JEECUP Group A Physics Sample Paper – 17

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 standing between two vertical cliffs fires a gun and hears the first echo after 1.5 seconds and the second echo after 2.5 seconds. If the speed of sound in air is 340 m/s, the distance between the two cliffs is:

(A) 680 m

(B) 510 m

(C) 1360 m

(D) 425 m

Q2. A circuit consists of a liquid resistor of resistance R connected to a constant voltage source. If the distance between the electrodes in the liquid is doubled while keeping their cross-sectional area the same, the current flowing through the circuit becomes:

(A) Double

(B) Half

(C) Four times

(D) One-fourth

Q3. A ray of light passes from vacuum into a medium of refractive index μ.

If the angle of incidence is twice the angle of refraction, then the angle of incidence is:

(A) $\cos^{-1}\left(\frac{\mu}{2}\right)$

(B) $2\cos^{-1}\left(\frac{\mu}{2}\right)$

(C) $2\sin^{-1}\left(\frac{\mu}{2}\right)$

(D) $\sin^{-1}\left(\frac{\mu}{2}\right)$

Q4. A bullet of mass 20 g moving with a speed of 100 m/s penetrates a sandbag and comes to rest in 0.05 seconds. The average retarding force exerted by the sand on the bullet is:

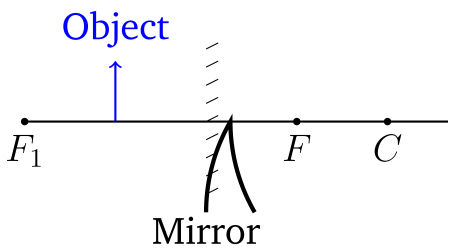
(A) 20 N

(B) 40 N

(C) 100 N

(D) 200 N

Q5. An object is placed at a distance of 15 cm from a convex mirror of focal length 30 cm. The image formed by the mirror is:



(A) Real, inverted and magnified

(B) Virtual, upright and diminished

(C) Virtual, upright and magnified

(D) Real, inverted and diminished

Q6. A radioactive sample has a half-life of 4 hours. If the initial mass of the sample is 200 g, the mass of the sample left undecayed after 12 hours will be:

(A) 50 g

(B) 25 g

(C) 12.5 g

(D) 6.25 g

Q7. An electric kettle rated at 220 V, 2.2 kW operates for 3 hours daily. The electrical energy consumed by the kettle in the month of April (30 days) is:

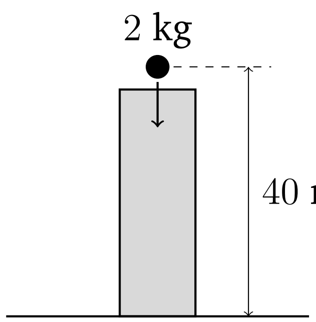
(A) 198 kWh

(B) 6.6 kWh

(C) 66 kWh

(D) 19.8 kWh

Q8. A body of mass 2 kg is dropped from a tower of height 40 m. After falling for 2 seconds, its kinetic energy will be (take $g = 10$ m/s^2):



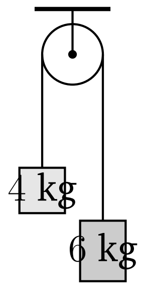
(A) 400 J

(B) 200 J

(C) 800 J

(D) 100 J

Q9. Two blocks of masses 4 kg and 6 kg are connected by a light string passing over a smooth, frictionless pulley. The acceleration of the system when released from rest is (take $g = 10$ m/s^2):



(A) $1\ m/s^2$

(B) $2\ m/s^2$

(C) $4\ m/s^2$

(D) $5\ m/s^2$

Q10. At what temperature will the reading on the Fahrenheit scale be exactly double the reading on the Celsius scale?

