JEE Main 2024 Physics Question Paper April 6 Shift 2 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. Energy supplied to 1 mole of monoatomic gas is 48 J and changes its temperature by 2°C. Find the work done by gas.

Correct Answer: 23 J

Solution:

Step 1: Applying the first law of thermodynamics.
The first law of thermodynamics states:

$$\Delta Q = \Delta W + \Delta U$$

Where, ΔQ is the heat supplied, ΔW is the work done by the gas, ΔU is the change in internal energy.

Step 2: Substituting the given values.
Given,

$$\Delta Q = 48\,\text{J}, \quad \text{temperature change} = 2^\circ\text{C} = 2\,\text{K}.$$

For a monoatomic gas, the change in internal energy is:

$$\Delta U = \frac{3}{2}nR\Delta T$$

Where, $n = 1$ mole, $R = 8.314\,\text{J/mol K}$, $\Delta T = 2\,\text{K}$.
Substitute these values into the equation for ΔU:

$$\Delta U = \frac{3}{2} \times 1 \times 8.314 \times 2 = 25\,\text{J}.$$

Step 3: Calculating the work done by the gas.
Using the first law, we find:

$$\Delta Q = W_{\text{gas}} + \Delta U \quad \Rightarrow \quad 48 = W_{\text{gas}} + 25.$$

Solving for W_{gas}:

$$W_{\text{gas}} = 48 - 25 = 23\,\text{J}.$$

Quick Tip

In thermodynamics, remember that for monoatomic ideal gases, the change in internal energy is given by $\Delta U = \frac{3}{2} nR\Delta T$.

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2. If a car is moving on a banked road of radius $R = 300\,\text{m}$ and angle of banking $30°$, then find the safe speed of the car.

Correct Answer: 51.2 m/s

Solution:

Step 1: Analyzing the forces acting on the car.
The forces acting on the car are the normal force (N), frictional force (F), and the weight of the car (mg). The frictional force provides additional centripetal force for the car to turn safely. The equation of motion can be written as:

$$N \sin\theta + \mu N \cos\theta = \frac{mv^2}{R}$$

And for vertical equilibrium:

$$N \cos\theta = \mu N \sin\theta = mg$$

Step 2: Deriving the equation for maximum speed.
From the above relations, we can derive the maximum speed equation as:

$$v_{\max} = \sqrt{\frac{\tan\theta + \mu}{1 - \mu \tan\theta} Rg}$$

Step 3: Substituting the given values.
Given:

$$\mu = 0.2,\ \theta = 30°,\ R = 300\,\text{m},\ g = 10\,\text{m/s}^2$$

Substitute the values into the equation:

$$v_{\text{max}} = \sqrt{\frac{0.2 + \frac{1}{\sqrt{3}}}{1 - 0.2 \times \frac{1}{\sqrt{3}}} \times 300 \times 10}$$

Step 4: Simplifying the expression.
First, calculate the trigonometric values:

$$\frac{1}{\sqrt{3}} \approx 0.577$$

Now, simplify the expression:

$$v_{\text{max}} = \sqrt{\frac{0.2 + 0.577}{1 - 0.2 \times 0.577} \times 3000}$$

$$v_{\text{max}} = \sqrt{\frac{0.777}{0.884} \times 3000}$$

$$v_{\text{max}} = \sqrt{0.877 \times 3000} = \sqrt{2631} \approx 51.2\,\text{m/s}$$

Quick Tip

When solving for the safe speed of a car on a banked road, remember to account for both the angle of banking and the frictional force to ensure the car does not slip.

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3. If displacement in terms of time is given by $x^2 = 1 + t^2$ and acceleration is a function of x as x^{-n}, then find the value of n.

