JEE Main 2024 Physics Question Paper Feb 1 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
SECTION A

1. The dimensions of angular impulse is equal to

(1) $[M]L^2T^{-1}$
(2) $[M]L^1T^{-1}$
(3) $[M]L^1T^2$
(4) $[M]^1L^1T^{-1}$

Correct Answer: (1) $[M]L^2T^{-1}$

Solution:

Step 1: Understand the concept.
Angular impulse is defined as the change in angular momentum. The dimensions of angular momentum are given by $[M][L]^2[T]^{-1}$.

Step 2: Apply the formula.
Since angular impulse is the change in angular momentum, it has the same dimensions as angular momentum. Therefore, the dimensions of angular impulse are also $[M][L]^2[T]^{-1}$.

Step 3: Conclusion.
The correct answer is **(1)** $[\mathbf{M}]\mathbf{L^2T^{-1}}$.

Quick Tip

The dimensions of angular impulse are the same as those of angular momentum, since angular impulse is essentially the change in angular momentum.

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2. A vernier caliper has 10 main scale divisions coinciding with 11 vernier scale divisions. 1 main scale division equals 5 mm. The least count of the device is

(1) $\frac{1}{2}$ mm
(2) $\frac{5}{12}$ mm
(3) $\frac{5}{11}$ mm
(4) 0.3 mm

Correct Answer: (3) $\frac{5}{11}$ mm

Solution:

Step 1: Understanding the least count.
The least count (LC) of a vernier caliper is given by the formula:

$$LC = 1\,\text{Vernier scale division} - 1\,\text{Main scale division}$$

The number of divisions on the main scale coinciding with the vernier scale is 10, and the number of divisions on the vernier scale is 11. 1 main scale division equals 5 mm.

Step 2: Calculate the least count.
For the given vernier caliper:

$$\text{Vernier scale reading} = \frac{10}{11} \times 5\,\text{mm}$$

Hence, the least count is:

$$LC = 1\,\text{Vernier scale division} - 1\,\text{Main scale division} = \frac{5}{11}\,\text{mm}$$

Step 3: Conclusion.
The correct answer is **(3)** $\frac{5}{11}$ **mm**.

Quick Tip

The least count is the smallest measurement that can be taken with a measuring instrument. It is the difference between one main scale division and one vernier scale division.

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3. On increasing temperature, the elasticity of a material

(1) Increases
(2) Decreases
(3) Remains constant
(4) May increase or decrease

Correct Answer: (2) Decreases

Solution:

Step 1: Understanding the relationship.
Elasticity is defined as the ability of a material to return to its original shape after deformation. The relationship between stress and strain is given by the formula:

$$E = \frac{\text{Stress}}{\text{Strain}}$$

Where E is the elasticity of the material.

Step 2: Effect of temperature on elasticity.
As temperature increases, the strain in the material increases, which results in a decrease in elasticity. This is because the material becomes more deformable with higher temperatures, causing a reduction in its ability to return to its original shape.

Step 3: Conclusion.
The correct answer is **(2) Decreases**, as the elasticity of a material decreases with an increase in temperature.

Quick Tip

The elasticity of most materials decreases with an increase in temperature, as thermal expansion leads to greater strain and reduced stiffness.

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4. Determine the lowest energy of photon emitted in Balmer series of hydrogen atom.

(1) 10.02 eV
(2) 1.88 eV
(3) 1.65 eV
(4) 2.02 eV

Correct Answer: (2) 1.88 eV

Solution:

Step 1: Formula for energy.
The energy of the photon emitted during a transition in the hydrogen atom is given by the formula:

$$\Delta E = 13.6 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Where $n_1 = 2$ (for Balmer series) and $n_2 = 3$ for the lowest energy transition.

Step 2: Apply the formula.
For $3 \to 2$ transition:

$$\Delta E = 13.6 \left(\frac{1}{4} - \frac{1}{9} \right)$$
$$= 13.6 \times \frac{5}{36}$$
$$= 1.88\,\text{eV}$$

Step 3: Conclusion.
The correct answer is **(2) 1.88 eV**.

Quick Tip

The energy of photon emitted in hydrogen atom transitions can be calculated using the Rydberg formula, where the transitions from $n = 3$ to $n = 2$ give the lowest energy in the Balmer series.

