I0)

The peak current through a resistor connected to an AC source is given by the formula:

$I0 = E0/R$

where:

- E0 is the peak voltage (in volts)

Substituting the given values, we get:

$I_0 = 140 \text{ V} / 50\ \Omega = 2.8 \text{ A}$

3. Calculate the root mean square (rms) current (Irms)

The root mean square (rms) current of a sinusoidal wave is given by the formula:

$I_{rms} = I_0/\sqrt{2}$

Substituting the given value of I0, we get:

$I_{rms} = 2.8 \text{ A} / \sqrt{2} \approx 1.98 \text{ A}$

Therefore, the rms current through the resistor is approximately 1.98 A.

ii. the r.m.s current through the resistor

Answer. The root-mean-square (rms) current through a resistor connected to an AC source can be calculated using the formula:

$I_{rms} = E_0 / \sqrt{2}R$

where:

- Irms is the rms current (in amperes)
- E0 is the peak voltage (in volts)
- R is the resistance (in ohms)

Given that the peak voltage is 140 V and the resistance is 50 Ω, the rms current can be calculated as follows:

$I_{rms} = 140 \text{ V} / \sqrt{2} * 50\ \Omega \approx 1.98 \text{ A}$

Therefore, the rms current through the resistor is approximately 1.98 A.

Question 26. An electric dipole consists of two opposite charges each of magnitude 1 μC, separated by 2 cm. The dipole is placed in an

external electric field of 105 N/C.
Calculate the :
i. maximum torque experienced by the dipole and

Answer. Here is the solution to the problem:

Given:

- Charge of each dipole (q) = 1 μC = 1 × 10^(-6) C
- Separation between charges (d) = 2 cm = 0.02 m
- Electric field strength (E) = 105 N/C

Solution:

1. Calculate the dipole moment (p)

The dipole moment of an electric dipole is defined as the product of the magnitude of the charge on each dipole and the separation between the charges. It is a vector quantity that points from the negative charge to the positive charge.

The formula for the dipole moment is:

p = qd

Substituting the given values, we get:

p = (1 × 10^(-6) C)(0.02 m) = 2 × 10^(-8) C·m

2. Calculate the maximum torque (τmax)

The maximum torque experienced by an electric dipole in an external electric field is given by the formula:

τmax = pE sinθ

where:

- θ is the angle between the dipole moment and the electric field

The maximum torque occurs when the dipole moment is perpendicular to the electric field, i.e., $\theta = 90°$.

Substituting the given values, we get:

$\tau_{max} = (2 \times 10^{-8}\ C\cdot m)(105\ N/C)\sin(90°) \approx 2.10 \times 10^{-6}\ N\cdot m$

Therefore, the maximum torque experienced by the dipole is approximately $2.10 \times 10^{-6}\ N\cdot m$.

ii. work done by the external field to turn the dipole through 180°.

Answer. Here is the solution to part ii of the problem:

The work done by an external field to turn an electric dipole through an angle θ is given by the formula:

$W = pE(\cos\theta_1 - \cos\theta_2)$

where:

- p is the dipole moment (in C·m)
- E is the electric field strength (in N/C)
- θ_1 is the initial angle between the dipole moment and the electric field
- θ_2 is the final angle between the dipole moment and the electric field

Given that the dipole is initially aligned with the electric field ($\theta_1 = 0°$) and is rotated through 180° ($\theta_2 = 180°$), we can calculate the work done as follows:

$W = (2 \times 10^{-8}\ C\cdot m)(105\ N/C)(\cos(0°) - \cos(180°)) \approx 4.20 \times 10^{-6}\ J$

Therefore, the work done by the external field to turn the dipole through 180° is approximately 4.20×10^{-6} J.

SECTION D

Attempt any THREE questions of the following:

Question 27. On the basis of kinetic theory of gases obtain an expression for pressure exerted by gas molecules enclosed in a container on its walls.

Answer. Here is an expression for the pressure exerted by gas molecules enclosed in a container on its walls, based on the kinetic theory of gases:

The kinetic theory of gases is a model that describes the behavior of gases based on the motion of the individual gas molecules. According to this theory, gas molecules are constantly moving in random directions at high speeds. They collide with each other and with the walls of the container. It is these collisions that create the pressure exerted by the gas on the walls.

To derive an expression for the pressure, consider a cube-shaped container with sides of length L. The volume of the container is $V = L^3$. There are N gas molecules in the container, each with mass m. The average speed of the gas molecules is v.

The momentum of a single gas molecule is $p = mv$. When a gas molecule collides with a wall, it transfers its momentum to the wall. The rate at which gas molecules collide with a wall is given by:

$R = Nv/4L$

This is because the molecules are moving in random directions, and half of them will be moving towards any given wall. The force exerted by a gas molecule on a wall is equal to the change in its momentum per unit time. Since the molecule's momentum is completely transferred to the wall, the change in momentum is equal to the original momentum. Therefore, the force exerted by a single gas molecule on a wall is:

$F = mv$

The total force exerted on the wall by all of the gas molecules is:

F = Nmv/4L

The pressure is defined as the force per unit area. Since the area of the wall is L^2, the pressure exerted by the gas on the walls is:

P = F/L^2 = Nmv/4L^3

Substituting the expression for V = L^3, we get:

P = Nmv/4V

This is the expression for the pressure exerted by gas molecules enclosed in a container on its walls. It is known as the kinetic theory of gases ideal gas law.