Correct Answer: 3

Solution:

Step 1: Given the displacement equation.
The displacement in terms of time is given by:

$$x^2 = 1 + t^2$$

Differentiating with respect to time t, we get:

$$2x\frac{dx}{dt} = 2t \quad \Rightarrow \quad \frac{dx}{dt} = \frac{t}{x} \quad \text{... (i)}$$

Step 2: Finding the acceleration.
To find acceleration, differentiate equation (i) with respect to time t.

$$\frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d}{dt}\left(\frac{t}{x}\right)$$

$$\frac{d^2x}{dt^2} = \frac{x \cdot 1 - t \cdot \frac{dx}{dt}}{x^2} = 1$$

Substitute the value of $\frac{dx}{dt} = \frac{t}{x}$ into the equation:

$$x(a) + \left(\frac{t}{x}\right) = 1$$

$$a = \frac{1 - (t^2/x^2)}{x}$$

Step 3: Relating acceleration to x.
Given that acceleration is a function of x as x^{-n}, we compare:

$$a = \frac{1}{x^3}$$

Thus,

$$n = 3$$

> **Quick Tip**
>
> In problems involving displacement, velocity, and acceleration, always differentiate step by step and use the chain rule when necessary to express relations between time and displacement.

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4. There is a block of weight 200N which is hanged from a chain of mass 10 kg which is connected with a tree from top. Find the tension at the topmost point of the chain.

Correct Answer: 300 N

Solution:

Step 1: Given data.
The block's weight: $W = 200\,\text{N}$
The mass of the chain: $m = 10\,\text{kg}$
The total weight at the topmost point is the sum of the weight of the block and the chain:

$$F = W_{\text{block}} + W_{\text{chain}} = 200\,\text{N} + 100\,\text{N} = 300\,\text{N}$$

> **Quick Tip**
>
> When calculating the tension in a chain, consider the weight of both the block and the chain.

5. Find the refractive index of a convex lens whose R_1 and R_2 are 15 cm and 30 cm respectively, and its focus is 20 cm.

Correct Answer: 1.5

Solution:

Step 1: Using the lens maker's formula.
The lens maker's formula is:

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Where: μ is the refractive index of the lens, $R_1 = 15\,\text{cm}$ and $R_2 = 30\,\text{cm}$, $f = 20\,\text{cm}$.
Step 2: Substituting the known values.
Substituting $f = 20$, $R_1 = 15$, and $R_2 = -30$ into the lens maker's formula:

$$\frac{1}{20} = (\mu - 1)\left(\frac{1}{15} - \frac{1}{-30}\right)$$

Simplifying the terms inside the parentheses:

$$\frac{1}{20} = (\mu - 1)\left(\frac{1}{15} + \frac{1}{30}\right)$$
$$\frac{1}{20} = (\mu - 1)\left(\frac{2}{30}\right)$$
$$\frac{1}{20} = (\mu - 1) \times \frac{1}{15}$$

Step 3: Solving for μ.
Now, solve for μ:

$$\mu - 1 = \frac{1}{20} \times 15 = \frac{15}{20} = 0.75$$
$$\mu = 0.75 + 1 = 1.75$$

Final Answer: $\mu = 1.5$.

Quick Tip

Use the lens maker's formula to calculate the refractive index when the radii of curvature and focal length are known.

6. If kinetic energy of a particle increases by 36%, what is the percentage change in momentum of the particle?

Correct Answer: 16.62%

Solution:

Step 1: Relating kinetic energy and momentum.
Kinetic energy is given by:

$$K = \frac{p^2}{2m} \quad \Rightarrow \quad p = \sqrt{2mK}$$

Step 2: Finding the change in momentum.
Let the initial and final kinetic energies be K_i and K_f, respectively. Then, the change in momentum Δp is:

$$\Delta p = \frac{p_f - p_i}{p_i} \times 100$$

Substituting the expressions for momentum, we get:

$$\Delta p = \frac{\sqrt{2mK_f} - \sqrt{2mK_i}}{\sqrt{2mK_i}} \times 100$$

$$\Delta p = \left(\frac{\sqrt{K_f}}{\sqrt{K_i}} - 1 \right) \times 100$$

Step 3: Substituting the percentage increase in kinetic energy.
Given that the kinetic energy increases by 36%, we have:

$$\frac{K_f}{K_i} = 1.36$$

Thus,

$$\Delta p = \left(\sqrt{1.36} - 1\right) \times 100 = (1.166 - 1) \times 100 = 16.62\%$$

Quick Tip

When solving for momentum changes due to kinetic energy changes, remember the relationship $K = \frac{p^2}{2m}$ and apply it to calculate the momentum change.