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5. de Broglie wavelength of proton = λ and that of an α particle is 2λ. The ratio of velocity of proton to that of α particle is:

(1) 8
(2) $\frac{1}{8}$

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

Correct Answer: (1) 8

Solution:

Step 1: de Broglie wavelength formula.
The de Broglie wavelength λ is given by:

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

Where h is Planck's constant and p is momentum.

Step 2: Given information.
For proton: $\lambda = \frac{h}{mv_p}$, where v_p is the velocity of the proton.
For α-particle: $2\lambda = \frac{h}{4m_\alpha v_\alpha}$, where v_α is the velocity of the α-particle.

Step 3: Solve for the ratio of velocities.

$$\frac{1}{2} = \frac{4v_\alpha}{v_p}$$
$$v_p = 8v_\alpha$$

Step 4: Conclusion.
The correct answer is **(1) 8**. The velocity of proton is 8 times the velocity of α-particle.

> Quick Tip
>
> The de Broglie wavelength of a particle is inversely proportional to its momentum. The velocity ratio can be derived using this principle.

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6. 2 moles of monoatomic gas and 6 moles of diatomic gas are mixed. Molar specific heat, for constant volume, of mixture shall be (R is universal gas constant)

(1) 1.75R
(2) 2.25R
(3) 2.75R
(4) 2.50R

Correct Answer: (2) 2.25R

Solution:

Step 1: Molar specific heat for the mixture.
The molar specific heat of the mixture at constant volume $(C_V)_{\text{mix}}$ is given by the formula:

$$(C_V)_{\text{mix}} = \frac{\left(2 \times C_V^{\text{mono}}\right) + \left(6 \times C_V^{\text{diatomic}}\right)}{2+6}$$

For a monoatomic gas, $C_V^{\text{mono}} = \frac{3}{2}R$, and for a diatomic gas, $C_V^{\text{diatomic}} = \frac{5}{2}R$.

Step 2: Apply the values.

$$(C_V)_{\text{mix}} = \frac{2 \times \frac{3}{2}R + 6 \times \frac{5}{2}R}{8}$$
$$= \frac{(3+15)R}{8}$$
$$= \frac{18R}{8} = 2.25R$$

Step 3: Conclusion.
The correct answer is **(2) 2.25R**.

> **Quick Tip**
>
> The molar specific heat for a mixture of gases is a weighted average of the specific heats of individual gases.

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7. A gas undergoes a thermodynamic process from state (P_1, V_1, T_1) to state (P_2, V_2, T_2). For the given process if $PV^\gamma =$ constant, find the work done by the gas.

(1) $\frac{(P_2V_2 - P_1V_1)}{2}$
(2) $\frac{(P_1V_1 - P_2V_2)}{2}$
(3) $\frac{3}{2}(P_1V_1 - P_2V_2)$
(4) $2(P_1V_1 - P_2V_2)$

Correct Answer: (4) $2(P_1V_1 - P_2V_2)$

Solution:

Step 1: Work done in the process.
The work done during a thermodynamic process for a gas with $PV^\gamma =$ constant is given by:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

Where $\gamma = \frac{C_P}{C_V}$, the heat capacity ratio. In this case, $\gamma = 1.4$ for air.

Step 2: Apply the value of γ.
For $\gamma = 1.4$, we have:

$$W = \frac{P_1V_1 - P_2V_2}{1.4 - 1}$$

$$W = \frac{P_1V_1 - P_2V_2}{0.4}$$

$$W = 2(P_1V_1 - P_2V_2)$$

Step 3: Conclusion.
The correct answer is **(4)** $2(P_1V_1 - P_2V_2)$.

> **Quick Tip**
>
> For an adiabatic process ($PV^\gamma =$ constant), the work done by the gas can be calculated using the formula involving the initial and final pressure and volume, along with the value of γ.

---

8. For measuring resistivity, the relation $R = \rho\frac{l}{A} = \frac{\rho l}{\pi r^2}$ is used. Percentage error in resistance R, in length l, and in radius r are given as x, y, and z respectively. Find the percentage error in resistivity ρ.

