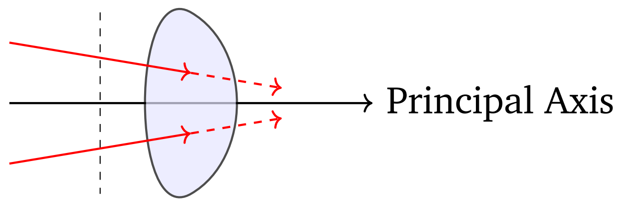
JEECUP Group A Physics Sample Paper – 14

Duration: 45 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **25** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**. No marks will be deducted for incorrect answers. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. A person cannot see objects clearly beyond a distance of 1.5 m. To correct this defect, what should be the power of the lens used?



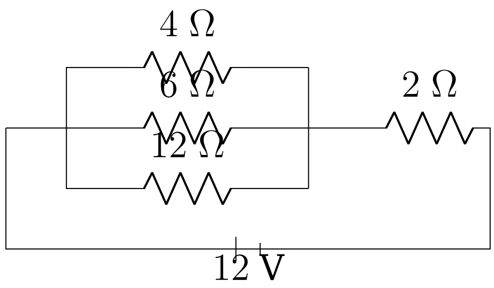
(A) -1.5 D

(B) $+0.67$ D

(C) -0.67 D

(D) $+1.5$ D

Q2. Three resistors of resistances $4\ \Omega$, $6\ \Omega$, and $12\ \Omega$ are connected in parallel. This combination is connected in series with a $2\ \Omega$ resistor and a 12 V battery. What is the current flowing through the $2\ \Omega$ resistor?



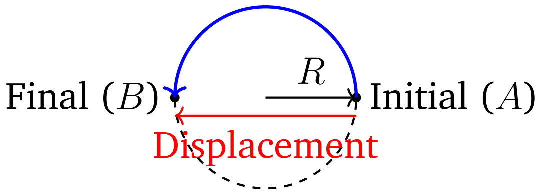
(A) 2.0 A

(B) 3.0 A

(C) 4.0 A

(D) 1.5 A

Q3. A particle is moving in a circular path of radius R. What will be the displacement of the particle after completing half a circle?



(A) Zero

(B) πR

(C) $2R$

(D) $2\pi R$

Q4. An engine pumps 400 kg of water through a height of 10 m in 20 seconds. What is the power of the engine? (Take $g = 10$ m/s^2)

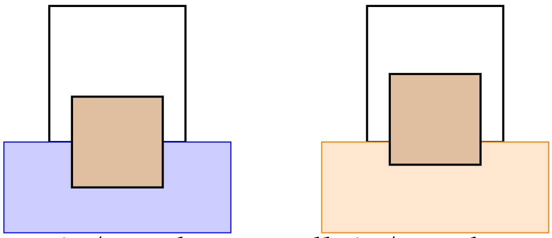
(A) 200 W

(B) 2000 W

(C) 4000 W

(D) 8000 W

Q5. A block of wood floats in water with two-thirds of its volume submerged. When floating in a certain oil, it floats with half of its volume submerged. What is the density of the oil? (Take density of water = 1000 kg/m^3)



(A) 750 kg/m^3

(B) 1333 kg/m^3

(C) 600 kg/m^3

(D) 1200 kg/m^3

Q6. A ray of light passes from water into a glass prism. If the refractive indices of water and glass with respect to air are $4/3$ and $3/2$ respectively, what is the refractive index of glass with respect to water?

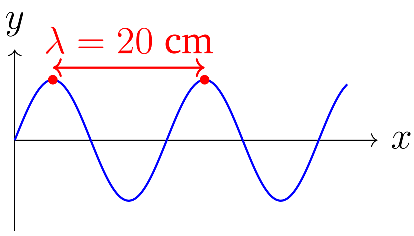
(A) 2

(B) $8/9$

(C) $9/8$

(D) $1/2$

Q7. If the distance between two consecutive crests in a wave is 20 cm and the velocity of the wave is 120 m/s, what is the frequency of the wave?



(A) 6 Hz

(B) 60 Hz

(C) 600 Hz

(D) 24 Hz

Q8. A body of mass 5 kg undergoes a change in velocity from 20 m/s to 10 m/s in 2 seconds due to a uniform force. What is the magnitude of the force acting on the body?

(A) 25 N

(B) -25 N

(C) 15 N

(D) 50 N

Q9. During radioactive decay, a nucleus emits one α-particle followed by two β^--particles. How do the mass number (A) and atomic number (Z) of the final daughter nucleus compare with the original parent nucleus?

(A) A decreases by 4, Z decreases by 2

(B) A decreases by 4, Z remains unchanged

(C) A remains unchanged, Z increases by 2

(D) A decreases by 2, Z decreases by 2

Q10. How much heat energy is required to completely convert 20 g of ice at $0°$C into water at $20°$C? (Take latent heat of fusion of ice $= 80$ cal/g, specific heat capacity of water $= 1$ cal/g$^\circ$C)

(A) 1600 cal

(B) 400 cal

(C) 2000 cal

(D) 1200 cal

Q11. An electric bulb rated 60 W, 220 V is operated at 110 V. What is the power consumed by the bulb at this lower voltage?

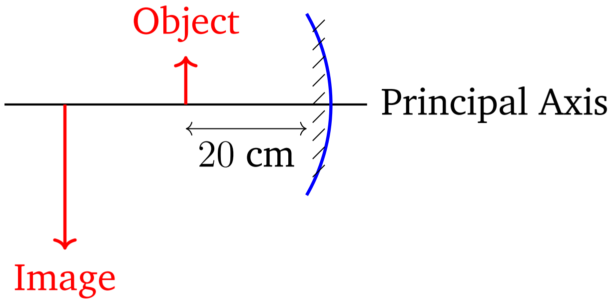
(A) 30 W

(B) 15 W

(C) 45 W

(D) 20 W

Q12. A concave mirror produces a real image three times magnified when an object is placed 20 cm in front of it. What is the focal length of the mirror?



(A) -15 cm

(B) -30 cm

(C) -60 cm

(D) -10 cm

Q13. Two bodies of masses 2 kg and 8 kg possess equal kinetic energies. What is the ratio of their linear momenta?

(A) $1 : 4$

(B) $4 : 1$

(C) $1 : 2$

(D) $2 : 1$

Q14. The temperature of a gas is increased from $27°$C to $327°$C. By what factor does the average kinetic energy of the gas molecules change?