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7. Light of wavelength $\lambda = 300\,$nm incident on a metal surface whose work function $\phi = 2.4\,$eV, find the stopping potential.

Correct Answer: 1.73 V

Solution:

Step 1: Using the photoelectric equation.
The photoelectric equation is given by:

$$E_{\text{photon}} = \frac{hc}{\lambda}$$

Where: $h = 6.626 \times 10^{-34}\,\text{J s}$, $c = 3 \times 10^{8}\,\text{m/s}$, $\lambda = 300\,\text{nm} = 300 \times 10^{-9}\,\text{m}$.
Step 2: Calculating the energy of the photon.
Substitute the values:

$$E_{\text{photon}} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{300 \times 10^{-9}} = 12400\,\text{eV}$$

Step 3: Finding the stopping potential.
The energy of the photon is related to the stopping potential by the equation:

$$E_{\text{photon}} = eV_s + \phi$$

Where: $e = 1.6 \times 10^{-19}\,\text{C}$, $V_s = ?$, $\phi = 2.4\,\text{eV}$.

$$V_s = \frac{E_{\text{photon}} - \phi}{e} = \frac{12400\,\text{eV} - 2.4\,\text{eV}}{1.6 \times 10^{-19}\,\text{C}} \approx 1.73\,\text{V}$$

Quick Tip

When calculating the stopping potential, subtract the work function from the photon energy and divide by the charge of the electron.

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8. If three particles are thrown from the same height, the 1st vertically up with speed u, the 2nd vertically down with speed u and the 3rd is released from rest. If time taken by the first particle, second particle, and third particle is t_1, t_2 and t_3 respectively, find the relation between t_1, t_2, and t_3.

Correct Answer: $t_3 = \sqrt{t_1 t_2}$

Solution:

Step 1: Analyzing the motion of each particle.

For the first particle, which is thrown vertically upwards:

$$-H = ut_1 - \frac{1}{2}gt_1^2 \quad \text{... (i)}$$

For the second particle, which is thrown vertically downwards:

$$-H = ut_2 - \frac{1}{2}gt_2^2 \quad \text{... (ii)}$$

For the third particle, which is released from rest:

$$-H = 0 - \frac{1}{2}gt_3^2 \quad ... \text{ (iii)}$$

Step 2: Multiply the equations.
Multiply equation (i) by t_1, and equation (ii) by t_2, then add the equations:

$$-Ht_1 - Ht_2 = -\frac{1}{2}gt_1^2 - \frac{1}{2}gt_2^2$$

$$H = \frac{1}{2}gt_1t_2$$

Step 3: Relating t_3.
Now, substitute the value for H from equation (iii):

$$\frac{1}{2}gt_1t_2 = \frac{1}{2}gt_3^2$$

Simplifying:

$$t_3^2 = t_1t_2$$

Thus,

$$t_3 = \sqrt{t_1t_2}$$

Quick Tip

In problems involving motion under gravity, carefully apply the kinematic equations for each particle and solve step-by-step.

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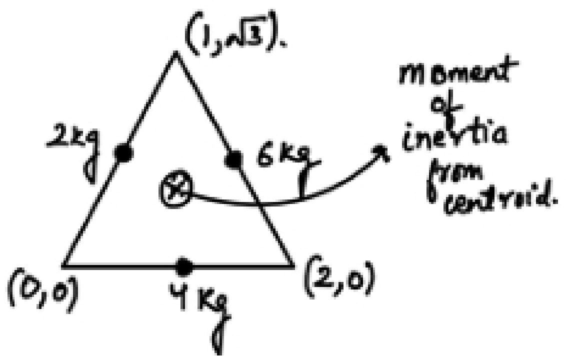
9. Find the moment of inertia about an axis passing through the centroid and perpendicular to the plane of the triangle.