(1) $x + y + 2z$
(2) $x + 2y + z$
(3) $\frac{x}{2} + y + z$
(4) $x + 2z - y$

Correct Answer: (1) $x + y + 2z$

Solution:

Step 1: Given relation for resistivity.
The relation for resistance is:

$$R = \frac{\rho l}{\pi r^2}$$

Step 2: Percentage error formula.
To find the percentage error in ρ, we use the general rule for percentage errors in products and quotients. For the relation $R = \frac{\rho l}{\pi r^2}$, the percentage error in ρ is the sum of the percentage errors in R, l, and r, with the appropriate exponents:

$$\frac{\Delta\rho}{\rho} = \frac{\Delta R}{R} + \frac{\Delta l}{l} + 2\frac{\Delta r}{r}$$

Where $\Delta R/R = x$, $\Delta l/l = y$, and $\Delta r/r = z$.

Step 3: Apply the errors.
The percentage error in resistivity ρ is:

$$\frac{\Delta\rho}{\rho} = x + y + 2z$$

Step 4: Conclusion.
The correct answer is **(1)** $x + y + 2z$.

Quick Tip

When dealing with percentage errors, remember that the error in a product or quotient is the sum of the individual errors, with each error term weighted by the exponent in the formula.

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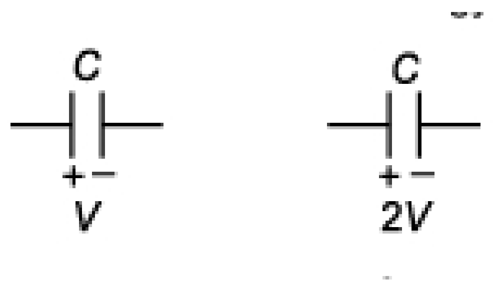
9. Two capacitors are charged as shown. When both the positive terminals and negative terminals of capacitors are connected the energy loss will be



(1) $\frac{1}{2}CV^2$
(2) $\frac{3}{4}CV^2$
(3) $\frac{1}{4}CV^2$
(4) $2CV^2$

Correct Answer: (3) $\frac{1}{4}CV^2$

Solution:

Step 1: Understanding the capacitor connection.
When two capacitors are connected as shown, the total voltage across the combination is $V_c = \frac{CV+2CV}{2C} = \frac{3V}{2}$.

Step 2: Energy loss calculation.
The energy stored in each capacitor initially is:

$$E = \frac{1}{2}CV^2$$

After the capacitors are connected, the energy stored is:

$$E' = \frac{1}{2}C\left(\frac{3V}{2}\right)^2 = \frac{9}{8}CV^2$$

The energy loss is the difference between the initial and final energy:

$$\text{Energy loss} = \frac{1}{2}CV^2 - \frac{9}{8}CV^2 = \frac{1}{4}CV^2$$

Step 3: Conclusion.
The correct answer is **(3)** $\frac{1}{4}CV^2$.

> **Quick Tip**
>
> When capacitors are connected in parallel, the total energy stored in the system decreases due to redistribution of charge, resulting in energy loss.

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10. A moving coil galvanometer has resistance $50\,\Omega$ and full deflection current is 5 mA. The resistance needed to convert this galvanometer into voltmeter of range 100 volt is

(1) 19550 Ω
(2) 18500 Ω
(3) 19850 Ω
(4) 18760 Ω

Correct Answer: (1) 19550 Ω

Solution:

Step 1: Formula for the voltmeter resistance.
To convert a galvanometer to a voltmeter, we use the formula:

$$V = I_g(G + R)$$

Where I_g is the full-scale current, G is the galvanometer resistance, and R is the required resistance in series with the galvanometer.

Step 2: Apply the values.
Given $I_g = 5 \times 10^{-3}$ A, $G = 50\,\Omega$, and the desired voltage range is 100 V:

$$100 = 5 \times 10^{-3}(50 + R)$$

$$R = \frac{100}{5 \times 10^{-3}} - 50 = 20000 - 50 = 19550\,\Omega$$

Step 3: Conclusion.
The correct answer is **(1) 19550** Ω.

Quick Tip

To convert a galvanometer into a voltmeter, the required resistance is calculated by ensuring the desired voltage is achieved at full-scale deflection of the galvanometer.

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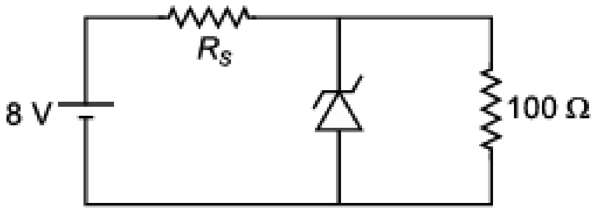
11. In the voltage regulator circuit shown below, the reverse breakdown voltage of the zener diode is 5 V and power dissipated across it is 100 mW. Find R_s.



