JEE Main 2024 Physics Question Paper April 9 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. Find the work done by one mole of monoatomic gas undergoing adiabatic expansion such that the volume changes from V to $2V$.

Solution:

Step 1: Understanding the Adiabatic Process.
In an adiabatic process, no heat is exchanged, and the work done is related to the change in volume. For an ideal monoatomic gas, the work done W during an adiabatic expansion is given by the equation:

$$W = \frac{P_1 V_1}{\gamma - 1}\left(1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}\right)$$

where $\gamma = \frac{5}{3}$ for monoatomic gas. P_1 and V_1 are the initial pressure and volume, and V_2 is the final volume. The formula accounts for the change in volume during the adiabatic expansion.
Step 2: Apply the given information.
Given that the volume changes from V to $2V$, substitute these values into the formula:

$$W = \frac{P_1 V_1}{\gamma - 1}\left(1 - \left(\frac{2V}{V}\right)^{\gamma-1}\right)$$

Simplify and compute the final result.

Quick Tip

In adiabatic processes, the relationship PV^γ = constant holds true, which can help simplify equations when necessary.

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2. Angle between two vectors is $\cos^{-1}\left(\frac{5}{9}\right)$, if $|\vec{A}+\vec{B}| = \sqrt{2}|\vec{A}-\vec{B}|$ and $\vec{A} = n\vec{B}$, find the value of n.

Solution:

Step 1: Analyze the given equation.
We are given that $|\vec{A}+\vec{B}| = \sqrt{2}|\vec{A}-\vec{B}|$. Using the formula for the magnitude of vectors, we can express this equation as:

$$|\vec{A}+\vec{B}|^2 = 2|\vec{A}-\vec{B}|^2$$

Step 2: Expand both sides of the equation.
Expanding both sides using vector identities:

$$|\vec{A}|^2 + 2\vec{A}\cdot\vec{B} + |\vec{B}|^2 = 2(|\vec{A}|^2 - 2\vec{A}\cdot\vec{B} + |\vec{B}|^2)$$

Substitute $\vec{A} = n\vec{B}$ into the equation and solve for n.

Quick Tip

For vector magnitude calculations, always use the formula $|\vec{A}|^2 = A_x^2 + A_y^2 + A_z^2$ when working in Cartesian coordinates.

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3. Find the dimensional formula of latent heat.

Solution:

Step 1: Formula for latent heat.
Latent heat L is the amount of heat required to change the phase of a unit mass of a substance at constant temperature. The formula is:

$$L = \frac{Q}{m}$$

where Q is the heat supplied, and m is the mass.
Step 2: Dimension of heat.
The dimensional formula of heat Q is $[ML^2T^{-2}]$, and mass m has the dimension $[M]$.

Step 3: Finding the dimensional formula of latent heat.
Substituting these into the formula for latent heat:

$$L = \frac{[ML^2T^{-2}]}{[M]} = [L^2T^{-2}]$$

> **Quick Tip**
>
> Latent heat involves phase changes, and its dimensional formula reflects the energy required per unit mass.

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4. Find the energy equivalent (in MeV) for 1 gm mass of substance.

Solution:

Step 1: Use the equation $E = mc^2$.
The energy equivalent of a mass is given by Einstein's equation $E = mc^2$, where m is the mass, and c is the speed of light in vacuum.
Step 2: Substitute the values.
We are given that the mass is 1 gram ($1\,\text{gm} = 10^{-3}\,\text{kg}$) and $c = 3 \times 10^8$ m/s. Substituting these into the equation:

$$E = (1 \times 10^{-3}) \times (3 \times 10^8)^2$$

Convert the result into MeV using the conversion factor $1\,\text{kg} \cdot \text{m}^2/\text{s}^2 = 9 \times 10^{13}\,\text{MeV}$.

> **Quick Tip**
>
> Use the equation $E = mc^2$ to find energy equivalents for different masses. Be sure to convert units properly.

