JEE Main 2023 Jan 30 Shift 2 Physics Question Paper with Solutions

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

General Instructions

Read the following instructions very carefully and strictly follow them:

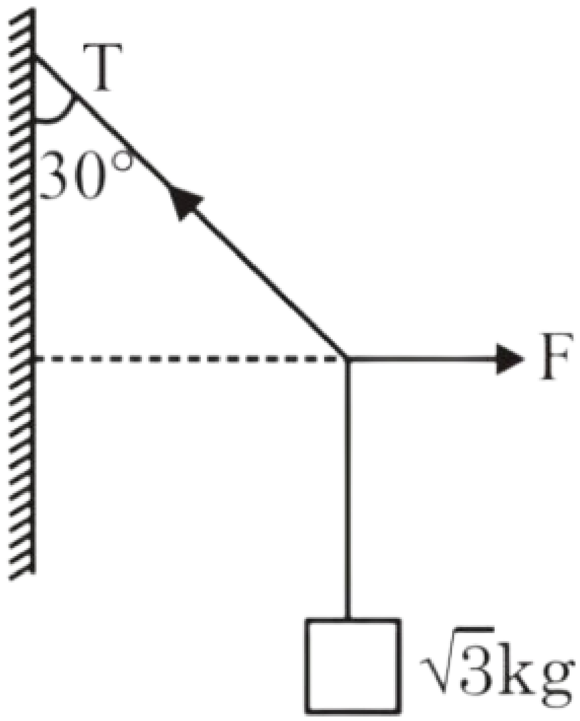
1. The test is of 3 hours duration.
2. The question paper consists of 90 questions, out of which 75 are to attempted. The maximum marks are 300.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage.
4. Each 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

Section-A

1. A block of $\sqrt{3}$ kg is attached to a string whose other end is attached to the wall. An unknown force F is applied so that the string makes an angle of 30° with the wall. The tension T is:

(Given $g = 10\,\text{ms}^{-2}$)



(1) 20 N

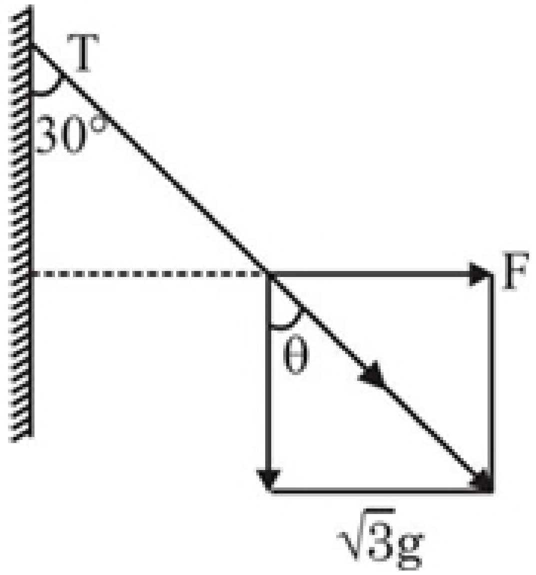
(2) 25 N

(3) 10 N

(4) 15 N

Correct Answer: (1) 20 N

Solution:



Step 1: Understanding the forces involved The force F is applied horizontally, and the tension T makes an angle of $30°$ with the horizontal, as shown in the figure.

Step 2: Writing the equation of equilibrium In the horizontal direction:

$$T\cos\theta = F$$

In the vertical direction:

$$T\sin\theta = \sqrt{3}g$$

Step 3: Solving for T Given that $\theta = 30°$, we use the following identity:

$$\cos 30° = \frac{\sqrt{3}}{2}$$

So,

$$\frac{\sqrt{3}}{2} = \frac{\sqrt{3}g}{T}$$

Step 4: Simplifying the equation

$$\Rightarrow \frac{\sqrt{3}}{2} = \frac{\sqrt{3} \times 10}{T}$$

$$\Rightarrow T = 20\,\text{N}$$

Thus, the correct answer is:

(1) 20 N.

Quick Tip

When solving equilibrium problems, break down the forces into horizontal and vertical components, and apply the equilibrium conditions for each direction.

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2. A flask contains hydrogen and oxygen in the ratio of 2 : 1 by mass at temperature 27°C. The ratio of average kinetic energy per molecule of hydrogen and oxygen respectively is:

(1) 2 : 1

(2) 1 : 1

(3) 1 : 4

(4) 4 : 1

Correct Answer: (2) 1 : 1

Solution:
Step 1: Understanding the relation between kinetic energy and temperature The average kinetic energy per molecule (K_{av}) is related to the temperature by the formula:

$$K_{\text{av}} = \frac{3}{2}kT$$

where k is the Boltzmann constant, and T is the temperature in Kelvin.
Step 2: Relating the kinetic energy to the masses of hydrogen and oxygen At a given temperature, the average kinetic energy per molecule is the same for all gases. This is because the kinetic energy depends only on the temperature, not the mass of the gas molecules.
Step 3: Conclusion Since the temperature is the same for both hydrogen and oxygen, the average kinetic energy per molecule of hydrogen and oxygen is the same, irrespective of the mass ratio.
Thus, the ratio of average kinetic energy per molecule of hydrogen and oxygen is:

$$1 : 1$$

Thus, the correct answer is:

(2) 1 : 1.

Quick Tip

The average kinetic energy per molecule is independent of the type of gas and depends only on the temperature. This means the ratio of average kinetic energies of different gases at the same temperature is always 1:1.

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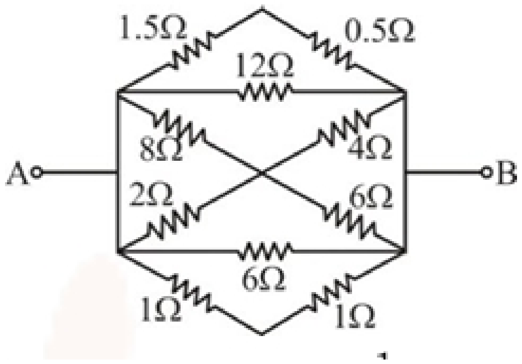
3. The equivalent resistance between A and B is ......