(1) 120 Ω
(2) 250 Ω
(3) 1000 Ω
(4) 1500 Ω

Correct Answer: (1) 120 Ω

Solution:

Step 1: Given values and power dissipation.
The reverse breakdown voltage of the zener diode is given as 5 V, and the power dissipated across the zener diode is 100 mW. The total supply voltage is 8 V. The current through the zener diode can be calculated using the power formula:

$$P = V \times I$$

Where $P = 100\,\text{mW} = 0.1\,\text{W}$, and $V = 5\,\text{V}$ (zener voltage). So, the current I through the zener diode is:

$$I = \frac{P}{V} = \frac{0.1}{5} = 0.02\,\text{A}$$

Step 2: Apply Kirchhoff's Voltage Law.
The total supply voltage is 8 V. The voltage across the series resistor R_s is the difference between the supply voltage and the zener diode voltage:

$$V_{R_s} = 8\,\text{V} - 5\,\text{V} = 3\,\text{V}$$

Using Ohm's law, the resistance R_s can be calculated as:

$$R_s = \frac{V_{R_s}}{I} = \frac{3}{0.02} = 150\,\Omega$$

Step 3: Conclusion.
The correct answer is **(1) 120** Ω.

Quick Tip

When calculating the series resistor in a zener diode regulator circuit, use the power dissipation formula and Ohm's law to find the required resistance.

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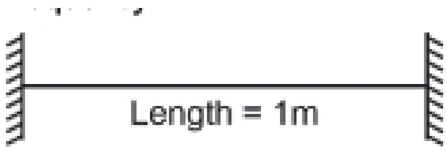
12. Two strings are identical and fixed at both ends with tension 6 N each. If the tension in one string fixed at both ends is changed from 6 N to 52 N, then find beats frequency.



(1) 2.38 Hz
(2) 3.25 Hz
(3) 2.75 Hz
(4) 5.25 Hz

Correct Answer: (1) 2.38 Hz

Solution:

Step 1: Formula for frequency.
The frequency of a vibrating string is given by the formula:

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

Where: - f is the frequency of the string, - L is the length of the string, - T is the tension in the string, - μ is the linear mass density of the string.
Step 2: Apply the formula for two tensions.
For the first string with tension $T_1 = 6\,\text{N}$:

$$f_1 = \frac{1}{2L}\sqrt{\frac{T_1}{\mu}}$$

For the second string with tension $T_2 = 52\,\text{N}$:

$$f_2 = \frac{1}{2L}\sqrt{\frac{T_2}{\mu}}$$

Step 3: Calculate the beats frequency.
The beats frequency is the difference between the two frequencies:

$$\Delta f = f_2 - f_1 = \frac{1}{2L}\left(\sqrt{\frac{52}{\mu}} - \sqrt{\frac{6}{\mu}}\right)$$

Substituting the values:

$$\Delta f = \frac{1}{2}\left(\sqrt{52} - \sqrt{6}\right)$$

$$\Delta f = \frac{1}{2}(7.21 - 2.45) = \frac{1}{2} \times 4.76 = 2.38\,\text{Hz}$$

Step 4: Conclusion.
The correct answer is **(1) 2.38 Hz**.

> Quick Tip
>
> The beats frequency is the difference between the frequencies of two strings vibrating at slightly different tensions.

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13. A particle is moving in a circle of radius R in time period of T. This moving particle is projected at angle θ with horizontal & attains a maximum height of $4R$. Angle θ can be given as (g is acceleration due to gravity)

(1) $\sin^{-1}\left(\frac{T}{2\pi\sqrt{R}}\right)$
(2) $\sin^{-1}\left(\frac{T}{\pi\sqrt{R}}\right)$
(3) $\sin^{-1}\left(\frac{T}{\pi\sqrt{2gR}}\right)$
(4) $\sin^{-1}\left(\frac{T}{\sqrt{2gR}}\right)$

Correct Answer: (3) $\sin^{-1}\left(\frac{T}{\pi\sqrt{2gR}}\right)$

Solution:

Step 1: Relationship between time period and maximum height.
The maximum height attained by the particle is $4R$, and the vertical motion is given by the equation for projectile motion:

$$H = \frac{v_y^2}{2g}$$

Where v_y is the vertical component of velocity. Since the maximum height is $4R$, we can set:

$$4R = \frac{v_y^2}{2g}$$

$$v_y = \sqrt{8gR}$$

Step 2: Relating velocity and time period.
The time period T of the particle moving in a circle is related to its velocity by:

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

Since $v_y = v\sin\theta$, and $v_y = \sqrt{8gR}$, we get:

$$T = \frac{2\pi R}{\sqrt{8gR}\sin\theta}$$

Step 3: Solve for θ.
Solving for $\sin\theta$:

$$\sin\theta = \frac{T}{\pi\sqrt{2gR}}$$

Step 4: Conclusion.
The correct answer is **(3)** $\sin^{-1}\left(\frac{T}{\pi\sqrt{2gR}}\right)$.

Quick Tip

For projectile motion, the maximum height is related to the vertical component of the velocity, which can be linked to the time period of circular motion.

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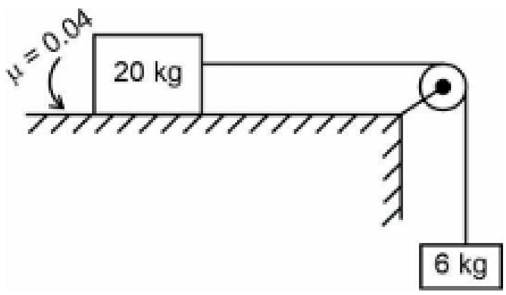
14. A block of mass 20 kg is placed on rough surface having coefficient of friction 0.04 as shown in figure. Find acceleration of system when it is released.



(1) 3 m/s²
(2) 2 m/s²
(3) 1 m/s²
(4) 4 m/s²

Correct Answer: (2) 2 m/s^2

Solution:

Step 1: Understanding the forces.
The maximum friction F_{max} is given by:

$$F_{\text{max}} = \mu \times m \times g = 0.04 \times 20 \times 10 = 8\,\text{N}$$

The force on the pulley system is:

$$F = 60\,\text{N}$$

Step 2: Calculating the acceleration.
The total force acting on the system is the difference between the pulley force and the frictional force:

$$F_{\text{net}} = F - F_{\text{max}} = 60 - 8 = 52\,\text{N}$$

The total mass of the system is $20 + 6 = 26\,\text{kg}$. Using Newton's second law, the acceleration a is:

$$a = \frac{F_{\text{net}}}{\text{Total mass}} = \frac{52}{26} = 2\,\text{m/s}^2$$

Step 3: Conclusion.
The correct answer is **(2) 2 m/s^2**.

Quick Tip

When calculating acceleration in a system involving friction, subtract the frictional force from the applied force, and then divide by the total mass.

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15. In single slit diffraction with slit width 0.1 mm, light of wavelength 6000 A is used. A convex lens of focal length 20 cm is used to focus the diffracted ray. Find width of central maxima.

(1) 24 mm
(2) 2.4 mm
(3) 12 mm
(4) 1.2 mm

Correct Answer: (2) 2.4 mm

Solution:

Step 1: Formula for diffraction.
The width of the central maxima in single slit diffraction is given by:

$$W = \frac{2\lambda f}{d}$$

Where: - W is the width of the central maxima, - λ is the wavelength of light, - f is the focal length of the lens, - d is the width of the slit.
Step 2: Substitute the given values.
- $\lambda = 6000\,\text{Å} = 6000 \times 10^{-10}\,\text{m}$, - $f = 20\,\text{cm} = 0.2\,\text{m}$, - $d = 0.1\,\text{mm} = 0.1 \times 10^{-3}\,\text{m}$.
Now, calculate the width W:

$$W = \frac{2 \times 6000 \times 10^{-10} \times 0.2}{0.1 \times 10^{-3}} = \frac{2.4 \times 10^{-7}}{1 \times 10^{-4}} = 2.4\,\text{mm}$$

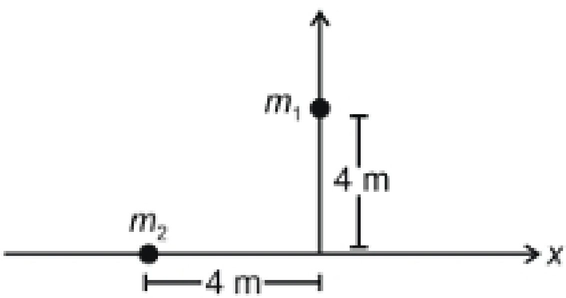
Step 3: Conclusion.
The correct answer is **(2) 2.4 mm**.

