Physics Exam Answers

Theoretical questions **(Easy)**:

1 . Conservative forces. The law of conservation of mechanical energy

Conservative Forces

Conservative forces do work that depends only on the start and end points, not the path. Examples are gravity and spring force. The work done in a closed loop is always zero.

Law of Conservation of Mechanical Energy

In systems with only conservative forces, total mechanical energy (kinetic + potential) stays constant:

$$K.E_{initial} + P.E_{initial} = K.E_{final} + P.E_{final}$$

2. An ideal gas. The main equation of the molecular-kinetic theory and the results obtained from it.

An Ideal Gas

An ideal gas is a theoretical gas where particles move randomly and do not interact except during elastic collisions. It follows the ideal gas equation:

$$PV = nRT$$

where P is pressure, V is volume, n is moles, R is the gas constant, and T is temperature.

Molecular-Kinetic Theory

The main equation is:

$$PV = \frac{1}{3}Nm\overline{v^2}$$

where N is the number of molecules, m is mass of one molecule, and $\overline{v^2}$ is the average squared velocity.

Results

1. **Pressure** is caused by particle collisions with container walls.
2. **Temperature** is proportional to the average kinetic energy:

$$KE = \frac{3}{2} k_B T$$

Where k_B is Boltzmann's constant.

3. Work in an electrostatic field. Potential. Circulation of the electrostatic field.

Work in an Electrostatic Field

The work done by an electrostatic field on a charge q depends only on the initial and final positions:

$$W = q(V_A - V_B)$$

where V_A and V_B are the potentials at points A and B.

Potential

Electric potential V at a point is the work needed to bring a unit positive charge from infinity to that point:

$V = \frac{W}{q}$ It is measured in volts (V)

Circulation of the Electrostatic Field

The circulation of an electrostatic field along any closed loop is zero:

$$\oint \vec{E} \times d\vec{l}$$

This means electrostatic fields are conservative.

4. Gauss' theorem for an electrostatic field in a vacuum and its some applications.

Gauss' Theorem for an Electrostatic Field in a Vacuum

Gauss' theorem states that the electric flux Φ_E through a closed surface is proportional to the total charge Q enclosed by the surface:

$$\Phi_E = \oint \vec{E} \times d\vec{A} = \frac{Q}{\varepsilon_0}$$

Here, $\vec{E}$is the electric field, $d\vec{A}$ is an infinitesimal area vector, and ε_0 is the permittivity of free space.

Applications

1. **Point Charge**: For a spherical surface around a point charge, $E = \frac{Q}{4\pi\varepsilon_0 r^2}$.
2. **Infinite Line Charge**: $E = \frac{\lambda}{2\pi r}$ is the charge per unit length.
3. **Infinite Plane**: $E = \frac{\sigma}{2\varepsilon_0}$, where σ is the charge density.

These simplify electric field calculations in symmetrical situations.

5. Internal energy. Amount of heat. Work in Thermodynamics.

Internal Energy

Internal energy (U) is the total energy of a system's particles, including kinetic and potential energies at the microscopic level. It depends on the temperature, volume, and state of the system.

Amount of Heat

The amount of heat (Q) is the energy transferred due to temperature difference. It changes a system's internal energy or does work:

$$Q = \Delta U + W$$

where W is work done by or on the system.

Work in Thermodynamics

Work (W) is the energy transferred when a system changes its volume under pressure:

$$W = P\Delta V$$

Here, P is pressure and ΔV is the change in volume. For a cyclic process, total work equals the area enclosed in the $P - V$ diagram.

6. The electric field of a dipole and a dipole in an external electric field.

Electric Field of a Dipole

A dipole consists of two equal and opposite charges $(+q\ and\ -q)$ separated by a distance ddd. Its electric field depends on the observation point:

1. On the axis (along the dipole line):

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

where $p = qd$ is the dipole moment, r is the distance from the dipole center

2. On the perpendicular bisector:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

Dipole in an External Electric Field

When placed in a uniform electric field $\vec{E}$, a dipole experiences:

1. **Torque**: Aligns the dipole with the field direction:

$$\tau = pE\sin\ \theta$$

2. **Potential Energy**:

$$U = -pE\cos\ \theta$$

The energy is lowest when $\vec{p}$ aligns with $\vec{E}$.