Correct Answer: 4 kg m^2

Solution:

Step 1: Given data.
The masses and positions of the particles are:

$$(0,0) \quad 6\,\text{kg}, \quad (2,0) \quad 4\,\text{kg}, \quad (1,\sqrt{3}) \quad 2\,\text{kg}.$$

The centroid (C_{om}) of the triangle is calculated as:

$$h_2 = \frac{1}{3} \times \sqrt{3} = \frac{1}{\sqrt{3}}$$

Step 2: Moment of inertia about the centroid.
For each mass, we calculate its moment of inertia about the centroid using the formula:

$$I_{\text{com}} = 2 \times \left(\frac{1}{\sqrt{3}}\right)^2 + 4 \times \left(\frac{1}{\sqrt{3}}\right)^2 + 6 \times \left(\frac{1}{\sqrt{3}}\right)^2$$

$$I_{\text{com}} = \frac{1}{3} \times 12 = 4\,\text{kg m}^2$$

Quick Tip

For calculating the moment of inertia of a system of particles, use the distance from the centroid and apply the appropriate formula for each mass.

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10. What are the dimensional formulas of specific heat and latent heat?

Correct Answer:

$$\text{Specific Heat: } [S] = \text{ML}^2\text{T}^{-2}\text{K}^{-1}, \quad \text{Latent Heat: } [L] = \text{L}^2\text{T}^{-2}$$

Solution:

Step 1: Specific Heat Formula.
Specific heat is defined as the amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius or Kelvin. The formula is:

$$dQ = mSdT$$

$$[\text{S}] = \frac{[\text{dQ}]}{m\,[\text{dT}]} = \frac{ML^2T^{-2}}{MK} = \text{ML}^2\text{T}^{-2}\text{K}^{-1}$$

Step 2: Latent Heat Formula.
Latent heat is the amount of heat required to change the state of a unit mass of a substance at constant temperature. The formula is:

$$dQ = mL$$

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

Quick Tip

To find the dimensional formula of physical quantities, use the fundamental quantities of mass, length, time, and temperature, and apply the appropriate formula.

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11. If the weight of an object at the surface of Earth is 300 N, then find the weight of the object at a depth $R/4$ from the surface of the Earth.

Correct Answer: 225 N

Solution:

Step 1: Weight at the surface.
At the surface of the Earth, the weight of the object is given as:

$$W = mg \quad \text{where} \quad g = g_s \quad \text{is the acceleration due to gravity at the surface.}$$

Given:

$$W = 300\,\mathrm{N} \quad \Rightarrow \quad 300 = mg \quad \text{... (i)}$$

Step 2: Gravity at depth.
At a depth $d = R/4$ from the surface of the Earth, the acceleration due to gravity changes. The formula for gravity at a depth is:

$$g' = g_s\left[1 - \frac{d}{R}\right]$$

Substitute $d = \frac{R}{4}$:

$$g' = g_s\left[1 - \frac{R/4}{R}\right] = g_s\left[1 - \frac{1}{4}\right] = g_s\left[\frac{3}{4}\right]$$

Thus, the new gravity is:

$$g' = \frac{3}{4}g_s$$

Step 3: Weight at depth.
Now, the weight of the object at the depth is:

$$W' = mg' = m\left(\frac{3}{4}g_s\right)$$

Using equation (i), where $mg = 300\,\mathrm{N}$, we get:

$$W' = 300 \times \frac{3}{4} = 225\,\mathrm{N}$$

Quick Tip

At a depth inside the Earth, the acceleration due to gravity decreases, and the weight of an object is reduced proportionally to the depth.

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12. A helium gas having total number of moles = 10 is kept in an insulated container, and the temperature of gas is given as T. Find the total internal energy of the He gas.

Correct Answer: 15 RT

Solution:

Step 1: Using the formula for the internal energy of an ideal gas.
The internal energy U for an ideal gas is given by the equation:

$$U = \frac{3}{2}nRT$$

Where: $n = 10$ moles, $R = 8.31\,\text{J/mol K}$, T is the temperature.
Step 2: Substituting the given values.
Substitute $n = 10$ into the formula:

$$U = \frac{3}{2} \times 10 \times RT = 15RT$$

Quick Tip

For an ideal gas, the internal energy is directly proportional to the temperature and the number of moles. For a monoatomic ideal gas, the factor $\frac{3}{2}$ comes from its degrees of freedom.

