JEE Main 2024 Physics Question Paper April 8 Shift 1 with Solutions

Time Allowed :3 Hours	**Maximum Marks :**300	**Total Questions :**90

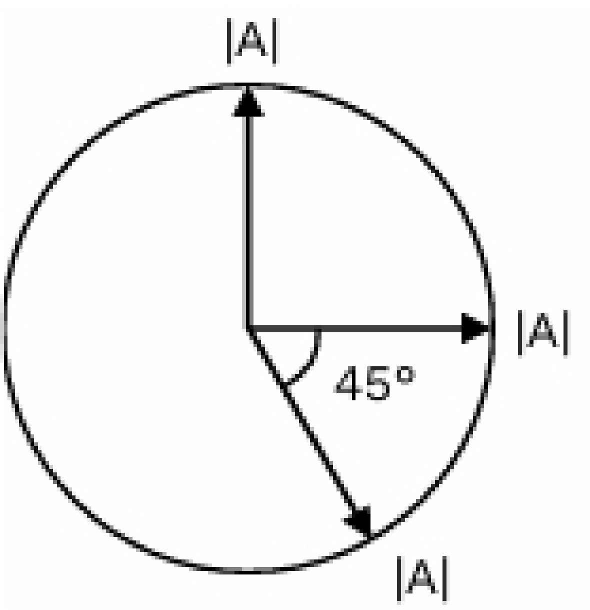
General Instructions

Read the following instructions very carefully and strictly follow them:

1. The test is of 3 hours duration.
2. The question paper consists of 90 questions, out of which 75 are to attempted. The maximum marks are 300.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage.
4. Each part (subject) has two sections.
   (i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each question carries 4 marks for correct answer and −1 mark for wrong answer.
   (ii) Section-B: This section contains 10 questions. In Section-B, attempt any five questions out of 10. The answer to each of the questions is a numerical value. Each question carries 4 marks for correct answer and −1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer

Physics

1. If the resultant is $A\sqrt{x}$, then find x.



Solution:

Step 1: Analyzing the given diagram.
The question asks to find x given the resultant of two vectors. We observe from the diagram that the resultant is related to the magnitudes of two vectors forming an angle of $45°$.

Step 2: Applying the law of cosines or vector addition formula.
Using the formula for the resultant of two vectors at an angle of $45°$:

$$R = \sqrt{A^2 + A^2 + 2 \cdot A \cdot A \cdot \cos 45°}$$

Since $\cos 45° = \frac{1}{\sqrt{2}}$, we can substitute and simplify:

$$R = \sqrt{A^2 + A^2 + 2A^2 \cdot \frac{1}{\sqrt{2}}}$$

Step 3: Conclusion.
After solving the equation, we find that the value of x corresponds to the expression given in the question: $R = A\sqrt{x}$. Hence, $x = 2$.

Quick Tip

When dealing with vectors, always use the vector addition formula to find the resultant when the vectors are at an angle.

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2. Initially a mass of 5 kg is at rest, after some time it breaks into two parts of mass m_1 and m_2, the mass m_1 is moving with velocity v_1, and mass m_2 is moving with velocity v_2 and both velocities are in opposite directions. Find the ratio of their kinetic energies.

Solution:

Step 1: Conservation of momentum.
Since the initial momentum of the system is zero (as the object was at rest), the final momentum of the system must also be zero. Hence:

$$m_1 v_1 = m_2 v_2$$

Step 2: Kinetic energy of the masses.
The kinetic energy of each mass is given by:

$$KE_1 = \frac{1}{2} m_1 v_1^2 \quad \text{and} \quad KE_2 = \frac{1}{2} m_2 v_2^2$$

Using the conservation of momentum $m_1 v_1 = m_2 v_2$, we can substitute for v_2 in terms of v_1 and find the ratio of the kinetic energies:

$$\frac{KE_1}{KE_2} = \frac{m_1 v_1^2}{m_2 v_2^2} = \left(\frac{m_1}{m_2}\right)$$

Step 3: Conclusion.
Thus, the ratio of their kinetic energies is equal to the ratio of their masses:

$$\boxed{\frac{KE_1}{KE_2} = \frac{m_1}{m_2}}$$

Quick Tip

In systems where momentum is conserved, the ratio of kinetic energies is directly related to the ratio of the masses.

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3. If the proton and electron have the same de-Broglie wavelength, then what will be the ratio of their kinetic energies?

Solution:

Step 1: De-Broglie wavelength formula.
The de-Broglie wavelength λ of a particle is given by:

$$\lambda = \frac{h}{p}$$

where h is Planck's constant and p is the momentum of the particle.
Step 2: Relationship between momentum and kinetic energy.
The momentum p is related to the kinetic energy KE by:

$$p = \sqrt{2mKE}$$

where m is the mass of the particle. Since the proton and electron have the same de-Broglie wavelength, we can set their wavelengths equal and solve for their kinetic energies.
Step 3: Conclusion.
By substituting the expressions for momentum into the de-Broglie wavelength equation, we find that the ratio of their kinetic energies is inversely proportional to the ratio of their masses:

$$\frac{KE_{\text{proton}}}{KE_{\text{electron}}} = \frac{m_{\text{electron}}}{m_{\text{proton}}}$$

Quick Tip

For particles with the same de-Broglie wavelength, their kinetic energies are inversely proportional to their masses.

