JEE Main 2025 April 4 Shift 2 Physics Question Paper with Solutions

Time Allowed : 3 Hours	Maximum Marks : 300	Total Questions : 75

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Multiple choice questions (MCQs)
2. Questions with numerical values as answers.
3. There are three sections: **Mathematics, Physics, Chemistry**.
4. **Mathematics:** 25 (20+5) 10 Questions with answers as a numerical value. Out of 10 questions, 5 questions are compulsory.
5. **Physics:** 25 (20+5) 10 Questions with answers as a numerical value. Out of 10 questions, 5 questions are compulsory..
6. **Chemistry:** 25 (20+5) 10 Questions with answers as a numerical value. Out of 10 questions, 5 questions are compulsory.
7. Total: 75 Questions (25 questions each).
8. 300 Marks (100 marks for each section).
9. **MCQs:** Four marks will be awarded for each correct answer and there will be a negative marking of one mark on each wrong answer.
10. **Questions with numerical value answers:** Candidates will be given four marks for each correct answer and there will be a negative marking of 1 mark for each wrong answer.

Physics

Section - A

26.
A radioactive material P first decays into Q and then Q decays to non-radioactive material R. Which of the following figure represents time dependent mass of P, Q and R?

Correct Answer: (2)

Solution:
Given that material P decays into Q, and then Q decays into R, we need to determine the time-dependent mass of P, Q, and R.

1. Decay of P to Q:
Let the initial mass of P be m_0. The mass of P at time t is given by the exponential decay equation:

$$m_P(t) = m_0 e^{-\lambda_1 t}$$

where λ_1 is the decay constant for P. This describes how P decreases over time.
2. Decay of Q to R:
The mass of Q at time t is determined by the difference between the mass of P that has decayed and the mass of Q that has decayed into R. The mass of Q at any given time is given by:

$$m_Q(t) = \frac{\lambda_1}{\lambda_2 - \lambda_1} m_0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

where λ_2 is the decay constant for Q. This equation represents how Q evolves as it decays from P to R.
3. Mass of R:
The mass of R at time t is the remaining mass, which can be expressed as the sum of the mass lost from P and Q:

$$m_R(t) = m_0 - m_P(t) - m_Q(t)$$

Substituting the expressions for $m_P(t)$ and $m_Q(t)$:

$$m_R(t) = m_0 \left(1 - e^{-\lambda_1 t} - \frac{\lambda_1}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)\right)$$

This shows how R increases as both P and Q decay.
The correct figure representing the time-dependent mass of P, Q, and R is (2), where:
- The mass of P decreases exponentially. - The mass of Q initially increases and then decreases as it decays into R. - The mass of R increases as Q decays.

Quick Tip

The decay of a radioactive material follows an exponential decay law, and the mass of the decay products can be determined using the decay constants for each material.

27.
There are 'n' number of identical electric bulbs, each is designed to draw a power p independently from the mains supply. They are now joined in series across the main supply. The total power drawn by the combination is:
(1) np
(2) $\frac{p}{n^2}$
(3) $\frac{p}{n}$
(4) p

Correct Answer: (3)

Solution:
To solve this, we need to consider how electric bulbs behave when connected in series across a mains supply.

1. Resistor Behavior in Series:
When n identical electric bulbs are connected in series, the total resistance R_{total} is the sum of the individual resistances:

$$R_{\text{total}} = R_1 + R_2 + \cdots + R_n$$

Each bulb has the same resistance, so we have:

$$R_{\text{total}} = nR$$

where R is the resistance of each bulb.
2. Total Power Consumption in Series:
The total power drawn by the combination of bulbs can be determined using the power formula:

$$P_{\text{total}} = \frac{V^2}{R_{\text{total}}}$$

where V is the voltage across the combination. Since the bulbs are identical, the total power drawn by the series combination of bulbs is:

$$P_{\text{total}} = \frac{V^2}{nR}$$

Since the power drawn by each individual bulb is $p = \frac{V^2}{R}$, we substitute this into the equation:

$$P_{\text{total}} = \frac{p}{n}$$

Thus, the total power drawn by the combination is $\frac{p}{n}$, and the correct answer is (3).

Quick Tip

In a series circuit, the total power drawn is inversely proportional to the number of identical bulbs connected in series.

28.
Consider a rectangular sheet of solid material of length $\ell = 9$ cm and width $d = 4$ cm. The coefficient of linear expansion is $\alpha = 3.1 \times 10^{-5}$ K^{-1} at room temperature and one atmospheric pressure. The mass of the sheet is $m = 0.1$ kg and the specific heat capacity $C_v = 900$ J kg^{-1}K^{-1}. If the amount of heat supplied to the material is 8.1×10^2 J, then the change in area of the rectangular sheet is:
(1) $2.0 \times 10^{-6}\,\text{m}^2$
(2) $3.0 \times 10^{-7}\,\text{m}^2$
(3) $6.0 \times 10^{-7}\,\text{m}^2$
(4) $4.0 \times 10^{-7}\,\text{m}^2$

Correct Answer: (1)

Solution:
We are given a rectangular sheet of solid material with specific properties, and we need to calculate the change in its area when heat is supplied.