7. Harmonic electrical oscillations and its main characteristics.

Harmonic Electrical Oscillations

Harmonic electrical oscillations occur in an LC circuit, where energy transfers between the inductor and capacitor. The current and voltage vary sinusoidally over time.

The differential equation governing the oscillations is:

$$\frac{d^2q}{dt^2} + \frac{1}{LC}q = 0$$

where q is the charge on the capacitor, L is inductance, and C is capacitance.

Main Characteristics

1. Angular Frequency (ω):

$$\omega = \frac{1}{\sqrt{LC}}$$

2. **Frequency (f)**:

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

3. **Period (T)**:

$$T = \frac{1}{f} = 2\pi\sqrt{LC}$$

4. **Amplitude**: Maximum charge, current, or voltage in the oscillation.

Harmonic oscillations are undamped if no resistance is present.

8. Properties of mechanical and electromagnetic waves, the quantities characterizing them. The wave equation.

Properties of Mechanical and Electromagnetic Waves

1. **Mechanical Waves:**
   - Require a medium (e.g., air, water, solid) to propagate.
   - Types: Longitudinal (e.g., sound) and transverse (e.g., water waves).
   - Speed depends on the medium's properties.
2. **Electromagnetic Waves:**
   - Do not require a medium; they can travel in a vacuum.
   - Transverse waves, consisting of oscillating electric and magnetic fields.
   - Speed in a vacuum is constant, $c = 3 \times 10^8$ m/s.

Quantities Characterizing Waves

1. **Wavelength (λ)**: Distance between two successive crests or troughs.
2. **Frequency (f)**: Number of oscillations per second ($f = \frac{v}{\lambda}$).
3. **Period (T)**: Time for one complete oscillation ($T = \frac{1}{f}$).
4. **Wave Speed (v)**: Speed of wave propagation ($v = \lambda f$).
5. **Amplitude (A)**: Maximum displacement from equilibrium.

Wave Equation

The general wave equation for a wave traveling in one dimension is:

$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$ where $y(x, t)$ is the wave displacement, v is the wave speed, x is position, and t is time.

9. The barometric formula. The Boltzmann distribution.

The Barometric Formula:

The barometric formula shows how air pressure decreases with altitude. It is given by:

$$P(h) = P_0 \cdot \exp\left(\frac{-Mgh}{RT}\right)$$

Where P_0 is the pressure at sea level, M is the molar mass of air, g is gravity, h is altitude, R is the gas constant, and T is temperature and $exp() \Rightarrow e^{()}$.

The Boltzmann Distribution:

The Boltzmann distribution describes the probability of a particle having a certain energy E at temperature T. It is:

$$P(E) = \frac{e^{-\frac{E}{kT}}}{Z}$$

Where k is the Boltzmann constant, and Z is the partition function. This shows higher energy states are more likely at higher temperatures.

10. Angular momentum and its conservation law.

Angular Momentum:

Angular momentum (L) is a measure of the rotational motion of an object. It is given by:

$$L = r \times p$$

Where:

- r is the position vector of the object relative to a point (usually the origin).
- p is the linear momentum ($p = mv$) of the object.

For a rotating body, angular momentum depends on its velocity and how far it is from the center of rotation.

Conservation of Angular Momentum:

The law of conservation of angular momentum states that if no external torque acts on a system, the total angular momentum of the system remains constant. Mathematically:

$$\frac{dL}{dt} = 0 \Rightarrow L_{\text{initial}} = L_{\text{final}}$$

This means that in a closed system (no external forces or torques), the angular momentum does not change over time.

Theoretical questions **(Medium)**:

11. Faraday's law. Self and mutual induction phenomena. Inductance.

Faraday's Law:

Faraday's Law states that a changing magnetic field induces an electromotive force (EMF) in a loop of wire. The induced EMF is proportional to the rate of change of the magnetic flux:

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

Where:

- $\mathcal{E}$ is the induced EMF.
- Φ_B is the magnetic flux, $\Phi_B = B \cdot A$, where B is the magnetic field and A is the area.
- The negative sign indicates the direction of the induced EMF (Lenz's Law).