(A) It becomes 12 times

(B) It is doubled

(C) It is halved

(D) It remains unchanged

Q15. A uniform wire of resistance R is stretched uniformly to double its original length. What is the new resistance of the stretched wire?

(A) $2R$

(B) $R/2$

(C) $4R$

(D) $R/4$

Q16. A sound wave travels from air into water. Which of the following wave properties remains completely unchanged?

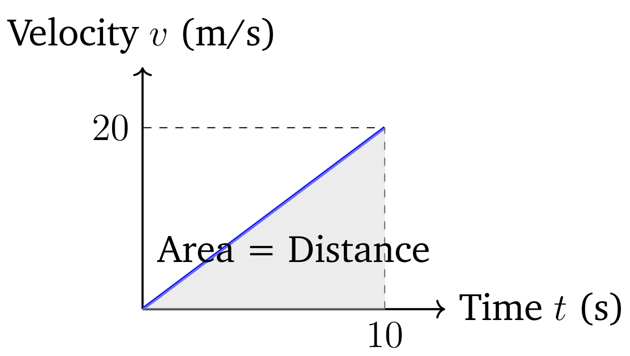
(A) Velocity

(B) Wavelength

(C) Frequency

(D) Amplitude

Q17. A car accelerates uniformly from rest and acquires a velocity of 72 km/h in 10 seconds. What is the total distance covered by the car during this time interval?



(A) 720 m

(B) 100 m

(C) 200 m

(D) 50 m

Q18. A convex lens of focal length 20 cm is placed coaxially in contact with a concave lens of focal length 25 cm. What is the power of this lens combination?

(A) +1.0 D

(B) -1.0 D

(C) $+9.0$ D

(D) -9.0 D

Q19. A light and a heavy body are dropped simultaneously from the same height in a complete vacuum. Which body will reach the ground first?

(A) The heavier body

(B) The lighter body

(C) Both will reach the ground at the exact same time

(D) It depends on the surface area of the bodies

Q20. An electric kettle connected to a 220 V supply draws a current of 5 A. If it is used for 2 hours daily, what is the cost of energy consumed in 30 days at the rate of Rs. 5 per kWh?

(A) Rs. 330

(B) Rs. 165

(C) Rs. 660

(D) Rs. 99

Q21. A real gas behaves closest to an ideal gas under which of the following physical conditions?

(A) High temperature and high pressure

(B) Low temperature and low pressure

(C) High temperature and low pressure

(D) Low temperature and high pressure

Q22. A bullet of mass 20 g moving with a speed of 150 m/s penetrates a sand-bag and comes to rest in 0.05 seconds. What is the distance penetrated by the bullet into the sandbag?

(A) 7.5 m

(B) 3.75 m

(C) 1.5 m

(D) 0.75 m

Q23. The half-life of a specific radioactive substance is 10 days. What fraction of the original active nuclei will remain un-decayed after a period of 40 days?

(A) $1/4$

(B) $1/8$

(C) $1/16$

(D) $1/32$

Q24. An object is placed at a distance of 15 cm in front of a convex mirror of focal length 30 cm. What is the nature and position of the image formed?

(A) Real, inverted and at 10 cm behind the mirror

(B) Virtual, erect and at 10 cm behind the mirror

(C) Virtual, erect and at 30 cm behind the mirror

(D) Real, inverted and at 30 cm in front of the mirror

Q25. A moving body hits a stationary body of identical mass head-on in a perfectly elastic collision. After the impact, how do the velocities change?

(A) The moving body stops completely and the stationary body moves with the initial velocity of the first body

(B) Both bodies stick together and move with half the initial velocity

(C) The moving body rebounds with the same speed

(D) Both bodies start moving with equal velocities in opposite directions

Detailed Solutions

Q1.

Solution

Concept:

Myopia (near-sightedness) is a vision defect where a person can see nearby objects clearly but cannot see distant objects distinctly. The far point of a myopic eye shifts from infinity to a finite distance d. To correct this defect, a divergent (concave) lens is used. The focal length f of the required corrective lens must be equal to the negative of the person's far point distance, so that an object at infinity forms a virtual image at the person's actual far point. The power of a lens P is given by the reciprocal of its focal length measured in meters, expressed as $P = \frac{1}{f}$.

Solution:

Step 1: Identify the given values from the problem statement. The maximum distance up to which the person can see clearly is their far point. Here, the far point distance is $d = 1.5$ m.

Step 2: To see distant objects clearly, the lens must form a virtual image of an object at infinity ($u = -\infty$) at the far point of the eye ($v = -1.5$ m). Using the standard lens formula:

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

Step 3: Substitute the values of u and v into the lens formula:

$$\frac{1}{f} = \frac{1}{-1.5} - \frac{1}{-\infty}$$

Since $\frac{1}{-\infty} = 0$, we find:

$$\frac{1}{f} = -\frac{1}{1.5}$$

Therefore, the focal length of the concave lens required is $f = -1.5$ m.

Step 4: Calculate the optical power P of the lens using the power formula:

$$P = \frac{1}{f} = \frac{1}{-1.5 \text{ m}}$$

Step 5: Perform the division to convert the value into decimal form:

$$P = -\frac{10}{15} = -\frac{2}{3} \text{ D} \approx -0.67 \text{ D}$$

The negative sign confirms that a concave lens is needed to fix the vision defect.

Final Answer: -0.67 D

Answer: (C) Go Back to Question 1

Q2.

Solution

Concept:
This problem requires the application of Ohm's law and combination laws for electrical networks. When resistors are connected in parallel, the reciprocal of the equivalent resistance is the sum of the reciprocals of the individual resistances. When resistors are connected in series, the total equivalent resistance is simply the algebraic sum of the individual resistances. According to Ohm's law, the total current drawn from a battery source is equal to the total voltage divided by the total equivalent resistance of the entire circuit.