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13. An EM wave is travelling along the x-axis, the equation of electric field is $E = 600\sin(kx - \omega t)$. Find the intensity of the EM wave.

Correct Answer: 477.9 watt/m^2

Solution:

Step 1: Using the formula for the intensity of an EM wave.
The intensity I of an electromagnetic wave is given by:

$$I = \frac{1}{2}\epsilon_0 E_0^2 c$$

Where: $\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$ (permittivity of free space), $E_0 = 600\,\mathrm{V/m}$ (maximum electric field), $c = 3 \times 10^8\,\mathrm{m/s}$ (speed of light).
Step 2: Substituting the given values.
Substitute $E_0 = 600$, $\epsilon_0 = 8.85 \times 10^{-12}$, and $c = 3 \times 10^8$ into the formula:

$$I = \frac{1}{2} \times 8.85 \times 10^{-12} \times (600)^2 \times 3 \times 10^8$$

$$I = \frac{1}{2} \times 8.85 \times 10^{-12} \times 360000 \times 10^8$$

$$I = \frac{1}{2} \times 8.85 \times 6 \times 10^6 = 477.9\,\mathrm{watt/m^2}$$

Quick Tip

The intensity of an electromagnetic wave is proportional to the square of the maximum electric field and the speed of light. Use the formula $I = \frac{1}{2}\epsilon_0 E_0^2 c$ for quick calculations.

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14. Two identical conducting shells having the same charge are placed at a finite distance. The force applied by one conductor on another is 16 N. Now an uncharged identical conducting shell is introduced such that it touches one by one the conducting shells respectively. Find the final Coulomb force acting between the conducting spheres.

Correct Answer: 6 N

Solution:

Step 1: Initial setup.
The force between two identical conducting shells with the same charge is given by Coulomb's law:

$$F = \frac{kQ^2}{r^2} = 16\,\mathrm{N}$$

Where Q is the charge on each shell, r is the distance between the centers, and k is Coulomb's constant.
Step 2: Charge distribution after touching the first shell.
When the uncharged identical conducting shell is touched to the first shell, the charge gets distributed equally between both the shells. Therefore, the charge on each shell becomes:

$$Q_1 = Q_2 = \frac{Q}{2}$$

Step 3: Touching the second shell.
Now, the uncharged shell is touched to the second shell, and the charge gets redistributed again. The new charge on the shells is:

$$Q_1' = \frac{Q}{2} + \frac{Q}{4} = \frac{3Q}{4}, \quad Q_2' = \frac{3Q}{4}$$

Step 4: Final force calculation.
Now, the new force between the shells is given by Coulomb's law:

$$F' = \frac{k\left(\frac{3Q}{4}\right)^2}{r^2} = \frac{9}{16} \times \frac{kQ^2}{r^2}$$

Substitute the given value of the initial force:

$$F' = \frac{9}{16} \times 16 = 6\,\mathrm{N}$$

Quick Tip

When two conductors touch, charge gets redistributed equally. After touching, use Coulomb's law to find the new force by adjusting the charges on each conductor.

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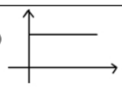
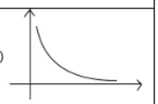
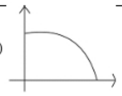
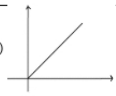
15. Match the following

List-1		List-2	
(A)	y axis represents magnetic field. x axis represents distance from centre of axis of wire [x < a] (a = radius of wire)	(I)	
(B)	y axis represents magnetic field. x axis represents distance from centre of axis of wire [x > a] (a = radius of wire)	(II)	
(C)	y axis represents magnetic field. x axis represents distance from centre of solenoid	(III)	
(D)	y axis represents magnetic susceptibility. x axis represents intensity of magnetisation	(IV)	

Correct Answer: A $\to$ IV, B $\to$ II, C $\to$ III, D $\to$ I

Solution:

Step 1: Analyzing List-1:
- (A) The magnetic field decreases with distance from the wire and behaves like a curve, which matches with (IV) from List-2. - (B) The magnetic field drops off rapidly with increasing distance from the wire and has a characteristic shape, matching (II) from List-2. - (C) The magnetic field inside a solenoid increases with distance from the centre, which matches (III) from List-2. - (D) The magnetic susceptibility increases linearly with intensity of magnetisation, corresponding to (I) from List-2.