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5. A vehicle travels half of the distance with speed 3 m/s and other half of distance in two equal time intervals with speed 6 m/s and 9 m/s. The average speed of vehicle is:

Solution:

Step 1: Understand the concept of average speed.
Average speed is the total distance traveled divided by the total time taken. Let the total distance be D. The vehicle covers the first half of the distance $\frac{D}{2}$ at 3 m/s, and the second half in two equal time intervals at speeds of 6 m/s and 9 m/s.

Step 2: Calculate the time for each part.
The time for the first half of the journey is:

$$t_1 = \frac{D/2}{3} = \frac{D}{6}$$

For the second half, the distance is $\frac{D}{2}$, and the vehicle travels it in two equal time intervals. Let each time interval be t_2 for the first interval (at 6 m/s) and t_3 for the second interval (at 9 m/s).
The total time for the second half is:

$$t_2 = \frac{D/4}{6} = \frac{D}{24}, \quad t_3 = \frac{D/4}{9} = \frac{D}{36}$$

Thus, the total time for the journey is:

$$T = t_1 + t_2 + t_3 = \frac{D}{6} + \frac{D}{24} + \frac{D}{36}$$

Step 3: Find the total time and average speed.
Now, find the common denominator and sum the times:

$$T = \frac{D}{6} + \frac{D}{24} + \frac{D}{36} = \frac{12D}{72} + \frac{3D}{72} + \frac{2D}{72} = \frac{17D}{72}$$

The average speed is then:

$$\text{Average speed} = \frac{D}{T} = \frac{D}{\frac{17D}{72}} = \frac{72}{17} \approx 4.24\,\text{m/s}$$

Quick Tip

When calculating average speed, remember that it depends on the total time and total distance, not just the individual speeds.

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6. What will be the order of de-Broglie wavelength of α-particle, proton, electron if their kinetic energies are the same?

Solution:

Step 1: Formula for de-Broglie wavelength.
The de-Broglie wavelength λ is given by the formula:

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

where h is Planck's constant and p is the momentum of the particle.
Step 2: Relating kinetic energy and momentum.
The kinetic energy K of a particle is related to its momentum p by the equation:

$$K = \frac{p^2}{2m}$$

Thus, the momentum p can be expressed as:

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

Step 3: de-Broglie wavelength for each particle.
For each particle, the de-Broglie wavelength is:

$$\lambda = \frac{h}{\sqrt{2mK}}$$

Since the kinetic energy K is the same for all particles, the wavelength depends on the mass m of the particle.
Step 4: Compare the masses.
The mass of the α-particle is much greater than the mass of the proton, and the proton is much heavier than the electron. Therefore, the de-Broglie wavelength is inversely proportional to the square root of the mass:

$$\lambda_\alpha < \lambda_{\text{proton}} < \lambda_{\text{electron}}$$

Thus, the order of the de-Broglie wavelengths is:

$$\lambda_\alpha < \lambda_{\text{proton}} < \lambda_{\text{electron}}$$

> Quick Tip
>
> The de-Broglie wavelength is inversely proportional to the square root of the particle's mass. Heavier particles have smaller wavelengths.

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7. In an Atwood machine, two masses m_1 and m_2 are suspended and the magnitude of acceleration of the masses is $\frac{g}{8}$. Find the ratio of masses.