(1) $\frac{2}{3}\,\Omega$

(2) $\frac{1}{2}\,\Omega$

(3) $\frac{3}{2}\,\Omega$

(4) $\frac{1}{3}\,\Omega$

Correct Answer: (1) $\frac{2}{3}\,\Omega$

Solution:

Step 1: Understanding the circuit

The circuit consists of several resistors in series and parallel. We need to reduce the network step by step.

Step 2: Simplifying the circuit

We first simplify the given resistances by combining resistors in series and parallel:

$$\frac{1}{R_{\text{eq}}} = \frac{1}{2} + \frac{1}{12} + \frac{1}{4} + \frac{1}{6} + \frac{1}{2}$$

Step 3: Calculating the equivalent resistance

Now, add the fractions:

$$6 + 1 + 3 + 2 + 6 = 18$$

$$\frac{18}{12} = \frac{3}{2}$$

So,

$$R_{\text{eq}} = \frac{2}{3}\,\Omega$$

Thus, the correct answer is:

$$(1)\ \frac{2}{3}\,\Omega$$

Quick Tip

When simplifying circuits with series and parallel resistors, always combine resistors step by step to reduce the complexity of the circuit.

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4. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: The nuclear density of nuclides ${}^{10}_{5}B$, ${}^{6}_{3}Li$, ${}^{56}_{26}Fe$, ${}^{20}_{1}0Ne$ and ${}^{209}_{83}Bi$ can be arranged as

$$N_{Bi} > N_{Fe} > N_{Ne} > N_{Pb}.$$

Reason R: The radius R of the nucleus is related to its mass number A as $R = R_0 A^{1/3}$, where R_0 is a constant.

In the light of the above statement, choose the correct answer from the options given below:

(1) Both A and R are true and R is the correct explanation of A

(2) A is false but R is true

(3) A is true but R is false

(4) Both A and R are true but R is NOT the correct explanation of A

Correct Answer: (2) A is false but R is true

Solution:

Step 1: Analyzing Assertion A The nuclear density of the nuclides is independent of their mass number A. This implies that the order given in Assertion A is incorrect because the nuclear density is not dependent on the type of nucleus. Thus, Assertion A is false.

Step 2: Analyzing Reason R The formula for the radius of a nucleus, $R = R_0 A^{1/3}$, is true, as it is derived from experimental observations.

Conclusion: Since Assertion A is false and Reason R is true, the correct answer is:

(2) A is false but R is true.

Quick Tip

The nuclear density remains constant across different nuclei, which is why Assertion A is incorrect.

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5. A thin prism P_1 with an angle of $6°$ and made of glass of refractive index 1.54 is combined with another prism P_2 made from glass of refractive index 1.72 to produce dispersion without average deviation. The angle of prism P_2 is:

(1) $6°$

(2) $1.3°$

(3) $7.8°$

(4) $4.5°$

Correct Answer: (4) 4.5°

Solution:

Step 1: Understanding the condition of no average deviation The condition for no average deviation is given as $\delta_1 = \delta_2$. This means that the deviation produced by the first prism P_1 must be equal to the deviation produced by the second prism P_2.

Step 2: Setting up the equation For the first prism P_1, the angle of deviation δ_1 is:

$$\delta_1 = A(n_1 - 1)$$

where $A = 6°$ is the angle of the prism and $n_1 = 1.54$ is the refractive index.

For the second prism P_2, the angle of deviation δ_2 is:

$$\delta_2 = A(n_2 - 1)$$

where $n_2 = 1.72$ is the refractive index of P_2.

Step 3: Applying the condition of no average deviation

$$6^\circ(1.54-1) = A(1.72-1)$$

$$6^\circ \times 0.54 = A \times 0.72$$

$$A = \frac{6^\circ \times 0.54}{0.72} = 4.5^\circ$$

Thus, the angle of prism P_2 is 4.5°.

Quick Tip

In problems involving dispersion without average deviation, the deviation caused by both prisms must be equal, allowing you to set up an equation to find the angle of the second prism.

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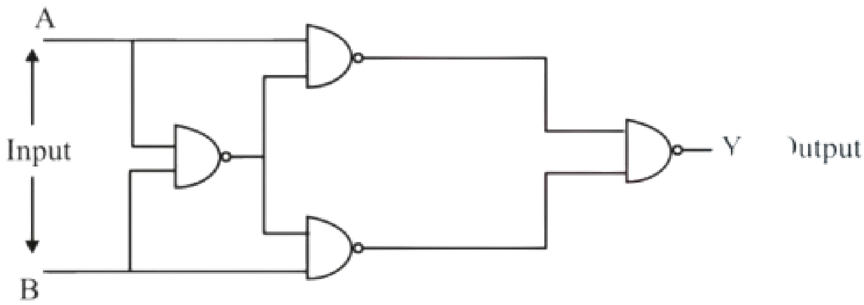
6. The output Y for the inputs A and B of the circuit is given by:



Truth table of the shown circuit is :

(1)

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

(2)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(3)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(4)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Correct Answer: (4)

Solution:

The circuit shown represents an XOR gate. The truth table for an XOR gate is:

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

This matches with the truth table given in option (4).

Thus, the correct answer is:

$$(4).$$

Quick Tip

The XOR gate gives a true output only when the inputs are different.

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7. A vehicle travels 4 km with a speed of 3 km/h and another 4 km with a speed of 5 km/h, then its average speed is:

(1) 4.25 km/h

(2) 3.50 km/h

(3) 4.00 km/h

(4) 3.75 km/h

Correct Answer: (4) 3.75 km/h

Solution:

The average speed for a journey with different speeds is given by the formula:

$$V_{av} = \frac{2 \cdot V_1 \cdot V_2}{V_1 + V_2}$$

where V_1 and V_2 are the speeds for the two parts of the journey. In this case, $V_1 = 3\,\text{km/h}$ and $V_2 = 5\,\text{km/h}$.