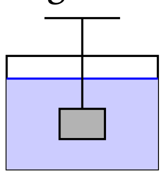
(A) $40°C$

(B) $160°C$

(C) $-40°C$

(D) $80°C$

Q11. A piece of metal weighs 50 g in air and 40 g in water. The relative density of the metal is:



(A) 2.5

(B) 4.0

(C) 5.0

(D) 1.25

Q12. A concave lens of focal length 20 cm forms an image at a distance of 10 cm from the lens. The distance of the object from the lens is:

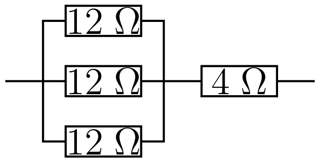
(A) 20 cm

(B) 10 cm

(C) 30 cm

(D) 40 cm

Q13. Three identical resistors, each of resistance $12\ \Omega$, are connected in parallel. This combination is then connected in series with a $4\ \Omega$ resistor. The equivalent resistance of the complete network is:



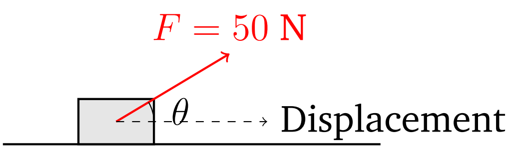
(A) $8\ \Omega$

(B) $40\ \Omega$

(C) $16\ \Omega$

(D) $6\ \Omega$

Q14. A constant force of 50 N shifts a block by 5 m along a horizontal surface. If the work done by this force is 125 J, the angle between the force and the direction of motion is:



(A) $30°$

(B) $45°$

(C) $60°$

(D) $90°$

Q15. During a nuclear β^- (beta minus) decay process:

(A) The mass number increases by 1 while the atomic number remains the same

(B) The atomic number increases by 1 while the mass number remains the same

(C) Both atomic number and mass number decrease by 1

(D) The atomic number decreases by 1 while the mass number remains the same

Q16. A sound wave travelling in air has a wavelength of 20 cm. If the velocity of sound in air is 340 m/s, the frequency of this wave is:

(A) 1700 Hz

(B) 68 Hz

(C) 6800 Hz

(D) 170 Hz

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

(A) 200 m

(B) 100 m

(C) 720 m

(D) 360 m

Q18. Equal masses of two liquids A and B at temperatures $20°$C and $40°$C are mixed together. If the final steady temperature of the mixture is $32°$C, the ratio of their specific heat capacities ($C_A : C_B$) is:

(A) $2 : 3$

(B) $3 : 2$

(C) $1 : 2$

(D) $2 : 1$

Q19. When a certain amount of ice at $0°$C melts completely into water at $0°$C, the density of the substance:

(A) Decreases

(B) Increases

(C) Remains exactly the same

(D) First decreases then increases

Q20. Two copper wires have lengths in the ratio $1 : 2$ and radii in the ratio $2 : 1$. The ratio of their electrical resistances ($R_1 : R_2$) will be:

(A) $1 : 4$

(B) $1 : 8$

(C) $1 : 2$

(D) $8 : 1$

Q21. An engine pumps 600 kg of water per minute from a well 20 m deep. The power of the engine is (take $g = 10$ m/s^2):

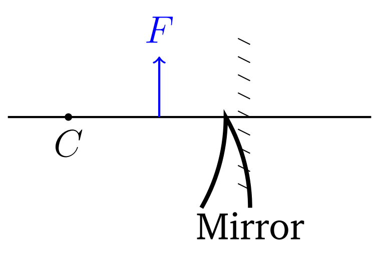
(A) 1.2 kW

(B) 2.0 kW

(C) 12 kW

(D) 120 kW

Q22. An object is placed at the principal focus of a concave mirror. The position of the image formed by the mirror will be:



(A) At the center of curvature

(B) Between focus and center of curvature

(C) At infinity

(D) Behind the mirror

Q23. A constant current flows through a metallic wire. The heat developed in the wire due to the passage of current is directly proportional to:

(A) The square root of the time duration

(B) The time duration of the current flow

(C) The inverse of the time duration

(D) The square of the time duration

Q24. A swimmer jumps into a swimming pool. As he goes deeper into the pool, the buoyant force acting on him:

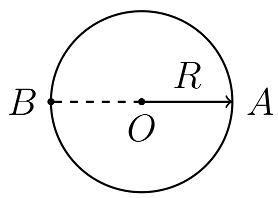
(A) Increases continuously

(B) Decreases continuously

(C) Remains constant once he is completely submerged

(D) Becomes zero

Q25. A particle travels along a circular path of radius R. After completing two and a half revolutions, the magnitude of the displacement of the particle is:



(A) $5\pi R$

(B) $2\pi R$

(C) $2R$

(D) Zero

Detailed Solutions

Q1.

Solution

Concept: The problem is based on the phenomenon of echoes in sound waves. When a sound is produced between two barriers, it travels in opposite directions, reflects off the surfaces, and returns to the source. The time taken to hear an echo is the total time required for the sound wave to travel to the reflecting surface and back.

