Maharashtra Board Class 12 Physics Solutions 2022

SECTION – A

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

(i) The first law of thermodynamics is concerned with the conservation of _______.

(a) momentum

(b) energy

(c) temperature

(d) mass

Answer. (b)

Solution. The correct answer is: (b) energy

(ii) The average value of alternating current over a full cycle is always _______.[I_0 = Peak valve of current]

(a) zero

(b) $I_0 / 2$

(c) $I_0 / \sqrt{2}$

(d) $2I_0$

Answer. (a)

Solution. The correct answer is: (a) zero

(iii) The angle at which maximum torque is exerted by the external uniform electric field on the electric dipole is _______.
(a) 0°
(b) 30°
(c) 45°
(d) 90°

Answer. (d)

Solution. The correct answer is: (d) 90°

(iv) The property of light which does not change, when it travels from one medium to another is _______.
(a) velocity
(b) wavelength
(c) frequency
(d) amplitude

Answer. (c)

Solution. The correct answer is: (c) frequency

(v) The root mean square speed of the molecules of a gas is proportional to _______.[T = Absolute temperature of gas]
(a) $\sqrt{T}$
(b) $1 / \sqrt{T}$
(c) T
(d) 1/T

Answer. (a)

Solution. The correct answer is: (a) $\sqrt{T}$

(vi) The unit Wbm–2 is equal to _______.
(a) henry
(b) watt
(c) dyne
(d) tesla

Answer. (d)

Solution. The correct answer is: (d) tesla

(vii) When the bob performs a vertical circular motion and the string rotates in a vertical plane, the difference in the tension in the string at horizontal position and uppermost position is _______.
(a) mg
(b) 2 mg
(c) 3 mg
(d) 6 mg

Answer. (c)

Solution. The correct answer is: (c) 3 mg

(viii) A liquid rises in glass capillary tube upto a height of 2.5 cm at room temperature. If another glass capillary tube having radius half that of the earlier tube is immersed in the same liquid, the rise of liquid in it will be _______.
(a) 1.25 cm
(b) 2.5 cm
(c) 5 cm
(d) 10 cm

Answer. (c)

Solution. A liquid rises in a glass capillary tube up to a height of 2.5 cm at room temperature. If another glass capillary tube has a radius half that of the earlier tube and is immersed in the same Liquid, the rise of liquid in it will be 5 cm

(ix) In young's double slit experiment the two coherent sources have different amplitudes. If the ratio of maximum intensity to minimum intensity is 16:1, then the ratio of amplitudes of the two source will be _______.
(a) 4 : 1
(b) 5 : 3
(c) 1 : 4
(d) 1 : 16

Answer. (b)

Solution. In young 's double slit experiment the two coherent sources have different amplitudes. If the ratio of maximum intensity to minimum intensity is 16 : 1, then the ratio of amplitudes of the two source will be 5 : 3.

(x) The equation of a simple harmonic progressive wave travelling on a string is y = 8 sin (0.02 x – 4t) cm. The speed of the wave is _______.
(a) 10 cm/s
(b) 20 cm/s
(c) 100 cm/s
(d) 200 cm/s

Answer. (d)

Solution. The equation of a simple harmonic progressive wave travelling on a string is y = 8 sin (0.02x - 4t) cm. The speed of the wave is 200 cm/s.

Question 2. Answer the following questions:
(i) Define potential gradient of the potentiometer wire.

Answer. The potential gradient of a potentiometer wire refers to the rate of change of potential (voltage) per unit length along the length of the wire.

Mathematically, it is expressed as:

Potential Gradient = Change in Potential (Voltage) / Length

In a potentiometer, a uniform wire is often used, and the potential gradient is maintained constant along its length. This constant potential gradient allows for precise and accurate measurements of potential differences across the length of the wire. The potential gradient is an essential factor in determining the potential difference when a null point is reached in a potentiometric measurement, where the potential difference across the length of the wire is equal to the potential difference across the component under investigation.

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

Answer. The critical velocity in terms of Reynolds number for the flow of a fluid can be expressed by the following formula:

Re=Inertial force / Viscous force

For fluid flow through a pipe, the Reynolds number (Re) is given by:

Re=Density of the fluid×Velocity×Diameter of the pipe / Viscosity of the fluid

The critical velocity (v_c) is the velocity of the fluid at which the flow changes from laminar to turbulent. The critical Reynolds number (Re_c) is a dimensionless quantity that characterizes this transition. It depends on the specific conditions of the flow and the nature of the fluid. When the Reynolds number exceeds the critical value, the flow becomes turbulent.

(iii) Is it always necessary to use red light to get photoelectric effect?

Answer. No, it is not always necessary to use red light to observe the photoelectric effect. The photoelectric effect refers to the phenomenon where electrons are emitted from a material when it is exposed to light. The color (or wavelength) of light is a critical factor in the photoelectric effect.

The key point related to the color of light in the photoelectric effect is that the energy of the individual photons is directly proportional to their frequency (or inversely proportional to their wavelength) according to the equation E=hf, where E is the energy of the photon, hh is Planck's constant, and f is the frequency.

Different colors of light have different frequencies and energies. The photoelectric effect can occur with light of any color, as long as the energy of the photons is sufficient to overcome the work function of the material. If the energy of the incident photons is below the material's work function, no photoelectric effect will be observed, regardless of the color of the light.

In experiments, red light is often used because it has lower energy per photon compared to higher-energy colors like blue or ultraviolet. This makes it easier to observe the photoelectric effect with materials that have relatively low work functions. However, the phenomenon is not restricted to red light; it depends on the energy of the photons and the characteristics of the material being illuminated.

(iv) Write the Boolean expression for Exclusive – OR (X – OR) gate.

Answer. The Boolean expression for the Exclusive-OR (XOR) gate is typically denoted by the symbol ⊕ and can be expressed as follows:
Q=A⊕B

where:

- Q is the output of the XOR gate,
- A and B are the two input values.

The truth table for an XOR gate is as follows:

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

In words, the output Q is true (1) when the number of true inputs is odd. If both inputs are the same (both 0 or both 1), the output is false (0).

(v) Write the differential equation for angular S.H.M.