Solution:
Step 1: Identify the given resistances. We have three resistors connected in parallel: $R_1 = 4\ \Omega$, $R_2 = 6\ \Omega$, and $R_3 = 12\ \Omega$.
Step 2: Calculate the equivalent resistance R_p of this parallel branch using the parallel combination formula:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_p} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$$

Step 3: Find a common denominator to add the fractions, which is 12:

$$\frac{1}{R_p} = \frac{3+2+1}{12} = \frac{6}{12} = \frac{1}{2}$$

Taking the reciprocal, we get $R_p = 2\ \Omega$.
Step 4: This parallel combination is now connected in series with a fourth resistor $R_4 = 2\ \Omega$. Calculate the total equivalent resistance R_{total} of the circuit:

$$R_{\text{total}} = R_p + R_4 = 2\ \Omega + 2\ \Omega = 4\ \Omega$$

Step 5: Use Ohm's law to find the total current I supplied by the 12 V battery source:

$$I = \frac{V}{R_{\text{total}}} = \frac{12\ \text{V}}{4\ \Omega} = 3.0\ \text{A}$$

Since R_4 is connected in series with the main circuit path, the total circuit current of 3.0 A flows directly through it.

Final Answer: 3.0 A

Answer: (B) Go Back to Question 2

Q3.

Solution

Concept:
Distance and displacement are fundamental concepts in kinematics. Distance is a scalar quantity representing the total path length traversed by an object during its motion. In contrast, displacement is a vector quantity defined as the shortest straight-line distance between the initial position and the final position of the object, directed from start to finish. For an object moving along a circular perimeter, completing half a revolution places it exactly at the opposite end of the diameter from where it started.

Solution:
Step 1: Visualize the path of the particle moving along a circle of radius R. Let the initial position of the particle be point A on one side of the circular path.
Step 2: When the particle travels and completes exactly half of the circular revolution, it moves along the curved arc of the semi-circle. The distance traveled would be half the circumference, which equals πR.
Step 3: Locate the final position, point B, after half a circle. Point B is located directly opposite to point A across the center of the circle.
Step 4: Determine the displacement by drawing a straight line from the initial point A to the final point B. This straight-line path passes through the center of the circle.
Step 5: The length of this straight line is equal to the diameter of the circular path. Since diameter is twice the radius, the length is:

$$\text{Displacement} = AB = R + R = 2R$$

Thus, the magnitude of the displacement is $2R$.

Final Answer: $2R$

Answer: (C) Go Back to Question 3

Q4.

Solution

Concept:
Power is defined as the rate at which work is done or energy is transferred over time. Mathematically, it is expressed as $P = \frac{W}{t}$, where W is work done and t is the time interval. When an engine lifts a certain mass of water vertically upward against the force of gravity, the work done by the engine is equal to the gravitational potential energy gained by the water mass. This potential energy is given by the formula $U = mgh$, where m is the mass, g is the acceleration due to gravity, and h is the vertical height.

Solution:
Step 1: Note down the given numerical values from the problem statement: mass of water $m = 400$ kg, vertical lifting height $h = 10$ m, time duration $t = 20$ seconds, and acceleration due to gravity $g = 10$ m/s^2.
Step 2: Calculate the total work done W by the pump engine to lift this mass of water. The work is equivalent to the change in potential energy:

$$W = mgh$$

$$W = 400 \text{ kg} \times 10 \text{ m/s}^2 \times 10 \text{ m}$$

$$W = 40000 \text{ Joules}$$

Step 3: Use the power formula to find the rate of energy consumption per second:

$$P = \frac{W}{t}$$

Step 4: Substitute the values of work and time into the power expression:

$$P = \frac{40000 \text{ J}}{20 \text{ s}}$$

Step 5: Simplify the fraction to find the power in Watts:

$$P = 2000 \text{ W}$$

The output power of the pump engine is therefore 2000 W (or 2 kW).

Final Answer: 2000 W

Answer: (B) Go Back to Question 4

Q5.

Solution

Concept:
According to Archimedes' principle and the law of floatation, a floating body displaces a volume of fluid whose weight is exactly equal to the total weight of the floating body. Mathematically, for a body of total volume V and density ρ_b floating in a fluid of density ρ_f, the buoyant force equals the weight of the object: $V_{\text{sub}} \times \rho_f \times g = V \times \rho_b \times g$, where V_{sub} is the submerged volume. This simplifies to the equilibrium relation: $V_{\text{sub}} \times \rho_f = V \times \rho_b$.

Solution:
Step 1: Let the total volume of the wooden block be V and its density be ρ_w. Let the density of water be $\rho_{\text{water}} = 1000\ \text{kg/m}^3$ and the density of the unknown oil be ρ_{oil}.
Step 2: Write the floatation equation for the block when it is floating in water. The problem states that two-thirds of its volume is submerged ($V_{\text{sub}} = \frac{2}{3}V$):

$$\left(\frac{2}{3}V\right) \times \rho_{\text{water}} = V \times \rho_w$$

$$\rho_w = \frac{2}{3}\rho_{\text{water}}$$

Step 3: Write the floatation equation for the same block when it is floating in the oil. The problem states that half of its volume is submerged ($V_{\text{sub}} = \frac{1}{2}V$):

$$\left(\frac{1}{2}V\right) \times \rho_{\text{oil}} = V \times \rho_w$$

$$\rho_w = \frac{1}{2}\rho_{\text{oil}}$$

Step 4: Equate the two expressions for the density of the wooden block ρ_w obtained from Step 2 and Step 3:

$$\frac{1}{2}\rho_{\text{oil}} = \frac{2}{3}\rho_{\text{water}}$$

Step 5: Solve for the density of the oil ρ_{oil} by rearranging the terms and substituting the known density of water:

$$\rho_{\text{oil}} = \frac{4}{3}\rho_{\text{water}}$$

$$\rho_{\text{oil}} = \frac{4}{3} \times 1000\ \text{kg/m}^3 \approx 1333.33\ \text{kg/m}^3$$

Thus, the density of the oil is $1333\ \text{kg/m}^3$.

Final Answer: $1333\ \text{kg/m}^3$

Answer: (B) Go Back to Question 5

Q6.

Solution

Concept:

The refractive index of a medium is defined relative to another medium. The absolute refractive index of a medium is its refractive index with respect to vacuum or air. According to the principles of optics, the relative refractive index of medium 2 with respect to medium 1 (denoted as ${}^1\mu_2$ or μ_{21}) is calculated as the ratio of the absolute refractive index of medium 2 (μ_2) to the absolute refractive index of medium 1 (μ_1). This can be written mathematically as $\mu_{21} = \frac{\mu_2}{\mu_1}$.

Solution:

Step 1: Identify the given absolute refractive indices from the problem statement. The refractive index of water with respect to air is $\mu_w = \frac{4}{3}$. The refractive index of glass with respect to air is $\mu_g = \frac{3}{2}$.