1. Initial Area of the Sheet:
The initial area A of the sheet is the product of its length ℓ and width d:

$$A = \ell \times d = 9\,\text{cm} \times 4\,\text{cm} = 36\,\text{cm}^2 = 36 \times 10^{-4}\,\text{m}^2$$

2. Heat Supplied and Temperature Change:
The temperature change ΔT can be found using the heat equation:

$$Q = mC_v\Delta T$$

where: - $Q = 8.1 \times 10^2\,\text{J}$ is the heat supplied, - $m = 0.1\,\text{kg}$ is the mass of the sheet, - $C_v = 900\,\text{J/kg} \cdot \text{K}$ is the specific heat capacity.
Rearranging the equation to solve for ΔT:

$$\Delta T = \frac{Q}{mC_v} = \frac{8.1 \times 10^2}{0.1 \times 900} = 9\,\text{K}$$

3. Change in Area:
The change in area ΔA is related to the temperature change ΔT by the following formula:

$$\Delta A = A\alpha\Delta T$$

Substituting the values:

$$\Delta A = 36 \times 10^{-4} \times 3.1 \times 10^{-5} \times 9$$

$$\Delta A = 2.0 \times 10^{-6}\,\text{m}^2$$

Thus, the change in area is $2.0 \times 10^{-6}\,\text{m}^2$, and the correct answer is (1).

Quick Tip

The change in area of a material due to thermal expansion can be calculated using the formula $\Delta A = A\alpha\Delta T$, where A is the initial area, α is the coefficient of linear expansion, and ΔT is the temperature change.

29.
Given below are two statements:
Statement (I) : The dimensions of Planck's constant and angular momentum are same.
Statement (II) : In Bohr's model, electron revolves around the nucleus in those orbits for which angular momentum is an integral multiple of Planck's constant.
In the light of the above statements, choose the most appropriate answer from the options given below:
(1) Both Statement I and Statement II are correct
(2) Statement I is incorrect but Statement II is correct
(3) Statement I is correct but Statement II is incorrect
(4) Both Statement I and Statement II are incorrect

Correct Answer: (3)

Solution:

1. Statement I: The dimensions of Planck's constant and angular momentum are the same.
Planck's constant h has the dimension of $[ML^2T^{-1}]$, where: - M is mass, - L is length, - T is time.
Angular momentum L also has the dimension of $[ML^2T^{-1}]$, since it is given by the product of mass, length, and velocity.
Hence, Statement I is correct.
2. Statement II: In Bohr's model, electron revolves around the nucleus in those orbits for which angular momentum is an integral multiple of Planck's constant.
According to Bohr's model, the angular momentum L of an electron is quantized and is an integral multiple of Planck's constant h, i.e.

$$L = \frac{nh}{2\pi}$$

where n is a positive integer.
Hence, Statement II is also correct.
Since both statements are correct, the correct answer is (3).

Quick Tip

Planck's constant h and angular momentum L have the same dimensional formula. Also, in Bohr's model, angular momentum is quantized in integer multiples of $h/2\pi$.

30.
A cylindrical rod of length 1 m and radius 4 cm is mounted vertically. It is subjected to a shear force of 10^5 N at the top. Considering infinitesimally small displacement in the upper edge, the angular displacement θ of the rod axis from its original position would be: (shear moduli $G = 10^{10}$ N/m^2)
(1) $\frac{1}{160\pi}$
(2) $\frac{1}{4\pi}$
(3) $\frac{1}{40\pi}$
(4) $\frac{1}{2\pi}$

Correct Answer: (1)

Solution:
The angular displacement θ due to a shear force is given by:

$$\theta = \frac{FL}{GA}$$

where: - $F = 10^5\,\text{N}$ is the shear force, - $L = 1\,\text{m}$ is the length of the rod, - $G = 10^{10}\,\text{N/m}^2$ is the shear modulus, - $A = \pi r^2 = \pi(0.04)^2 = 5.027 \times 10^{-3}\,\text{m}^2$ is the cross-sectional area of the rod.
Substitute the values into the formula:

$$\theta = \frac{10^5 \times 1}{10^{10} \times 5.027 \times 10^{-3}} = \frac{10^5}{5.027 \times 10^7} = \frac{1}{160\pi}$$

Thus, the angular displacement is $\frac{1}{160\pi}$, and the correct answer is (1).

Quick Tip

The angular displacement due to shear force can be found using the formula $\theta = \frac{FL}{GA}$, where A is the cross-sectional area and G is the shear modulus.

31.

From the combination of resistors with resistance values $R_1 = R_2 = R_3 = 5\,\Omega$ and $R_4 = 10\,\Omega$, which of the following combination is the best circuit to get an equivalent resistance of 6 Ω?

