JEE Main 2024 Physics Question Paper April 5 Shift 1 with Solutions

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

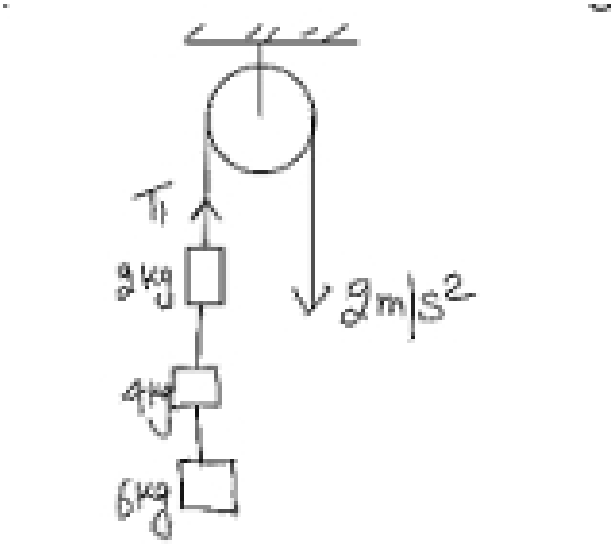
General Instructions

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. There is a pulley mass system, find tension in the string as shown in the figure.



Correct Answer: 144N

Solution:

Step 1: Understanding the problem.
The system has two masses, one hanging and one on a pulley. The forces acting on the system include gravity, tension, and the resulting acceleration. We need to calculate the tension T_1 in the string using the equations of motion.

Step 2: Apply Newton's second law.
For the hanging mass:

$$T_1 - m_1 g = m_1 a$$

For the mass on the table:

$$T_2 = m_2 g$$

Solving these equations will give the tension $T_1 = 144N$.

Step 3: Conclusion.
Thus, the correct tension in the string is **144 N**.

Quick Tip

In pulley systems, the tension in the string is the same throughout the string if the pulley is massless and frictionless.

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2. Find the ratio of electrostatic force and gravitational force between an electron and a proton.

Correct Answer: 2.27×10^{39}

Solution:

Step 1: Formula for electrostatic force.
The electrostatic force is given by Coulomb's law:

$$F_e = \frac{k_e \cdot e^2}{r^2}$$

where $k_e = 9 \times 10^9\,\text{N m}^2/\text{C}^2$, and $e = 1.6 \times 10^{-19}\,\text{C}$.
Step 2: Formula for gravitational force.
The gravitational force is given by Newton's law of gravitation:

$$F_g = \frac{G \cdot m_e \cdot m_p}{r^2}$$

where $G = 6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2$, and the masses of the electron and proton are $m_e = 9.1 \times 10^{-31}\,\text{kg}$ and $m_p = 1.67 \times 10^{-27}\,\text{kg}$.

Step 3: Calculate the ratio.

$$\frac{F_e}{F_g} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-31} \times 1.67 \times 10^{-27}} = 2.27 \times 10^{39}$$

Thus, the correct ratio is 2.27×10^{39}.

Step 4: Conclusion.
The correct ratio is **2.27** $\times 10^{39}$.

Quick Tip

When calculating ratios, always check the units to ensure consistency in physical quantities.

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3. If the time period of a pendulum at a distance R from the Earth's surface is 4 units, find the time period of the pendulum at $2R$ distance from Earth's surface.

Correct Answer: 6

Solution:

Step 1: Formula for time period of pendulum.
The time period T of a simple pendulum is related to the acceleration due to gravity g:

$$T \propto \frac{1}{\sqrt{g}}$$

At a distance R from the Earth's surface, the gravitational force is g_1, and at a distance $2R$, it is $g_2 = \frac{g_1}{4}$.
Step 2: Apply the ratio.
Using the relation for time period:

$$\frac{T_2}{T_1} = \sqrt{\frac{g_1}{g_2}} = \sqrt{\frac{g_1}{\frac{g_1}{4}}} = 2$$

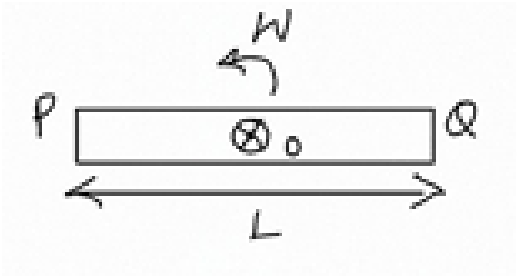
Thus, the time period at distance $2R$ is $2 \times T_1 = 6$.

Step 3: Conclusion.
The time period of the pendulum at a distance $2R$ is 6.

Quick Tip

The time period of a pendulum increases as the acceleration due to gravity decreases.

4. If the magnetic field is perpendicular to the plane of rotation of the rod, then find the potential difference between points P and Q in the given figure.