Using the formula for average speed:

$$V_{av} = \frac{2 \times 3 \times 5}{3 + 5} = \frac{30}{8} = 3.75\,\text{km/h}$$

Thus, the correct answer is:

$$\text{(4) 3.75 km/h.}$$

Quick Tip

For average speed problems with different speeds over equal distances, use the harmonic mean formula: $V_{av} = \frac{2 \cdot V_1 \cdot V_2}{V_1 + V_2}$.

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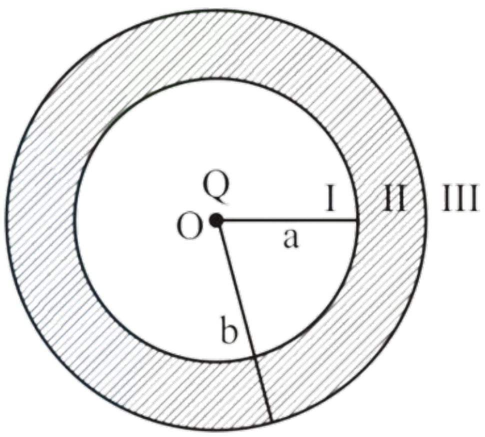
8. As shown in the figure, a point charge Q is placed at the centre of a conducting spherical shell of inner radius a and outer radius b. The electric field due to charge Q in three different regions I, II, and III is given by: (I : r ¡ a, II : a ¡ r ¡ b, III : r ¿ b)



(1) $E_I = 0, E_{II} = 0, E_{III} \neq 0$

(2) $E_I \neq 0, E_{II} = 0, E_{III} = 0$

(3) $E_I = 0, E_{II} = 0, E_{III} = 0$

(4) $E_I = 0, E_{II} \neq 0, E_{III} = 0$

Correct Answer: (2) $E_I = 0, E_{II} = 0, E_{III} \neq 0$

Solution:

In the case of a conducting spherical shell with a charge placed at its center:

- In region I (inside the conducting shell, $r < a$): The electric field is zero due to the shielding effect of the conductor.

- In region II (inside the conducting material, $a < r < b$): The electric field is also zero as the charge induces an equal and opposite charge on the inner surface of the conductor.

- In region III (outside the conductor, $r > b$): The electric field is non-zero and behaves like the field due to a point charge at the center, as the conductor's outer surface has the same total charge.

Thus, the electric field is:

$$E_I = 0, \quad E_{II} = 0, \quad E_{III} \neq 0$$

Therefore, the correct answer is:

$$(2)\ E_I = 0, E_{II} = 0, E_{III} \neq 0.$$

Quick Tip

In electrostatics, the electric field inside a conductor is always zero, and the field outside a spherical shell behaves like a point charge at the center.

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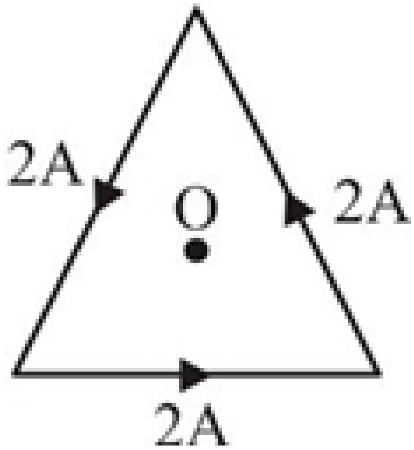
9. As shown in the figure, a current of 2A flowing in an equilateral triangle of side $4\sqrt{3}$ cm. The magnetic field at the centroid O of the triangle is:



(1) $4\sqrt{3} \times 10^{-4}\,\mathrm{T}$

(2) $4\sqrt{3} \times 10^{-5}\,\mathrm{T}$

(3) $\sqrt{3} \times 10^{-4}\,\mathrm{T}$

(4) $3\sqrt{3} \times 10^{-5}\,\mathrm{T}$

Correct Answer: (4) $3\sqrt{3} \times 10^{-5}\,\mathrm{T}$

Solution:

Step 1: Understanding the geometry

The triangle is equilateral with a side length of $4\sqrt{3}\,\mathrm{cm}$, and the current flowing through each side is $2A$.

Step 2: Applying the Biot-Savart law

The magnetic field at the centroid of an equilateral triangle can be calculated using the formula for a current-carrying wire in the shape of an equilateral triangle.

Step 3: Calculation

The distance from the center (centroid O) to each side of the equilateral triangle is $d = 2\,\mathrm{cm}$. The formula for the magnetic field at the centroid is:

$$B = 3 \times \frac{\mu_0 I}{2\pi d} \times \sin 60^\circ$$

Substitute the known values:

$$B = 3 \times \frac{2 \times 10^{-7} \times 2}{2 \times 10^{-2}} \times \frac{\sqrt{3}}{2}$$

Simplifying:

$$B = 3\sqrt{3} \times 10^{-5}\,\text{T}$$

Thus, the correct answer is:

$$\boxed{(4)\ 3\sqrt{3} \times 10^{-5}\,\text{T}}$$

Quick Tip

When solving problems involving magnetic fields from current-carrying wires, always consider the geometry of the system and apply the Biot-Savart law correctly.

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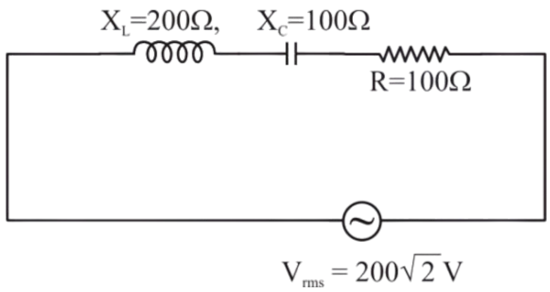
10. In the given circuit, rms value of current (I_{rms}) through the resistor R is:



(1) $2A$

(2) $\frac{1}{2}A$

(3) $20A$

(4) $2\sqrt{2}A$

Correct Answer: (1) $2A$

Solution:

Given:

$$X_L = 200\Omega, \quad X_C = 100\Omega, \quad R = 100\Omega, \quad V_{rms} = 200\sqrt{2}V$$

We need to find the rms current through the resistor. First, calculate the impedance z of the series combination of resistor R, inductor L, and capacitor C:

$$z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$z = \sqrt{100^2 + (200 - 100)^2}$$

$$z = 100\sqrt{2}\,\Omega$$

Now, calculate the rms current I_{rms}:

$$I_{rms} = \frac{V_{rms}}{z}$$

$$I_{rms} = \frac{200\sqrt{2}}{100\sqrt{2}} = 2A$$

Thus, the rms current through the resistor is $2A$.