Step 2: We need to determine the relative refractive index of glass with respect to water, which is written notationally as ${}^w\mu_g$ or μ_{gw}.

Step 3: Set up the ratio using the mathematical definition of relative refractive index:

$$\mu_{gw} = \frac{\mu_g}{\mu_w}$$

Step 4: Substitute the given fraction values into this equation:

$$\mu_{gw} = \frac{\frac{3}{2}}{\frac{4}{3}}$$

Step 5: Simplify the complex fraction by multiplying the numerator by the reciprocal of the denominator:

$$\mu_{gw} = \frac{3}{2} \times \frac{3}{4} = \frac{3 \times 3}{2 \times 4} = \frac{9}{8}$$

Thus, the refractive index of the glass prism with respect to water is $9/8$.

Final Answer: 9/8

Answer: (C) Go Back to Question 6

Q7.

Solution

Concept:
A wave is a disturbance that propagates through a medium, transporting energy. The distance between any two consecutive points in the same phase, such as between two consecutive crests or two consecutive troughs, is defined as the wavelength (λ) of the wave. The velocity (v), frequency (f), and wavelength (λ) of a wave are fundamentally interconnected by the wave propagation equation: $v = f\lambda$. Rearranging this equation allows us to find the frequency if velocity and wavelength are known: $f = \frac{v}{\lambda}$.

Solution:
Step 1: Note the given parameters. The distance between two consecutive crests is the wavelength, so $\lambda = 20$ cm. The wave velocity is given as $v = 120$ m/s.
Step 2: Convert the wavelength from centimeters to meters to match standard SI units:

$$\lambda = 20 \text{ cm} = \frac{20}{100} \text{ m} = 0.2 \text{ m}$$

Step 3: Write down the primary formula connecting wave velocity, frequency, and wavelength:

$$v = f\lambda$$

Step 4: Rearrange the formula to solve for the frequency f:

$$f = \frac{v}{\lambda}$$

Step 5: Substitute the numerical values into the rearranged equation:

$$f = \frac{120 \text{ m/s}}{0.2 \text{ m}} = \frac{1200}{2} \text{ Hz} = 600 \text{ Hz}$$

Hence, the frequency of the wave is 600 Hz.

Final Answer: 600 Hz

Answer: (C) Go Back to Question 7

Q8.

Solution

Concept:
According to Newton's second law of motion, the net force acting on an object is proportional to the rate of change of its linear momentum. For a body of constant mass m, Newton's second law simplifies to the formula $F = ma$, where F is the net force applied and a is the uniform acceleration. Acceleration is defined as the rate of change of velocity over time, given by $a = \frac{v-u}{t}$, where u is the initial velocity, v is the final velocity, and t is the elapsed time. Combining these gives $F = \frac{m(v-u)}{t}$.

Solution:
Step 1: Extract the given quantities from the problem: mass of the body $m = 5$ kg, initial velocity $u = 20$ m/s, final velocity $v = 10$ m/s, and time interval $t = 2$ seconds.
Step 2: Calculate the acceleration a experienced by the body using the kinematics formula:

$$a = \frac{v-u}{t}$$

$$a = \frac{10 \text{ m/s} - 20 \text{ m/s}}{2 \text{ s}} = \frac{-10 \text{ m/s}}{2 \text{ s}} = -5 \text{ m/s}^2$$

The negative sign indicates deceleration (retardation).
Step 3: Calculate the force F acting on the body using Newton's second law:

$$F = ma = 5 \text{ kg} \times (-5 \text{ m/s}^2) = -25 \text{ N}$$

Step 4: The problem asks for the "magnitude" of the force acting on the body. The magnitude is the absolute value of the force, ignoring the direction sign.
Step 5: Take the absolute value:

$$\text{Magnitude of Force} = |F| = |-25 \text{ N}| = 25 \text{ N}$$

The magnitude of the force is therefore 25 N.

Final Answer: 25 N

Answer: (A) Go Back to Question 8

Q9.

Solution

Concept:

Radioactive decay processes alter the composition of an unstable atomic nucleus. An alpha (α) particle is a helium nucleus, represented as ${}^4_2$He. When a parent nucleus emits an α-particle, its mass number A decreases by 4 and its atomic number Z decreases by 2. A beta-minus (β^-) particle is an electron, represented as ${}^{0}_{-1}$e. When a nucleus emits a β^--particle, a neutron changes into a proton; thus, the mass number A remains unchanged while the atomic number Z increases by 1.

Solution:

Step 1: Let the original parent nucleus be represented as ${}^A_Z$X, where A is the initial mass number and Z is the initial atomic number.

Step 2: Analyze the first step of the decay where one α-particle (${}^4_2$He) is emitted. The intermediate nucleus ${}^{A'}_{Z'}$Y will have:

$$A' = A - 4$$

$$Z' = Z - 2$$

Step 3: Analyze the next stage where two β^--particles (${}^{0}_{-1}$e) are emitted from this intermediate nucleus. Each β^- emission keeps the mass number the same but increases the atomic number by 1.

Step 4: For two β^- emissions, the final atomic number Z'' changes by $+2$, while the final mass number A'' remains equal to A':

$$A'' = A' = A - 4$$

$$Z'' = Z' + 1 + 1 = Z' + 2$$

Step 5: Substitute the expression for Z' from Step 2 into the equation for Z'':

$$Z'' = (Z - 2) + 2 = Z$$

Comparing the final daughter nucleus ${}^{A-4}_{Z}$D with the original parent nucleus ${}^A_Z$X, the mass number A decreases by 4, while the atomic number Z remains unchanged.

Final Answer: A decreases by 4, Z remains unchanged

Answer: (B) Go Back to Question 9

Q10.

Solution

Concept:
The total heat required for a phase transformation followed by a temperature change involves two distinct steps: latent heat and specific heat. First, the substance changes its phase at a constant temperature; the heat required is given by $Q_1 = mL_f$, where m is the mass and L_f is the latent heat of fusion. Second, once the phase change is complete, the temperature of the substance increases; the heat required for this temperature change is given by $Q_2 = ms\Delta\theta$, where s is the specific heat capacity and $\Delta\theta$ is the temperature difference. The total heat is $Q_{\text{total}} = Q_1 + Q_2$.