Answer. Angular Simple Harmonic Motion (S.H.M.) is characterized by an angular displacement that varies sinusoidally with time. The differential equation governing angular S.H.M. is analogous to the differential equation for linear S.H.M., with angular displacement (θ) taking the role of linear displacement.

The general form of the differential equation for angular S.H.M. is:

$d^2\theta / dt^2 + \omega^2\theta = 0$

where:

- $d^2\theta / dt^2$ is the second derivative of angular displacement with respect to time, representing angular acceleration,
- θ is the angular displacement,
- ω is the angular frequency, related to the frequency (f) and period (T) by $\omega = 2\pi f = 2\pi / T$.

This differential equation is similar to the one describing linear S.H.M., but with angular quantities. The solution to this differential equation yields the angular displacement as a function of time for angular S.H.M.

(vi) What is the mathematical formula for third postulate of Bohr's atomic model?

Answer. The third postulate of Bohr's atomic model is often stated as follows:

"The electron revolves around the nucleus in certain stable orbit without the emission of radiant energy."

Mathematically, this postulate is expressed using the concept of quantized angular momentum. The angular momentum (L) of the electron in the nn-th orbit is quantized and is given by the formula:

$L = n \cdot h / 2\pi$

where:

- L is the angular momentum,
- n is the principal quantum number of the orbit,
- h is Planck's constant.

This formula indicates that the angular momentum of the electron is quantized and can only take on certain discrete values determined by the quantum number nn. The quantization of angular momentum is a key aspect of Bohr's model and is related to the stability of electron orbits without the emission of radiant energy, as long as the electron remains in one of these quantized orbits.

(vii) Two inductor coils with inductance 10 mH and 20 mH are connected in series. What is the resultant inductance of the

combination of the two coils?

Answer. When inductors are connected in series, the total inductance (L_{total}) is given by the sum of the individual inductances. For two inductors in series, the formula is:

$L_{total} = L_1+L_2$

where:

- L_{total} is the total inductance,
- L_1 and L_2 are the inductances of the individual coils.

In this case, with inductances L_1 = 10 mH and L_2 = 20 mH, the total inductance (L_{total}) is:

L_{total} = 10 mH + 20 mH = 30 mH

Therefore, the resultant inductance of the combination of the two coils connected in series is 30 mH.

(viii) Calculate the moment of inertia of a uniform disc of mass 10 kg and radius 60 cm about an axis perpendicular to its length and passing through its centre.

Answer. The moment of inertia (I) of a uniform disc about an axis perpendicular to its plane and passing through its center is given by the formula:

$I=1/2mr^2$

where:

- m is the mass of the disc,
- r is the radius of the disc.

In this case, m = 10 kg and r = 60 cm. To use the formula, it's important to convert the radius to meters:

$r = 60\text{ cm} = 0.6\text{ m}$

Now, plug these values into the formula:

$I = 1/2 \times 10\text{ kg} \times (0.6\text{ m})^2$

$I = 1/2 \times 10\text{ kg} \times 0.36\text{ m}^2$

$I = 5\text{ kg} \times 0.36\text{ m}^2$

$I = 1.8\text{ kg m}^2$

So, the moment of inertia of the uniform disc about the given axis is 1.8 kg m^2.

SECTION − B

Attempt any EIGHT questions of the following:
Question 3. Define moment of inertia of a rotating rigid body. State its SI unit and dimensions.

Answer. The moment of inertia, often denoted by I, is a measure of an object's resistance to changes in its rotation. It is defined as the sum of the products of the mass of each particle in the body and the square of its distance from the axis of rotation. For a continuous body, the moment of inertia (I) is expressed as an integral:

$I = \int r^2\, dm$

where r is the perpendicular distance from the axis of rotation to each infinitesimally small mass element dm.

The SI unit of moment of inertia is kilogram meter squared ($kg \cdot m^2$), and its dimensions are [M][L]^2, where [M] represents the dimension of mass, and

[L] represents the dimension of length.

In simpler terms, the moment of inertia depends not only on the mass distribution of the object but also on how that mass is distributed relative to the axis of rotation. Objects with more mass located farther from the axis of rotation have a larger moment of inertia and are more resistant to changes in their rotational motion.

Question 4. What are polar dielectrics and non polar dielectrics?

Answer. Dielectrics are insulating materials that can be polar or nonpolar, depending on the distribution of charges within the material.

1. Polar Dielectrics:
    - In polar dielectrics, the individual molecules or atoms have an inherent dipole moment, meaning there is an uneven distribution of charge within the molecule.
    - Polar molecules have a positive and a negative end, creating a net dipole moment.
    - When an external electric field is applied, polar dielectrics tend to align their dipole moments with the field, resulting in an induced polarization.
    - Examples of polar dielectrics include water (H_2O) and many organic compounds.
2. Nonpolar Dielectrics:
    - In nonpolar dielectrics, the individual molecules or atoms have a symmetrical distribution of charges, resulting in no permanent dipole moment.
    - Nonpolar molecules have a uniform distribution of charge, and their centers of positive and negative charge coincide.
    - When an external electric field is applied, nonpolar dielectrics can still experience induced polarization, but the overall dipole moment remains zero in the absence of the external field.
    - Examples of nonpolar dielectrics include noble gases like helium (He) and diatomic molecules like oxygen (O_2) and

nitrogen (N_2).

Both polar and nonpolar dielectrics are used in capacitors and electrical devices. The ability of dielectrics to become polarized under the influence of an electric field makes them valuable in applications such as energy storage and insulation in electronic circuits.

Question 5. What is a thermodynamic process? Give any two types of it.

Answer. A thermodynamic process is a path that a thermodynamic system takes from one equilibrium state to another. It involves changes in the system's properties, such as temperature, pressure, volume, and energy. The study of thermodynamic processes is fundamental to understanding how energy is transferred and transformed in physical systems.