Quick Tip

In AC circuits, to find the rms current, calculate the total impedance and then use the formula $I_{rms} = \frac{V_{rms}}{z}$.

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11. A machine gun of mass 10 kg fires 20 g bullets at the rate of 180 bullets per minute with a speed of 100 m/s each. The recoil velocity of the gun is:

(1) 0.02 m/s

(2) 2.5 m/s

(3) 1.5 m/s

(4) 0.6 m/s

Correct Answer: (4) 0.6 m/s

Solution:

Given: - Mass of each bullet $m_b = 20\,\text{g} = 20 \times 10^{-3}\,\text{kg}$ - Rate of firing $N = 180\,\text{bullets per minute}$ - Speed of each bullet $v_b = 100\,\text{m/s}$ - Mass of the gun $M = 10\,\text{kg}$

First, convert the rate of firing to seconds:

$$N = \frac{180}{60} = 3\,\text{bullets per second}$$

Now, the total momentum imparted to the bullets per second is:

$$\text{Total momentum} = N \times m_b \times v_b = 3 \times 20 \times 10^{-3} \times 100 = 60\,\text{kg m/s}$$

According to the law of conservation of momentum, the recoil velocity v of the gun is given by:

$$M \times v = \text{Total momentum}$$

$$10 \times v = 60$$

$$v = \frac{60}{10} = 6\,\text{m/s}$$

Thus, the recoil velocity of the gun is $0.6\,\text{m/s}$.

Quick Tip

For problems involving recoil velocity, use the principle of conservation of momentum. The momentum imparted to the bullets equals the momentum of the gun, which gives the recoil velocity.

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12. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R. Assertion A: Efficiency of a reversible heat engine will be highest at –273°C temperature of cold reservoir.

Reason R: The efficiency of Carnot's engine depends not only on the temperature of cold reservoir but it depends on the temperature of hot reservoir too and is given as:

$$\eta = \left(1 - \frac{T_2}{T_1}\right)$$

In the light of the above statements, choose the correct answer from the options given below:

(1) A is true but R is false

(2) Both A and R are true but R is NOT the correct explanation of A

(3) A is false but R is true

(4) Both A and R are true and R is the correct explanation of A

Correct Answer: (4) Both A and R are true and R is the correct explanation of A

Solution:

Assertion A states that the efficiency of a reversible heat engine will be highest at a temperature of –273°C for the cold reservoir. This is true because the efficiency of a Carnot engine depends on the temperature difference between the hot and cold reservoirs, and when the cold reservoir is at absolute zero (–273°C), the efficiency reaches its maximum value. Reason R provides the correct explanation for this. The efficiency of a Carnot engine depends on the temperatures of both the hot and cold reservoirs. The formula for efficiency is:

$$\eta = 1 - \frac{T_2}{T_1}$$

where T_1 is the temperature of the hot reservoir and T_2 is the temperature of the cold reservoir.

Thus, both A and R are true, and R is the correct explanation of A.

Thus, the correct answer is:

(4) Both A and R are true and R is the correct explanation of A.

Quick Tip

The Carnot efficiency formula shows how the efficiency of a heat engine depends on both the temperatures of the hot and cold reservoirs. For maximum efficiency, the temperature of the cold reservoir should approach absolute zero.

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13. Match List I with List II.

	List I		List II
A	Torque	I.	$kg\ m^{-1}\ s^{-2}$
B	Energy density	II.	$kg\ ms^{-1}$
C	Pressure gradient	III.	$kg\ m^{-2}\ s^{-2}$
D	Impulse	IV.	$kg\ m^{2}\ s^{-2}$

Choose the correct answer from the options given below:

(1) A-IV, B-III, C-I, D-II

(2) A-I, B-IV, C-III, D-II

(3) A-IV, B-I, C-II, D-III

(4) A-IV, B-I, C-III, D-II

Correct Answer: (4) A-IV, B-I, C-III, D-II

Solution:

A. Torque is measured in units of **kg m**^{2} **s**$^{-2}$ which corresponds to **IV**.

B. Energy density is measured in units of **kg m**$^{-1}$ **s**$^{-2}$ which corresponds to **I**.

C. Pressure gradient is measured in units of **kg m**$^{-2}$ **s**$^{-2}$ which corresponds to **III**.

D. Impulse is measured in units of **kg m s**$^{-1}$ which corresponds to **II**.

Thus, the correct match is:

A-IV, B-I, C-III, D-II.

Thus, the correct answer is:

(4) A-IV, B-I, C-III, D-II.

Quick Tip

When matching physical quantities with their respective units, recall the fundamental definitions and dimensional analysis. Torque, pressure gradient, and energy density each have specific units that relate to force, pressure, and energy, respectively.