Solution:

Step 1: Write the equation for the acceleration.
In an Atwood machine, the acceleration a is given by the equation:

$$a = \frac{g(m_2 - m_1)}{m_1 + m_2}$$

where m_1 and m_2 are the masses, and g is the acceleration due to gravity.
Step 2: Use the given value of acceleration.
We are given that the acceleration is $\frac{g}{8}$, so we substitute this into the equation:

$$\frac{g}{8} = \frac{g(m_2 - m_1)}{m_1 + m_2}$$

Step 3: Solve for the ratio of masses.
Cancel g from both sides:

$$\frac{1}{8} = \frac{m_2 - m_1}{m_1 + m_2}$$

Now, cross-multiply and solve for the ratio $\frac{m_2}{m_1}$:

$$8(m_2 - m_1) = m_1 + m_2$$

$$8m_2 - 8m_1 = m_1 + m_2$$

$$7m_2 = 9m_1$$

Thus, the ratio of masses is:

$$\frac{m_2}{m_1} = \frac{9}{7}$$

Quick Tip

In an Atwood machine, the acceleration is dependent on the difference between the masses. Use this relationship to find the ratio of masses.

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8. Statement-1: Concave lens always forms erect and virtual images.
Statement-2: If an object is placed at one centre of curvature of concave lens, then image forms at the centre of curvature of the other side.

(1) Only statement -1 is correct.
(2) Only statement -2 is correct.
(3) Both of the statements are correct.
(4) None of the statements is correct.

Correct Answer: (3) Both of the statements are correct.

Solution:

Step 1: Analyze Statement-1.
A concave lens is a diverging lens. It always forms virtual and erect images, regardless of the object's position (when the object is placed in front of the lens). This is because the rays diverge, and the virtual image is formed on the same side as the object. Thus, Statement-1 is correct.
Step 2: Analyze Statement-2.
For Statement-2, if an object is placed at the center of curvature of a concave lens, the image will form at the center of curvature on the opposite side. This is a well-established rule in optics, as the image is formed at the same distance but on the opposite side of the lens. Therefore, Statement-2 is also correct.
Step 3: Conclusion.
Both Statement-1 and Statement-2 are correct. Therefore, the correct answer is option (3).

Quick Tip

Concave lenses always form virtual and erect images, and the position of the object relative to the lens determines where the image is formed.

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9. Find the ratio of initial to final pressure for a gas compressed adiabatically from 5 litres to 4 litres. (Given $\gamma = \frac{3}{2}$)

Solution:

Step 1: Use the adiabatic equation.
For an adiabatic process, the relationship between pressure and volume is given by:

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

where P_1 and P_2 are the initial and final pressures, V_1 and V_2 are the initial and final volumes, and γ is the adiabatic index.
Step 2: Substitute the given values.
Given that $V_1 = 5\,\text{litres}$, $V_2 = 4\,\text{litres}$, and $\gamma = \frac{3}{2}$, we can find the ratio $\frac{P_1}{P_2}$ by rearranging the equation:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^\gamma$$

Substitute the values:

$$\frac{P_1}{P_2} = \left(\frac{4}{5}\right)^{\frac{3}{2}}$$

Now, calculate the value.

Quick Tip

In adiabatic processes, the pressure and volume are related by $PV^\gamma = \text{constant}$. Use this relationship to find the pressure ratio.

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10. If particle A is on the Earth's surface and another particle B is revolving around the Earth $R/20$ above Earth's surface, then the difference in mechanical energies of A and B will be: (Radius of Earth is $R = 6570\,\text{km}$)

Solution:

Step 1: Use the formula for gravitational potential energy.
The mechanical energy of a particle is the sum of its potential energy U and kinetic energy K.

For two particles, A and B, with the same kinetic energy, the difference in their mechanical energies is due to the difference in their gravitational potential energy.
The gravitational potential energy of a particle at a distance r from the center of the Earth is:

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

where G is the gravitational constant, M is the mass of the Earth, and r is the distance from the center of the Earth.
Step 2: Calculate the potential energies of A and B.
For particle A at the Earth's surface, the distance is $r_A = R$. For particle B at $R/20$ above the Earth's surface, the distance is $r_B = R + R/20 = 21R/20$.
The difference in potential energy is:

$$\Delta U = U_A - U_B = -\frac{GMm}{R} + \frac{GMm}{\frac{21R}{20}}$$

Simplify and calculate the value.