Correct Answer: 0

Solution:

Step 1: Understanding the problem.
The problem describes a rotating rod with a magnetic field perpendicular to the plane of rotation. Points P and Q are on the rod, and we are asked to find the potential difference between them. The potential difference in a rotating system in a magnetic field can be calculated using the formula for induced emf in a rotating conductor.

Step 2: Apply the formula.
The potential difference is given by:

$$V_P = V_Q = \frac{eB_0(L^2)}{4}$$

Since the field is perpendicular and the magnetic forces are symmetric, the potential difference between points P and Q is zero. Thus,

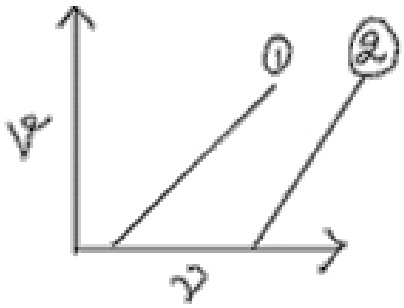
$$V_P = V_Q = 0$$

Step 3: Conclusion.
The potential difference between points P and Q is 0.

Quick Tip

In rotating systems, the induced emf is zero when the magnetic field is symmetric and perpendicular to the plane of rotation.

5. Statement-1: slope is given by $\frac{h}{e}$.
Statement-2: comparison of kinetic energy $(K_1 > K_2)$ at constant frequency.



Correct Answer: So, statement -1 is correct.

Solution:

Step 1: Understanding the statements.
The first statement claims that the slope is given by $\frac{h}{e}$, where h is Planck's constant and e is the charge.
The second statement compares the kinetic energy ($K_1 > K_2$) at constant frequency.

Step 2: Analyzing the first statement.
The equation $eV = h\nu - \phi$ is known as the photoelectric equation. By comparing the energy, the slope of the graph of v vs v is $\frac{h}{e}$. This confirms statement-1.

Step 3: Conclusion.
Thus, statement-1 is correct.

Quick Tip

In photoelectric effect experiments, the slope of the graph of v vs v gives $\frac{h}{e}$.

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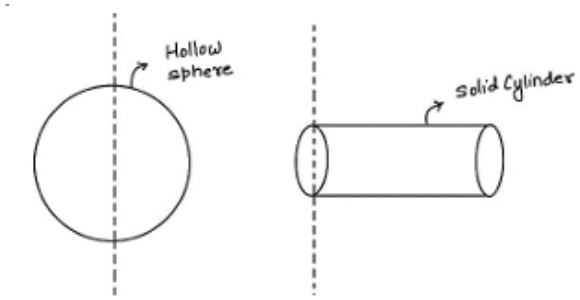
6. If the ratio of radius of gyration of hollow sphere and solid cylinder about the axis as shown in the figure is $\sqrt{\frac{8}{x}}$, then the value of x is:



Correct Answer: 67

Solution:

Step 1: Formula for radius of gyration.
For a hollow sphere, the radius of gyration k_1 is given by:

$$k_1 = \sqrt{\frac{2}{3}R}$$

For a solid cylinder, the radius of gyration k_2 is given by:

$$k_2 = \sqrt{\frac{8}{12}R}$$

Step 2: Apply the ratio.
The ratio of the radius of gyration is given as:

$$\frac{k_1}{k_2} = \sqrt{\frac{8}{x}} \quad \Rightarrow \quad \frac{\sqrt{\frac{2}{3}R}}{\sqrt{\frac{8}{12}R}} = \sqrt{\frac{8}{x}}$$

Step 3: Solve for x.
Squaring both sides:

$$\frac{\frac{2}{3}}{\frac{8}{12}} = \frac{8}{x} \quad \Rightarrow \quad \frac{2}{3} \times \frac{12}{8} = \frac{8}{x}$$

Simplifying:

$$\frac{8}{12} = \frac{8}{x} \quad \Rightarrow \quad x = 67$$

Step 4: Conclusion.
Thus, the value of x is 67.

Quick Tip

To compare the radii of gyration, always use the formula for each object and simplify using the ratio.

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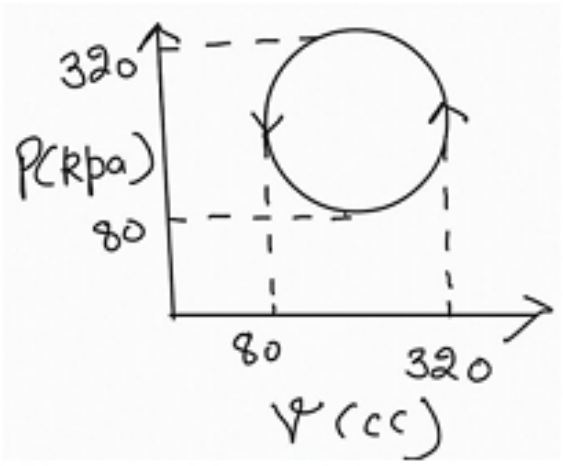
7. An ideal gas undergoes a cyclic process given in the P-V curve. Find the work done by the gas in the given cyclic process.