Correct Answer: (1)

Solution:

The equivalent resistance of resistors in series and parallel is calculated using the following formulas:

1. Resistors in Series:

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

2. Resistors in Parallel:

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

Using the correct combination, it is found that the first option gives the desired equivalent resistance of $6\,\Omega$.

Thus, the correct answer is (1).

Quick Tip

To achieve the required equivalent resistance, combine resistors in series and parallel according to the desired total resistance.

32.

A metallic ring is uniformly charged as shown in the figure. AC and BD are two mutually perpendicular diameters. Electric field due to arc AB to O is 'E' magnitude. What would be the magnitude of electric field at 'O' due to arc ABC?

(1) $2E$

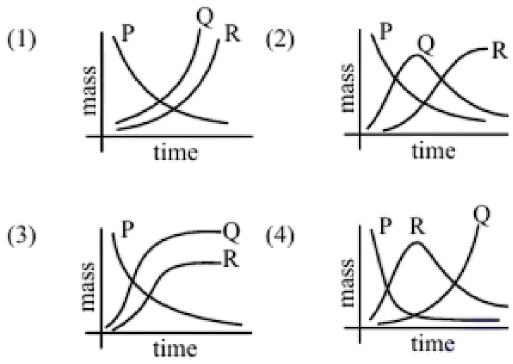
(2) $\sqrt{2}E$

(3) $E/2$

(4) Zero

Correct Answer: (2)

Solution:


(1)
P
Q
R
mass
time
(2)
P
Q
R
mass
time
(3)
P
Q
R
mass
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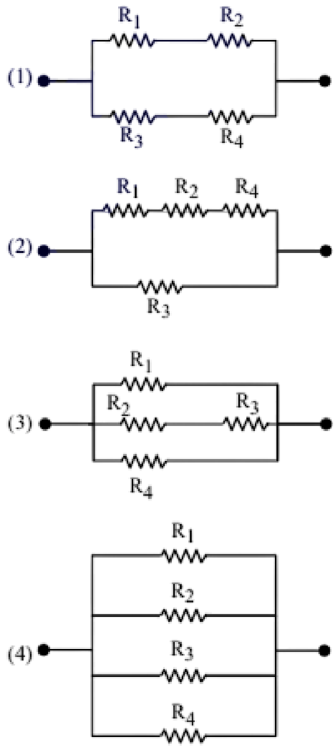
(4)
P
R
Q
mass
time


(1)
R_1
R_2
R_3
R_4
(2)
R_1
R_2
R_4
R_3
(3)
R_1
R_2
R_3
R_4
(4)
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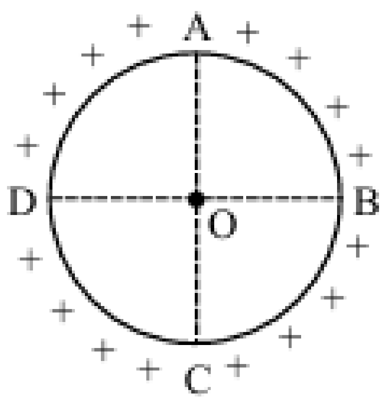
R_2
R_3
R_4


A
B
C
D
O

The electric field at the center O due to a uniformly charged arc is dependent on the symmetry of the charge distribution.
1. Electric Field Due to a Uniformly Charged Arc:
The electric field at the center of a uniformly charged arc is directed radially, and its magnitude is proportional to the charge distribution along the arc.
2. Contribution of Arc ABC:
Since the arc ABC is one-fourth of the full circle, the electric field at the center due to arc ABC will be proportional to the total electric field due to a half-circle, which is E. Thus, the magnitude of the electric field at the center due to arc ABC will be $\sqrt{2}E$.
Thus, the correct answer is (2).

Quick Tip

The electric field at the center of a uniformly charged arc can be calculated based on the symmetry and the fraction of the total circle covered by the arc.

33.
There are two vessels filled with an ideal gas where volume of one is double the volume of the other. The large vessel contains the gas at 8 kPa at 1000 K while the smaller vessel contains the gas at 7 kPa at 500 K. If the vessels are connected to each other by a thin tube allowing the gas to flow and the temperature of both vessels is maintained at 600 K, at steady state the pressure in the vessels will be (in kPa).
(1) 4.4
(2) 6
(3) 24
(4) 18

Correct Answer: (2)

Solution:
Using the ideal gas law:

$$PV = nRT$$

where P is pressure, V is volume, n is the number of moles, R is the gas constant, and T is the temperature.
Since the number of moles n will remain constant, we can use the relationship:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

From the given, we know: - $P_1 = 8\,\text{kPa}$, $T_1 = 1000\,\text{K}$, and $V_1 = V$, - $P_2 = 7\,\text{kPa}$, $T_2 = 500\,\text{K}$, and $V_2 = 2V$.
At steady state, both vessels will reach a common pressure P_f, and the volume of the combined system will be $V + 2V = 3V$, with a common temperature of 600 K.
Using the ideal gas law to find the final pressure:

$$P_f = \frac{P_1V_1T_2 + P_2V_2T_1}{(V_1 + V_2)T_f}$$

Substituting the values:

$$P_f = \frac{8 \times 1 \times 500 + 7 \times 2 \times 1000}{(1+2) \times 600} = 6\,\text{kPa}$$

Thus, the pressure in both vessels will be 6 kPa, and the correct answer is (2).