Quick Tip

The potential energy difference is a key factor in determining the mechanical energy difference between two particles at different distances from the Earth's center.

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11. If a particle performing SHM has $x = 4\,\text{m}$, $v = 2\,\text{m/s}$, and $a = 16\,\text{m/s}^2$, then what will be its amplitude?

Solution:

Step 1: Use the SHM equations.
For simple harmonic motion (SHM), the displacement, velocity, and acceleration are related to the amplitude A as follows:

$$x = A\cos(\omega t)$$
$$v = -A\omega\sin(\omega t)$$
$$a = -A\omega^2\cos(\omega t)$$

Step 2: Relate acceleration and displacement.
From the equation for acceleration, we can write:

$$a = -\omega^2 x$$

Substitute the given values for $a = 16\,\text{m/s}^2$ and $x = 4\,\text{m}$:

$$16 = \omega^2 \times 4$$

$$\omega^2 = 4$$

Thus, $\omega = 2\,\text{rad/s}$.

Step 3: Use the velocity equation.

The velocity equation gives us:

$$v = A\omega\sin(\omega t)$$

Substitute the values $v = 2\,\text{m/s}$ and $\omega = 2\,\text{rad/s}$:

$$2 = A \times 2 \times \sin(\omega t)$$

Since the maximum value of $\sin(\omega t)$ is 1, we get:

$$A = 1\,\text{m}$$

> **Quick Tip**
>
> In SHM, the amplitude can be found by using the relationship between acceleration and displacement, or velocity and displacement.

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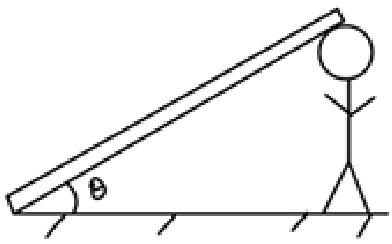
12. If a rod of weight W is resting on the head of a man at an angle θ as shown in the figure, find the load on the man's head.



Solution:

Step 1: Understand the force distribution.

The rod is resting at an angle θ, and its weight W is acting vertically downward. The man's head bears the reaction force. The load on the man's head is the vertical component of the rod's weight.

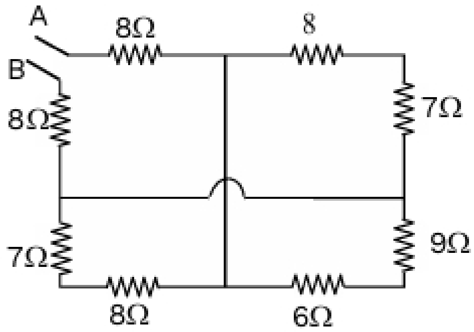
Step 2: Resolve the forces.

The force on the man's head is given by the vertical component of the rod's weight:

$$F = W\cos(\theta)$$

> **Quick Tip**
>
> When an object is resting at an angle, the load on a support is given by the vertical component of the weight force.

13. Find $R_{\text{equivalent}}$.



Solution:

Step 1: Analyze the circuit.
In this circuit, resistors are connected in both series and parallel combinations. To find the equivalent resistance, we need to combine these resistors step by step.
Step 2: Combine resistors in series.
Resistors $8\,\Omega$ and $8\,\Omega$ are in series, so their equivalent resistance is:

$$R_1 = 8\,\Omega + 8\,\Omega = 16\,\Omega$$

Step 3: Combine resistors in parallel.
Next, $16\,\Omega$ (from the previous combination) is in parallel with $7\,\Omega$. The formula for resistors in parallel is:

$$\frac{1}{R_2} = \frac{1}{16} + \frac{1}{7}$$

Now calculate the result for R_2.
Step 4: Continue combining resistors.
The next step involves combining the equivalent resistance from the previous step with other resistors in series or parallel until we find the final equivalent resistance.

> **Quick Tip**
>
> Always combine series resistors first and then simplify parallel combinations for easier calculations.