Two common types of thermodynamic processes are:

1. Isothermal Process:
    - An isothermal process is a thermodynamic process that occurs at constant temperature. During an isothermal process, the system exchanges heat with its surroundings in such a way that the temperature remains constant throughout the entire process.
    - For an ideal gas undergoing an isothermal process, the relationship between pressure (P) and volume (V) is given by Boyle's Law: $PV=\text{constant}$.
2. Adiabatic Process:
    - An adiabatic process is a thermodynamic process in which no heat is exchanged between the system and its surroundings. In other words, the system is thermally isolated.
    - For an adiabatic process, the first law of thermodynamics can be expressed as $Q=0$, indicating that there is no heat exchange. The change in internal energy (ΔU) is solely due to

work done on or by the system.
- For an ideal gas undergoing an adiabatic process, the relationship between pressure (P) and volume (V) is given by the adiabatic equation: PV^{γ}=constant, where γ is the ratio of specific heats.

These processes represent idealized cases, and real-world processes may involve a combination of different types of processes. Understanding thermodynamic processes is crucial for analyzing and designing various engineering systems, such as engines, refrigerators, and power plants.

Question 6. Derive an expression for the radius of the n th Bohr orbit of the electron in hydrogen atom.

Answer. The Bohr model provides an approximate description of the hydrogen atom, where the electron orbits the nucleus in quantized orbits. The expression for the radius of the nn-th Bohr orbit (rnrn) is given by:

r_n = constant×n^2 / Z

where:

- r_n is the radius of the nn-th Bohr orbit,
- n is the principal quantum number of the orbit,
- Z is the atomic number of the nucleus (for hydrogen, Z=1),
- The constant is a combination of fundamental constants and is represented by the expression $4\pi\epsilon 0\hbar^2 / mk^2e$, where ϵ0 is the vacuum permittivity, ℏ is the reduced Planck's constant, mm is the mass of the electron, and keke is Coulomb's constant.

Now, let's derive this expression.

The centripetal force required for the electron to orbit the nucleus is provided by the electrostatic attraction between the electron and the nucleus. According to Coulomb's law, this force is given by:

$F_c = k_e e^2 / r^2 n$

The centripetal force is also given by the equation:

$F_c = mv^2 r_n$

where v_n is the speed of the electron in the nn-th orbit.

Equating the two expressions for centripetal force, we get:

$k_e e^2 / r^2 n = mv^2 n / r_n$

Now, the speed of the electron can be related to the radius and the angular momentum ($mvr_n = n\hbar$):

$v_n = ke^2 / n\hbar$

Substitute this expression for v_n into the equation:

$k_e e^2 / r^2 n = m / r_n (k_e e^2 / n\hbar)^2$

Solve for r_n, and you'll arrive at the expression for the radius of the n-th Bohr orbit.

Question 7. What are harmonics and overtones (Two points)?

Answer. Harmonics:

- Harmonics are the frequencies that are integer multiples of the fundamental frequency in a complex waveform.
- In the context of sound, the fundamental frequency is the lowest frequency produced by a vibrating object or sound source. The harmonics are higher frequencies that occur at integer multiples of the fundamental. The first harmonic is the fundamental frequency, the second harmonic is twice the fundamental frequency, and so on.
- Harmonics play a crucial role in music and acoustics, contributing to the overall timbre or quality of a sound. Different

instruments and voices produce different sets of harmonics, leading to the characteristic sound of each.

2. Overtones:
    - Overtones are the higher frequencies present in a complex sound wave, beyond the fundamental frequency.
    - Overtones include both harmonics and additional frequencies that may not be integer multiples of the fundamental. The term "overtone" is broader than "harmonic" and encompasses all frequencies present in the sound except for the fundamental.
    - In musical instruments, the combination of overtones gives each instrument its unique sound color or timbre. The specific pattern and strength of overtones contribute to the richness and character of the sound produced.

Question 8. Distinguish between potentiometer and voltmeter.

Answer. Potentiometer and voltmeter are both electrical devices used to measure voltage, but they operate on different principles and serve different purposes. Here are the key distinctions between a potentiometer and a voltmeter:

1. Principle of Operation:
    - Potentiometer: A potentiometer is a device that works based on the principle of a variable resistor. It consists of a resistive wire or track and a sliding contact (wiper) that can be moved along the length of the wire. The potential difference (voltage) is measured by comparing it with a known reference voltage. Potentiometers are often used for precise voltage measurements and calibration purposes.
    - Voltmeter: A voltmeter is an instrument designed to measure the potential difference between two points in an electrical circuit. It is connected in parallel to the points of interest and measures the voltage directly. Voltmeters are generally constructed using a combination of resistors and amplifiers to

ensure high input impedance and minimize the impact on the circuit being measured.

2. Connection in a Circuit:
   - Potentiometer: In a potentiometer, the device is connected in series with the circuit under investigation, and the voltage is measured by adjusting the position of the sliding contact along the resistive track.
   - Voltmeter: A voltmeter is connected in parallel across the points between which the voltage is to be measured. It provides a low-resistance path so that most of the current flows through the circuit, ensuring minimal disruption to the original circuit.
3. Use and Application:
   - Potentiometer: Potentiometers are often used in laboratory setups for calibrating and comparing voltages. They are particularly useful when high precision and accuracy are required.
   - Voltmeter: Voltmeters are common instruments used in various electrical and electronic applications to measure the voltage at specific points in a circuit. They are available in various types, including analog and digital, and are essential tools for troubleshooting and circuit analysis.

In summary, while both potentiometers and voltmeters measure voltage, potentiometers are more specialized devices used for precision measurements and calibration, while voltmeters are general-purpose instruments used to measure voltage in electrical circuits.

Question 9. What are mechanical equilibrium and thermal

equilibrium?

Answer. Mechanical Equilibrium: Mechanical equilibrium refers to a state in which the net force acting on a system is zero, and there is no acceleration. In other words, the system is at rest or moving with a constant velocity. For an object to be in mechanical equilibrium, the vector sum of all the forces acting on it must be zero. Mathematically, in the absence of acceleration (a=0), the condition for mechanical equilibrium is given by Newton's first law:

$\sum F=0$

This implies that the forces acting in different directions balance each other, resulting in no overall force. Mechanical equilibrium is a fundamental concept in classical mechanics and is applicable to various systems, including objects at rest or moving with constant velocity.

Thermal Equilibrium: Thermal equilibrium is a state in which two or more objects or systems are at the same temperature, and there is no net flow of heat between them. When two systems are in thermal equilibrium, they do not exchange heat energy because there is no temperature difference driving such exchange. The concept is based on the zeroth law of thermodynamics, which states that if two systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

In practical terms, when you have a cup of hot coffee and leave it on a table, the coffee eventually reaches thermal equilibrium with the surrounding air. This means the temperature of the coffee becomes the same as the temperature of the air in the room, and there is no more net heat transfer between the coffee and the air.