Solution: Step 1: Let the person stand between two cliffs, Cliff 1 and Cliff 2. Let the distance from the person to Cliff 1 be d_1 and the distance to Cliff 2 be d_2. The total distance between the two cliffs will be $D = d_1 + d_2$. Step 2: The first echo is heard from the closer cliff, Cliff 1, after a time interval $t_1 = 1.5$ seconds. The sound travels to the cliff and back, covering a distance of $2d_1$. Using the speed of sound $v = 340$ m/s, we can set up the equation:

$$2d_1 = v \times t_1$$

$$2d_1 = 340 \times 1.5$$

$$2d_1 = 510$$

$$d_1 = 255 \text{ m}$$

Step 3: The second echo is heard from the farther cliff, Cliff 2, after a time interval $t_2 = 2.5$ seconds. The sound covers a round-trip distance of $2d_2$. Using the same velocity formula, we can write:

$$2d_2 = v \times t_2$$

$$2d_2 = 340 \times 2.5$$

$$2d_2 = 850$$

$$d_2 = 425 \text{ m}$$

Step 4: Now, to find the total distance D between the two vertical cliffs, we sum the individual distances calculated from the person to each cliff:

$$D = d_1 + d_2$$

$$D = 255 + 425 = 680 \text{ m}$$

Step 5: Alternatively, the total distance can be found directly by adding the two echo times, since the total distance traveled by both individual sound waves combined is $2(d_1 + d_2) = v(t_1 + t_2)$. This yields $2D = 340 \times (1.5 + 2.5) = 340 \times 4 = 1360$ m, which gives $D = 680$ m.

Final Answer: 680 m

Answer: (A) Go Back to Question 1

Q2.

Solution

Concept: The electrical resistance R of a conductor or electrolytic solution depends on its intrinsic properties and geometry. It is directly proportional to its length L and inversely proportional to its cross-sectional area A, governed by the formula $R = \rho\frac{L}{A}$, where ρ is the resistivity. According to Ohm's law, the current I flowing through a circuit is inversely proportional to the total resistance when connected to a constant voltage source ($I = \frac{V}{R}$).

Solution: Step 1: Write down the initial expression for the resistance of the liquid medium between the two electrodes. Let the initial distance between the electrodes be L and the cross-sectional area be A. The initial resistance is:

$$R_1 = \rho\frac{L}{A}$$

Step 2: According to the problem statement, the distance between the electrodes is doubled, so the new length becomes $L' = 2L$. The cross-sectional area remains unchanged, so $A' = A$. The material remains the same, meaning the resistivity ρ is constant.

Step 3: Calculate the new resistance R_2 using the modified parameters:

$$R_2 = \rho\frac{L'}{A'} = \rho\frac{2L}{A} = 2\left(\rho\frac{L}{A}\right) = 2R_1$$

Thus, doubling the distance between the plates doubles the electrical resistance of the liquid resistor.

Step 4: Analyze the impact on the electric current using Ohm's law. The circuit is connected to a constant voltage source V. The initial current is $I_1 = \frac{V}{R_1}$. The new current I_2 after the modification is:

$$I_2 = \frac{V}{R_2} = \frac{V}{2R_1} = \frac{1}{2}I_1$$

Therefore, the current flowing through the circuit becomes exactly half of its initial value.

Final Answer: Half

Answer: (B) Go Back to Question 2

Q3.

Solution

Concept: This problem involves light refraction at the boundary of a medium, which is governed by Snell's Law. Snell's Law states that the ratio of the sine of the angle of incidence i to the sine of the angle of refraction r is equal to the refractive index of the second medium with respect to the first medium. Mathematically, $\frac{\sin i}{\sin r} = \mu$ when light travels from a vacuum or air into a medium. Trigonometric identity $\sin(2\theta) = 2\sin\theta\cos\theta$ is required to solve the equation.