14. Find the wavelength of light emitted by the bulb which uses the LED having the band gap of 1.42 eV.

Solution:

Step 1: Use the relation between energy and wavelength.
The energy E of the photon emitted by the LED is related to the wavelength λ by the equation:

$$E = \frac{hc}{\lambda}$$

where: - h is Planck's constant ($6.626 \times 10^{-34}\,\text{J} \cdot \text{s}$), - c is the speed of light ($3 \times 10^8\,\text{m/s}$), - λ is the wavelength of the light.
Step 2: Convert the given band gap to joules.
The band gap is given in electron volts (eV), and we need to convert it to joules. The conversion factor is:

$$1\,\text{eV} = 1.602 \times 10^{-19}\,\text{J}$$

Thus, the energy in joules is:

$$E = 1.42\,\text{eV} \times 1.602 \times 10^{-19}\,\text{J/eV}$$

Step 3: Calculate the wavelength.
Substitute the value of energy into the equation and solve for λ:

$$\lambda = \frac{hc}{E}$$

Now calculate the wavelength.

Quick Tip

To find the wavelength of emitted light, use the energy-wavelength relationship and make sure to convert units properly.

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15. If the velocity of a particle of mass m is given by $v = \alpha\sqrt{x}$, find the work done by the particle to go from $x = 0$ to $x = d$.

Solution:

Step 1: Work done by a particle.
The work done by a force on a particle is given by:

$$W = \int_{x_1}^{x_2} F\,dx$$

where F is the force, and x_1 and x_2 are the initial and final positions of the particle.
Step 2: Use the relationship between velocity and force.
From the given velocity equation $v = \alpha\sqrt{x}$, we can find the acceleration a by differentiating the velocity with respect to time:

$$a = \frac{dv}{dt}$$

Using the chain rule, $a = \frac{dv}{dx} \cdot \frac{dx}{dt} = \frac{dv}{dx} \cdot v$. Then, substitute this into the equation for work.

Step 3: Calculate the work.
The force is related to the acceleration by $F = ma$, where m is the mass of the particle. Substitute the expression for acceleration into this formula and integrate to find the work done.

> **Quick Tip**
>
> When velocity is given as a function of position, use the relation between force and acceleration to calculate work by integrating over the path.

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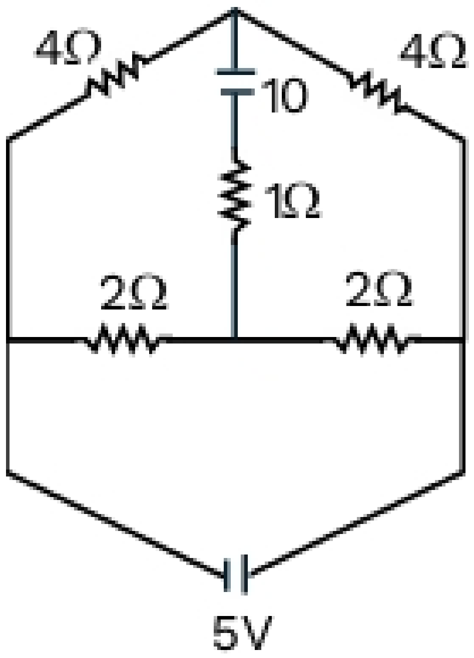
16. Find the current passing through 1 Ω resistance.



Solution:

Step 1: Analyze the circuit.
In this circuit, resistors are arranged in both series and parallel combinations. To find the current through the $1\,\Omega$ resistor, we need to first find the equivalent resistance of the entire circuit.
Step 2: Combine resistances.
Start by combining resistors in series and parallel to find the total equivalent resistance of the circuit.
Step 3: Use Ohm's law.
Once the total resistance R_{total} is found, apply Ohm's law:

$$I = \frac{V}{R_{\text{total}}}$$

where $V = 5\,\text{V}$ is the voltage source and R_{total} is the total equivalent resistance.