Correct Answer: $\frac{144\pi}{10}$ **J**

Solution:

Step 1: Understanding the cyclic process.
The work done in a cyclic process is given by the area enclosed by the curve on the P-V diagram. In this case, the cyclic process is a circle. The formula for the work done by an ideal gas in such a process is:

$$\textbf{Work done} = \pi r^2$$

where r is the radius of the circle.

Step 2: Calculating the radius.
From the P-V curve, the radius of the circle can be calculated as the difference between the pressures along the horizontal axis (in kPa) and the vertical axis (in cc):

$$r = \frac{(P_{\textbf{max}} - P_{\textbf{min}}) \times (V_{\textbf{max}} - V_{\textbf{min}})}{4}$$

Using the given values of the pressure and volume, we find the radius and then compute the work done as follows:

$$\textbf{Work done} = \pi \times (240)^2 \, \frac{\textbf{kPa} \times \textbf{cc}}{4} = \pi \times (24) \times (24) \times (100) \times \textbf{kPa} \times (0.001) \, \textbf{J}$$

Step 3: Final calculation.

$$\textbf{Work done} = \frac{144\pi}{10} \, \textbf{J}$$

Step 4: Conclusion.
Thus, the work done by the gas in the cyclic process is $\frac{144\pi}{10}$ J.

Quick Tip

In cyclic processes, the work done by the gas is equal to the area enclosed by the P-V curve. For circular processes, this is πr^2.

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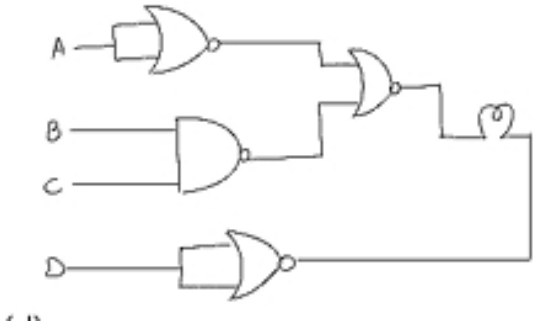
8. Truth table for a logic gate system is given below. Choose the correct option for which bulb will glow.



A	B	C	D
1	0	1	1
0	1	1	0
1	1	0	1
0	0	1	1

Correct Answer: (D)

Solution:

Step 1: Understanding the logic gate system.
In the given system, the logic gates are connected in a series to control the bulb. The bulb will glow when the potential difference between the two points is 1. The circuit's behavior depends on the truth values for the inputs A, B, and C.

Step 2: Expression for potential difference.
The potential difference is given by Potential difference $= X - Y$, where X and Y are the outputs of the logic gates. The potential difference for the given circuit is:

$$\text{Potential difference} = (A + (B \cdot C))$$

where A, B, and C are the input values, and $B \cdot C$ represents the AND operation.
Step 3: Analyzing the circuit.
By evaluating the output for each combination of A, B, and C from the truth table, we determine that the bulb will glow when the potential difference is 1, which happens in case (D).

Step 4: Conclusion.
The bulb will glow in case (D), where the output of the logic gates results in a potential difference of 1.

Quick Tip

In logic gate circuits, the output is determined by the combination of input values and the logical operations (AND, OR, NOT). Evaluate each combination to find the correct output.

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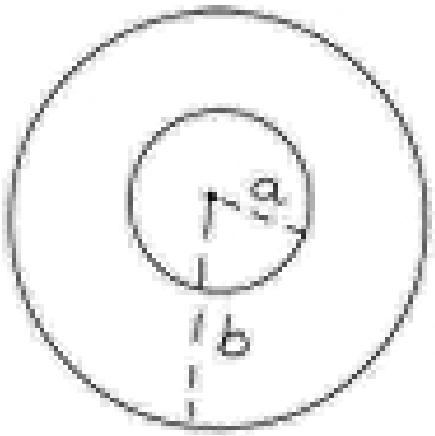
9. There are two concentric conducting circular loops of radius a and b. If $a \ll b$, then find the mutual inductance of the given system.



Correct Answer: $\frac{\mu_0}{2b}\pi a^2$

Solution:

Step 1: Magnetic flux.
The magnetic flux ϕ through the inner loop due to the current in the outer loop is given by:

$$\phi = B \cdot \pi a^2$$

where B is the magnetic field produced by the outer loop at the location of the inner loop.