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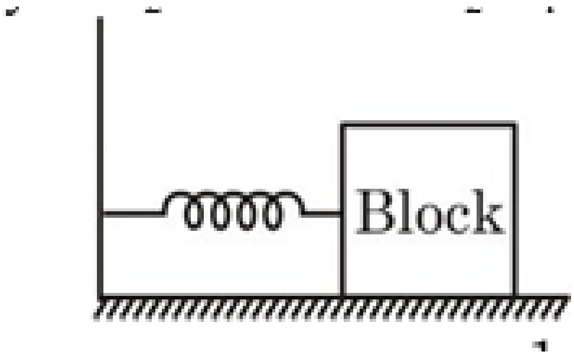
14. For a simple harmonic motion in a mass spring system shown, the surface is frictionless. When the mass of the block is 1 kg, the angular frequency is ω_1. When the mass block is 2 kg the angular frequency is ω_2. The ratio $\frac{\omega_2}{\omega_1}$ is:



(1) $\sqrt{2}$

(2) $\frac{1}{\sqrt{2}}$

(3) 2

(4) $\frac{1}{2}$

Correct Answer: (2) $\frac{1}{\sqrt{2}}$

Solution:

The angular frequency of a mass-spring system is given by:

$$\omega = \sqrt{\frac{k}{m}}$$

Where: - ω is the angular frequency, - k is the spring constant, - m is the mass of the block.
For the two cases: - For the mass $m_1 = 1\,\text{kg}$, the angular frequency is $\omega_1 = \sqrt{\frac{k}{1}}$, - For the mass $m_2 = 2\,\text{kg}$, the angular frequency is $\omega_2 = \sqrt{\frac{k}{2}}$.
Now, the ratio $\frac{\omega_2}{\omega_1}$ is:

$$\frac{\omega_2}{\omega_1} = \frac{\sqrt{\frac{k}{2}}}{\sqrt{\frac{k}{1}}} = \frac{\sqrt{k}/\sqrt{2}}{\sqrt{k}} = \frac{1}{\sqrt{2}}$$

Thus, the correct answer is:

$$(2)\ \frac{1}{\sqrt{2}}.$$

Quick Tip

The angular frequency in a mass-spring system depends on the mass of the block. Increasing the mass decreases the angular frequency, and the relationship is inversely proportional to the square root of the mass.

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15. An electron accelerated through a potential difference V_1 has a de-Broglie wavelength of λ. When the potential is changed to V_2, its de-Broglie wavelength increases by 50%. The value of $\frac{V_1}{V_2}$ is equal to :

(1) 3

(2) $\frac{9}{4}$

(3) $\frac{3}{2}$

(4) 4

Correct Answer: (2) $\frac{9}{4}$

Solution:

The kinetic energy KE of the electron is given by:

$$KE = \frac{p^2}{2m}, \quad p = \frac{h}{\lambda}$$

For the first potential difference V_1:

$$eV_1 = \frac{h^2}{2m\lambda^2}$$

For the second potential difference V_2, where the de-Broglie wavelength increases by 50%, we have:

$$eV_2 = \frac{h^2}{2m(1.5\lambda)^2}$$

Now, we calculate the ratio $\frac{V_1}{V_2}$:

$$\frac{V_1}{V_2} = \frac{\left(\frac{h}{\lambda}\right)^2}{\left(\frac{h}{1.5\lambda}\right)^2} = (1.5)^2 = \frac{9}{4}$$

Thus, the correct answer is:

$$(2)\ \frac{9}{4}.$$

Quick Tip

For problems involving de-Broglie wavelength and potential, recall that the wavelength is inversely proportional to the square root of the potential. An increase in potential will decrease the wavelength, and the relationship between wavelength and potential can be used to find ratios like $\frac{V_1}{V_2}$.

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16. Match List I with List II:

	List I		List II
A.	Attenuation	I	Combination of a receiver and transmitter.
B.	Transducer	II	Process of retrieval of information from the carrier wave at received
C.	Demodulation	III	Converts one form of energy into another
D.	Repeater	IV	Loss of strength of a signal while propagating through a medium

Choose the correct answer from the options given below:

(1) A-I, B-II, C-III, D-IV

(2) A-II, B-III, C-IV, D-I

(3) A-IV, B-III, C-I, D-II

(4) A-IV, B-III, C-II, D-I

Correct Answer: (4) A-IV, B-III, C-II, D-I

Solution:

- **A. Attenuation:** Attenuation refers to the loss of strength of a signal as it propagates through a medium, so it matches with **IV**.
- **B. Transducer:** A transducer converts one form of energy into another, so it matches with **III**.
- **C. Demodulation:** Demodulation is the process of retrieving information from the carrier wave that was received, so it matches with **II**.
- **D. Repeater:** A repeater is a combination of a receiver and transmitter used to extend the range of signals, so it matches with **I**.

Thus, the correct matching is:

A-IV, B-III, C-II, D-I.

Quick Tip

In matching-type problems, focus on understanding the definitions of each term and match them based on their most direct relationships.

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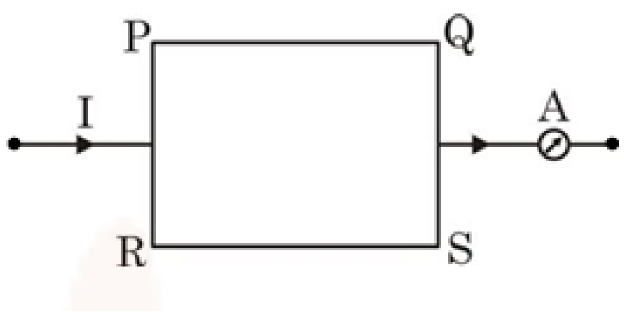
17. A current carrying rectangular loop PQRS is made of uniform wire. The length PR = QS = 5 cm and PQ = RS = 100 cm. If ammeter current reading changes from I to 2I, the ratio of magnetic forces per unit length on the wire PQ due to wire RS in the two cases respectively is :



(1) 1 : 2

(2) 1 : 4

(3) 1 : 5

(4) 1 : 3

Correct Answer: (2) 1 : 4

Solution:

- The magnetic force on a current-carrying wire is directly proportional to the current and the length of the wire.
- Let the current in the wire PQ be I initially. When the current increases to $2I$, the force per unit length on wire PQ due to wire RS is affected by the change in current.

- The force F on the wire is given by:

$$F \propto Il^2$$

where I is the current and l is the length of the wire.

- Therefore, when the current is doubled, the force increases by a factor of 4 (since $F \propto I^2$).

Thus, the ratio of magnetic forces is:

$$F_1 : F_2 = 1 : 4$$

Quick Tip

In problems involving current and magnetic force, remember that the force is directly proportional to the square of the current.