Step 4: Calculate the current.
Now, calculate the total resistance and find the current passing through the $1\,\Omega$ resistor using the formula above.

> **Quick Tip**
>
> To solve for current in complex circuits, always reduce the circuit step-by-step, combining resistors in series and parallel.

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17. An inductor when connected to a 20V DC battery gives a current of 5A and when connected to a (20V, 50Hz) AC supply the current through the inductor is 4A. Find the inductance of the loop.

Solution:

Step 1: Use the formula for current in an RL circuit.
For an RL circuit, the current I is given by the formula:

$$I = \frac{V}{\sqrt{R^2 + (\omega L)^2}}$$

where: - V is the voltage, - R is the resistance, - L is the inductance, - $\omega = 2\pi f$ is the angular frequency of the AC supply.
Step 2: Analyze the DC case.
For DC, the current is steady, and the inductance doesn't oppose the current, so we have:

$$I_{\text{DC}} = \frac{V_{\text{DC}}}{R}$$

Given $I_{\text{DC}} = 5\,\text{A}$ and $V_{\text{DC}} = 20\,\text{V}$, solve for R.
Step 3: Analyze the AC case.
For AC, we can use the formula:

$$I_{\text{AC}} = \frac{V_{\text{AC}}}{\sqrt{R^2 + (\omega L)^2}}$$

Given $I_{\text{AC}} = 4\,\text{A}$, $V_{\text{AC}} = 20\,\text{V}$, and $f = 50\,\text{Hz}$, substitute these values and solve for L.

> **Quick Tip**
>
> In an RL circuit, for DC, the inductance has no effect on the current, while for AC, the inductance determines the reactance that opposes the current.

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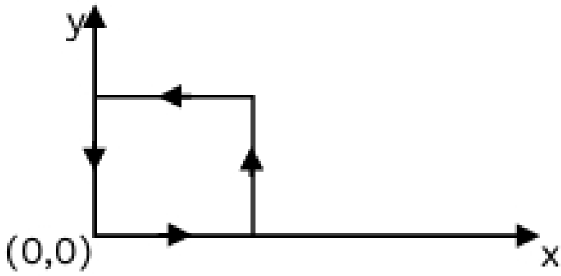
18. A square loop of side 2 m carrying current i is placed in a magnetic field $\vec{B} = (1 + 4x)\hat{k}$. Find the net force acting on the loop.



Solution:

Step 1: Use the formula for the force on a current-carrying wire in a magnetic field.
The force on a current-carrying wire in a magnetic field is given by:

$$\vec{F} = I \int (\vec{L} \times \vec{B})\, dl$$

where $\vec{L}$ is the length element of the wire and $\vec{B}$ is the magnetic field.
Step 2: Set up the integral.
For each side of the square loop, express the magnetic field $B = (1 + 4x)\hat{k}$ and integrate the force over the length of each side. Since the magnetic field depends on x, the force will vary along the length of the wire.
Step 3: Calculate the net force.
After calculating the force on each side of the loop, sum up the forces to find the net force. Since the field varies linearly, some symmetry in the problem might simplify the calculations.

Quick Tip

For non-uniform magnetic fields, break the calculation into smaller integrals for each segment of the wire.

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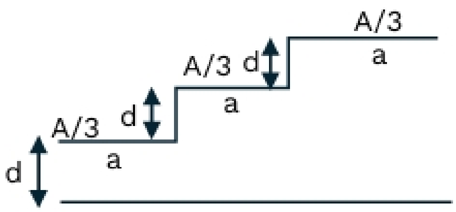
19. A capacitor is made of a flat plate of area A and a second plate having a stair-like structure as shown in the figure. The width of each stair is a and the height is d. Find the capacitance of the assembly.