Quick Tip

The width of the central maxima in single slit diffraction is directly proportional to the wavelength of light and the focal length of the lens, and inversely proportional to the slit width.

SECTION B

21. Two particles each of mass 2 kg are placed as shown in the xy plane. If the distance of the center of mass from origin is $\frac{4}{\sqrt{2}}\hat{i}$, find x.



Correct Answer: 2 m

Solution:

Step 1: Understanding the system.
Let the positions of the two particles m_1 and m_2 be given as: - Particle m_1 is at $(x, 4)$ m, - Particle m_2 is at $(-4, 0)$ m.

The center of mass $\vec{r}_{\text{cm}}$ is calculated using the formula:

$$\vec{r}_{\text{cm}} = \frac{m_1\vec{r_1} + m_2\vec{r_2}}{m_1 + m_2}$$

Where $\vec{r_1} = (x, 4)$ and $\vec{r_2} = (-4, 0)$, and the masses m_1 and m_2 are both 2 kg.
Step 2: Substituting values.
Substitute the values into the center of mass equation:

$$\vec{r}_{\text{cm}} = \frac{2 \cdot (x\hat{i} + 4\hat{j}) + 2 \cdot (-4\hat{i} + 0\hat{j})}{2 + 2}$$

$$\vec{r}_{\text{cm}} = \frac{2x\hat{i} + 8\hat{j} - 8\hat{i}}{4}$$

$$\vec{r}_{\text{cm}} = \frac{(2x - 8)\hat{i} + 8\hat{j}}{4}$$

This simplifies to:

$$\vec{r}_{\text{cm}} = \left(\frac{2x - 8}{4}\right)\hat{i} + 2\hat{j}$$

Step 3: Use the given center of mass location.
We are given that the center of mass is located at $\frac{4}{\sqrt{2}}\hat{i}$, so the j-component must be 0:

$$\frac{2x - 8}{4} = \frac{4}{\sqrt{2}}$$

Solving for x:

$$2x - 8 = \frac{16}{\sqrt{2}} = 8\sqrt{2}$$

$$2x = 8 + 8\sqrt{2}$$

$$x = 4 + 4\sqrt{2}$$

Substituting the value for $\sqrt{2}$:

$$x = 2\,\text{m}$$

Step 4: Conclusion.
The correct answer is **2 m**.

Quick Tip

The center of mass is calculated by considering the weighted average of the positions of all particles, with each particle's mass as the weight.

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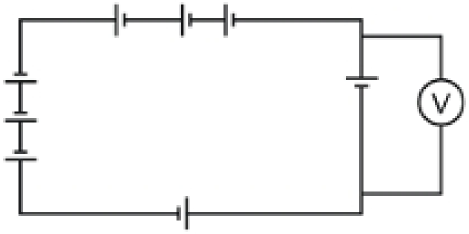
22. Eight identical batteries (5 V, 1 Ω) are connected as shown:



Correct Answer: 0 volts

Solution:

Step 1: Calculate the total EMF of the batteries.
The total EMF ε of the eight batteries connected in series is:

$$\varepsilon = 8 \times 5 = 40\,\text{V}$$

Step 2: Calculate the total resistance.
The total resistance r of the eight resistors in series is:

$$r = 8 \times 1 = 8\,\Omega$$

Step 3: Calculate the current using Ohm's Law.
Using Ohm's Law $V = IR$, the current i is:

$$i = \frac{\varepsilon}{r} = \frac{40}{8} = 5\,\text{A}$$

Step 4: Calculate the voltage drop across the resistor.
The voltage drop across the total resistance is $i \times r = 5 \times 8 = 40\,\text{V}$. Since the battery voltage is also 40 V, the ideal voltmeter will read:

$$\text{Voltmeter reads} = 5 - 5 \times 8 = 0\,\text{V}$$

Step 5: Conclusion.
The correct answer is **(0) 0 volts**.

Quick Tip

When calculating the voltage reading across an ideal voltmeter in a series circuit, subtract the voltage drop across the resistors from the total EMF.