In summary, mechanical equilibrium deals with forces and accelerations in a system, ensuring that there is no net force and, hence, no acceleration. Thermal equilibrium, on the other hand, is concerned with temperature and heat transfer, indicating a state where there is no net heat flow between systems due to them having the same temperature.

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

Answer. The angular momentum (L) of an electron in a circular orbit can be calculated using the formula:

$L=mvr$

where:

- m is the mass of the electron,
- v is the speed of the electron,
- r is the radius of the circular orbit.

Given that the radius of the circular orbit (r) is 5.3×10^{-11} m and the speed (v) is 3×10^{6} m/s, we need to use the mass of an electron, which is approximately 9.11×10^{-31} kg.

$L=(9.11\times10^{-31}\text{ kg})\times(3\times10^{6}\text{ m/s})\times(5.3\times10^{-11}\text{ m})$

$L\approx1.45\times10^{-23}\text{ kg}\cdot\text{m/s}$

Therefore, the angular momentum of the electron in the given circular orbit is approximately 1.45×10^{-23} kg.

Question 11. Plane wavefront of light of wavelength 6000 Å is incident on two slits on a screen perpendicular to the direction of light rays. If

the total separation of 10 bright fringes on a screen 2 m away is 2 cm, find the distance between the slits.

Answer. Given:

Wavelength of light (λ) = 6000 Å = 6 × 10^-7 m Distance between the screen and the slits (D) = 2 m Total separation of 10 bright fringes (x) = 2 cm = 0.02 m

To find the distance between the slits (d), we can use the formula for the fringe spacing in a double-slit experiment:

x = λD / d

Rearranging to solve for d:

d = λD / x

Substituting the given values:

d = (6 × 10^-7 m) × (2 m) / (0.02 m)

d = 6 × 10^-4 m

Therefore, the distance between the slits is 6 × 10^-4 m or 0.6 mm.

Question 12. Eight droplets of water each of radius 0.2 mm coalesce into a single drop. Find the decrease in the surface area.

Answer. The surface area of a sphere is given by the formula:

A = 4πr^2

where:

- A is the surface area
- r is the radius

The radius of each droplet is 0.2 mm, which is equal to 0.0002 m.

Therefore, the surface area of each droplet is:

$A_{droplet} = 4\pi(0.0002 m)^2 = 5.024 \times 10^{-6} m^2$

The total surface area of the eight droplets is:

$A_{total} = 8 \times A_{droplet} = 4.0192 \times 10^{-5} m^2$

When the droplets coalesce into a single drop, the radius of the new drop is given by:

$R = (3V / 4\pi)^{(1/3)}$

where:

- R is the radius of the new drop
- V is the volume of each droplet

The volume of each droplet is given by the formula:

$V_{droplet} = (4/3)\pi r^3$

where:

- $V_{droplet}$ is the volume of each droplet
- r is the radius of each droplet

The radius of each droplet is 0.2 mm, which is equal to 0.0002 m.
Therefore, the volume of each droplet is:

$V_{droplet} = (4/3)\pi(0.0002 m)^3 = 3.351 \times 10^{-11} m^3$

The total volume of the eight droplets is:

$V_{total} = 8 \times V_{droplet} = 2.6808 \times 10^{-10} m^3$

The radius of the new drop is:

$R = (3V_{total} / 4\pi)^{(1/3)} = (3 \times 2.6808 \times 10^{-10} m^3 / 4\pi)^{(1/3)} \approx 0.00034$ m

The surface area of the new drop is:

A_new = 4πR^2 = 4π(0.00034 m)^2 = 4.589 × 10^-6 m^2

The decrease in surface area is:

A_old - A_new = 4.0192 × 10^-5 m^2 - 4.589 × 10^-6 m^2 = 3.5603 × 10^-5 m^2

Therefore, the decrease in surface area is 3.5603 × 10^-5 m^2.

Summary:

The decrease in surface area when eight droplets of water each of radius 0.2 mm coalesce into a single drop is 3.5603 × 10^-5 m^2.

Question 13. A 0.1 H inductor, a 25 × 10^{-6} F capacitor and a 15 Ω resistor are connected in series to a 120 V, 50 Hz AC source. Calculate the resonant frequency.

Answer. The resonant frequency of an RLC circuit is the frequency at which the impedance of the circuit is purely resistive. This occurs when the inductive reactance (XL) equals the capacitive reactance (XC).

The inductive reactance is given by the formula:

XL = 2πfL

where:

- XL is the inductive reactance in ohms (Ω)
- f is the frequency in hertz (Hz)
- L is the inductance in henries (H)

The capacitive reactance is given by the formula:

XC = 1/(2πfC)

where:

- XC is the capacitive reactance in ohms (Ω)
- f is the frequency in hertz (Hz)
- C is the capacitance in farads (F)

In this case, the inductance (L) is 0.1 H, the capacitance (C) is 25 × 10^-6 F, and the frequency (f) is 50 Hz. Plugging these values into the formulas above, we get:

XL = 2π(50 Hz)(0.1 H) = 31.42 Ω XC = 1/(2π(50 Hz)(25 × 10^-6 F)) = 125.66 Ω

Setting XL equal to XC, we get:

31.42 Ω = 125.66 Ω - XC

Solving for XC, we get:

XC = 94.24 Ω

The resonant frequency is therefore:

$f_r = 1/(2\pi\sqrt{(LC)})$

Substituting the values of L and C, we get:

$f_r = 1/(2\pi\sqrt{(0.1 \text{ H} \times 25 \times 10^{-6} \text{ F})}) \approx 100.65$ Hz

Therefore, the resonant frequency of the circuit is approximately 100.65 Hz.

Question 14. The difference between the two molar specific heats of a gas is 9000 J/kg K. If the ratio of the two specific heats is 1.5, calculate the two molar specific heats.

Answer. Let's denote the two molar specific heats as Cv (specific heat at constant volume) and Cp (specific heat at constant pressure). We are given that the difference between Cv and Cp is 9000 J/kg K and the ratio of Cp to Cv is 1.5.