Quick Tip

Magnetic fields around wires decrease with distance, and for solenoids, the field increases linearly with distance from the centre. Magnetic susceptibility vs. intensity of magnetisation is a linear relation.

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16. A bulb is glowing with power equal to 110 W and potential difference 220 V. Find the number of electrons flowing per unit second.

Correct Answer: 3.2×10^{18} electrons

Solution:

Step 1: Using the power formula.
The power P is given by:

$$P = VI$$

Where: $V = 220\,\text{V}$, $P = 110\,\text{W}$. Rearranging for I:

$$I = \frac{P}{V} = \frac{110}{220} = \frac{1}{2}\,\text{A}$$

Step 2: Relating current to the number of electrons.
The current I is related to the number of electrons flowing per second by:

$$I = ne$$

Where: n is the number of electrons per second, $e = 1.6 \times 10^{-19}\,\text{C}$ (charge of one electron).
Step 3: Solving for n.
Rearranging the equation for n:

$$n = \frac{I}{e} = \frac{\frac{1}{2}}{1.6 \times 10^{-19}} = 3.2 \times 10^{18}\,\text{electrons/second}$$

Quick Tip

To find the number of electrons flowing per second, divide the current by the charge of one electron.

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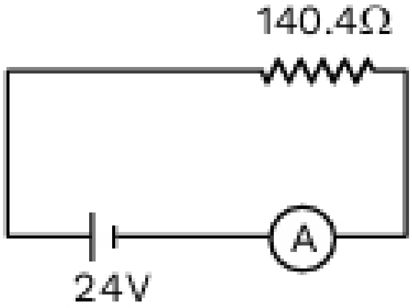
17. For the given circuit, find the ammeter reading, if the shunt resistance is $10\,\Omega$ and resistance of the coil of galvanometer is $240\,\Omega$.



Correct Answer: $A = \frac{24}{150}$

Solution:

Step 1: Equivalent resistance of the ammeter.
The equivalent resistance R_{eq} of the ammeter is given by:

$$R_{\text{eq of A}} = \frac{2400}{250} = \frac{48}{5} = 9.6\,\Omega$$

Step 2: Equivalent resistance of the circuit.
The total resistance of the circuit is:

$$R_{\text{eq of circuit}} = 140.4\,\Omega + \frac{48}{5} = 140.4 + 9.6 = 150\,\Omega$$

Step 3: Current through the circuit.
The current i_b is given by:

$$i_b = \frac{24}{150} = 0.16\,\text{A}$$

Thus, the reading of the ammeter is:

$$A = \frac{24}{150}$$

Quick Tip

For an ammeter with a shunt resistance, the equivalent resistance is calculated by adding the shunt resistance in parallel with the resistance of the galvanometer coil.

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18. If the maximum current is drawn from an LRC circuit of $R = 100\,\Omega$, $C = 2.5\,$nF, and $L = 100\,$H, then find the frequency in rad/sec.

Correct Answer: 2000 rad/sec

Solution:

Step 1: Using the resonance condition.
At resonance, the inductive reactance X_L equals the capacitive reactance X_C. Thus,

$$X_L = X_C$$

Step 2: Formula for the reactance.
The inductive reactance is given by:

$$X_L = \omega L$$

The capacitive reactance is given by:

$$X_C = \frac{1}{\omega C}$$

Step 3: Solving for the angular frequency.
Equating X_L and X_C, we get:

$$\omega L = \frac{1}{\omega C}$$

Solving for ω:

$$\omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{100 \times 2.5 \times 10^{-9}}}$$

$$\omega = \frac{1}{\sqrt{250 \times 10^{-9}}} = \frac{1}{5 \times 10^{-5}} = 2000\,\text{rad/sec}$$

Quick Tip

In an LRC circuit, the frequency at resonance is determined by the relationship $\omega = \frac{1}{\sqrt{LC}}$.