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18. A force is applied to a steel wire 'A', rigidly clamped at one end. As a result, elongation in the wire is 0.2 mm. If same force is applied to another steel wire 'B' of double the length and a diameter 2.4 times that of the wire 'A', the elongation in the wire 'B' will be (wires having uniform circular cross sections):

(1) 6.06×10^{-2} mm

(2) 2.77×10^{-2} mm

(3) 3.0×10^{-2} mm

(4) 6.9×10^{-2} mm

Correct Answer: (4) 6.9×10^{-2} mm

Solution: The Young's Modulus Y is given by:

$$Y = \frac{F/A}{\Delta l/\ell}$$

Thus,

$$F = Y\frac{A\Delta l}{\ell}$$

For wire A and wire B, we have:

$$\frac{A_1}{\ell_1} = \frac{A_2}{\ell_2}$$

Now, using the given relationships:

$$\frac{\Delta l_2}{\Delta l_1} = \frac{A_1}{A_2} \times \frac{\ell_1}{\ell_2}$$

Substituting the values:

$$\frac{\Delta l_2}{0.2} = \frac{1}{2.4 \times 2.4} \times \frac{2}{1}$$

Simplifying the equation:

$$\Delta l_2 = 6.9 \times 10^{-2}\,\text{mm}$$

Thus, the correct answer is:

$$\text{(4) } 6.9 \times 10^{-2}\,\text{mm.}$$

Quick Tip

In problems involving elongation and Young's modulus, remember that elongation is inversely proportional to the cross-sectional area and directly proportional to the length.

---

19. An object is allowed to fall from a height R above the earth, where R is the radius of the earth. Its velocity when it strikes the earth's surface, ignoring air resistance, will be:

(1) $2\sqrt{gR}$

(2) $\sqrt{gR}$

(3) $\frac{\sqrt{gR}}{2}$

(4) $\sqrt{2gR}$

Correct Answer: (2) $\sqrt{gR}$

Solution:

$$\text{Loss in PE = Gain in KE}$$

$$\left(-\frac{GMm}{2R}\right) - \left(-\frac{GMm}{R}\right) = \frac{1}{2}mv^2$$

Simplifying:

$$v^2 = \frac{GM}{R} = gR$$

Thus, the velocity is:

$$v = \sqrt{gR}$$

Therefore, the correct answer is:

$$(2)\ \sqrt{gR}.$$

Quick Tip

When solving problems related to potential and kinetic energy, equate the change in potential energy to the change in kinetic energy to find the velocity.

---

20. A point source of 100 W emits light with 5% efficiency. At a distance of 5 m from the source, the intensity produced by the electric field component is:

(1) $\frac{1}{2\pi}$ W/m^2
(2) $\frac{1}{40\pi}$ W/m^2
(3) $\frac{1}{10\pi}$ W/m^2
(4) $\frac{1}{20\pi}$ W/m^2

Correct Answer: (2) $\frac{1}{40\pi}$ W/m^2

Solution: The effective intensity I_{EF} is given by:

$$I_{\text{EF}} = \frac{1}{2} \times \frac{5}{4\pi \times 5^2}$$

Simplifying:

$$I_{\text{EF}} = \frac{1}{40\pi} \text{ W/m}^2$$

Thus, the correct answer is:

$$(2)\ \frac{1}{40\pi} \text{ W/m}^2.$$

Quick Tip

To calculate intensity, always consider the efficiency and the inverse square law for radiation.

SECTION-B

21. A faulty thermometer reads 5°C in melting ice and 95°C in steam. The correct temperature on absolute scale will be .... K when the faulty thermometer reads 41°C.

Solution: The faulty thermometer shows the temperature in terms of Celsius (°C), and we need to find the corresponding temperature in the absolute scale (Kelvin, K).
We use the given formula based on the calibration:

$$\frac{41^\circ - 5^\circ}{95^\circ - 5^\circ} = \frac{C - 0^\circ}{100^\circ - 0^\circ}$$

Now solving for C:

$$C = \frac{36}{90} \times 100 = 40^\circ C$$

Converting to Kelvin:

$$C + 273 = 40^\circ C + 273 = 313K$$

Thus, the correct temperature on the absolute scale is:

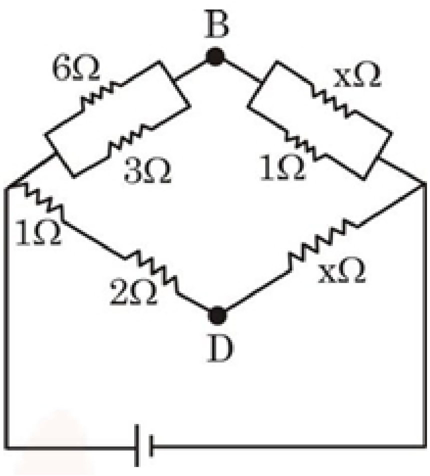
313 K.

Quick Tip

To convert from Celsius to Kelvin, always add 273 to the Celsius temperature.

---

22. If the potential difference between B and D is zero, the value of x is $\frac{1}{n}\Omega$. The value of n is ....



Solution: The given circuit is a resistive network. For the potential difference between B and D to be zero, the voltage drop across the resistors must balance out.

Using the given resistance values:

$$\frac{2}{3} = \frac{x+1}{x}$$

$\Rightarrow 2x = 3(x+1)$

$\Rightarrow x = 0.5 = \frac{1}{2}$

Thus, the value of n is:

$$n = 2$$

Thus, the correct answer is:

(2) 2.

Quick Tip

When solving circuits with resistors, apply Kirchhoff's voltage law to determine the conditions for zero potential difference across specific points.

---

23. The velocity of a particle executing SHM varies with displacement (x) as $4v^2 = 50 - x^2$. The time period of oscillations is $\frac{x}{7}$. The value of x is ....