Solution: Step 1: State the given condition from the question. The angle of incidence i is twice the angle of refraction r. Therefore, we can express this relationship as:

$$i = 2r \implies r = \frac{i}{2}$$

Step 2: Apply Snell's Law for the ray of light passing from vacuum (refractive index $= 1$) into the medium of refractive index μ:

$$\frac{\sin i}{\sin r} = \mu$$

Step 3: Substitute the value of $i = 2r$ into Snell's Law expression:

$$\frac{\sin(2r)}{\sin r} = \mu$$

Step 4: Use the double-angle trigonometric identity $\sin(2r) = 2\sin r\cos r$ to expand the numerator:

$$\frac{2\sin r\cos r}{\sin r} = \mu$$

Assuming $r \neq 0$, we can cancel $\sin r$ from both the numerator and the denominator:

$$2\cos r = \mu \implies \cos r = \frac{\mu}{2}$$

Step 5: Express r in terms of an inverse trigonometric function, and then find the angle of incidence i:

$$r = \cos^{-1}\left(\frac{\mu}{2}\right)$$

Since the question asks for the angle of incidence i, and we know $i = 2r$, we multiply by 2:

$$i = 2\cos^{-1}\left(\frac{\mu}{2}\right)$$

Final Answer: $\boxed{2\cos^{-1}\left(\frac{\mu}{2}\right)}$

Answer: (B) Go Back to Question 3

Q4.

Solution

Concept: The question is based on Newton's Second Law of Motion and the impulse-momentum theorem. The average retarding force acting on an object is equal to the rate of change of momentum of the object ($F = \frac{\Delta p}{\Delta t} = \frac{m(v-u)}{t}$). Alternatively, one can compute the uniform deceleration using the first equation of motion ($v = u + at$) and then determine the force using $F = ma$.

Solution: Step 1: Convert all the given physical quantities into standard SI units. Mass of the bullet, $m = 20\text{ g} = \frac{20}{1000}\text{ kg} = 0.02\text{ kg}$ Initial velocity of the bullet, $u = 100\text{ m/s}$ Final velocity of the bullet, $v = 0\text{ m/s}$ (since it comes to rest) Time taken to stop, $t = 0.05$ seconds

Step 2: Calculate the acceleration a of the bullet using the first kinematic equation of motion:

$$v = u + at$$

$$0 = 100 + a(0.05)$$

$$-100 = 0.05a$$

$$a = -\frac{100}{0.05} = -2000\text{ m/s}^2$$

The negative sign indicates a retardation or deceleration experienced by the bullet.

Step 3: Use Newton's Second Law of Motion to find the magnitude of the average retarding force F:

$$F = m \times |a|$$

$$F = 0.02\text{ kg} \times 2000\text{ m/s}^2$$

$$F = 2 \times 20 = 40\text{ N}$$

Thus, the average opposing force exerted by the sandbag on the bullet is 40 N.

Final Answer: 40 N

Answer: (B) Go Back to Question 4

Q5.

Solution

Concept: This problem relates to the reflection of light by spherical mirrors. A convex mirror is a diverging mirror. According to the properties of convex mirrors, for any real object placed at any position in front of the mirror, the image formed is always virtual, erect (upright), and diminished in size. We can verify this mathematically using the mirror formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ and the magnification formula $m = -\frac{v}{u}$.

Solution: Step 1: Identify the values along with their proper signs using the standard Cartesian sign convention. Object distance, $u = -15$ cm (measured against the direction of incident light) Focal length of a convex mirror is always positive, so $f = +30$ cm Step 2: Apply the standard mirror formula to determine the image distance v:

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

$$\frac{1}{30} = \frac{1}{v} + \left(\frac{1}{-15}\right)$$

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

Step 3: Rearrange the terms to isolate $\frac{1}{v}$:

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

Take the least common multiple (LCM) of 30 and 15, which is 30:

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

$$v = +10 \text{ cm}$$

The positive sign of v establishes that the image is formed behind the mirror, meaning it is a virtual image. Virtual images are always upright. Step 4: Calculate the linear magnification m to verify the size of the image:

$$m = -\frac{v}{u} = -\frac{10}{-15} = +\frac{2}{3}$$

Since the absolute value of magnification $|m| = \frac{2}{3} < 1$, the image is diminished. The positive sign indicates that the image is upright. Thus, the image is virtual, upright, and diminished.

Final Answer: Virtual, upright and diminished

Answer: (B) Go Back to Question 5

Q6.

Solution

Concept: The decay of a radioactive material follows the law of radioactive disintegration. The half-life ($T_{1/2}$) is the time duration required for a given quantity of a radioactive substance to reduce to exactly half of its initial value. The remaining mass M after n half-lives can be computed using the relation $M = M_0\left(\frac{1}{2}\right)^n$, where M_0 is the initial mass and $n = \frac{t}{T_{1/2}}$ represents the total number of elapsed half-lives.