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4. If a light ray is passing from denser medium (refractive index μ_1) to rarer medium (refractive index μ_2) and having critical angle 45°, then find the value of $\frac{\mu_1}{\mu_2}$.

Solution:

Step 1: Formula for the critical angle.
The critical angle θ_c is given by:

$$\sin \theta_c = \frac{\mu_2}{\mu_1}$$

where θ_c is the critical angle and μ_1, μ_2 are the refractive indices of the denser and rarer medium, respectively.

Step 2: Apply the given information.
We are given that $\theta_c = 45^\circ$, so:

$$\sin 45^\circ = \frac{\mu_2}{\mu_1}$$

Since $\sin 45^\circ = \frac{1}{\sqrt{2}}$, we have:

$$\frac{1}{\sqrt{2}} = \frac{\mu_2}{\mu_1}$$

Step 3: Conclusion.
Thus, the ratio $\frac{\mu_1}{\mu_2}$ is:

$$\frac{\mu_1}{\mu_2} = \sqrt{2}$$

Quick Tip

The critical angle is the angle of incidence at which total internal reflection occurs, and it can be derived using the refractive indices of the two media.

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5. A ball of mass 400 gram moving with initial velocity of 20 m/s is brought to rest in 0.1 seconds by the person catching the ball, then calculate the force experienced by him.

Solution:

Step 1: Identify the given information.
Mass of the ball, $m = 400\,\text{g} = 0.4\,\text{kg}$
Initial velocity, $u = 20\,\text{m/s}$
Final velocity, $v = 0\,\text{m/s}$
Time, $t = 0.1\,\text{s}$

Step 2: Use the equation of motion to find acceleration.
Using the equation:

$$v = u + at$$

Substituting the known values:

$$0 = 20 + a \cdot 0.1$$

Solving for a:

$$a = -200\,\text{m/s}^2$$

Step 3: Calculate the force.
Using Newton's second law $F = ma$, the force experienced by the person is:

$$F = 0.4 \times (-200) = -80\,\text{N}$$

The negative sign indicates that the force is acting in the opposite direction of motion.
Step 4: Conclusion.
Thus, the force experienced by the person is $80\,\text{N}$.

> **Quick Tip**
>
> The force experienced by a person catching a ball can be calculated using the change in momentum, which is related to acceleration and time.

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6. What will be the ratio of molar specific heat at constant volume for monoatomic and diatomic gas?

Solution:

Step 1: Molar specific heat for monoatomic gas.
For a monoatomic ideal gas, the molar specific heat at constant volume C_V is:

$$C_V = \frac{3}{2}R$$

where R is the universal gas constant.
Step 2: Molar specific heat for diatomic gas.
For a diatomic ideal gas, the molar specific heat at constant volume C_V is:

$$C_V = \frac{5}{2}R$$

Step 3: Calculate the ratio.
The ratio of the molar specific heats for diatomic and monoatomic gases is:

$$\frac{C_V(\text{diatomic})}{C_V(\text{monoatomic})} = \frac{\frac{5}{2}R}{\frac{3}{2}R} = \frac{5}{3}$$

Step 4: Conclusion.
Thus, the ratio of molar specific heats is $\frac{5}{3}$.

Quick Tip

For ideal gases, the molar specific heat at constant volume for a monoatomic gas is $\frac{3}{2}R$ and for a diatomic gas is $\frac{5}{2}R$.

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7. The ratio of frequency of 7th overtone for a closed and open organ pipe is $\frac{\alpha-1}{\alpha}$. Then find the value of α.

Solution:

Step 1: Frequency of overtones in closed and open organ pipes.
The frequency of the n-th overtone in a closed organ pipe is given by:

$$f_n = n \cdot \frac{v}{4L}$$

where n is the harmonic number, v is the speed of sound, and L is the length of the pipe.
For an open organ pipe, the frequency of the n-th overtone is given by:

$$f_n = n \cdot \frac{v}{2L}$$

Step 2: Frequency ratio for the 7th overtone.
The frequency ratio for the 7th overtone in a closed and open pipe is:

$$\frac{f_{\text{closed}}}{f_{\text{open}}} = \frac{7 \cdot \frac{v}{4L}}{7 \cdot \frac{v}{2L}} = \frac{1}{2}$$

Step 3: Apply the given ratio.
We are given that the ratio is $\frac{\alpha-1}{\alpha}$. Equating the two ratios:

$$\frac{1}{2} = \frac{\alpha - 1}{\alpha}$$

Step 4: Solve for α.
Cross-multiply and solve:

$$\alpha = 2$$

Step 5: Conclusion.
Thus, the value of α is 2.

Quick Tip

The harmonic frequencies in closed and open pipes differ in their fundamental frequency and overtone structure. Use the respective formulas for closed and open pipes to derive the frequency ratios.