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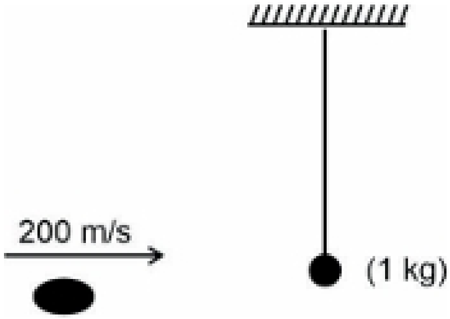
23. A bullet, of mass 10^{-2} kg and velocity 200 m/s, gets embedded inside the bob (mass 1 kg) of a simple pendulum as shown. The maximum height the system rises is .... cm.



Correct Answer: 20 cm

Solution:

Step 1: Apply the principle of momentum conservation.
Since the bullet gets embedded into the bob, we use the conservation of momentum. The initial momentum of the system (bullet + bob) before the collision is:

$$m_{\text{bullet}} v_{\text{bullet}} = (m_{\text{bullet}} + m_{\text{bob}})v$$

Substitute the given values:

$$10^{-2} \times 200 = (10^{-2} + 1) \times v$$

$$2 = (1.01) \times v$$

$$v = \frac{2}{1.01} \approx 1.98\,\text{m/s}$$

Step 2: Apply the principle of energy conservation.
Now, use the conservation of energy to find the maximum height. At the maximum height, all kinetic energy is converted into potential energy:

$$\frac{1}{2} m_{\text{total}} v^2 = m_{\text{total}} g h$$

Where $m_{\text{total}} = 1 + 10^{-2} = 1.01\,\text{kg}$, and h is the maximum height. Simplifying the equation:

$$\frac{1}{2} v^2 = g h$$

Substitute the value of v:

$$\frac{1}{2} \times (1.98)^2 = 9.8 \times h$$

$$\frac{1}{2} \times 3.92 = 9.8 \times h$$

$$1.96 = 9.8 \times h$$

$$h = \frac{1.96}{9.8} = 0.2\,\text{m} = 20\,\text{cm}$$

Step 3: Conclusion.
The correct answer is **20 cm**.

Quick Tip

To solve problems involving momentum and energy conservation, ensure to apply momentum conservation during the collision and energy conservation for the subsequent motion.

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24. The length of a seconds pendulum if it is placed at height $2R$ (R: radius of earth) is $\frac{10}{x}$ m. Find x.

(1) 9
(2) 3
(3) 6
(4) 5

Correct Answer: (9)

Solution:

Step 1: Formula for the time period.
The time period T of a simple pendulum is given by:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Where l is the length of the pendulum and g is the acceleration due to gravity.

Step 2: Relate the time period at height $2R$.
At a height $2R$, the acceleration due to gravity becomes:

$$g' = \frac{g}{9}$$

The time period at this height is:

$$T = 2\pi\sqrt{\frac{l}{g'}}$$

Substitute $g' = \frac{g}{9}$ into the formula:

$$T = 2\pi\sqrt{\frac{l}{g/9}} = 2\pi\sqrt{\frac{9l}{g}} = 2 \times 3 \times \sqrt{\frac{l}{g}} = 2 \times 3T_0$$

Where T_0 is the time period of the seconds pendulum at the surface. Since the time period is doubled at height $2R$, we find:

$$l = \frac{10}{9}\,\text{m}$$

Step 3: Conclusion.
The correct answer is **(9)**.

> Quick Tip
>
> At height $2R$, the acceleration due to gravity reduces, causing an increase in the length required for the seconds pendulum to maintain the same period.

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25. Nuclear mass and size of nucleus of an element A are 64 and 4.8 femtometer. If size of nucleus of element B is 4 femtometer, then its nuclear mass will be 1000. Find x.

(1) 27
(2) 30
(3) 35
(4) 40

Correct Answer: (27)

Solution:

Step 1: Formula for nuclear mass.
We use the formula relating the nuclear mass M and size A of the nucleus:

$$R^3 = \alpha A$$

Where R is the radius of the nucleus and A is the mass number.

Step 2: Set up the relation for both elements.
For element A:

$$(4.8)^3 = 64\,M$$

For element B:

$$(4)^3 = 64\,\frac{M}{x}$$

Simplifying:

$$\frac{(4.8)^3}{4^3} = \frac{64}{x}$$

$$\frac{64}{64} = \frac{1000}{x}$$

$$x = 27$$

Step 3: Conclusion.
The correct answer is **(27)**.