We can set up a system of two equations to represent the given information:

Equation 1: Cp - Cv = 9000 J/kg K
Equation 2: Cp / Cv = 1.5

Rearranging Equation 2 to solve for Cp in terms of Cv:

Cp = 1.5Cv

Substituting this expression for Cp into Equation 1:

1.5Cv - Cv = 9000 J/kg K

Simplifying the equation:

0.5Cv = 9000 J/kg K

Solving for Cv:

Cv = 18000 J/kg K

Now that we know Cv, we can substitute it back into the expression for Cp to find Cp:

Cp = 1.5Cv = 1.5 * 18000 J/kg K = 27000 J/kg K

Therefore, the two molar specific heats are 18000 J/kg K for Cv and 27000 J/kg K for Cp.

SECTION – C

Attempt any EIGHT questions of the following:

Question 15. With the help of a neat diagram, explain the reflection of light on a plane reflecting surface.

Question 16. What is magnetization, magnetic intensity and magnetic susceptibility?

Answer. Magnetization, magnetic intensity, and magnetic susceptibility are fundamental concepts in magnetism that describe the interaction of materials with magnetic fields.

Magnetization

Magnetization (M) is a vector quantity that measures the density of magnetic moment per unit volume in a magnetic material. It is defined as:

$M = \mu 0M\_j$

where:

- $\mu 0$ is the permeability of free space ($4\pi \times 10^{-7}$ H/m)
- M_j is the magnetization vector (A/m)

Magnetization is a measure of the alignment of magnetic dipoles within a material. In diamagnetic materials, the magnetic dipoles are aligned in a way that opposes an external magnetic field, resulting in a negative magnetization. In paramagnetic materials, the magnetic dipoles are randomly oriented in the absence of an external magnetic field but align with the field when applied, resulting in a positive magnetization. In ferromagnetic materials, the magnetic dipoles are strongly aligned even in the absence of an external magnetic field, giving them a permanent magnetization.

Magnetic Intensity

Magnetic intensity (H) is a vector quantity that describes the strength of an external magnetic field. It is defined as:

$H = B/\mu 0$

where:

- B is the magnetic field strength (T)
- $\mu 0$ is the permeability of free space ($4\pi \times 10^{-7}$ H/m)

Magnetic intensity is a measure of the force per unit current experienced by a moving charge in a magnetic field. It is also related to the magnetic flux density (B) through the equation:

$B = \mu 0(H + M)$

where:

- M is the magnetization vector (A/m)

This equation shows that the total magnetic field strength (B) is the sum of the contributions from the external magnetic field (H) and the magnetization (M) of the material.

Magnetic Susceptibility

Magnetic susceptibility (χ) is a dimensionless proportionality constant that describes the response of a material to an external magnetic field. It is defined as:

$\chi = M/H$

where:

- M is the magnetization vector (A/m)
- H is the magnetic intensity vector (A/m)

Magnetic susceptibility is a measure of how easily a material can be magnetized. Diamagnetic materials have a negative magnetic susceptibility, paramagnetic materials have a positive magnetic susceptibility, and ferromagnetic materials have a very high positive magnetic susceptibility.

Relationship between Magnetization, Magnetic Intensity, and Magnetic Susceptibility

The relationship between magnetization (M), magnetic intensity (H), and magnetic susceptibility (χ) can be expressed as:

$M = \chi H$

This equation shows that magnetization is directly proportional to the magnetic intensity and the magnetic susceptibility of the material.

Summary

Magnetization, magnetic intensity, and magnetic susceptibility are fundamental concepts in magnetism that describe the interaction of materials with magnetic fields. Magnetization is a measure of the alignment of magnetic dipoles within a material, magnetic intensity is a measure of the strength of an external magnetic field, and magnetic susceptibility is a measure of how easily a material can be magnetized. These concepts are essential for understanding the behavior of magnetic materials and their applications in various fields, such as electronics, medicine, and technology.

Question 17. Prove that the frequency of beats is equal to the difference between the frequencies of the two sound notes giving rise to beats.

Answer. To prove that the frequency of beats is equal to the difference between the frequencies of two sound notes giving rise to beats, let's consider two sound waves with slightly different frequencies. We'll use the principle of superposition, which states that when two or more waves overlap, the resulting wave is the sum of the individual waves.

Let f1 and f2 be the frequencies of the two sound notes, and let A represent the amplitude of the waves. The two sound waves can be expressed mathematically as:

Wave 1: $A\cos(2\pi f1t)$

Wave 2: $A\cos(2\pi f2t)$

The superposition of these waves is given by adding them together:

Resulting Wave: $A\cos(2\pi f1t)+A\cos(2\pi f2t)$

Now, use the trigonometric identity $\cos(A)+\cos(B)=2\cos(A+B / 2)\cos(A-B / 2)$ to express the resulting wave in a more simplified form:

$A\cos(2\pi f1t)+A\cos(2\pi f2t)=2A\cos(2\pi(f1+f2 / 2)t)\cos(2\pi(f1-f2 / 2)t)$

The frequency of the beats is given by the term $f1-f2 / 2$. Thus, the frequency of beats is equal to half the difference between the frequencies of the two sound notes giving rise to the beats.

This phenomenon is known as the beat frequency, and it is the frequency at which the amplitude of the resulting wave (beats) varies. If you were to listen to this combined sound, you would perceive a fluctuation in loudness at the beat frequency.

Question 18. Define:
(a) Inductive reactance

Answer. (a) Inductive Reactance: Inductive reactance (XLXL) is the opposition that an inductor presents to the flow of alternating current (AC). It is a measure of how the inductor resists changes in the current. Inductive reactance is directly proportional to the frequency of the AC signal and the inductance of the coil and is given by the formula:

$XL=2\pi fLXL=2\pi fL$

where:

- XLXL is the inductive reactance,
- πππ is a mathematical constant (approximately 3.14159),
- ff is the frequency of the AC signal,
- LL is the inductance of the coil.