Solution:
Step 1: Break down the physical process into two chronological stages: Stage 1: Melting of 20 g of ice at $0°$C into 20 g of water at $0°$C. Stage 2: Heating of 20 g of water from $0°$C to $20°$C.
Step 2: Calculate the heat Q_1 required for Stage 1 using the latent heat formula:

$$Q_1 = m \times L_f$$

Given $m = 20$ g and $L_f = 80$ cal/g:

$$Q_1 = 20 \text{ g} \times 80 \text{ cal/g} = 1600 \text{ cal}$$

Step 3: Calculate the heat Q_2 required for Stage 2 using the specific heat formula:

$$Q_2 = m \times s \times \Delta\theta$$

Given $s = 1$ cal/g$°$C and $\Delta\theta = 20°\text{C} - 0°\text{C} = 20°\text{C}$:

$$Q_2 = 20 \text{ g} \times 1 \text{ cal/g}°\text{C} \times 20°\text{C} = 400 \text{ cal}$$

Step 4: Compute the total heat energy Q_{total} by summing the heat values from both steps:

$$Q_{\text{total}} = Q_1 + Q_2 = 1600 \text{ cal} + 400 \text{ cal} = 2000 \text{ cal}$$

Therefore, the total heat required is 2000 cal.

Final Answer: 2000 cal

Answer: (C) Go Back to Question 10

Q11.

Solution

Concept:

The electrical resistance R of a filament wire inside an electric bulb is a structural property that remains constant, provided temperature fluctuations do not significantly alter it. The rated power P_1 and rated voltage V_1 of an electrical appliance are related to its resistance by the formula $P = \frac{V^2}{R}$, which can be rearranged as $R = \frac{V_1^2}{P_1}$. When the appliance is operated at a different applied voltage V_2, the new power consumption P_2 can be calculated using the same resistance value: $P_2 = \frac{V_2^2}{R}$.

Solution:

Step 1: Identify the values from the bulb's rating: specifications are $P_1 = 60$ W and $V_1 = 220$ V. The actual operational voltage is $V_2 = 110$ V.

Step 2: Express the internal resistance R of the bulb filament using its rated values:

$$R = \frac{V_1^2}{P_1} = \frac{(220)^2}{60}$$

Step 3: Write down the expression for the new power consumption P_2 when operating at the lower voltage V_2:

$$P_2 = \frac{V_2^2}{R}$$

Step 4: Substitute the expression for R from Step 2 into the formula for P_2:

$$P_2 = \frac{V_2^2}{\frac{V_1^2}{P_1}} = \left(\frac{V_2}{V_1}\right)^2 \times P_1$$

Step 5: Substitute the numerical values of the voltages and original power into this relation:

$$P_2 = \left(\frac{110 \text{ V}}{220 \text{ V}}\right)^2 \times 60 \text{ W}$$

Simplify the fraction inside the square:

$$P_2 = \left(\frac{1}{2}\right)^2 \times 60 \text{ W} = \frac{1}{4} \times 60 \text{ W} = 15 \text{ W}$$

The power consumed by the bulb at 110 V is 15 W.

Final Answer: 15 W

Answer: (B) Go Back to Question 11

Q12.

Solution

Concept:
In geometric optics, the linear magnification m produced by a spherical mirror is defined as the ratio of the height of the image to the height of the object. It is related to the object distance u and image distance v by the formula $m = -\frac{v}{u}$. For a real image formed by a concave mirror, the image is inverted, which means the magnification m is negative. According to Cartesian sign conventions, distances measured in the direction of incident light are positive, while distances measured against it are negative. Thus, for an object placed in front of a mirror, u is negative.

Solution:
Step 1: Apply Cartesian sign conventions to the given information. The object is placed in front of the mirror, so the object distance is $u = -20$ cm.
Step 2: The mirror forms a real, inverted image that is three times magnified. Therefore, the magnification value is $m = -3$.
Step 3: Use the mirror magnification formula to establish a relation between v and u:

$$m = -\frac{v}{u}$$

Substitute $m = -3$ into the formula:

$$-3 = -\frac{v}{u} \implies v = 3u$$

Step 4: Substitute the value of $u = -20$ cm to calculate the image distance v:

$$v = 3 \times (-20 \text{ cm}) = -60 \text{ cm}$$

The negative sign indicates that the real image is formed in front of the mirror.
Step 5: Use the standard spherical mirror formula to solve for the focal length f:

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

$$\frac{1}{f} = \frac{1}{-60} + \frac{1}{-20} = \frac{-1-3}{60} = \frac{-4}{60} = \frac{-1}{15}$$

Taking the reciprocal yields $f = -15$ cm. The negative focal length confirms it is a concave mirror.

Final Answer: -15 cm

Answer: (A) Go Back to Question 12

Q13.

Solution

Concept:
Linear momentum (p) and kinetic energy (K) are core mechanical properties of a moving body. Linear momentum is defined as the product of mass and velocity ($p = mv$), while kinetic energy is defined as half the product of mass and the square of velocity ($K = \frac{1}{2}mv^2$). By algebraic manipulation, these two variables can be directly related through the mass (m) of the body using the formula: $K = \frac{p^2}{2m}$. Rearranging this equation expresses linear momentum as a function of kinetic energy and mass: $p = \sqrt{2mK}$.

Solution:
Step 1: Let the two bodies be labeled as Body 1 and Body 2. Their respective masses are given as $m_1 = 2$ kg and $m_2 = 8$ kg.
Step 2: The problem states that both bodies possess equal kinetic energies. Let this common kinetic energy value be represented by the variable K, so $K_1 = K_2 = K$.
Step 3: Write down the formula for the momentum of each body based on the relationship derived in the concept section:

$$p_1 = \sqrt{2m_1K}$$

$$p_2 = \sqrt{2m_2K}$$

Step 4: Set up the ratio of their linear momenta $\frac{p_1}{p_2}$ by dividing the two expressions:

$$\frac{p_1}{p_2} = \frac{\sqrt{2m_1K}}{\sqrt{2m_2K}} = \sqrt{\frac{m_1}{m_2}}$$

Notice that the common constants 2 and K cancel out completely from the numerator and denominator.
Step 5: Substitute the numerical values of the masses into the simplified ratio:

$$\frac{p_1}{p_2} = \sqrt{\frac{2\text{ kg}}{8\text{ kg}}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Thus, the ratio of their linear momenta is $1 : 2$.

Final Answer: $1 : 2$

Answer: (C) Go Back to Question 13

Q14.