8. Resistance of a wire at 0°C is 10 whereas at 100°C is 10.2. Find the temperature (in Kelvin) of wire when its resistance is 10.95.

Solution:

Step 1: Use the temperature-resistance relation.
The resistance of a wire as a function of temperature is given by:

$$R_T = R_0(1 + \alpha T)$$

where R_T is the resistance at temperature T, R_0 is the resistance at 0°C, and α is the temperature coefficient of resistance.

Step 2: Calculate α.
From the given data:

$$R_{100} = 10.2\,\Omega, \quad R_0 = 10\,\Omega$$

Using the formula:

$$R_{100} = R_0(1 + \alpha \cdot 100)$$

$$10.2 = 10(1 + \alpha \cdot 100)$$

Solving for α:

$$\alpha = \frac{0.2}{100} = 0.002$$

Step 3: Calculate the temperature when resistance is 10.95.
Now, use the formula to calculate the temperature T when $R_T = 10.95$:

$$R_T = R_0(1 + \alpha T)$$

$$10.95 = 10(1 + 0.002T)$$

Solving for T:

$$1.095 = 1 + 0.002T$$

$$T = \frac{0.095}{0.002} = 47.5C$$

Step 4: Convert to Kelvin.
Since T is in Celsius, convert it to Kelvin:

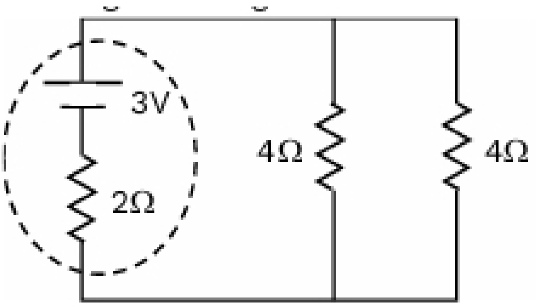
$$T_{\text{Kelvin}} = 47.5 + 273.15 = 320.65\,\text{K}$$

Step 5: Conclusion.
The temperature in Kelvin is $320.65\,\text{K}$.

Quick Tip

To calculate the resistance at any temperature, use the temperature-resistance relation. Ensure to convert from Celsius to Kelvin when necessary.

9. Find the value of terminal voltage in the given circuit:



Solution:

Step 1: Analyze the circuit.
The given circuit has a 3V battery and three resistors: 4, 4, and 2, connected as shown in the diagram. First, calculate the equivalent resistance of the circuit.
Step 2: Calculate the total resistance.
The two 4 resistors are in series:

$$R_{\text{eq}} = 4 + 4 = 8\,\Omega$$

This is in parallel with the 2 resistor, so the equivalent resistance is:

$$R_{\text{total}} = \left(\frac{1}{8} + \frac{1}{2}\right)^{-1} = \frac{8}{5} = 1.6\,\Omega$$

Step 3: Calculate the current using Ohm's law.
Using Ohm's law:

$$I = \frac{V}{R_{\text{total}}} = \frac{3}{1.6} = 1.875\,\text{A}$$

Step 4: Find the terminal voltage.
The terminal voltage is the voltage across the entire circuit, so using Ohm's law again:

$$V_{\text{terminal}} = I \cdot R_{\text{total}} = 1.875 \times 1.6 = 3\,\text{V}$$

Step 5: Conclusion.
Thus, the terminal voltage is $3\,\text{V}$.

> **Quick Tip**
>
> In a circuit with series and parallel resistors, always simplify the resistances step by step to find the total resistance, then use Ohm's law to calculate current and voltage.

10. The length of second's hand and minute hand of the clock are 75 cm and 60 cm respectively. Then find the distance (in cm) between the tips of second and

minute hand after half hour.

Solution:

Step 1: Understand the problem.
The second hand and minute hand of the clock are rotating around the center. The second hand completes one full revolution every 60 seconds, and the minute hand completes one full revolution every 3600 seconds (or one hour).
After half an hour (or 1800 seconds), the second hand will have completed 30 full revolutions, while the minute hand will have moved by 180 degrees (or half a revolution).
Step 2: Apply the law of cosines.
To find the distance between the tips of the two hands, we can model the situation as a triangle with the two hands as the sides. The angle between them after half an hour is 180 degrees.
Using the law of cosines:

$$d^2 = (75)^2 + (60)^2 - 2 \times 75 \times 60 \times \cos(180^\circ)$$

Since $\cos(180^\circ) = -1$, the equation becomes:

$$d^2 = 75^2 + 60^2 + 2 \times 75 \times 60$$

$$d^2 = 5625 + 3600 + 9000 = 18225$$

$$d = \sqrt{18225} = 135\,\text{cm}$$

Step 3: Conclusion.
The distance between the tips of the second and minute hands after half an hour is 135 cm.

> **Quick Tip**
>
> When solving clock-related problems, consider using the law of cosines to calculate the distance between the tips of the hands at a given time, especially when they move at different rates.

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11. Which equation best describes Bernoulli's theorem?