Solution:

Step 1: Understand the configuration of the capacitor.
The capacitor consists of two plates: one flat and the other with a stair-like structure. The capacitance depends on the surface area of the plates and the separation between them.
Step 2: Calculate the effective area.
The effective area A_{eff} of the stair-like plate can be approximated by summing the area of each stair. Since the width of each stair is a and the height is d, the area of each stair is $a \cdot d$. The total area is the sum of all the stairs.
Step 3: Use the formula for capacitance.
The capacitance C is given by the formula:

$$C = \epsilon_0 \frac{A_{\text{eff}}}{d}$$

where ϵ_0 is the permittivity of free space, and A_{eff} is the effective area.
Step 4: Final Calculation.
Substitute the expression for A_{eff} into the formula for capacitance and calculate the result.

Quick Tip

For capacitors with irregularly shaped plates, break the plate into smaller sections and calculate the effective area.

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20. In a Young's double slit experiment, the slits are 1 mm apart and are illuminated by a light of $\lambda = 600\,\text{nm}$. What should be the minimum distance from central maximum where intensity of light is $\frac{1}{4}$ of maximum intensity on a screen placed 1 m distance from the plane of slits?

Solution:

Step 1: Understand the intensity distribution.
In Young's double slit experiment, the intensity I at a point on the screen is given by:

$$I = I_0 \cos^2\left(\frac{\pi d y}{\lambda L}\right)$$

where: - I_0 is the maximum intensity, - d is the slit separation, - y is the distance from the central maximum, - L is the distance from the slits to the screen, - λ is the wavelength of light.
Step 2: Set up the equation for intensity.
The intensity is given as $\frac{1}{4}$ of the maximum intensity, so we have:

$$\frac{I}{I_0} = \frac{1}{4}$$

Thus:

$$\cos^2\left(\frac{\pi d y}{\lambda L}\right) = \frac{1}{4}$$

Taking the square root:

$$\cos\left(\frac{\pi dy}{\lambda L}\right) = \frac{1}{2}$$

The solution to this is:

$$\frac{\pi dy}{\lambda L} = \frac{\pi}{3}$$

Step 3: Solve for y.
Substitute the given values $d = 1\,\text{mm} = 10^{-3}\,\text{m}$, $\lambda = 600\,\text{nm} = 600 \times 10^{-9}\,\text{m}$, and $L = 1\,\text{m}$ into the equation and solve for y.

> **Quick Tip**
>
> In Young's experiment, the positions of minima and maxima can be calculated using the condition for destructive and constructive interference, respectively.

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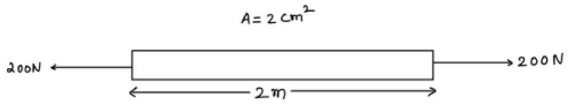
21. If the Young's modulus of the rod (shown in the figure) is $Y = 10^{11}\,\text{N/m}^2$, then find elongation in the rod (ΔL).



Solution:

Step 1: Understand the formula for elongation.
The elongation ΔL of a rod under a force F is given by the formula:

$$\Delta L = \frac{FL}{AY}$$

where: - F is the force applied, - L is the length of the rod, - A is the cross-sectional area of the rod, - Y is the Young's modulus.
Step 2: Substitute the given values.
Given that: - $F = 200\,\text{N}$, - $L = 2\,\text{m}$, - $A = 2\,\text{cm}^2 = 2 \times 10^{-4}\,\text{m}^2$, - $Y = 10^{11}\,\text{N/m}^2$,
Substitute these values into the elongation formula:

$$\Delta L = \frac{200 \times 2}{2 \times 10^{-4} \times 10^{11}}$$

Now calculate the value of ΔL.

> **Quick Tip**
>
> To find the elongation in a rod, ensure that all units are in SI units (meters, newtons, etc.) for consistency in the formula.