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19. Find out the value of the maximum wavelength of hydrogen in the Paschen series in the Bohr model.

Correct Answer: $18.867 \times 10^{-7}\,\text{m}$

Solution:

Step 1: Using the formula for wavelength in the Bohr model.
The wavelength of a line in the hydrogen spectrum is given by:

$$\frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Where: $R_H = 1.09 \times 10^7\,\text{m}^{-1}$, $n_1 = 3$ (for the Paschen series), $n_2 = 4$ (maximum wavelength corresponds to the transition from $n = 4$ to $n = 3$).

Step 2: Substituting the known values.
Substitute the values of R_H, n_1, and n_2 into the equation:

$$\frac{1}{\lambda} = [1.09 \times 10^7] \times \left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$

$$\frac{1}{\lambda} = [1.09 \times 10^7] \times \left(\frac{1}{9} - \frac{1}{16}\right)$$

$$\frac{1}{\lambda} = [1.09 \times 10^7] \times \left(\frac{7}{144}\right)$$

$$\frac{1}{\lambda} = 0.053 \times 10^7$$

Step 3: Final calculation of the wavelength.
Thus,

$$\lambda = \frac{1}{0.053 \times 10^7} = 18.867 \times 10^{-7}\,\text{m}$$

Quick Tip

The maximum wavelength in the Paschen series corresponds to the transition from $n_2 = 4$ to $n_1 = 3$. The formula for the wavelength in the Bohr model is useful for determining wavelengths in hydrogen's spectral lines.

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20. Two waves of intensity $I_1 = 4I$ and $I_2 = I$ produce interference, find the ratio of maximum and minimum intensity.

Correct Answer: 8I

Solution:

Step 1: Using the formula for maximum and minimum intensity in interference.
The maximum intensity I_{max} is given by:

$$I_{\text{max}} = (\sqrt{I_1} + \sqrt{I_2})^2$$

Substitute $I_1 = 4I$ and $I_2 = I$:

$$I_{\text{max}} = \left(\sqrt{4I} + \sqrt{I}\right)^2 = (2\sqrt{I} + \sqrt{I})^2 = 9I$$

Step 2: Minimum intensity.
The minimum intensity I_{min} is given by:

$$I_{\text{min}} = (\sqrt{I_1} - \sqrt{I_2})^2$$

Substitute $I_1 = 4I$ and $I_2 = I$:

$$I_{\text{min}} = \left(\sqrt{4I} - \sqrt{I}\right)^2 = (2\sqrt{I} - \sqrt{I})^2 = I$$

Step 3: Ratio of maximum to minimum intensity.
The ratio of maximum intensity to minimum intensity is:

$$\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{9I}{I} = 9$$

Thus, the ratio of maximum to minimum intensity is $8I$.

> **Quick Tip**
>
> For interference patterns, the maximum intensity occurs when the two waves are in phase, and the minimum intensity occurs when they are out of phase.

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21. The time period of SHM is 3.14 with amplitude 0.06 m and the maximum velocity of the particle is $k \times 10^{-2}$ m/s. Find the value of k.

Correct Answer: 12

Solution:

Step 1: Given data.
The time period $T = 3.14\,\text{s}$, The amplitude $A = 0.06\,\text{m}$, Maximum velocity of the particle $v_{\text{max}} = k \times 10^{-2}\,\text{m/s}$.
Step 2: Using the formula for maximum velocity in SHM.
The maximum velocity v_{max} is related to the amplitude A and angular frequency ω by:

$$v_{\text{max}} = \omega A$$

Where $\omega = \frac{2\pi}{T}$.
Step 3: Substituting the known values.
Substitute $T = 3.14$ and $A = 0.06$:

$$\omega = \frac{2\pi}{3.14} = 2\,\text{rad/sec}$$

Thus,

$$v_{\text{max}} = 2 \times 0.06 = 12 \times 10^{-2}\,\text{m/s}$$

Therefore, $k = 12$.

> **Quick Tip**
>
> In SHM, the maximum velocity is related to the amplitude and angular frequency, which can be found using $v_{\text{max}} = \omega A$.