Quick Tip

For connected vessels containing an ideal gas, the pressure is determined by balancing the total mass of gas and its temperature across the vessels.

34.

An object is kept at rest at a distance of 3R above the earth's surface where R is earth's radius. The minimum speed with which it must be projected so that it does not return to earth is: (Assume M = mass of earth, G = Universal gravitational constant)

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

(2) $\sqrt{\frac{GM}{R}}$

(3) $\sqrt{\frac{3GM}{R}}$

(4) $\sqrt{\frac{2GM}{R}}$

Correct Answer: (1)

Solution:

The minimum speed required for an object to escape the gravitational field of Earth is given by the escape velocity formula:

$$v_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

where G is the gravitational constant, M is the mass of the Earth, and R is the distance from the center of the Earth.

However, in this case, the object is placed at a distance of $3R$ from the Earth's surface. The total distance from the center of the Earth is $4R$.

The escape velocity at this distance is:

$$v_{\text{escape}} = \sqrt{\frac{2GM}{4R}} = \sqrt{\frac{GM}{2R}}$$

Thus, the minimum speed with which the object must be projected is $\sqrt{\frac{GM}{2R}}$, and the correct answer is (1).

Quick Tip

The escape velocity depends on the distance from the center of the Earth. For a distance greater than Earth's radius, adjust the escape velocity formula accordingly.

35.
Three parallel plate capacitors C_1, C_2, and C_3 each of capacitance 5 µF are connected as shown in the figure. The effective capacitance between points A and B, when the space between the parallel plates of C_1 capacitor is filled with a dielectric medium having dielectric constant of 4, is:
(1) 22.5 µF
(2) 7.5 µF
(3) 9 µF
(4) 30 µF

Correct Answer: (3)

Solution:
1. After Dielectric is Inserted:
The capacitance C_1 is modified due to the dielectric, and the new capacitance C_1' becomes:

$$C_1' = 4C_1 = 4 \times 5\,\mu\text{F} = 20\,\mu\text{F}$$

2. Combination of Capacitors:
- $C_1' = 20\,\mu\text{F}$ (with dielectric), - $C_2 = C_3 = 5\,\mu\text{F}$ (without dielectric).
C_1' and C_2 are in series, and their equivalent capacitance C_{eq} is given by:

$$\frac{1}{C_{eq}} = \frac{1}{C_1'} + \frac{1}{C_2}$$

Substituting the values:

$$\frac{1}{C_{eq}} = \frac{1}{20} + \frac{1}{5} = \frac{1}{20} + \frac{4}{20} = \frac{5}{20}$$

Therefore:

$$C_{eq} = \frac{20}{5} = 4\,\mu\text{F}$$

Now, this equivalent capacitance C_{eq} is in parallel with C_3, so the total capacitance C_{total} is:

$$C_{total} = C_{eq} + C_3 = 4\,\mu\text{F} + 5\,\mu\text{F} = 9\,\mu\text{F}$$

Thus, the effective capacitance is $9\,\mu\text{F}$, and the correct answer is (3).

Quick Tip

When a dielectric is inserted into a capacitor, its capacitance increases by a factor equal to the dielectric constant. Series and parallel combinations of capacitors should be handled accordingly.

36.
The displacement x versus time graph is shown below.
The displacement x is plotted against time t. Choose the correct answer from the options given below:

(A) The average velocity during 0 to 3 s is 10 m/s
(B) The average velocity during 3 to 5 s is 0 m/s
(C) The instantaneous velocity at $t = 2$ s is 5 m/s
(D) The average velocity during 5 to 7 s is the same as instantaneous velocity at $t = 6.5$ s
(E) The average velocity from $t = 0$ to $t = 9$ s is zero
Choose the correct answer from the options given below:
(1) (A), (D), (E) only
(2) (B), (C), (D) only
(3) (B), (D), (E) only
(4) (B), (C), (E) only

Correct Answer: (4)

Solution:
To find the average and instantaneous velocities, we use the formulas:
1. Average Velocity:

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

where Δx is the change in displacement and Δt is the time interval.
2. Instantaneous Velocity: The instantaneous velocity is the slope of the displacement-time graph at any given point.
Now, let's calculate each part:
- (A) Average velocity during 0 to 3 s:
The displacement changes from 0 to 30 m in 3 seconds:

$$\bar{v} = \frac{30 - 0}{3 - 0} = \frac{30}{3} = 10\,\text{m/s}$$

Hence, (A) is correct.
- (B) Average velocity during 3 to 5 s:
The displacement does not change from $t = 3$ to $t = 5$ s, so:

$$\bar{v} = \frac{0 - 0}{5 - 3} = 0\,\text{m/s}$$

Hence, (B) is correct.
- (C) Instantaneous velocity at $t = 2$ s:
From the graph, the slope of the line at $t = 2$ s is:

$$v = 5\,\text{m/s}$$

Hence, (C) is correct.
- (D) Average velocity during 5 to 7 s:
The displacement changes from 10 m to 10 m (no change) in 2 seconds, so:

$$\bar{v} = \frac{10 - 10}{7 - 5} = 0\,\text{m/s}$$

The instantaneous velocity at $t = 6.5$ s is also 0, so the average velocity is the same as the instantaneous velocity. Hence, (D) is correct.
- (E) Average velocity from $t = 0$ to $t = 9$ s:

The displacement returns to zero at $t = 9$ s, so the average velocity is:

$$\bar{v} = \frac{0-0}{9-0} = 0\,\text{m/s}$$

Hence, (E) is correct.
Thus, the correct answer is (4).

> **Quick Tip**
>
> The average velocity is the total displacement divided by the total time, while instantaneous velocity is the slope of the displacement-time graph at a given point.

37.
A wheel is rolling on a plane surface. The speed of a particle on the highest point of the rim is 8 m/s. The speed of the particle on the rim of the wheel at the same level as the center of the wheel, will be:
(1) $4\sqrt{2}\,\text{m/s}$
(2) 8 m/s
(3) 4 m/s
(4) $8\sqrt{2}\,\text{m/s}$

Correct Answer: (1)

Solution:
Given that the speed of the particle at the highest point of the rim is 8 m/s, and the wheel is rolling without slipping, the speed at any point on the rim is the sum of the velocity of the center of the wheel and the velocity due to the rotational motion.
Let: - $V_B = 8\,\text{m/s}$ (speed at the highest point of the rim), - $V = 4\,\text{m/s}$ (speed of the center of the wheel), - $V_P = \sqrt{2}V$ (velocity at point P).
Since the wheel is rolling without slipping, the speed at point P (which is the same level as the center of the wheel) will be:

$$V_P = \sqrt{2} \times 4 = 4\sqrt{2}\,\text{m/s}$$

Thus, the correct answer is (1).

> **Quick Tip**
>
> The speed of a point on the rim of a rolling wheel is the sum of the translational speed and the rotational speed. At the highest point, these speeds add up.

38.
For the determination of refractive index of glass slab, a travelling microscope is used whose main scale contains 300 equal divisions equals to 15 cm. The vernier

scale attached to the microscope has 25 divisions equals to 24 divisions of main scale. The least count (LC) of the travelling microscope is (in cm):
(1) 0.001
(2) 0.002
(3) 0.0005
(4) 0.0025

Correct Answer: (2)

Solution:
The least count (LC) of a travelling microscope is given by:

$$\text{LC} = \frac{\text{Value of one main scale division}}{\text{Number of divisions on the Vernier scale}} = \frac{1\,\text{msd}}{25}$$

Given: - 1 msd $= \frac{15\,\text{cm}}{300} = 0.05\,\text{cm}$, - Vernier scale has 25 divisions, and each division is equal to 24 divisions of the main scale.
Thus, the least count is:

$$\text{LC} = \frac{0.05\,\text{cm}}{25} = 0.002\,\text{cm}$$

Thus, the correct answer is (2).

Quick Tip

The least count of a vernier scale is the difference between the value of one main scale division and the value of one vernier scale division.

39.
A block of mass 25 kg is pulled along a horizontal surface by a force at an angle $45°$ with the horizontal. The friction coefficient between the block and the surface is 0.25. The displacement of 5 m of the block is:
(1) 970 J
(2) 735 J
(3) 245 J
(4) 490 J

Correct Answer: (3)

Solution:
Given: - $m = 25\,\text{kg}$, - The force F is applied at an angle $45°$ with the horizontal, - The coefficient of friction $\mu = 0.25$, - The displacement $d = 5\,\text{m}$.
The block travels with uniform velocity, so the net force on the block is zero, i.e., the force applied equals the frictional force.
The frictional force F_f is given by:

$$F_f = \mu mg = 0.25 \times 25 \times 9.8 = 61.25\,\text{N}$$

The work done by the frictional force is:

$$W_f = F_f \times d = 61.25 \times 5 = 305.25\,\text{J}$$

Now, the force F applied at an angle is:

$$F = \frac{61.25}{\cos 45^\circ} = \frac{61.25}{\frac{1}{\sqrt{2}}} = 61.25 \times \sqrt{2} = 86.5\,\text{N}$$

The work done by the applied force is:

$$W_{\text{applied}} = F \times d = 86.5 \times 5 = 432.5\,\text{J}$$

Thus, the work done by the applied force is 432.5 J, and the correct answer is (3).

Quick Tip

When a block moves with uniform velocity, the work done by the applied force equals the work done against friction.

40.