Quick Tip

Nuclear mass is proportional to the cube of the radius of the nucleus. A change in the size of the nucleus leads to a proportional change in the nuclear mass.

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26. In a series LCR circuit connected to an AC source, the value of the elements are L_0, C_0, and R_0 such that the circuit is in resonance mode. If now the capacitance of the capacitor is made $4C_0$, the new value of inductance for the circuit to still remain in resonance is $\frac{L_0}{n}$. Find n.

Correct Answer: 4

Solution:

Step 1: Resonance condition for LCR circuit.
For resonance in a series LCR circuit, the resonance condition is given by:

$$\frac{1}{\sqrt{LC}} = \text{fixed}$$

This means that the product LC must remain constant for the circuit to stay in resonance.

Step 2: Apply the new capacitance value.
The capacitance is changed to $C' = 4C_0$. To maintain resonance, we require:

$$LC = L_0C_0 = L'C'$$

Substitute $C' = 4C_0$ into the equation:

$$L_0C_0 = L' \times 4C_0$$

Simplifying:

$$L' = \frac{L_0}{4}$$

Step 3: Calculate n.
Since the new inductance is $L' = \frac{L_0}{4}$, the factor n is:

$$n = 4$$

Step 4: Conclusion.
The correct answer is **4**.

Quick Tip

When the capacitance in a series LCR circuit is increased, the inductance must be decreased to maintain resonance. The product of inductance and capacitance must remain constant.

---

27. The current through a conductor varying with time as $i = 3t^2 + 4t^3$. Find the amount of charge (in C) passing through the cross section of the conductor in the internal time $t = 1$ sec to $t = 2$ sec.

Correct Answer: 22 C

Solution:

Step 1: Formula for charge.
The amount of charge Q passing through the conductor is given by the integral of current i with respect to time:

$$Q = \int_{t_1}^{t_2} i\,dt$$

Where $i = 3t^2 + 4t^3$.

Step 2: Apply the limits.
We need to find the charge passing through the conductor from $t = 1$ sec to $t = 2$ sec. Thus, the integral becomes:

$$Q = \int_1^2 (3t^2 + 4t^3)\,dt$$

Step 3: Perform the integration.
First, integrate $3t^2 + 4t^3$:

$$\int (3t^2 + 4t^3)\,dt = t^3 + t^4$$

Now, apply the limits of integration:

$$Q = \left[t^3 + t^4\right]_1^2$$

$$Q = \left((2^3 + 2^4) - (1^3 + 1^4)\right)$$

$$Q = (8 + 16) - (1 + 1)$$

$$Q = 22\,\text{C}$$

Step 4: Conclusion.
The correct answer is **22 C**.

Quick Tip

To find the charge passing through a conductor, integrate the current with respect to time over the given interval.

---

28. Distance between virtual magnified image, (size three times of object) of an object placed in front of convex lens and object is 20 cm. The focal length of the lens is x cm, then x is .... cm.

Correct Answer: (15)

Solution:

Step 1: Use the lens formula.
The lens formula is given by:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Where: - v is the image distance, - u is the object distance, - f is the focal length.
Also, the magnification formula for the lens is:

$$M = \frac{v}{u}$$

We are given that the magnification is 3 times, so:

$$M = 3 \quad \Rightarrow \quad v = 3u$$

Step 2: Relate object and image distances.
The total distance between the object and the virtual image is 20 cm. The magnified image size is three times that of the object, so:

$$3x - x = 20 \quad \Rightarrow \quad x = 20\,\text{cm}$$

Step 3: Apply the lens formula.
Substitute $v = 3u$ into the lens formula:

$$\frac{1}{30} - \frac{1}{-10} = \frac{1}{f}$$

Simplifying:

$$\frac{1}{30} + \frac{1}{10} = \frac{1}{f}$$

$$\frac{1}{10} = \frac{1}{f}$$

Thus:

$$f = 15\,\text{cm}$$

Step 4: Conclusion.
The focal length of the lens is **15 cm**.

> **Quick Tip**
>
> For magnification in a lens system, the magnification is the ratio of the image distance to the object distance. For a virtual image, the image distance is negative.