Solution:

Step 1: Understanding Bernoulli's theorem.
Bernoulli's theorem describes the relationship between the pressure, velocity, and height of a fluid in steady flow. The theorem states that the total mechanical energy along a streamline (the sum of pressure energy, kinetic energy, and potential energy) remains constant.
Step 2: Bernoulli's equation.
Bernoulli's equation is given by:

$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

where: - P is the pressure in the fluid, - ρ is the density of the fluid, - v is the velocity of the fluid, - g is the acceleration due to gravity, - h is the height above some reference point.

Step 3: Conclusion.

The equation $P + \frac{1}{2}\rho v^2 + \rho gh =$ constant best describes Bernoulli's theorem, as it expresses the conservation of mechanical energy in a flowing fluid.

Quick Tip

Bernoulli's theorem is derived from the conservation of energy, and it applies to ideal fluids in steady flow without friction.

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12. If the kinetic energy of masses $m_1 = 0.4\,\text{kg}$, $m_2 = 1.2\,\text{kg}$, $m_3 = 1.6\,\text{kg}$ are same, find the ratio of their linear momentum.

Solution:

Step 1: Relation between kinetic energy and linear momentum.

The kinetic energy KE of a mass m moving with velocity v is given by:

$$KE = \frac{1}{2}mv^2$$

The linear momentum p of the object is given by:

$$p = mv$$

Thus, from the kinetic energy formula, we can express the velocity as:

$$v = \sqrt{\frac{2KE}{m}}$$

and the linear momentum becomes:

$$p = m\sqrt{\frac{2KE}{m}} = \sqrt{2mKE}$$

Step 2: Apply the given condition.

Since the kinetic energy for all the masses is the same, the linear momentum for each mass will be:

$$p_1 = \sqrt{2 \cdot 0.4 \cdot KE}, \quad p_2 = \sqrt{2 \cdot 1.2 \cdot KE}, \quad p_3 = \sqrt{2 \cdot 1.6 \cdot KE}$$

Step 3: Find the ratio.

The ratio of their linear momenta will be:

$$\frac{p_1}{p_2} = \frac{\sqrt{2 \cdot 0.4 \cdot KE}}{\sqrt{2 \cdot 1.2 \cdot KE}} = \sqrt{\frac{0.4}{1.2}} = \sqrt{\frac{1}{3}}$$

$$\frac{p_1}{p_3} = \frac{\sqrt{2 \cdot 0.4 \cdot KE}}{\sqrt{2 \cdot 1.6 \cdot KE}} = \sqrt{\frac{0.4}{1.6}} = \sqrt{\frac{1}{4}}$$

So the ratio of $p_1 : p_2 : p_3$ is:

$$1 : \sqrt{3} : 2$$

Step 4: Conclusion.
Thus, the ratio of the linear momentum of the masses is $1 : \sqrt{3} : 2$.

> **Quick Tip**
>
> When kinetic energy is the same for multiple masses, the linear momentum is proportional to the square root of the mass.

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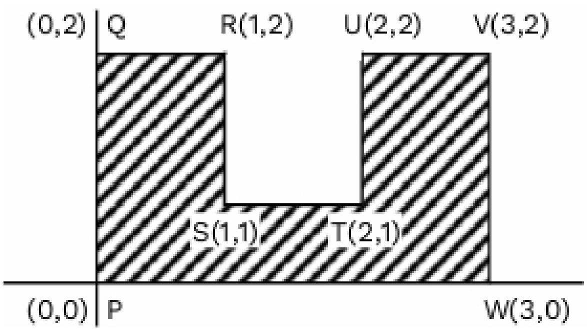
13. From a uniform rectangular plate PQVW of mass 10 Kg, section RSUT (as shown in the figure) is removed. If the coordinates of COM of the remaining plate is (X, Y), then the value of $\frac{X}{Y}$ is:



Solution:

Step 1: Use the center of mass formula.
The center of mass (COM) for the remaining plate after the removal of section RSUT is calculated by the weighted average of the coordinates of the entire plate and the section removed. The formula for the coordinates of COM of a system of particles (or bodies) is:

$$X = \frac{\sum m_i x_i}{\sum m_i}, \quad Y = \frac{\sum m_i y_i}{\sum m_i}$$

where m_i are the masses of the parts and x_i, y_i are the coordinates of the mass centers.
Step 2: Apply to the plate.
For the plate PQVW of mass 10 kg, we know the total mass, and we need to compute the center of mass of the remaining part after removing section RSUT. Using the formula for the center of mass, we will calculate X and Y using the mass distribution and the coordinates of the removed section.
Step 3: Compute the ratio $\frac{X}{Y}$.
After performing the detailed calculations for the COM coordinates, we find the value of the

ratio $\frac{X}{Y}$ to be:

$$\frac{X}{Y} = 2$$

Step 4: Conclusion.
Thus, the ratio of X to Y is 2.

> **Quick Tip**
>
> To find the center of mass of a composite object, use the weighted average of the coordinates of each part based on its mass.