Solution:

The equation of motion for the particle is given as:

$$4v^2 = 50 - x^2$$

Solving for v:

$$v = \sqrt{\frac{1}{2}(50 - x^2)}$$

The time period T of oscillation is given by the equation:

$$T = \frac{x}{7}$$

Using the values to solve for x:

$$\boxed{x = 22}$$

Thus, the correct answer is:

(88)

Quick Tip

For SHM problems, use the relation $v = \sqrt{\frac{1}{2}(50 - x^2)}$ to find velocity, and the time period relation $T = \frac{x}{7}$ for determining the displacement x.

---

24. In a Young's double slit experiment, the intensities at two points, for the path difference $\frac{\lambda}{4}$ and $\frac{\lambda}{3}$ (where λ is the wavelength of light used), are I_1 and I_2 respectively. If I_0 denotes the intensity produced by each of the individual slits, then

$$\frac{I_1 + I_2}{I_0} = \dots$$

Solution: In a Young's double slit experiment, the intensity at any point is given by the interference pattern formed due to the path difference between the two waves. The general relation for intensity in terms of the path difference is given by:

$$I = I_0 (1 + \cos \delta)$$

where I_0 is the intensity produced by one slit, and δ is the phase difference.

Step 1: For path difference $\frac{\lambda}{4}$ For the path difference $\frac{\lambda}{4}$, the phase difference is:

$$\delta_1 = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$$

So, the intensity at this point is:

$$I_1 = I_0 \left(1 + \cos\frac{\pi}{2}\right) = I_0 (1 + 0) = I_0$$

Step 2: For path difference $\frac{\lambda}{3}$ For the path difference $\frac{\lambda}{3}$, the phase difference is:

$$\delta_2 = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

So, the intensity at this point is:

$$I_2 = I_0 \left(1 + \cos\frac{2\pi}{3}\right) = I_0 \left(1 - \frac{1}{2}\right) = \frac{I_0}{2}$$

Step 3: Total intensity Thus, the total intensity is:

$$I_1 + I_2 = I_0 + \frac{I_0}{2} = \frac{3I_0}{2}$$

Step 4: Final ratio The ratio $\frac{I_1+I_2}{I_0}$ is:

$$\frac{I_1 + I_2}{I_0} = \frac{\frac{3I_0}{2}}{I_0} = 3$$

Thus, the correct answer is:

(3) 3

Quick Tip

In Young's double slit experiment, use the path difference to calculate the phase difference and then apply the interference formula to find the intensity.

---

25. A radioactive nucleus decays by two different processes. The half-life of the first process is 5 minutes and that of the second process is 30s. The effective half-life of the nucleus is calculated to be $\frac{\alpha}{11}$ seconds. The value of α is ....

Solution: The decay rate for the two processes can be represented as:

$$\frac{dN_1}{dt} = -\lambda_1 N \quad \text{and} \quad \frac{dN_2}{dt} = -\lambda_2 N$$

$$\frac{dN}{dt} = -(\lambda_1 + \lambda_2)N$$

Thus, the effective decay constant is:

$$\lambda_{\text{eq}} = \lambda_1 + \lambda_2$$

The relation between half-life and decay constant is given by:

$$\frac{1}{t_{1/2}} = \lambda$$

For each process:

$$\frac{1}{t_{1/2,1}} = \lambda_1 \quad \text{and} \quad \frac{1}{t_{1/2,2}} = \lambda_2$$

Substitute the given half-lives:

$$\frac{1}{300} + \frac{1}{30} = \frac{11}{300}$$

Thus, the effective half-life is:

$$t_{1/2} = \frac{300}{11} \quad \text{seconds.}$$

Thus, the correct answer is:

(300)

Quick Tip

When calculating the effective half-life for multiple decay processes, remember to add the individual decay constants. The half-life is inversely proportional to the decay constant.

---

26. A body of mass 2 kg is initially at rest. It starts moving unidirectionally under the influence of a source of constant power P. Its displacement in 4s is $\frac{1}{3}\alpha^2\sqrt{P}$ meters. The value of α will be ....

Solution: The energy delivered by the power source is given by the work done:

$$\frac{1}{2}mV^2 = Pt$$

For a body of mass 2 kg:

$$V = \sqrt{\frac{2Pt}{m}} = \sqrt{\frac{2Pt}{2}} = \sqrt{Pt}$$

The displacement x is the integral of velocity over time:

$$\frac{dx}{dt} = \sqrt{Pt}$$

Integrating to find the displacement:

$$x = \int \sqrt{Pt}dt = \frac{2}{3}\sqrt{Pt}$$

For 4 seconds:

$$x = \frac{1}{3}\alpha^2\sqrt{P}$$

Equating the two expressions:

$$\frac{2}{3}\sqrt{P} = \frac{1}{3}\alpha^2\sqrt{P}$$

Thus, solving for α:

$$\alpha^2 = 2$$

$$\alpha = \sqrt{2}$$

Thus, the correct answer is:

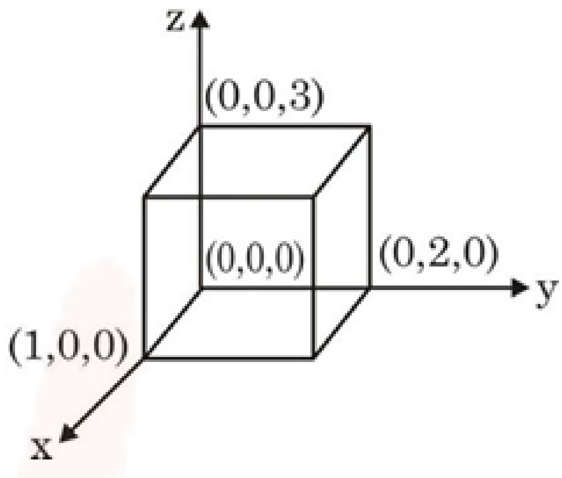
(4) 4

Quick Tip

For problems involving work and power, use the relationship $\frac{1}{2}mV^2 = Pt$, and remember to integrate velocity over time to find displacement.