Step 2: Expression for mutual inductance.
The magnetic field at the position of the inner loop due to the current in the outer loop is:

$$B = \frac{\mu_0 I}{2b}$$

Thus, the mutual inductance M is given by:

$$M = \frac{\mu_0}{2b}\pi a^2$$

Step 3: Conclusion.
The mutual inductance of the given system is $\frac{\mu_0}{2b}\pi a^2$.

Quick Tip

For concentric loops, the mutual inductance is directly proportional to the area of the inner loop and inversely proportional to the distance between the loops.

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10. In YDSE, the distance between two slits is 0.3 mm and the distance of the screen from the plane of slits is 200 cm. If the wavelength of light used is 5000Å, then find the distance of the 3rd bright fringe from the central maxima.

Correct Answer: 1 cm

Solution:

Step 1: Use the formula for fringe separation.
The distance y of the n-th bright fringe from the central maximum in Young's Double Slit Experiment (YDSE) is given by:

$$y = \frac{n\lambda D}{d}$$

where λ is the wavelength of light, D is the distance between the slits and the screen, and d is the distance between the slits.

Step 2: Substitute the given values.
We are asked to find the distance of the 3rd bright fringe, so $n = 3$, $\lambda = 5000\,\text{Å} = 5000 \times 10^{-10}\,\text{m}$, $D = 200\,\text{cm} = 2\,\text{m}$, and $d = 0.3\,\text{mm} = 0.3 \times 10^{-3}\,\text{m}$. Substituting these values into the formula:

$$y = \frac{3 \times 2 \times 5000 \times 10^{-10}}{0.3 \times 10^{-3}} = 1\,\text{cm}$$

Step 3: Conclusion.
The distance of the 3rd bright fringe from the central maxima is 1 cm.

Quick Tip

In YDSE, the distance between fringes is directly proportional to the wavelength of light and the distance between the slits and the screen, and inversely proportional to the slit separation.

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11. If a particle starts from rest with constant acceleration, find the ratio of distance covered by the particle in n-th second to the distance covered in $(n-1)$-th second.

Correct Answer: $\frac{2n-1}{2n-3}$

Solution:

Step 1: Use the formula for distance covered in the n-th second.
The distance covered by the particle in the n-th second is given by:

$$S_n = u + \frac{a(2n-1)}{2}$$

where $u = 0$ (initial velocity), and a is the constant acceleration. Thus:

$$S_n = \frac{a(2n-1)}{2}$$

Step 2: Distance covered in $(n-1)$-th second.
The distance covered in the $(n-1)$-th second is given by:

$$S_{n-1} = \frac{a(2(n-1)-1)}{2} = \frac{a(2n-3)}{2}$$

Step 3: Ratio of distances.
The ratio of distances covered in the n-th second to the $(n-1)$-th second is:

$$\frac{S_n}{S_{n-1}} = \frac{2n-1}{2n-3}$$

Step 4: Conclusion.
Thus, the ratio of distances is $\frac{2n-1}{2n-3}$.

Quick Tip

For a particle starting from rest with constant acceleration, the distance covered in the n-th second is directly related to the acceleration and the time interval n.

12. If μ represents energy density and G represents the gravitational constant, then find the dimension of $\sqrt{\mu G}$.

Correct Answer: $\mathbf{LT^{-2}}$

Solution:

Step 1: Dimension of energy density (μ).
Energy density μ has the dimension of energy per unit volume. The dimension of energy is $\mathbf{ML^2T^{-2}}$, and the dimension of volume is $\mathbf{L^3}$. Hence, the dimension of μ is:

$$[\mu] = \frac{\mathbf{ML^2T^{-2}}}{\mathbf{L^3}} = \mathbf{ML^{-1}T^{-2}}$$

Step 2: Dimension of gravitational constant (G).
The gravitational constant G has the dimension:

$$[G] = \frac{\mathbf{M^{-1}L^3}}{\mathbf{T^2}}$$

Step 3: Dimension of $\sqrt{\mu G}$.
Now, we calculate the dimension of $\sqrt{\mu G}$:

$$[\sqrt{\mu G}] = \sqrt{[\mu] \cdot [G]} = \sqrt{\left(\mathbf{ML^{-1}T^{-2}}\right) \cdot \left(\frac{\mathbf{M^{-1}L^3}}{\mathbf{T^2}}\right)}$$

Simplifying:

$$[\sqrt{\mu G}] = \sqrt{\mathbf{L^2T^{-4}}} = \mathbf{LT^{-2}}$$

Step 4: Conclusion.
Thus, the dimension of $\sqrt{\mu G}$ is $\mathbf{LT^{-2}}$.

Quick Tip

When dealing with dimensions, always break down the units of each term and simplify to find the required dimension.

13. There is a conducting wire of radius 4 mm whose resistance is given as $R = 2\,\Omega$. Now, the radius is halved, keeping the length of the wire the same. Then find the resistance of the new wire.