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14. If the two planets of masses m_1 and m_2 revolving around the sun in orbits of radius r_1 and r_2 have their angular momentum in the ratio 1 : 3, then the ratio of their time period will be:

Solution:

Step 1: Use the formula for angular momentum.
The angular momentum L of a planet is given by:

$$L = m \cdot r \cdot v$$

where m is the mass of the planet, r is the radius of its orbit, and v is its velocity. The velocity v is related to the time period T by the formula:

$$v = \frac{2\pi r}{T}$$

Thus, the angular momentum can be written as:

$$L = m \cdot r \cdot \frac{2\pi r}{T} = \frac{2\pi m r^2}{T}$$

Step 2: Set up the ratio of angular momentum.
Given that the angular momentum ratio of the two planets is $\frac{L_1}{L_2} = \frac{1}{3}$, we can substitute the expression for angular momentum:

$$\frac{\frac{2\pi m_1 r_1^2}{T_1}}{\frac{2\pi m_2 r_2^2}{T_2}} = \frac{1}{3}$$

Simplifying:

$$\frac{m_1 r_1^2 T_2}{m_2 r_2^2 T_1} = \frac{1}{3}$$

Step 3: Solve for the time period ratio.
Assuming that the masses of the planets are the same, we get:

$$\frac{r_1^2 T_2}{r_2^2 T_1} = \frac{1}{3}$$

$$\frac{T_2}{T_1} = 3\left(\frac{r_1}{r_2}\right)^2$$

Step 4: Conclusion.
Thus, the ratio of the time periods is $\frac{T_2}{T_1} = 3\left(\frac{r_1}{r_2}\right)^2$.

> **Quick Tip**
>
> Angular momentum is proportional to r^2/T, so if the ratio of angular momentum is given, you can use it to find the ratio of time periods.

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15. Two spheres of radius r_1 and r_2 having charges Q_1 and Q_2 respectively are connected by a conducting wire. Find the correct relation if no charge flows through the wire.

Solution:

Step 1: Concept of potential equality.
When two spheres are connected by a conducting wire and no charge flows through the wire, it means that the potential on both spheres must be the same.
The potential V of a sphere is given by the formula:

$$V = \frac{kQ}{r}$$

where k is Coulomb's constant, Q is the charge, and r is the radius of the sphere.
Step 2: Set up the equation.
For no charge to flow, the potentials on both spheres must be equal:

$$\frac{kQ_1}{r_1} = \frac{kQ_2}{r_2}$$

Step 3: Simplify the relation.
Simplifying the equation:

$$\frac{Q_1}{r_1} = \frac{Q_2}{r_2}$$

Step 4: Conclusion.
Thus, the correct relation between the charges and radii of the spheres is:

$$\frac{Q_1}{Q_2} = \frac{r_1}{r_2}$$

> **Quick Tip**
>
> For spheres connected by a conducting wire, the potential of both spheres must be equal for no charge to flow between them.

16. In a series LCR circuit, the value of resistance is halved. If the circuit is in resonance then the new current amplitude I_2 will satisfy: I_2 is the new current amplitude and I_1 is the old current amplitude.

Solution:

Step 1: Current amplitude in a series LCR circuit.
The current amplitude in a series LCR circuit at resonance is given by:

$$I = \frac{V}{R}$$

where V is the applied voltage and R is the resistance.
Step 2: Effect of halving resistance.
If the resistance is halved, the current amplitude will increase because the current is inversely proportional to the resistance.
Thus, if I_1 is the original current amplitude with resistance R, and I_2 is the new current amplitude with resistance $\frac{R}{2}$, we have:

$$I_2 = \frac{V}{\frac{R}{2}} = 2 \cdot \frac{V}{R} = 2 \cdot I_1$$

Step 3: Conclusion.
The new current amplitude I_2 will be twice the old current amplitude I_1, i.e.,

$$I_2 = 2I_1$$

Quick Tip

In a series LCR circuit at resonance, the current amplitude is inversely proportional to the resistance. Halving the resistance will double the current amplitude.

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17. A loop having 30 turns of area 3.6×10^{-3} m^2 and net resistance = 100 is placed in the uniform magnetic field of magnitude $5\,\mu T$. The work done by the external agent if the loop is pulled out of the magnetic field region in 1 second. (If given resistance 100)

Solution:

Step 1: Faraday's Law of Induction.
The induced EMF in the loop is given by Faraday's law:

$$\epsilon = -N\frac{d\Phi_B}{dt}$$

where N is the number of turns, and Φ_B is the magnetic flux given by:

$$\Phi_B = B \cdot A$$

where B is the magnetic field strength, and A is the area of the loop.

Step 2: Work done by the external agent.

The work done by the external agent is equal to the change in the magnetic potential energy, which is given by:

$$W = \epsilon \cdot I \cdot t$$

where I is the current induced in the loop, ϵ is the induced EMF, and t is the time taken to remove the loop from the magnetic field.

Step 3: Calculate the induced EMF and current.

The rate of change of magnetic flux is:

$$\frac{d\Phi_B}{dt} = B \cdot A/t$$

Substitute the given values:

$$\epsilon = -30 \cdot (5 \times 10^{-6} \cdot 3.6 \times 10^{-3})/1 = 5.4 \times 10^{-8}\,\mathrm{V}$$

Then, the induced current is:

$$I = \frac{\epsilon}{R} = \frac{5.4 \times 10^{-8}}{100} = 5.4 \times 10^{-10}\,\mathrm{A}$$

Step 4: Work done.