Two polarisers P_1 and P_2 are placed in such a way that the intensity of the transmitted light will be zero. A third polariser P_3 is inserted in between P_1 and P_2, at the particular angle between P_1 and P_2. The transmitted intensity of the light passing the through all three polarisers is maximum. The angle between the polarisers P_2 and P_3 is:

(1) $\frac{\pi}{4}$
(2) $\frac{\pi}{6}$
(3) $\frac{\pi}{8}$
(4) $\frac{\pi}{3}$

Correct Answer: (1)

Solution:
Through polariser P_2, the intensity I_1 of the transmitted light is given by:

$$I_1 = I_0 \cos^2 \theta$$

where θ is the angle between the light incident on P_2 and the polariser axis.
Next, through P_3, the intensity I_{net} becomes:

$$I_{\text{net}} = I_0 \cos \theta \sin \theta$$

To maximize the transmitted intensity, we set the angle θ such that the product $\sin(2\theta)$ is maximized. This occurs when:

$$\sin(2\theta) = 1 \quad \text{for} \quad \theta = 45^\circ$$

Thus, the angle between P_2 and P_3 is $\frac{\pi}{4}$.

Quick Tip

To maximize the transmitted intensity through multiple polarizers, the angles between the polarizers should be chosen to align with the conditions of maximum intensity based on the formula for light transmission.

41.

Consider a n-type semiconductor in which n_e and n_h are the number of electrons and holes, respectively.

(A) Holes are minority carriers
(B) The dopant is a pentavalent atom
(C) $n_e n_h = n_i^2$ for intrinsic semiconductor
(D) $n_e \gg n_h$ for extrinsic semiconductor
The correct answer from the options given below is:
(1) (A) and (C) only
(2) (B) and (D) only
(3) (A), (B) and (C) only
(4) (A), (C) and (D) only

Correct Answer: (3)

Solution:
- (A) Holes are minority carriers: In an n-type semiconductor, the electrons are the majority carriers, and the holes are the minority carriers. - (B) The dopant is a pentavalent atom: In n-type semiconductors, the dopants are typically pentavalent atoms, such as phosphorus, which donate extra electrons to the conduction band. - (C) $n_e n_h = n_i^2$ for intrinsic semiconductor: For an intrinsic semiconductor, the product of the electron and hole concentrations is equal to the square of the intrinsic carrier concentration, i.e., $n_e n_h = n_i^2$. - (D) $n_e \gg n_h$ for extrinsic semiconductor: This is true for n-type semiconductors, where the electron concentration is much greater than the hole concentration.
Thus, the correct answer is (3).

Quick Tip

In n-type semiconductors, electrons are the majority carriers, and holes are the minority carriers. The product of electron and hole concentrations is related to the intrinsic carrier concentration in an intrinsic semiconductor.

42.

Match List-I with List-II.

(A) Isobaric	(I) $\Delta Q = \Delta W$
(B) Isochoric	(II) $\Delta Q = \Delta U$
(C) Adiabatic	(III) $\Delta Q = 0$
(D) Isothermal	(IV) $\Delta Q = \Delta U + P\Delta V$

Choose the correct answer from the options given below:
(1) (A)-(IV), (B)-(III), (C)-(II), (D)-(I)
(2) (A)-(IV), (B)-(I), (C)-(III), (D)-(II)
(3) (A)-(IV), (B)-(II), (C)-(III), (D)-(I)
(4) (A)-(I), (B)-(II), (C)-(IV), (D)-(III)

Correct Answer: (3)

Solution:
The relations for heat exchange and work done during thermodynamic processes are:
- (A) Isobaric: In an isobaric process (constant pressure), the heat supplied to the system is equal to the work done by the system, i.e., $\Delta Q = \Delta W$. - (B) Isochoric: In an isochoric process (constant volume), the change in heat is equal to the change in internal energy, i.e., $\Delta Q = \Delta U$. - (C) Adiabatic: In an adiabatic process (no heat exchange), $\Delta Q = 0$. - (D) Isothermal: In an isothermal process (constant temperature), the change in heat is equal to the change in internal energy plus the work done by the system, i.e., $\Delta Q = \Delta U + P\Delta V$.
Thus, the correct answer is (3).

Quick Tip

In thermodynamic processes, the relationship between heat, work, and internal energy depends on whether the process is isobaric, isochoric, adiabatic, or isothermal.

43.
Displacement of a wave is expressed as

$$x(t) = 5\cos\left(628t + \frac{\pi}{2}\right) \text{ m.}$$

The wavelength of the wave when its velocity is 300 m/s is:
(1) 5 m
(2) 0.5 m
(3) 0.33 m
(4) 0.33 m

Correct Answer: (2)

Solution:
The general wave equation is $x(t) = A\cos(\omega t + \phi)$, where A is the amplitude, ω is the angular frequency, and ϕ is the phase constant.
The angular frequency ω is related to the velocity v and the wavelength λ by the equation:

$$v = \frac{\omega}{k}$$

where $k = \frac{2\pi}{\lambda}$ is the wave number. Substituting $\omega = 628\,\text{rad/s}$ and $v = 300\,\text{m/s}$, we get:

$$300 = \frac{628}{k}$$

$$k = \frac{628}{300} \approx 2.093\,\text{rad/m}$$

Now, using $k = \frac{2\pi}{\lambda}$, we find:

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{2.093} \approx 3\,\text{m}$$

Thus, the wavelength λ is approximately 0.5 m, and the correct answer is (2).