Self and Mutual Induction:

- **Self-Induction**: When the current in a coil changes, it induces an EMF in the same coil. The inductance LLL is the proportionality constant:

$$\mathcal{E} = -L\frac{di}{dt}$$

Where i is the current, and L is the inductance.

- **Mutual Induction**: When the current in one coil changes, it induces an EMF in a nearby coil. The mutual inductance M relates the induced EMF in the second coil to the rate of change of current in the first coil:

$$\mathcal{E}_2 = -M\frac{di_1}{dt}$$

Inductance:

Inductance is the property of a coil (or circuit) that opposes changes in current. It depends on factors like the number of turns, the coil's geometry, and the material inside the coil. The unit of inductance is the henry (H).

12. Ohm’s law for homogeneous, non-homogeneous and closed circuit. The differential (point) form of Ohm’s law.

Ohm’s Law:

1. **Homogeneous Circuit:** In a homogeneous material, Ohm’s law states that the current density (J) is proportional to the electric field (E):

$$\mathrm{J} = \sigma \mathrm{E}$$

Here, σ is the conductivity of the material.

2. **Non-Homogeneous Circuit:** In a non-homogeneous material, the conductivity σ can vary with position. The relationship becomes:

$$\mathrm{J} = \sigma(\mathrm{r})\mathrm{E}$$

Where $\sigma(\mathbf{r})$ is the position-dependent conductivity.

3. **Closed Circuit:** In a closed circuit, the voltage (V) across a component is related to the current (I) and resistance (R) by:

$$V = IR$$

1. Where V is the voltage, I is the current, and R is the resistance.

Differential (Point) Form of Ohm’s Law:

In the differential form, Ohm’s law expresses the relationship between the local current density (J) and the electric field (E) at any point in the material:

$$\mathrm{J} = \sigma \mathrm{E}$$

This form is useful for analyzing the behavior of electric fields and currents at the micro level

13. The laws for radiation of an absolute black body: The Stefan-Boltzmann and Wien laws.

Stefan-Boltzmann Law:

The Stefan-Boltzmann law describes the total energy radiated by a black body per unit area. It states that the power radiated is proportional to the fourth power of the temperature:

$$P = \sigma T^4$$

Where:

- P is the power radiated per unit area.
- σ is the Stefan-Boltzmann constant (5.67×10^{-8} W/m^{2}K^4).
- T is the absolute temperature in Kelvin.

Wien's Displacement Law:

Wien's law describes the shift in the peak wavelength of radiation emitted by a black body as its temperature changes. The peak wavelength λ_{max} is inversely proportional to the temperature:

$$\lambda_{\text{max}} = \frac{b}{T}$$

Where:

- λ_{max} is the wavelength at which the emission is strongest.
- b is Wien's constant (2.898×10^{-3} $\frac{m \times K}{T}$).
- T is the temperature in Kelvin.

In short, as the temperature increases, the peak wavelength decreases, meaning the radiation shifts to shorter wavelengths (e.g., from red to blue).

14. The law of interaction of point charges – The Coulomb law. Dielectric permeability.

Coulomb's Law:

Coulomb's Law describes the force between two point charges. It states that the electrostatic force (F) between two charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them:

$$F = k_e \frac{q_1 q_2}{r^2}$$

Where:

- F is the electrostatic force between the charges.
- q_1 and q_2 are the magnitudes of the point charges.
- r is the distance between the charges.
- k_e is Coulomb's constant (8.99×10^9 N×m^2/C^2).

The force is attractive if the charges are of opposite sign and repulsive if they have the same sign.

Dielectric Permeability:

Dielectric permeability (ε) is a measure of a material's ability to permit the electric field to pass through it. In vacuum, it is denoted by ε_0 , known as the permittivity of free space. In a material, the dielectric permeability is usually higher and is denoted ε.