Solution

Concept:
According to the kinetic theory of gases, the average translational kinetic energy of the molecules of an ideal gas is directly proportional to its absolute temperature measured on the Kelvin scale. The formula for the average kinetic energy of a molecule is given by $E = \frac{3}{2}k_BT$, where k_B is the Boltzmann constant and T is the absolute temperature in Kelvin. Crucially, Celsius temperature values must always be converted to the Kelvin scale by adding 273.15 (or 273 for standard approximations) before applying any gas laws.

Solution:
Step 1: Identify the initial and final temperatures given in the problem statement in degrees Celsius: initial temperature $\theta_1 = 27°\text{C}$ and final temperature $\theta_2 = 327°\text{C}$.
Step 2: Convert both temperatures into absolute temperatures on the Kelvin scale:

$$T_1 = 27 + 273 = 300 \text{ K}$$

$$T_2 = 327 + 273 = 600 \text{ K}$$

Step 3: Establish the proportional relationship between the average kinetic energy E and the absolute temperature T:

$$E \propto T \implies \frac{E_2}{E_1} = \frac{T_2}{T_1}$$

Step 4: Substitute the Kelvin temperature values into the ratio equation:

$$\frac{E_2}{E_1} = \frac{600 \text{ K}}{300 \text{ K}} = 2$$

Step 5: Interpret the mathematical result. Since the ratio $\frac{E_2}{E_1}$ is equal to 2, it means $E_2 = 2E_1$. Therefore, the average kinetic energy of the gas molecules is exactly doubled.

Final Answer: It is doubled

Answer: (B) Go Back to Question 14

Q15.

Solution

Concept:
The electrical resistance R of a conductor of uniform cross-sectional area is given by the formula $R = \rho\frac{l}{A}$, where ρ is the electrical resistivity of the material, l is the length of the conductor, and A is its cross-sectional area. When a wire is stretched uniformly, its length increases while its cross-sectional area decreases because the total volume $V = l \cdot A$ of the wire material must remain perfectly constant. Therefore, if the length is multiplied by a factor, the cross-sectional area must decrease by the exact same factor.

Solution:
Step 1: Let the initial length, cross-sectional area, and resistance of the wire be l_1, A_1, and $R_1 = R$ respectively. The initial resistance equation is:

$$R = \rho\frac{l_1}{A_1}$$

Step 2: The wire is stretched uniformly to double its original length, which means the new length is $l_2 = 2l_1$.
Step 3: Use the principle of conservation of volume ($V_1 = V_2$) to determine the new cross-sectional area A_2:

$$l_1A_1 = l_2A_2 \implies l_1A_1 = (2l_1)A_2$$

Canceling l_1 from both sides gives $A_2 = \frac{A_1}{2}$. The cross-sectional area is halved.
Step 4: Write down the expression for the new resistance R_2 after stretching:

$$R_2 = \rho\frac{l_2}{A_2}$$

Step 5: Substitute the expressions for l_2 and A_2 into the new resistance equation:

$$R_2 = \rho\frac{2l_1}{\frac{A_1}{2}} = \rho\frac{4l_1}{A_1} = 4\left(\rho\frac{l_1}{A_1}\right)$$

Since $\rho\frac{l_1}{A_1} = R$, we find $R_2 = 4R$. The new resistance is four times the original resistance.

Final Answer: $4R$

Answer: (C) Go Back to Question 15

Q16.

Solution

Concept:

When a wave (sound or light) travels from one medium into another, a phenomenon known as refraction occurs due to the difference in the propagation speed of the wave in different media. The velocity of a wave depends entirely on the physical properties of the medium through which it travels. The wavelength adjusts as the velocity changes to maintain the wave relationship $v = f\lambda$. Crucially, the frequency of a wave is determined solely by the source that creates the wave and does not depend on the medium. Therefore, frequency remains invariant during refraction.

Solution:

Step 1: Analyze what happens to a sound wave as it crosses the boundary from air into water. Sound is a mechanical longitudinal wave that travels faster in denser, more elastic media.

Step 2: Sound velocity in air is approximately 340 m/s, whereas its velocity in water is significantly higher, around 1500 m/s. Thus, the velocity v changes (increases).

Step 3: Examine the fundamental wave equation: $v = f\lambda$. Because the velocity v changes while the frequency f must stay constant, the wavelength λ must change proportionally.

Step 4: The amplitude of the wave also changes because some energy is reflected at the interface boundary, meaning only a fraction of the energy is transmitted into the new medium.

Step 5: Conclude that among the given parameters (velocity, wavelength, frequency, amplitude), frequency is the only property that is independent of the medium and remains completely unchanged.

Final Answer: Frequency

Answer: (C) Go Back to Question 16

Q17.

Solution

Concept:
This problem deals with uniformly accelerated linear motion. The equations of kinematics can be applied when acceleration is constant. To solve such problems, all physical quantities must first be converted into a consistent system of units, typically standard SI units (meters, seconds, kilograms). The conversion factor from kilometers per hour (km/h) to meters per second (m/s) is $\frac{5}{18}$. The distance covered s can be found using the kinematic equations, such as $v = u + at$ and $s = ut + \frac{1}{2}at^2$.

Solution:
Step 1: Identify the given values and convert them to standard SI units. The car starts from rest, so its initial velocity is $u = 0$ m/s. The time interval is $t = 10$ seconds.
Step 2: Convert the final velocity v from km/h to m/s:

$$v = 72 \text{ km/h} = 72 \times \frac{5}{18} \text{ m/s} = 4 \times 5 \text{ m/s} = 20 \text{ m/s}$$

Step 3: Calculate the uniform acceleration a using the first equation of motion:

$$v = u + at \implies 20 \text{ m/s} = 0 + a \times 10 \text{ s}$$

$$a = \frac{20}{10} \text{ m/s}^2 = 2 \text{ m/s}^2$$

Step 4: Calculate the total distance covered s using the second equation of motion:

$$s = ut + \frac{1}{2}at^2$$

Step 5: Substitute the numerical values into the distance equation:

$$s = (0 \times 10) + \frac{1}{2} \times 2 \text{ m/s}^2 \times (10 \text{ s})^2$$

$$s = 0 + \frac{1}{2} \times 2 \times 100 = 100 \text{ m}$$

Alternatively, using a velocity-time graph, the distance is the area of the triangle: $\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 10 \times 20 = 100$ m.