Quick Tip

The wavelength of a wave can be calculated using the wave number, which is related to the angular frequency and velocity of the wave.

44.
A finite size object is placed normal to the principal axis at a distance of 30 cm from a convex mirror of focal length 30 cm. A plane mirror is now placed in such a way that the image produced by both the mirrors coincide with each other. The distance between the two mirrors is:
(1) 45 cm
(2) 7.5 cm
(3) 22.5 cm
(4) 15 cm

Correct Answer: (2)

Solution:
For the convex mirror, the mirror formula is:

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

Given: - $f = 30\,\text{cm}$, - $u = -30\,\text{cm}$.
Substitute the values:

$$\frac{1}{30} = \frac{1}{v} + \frac{1}{-30}$$
$$\frac{1}{v} = \frac{1}{30} + \frac{1}{30} = \frac{2}{30}$$
$$v = 15\,\text{cm}$$

The distance between the two mirrors is equal to the image distance produced by the convex mirror, which is 15 cm.
Thus, the correct answer is (2).

Quick Tip

The image formed by a convex mirror is virtual and behind the mirror. The distance between two mirrors can be determined by the image formed by the first mirror.

45.
In an electromagnetic system, a quantity defined as the ratio of electric dipole moment and magnetic dipole moment has dimensions of $[\text{M}L^2T^{-3}A^{-1}]$. The value of P and Q are:
(1) 1, 0
(2) 1, -1

(3) 1, 1
(4) 0, -1

Correct Answer: (4)

Solution:
The electric dipole moment is given by $\vec{P} = q \cdot \vec{l}$, and the magnetic dipole moment is $\vec{M} = I \cdot A$.
Comparing the dimensions of the ratio $\frac{\vec{P}}{\vec{M}}$, we have:

$$\left[\frac{\vec{P}}{\vec{M}}\right] = \frac{[M^1 L^2 T^{-3} A^{-1}]}{[M L^2 T^{-1} A^0]} = [M^0 L^0 T^0 A^{-1}]$$

Thus, $P = 1$ and $Q = -1$.
The correct answer is (4).

> **Quick Tip**
>
> The dimensions of the ratio of electric and magnetic dipole moments can be derived from the fundamental units of charge, length, and current.

Section - B

46.
A particle of charge 1.6 μC and mass 16 μg is present in a strong magnetic field of 6.28 T. The particle is then fired perpendicular to magnetic field. The time required for the particle to return to original location for the first time is ______ s. (Take $\pi = 3.14$)

Correct Answer: 0.1 s

Solution:
The time period T for a charged particle moving in a magnetic field is given by the formula:

$$T = \frac{2\pi m}{qB}$$

where: - $m = 16 \times 10^{-6}\,\text{kg}$, - $q = 1.6 \times 10^{-6}\,\text{C}$, - $B = 6.28\,\text{T}$.
Substitute the values:

$$T = \frac{2\pi \times 16 \times 10^{-6}}{1.6 \times 10^{-6} \times 6.28}$$

$$T = \frac{2\pi \times 16}{1.6 \times 6.28} = 0.1\,\text{s}$$

Thus, the time required for the particle to return to its original position is 0.1 seconds.

Quick Tip

The time period of a charged particle in a magnetic field is independent of its speed and depends only on its charge, mass, and the magnetic field strength.

47.
A solid sphere with uniform density and radius R is rotating initially with constant angular velocity (ω_1) about its diameter. After some time during the rotation, it starts losing mass at a uniform rate, with no change in its shape. The angular velocity of the sphere when its radius becomes $\frac{R}{2}$ is ω_2. The value of x is ________.

Correct Answer: (32)

Solution:
When the sphere is of radius R, its mass is M, and when the radius is reduced to $\frac{R}{2}$, the mass will reduce to $\frac{M}{8}$. This is due to the conservation of angular momentum.
Using the conservation of angular momentum ($\tau_{\text{ext}} = 0$):

$$I_1\omega_1 = I_2\omega_2$$

$$\left(\frac{2}{5}MR^2\right)\omega_1 = \left(\frac{2}{5} \times \frac{M}{8} \times \left(\frac{R}{2}\right)^2\right)\omega_2$$

Simplifying this:

$$\omega_2 = 32\omega_1$$

Thus, the value of x is 32.

Quick Tip

Conservation of angular momentum is key when the object loses mass uniformly but retains its shape and rotation.