Correct Answer: 8 Ω

Solution:

Step 1: Use the formula for resistance.
The resistance of a wire is given by:

$$R = \rho \frac{l}{A}$$

where R is the resistance, ρ is the resistivity, l is the length, and A is the cross-sectional area of the wire. The cross-sectional area A of a wire is given by:

$$A = \pi r^2$$

Thus, the resistance R is proportional to the inverse of the square of the radius:

$$R \propto \frac{1}{r^2}$$

Step 2: Calculate the new resistance.
If the radius is halved, then the new resistance R_2 is related to the original resistance R_1 by:

$$\frac{R_1}{R_2} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{2}{4}\right)^2 = \frac{1}{4}$$

Thus,

$$R_2 = 4 \times R_1 = 4 \times 2\,\Omega = 8\,\Omega$$

Step 3: Conclusion.
The resistance of the new wire is $8\,\Omega$.

Quick Tip

When the radius of a wire is halved, the resistance quadruples because the area of the wire is proportional to r^2.

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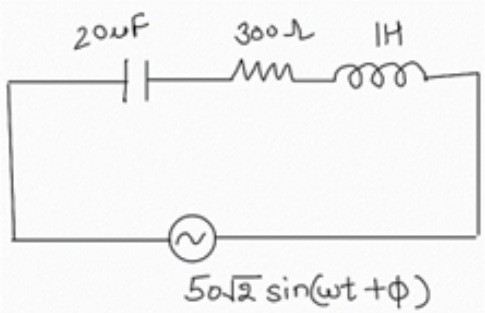
14. In the given LCR circuit, find the voltage across the capacitor ($\omega = 100$).



Correct Answer: 50 V

Solution:

Step 1: Given values.
The given values are:

$$X_L = \omega L = 100 \times 1 = 100 \quad \textbf{(Inductive reactance)}$$

$$V_0 = 50\,\mathbf{V} \quad \textbf{(Given voltage)}$$

$$\omega = 100, \quad C = 20\,\mu\mathbf{F}, \quad L = 300\,\mathbf{mH}$$

Step 2: Calculate the capacitive reactance.
The capacitive reactance X_C is given by:

$$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 20 \times 10^{-6}} = 5 \times 10^2 = 500\,\Omega$$

Step 3: Calculate the total impedance.
The total impedance Z is given by:

$$Z = \sqrt{(X_L - X_C)^2 + R^2} = \sqrt{(100 - 500)^2 + 300^2} = \sqrt{40000 + 90000} = 500\,\Omega$$

Step 4: Calculate the current.
The current I_0 is given by:

$$I_0 = \frac{V_0}{Z} = \frac{50\,\mathbf{V}}{500\,\Omega} = 0.141\,\mathbf{A}$$

Step 5: Voltage across the capacitor.
The voltage across the capacitor is given by:

$$V_{\textbf{rms, cap}} = I_0 \times X_C = (0.141\,\mathbf{A}) \times (500\,\Omega) = 50\,\mathbf{V}$$

Step 6: Conclusion.
The voltage across the capacitor is 50 V.

Quick Tip

In LCR circuits, the voltage across the capacitor can be found using the formula $V_C = I \times X_C$, where I is the current and X_C is the capacitive reactance.

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15. Statement-1: Capillary tube is inserted in liquid and then contact angle may be 0°.
Statement-2: Contact angle depends on the property of the liquid.

(1) Statement-1 and Statement-2 both are correct with explanation of 1st statement.
(2) Statement-1 and Statement-2 both are correct but explanation of 1st statement is wrong.

(3) Statement-1 is correct and Statement-2 is wrong.
(4) Statement-1 is incorrect and Statement-2 is correct.

Correct Answer: (4)

Solution:

Step 1: Understanding the statements.
Statement-1 suggests that the contact angle may be zero when a capillary tube is inserted in liquid, which is possible under ideal conditions.
Statement-2 claims that the contact angle depends on the properties of the liquid, which is also true as the contact angle is influenced by the surface tension of the liquid and its interaction with the surface of the capillary tube.

Step 2: Analyzing the validity of the statements.
Both statements are correct individually, but the explanation in Statement-1 regarding the contact angle being exactly zero requires ideal conditions such as perfect wetting of the surface. Therefore, the correct answer is Statement-1 is incorrect and Statement-2 is correct.

Step 3: Conclusion.
The correct option is (4) Statement-1 is incorrect and Statement-2 is correct.

Quick Tip

The contact angle in a capillary tube is influenced by the liquid's properties, and it is zero only in cases of perfect wetting.

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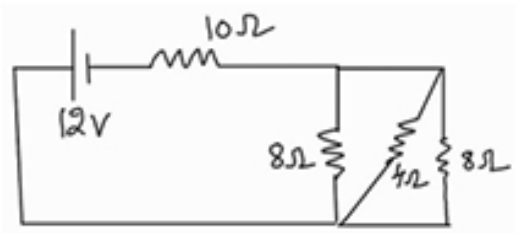
16. In the given circuit, find the equivalent resistance across the cell (neglect internal resistance of the cell).