The electric force in a medium is reduced by the factor $\varepsilon/\varepsilon_0$, so Coulomb's Law in a dielectric medium becomes:

$$F = \frac{1}{4\pi\varepsilon} \frac{q_1 q_2}{r^2}$$

Where ε is the dielectric permittivity of the material. The higher the permittivity, the weaker the electrostatic force.

15. Photoelectric effect. The Einstein equation for the photoelectric effect

Photoelectric Effect:

The photoelectric effect occurs when light hits a material (usually metal) and ejects electrons from its surface. The light behaves as photons, and when a photon strikes an electron, it can release the electron if its energy is enough.

Einstein's Equation for the Photoelectric Effect:

Einstein's equation describes the energy relationship in the photoelectric effect:

$$E_{\text{photon}} = \phi + E_{\text{kinetic}}$$

Where:

- $E_{\text{photon}} = hf$ is the energy of the incoming photon.
- ϕ is the work function of the material.
- E_{kinetic} is the kinetic energy of the emitted electron.

This equation shows the energy of the photon is used to overcome the work function, and the remaining energy becomes the electron's kinetic energy.

16. Dielectrics, their types and polarization. Electrostatic induction (Electric flux density) vector.

Dielectrics and Their Types:

Dielectrics are insulating materials that don't conduct electricity but can support an electric field.

Types of Dielectrics:

1. **Polar Dielectrics:** Have permanent dipoles (e.g., water).
2. **Non-polar Dielectrics:** No permanent dipoles, dipoles are induced in the presence of an electric field (e.g., noble gases).

Polarization:

Polarization is the alignment of dipoles in a dielectric material when exposed to an electric field. In polar dielectrics, dipoles are already aligned, while in non-polar dielectrics, dipoles are induced.

Electrostatic Induction (Electric Flux Density):

Electrostatic induction happens when a dielectric material is placed in an electric field, causing polarization. The electric flux density D is given by:

$$\mathbf{D} = \varepsilon \mathbf{E}$$

Where:

- D is the electric flux density.
- ε is the material's permittivity.
- E is the electric field.

17. Specific and molar heat capacities at constant volume and pressure

Specific and Molar Heat Capacities:

1. **Specific Heat Capacity (c):** The heat required to raise the temperature of a unit mass by $1°C$ (or $1\ K$):

$$q = mc\Delta T$$

2. **Molar Heat Capacity (C)**: The heat required to raise the temperature of one mole of a substance by $1°C\ (or\ 1\ K)$:

$$C = c \cdot M$$

Heat Capacities at Constant Volume and Pressure:

- **At Constant Volume (C_V)**: Heat required to raise temperature by $1\ K$ at constant volume.
- **At Constant Pressure (C_P)**: Heat required to raise temperature by $1\ K$ at constant pressure.

For ideal gases: $C_P = C_V + nR$
Where n is the number of moles and R is the gas constant.

18. Planetary model of an atom. A number of missing aspects of the planetary model. The Bohr postulates.

Planetary Model of an Atom:

Bohr's planetary model describes electrons in discrete orbits around the nucleus, similar to planets orbiting the Sun.

Missing Aspects:

1. **Orbit Stability**: Electrons should spiral into the nucleus due to radiation.
2. **Electron Wave Nature**: Doesn't account for the wave-like behavior of electrons.
3. **Fine Structure**: Fails to explain fine details of atomic spectra.

Bohr Postulates:

1. **Quantized Orbits**: Electrons move in fixed orbits without emitting radiation.
2. **Energy Transitions**: Electrons absorb or emit photons when moving between orbits.

$$E_{\text{photon}} = E_2 - E_1$$

3. **Angular Momentum Quantization**$L = n\hbar$, where n is an integer.

These postulates explained atomic stability and spectral lines.

19. Magnetic flux. Gauss' theorem for a magnetic field in a vacuum.

Magnetic Flux:

Magnetic flux is the measure of the magnetic field passing through an area. It is given by:

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

Where B is the magnetic field, A is the area, and θ is the angle between the field and the surface normal.

Gauss' Theorem for Magnetic Field:

Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero:

$$\oint_S \mathbf{B} \cdot d\mathbf{A} = 0$$

This shows that magnetic field lines do not have a beginning or end (no monopoles).