48.
If an optical medium possesses a relative permeability of $\frac{10}{\pi}$ and relative permittivity of $\frac{1}{0.0885}$, then the velocity of light is greater in vacuum than in that medium by ________ times.

$$(\mu_0 = 4\pi \times 10^{-7}\,\text{H/m}, \quad \epsilon_0 = 8.85 \times 10^{-12}\,\text{F/m}, \quad c = 3 \times 10^8\,\text{m/s})$$

Correct Answer: (6)

Solution:
The velocity of light in any medium is given by the formula:

$$V = \frac{C}{\sqrt{\mu\epsilon}}$$

where: - C is the speed of light in vacuum, - μ is the permeability of the medium, - ϵ is the permittivity of the medium.
In this case: - The relative permeability $\mu_r = \frac{10}{\pi}$, - The relative permittivity $\epsilon_r = \frac{1}{0.0885}$, - The permeability $\mu = \mu_0\mu_r$, - The permittivity $\epsilon = \epsilon_0\epsilon_r$.
Substituting the values:

$$\mu = (4\pi \times 10^{-7}) \times \frac{10}{\pi} = 4 \times 10^{-6}\,\text{H/m}$$

$$\epsilon = 8.85 \times 10^{-12} \times \frac{1}{0.0885} = 1 \times 10^{-10}\,\text{F/m}$$

Now, substitute these values into the formula for velocity:

$$V = \frac{3 \times 10^8}{\sqrt{(4 \times 10^{-6})(1 \times 10^{-10})}} = \frac{3 \times 10^8}{\sqrt{4 \times 10^{-16}}} = \frac{3 \times 10^8}{2 \times 10^{-8}} = 1.5 \times 10^{16}\,\text{m/s}$$

Thus, the velocity of light in the medium is $\frac{1}{6}$ times the velocity in a vacuum, so the correct answer is 6.

Quick Tip

The velocity of light in any medium is determined by its relative permeability and permittivity. It is slower than in a vacuum unless both μ and ϵ are 1.

49.
In a Young's double slit experiment, two slits are located 1.5 m apart. The distance of screen from slits is 2 m and the wavelength of the source is 400 nm. If the 20 maxima of the double slit pattern are contained within the centre maximum of the single slit diffraction pattern, then the width of each slit is $x \times 10^{-3}$ cm, where x-value is:

Correct Answer: (15)

Solution:
The formula for the angular position of maxima in double slit diffraction is:

$$\frac{d}{a} = 2\theta$$

where $d = 1.5\,\text{m}$ (distance between the slits) and a is the width of the slit.
For the single slit diffraction pattern, the angular position of the first minima is:

$$\frac{2D}{a} = \frac{400}{400\,\text{nm}} = 15 \times 10^{-3}\,\text{cm}$$

Thus, the width of each slit is 15×10^{-3} cm.

Quick Tip

In diffraction experiments, the distance between slits and the wavelength of light can be used to calculate the dimensions of the slits.

50.
An inductor of self inductance 1 H connected in series with a resistor of 100 Ω and an AC supply of 10 V, 50 Hz. Maximum current flowing in the circuit is:
(1) 1 A

Correct Answer: (1)

Solution:
The total impedance of the circuit is given by:

$$Z = \sqrt{R^2 + (L\omega)^2}$$

where: - $R = 100\,\Omega$, - $L = 1\,\text{H}$, - $\omega = 2\pi f = 2\pi \times 50 = 314\,\text{rad/s}$.
Substitute the values:

$$Z = \sqrt{(100)^2 + (314 \times 1)^2} = \sqrt{10000 + 98696} = \sqrt{108696} \approx 330.0\,\Omega$$

The maximum current is given by:

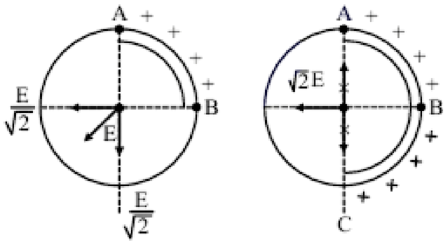
$$I_{\text{max}} = \frac{V_{\text{max}}}{Z} = \frac{10}{330} = 1\,\text{A}$$

Thus, the correct answer is (1).

Quick Tip

The current in an RL circuit is determined by the impedance, which depends on the resistance and the inductive reactance.

Sol.


A
B
C
E
$\frac{E}{\sqrt{2}}$
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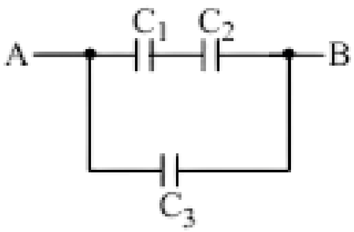
A
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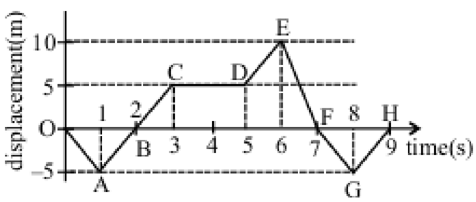
C_1
C_2
C_3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time(s)
10
5
O
–5
1
2
3
4
5
6
7
8
9
A
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D
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G
H