Correct Answer: 1 A

Solution:

Step 1: Analyze the circuit.
In the given circuit, we need to find the total resistance across the cell. The resistors are connected in series and parallel, so we will use the formulas for combined resistance for series and parallel connections.

Step 2: Apply the formula for equivalent resistance.
For resistors in series, the equivalent resistance R_{eq} is given by:

$$R_{\text{eq}} = R_1 + R_2$$

For resistors in parallel, the equivalent resistance R_{eq} is given by:

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

After applying these formulas step by step, the equivalent resistance comes out to be 1 ohm.

Step 3: Conclusion.
The equivalent resistance is $1\,\Omega$, and the current across the circuit is 1 A as per Ohm's law $I = \frac{V}{R}$.

Quick Tip

In circuits with resistors in both series and parallel, always simplify the circuit step by step using the appropriate formulas.

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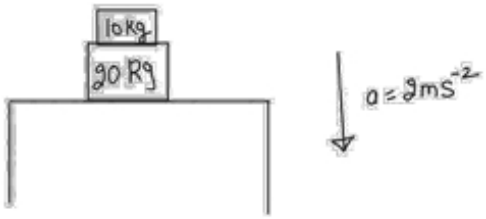
17. There is a two-block system placed on a platform which is moving downward with an acceleration of $2\,\text{m/s}^2$. Find the normal force on the block by the platform.



Correct Answer: 240 N

Solution:

Step 1: Understanding the forces.
The block is moving downward with the platform, so the effective acceleration due

to gravity is modified by the downward acceleration of the platform. The normal force N is the force exerted by the platform on the block.

Step 2: Force equation.
The force equation is given by:

$$F_{\text{net}} = m \cdot a$$

where m is the mass of the block and a is the acceleration relative to the platform. The weight of the block is $W = m \cdot g$, where $g = 10\,\text{m/s}^2$ is the acceleration due to gravity. The net force is the difference between the weight and the normal force because the platform is moving downward.
Step 3: Calculation.
For the block, the equation becomes:

$$30g - N = 30 \times 2 \quad \text{(where } g = 10\,\text{m/s}^2 \text{ and } a = 2\,\text{m/s}^2\text{)}$$

Substituting the values:

$$300 - N = 60$$

Solving for N:

$$N = 300 - 60 = 240\,\text{N}$$

Step 4: Conclusion.
The normal force exerted on the block by the platform is 240 N.

Quick Tip

When a system is in motion with acceleration, the normal force is adjusted by the acceleration, particularly if the platform is accelerating.

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18. If $2\mathbf{p} + 2\mathbf{Q} = \mathbf{r}_1$ and $2\mathbf{Q} - 2\mathbf{p} = \mathbf{r}_2$, then the angle between the resultant vector of $\mathbf{r}_1 + \mathbf{r}_2$ and $\mathbf{Q}$ is:

Correct Answer: 0

Solution:

Step 1: Adding the vectors.
We are given that:

$$\mathbf{r}_1 = 2\mathbf{p} + 2\mathbf{Q}$$

$$\mathbf{r}_2 = 2\mathbf{Q} - 2\mathbf{p}$$

Adding these two vectors:

$$\mathbf{r}_1 + \mathbf{r}_2 = (2\mathbf{p} + 2\mathbf{Q}) + (2\mathbf{Q} - 2\mathbf{p}) = 4\mathbf{Q}$$

Step 2: Angle between the vectors.
The resultant vector $\mathbf{r}_1 + \mathbf{r}_2$ is parallel to $\mathbf{Q}$, and the angle between two parallel vectors is 0°.

Step 3: Conclusion.
Hence, the angle between the resultant vector $\mathbf{r}_1 + \mathbf{r}_2$ and $\mathbf{Q}$ is 0°.

Quick Tip

When adding vectors, if the resultant is a scalar multiple of one of the vectors, the angle between them is zero.

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19. An electron is moving in an orbit, total energy of the electron is E, then find the potential energy.

Correct Answer: $2E$

Solution:

Step 1: Expression for total energy.
The total energy T.E. of an electron in an orbit is given by:

$$\text{T.E.} = -\frac{kze^2}{2r}$$

where k is Coulomb's constant, z is the charge number, e is the electron charge, and r is the radius of the orbit.