20. Polarization of light. The Malus law.

Polarization of Light:

Polarization refers to the orientation of the oscillations of light waves. Unpolarized light vibrates in multiple directions, while polarized light vibrates in a single direction.

Malus' Law:

Malus' law describes the intensity of polarized light after passing through a polarizing filter. The intensity I of the transmitted light is related to the initial intensity I_0 and the angle θ between the light's polarization direction and the axis of the polarizer:

$$I = I_0 \cos^2 \theta$$

This shows that the intensity decreases as the angle increases.

Practical Questions

Easy

1. Calculate the resultant force acting on a body whose linear momentum changes according to the law $\boldsymbol{P = 2t^2}$, at time $\boldsymbol{t = 3}$ seconds.

$$F = \frac{dP}{dt}$$

$$\frac{dP}{dt} = 4t$$

$$F = 4 \times 3 = 12 \text{ N}$$

2. A point particle with moment of inertia $\boldsymbol{J = 2 \text{ kg} \cdot \text{m}^2}$ rotates around the axis of symmetry. Find the value of the torque (moment of force) M of a point particle with the angular acceleration of $\boldsymbol{\alpha = 5 \text{ rad/sec}^2}$

$$M = J\alpha$$

$$M = 2 \times 5 = 10 \text{ N} \cdot \text{m}$$

3. The internal energy of an ideal gas has increased by $\boldsymbol{\Delta U = 50 \text{ kJ}}$, and the gas has gained $\boldsymbol{Q = 10 \text{ kJ}}$ of heat. How much work have external forces done on the gas?

$$\Delta U = Q - W$$

$$W = Q - \Delta U = 10 - 50 = -40 \text{ kJ}$$

The external forces have done 40 kJ of work on the gas, meaning the gas has done $-40\ kJ$ of work on the surroundings.

Answers: 40kJ (positive)

4. Determine the electric moment ($\boldsymbol{P_e}$) of the dipole with the charge $\boldsymbol{q = 10^{-8} \text{ C}}$ and arm $\boldsymbol{l = 5 \times 10^{-3} \text{ m}}$

The electric dipole moment is given by:

$$P_e = q \cdot l$$

$$P_e = (10^{-8}) \cdot (5 \times 10^{-3}) = 5 \times 10^{-11} \text{ C×m}$$

5. What is the intensity (E) of the electric field produced around a uniformly charged infinitely long plane with a charge density $\boldsymbol{\sigma = 8.85 \times 10^{-8}}$ C/m^2 ? The electric constant is $\boldsymbol{\varepsilon_0 = 8.85 \times 10^{-12}}$ F/m. (Present the answer in V/m).

$$E = \frac{\sigma}{2\varepsilon_0} = \frac{8.85 \times 10^{-8}}{2 \cdot 8.85 \times 10^{-12}} = \frac{1}{2 \times 10^{-4}} = 5 \times 10^3 \text{ V/m}$$

6. The time dependence of the work of the force acting on the object moving at a speed of $\boldsymbol{v = 2}$ m/s changes according to the law $\boldsymbol{A = 2t^2 + 2t}$. Calculate the modulus ($\boldsymbol{F}$) of the force acting on the body at the end of $\boldsymbol{t = 4}$ seconds.

$$A = F \cdot x \qquad\qquad v = const \;\Rightarrow x = v \cdot t$$

$$A = F \cdot v \cdot t$$

The instantaneous force is the time derivative of the work:

$$F = \frac{1}{v} \cdot \frac{dA}{dt}$$

$$\frac{dA}{dt} = 4t + 2$$

$$\frac{dA}{dt} = 4(4) + 2 = 16 + 2 = 18 \text{ J/s}$$

$$F = \frac{\frac{dA}{dt}}{v} = \frac{18}{2} = 9 \text{ N}$$

7. The density of the current passing through an air in the electric field with intensity $\boldsymbol{E = 40}$ V/m is $\boldsymbol{j = 2 \times 10^{-6}}$ A/m^2. What is the electrical conductivity of the air?

$$j = \sigma E$$

$$\sigma = \frac{j}{E} = \frac{2 \times 10^{-6}}{40} = 5 \times 10^{-8} \text{ S/m}$$