22. EM wave traveling in x-direction with $E = 60\,\text{V/m}$. Find magnetic field B.

Solution:

Step 1: Understand the relationship between electric field and magnetic field.
In an electromagnetic wave, the electric and magnetic fields are related by:

$$B = \frac{E}{c}$$

where c is the speed of light in a vacuum ($c = 3 \times 10^8\,\text{m/s}$).
Step 2: Substitute the given values.
Given $E = 60\,\text{V/m}$, substitute this into the equation:

$$B = \frac{60}{3 \times 10^8}$$

Step 3: Calculate B.
Now, calculate the value of B.

> **Quick Tip**
>
> For electromagnetic waves, the electric and magnetic fields are perpendicular to each other and related by $B = \frac{E}{c}$.

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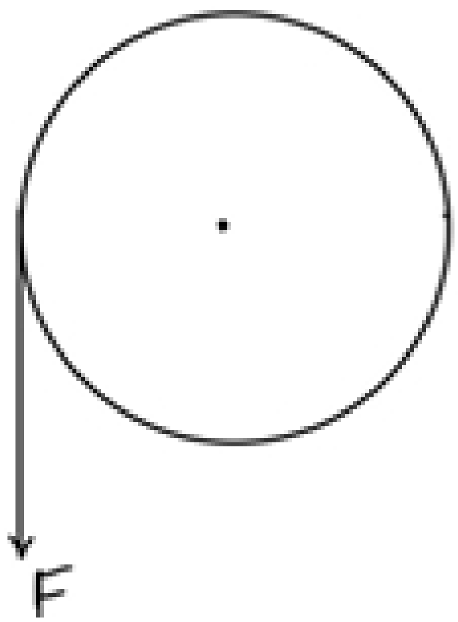
23. A body of moment of inertia $I = 0.4\,\text{kg} \cdot \text{m}^2$ and radius $r = 10\,\text{cm}$ is given as shown in the figure. If a force of $F = 40\,\text{N}$ is applied on the periphery of the body for 10 seconds, then angular velocity attained will be?



Solution:

Step 1: Understand the relationship between torque and angular acceleration.
Torque τ is related to angular acceleration α by:

$$\tau = I\alpha$$

where I is the moment of inertia and α is the angular acceleration.
Step 2: Relate torque to force.
Torque is also given by the force applied at a distance from the center:

$$\tau = F \times r$$

where r is the radius of the body.
Step 3: Calculate the angular acceleration.
Equating the two expressions for torque:

$$F \times r = I\alpha$$

Solving for α:

$$\alpha = \frac{F \times r}{I}$$

Step 4: Calculate the angular velocity.
The angular velocity ω after time t is given by:

$$\omega = \alpha \times t$$

Substitute the calculated value of α and the given time $t = 10\,\mathrm{s}$.

> Quick Tip
>
> The angular velocity of a body can be found by first calculating the angular acceleration using torque and moment of inertia, then multiplying by time.

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24. A half ring of $R = 10\,\mathrm{cm}$ and linear density is 4 nC/m. Find the potential at the center of the ring.

Solution:

Step 1: Formula for potential due to a charge distribution.
The electric potential V at the center of a uniformly charged ring is given by:

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

where: - $k = 9 \times 10^9\,\mathrm{N\,m^2/C^2}$ is Coulomb's constant, - Q is the total charge on the half-ring, - R is the radius of the ring.

Step 2: Calculate the total charge on the half-ring.
The total charge Q on the half-ring is:

$$Q = \lambda \times L$$

where $\lambda = 4\,\text{nC/m} = 4 \times 10^{-9}\,\text{C/m}$ is the linear charge density, and L is the length of the half-ring, which is $L = \pi R$.
Step 3: Calculate the potential.
Substitute the values into the formula for potential:

$$V = \frac{k\lambda\pi R}{R}$$

Simplify and calculate the result.

Quick Tip

For a ring with uniform charge distribution, the potential at the center is directly proportional to the total charge and inversely proportional to the radius.