(b) Capacitive reactance

Answer. Capacitive reactance (XC) is the opposition that a capacitor presents to the flow of alternating current (AC). It is a measure of how the capacitor resists changes in voltage. Capacitive reactance is inversely proportional to the frequency of the AC signal and the capacitance of the capacitor and is given by the formula:

$XC = 1 / 2\pi fC$

where:

- XC is the capacitive reactance,
- π is a mathematical constant (approximately 3.14159),
- f is the frequency of the AC signal,
- C is the capacitance of the capacitor.

(c) Impedance

Answer. Impedance (Z) is the overall opposition that a circuit presents to the flow of alternating current. It is a combination of resistance (R), inductive reactance (XL), and capacitive reactance (XC). In a circuit with resistance and reactance, the impedance is given by the formula:

$Z = \sqrt{(R^2+(XL-XC)^2)}$

where:

- Z is the impedance,
- R is the resistance,

- XL is the inductive reactance,
- XC is the capacitive reactance.

Impedance is a complex quantity, meaning it has both magnitude and phase. The phase relationship between the voltage and current in an AC circuit is determined by the values of resistance, inductive reactance, and capacitive reactance.

Question 19. Derive an expression for the kinetic energy of a body rotating with a uniform angular speed.

Answer. The kinetic energy (K) of a body rotating with a uniform angular speed can be derived based on the rotational kinetic energy formula. The rotational kinetic energy is analogous to the linear kinetic energy but involves rotational parameters.

The expression for the rotational kinetic energy (K_{rot}) is given by:

$K_{rot}=1/2I\omega^2$

where:

- II is the moment of inertia of the rotating body,
- ω is the angular speed of the body.

Now, let's derive an expression for kinetic energy (K) using the rotational kinetic energy formula.

Derivation:

The angular speed (ω) is related to the linear speed (v) and the radius (r) of rotation by the equation $v=r\omega$. Rearranging, we get $\omega=v/r$.

Substitute this expression for ω into the rotational kinetic energy formula:

$K_{rot}=1/2I(v/r)^2$

Now, the linear speed (v) is related to the angular speed (ω) by $v=r\omega$.

Substitute this into the equation:

$K_{rot}=1/2I(r\omega/r)^2$

Simplify further:

$K_{rot}=1/2I\omega^2$

The expression $1/2I\omega^2$ represents the rotational kinetic energy of the rotating body.

This derivation shows how the rotational kinetic energy is related to the moment of inertia and the square of the angular speed.

Question 20. Derive an expression for emf (e) generated in a conductor of length (l) moving in uniform magnetic field (B) with uniform velocity (v) along x-axis.

Answer. The electromotive force (emf, E) generated in a conductor moving in a uniform magnetic field can be derived using Faraday's law of electromagnetic induction. Faraday's law states that the emf induced in a closed loop is equal to the rate of change of magnetic flux through the loop.

The expression for emf (E) is given by:

$E=-d\Phi/dt$

where:

- E is the electromotive force,
- $d\Phi/dt$ is the rate of change of magnetic flux.

Now, let's consider a straight conductor of length l moving with a uniform velocity vv along the x-axis in a uniform magnetic field B directed into the paper. The magnetic flux (Φ) through a loop formed by the conductor is given by the product of the magnetic field, the area, and the cosine of the angle between the magnetic field and the normal to the area:

$\Phi = B \cdot A \cdot \cos\theta$

For a straight conductor moving parallel to the magnetic field, the angle (θ) is 0, and cos0=1. Therefore, $\Phi = B \cdot A$.

Since the conductor is moving along the x-axis, the area (A) swept out in time (t) is $A = l \cdot v \cdot t$.

Now, the rate of change of magnetic flux (dΦ/dt) is:

$d\Phi/dt = d/dt(B \cdot A) = B \cdot dA/dt$

Substitute the expression for area (A):

$d\Phi/dt = B \cdot d/dt(l \cdot v \cdot t)$

$d\Phi/dt = B \cdot (l \cdot v)$

Now, substitute this expression into Faraday's law:

$E = -d\Phi/dt = -B \cdot (l \cdot v)$

Therefore, the expression for the electromotive force (E) generated in the conductor moving in a uniform magnetic field with uniform velocity along the x-axis is $E = -B \cdot (l \cdot v)$. The negative sign indicates the direction of the induced emf according to Lenz's law, stating that the induced emf opposes the change in magnetic flux.

Question 21. Derive an expression for terminal velocity of a spherical object falling under gravity through a viscous medium.

Answer. To derive the expression for the terminal velocity of a spherical object falling under gravity through a viscous medium, we can use the balance of forces acting on the object.

When an object falls through a viscous medium, it experiences two main forces: gravitational force and viscous drag force.

The gravitational force ($F_{gravity}$) is given by:

$F_{gravity}=mg$

where:

- m is the mass of the object,
- g is the acceleration due to gravity.

The viscous drag force (F_{drag}) is given by Stokes' Law:

$F_{drag}=6\pi\eta rv$

where:

- η is the viscosity of the medium,
- r is the radius of the sphere,
- v is the velocity of the sphere through the medium.

At terminal velocity, the net force acting on the object is zero. Therefore, the gravitational force is balanced by the viscous drag force:

$F_{gravity}=F_{drag}$

$mg=6\pi\eta rv_{terminal}$

Now, solve for the terminal velocity ($v_{terminal}$):

$v_{terminal}=mg / 6\pi\eta rv$

This expression represents the terminal velocity of a spherical object falling under gravity through a viscous medium. The terminal velocity is the constant velocity reached when the drag force equals the gravitational force, and the object no longer accelerates. The terminal velocity depends on the mass of the object, the gravitational acceleration, the viscosity of the medium, and the radius of the sphere.

Question 22. Determine the shortest wavelengths of Balmer and Paschen series. Given the limit for Lyman series is 912 Å.

Answer. The Balmer and Paschen series are two series of spectral lines in the hydrogen spectrum.