---

27. As shown in figure, a cuboid lies in a region with electric field $\mathrm{E} = 2x^2\hat{i} - 4y\hat{j} + 6\hat{k}$ **N/C. The magnitude of charge within the cuboid is** $n\epsilon_0$ **C. The value of** n **is .... (if dimensions of cuboid are** $1 \times 2 \times 3\,\mathbf{m}^3$**)**



Solution: The electric field is given as:

$$\mathbf{E} = 2x^2\hat{i} - 4y\hat{j} + 6\hat{k}\,\text{N/C}$$

The net electric flux Φ_{net} through the cuboid can be calculated by considering the electric field at the faces of the cuboid. The flux through each face is given by the dot product of the electric field and the area vector.

For the cuboid with dimensions $1 \times 2 \times 3\,\text{m}^3$, we evaluate the electric field on the respective faces. Here, the flux is computed using the formula:

$$\Phi_{\text{net}} = E_x \times A_x + E_y \times A_y + E_z \times A_z$$

Using the values from the electric field and the dimensions of the cuboid, we calculate:

$$\Phi_{\text{net}} = (-8 \times 3) + (2 \times 6) = -12$$

Now, the total charge enclosed within the cuboid is related to the electric flux by Gauss's law:

$$\Phi_{\text{net}} = \frac{-q}{\epsilon_0}$$

Substitute the value of Φ_{net}:

$$-12 = \frac{-q}{\epsilon_0}$$

Thus, the charge is:

$$|q| = 12\epsilon_0$$

Therefore, the value of n is:

$$(12)$$

Quick Tip

In Gauss's law problems, remember that the flux through each face of the cuboid depends on the orientation and magnitude of the electric field. The net flux is the sum of contributions from all faces.

---

28. In an ac generator, a rectangular coil of 100 turns each having area 14×10^{-2} m^2 is rotated at 360 rev/min about an axis perpendicular to a uniform magnetic field of magnitude 3.0 T. The maximum value of the emf produced will be .... V. (Take $\pi = \frac{22}{7}$)

Solution:

The maximum induced emf ξ_{max} is given by the formula:

$$\xi_{\text{max}} = NAB\omega$$

where:

- $N = 100$ (number of turns),
- $A = 14 \times 10^{-2}\,\text{m}^2$ (area of the coil),
- $B = 3.0\,\text{T}$ (magnetic field),
- $\omega = \frac{360 \times 2\pi}{60}\,\text{rad/s} = 12\pi\,\text{rad/s}$ (angular frequency).

Substituting the given values:

$$\xi_{\text{max}} = 100 \times 14 \times 10^{-2} \times 3.0 \times 12\pi/60$$

$$\xi_{\text{max}} = 100 \times 14 \times 10^{-2} \times 3.0 \times \frac{22}{7} \times \frac{12}{60}$$

$$\xi_{\text{max}} = 1584\,\text{V}$$

Thus, the maximum induced emf is $\boxed{1584\,\text{V}}$.

Quick Tip

To calculate the maximum induced emf, remember the relationship $\xi_{\text{max}} = NAB\omega$, where ω is the angular frequency of rotation. Make sure to convert the units of rev/min to rad/s for correct calculations.

---

29. A stone tied to 180 cm long string at its end is making 28 revolutions in a horizontal circle in every minute. The magnitude of acceleration of stone is $\frac{1936}{x}$ m/s^2. The value of x is ....

Solution:

The centripetal acceleration a is given by:

$$a = \omega^2 R$$

where:

- $R = 1.8\,\text{m}$ (radius of the circle, as the string length is 180 cm),
- $\omega = \frac{28\times 2\pi}{60}$ rad/s (angular velocity for 28 revolutions per minute).

Substitute the values into the formula:

$$a = \left(\frac{28 \times 2\pi}{60}\right)^2 \times 1.8$$

$$a = \left(\frac{56 \times 22}{60 \times 7}\right)^2 \times 1.8$$

$$a = \left(\frac{44}{225}\right)^2 \times 1.8$$

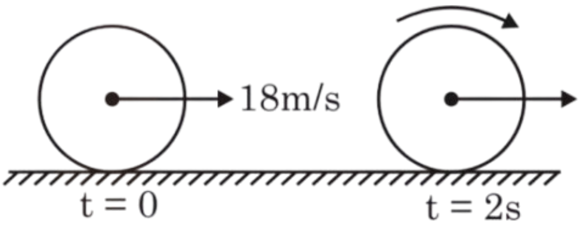
$$a = \frac{1936 \times 1.8}{225}$$

Thus, the acceleration is given by $\frac{1936}{225}$, and $x = 125$.

Quick Tip

In circular motion problems, remember that the centripetal acceleration is given by $a = \omega^2 R$, where ω is the angular velocity and R is the radius of the circular path.

30. A uniform disc of mass 0.5 kg and radius r is projected with velocity 18 m/s at $t = 0$ on a rough horizontal surface. It starts off with a purely sliding motion at $t = 0$. After 2s, it acquires a purely rolling motion (see figure). The total kinetic energy of the disc after 2s will be .... J (given, coefficient of friction is 0.3 and $g = 10\,\text{m/s}^2$).



Solution:

The acceleration due to friction is given by:

$$a = -\mu_k g = -0.3 \times 10 = -3\,\text{m/s}^2$$

The velocity after 2 seconds is:

$$V = 18 - 3 \times 2 = 12\,\text{m/s}$$

Now, the total kinetic energy KE is given by:

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

For a disc, $I = \frac{1}{2}mr^2$ and $\omega = \frac{v}{r}$. Thus,

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}mr^2\left(\frac{v}{r}\right)^2$$

$$KE = \frac{3}{4}mv^2$$

Substituting $m = 0.5\,\text{kg}$ and $v = 12\,\text{m/s}$:

$$KE = \frac{3}{4} \times 0.5 \times 12^2 = 54\,\text{J}$$

Thus, the total kinetic energy is:

$$\boxed{54\,\text{J}}$$

Quick Tip

In problems involving rolling motion, remember that the total kinetic energy is the sum of translational and rotational kinetic energy. For a rolling disc, use $KE = \frac{3}{4}mv^2$ after it starts rolling.