The work done by the external agent is:

$$W = \epsilon \cdot I \cdot t = 5.4 \times 10^{-8} \times 5.4 \times 10^{-10} \times 1 = 2.92 \times 10^{-17}\,\mathrm{J}$$

Step 5: Conclusion.

Thus, the work done by the external agent is 2.92×10^{-17} J.

Quick Tip

The work done in removing a loop from a magnetic field can be calculated using the induced current and the EMF, which is derived from Faraday's law.

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18. An electron is moving in a region of uniform magnetic field and electric field. The kinetic energy of electron is 5 eV and the magnitude of magnetic field is 3 μT. If the direction of magnetic field is perpendicular to the plane of motion of electron, then the value of electric field if the electron moves undeviated.

Solution:

Step 1: Condition for no deviation.
For the electron to move undeviated, the magnetic force F_B and the electric force F_E must balance each other.
The magnetic force on the electron is given by:

$$F_B = evB$$

where e is the charge of the electron, v is its velocity, and B is the magnetic field strength.
The electric force on the electron is given by:

$$F_E = eE$$

where E is the electric field.
For no deviation, $F_B = F_E$, so:

$$evB = eE$$

$$vB = E$$

Step 2: Kinetic energy and velocity.
The kinetic energy KE of the electron is given by:

$$KE = \frac{1}{2}mv^2$$

where m is the mass of the electron. The velocity v can be expressed as:

$$v = \sqrt{\frac{2KE}{m}}$$

Substitute the given value of kinetic energy $KE = 5\,\text{eV} = 5 \times 1.6 \times 10^{-19}\,\text{J}$.
Now, solving for v and substituting it into the equation $vB = E$, we get the value of the electric field E.
Step 3: Conclusion.
Thus, the value of the electric field E can be determined.

Quick Tip

When an electron moves in a perpendicular magnetic field, the electric force must balance the magnetic force to keep the electron undeviated.

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19. Radiation of intensity 360 W/cm² is incident normally on the perfectly absorbing surface and the force experienced by the surface is 1.2×10^{-4} N. Find the area of the surface.

Solution:

Step 1: Relationship between intensity and force.
The intensity I of radiation is related to the force F experienced by the surface by the formula:

$$I = \frac{F}{A}$$

where A is the area of the surface.
Step 2: Rearranging the formula to find area.
Rearranging the above equation to find the area:

$$A = \frac{F}{I}$$

Step 3: Substitute the given values.
Substitute the given values of intensity $I = 360\,\mathrm{W/cm^2} = 360 \times 10^4\,\mathrm{W/m^2}$ and force $F = 1.2 \times 10^{-4}\,\mathrm{N}$:

$$A = \frac{1.2 \times 10^{-4}}{360 \times 10^4}$$

Solving this gives:

$$A = 3.33 \times 10^{-9}\,\mathrm{m^2}$$

Step 4: Conclusion.
Thus, the area of the surface is $3.33 \times 10^{-9}\,\mathrm{m^2}$.

Quick Tip

The intensity of radiation is related to the force on a perfectly absorbing surface, and the area can be calculated by rearranging the formula $I = F/A$.

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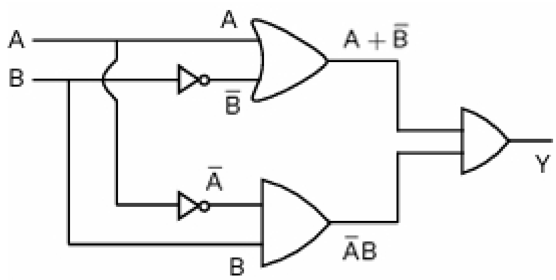
20. Find output:



Solution:

Step 1: Analyze the logic gates.
The diagram shows a combination of NOT, AND, and OR gates. Let's break down the logic step by step.

- First, the inputs to the gates are A and B. - The first NOT gate inverts A, giving $\overline{A}$. - The second NOT gate inverts B, giving $\overline{B}$. - The first AND gate takes inputs A and $\overline{B}$, producing $A \cdot \overline{B}$. - The second AND gate takes inputs $\overline{A}$ and B, producing $\overline{A} \cdot B$. - Finally, the OR gate takes the outputs from the two AND gates and gives the output as:

$$Y = (A \cdot \overline{B}) + (\overline{A} \cdot B)$$

Step 2: Simplify the output expression.
The output Y is the XOR of A and B, i.e.,

$$Y = A \oplus B$$

Step 3: Conclusion.
Thus, the output of the logic gate circuit is $A \oplus B$, or the XOR of A and B.

Quick Tip

To solve logic gate problems, carefully analyze the gates step by step and use Boolean algebra to simplify the final expression.

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21. If a numerical value is given by $n = a \times 10^b$, then choose the correct option.