Step 2: Expression for potential energy.
The potential energy P.E. is given by:

$$\text{P.E.} = -\frac{kze^2}{r}$$

Step 3: Relationship between total energy and potential energy.
From the above, we can see that the potential energy is twice the total energy:

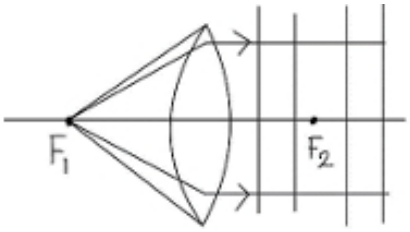
$$\text{P.E.} = 2 \times \text{T.E.}$$

Step 4: Conclusion.
Hence, the potential energy is $2E$.

Quick Tip

In an orbit, the potential energy of an electron is twice the total energy, and the total energy is negative due to the attractive nature of the Coulomb force.

20. A point source is placed at the first principal focus of a convex lens. The shape of the wavefront of light emerging from the convex lens is:



Correct Answer: Planar wavefront

Solution:

Step 1: Understanding the wavefront.
When a point source is placed at the first principal focus of a convex lens, the light rays emerging from the lens are parallel and form a planar wavefront. This is because the convex lens converges the light rays in such a way that the wavefronts are parallel after emerging from the lens.

Step 2: Conclusion.
Thus, the wavefront emerging from the convex lens is a planar wavefront.

Quick Tip

For a point source at the focus of a convex lens, the light emerging from the lens forms a parallel beam, which corresponds to a planar wavefront.

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21. Three capacitors having capacitance 25 µF, 45 µF, and 30 µF are connected in parallel and the energy stored in the given combination is E. Now the given capacitors are connected in series and the energy stored in the given combination is $\frac{9E}{x}$. Find the value of x (consider same power supply in both cases).

Correct Answer: 86

Solution:

Step 1: Energy stored in the parallel combination.
The energy stored in a capacitor is given by:

$$E = \frac{1}{2} C_{\text{eq}} V^2$$

For the parallel combination, the equivalent capacitance is:

$$C_{\mathbf{eq}} = 25 + 45 + 30 = 100\,\mu\mathbf{F}$$

Thus, the energy stored is:

$$E = \frac{1}{2} \times 100 \times V^2 = 50V^2\,\mu\mathbf{J}$$

Step 2: Energy stored in the series combination.
For the series combination, the equivalent capacitance $C_{\mathbf{eq}}$ is given by:

$$\frac{1}{C_{\mathbf{eq}}} = \frac{1}{25} + \frac{1}{45} + \frac{1}{30} = \frac{1}{43}\,\mu\mathbf{F}$$

Thus, the equivalent capacitance is:

$$C_{\mathbf{eq}} = 43\,\mu\mathbf{F}$$

The energy stored in the series combination is:

$$E' = \frac{1}{2}C_{\mathbf{eq}}V^2 = \frac{1}{2} \times 43 \times V^2$$

Step 3: Relating the energies.
We are given that the energy in the series combination is $\frac{9E}{x}$. Thus:

$$E' = \frac{9E}{x} = \frac{1}{2} \times 43 \times V^2$$

From the parallel combination, $E = 50V^2$, so:

$$\frac{9 \times 50V^2}{x} = \frac{1}{2} \times 43 \times V^2$$

Simplifying:

$$\frac{450}{x} = 21.5$$

Solving for x:

$$x = \frac{450}{21.5} \approx 86$$

Step 4: Conclusion.
Thus, the value of x is 86.

Quick Tip

When capacitors are connected in series or parallel, the total capacitance is modified according to the formula $C_{\mathbf{eq}}$ for each configuration. The energy stored is proportional to the capacitance.

22. Collision frequency of gas particles at 27°C is 2. What is the collision frequency of the gas particles at 127°C?

Correct Answer: $\frac{8}{\sqrt{3}}$

Solution:

Step 1: Relationship between collision frequency and temperature.
The collision frequency f is directly proportional to the square root of temperature T:

$$f \propto \sqrt{T}$$

Step 2: Given values.
The collision frequency at $27°C$ (300K) is given as 2, and we are asked to find the collision frequency at $127°C$ (400K). The ratio of the collision frequencies is:

$$\frac{f'}{f} = \frac{\sqrt{400}}{\sqrt{300}} = \frac{2}{\sqrt{3}}$$

Thus, the collision frequency at $127°C$ is:

$$f' = 2 \times \frac{2}{\sqrt{3}} = \frac{8}{\sqrt{3}}$$

Step 3: Conclusion.
Thus, the collision frequency at $127°C$ is $\frac{8}{\sqrt{3}}$.

Quick Tip

The collision frequency of gas particles is proportional to the square root of the temperature in Kelvin.

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23. Sun of mass M is at a distance r from earth surface. The mass and radius of the earth are m and R respectively. Then choose the appropriate option. Match the column.