Final Answer: 100 m

Answer: (B) Go Back to Question 17

Q18.

Solution

Concept:
When two or more thin lenses are placed coaxially in direct physical contact with one another, the total equivalent focal length F of the lens combination can be determined by adding the reciprocal focal lengths of the individual lenses. This is expressed as $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$. Since the optical power P of a lens is defined as the reciprocal of its focal length in meters ($P = \frac{1}{f}$), the total power of the combination is simply the algebraic sum of the individual powers: $P_{\text{total}} = P_1 + P_2$. Sign conventions must be strictly followed: convex lenses have positive focal lengths, while concave lenses have negative focal lengths.

Solution:
Step 1: Assign the correct sign to the focal lengths based on the type of lens. For the convex lens, $f_1 = +20$ cm. For the concave lens, $f_2 = -25$ cm.
Step 2: Convert these focal lengths from centimeters to meters to calculate power in Diopters (D):

$$f_1 = +0.20 \text{ m}$$

$$f_2 = -0.25 \text{ m}$$

Step 3: Compute the individual optical power of each lens:

$$P_1 = \frac{1}{f_1} = \frac{1}{+0.20 \text{ m}} = +5 \text{ D}$$

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.25 \text{ m}} = -4 \text{ D}$$

Step 4: Use the power addition formula for thin lenses in contact to find the net power:

$$P_{\text{total}} = P_1 + P_2$$

Step 5: Substitute the individual power values into the equation:

$$P_{\text{total}} = (+5 \text{ D}) + (-4 \text{ D}) = +1.0 \text{ D}$$

The net power of this combination is $+1.0$ D.

Final Answer: $+1.0$ D

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept:

Galileo's historic principle of free fall states that in the absence of air resistance (i.e., in a perfect vacuum), all bodies independent of their mass, shape, size, or material composition experience the exact same acceleration due to gravity (g) at a given location. The motion of a freely falling body is governed by the equations of kinematics. For an object dropped from rest from a vertical height h, the time taken t to reach the ground is determined by the formula $h = \frac{1}{2}gt^2$, which simplifies to $t = \sqrt{\frac{2h}{g}}$.

Solution:

Step 1: Analyze the equations governing motion under gravity. When an object is dropped from rest, its initial velocity is $u = 0$ m/s.

Step 2: In a complete vacuum, there are no air molecules present to exert any upward aerodynamic drag or air resistance forces on the falling objects. Thus, gravity is the only force acting on them.

Step 3: Write down the expression for the time of fall derived from the second equation of motion:

$$t = \sqrt{\frac{2h}{g}}$$

Step 4: Examine the variables present in this mathematical formula. The time of fall t depends exclusively on the initial release height h and the local acceleration due to gravity g.

Step 5: Notice that the mass (m) of the falling object does not appear anywhere in the formula. Since both the light body and the heavy body are dropped from the same height h with the same acceleration g, they will take the exact same time to fall and will reach the ground simultaneously.

Final Answer: Both will reach the ground at the exact same time

Answer: (C) Go Back to Question 19

Q20.

Solution

Concept:
The electrical energy consumed by an appliance depends on its power rating and the total duration for which it is operated. Electrical power P is calculated as the product of the operating voltage V and the current draw I, given by $P = VI$. The commercial unit of electrical energy is the kilowatt-hour (kWh), often referred to as a "unit" of electricity. Total energy consumption in kWh is calculated by multiplying the power in kilowatts (kW) by the total operating time in hours. The total cost is then found by multiplying the total units consumed by the rate per unit.

Solution:
Step 1: Calculate the electrical power rating P of the kettle using the voltage and current values provided:

$$P = V \times I = 220 \text{ V} \times 5 \text{ A} = 1100 \text{ Watts}$$

Step 2: Convert the power from Watts to kilowatts (kW) by dividing by 1000:

$$P = \frac{1100}{1000} \text{ kW} = 1.1 \text{ kW}$$

Step 3: Calculate the total operating hours t over the 30-day period. The kettle is used for 2 hours every day:

$$\text{Total time } t = 2 \text{ hours/day} \times 30 \text{ days} = 60 \text{ hours}$$

Step 4: Compute the total electrical energy consumed E in commercial units (kWh):

$$E = \text{Power (in kW)} \times \text{Time (in hours)}$$

$$E = 1.1 \text{ kW} \times 60 \text{ hours} = 66 \text{ kWh (units)}$$

Step 5: Determine the total cost of this energy consumption at the specified financial rate of Rs. 5 per kWh:

$$\text{Total Cost} = 66 \text{ units} \times \text{Rs. } 5 = \text{Rs. } 330$$

The total operating cost for 30 days is Rs. 330.

Final Answer: Rs. 330

Answer: (A) Go Back to Question 20

Q21.

Solution

Concept:
An ideal gas is a theoretical gas model whose molecules experience perfectly elastic collisions and have no intermolecular attractive forces between them. In reality, real gas molecules do possess finite volumes and exert intermolecular van der Waals attractive forces on each other. A real gas behaves closest to an ideal gas under specific physical conditions that minimize these intermolecular forces and make the molecular volume negligible compared to the total volume of the container.

Solution:
Step 1: Analyze the effect of temperature on gas molecules. At very high temperatures, the thermal kinetic energy of the gas molecules is extremely large ($\frac{3}{2}k_B T$).
Step 2: Because the molecules are moving at high speeds, they can easily overcome any mutual intermolecular attractive forces during interactions, making these forces negligible.
Step 3: Analyze the effect of pressure on gas molecules. At very low pressures, the total volume occupied by the gas is very large.
Step 4: When the container volume is extremely large, the actual physical volume of the individual gas molecules becomes completely negligible in comparison to the total empty space.
Step 5: Combine these observations. High temperature minimizes the impact of intermolecular forces, and low pressure minimizes the volume fraction of the molecules. Therefore, a real gas behaves most like an ideal gas under conditions of high temperature and low pressure.

Final Answer: High temperature and low pressure

Answer: (C) Go Back to Question 21

Q22.

Solution

Concept:
This mechanics problem involves motion with uniform deceleration as a projectile is brought to a stop inside a medium. The distance covered s during a uniform deceleration process can be found using fundamental kinematics equations. If an object with an initial velocity u slows down uniformly and comes to a complete rest ($v = 0$) in a time interval t, its average velocity during this period is simply given by $v_{\text{avg}} = \frac{u+v}{2}$. The total displacement is then the product of this average velocity and the elapsed time: $s = v_{\text{avg}} \cdot t = \frac{(u+v)t}{2}$.