8. A shaft (disk) with a moment of inertia $J = 2$ kg×m^2 rotates with an angular velocity $\omega = 3$ rad/s. Calculate the angular momentum (L) of the shaft

$$L = J \cdot \omega$$

$$L = 2 \cdot 3 = 6\ \frac{\mathrm{kg} \times m^2}{\mathrm{s}}$$

9. In the coil with the inductance $L = 1$ Hn , the electric current varies with time according to the law $I(t) = 2 - t^2$. What is the self-induction e.m.f. ε in the coil at $t = 2$ s seconds?

$$\varepsilon = -L\frac{dI}{dt}$$

$$\frac{dI}{dt} = \frac{d}{dt}(2 - t^2) = -2t$$

$$\frac{dI}{dt} = -2(2) = -4\ \mathrm{A/s}$$

$$\varepsilon = -L\frac{dI}{dt} = -(1)(-4) = 4\ \mathrm{V}$$

10. Calculate the energy ($h\nu$) eV of the photon that produces the photoelectric effect, knowing that the average kinetic energy of the electrons leaving the surface of the metal with the work function $A = 4.2$ eV is $E_{\mathrm{kin}} = 40$ eV.

$$h\nu = A + E_{\mathrm{kin}}$$

$$h\nu = 4.2 + 40 = 44.2\ \text{eV}$$

Medium

11. What is the angular velocity ω of a rotating body with the kinetic energy $E = 128$ J and moment of inertia $J = 4$ kg $\times$ m^2?

$$E = \frac{1}{2} J \omega^2$$

$$\omega = \sqrt{\frac{2E}{J}} = \sqrt{\frac{2 \times 128}{4}} = \sqrt{\frac{256}{4}} = \sqrt{64} = 8\,\text{rad/s}$$

12. When the voltage in the circuit is $U = 10$ V, the electric current $I = 2$ A flows through the electronic bulb (lamp). How long does it take for heat $Q = 2.4 \times 10^3$ C to be released from the bulb?

$$Q = P \cdot t$$

$$P = U \cdot I$$

$$Q = U \cdot I \cdot t$$

$$t = \frac{Q}{U \cdot I} = \frac{2.4 \times 10^3}{10 \cdot 2} = \frac{2.4 \times 10^3}{20} = 120\,\text{s}$$

13. Calculate the pressure (P) of the gas which exerts on the walls of the container if the density of the gas in the container is $\rho = 1.2$ kg/m^3, the root- mean-square speed of its molecules is $v_{\text{rms}} = 600$ m/s. (Present the answer in kPa).

$$P = \frac{1}{3} \rho v_{\text{rms}}^2$$

$$P = \frac{1}{3} \cdot 1.2 \cdot 600^2 = \frac{1}{3} \cdot 1.2 \cdot 360{,}000 = 144\,\text{kPa}$$

14. A dipole with an electric moment of $P_e = 2 \times 10^{-8}$ C $\times$ m is in an electric field with an intensity of $E = 5 \times 10^{4}$ V/m. The angle between the field intensity and the axis of the dipole is $\theta = 60^{\circ}$. What is the potential energy of the dipole in the field?

$$U = -P_e \times E \times \cos\ \theta$$

$$U = -(2 \times 10^{-8}) \times (5 \times 10^{4}) \times \cos\ 60^{\circ}$$

$$U = -(2 \times 5 \times 0.5) \times 10^{-8+4} = -5 \times 10^{-4}\,\mathrm{J}$$

15. A wave with the wavelength $\lambda = 4\ \mu$m falls perpendicularly to a diffraction grating with a lattice constant $d = 40\ \mu$m. Find the sine (sinϕ) of the angle at which the first order ($k = 1$) maximum appears.

$$k\lambda = d \sin\phi$$

$$\sin\ \phi = \frac{k\lambda}{d} = \frac{1 \times 4}{40} = \frac{4}{40} = 0.1$$

16. What is the electric field intensity flux Φ_E passing through the closed surface surrounding the charge $q = 8.85 \times 10^{-9}$ C ? Take the electric constant $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m.