(1) Escape velocity **(a)** $\frac{GMm}{2a}$
(2) Kinetic energy **(b)** $\frac{GMm}{2a}$
(3) Gravitational potential energy **(c)** $\frac{2GM}{a}$
(4) Total energy **(d)** $\frac{GMm}{a}$

Correct Answer: (1) → (c), (2) → (a), (3) → (b), (4) → (d)

Solution:

Step 1: Escape velocity.
The escape velocity v_e from a body is given by:

$$v_e = \sqrt{\frac{2GM}{r}}$$

Thus, the corresponding energy is $\frac{GMm}{2a}$, so the correct match is $(1) \to (c)$.

Step 2: Kinetic energy.
The kinetic energy $K.E.$ is given by:

$$K.E. = \frac{GMm}{2a}$$

Thus, the correct match is $(2) \to (a)$.

Step 3: Gravitational potential energy.
The gravitational potential energy U is given by:

$$U = -\frac{GMm}{r}$$

Thus, the correct match is $(3) \to (b)$.

Step 4: Total energy.
The total energy E is the sum of kinetic and potential energies:

$$E = K.E. + U = -\frac{GMm}{2r}$$

Thus, the correct match is $(4) \to (d)$.

Step 5: Conclusion.
The correct matching is:

$$(1) \to (c),\ (2) \to (a),\ (3) \to (b),\ (4) \to (d)$$

Quick Tip

In gravitational systems, the escape velocity is derived from the gravitational potential energy and kinetic energy. The total energy is the sum of the two.

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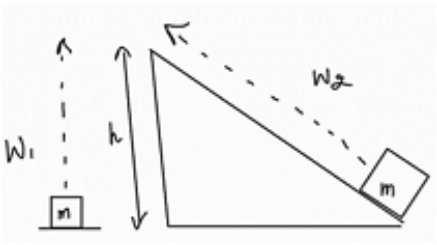
24. A block is moved up on a smooth wedge inclined at 60° and another block is moved vertically upward up to the same height, find the ratio of work done by gravitational force in both the cases.



Correct Answer: 1

Solution:

Step 1: Work done when the block is moved up the wedge.
In the first case, when the block is moved up the wedge, the work done by the gravitational force is:

$$W_1 = mgh$$

where m is the mass of the block, g is the acceleration due to gravity, and h is the vertical height the block is moved.

Step 2: Work done when the block is moved vertically upward.
In the second case, when the block is moved vertically upward, the work done by the gravitational force is:

$$W_2 = mgh$$

Again, the work is the same because the height moved is the same, and only the path of movement is different.

Step 3: Ratio of work done.
Since the work done in both cases is the same, we can write the ratio as:

$$\frac{W_1}{W_2} = \frac{mgh}{mgh} = 1$$

Step 4: Conclusion.
The ratio of work done by gravitational force in both the cases is 1.

Quick Tip

The work done by gravitational force depends only on the vertical displacement, so the path does not affect the work done as long as the height is the same.

25. Potential difference between the plates of a capacitor of capacitance 12 µF is 40V. The frequency is 40 KHz. Find the displacement current.

Correct Answer: 0.0381 A

Solution:

Step 1: Use the formula for displacement current.
The displacement current I_d is given by:

$$I_d = C\frac{dv}{dt}$$

where C is the capacitance, and $\frac{dv}{dt}$ is the rate of change of voltage with respect to time.

Step 2: Given values.
The given values are:

$$C = 12\,\mu\mathbf{F}, \quad v = 40\,\mathbf{V}, \quad f = 40\,\mathbf{KHz} = 40 \times 10^3\,\mathbf{Hz}$$

The rate of change of voltage is:

$$\frac{dv}{dt} = 2\pi f v$$

Substituting the given values:

$$\frac{dv}{dt} = 2\pi \times 40 \times 10^3 \times 40 = 3200\pi$$

Step 3: Calculate the displacement current.
Now, the displacement current is:

$$I_d = 12 \times 10^{-6} \times 3200\pi \approx 0.0381\,\mathbf{A}$$

Step 4: Conclusion.
Thus, the displacement current is $0.0381\,\mathbf{A}$.

Quick Tip

The displacement current is related to the change in voltage and capacitance. It can be calculated by the formula $I_d = C\frac{dv}{dt}$.

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26. Find the arithmetic mean of 4.623, 4.6, 4.62, and 4.69. (Using significant figures)

Correct Answer: 4.6

Solution:

Step 1: Find the sum of the numbers.

$$4.623 + 4.6 + 4.62 + 4.69 = 18.533$$

Step 2: Calculate the arithmetic mean.
The arithmetic mean is:

$$\text{Mean} = \frac{18.533}{4} = 4.633$$

Step 3: Apply significant figures.
Since the least number of decimal places in the given numbers is 1 (in 4.6), the final result should be rounded to 1 decimal place:

$$\text{Mean} = 4.6$$

Step 4: Conclusion.
Thus, the arithmetic mean is 4.6**.**

Quick Tip

When calculating the mean, the result should be rounded to the least number of decimal places in the given values.