Solution: Step 1: Note down the given parameters from the question statement. Initial mass of the radioactive sample, $M_0 = 200$ g Half-life of the sample, $T_{1/2} = 4$ hours Total time elapsed for decay, $t = 12$ hours

Step 2: Determine the total number of half-lives (n) that occur during the given time interval of 12 hours:

$$n = \frac{\text{Total time } (t)}{\text{Half-life } (T_{1/2})}$$

$$n = \frac{12}{4} = 3$$

This means the sample undergoes three consecutive divisions by half.

Step 3: Calculate the mass of the remaining undecayed sample (M) after 3 half-lives using the standard exponential decay formula:

$$M = M_0\left(\frac{1}{2}\right)^n$$

$$M = 200 \times \left(\frac{1}{2}\right)^3$$

$$M = 200 \times \frac{1}{8}$$

Step 4: Perform the final division:

$$M = \frac{200}{8} = 25 \text{ g}$$

Thus, after 12 hours, the mass of the sample left undecayed is exactly 25 g.

Final Answer: 25 g

Answer: (B) Go Back to Question 6

Q7.

Solution

Concept: Electrical energy consumption is calculated as the product of the power rating of an appliance and the total time duration for which it is operated. The commercial unit of electrical energy is the kilowatt-hour (kWh), often referred to as a 'unit'. Mathematically, Energy (kWh) $=$ Power (kW) $\times$ Time (hours). To find the total monthly consumption, this daily energy value must be multiplied by the total number of operational days in that specific month.

Solution: Step 1: Extract the given specifications of the electric kettle from the text. Power rating, $P = 2.2$ kW Daily usage time, $t = 3$ hours Month specified: April, which contains exactly 30 days.

Step 2: Calculate the electrical energy consumed by the kettle in a single day:

$$\text{Daily Energy} = \text{Power (kW)} \times \text{Time (hours)}$$

$$\text{Daily Energy} = 2.2 \text{ kW} \times 3 \text{ hours} = 6.6 \text{ kWh}$$

Step 3: Determine the total electrical energy consumed during the entire month of April by multiplying the daily consumption by the number of days in the month (30 days):

$$\text{Total Energy} = \text{Daily Energy} \times \text{Number of days}$$

$$\text{Total Energy} = 6.6 \text{ kWh/day} \times 30 \text{ days}$$

Step 4: Perform the arithmetic multiplication:

$$\text{Total Energy} = 6.6 \times 30 = 66 \text{ kWh}$$

Hence, the total electrical energy consumed by the kettle in the month of April is 66 kWh.

Final Answer: 66 kWh

Answer: (C) Go Back to Question 7

Q8.

Solution

Concept: The question is based on the laws of motion under gravity and the concept of kinetic energy. When an object is dropped from a certain height, its initial velocity u is zero. As it falls freely under the influence of gravity, its velocity increases uniformly. The velocity v after a time t is given by $v = u + gt$. The kinetic energy (KE) possessed by the moving body is calculated using the formula $\text{KE} = \frac{1}{2}mv^2$.

Solution: Step 1: List the values given in the problem statement. Mass of the body, $m = 2$ kg Initial velocity, $u = 0$ m/s (since it is dropped) Time of fall, $t = 2$ seconds Acceleration due to gravity, $g = 10$ m/s^2 The height of the tower is 40 m, but we must verify if the body has reached the ground within 2 seconds. The distance fallen in 2 seconds is $h = \frac{1}{2}gt^2 = \frac{1}{2}(10)(2)^2 = 20$ m. Since 20 m < 40 m, the body is still in free fall.

Step 2: Find the final velocity v of the body after it has been falling for 2 seconds using the first equation of motion:

$$v = u + gt$$

$$v = 0 + (10 \times 2)$$

$$v = 20 \text{ m/s}$$

Step 3: Use the velocity value to determine the kinetic energy of the body at that particular instant:

$$\text{KE} = \frac{1}{2}mv^2$$

$$\text{KE} = \frac{1}{2} \times 2 \text{ kg} \times (20 \text{ m/s})^2$$

Step 4: Simplify the expression:

$$\text{KE} = 1 \times 400 = 400 \text{ J}$$

Therefore, the kinetic energy of the body after falling for 2 seconds is 400 J.

Final Answer: 400 J

Answer: (A) Go Back to Question 8

Q9.