1. Balmer Series:
   - The Balmer series corresponds to transitions in hydrogen atoms where the electron comes to the n=2 energy level.
   - The shortest wavelength in the Balmer series occurs when the electron transitions from n=3 to n=2.
   - The formula for the wavelength (λ) in the Balmer series is given by the Balmer formula: $1\lambda=R_H(1/2^2-1/n^2)$
   - where R_H is the Rydberg constant for hydrogen ($1.097\times10^7\ m^{-1}$), and nn is the principal quantum number.
   - For the shortest wavelength in the Balmer series, n=3: $1/\lambda Balmer=R_H(1/2^2-1/3^2)$
2. Paschen Series:
   - The Paschen series corresponds to transitions in hydrogen atoms where the electron comes to the n=3 energy level.
   - The shortest wavelength in the Paschen series occurs when the electron transitions from n=4 to n=3.
   - The formula for the wavelength (λ) in the Paschen series is given by the Paschen formula: $1/\lambda=R_H(1/3^2-1/n^2)$ where R_H is the Rydberg constant for hydrogen ($1.097\times10^7\ m^{-1}$), and nn is the principal quantum number.
   - For the shortest wavelength in the Paschen series, n=4: $1/\lambda Paschen=R_H(1/3^2-1/4^2)$

Given that the limit for the Lyman series is 912 A°, the Lyman series corresponds to transitions where the electron comes to the n=1 energy level. The Lyman formula is similar to the Balmer and Paschen formulas but with n=1.

The relationships between the different series are based on the energy level transitions of electrons within the hydrogen atom.

Question 23. Calculate the value of magnetic field at a distance of 3 cm from a very long, straight wire carrying a current of 6A.

Answer. The formula for calculating the magnetic field around a long, straight wire is:
$B = \mu_0 * I / (2\pi * r)$

where:

- B is the magnetic field strength in Tesla (T)
- μ_0 is the permeability of free space, which is $4\pi \times 10^{-7}$ T·m/A
- I is the current in the wire in Amperes (A)
- r is the distance from the wire to the point where the magnetic field is being measured in meters (m)

In this case, we are given that:

- I = 6 A
- r = 0.03 m (3 cm = 0.03 m)

We can plug these values into the formula to solve for B:

$B = (4\pi \times 10^{-7} \text{ T·m/A}) * (6 \text{ A}) / (2\pi * 0.03 \text{ m})$

$B \approx 4 \times 10^{-5}$ T

Therefore, the magnetic field at a distance of 3 cm from a very long, straight wire carrying a current of 6A is approximately 4×10^{-5} T.

Question 24. A parallel plate capacitor filled with air has an area of 6 cm^2 and plate separation of a 3 mm. Calculate its capacitance.

Answer. The capacitance of a parallel plate capacitor can be calculated using the following formula:
$C = \varepsilon A/d$

where:

- C is the capacitance in farads (F)
- ε is the permittivity of the material between the plates in farads per meter (F/m)
- A is the area of each plate in square meters (m^2)
- d is the distance between the plates in meters (m)

In this case, we are given that:

- A = 6 cm^2 = 6 × 10^-4 m^2
- d = 3 mm = 3 × 10^-3 m

The permittivity of air is approximately 8.85 × 10^-12 F/m.

Plugging these values into the formula, we get:

C = (8.85 × 10^-12 F/m) × (6 × 10^-4 m^2) / (3 × 10^-3 m)

C ≈ 1.77 × 10^-12 F

Therefore, the capacitance of the parallel plate capacitor is approximately 1.77 × 10^-12 F.

Question 25. An emf of 91 mV is induced in the windings of a coil, when the current in a nearby coil is increasing at the rate of 1.3 A/s, what is the mutual inductance (M) of the two coils in mH?

Answer. The mutual inductance (M) of two coils is defined as the ratio of the induced emf in one coil to the rate of change of current in the other coil. It is measured in henries (H).

The formula for calculating mutual inductance is:

$M = \epsilon / \Delta I/\Delta t$

where:

- M is the mutual inductance in henries (H)
- ϵ is the induced emf in volts (V)
- ΔI is the change in current in amperes (A)
- Δt is the change in time in seconds (s)

In this problem, we are given that:

- $\epsilon = 91$ mV = 91 × 10^-3 V
- $\Delta I/\Delta t = 1.3$ A/s

Plugging these values into the formula, we get:

M = (91 × 10^-3 V) / (1.3 A/s)

M ≈ 0.070 H

Since 1 H is equal to 1000 mH, we can convert the answer to millihenries (mH) by multiplying by 1000:

M ≈ 0.070 H × 1000 mH/H = 70 mH

Therefore, the mutual inductance of the two coils is approximately 70 mH.

Question 26. Two cells of emf 4V and 2V having respective internal resistance of 1 Ω and 2 Ω are connected in parallel, so as to send current in the same direction through an external resistance of 5 Ω. Find the current through the external resistance.

Answer. To find the current through the external resistance, we need to first calculate the equivalent internal resistance of the two cells connected in parallel. Then, we can apply Kirchhoff's Law to find the current through each cell and the external resistance.

Step 1: Calculate the equivalent internal resistance

When two resistors are connected in parallel, their equivalent resistance is given by:

$1/R_{eq} = 1/R_1 + 1/R_2$

where:

- R_{eq} is the equivalent resistance
- R_1 and R_2 are the resistances of the two resistors

In this case, $R_1 = 1\ \Omega$ and $R_2 = 2\ \Omega$, so:

$1/R_{eq} = 1/1\ \Omega + 1/2\ \Omega = 3/2$

$R_{eq} = 2/3\ \Omega$

Step 2: Apply Kirchhoff's Law

Kirchhoff's Law states that the sum of the currents entering a junction is equal to the sum of the currents leaving the junction. We can apply this law to find the current through each cell and the external resistance.

Let I be the current through the external resistance. According to Kirchhoff's

Law, the current through cell 1 is I and the current through cell 2 is also I.

Now, we can apply Ohm's Law to each cell:

- For cell 1: I = (E1 - V1) / R1 = (4 V - I) / 1 Ω
- For cell 2: I = (E2 - V2) / R2 = (2 V - I) / 2 Ω

Simplifying these equations, we get:

- 5I = 4 V
- 2I = 2 V

Solving for I, we get:

- I = 0.8 A

Therefore, the current through the external resistance is 0.8 A.

SECTION − D

Attempt any THREE questions of the following:
Question 27. Derive an expression for a pressure exerted by a gas on the basis of kinetic theory of gases.

Answer. The kinetic theory of gases is a model of gas behavior that assumes that gases are composed of a large number of rapidly moving and colliding particles. According to this theory, the pressure exerted by a gas is due to the collisions of these particles with the walls of the container.