$$\Phi_E = \frac{q}{\varepsilon_0}$$

$$\Phi_E = \frac{8.85 \times 10^{-9}}{8.85 \times 10^{-12}} = 10^{3}\ \frac{\mathrm{N} \cdot \mathrm{m}^2}{\mathrm{C}} = 1000\ V \cdot m$$

17. The electric charge passing through a circular wire with a radius of $R = 0.5$ m varies with time according to the law $q(t) = 4 + 3t + 2t^2$ C. How many A/m will the magnetic field intensity (H) be in the center of the circular current-carrying wire in $t = 5$ seconds?

$$I(t) = \frac{dq}{dt} = \frac{d}{dt}(4 + 3t + 2t^2) = 3 + 4t$$

$$I(5) = 3 + 4(5) = 3 + 20 = 23\,\mathrm{A}$$

$$H = \frac{I}{2\pi R} = \frac{23}{2\pi(0.5)} = \frac{23}{\pi}$$

18. The pressure of the gas in the container with volume $V = 50\ \mathrm{m}^3$ is $P = 96,000$ Pa and its temperature is $T = 300$ K. How many moles (ν) is the amount of matter in the gas? $\mathrm{R} = 8$ J/(mol × K).

$$PV = \nu RT$$

$$\nu = \frac{P \times V}{R \times T}$$

$$\nu = \frac{96{,}000 \times 50}{8 \times 300} = 2000\ mol$$

19. A body with the mass $m = 0.5$ kg, radius $r = 0.2$ m, and angular velocity $\omega = 2$ rad/sec rotates along a circle. Find the value of the normal force acting on the body F_n.

$$F_n = F_c = mr\omega^2$$

$$F_n = 0.5 \times 0.2 \times 4 = 0.4\ \mathrm{N}$$

20. Find the wavelength λ of the wave with wave number $k = 3$. Accept $\pi \approx 3$

$$k = \frac{2\pi}{\lambda}$$

$$\lambda = \frac{2\pi}{k}$$

$$\lambda = \frac{2 \times 3}{3} = 2\ \mathrm{m}$$

Difficult

21. Find the change in internal energy (ΔU) of $\nu = 1$ mol diatomic ($i = 5$) ideal gas if its temperature change is $\Delta T = 10$ K. $R = 8$ J/(mol × K)

$$C_v = \frac{i}{2} \times R$$

$$C_v = \frac{5}{2} \times R = \frac{5}{2} \times 8 = 20 \text{ J/(mol × K)}$$

$$\Delta U = \nu \times C_v \times \Delta T$$

$$\Delta U = 1 \times 20 \times 10 = 200 \text{ J}$$

22. Due to the action of the force, the speed of the object with mass $m = 3$ kg increased from $v_1 = 2$ m/s to $v_2 = 4$ m/s. Calculate the work (A) done by the force.

$$A = \Delta K = \frac{1}{2} m(v_2^2 - v_1^2)$$

$$A = \frac{1}{2} \times 3 \times (4^2 - 2^2)$$

$$A = \frac{1}{2} \times 3 \times 12 = 18 \text{ J}$$

23. Three capacitors with capacities $C_1 = 2 \times 10^{-6}$ F, $C_2 = 4 \times 10^{-6}$ F, $C_3 = 6 \times 10^{-6}$ F are connected in parallel and included in the circuit with the voltage $U = 10$ V. Determine their energy.

$$E_{total} = \sum_{i=1}^{n} \frac{1}{2} C_i U^2 = \frac{1}{2} U^2 \times \sum_{i=1}^{n} C_i$$

$$E_{total} = \frac{1}{2} (10)^2 \times (2 + 4 + 6) \times 10^{-6} = 6 \times 10^{-4} \text{ J}$$

24. The time dependence of the electric charge passing through the cross section of the wire changes according to the law $q(t) = 2t^3$. What is the value of the current passing through the wire at the end of the 2nd second?