Question 28.
i. Derive an expression for energy stored in the magnetic field in terms of induced current.

Answer. Here is the derivation of an expression for the energy stored in the magnetic field in terms of induced current:

Consider a solenoid with N turns and a self-inductance of L. When a current I flows through the solenoid, it creates a magnetic field inside the solenoid. The energy stored in this magnetic field is given by:

U = 1/2 * L * I^2

where:

- U is the energy stored in the magnetic field (in joules)
- L is the self-inductance of the solenoid (in henries)
- I is the current flowing through the solenoid (in amperes)

The self-inductance of a solenoid is a measure of its ability to store energy in the magnetic field. It is defined as the ratio of the magnetic flux (Φ) linked with the solenoid to the current flowing through it:

$L = \Phi/I$

where:

- Φ is the magnetic flux linked with the solenoid (in webers)

The magnetic flux is a measure of the strength of the magnetic field inside the solenoid. It is given by:

$\Phi = B * A$

where:

- B is the magnetic field strength (in teslas)
- A is the area of the cross-section of the solenoid (in square meters)

Substituting the expressions for L and Φ into the expression for U, we get:

$U = 1/2 * (B * A * I^2)/I$

Simplifying the expression, we get:

$U = 1/2 * B * A * I$

This is an expression for the energy stored in the magnetic field in terms of the magnetic field strength, the area of the cross-section of the solenoid, and the current flowing through the solenoid.

Note that this expression is only valid for a solenoid with a uniform magnetic field. For more complex geometries, the expression for the energy stored in the magnetic field will be more complicated.

ii. A wire 5 m long is supported horizontally at a height of 15 m along

east-west direction. When it is about to hit the ground, calculate the average e.m.f. induced in it. (g = 10 m/s^2)

Answer. Here is the calculation of the average emf induced in the wire:

Given:

- Length of wire (L) = 5 m
- Height of wire above ground (h) = 15 m
- Acceleration due to gravity (g) = 10 m/s^2

Solution:

1. Calculate the velocity of the wire (v)

The velocity of the wire can be calculated using the formula:

$v = \sqrt{2gh}$

Substituting the given values, we get:

$v = \sqrt{2 * 10 \text{ m/s}^2 * 15 \text{ m}} \approx 17.32$ m/s

2. Calculate the magnetic field strength (B)

The magnetic field strength of the Earth is approximately 50 μT (microteslas) at the surface. Since the wire is moving perpendicular to the magnetic field, the magnetic field strength experienced by the wire is also 50 μT.

$B = 50\ \mu T = 50 \times 10^{-6}$ T

3. Calculate the average emf induced in the wire (Eavg)

The average emf induced in the wire can be calculated using the formula:

Eavg = Bvl

Substituting the given values, we get:

Eavg = $(50 \times 10^{-6} \text{ T})(5 \text{ m})(17.32 \text{ m/s}) \approx 0.0433$ V

Therefore, the average emf induced in the wire is approximately 0.0433 V.

Question 29.
i. Derive an expression for the work done during an isothermal process.

Answer. Derivation of the expression for work done during an isothermal process

An isothermal process is a thermodynamic process in which the temperature of the system remains constant throughout the process. This means that the internal energy of the system also remains constant. The only way to change the internal energy of a system during an isothermal process is through work or heat transfer.

The work done during an isothermal process can be calculated using the following formula:

$W = -nRT\ln(V2/V1)$

where:

- W is the work done (in joules)
- n is the number of moles of gas
- R is the gas constant (8.314 J/mol·K)
- T is the temperature (in kelvin)
- V1 is the initial volume of the gas (in cubic meters)
- V2 is the final volume of the gas (in cubic meters)

The negative sign in the formula indicates that the work done is negative if the gas expands and positive if the gas contracts. This is because the gas does work on the surroundings when it expands, and the surroundings do work on the gas when it contracts.

The formula for work done during an isothermal process can be derived from the first law of thermodynamics, which states that the change in internal energy of a system is equal to the heat added to the system plus the work done on the system.

$\Delta U = Q + W$

For an isothermal process, $\Delta U = 0$, so we have:

$W = -Q$

The heat added to the system during an isothermal process can be calculated using the following formula:

$Q = nRT\ln(V2/V1)$

Substituting this expression into the expression for W, we get the formula for work done during an isothermal process:

$W = -nRT\ln(V2/V1)$

ii. 104 J of work is done on certain volume of a gas. If the gas releases 125 kJ of heat, calculate the change in internal energy of the gas.

Answer. Here is the calculation of the change in internal energy of the gas:

Given:

- Work done on the gas (W) = 104 J
- Heat released by the gas (Q) = 125 kJ = 125,000 J

Solution:

The change in internal energy of a system is given by the first law of thermodynamics:

$\Delta U = Q + W$

Substituting the given values, we get:

$\Delta U = 125{,}000\ J + 104\ J \approx 125{,}104\ J$

Therefore, the change in internal energy of the gas is approximately 125,104 J.