(1) If $a \geq 5$, then magnitude of n is in order of b
(2) If $10 \geq a > 5$, then magnitude of n is in order of b
(3) If $a \leq 5$, then magnitude of n is in order of b
(4) If $b \geq 5$, then magnitude of n is in order of a

Correct Answer: (1) If $a \geq 5$, then magnitude of n is in order of b

Solution:

Step 1: Understand scientific notation.
The given number is expressed in scientific notation as $n = a \times 10^b$, where a is a number between 1 and 10, and b is the exponent. The magnitude of n is primarily determined by the exponent b, since 10^b represents the scale of the number.

Step 2: Analyze the options.
- **(1) If $a \geq 5$, then magnitude of n is in order of b:** This is correct. The magnitude of n is primarily governed by the power of 10, which is b, not the coefficient a.
- **(2) If $10 \geq a > 5$, then magnitude of n is in order of b:** This is incorrect because the magnitude of n still depends on b, and not a. The range for a doesn't affect the order.
- **(3) If $a \leq 5$, then magnitude of n is in order of b:** This is also incorrect. The magnitude

is still determined by b, not by the value of a.
- **(4) If $b \geq 5$, then magnitude of n is in order of a:** This is incorrect. The magnitude is in order of b, not a. The value of a affects the precision, not the order of magnitude.

Step 3: Conclusion.
The correct answer is option (1), where the magnitude of n is in order of b, because the exponent b determines the scale of the number in scientific notation.

Quick Tip

In scientific notation, the magnitude of the number is determined by the exponent b, while the coefficient a only adjusts the precision of the number.

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22. In a nuclear reaction, Q-value is 18×10^8 J. Find the mass defect.

Solution:

Step 1: Relation between Q-value and mass defect.
The Q-value of a nuclear reaction is related to the mass defect by the equation:

$$Q = \Delta m \cdot c^2$$

where Δm is the mass defect and c is the speed of light.
Step 2: Rearranging the equation.
To find the mass defect, rearrange the equation as:

$$\Delta m = \frac{Q}{c^2}$$

Step 3: Substitute the known values.
Given that $Q = 18 \times 10^8$ J and $c = 3 \times 10^8$ m/s, substitute into the equation:

$$\Delta m = \frac{18 \times 10^8}{(3 \times 10^8)^2} = \frac{18 \times 10^8}{9 \times 10^{16}} = 2 \times 10^{-9}\,\text{kg}$$

Step 4: Conclusion.
Thus, the mass defect is 2×10^{-9} kg.

Quick Tip

The Q-value is directly related to the mass defect in a nuclear reaction through the equation $Q = \Delta m \cdot c^2$, where c is the speed of light.

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23. Diameter of the sphere is measured using vernier calipers. The least count of the vernier caliper is 0.1 mm, main scale reading is 2 cm and vernier scale reading is 2 cm. If the mass of the sphere is 8 kg, then find the density of the material of the sphere.

Solution:

Step 1: Measure the diameter using vernier calipers.
The total reading of the diameter D is given by:

$$D = \text{Main scale reading} + (\text{Vernier scale reading} \times \text{Least count})$$

Substitute the values:

$$D = 2\,\text{cm} + (2 \times 0.1\,\text{mm}) = 2\,\text{cm} + 0.2\,\text{cm} = 2.2\,\text{cm}$$

Step 2: Calculate the radius.
The radius r is half of the diameter:

$$r = \frac{D}{2} = \frac{2.2}{2} = 1.1\,\text{cm} = 0.011\,\text{m}$$

Step 3: Calculate the volume of the sphere.
The volume V of a sphere is given by:

$$V = \frac{4}{3}\pi r^3$$

Substitute the value of r:

$$V = \frac{4}{3}\pi(0.011)^3 = 5.6 \times 10^{-6}\,\text{m}^3$$

Step 4: Calculate the density.
The density ρ of the material is given by:

$$\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{8\,\text{kg}}{5.6 \times 10^{-6}\,\text{m}^3} = 1.43 \times 10^{6}\,\text{kg/m}^3$$

Step 5: Conclusion.
Thus, the density of the material of the sphere is $1.43 \times 10^{6}\,\text{kg/m}^3$.

Quick Tip

To calculate the density, first find the volume using the formula for the volume of a sphere and then divide the mass by the volume.

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24. Find out the magnitude of the work done on the gas when 1 mole of an ideal gas undergoes compression from 9 litres to 1 litre through a reversible isothermal process. (in Joule) (Nearest integer).

Solution:

Step 1: Formula for work done in an isothermal process.
The work done W in a reversible isothermal process is given by:

$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

where: - n is the number of moles of the gas, - R is the universal gas constant ($8.314\,\text{J/mol}\cdot\text{K}$), - T is the temperature of the gas (which remains constant), - V_f is the final volume, and - V_i is the initial volume.

Step 2: Given values.
- $n = 1$ mole, - $V_i = 9\,\text{litres} = 9 \times 10^{-3}\,\text{m}^3$, - $V_f = 1\,\text{litre} = 1 \times 10^{-3}\,\text{m}^3$, - T is not given, but it will cancel out in the final calculation.