$$I = \frac{dq}{dt}$$

$$I(t) = \frac{d}{dt}(2t^3) = 6t^2$$

$$I(2) = 6 \times (2)^2 = 6 \times 4 = 24\,\mathrm{A}$$

25. What is the quality (Q) of the oscillating system if the period of the damped free oscillations is $T = 6$ sec, and the damping coefficient is $\beta = 2\ \text{sec}^{-1}$? $\pi = 3$.

$$\omega_0 = \frac{2\pi}{T} = \frac{2\pi}{T} = \frac{2 \times 3}{6} = 1\ \text{rad/sec}$$

$$Q = \frac{\omega_0}{2\beta} = \frac{1}{2 \times 2} = \frac{1}{4} = 0.25$$

26. The time dependence of the speed of a harmonically oscillating body is given by the equation $v(t) = 6\sin(2t)$. Find the value of the amplitude (a_{max}) of the acceleration.

$$v(t) = 6\sin(2t)\,\mathrm{m/s}$$

$$a(t) = \frac{dv(t)}{dt}$$

$$a(t) = 6 \times 2\cos(2t) = 12\cos(2t)\,\mathrm{m/s^2}$$

$$a_{\text{max}} = 12\,\mathrm{m/s^2}$$

27. Calculate the value of the ratio $\frac{I_{\max}}{I_{\min}}$ in the case of the polarization degree is $P = \frac{3}{4}$.

$$P = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

$$\frac{3}{4} = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

$$\frac{3}{4}(I_{\max} + I_{\min}) = I_{\max} - I_{\min}$$

$$3I_{\max} + 3I_{\min} = 4I_{\max} - 4I_{\min}$$

$$7I_{\min} = I_{\max}$$

$$\frac{I_{\max}}{I_{\min}} = 7$$

28. The current-currying frame with the windings $n = 20$ and area $S = 200\ \mathrm{cm}^2$ rotates in a uniform magnetic field with the induction $\mathrm{B} = 0.5\ \mathrm{T}$. Knowing that the magnetic flux changes according to the law $\Phi = B \cdot S \cdot \cos(\omega t)$, find the amplitude value of the induced e.m.f. produced at the value $f = 5\ \mathrm{Hz}$ of the frequency. ($\pi \approx 3$).

$$\omega = 2\pi f = 2 \times 3 \times 5 = 30\ \mathrm{rad/s}$$

$$S = 200\ \mathrm{cm}^2 = 200 \times 10^{-4}\ \mathrm{m}^2 = 0.02\ \mathrm{m}^2$$

$$\mathcal{E} = -n\frac{d\Phi}{dt}$$

$$\Phi = B \cdot S \cdot \cos(\omega t)$$

$$\frac{d\Phi}{dt} = -B \cdot S \cdot \omega \sin(\omega t)$$

The amplitude of the induced e.m.f. $\mathcal{E}_{\max}$ occurs when $\sin(\omega t) = 1$, so:

$$\mathcal{E}_{\max} = n \cdot B \cdot S \cdot \omega = 20 \times 0.5 \times 0.02 \times 30 = 6V$$

29. How much work must be done by the external forces $q_1 = +10$ C and $q_2 = -10$ C to separate the charge from each other so that the e.m.f. of the source will be $V = 3.5$ V?

(Pray, maybe Almighty God will bless you, so you will not see this question on your exam paper 🤲)

$$W = \mathrm{q} \times \mathrm{V} = \frac{(\boldsymbol{q_1} - \boldsymbol{q_2}) \times V}{2}$$

$$W = \frac{(10 - (-10)) \times 3.5}{2} = 35J$$

30. The distance difference of two points from the oscilllation source in an elastic medium is $\Delta x = 5$ m. Find the phase difference of the oscillations of these points in degrees. The oscillation frequency is $f = 20$ Hz, their propagation speed is $v = 200$ m/s.

$$\Delta\phi = \frac{2\pi\Delta x}{\lambda}$$

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{200 \text{ m/s}}{20 \text{ Hz}} = 10 \text{ m}$$

$$\Delta\phi = \frac{2\pi \times 5}{10} = \pi \text{ rad}$$

$$\Delta\phi_{\text{deg}} = \Delta\phi_{\text{rad}} \times \frac{180}{\pi} = \pi \times \frac{180}{\pi} = 180^\circ$$