To derive an expression for the pressure exerted by a gas, consider a cubic box of length L filled with gas molecules of mass m. Assume that the molecules are moving along the x-axis with a velocity vx.

When one molecule collides with the wall at x=0, it undergoes a completely elastic collision and reverses its direction. The momentum of the molecule before the collision is mvx, and the momentum after the collision is -mvx. The change in momentum of the molecule is therefore:

$\Delta p = -2mvx$

The force on the wall due to this collision is equal to the rate of change of momentum of the molecule:

$F = \Delta p/\Delta t = -2mvx/\Delta t$

Since the collision occurs over a very short time interval, we can approximate Δt by the time it takes for the molecule to travel the distance 2L:

$\Delta t \approx 2L/vx$

Substituting this into the expression for the force, we get:

$F \approx -mv^2 * 2L / vx$

The average force on the wall due to all the molecules colliding with it is given by:

$F\_avg = -mv^2 * 2L / (vx * N)$

where N is the number of molecules in the box.

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

$P = F\_avg / A = (-mv^2 * 2L / (vx * N)) / L^2$

Simplifying this expression, we get:

$P = Nmv^2 / (3L^3)$

This is the ideal gas law, which relates the pressure, volume, and temperature of an ideal gas. It is one of the most fundamental equations in physics, and it has many important applications in chemistry, engineering, and other fields.

Question 28. What is a rectifier? With the help of a neat circuit

diagram, explain the working of a half wave rectifier.

Question 29. Draw a neat, labelled diagram of a suspended coil type moving coil galvanometer. The initial pressure and volume of a gas enclosed in a cylinder are 2×10^5 N/m^2 and 6×10^{-3} m^3 respectively. If the work done in compressing the gas at constant pressure is 150 J, find the final volume of the gas.

Question 30. Define second's pendulum. Derive a formula for the length of second's pendulum. A particle performing linear S.H.M. has maximum velocity 25 cm/s and maximum acceleration 100 cm/s^2 . Find period of oscillations.

Answer. Second's Pendulum

A second's pendulum is a type of pendulum that has a period of one second. This means that it takes one second for the pendulum to complete one full oscillation, from its starting position to its highest point, back to its starting position, and then to its lowest point and back to its starting position.

The period of a pendulum is given by the following formula:

$T = 2\pi\sqrt{(L/g)}$

where:

- T is the period in seconds (s)
- L is the length of the pendulum in meters (m)
- g is the acceleration due to gravity in meters per second squared (m/s^2)

The acceleration due to gravity is approximately 9.81 m/s^2 on Earth. Therefore, the length of a second's pendulum on Earth is approximately 0.994 m.

Particle Performing Linear S.H.M.

A particle performing linear simple harmonic motion (SHM) is a particle that is oscillating back and forth along a straight line with a constant acceleration. The acceleration is always directed towards the center of the motion.

The maximum velocity of a particle performing SHM is given by the following formula:

$v_{max} = \sqrt{(\omega^2 A^2)}$

where:

- v_{max} is the maximum velocity in meters per second (m/s)
- ω is the angular frequency in radians per second (rad/s)
- A is the amplitude in meters (m)

The maximum acceleration of a particle performing SHM is given by the following formula:

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

where:

- a_{max} is the maximum acceleration in meters per second squared (m/s^2)
- ω is the angular frequency in radians per second (rad/s)
- A is the amplitude in meters (m)

The period of a particle performing SHM is given by the following formula:

$T = 2\pi/\omega$

where:

- T is the period in seconds (s)
- ω is the angular frequency in radians per second (rad/s)

Substituting the first formula into the second formula, we get:

$T = 2\pi\sqrt{(A/a_{max})}$

In this case, we are given that:

- $v_{max} = 25 \text{ cm/s} = 0.25 \text{ m/s}$
- $a_{max} = 100 \text{ cm/s}^2 = 1 \text{ m/s}^2$

Substituting these values into the formula, we get:

$T = 2\pi\sqrt{(A/1 \text{ m/s}^2)}$

$T \approx 6.28$ s

Therefore, the period of the particle's oscillations is approximately 6.28 seconds.

Question 31. Explain de Broglie wavelength. Obtain an expression for de Broglie wavelength of wave associated with material particles. The photoelectric work function for a metal is 4.2 eV. Find the threshold wavelength.

Answer. De Broglie Wavelength: Louis de Broglie proposed that if light waves could have particle-like behavior (as shown by Einstein's photoelectric effect), then particles like electrons, protons, and other matter could also exhibit wave-like behavior. This led to the concept of the de Broglie wavelength, which relates the wavelength (λ) of a matter wave to the momentum (p) of a particle. The de Broglie wavelength is given by the equation:

λ=hp

where:

- λ is the de Broglie wavelength,
- h is Planck's constant (6.626×10^{-34} J·s),
- p is the momentum of the particle.

Expression for De Broglie Wavelength: The momentum of a particle can be expressed as the product of its mass (m) and velocity (v): p=mv. Substitute this into the de Broglie wavelength equation:

$\lambda = h/mv$

Now, for particles with non-relativistic speeds (much less than the speed of light), the kinetic energy (K) can be expressed as $K=1/2mv^2$. Also, the kinetic energy can be related to the photoelectric work function (ϕ) by K=eV, where ee is the elementary charge and V is the voltage.

$1/2mv^2=eV$

Solve for vv: $v = \sqrt{(2eV / m)}$

Substitute this expression for vv into the de Broglie wavelength equation:

$\lambda = h / m\sqrt{(2eV / m)}$

Simplify further:

$\lambda = h / \sqrt{(2meV)}$

Threshold Wavelength: The threshold wavelength ($\lambda_{threshold}$) is related to the photoelectric work function (ϕ) by the equation:

$\lambda_{threshold}=hc / \phi$

Given that the photoelectric work function for the metal is 4.2 eV, convert this to joules ($1\ eV=1.602 \times 10^{-19}$ J):

$\phi=4.2 \times 1.602 \times 10^{-19}$ J

Now, substitute this value into the threshold wavelength equation:

$\lambda_{threshold} = hc / (4.2\times1.602\times10^{-19}\ J)$

This will give you the threshold wavelength. Note that cc is the speed of light (3.00×10^{8} m/s).