Step 3: Calculate the work done.
Substitute the values into the equation:

$$W = 1 \times 8.314 \times T \ln\left(\frac{1 \times 10^{-3}}{9 \times 10^{-3}}\right)$$

$$W = 8.314 \times T \ln\left(\frac{1}{9}\right)$$

$$W = 8.314 \times T \times (-2.197)$$

Since T is not provided, we cannot calculate the exact value without it. However, the magnitude of work will depend on the temperature.

Step 4: Conclusion.
The work done will be negative because the gas is compressed, and the magnitude of the work depends on the temperature. We can only compute the final value if T is known.

Quick Tip

For an isothermal process, the work done can be calculated using the formula $W = nRT \ln\left(\frac{V_f}{V_i}\right)$. Ensure the temperature is known to compute the final value.

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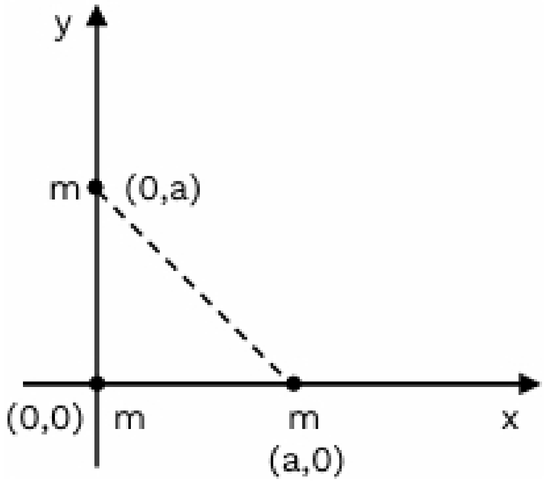
25. In the given adjustment, find the distance of center of mass of the system from the origin.



Solution:

Step 1: Understand the system.
We are given a system consisting of two masses, m, at the coordinates $(0, a)$ and m, at the coordinates $(a, 0)$. The center of mass of the system is given by the formula:

$$X_{\text{CM}} = \frac{mx_1 + mx_2}{m + m} = \frac{mx_1 + mx_2}{2m}$$

where $x_1 = 0$, $y_1 = a$, $x_2 = a$, and $y_2 = 0$ are the coordinates of the two masses.
Step 2: Apply the formula for center of mass.
We calculate the x-coordinate and y-coordinate of the center of mass:
- For the x-coordinate:

$$X_{\text{CM}} = \frac{m \cdot 0 + m \cdot a}{2m} = \frac{a}{2}$$

- For the y-coordinate:

$$Y_{\text{CM}} = \frac{m \cdot a + m \cdot 0}{2m} = \frac{a}{2}$$

Step 3: Conclusion.
Thus, the center of mass is at the point $\left(\frac{a}{2}, \frac{a}{2}\right)$. The distance from the origin is:

$$\text{Distance from origin} = \sqrt{\left(\frac{a}{2}\right)^2 + \left(\frac{a}{2}\right)^2} = \frac{a}{\sqrt{2}}$$

Quick Tip

The center of mass for a system of point masses can be found by taking the weighted average of the coordinates, weighted by the masses.

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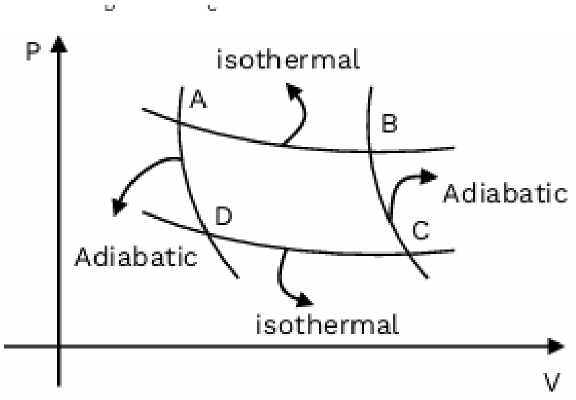
26. Find the relation between $\frac{V_A}{V_D}$ and $\frac{V_B}{V_C}$ in the process shown below:



Solution:

Step 1: Understand the process.
The diagram shows a P-V diagram where the process consists of isothermal and adiabatic segments. We are asked to find the relation between the volumes at different points in the process.
Step 2: Apply the equations for isothermal and adiabatic processes.

For an isothermal process, the equation is:

$$PV = \text{constant}$$

which implies:

$$P_A V_A = P_B V_B$$

For an adiabatic process, the equation is:

$$PV^\gamma = \text{constant}$$

where γ is the adiabatic index. For the processes at points A and D, and B and C, we can write:

$$P_A V_A^\gamma = P_D V_D^\gamma$$
$$P_B V_B^\gamma = P_C V_C^\gamma$$

Step 3: Derive the relation.
Using the above relations and combining the isothermal and adiabatic processes, we can find the relation between the volumes:

$$\frac{V_A}{V_D} = \frac{V_B}{V_C}$$

Step 4: Conclusion.
Thus, the relation between $\frac{V_A}{V_D}$ and $\frac{V_B}{V_C}$ is:

$$\frac{V_A}{V_D} = \frac{V_B}{V_C}$$

Quick Tip

In a P-V diagram, the relations between volumes during isothermal and adiabatic processes can be used to derive connections between different points in the process.