Solution:
Step 1: Extract the given physical parameters from the problem text: initial velocity of the bullet $u = 150$ m/s, final velocity $v = 0$ m/s (since it comes to rest), and time duration $t = 0.05$ seconds. Note that the mass of the bullet (20 g) is extra information not required to find the distance.
Step 2: Write down the kinematic expression for distance based on average velocity:

$$s = \left(\frac{u+v}{2}\right) \times t$$

Step 3: Substitute the numerical values of velocity and time into this equation:

$$s = \left(\frac{150 \text{ m/s} + 0 \text{ m/s}}{2}\right) \times 0.05 \text{ s}$$

Step 4: Simplify the term inside the parentheses:

$$s = 75 \times 0.05$$

Step 5: Calculate the final numerical value:

$$s = 3.75 \text{ m}$$

Alternatively, one can first find the deceleration $a = \frac{0-150}{0.05} = -3000 \text{ m/s}^2$, and then use $v^2 - u^2 = 2as \implies 0 - (150)^2 = 2(-3000)s \implies 22500 = 6000s \implies s = 3.75$ m.

Final Answer: 3.75 m

Answer: (B) Go Back to Question 22

Q23.

Solution

Concept:

Radioactive decay follows a statistical exponential decay law. The half-life ($T_{1/2}$) of a radioactive isotope is defined as the time duration required for exactly half of the initial unstable active parent nuclei to undergo decay. After each successive half-life period, the number of remaining un-decayed nuclei is halved again. If N_0 represents the initial number of undecayed nuclei, the number of active nuclei N left after n half-lives can be calculated using the fractional power formula: $N = N_0 \left(\frac{1}{2}\right)^n$. The remaining fraction is $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$.

Solution:

Step 1: Identify the given values: the half-life of the radioactive substance is $T_{1/2} = 10$ days. The total elapsed decay time is $t = 40$ days.

Step 2: Determine the total number of half-life cycles n that occur during this time frame:

$$n = \frac{\text{Total time } (t)}{\text{Half-life } (T_{1/2})} = \frac{40 \text{ days}}{10 \text{ days}} = 4 \text{ half-lives}$$

Step 3: Write down the decay fraction formula that describes the remaining un-decayed nuclei:

$$\text{Fraction remaining} = \frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

Step 4: Substitute the value $n = 4$ into this expression:

$$\text{Fraction remaining} = \left(\frac{1}{2}\right)^4$$

Step 5: Expand the exponential term to find the fraction:

$$\text{Fraction remaining} = \frac{1}{2 \times 2 \times 2 \times 2} = \frac{1}{16}$$

Therefore, after 40 days, exactly $1/16$ of the original active nuclei remain un-decayed.

Final Answer: $1/16$

Answer: (C) Go Back to Question 23

Q24.

Solution

Concept:
A convex mirror is a diverging spherical mirror. Regardless of where an object is placed in front of it, a convex mirror always forms a virtual, erect, and diminished image behind the mirror. According to standard Cartesian sign conventions, the object distance u is negative because it is measured against the direction of the incident light, while the focal length f of a convex mirror is positive. The positions of the object and image are related by the mirror formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$.

Solution:
Step 1: Apply Cartesian sign conventions to the given values. The object is placed in front of the mirror, so $u = -15$ cm. The mirror is convex, so its focal length is $f = +30$ cm.
Step 2: Write down the standard mirror formula:

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

Step 3: Rearrange the formula to solve for the reciprocal image distance $\frac{1}{v}$:

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

Step 4: Substitute the numerical values into this equation:

$$\frac{1}{v} = \frac{1}{30} - \frac{1}{-15} = \frac{1}{30} + \frac{1}{15}$$

Find a common denominator, which is 30:

$$\frac{1}{v} = \frac{1+2}{30} = \frac{3}{30} = \frac{1}{10}$$

Taking the reciprocal gives $v = +10$ cm.
Step 5: Interpret the final result. The positive sign indicates that the image is formed at a distance of 10 cm behind the mirror. Since it is formed behind the mirror by diverging rays, its nature is virtual and erect.

Final Answer: Virtual, erect and at 10 cm behind the mirror

Answer: (B) Go Back to Question 24

Q25.

Solution

Concept:
An elastic collision is an encounter between two bodies in which both total linear momentum and total kinetic energy are perfectly conserved. For a one-dimensional head-on elastic collision between two bodies of masses m_1 and m_2 with initial velocities u_1 and u_2, the final velocities v_1 and v_2 can be derived using conservation laws. A notable physical property of elastic collisions is that when two bodies of identical mass $(m_1 = m_2)$ collide elastically, they completely exchange their velocities after the impact.

Solution:
Step 1: Identify the given mass and velocity conditions. The two bodies have identical masses, so $m_1 = m_2 = m$.
Step 2: Set up the initial velocity parameters based on the problem statement. The first body is moving with an initial velocity $u_1 = u$, and the second body is stationary, meaning $u_2 = 0$.
Step 3: Recall the final velocity formulas for a one-dimensional elastic collision:

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1 + \left(\frac{2m_2}{m_1 + m_2}\right) u_2$$

$$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right) u_1 + \left(\frac{m_2 - m_1}{m_1 + m_2}\right) u_2$$

Step 4: Substitute the conditions $m_1 = m_2 = m$ into the formula for v_1:

$$v_1 = \left(\frac{m - m}{m + m}\right) u + \left(\frac{2m}{m + m}\right) (0) = 0$$

Thus, the moving body comes to a complete stop.
Step 5: Substitute the same conditions into the formula for v_2:

$$v_2 = \left(\frac{2m}{m + m}\right) u + \left(\frac{m - m}{m + m}\right) (0) = \left(\frac{2m}{2m}\right) u = u$$

The stationary body begins to move with the exact initial velocity of the first body. The velocities are completely exchanged.

Final Answer: The moving body stops completely and the stationary body moves with the initial velocity of the first body

Answer: (A)

Go Back to Question 25

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	C	4	B	5	B
6	C	7	C	8	A	9	B	10	C
11	B	12	A	13	C	14	B	15	C
16	C	17	B	18	A	19	C	20	A
21	C	22	B	23	C	24	B	25	A