Question 30.
i. Obtain the relation between surface energy and surface tension.

Answer. Here's the relation between surface energy and surface tension:

Surface Energy

Surface energy is the energy required to create a new unit of surface area. It is measured in joules per square meter (J/m^2). Surface energy is a property of materials and is related to the intermolecular forces between molecules at the surface.

Surface Tension

Surface tension is the force per unit length that acts along the surface of a liquid. It is measured in newtons per meter (N/m). Surface tension is caused by the cohesive forces between molecules at the surface of a liquid. These forces pull the molecules inward, minimizing the surface area of the liquid.

Relation between Surface Energy and Surface Tension

Surface energy and surface tension are related by the following equation:

$E_s = \gamma A$

where:

- E_s is the surface energy (in J/m^2)
- γ is the surface tension (in N/m)
- A is the surface area (in m^2)

This equation states that the surface energy of a liquid is equal to the product of its surface tension and its surface area.

Example

The surface tension of water is approximately 72 × 10^(-3) N/m. This means that it takes 72 × 10^(-3) J of energy to create one square meter of new surface area of water.

ii. 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.

Answer. Here is the calculation of the work done in blowing a soap bubble to a radius of 1 cm:

Given:

- Radius of soap bubble (r) = 1 cm = 0.01 m
- Surface tension of soap solution (γ) = 2.5 × 10^(-2) N/m

Solution:

The work done in blowing a soap bubble is equal to the surface energy required to create the surface of the bubble. The surface area of a sphere is given by the formula:

$A = 4\pi r^2$

where:

- A is the surface area (in m^2)
- r is the radius (in m)

Substituting the given values, we get:

$A = 4\pi(0.01\ m)^2 \approx 0.001257\ m^2$

The work done in blowing the soap bubble is:

W = γA = (2.5 × 10^(-2) N/m)(0.001257 m^2) ≈ 3.14 × 10^(-5) J

Therefore, the work done in blowing the soap bubble to a radius of 1 cm is approximately 3.14×10^{-5} J.

Question 31. Derive expressions for linear velocity at lowest position, mid-way position and the top-most position for a particle revolving in a vertical circle, if it has to just complete circular motion without string slackening at top.

Answer. Here is the derivation of expressions for linear velocity at the lowest position, mid-way position, and the top-most position for a particle revolving in a vertical circle, if it has to just complete circular motion without the string slackening at the top:

Lowest Position

At the lowest position, the particle is moving towards the center of the circle. The force of gravity is acting directly down on the particle, providing the centripetal force that keeps it moving in a circle. The tension in the string is at its maximum at this point, providing the additional force needed to keep the particle from falling straight down.

The linear velocity of the particle at the lowest position can be calculated using the following formula:

$v = \sqrt{(gr)}$

where:

- v is the linear velocity (in meters per second)
- g is the acceleration due to gravity (9.81 m/s^2)
- r is the radius of the circle (in meters)

Midway Position

At the midway position, the particle is moving horizontally. The force of gravity is still acting down on the particle, but it is now perpendicular to the direction of motion. The tension in the string is still providing some force, but it is now less than at the lowest position.

The linear velocity of the particle at the midway position can be calculated using the following formula:

$v = \sqrt{(gr/2)}$

Top-Most Position

At the top-most position, the particle is moving away from the center of the circle. The force of gravity is now acting directly up on the particle, opposing the centripetal force that keeps it moving in a circle. The tension in the string is at its minimum at this point, providing the additional force needed to keep the particle from flying off in a straight line.

The linear velocity of the particle at the top-most position can be calculated using the following formula:

$v = \sqrt{(gr)}$

This is the same formula as for the lowest position, but this time the particle is moving away from the center of the circle, so the direction of the velocity is reversed.

String Slackening at the Top

If the particle is to just complete circular motion without the string slackening at the top, then the linear velocity at the top-most position must be equal to the critical velocity at that point. The critical velocity is the minimum velocity required for the particle to just make it around the circle without the string slackening. It is given by the formula:

$v_c = \sqrt{(gR)}$

where:

- v_c is the critical velocity (in meters per second)

- R is the distance from the particle to the center of the circle (in meters)

Substituting this formula into the expression for linear velocity at the top-most position, we get:

$\sqrt{(gr)} = \sqrt{(gR)}$

Solving for r, we get:

$r = R$

This means that the particle must be at a distance of R from the center of the circle in order to have a velocity of $\sqrt{(gr)}$ at the top-most position. This is the maximum height that the particle can reach without the string slackening.

In conclusion, the expressions for linear velocity at the lowest position, mid-way position, and the top-most position for a particle revolving in a vertical circle, if it has to just complete circular motion without the string slackening at the top, are as follows:

- Lowest position: $v = \sqrt{(gr)}$
- Midway position: $v = \sqrt{(gr/2)}$
- Top-most position: $v = \sqrt{(gr)}$