Solution

Concept: This problem involves an Atwood machine, which consists of two masses connected by an inextensible string over a frictionless pulley. Newton's Second Law of Motion ($F_{\text{net}} = ma$) is applied to each block independently to set up a system of equations. Alternatively, the acceleration a of such a system can be found directly using the net pulling force divided by the total mass: $a = \frac{(m_2 - m_1)g}{m_1 + m_2}$, where $m_2 > m_1$.

Solution: Step 1: Identify the masses given in the problem. Mass of the lighter block, $m_1 = 4$ kg Mass of the heavier block, $m_2 = 6$ kg Acceleration due to gravity, $g = 10$ m/s^2

Step 2: Understand the forces acting on the system. The heavier mass m_2 moves downwards with an acceleration a, while the lighter mass m_1 moves upwards with the same acceleration a. The net pulling force causing the motion is the difference between their weights.

Step 3: Use the direct system equation for acceleration to find a:

$$a = \frac{\text{Net Pulling Force}}{\text{Total Mass}}$$

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

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

Step 4: Substitute the given numerical values into the formula:

$$a = \frac{(6 - 4) \times 10}{4 + 6}$$

$$a = \frac{2 \times 10}{10}$$

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

Thus, the uniform acceleration of the system when released from rest is 2 m/s^2.

Final Answer: 2 m/s^2

Answer: (B) Go Back to Question 9

Q10.

Solution

Concept: Temperature conversion between the Celsius scale (C) and the Fahrenheit scale (F) is governed by the standard linear relationship derived from their respective freezing and boiling points of water. This conversion formula is given by $\frac{C}{5} = \frac{F-32}{9}$ or equivalently $F = \frac{9}{5}C + 32$. We can find the required temperature by substituting the algebraic constraint given in the problem into this relation.

Solution: Step 1: State the mathematical condition given in the problem. The reading on the Fahrenheit scale is exactly twice the reading on the Celsius scale. This can be written as:

$$F = 2C$$

Step 2: Recall the standard relationship formula connecting the two temperature scales:

$$F = \frac{9}{5}C + 32$$

Step 3: Substitute $F = 2C$ into the conversion equation to eliminate F and solve for C:

$$2C = \frac{9}{5}C + 32$$

Step 4: Rearrange the equation by moving all terms involving C to the left-hand side:

$$2C - \frac{9}{5}C = 32$$

Take the common denominator on the left side:

$$\frac{10C - 9C}{5} = 32$$

$$\frac{C}{5} = 32$$

Step 5: Solve for C by multiplying both sides by 5:

$$C = 32 \times 5 = 160$$

Thus, the temperature is $160°$C. We can verify that at this point, the Fahrenheit value is $2 \times 160 = 320°$F.

Final Answer: 160°C

Answer: (B) Go Back to Question 10

Q11.

Solution

Concept: This problem is based on Archimedes' Principle and the concept of relative density. Archimedes' principle states that when a body is partially or fully immersed in a fluid, it experiences an upward buoyant force (upthrust) equal to the weight of the fluid displaced by it. The apparent loss of weight of the body in water is equal to this upthrust. Relative density (RD) of a solid is defined as the ratio of its weight in air to the loss of weight in water: $\text{RD} = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}$.

Solution: Step 1: Note down the given weight data from the problem description. Weight of the metal piece in air, $W_{\text{air}} = 50$ g Weight of the metal piece in water, $W_{\text{water}} = 40$ g

Step 2: Compute the apparent loss of weight of the metal piece when it is completely submerged in water:

$$\text{Loss of weight} = W_{\text{air}} - W_{\text{water}}$$

$$\text{Loss of weight} = 50 \text{ g} - 40 \text{ g} = 10 \text{ g}$$

According to Archimedes' principle, this loss of weight is exactly equal to the weight of the water displaced by the metal piece.

Step 3: Calculate the relative density (RD) of the metal using the standard formula:

$$\text{Relative Density} = \frac{\text{Weight in air}}{\text{Loss of weight in water}}$$

$$\text{Relative Density} = \frac{50 \text{ g}}{10 \text{ g}}$$

Step 4: Simplify the division to find the final dimensionless ratio:

$$\text{Relative Density} = 5$$

Hence, the relative density of the metal piece is 5.0.

Final Answer: 5.0

Answer: (C) Go Back to Question 11

Q12.

Solution

Concept: This problem involves the refraction of light through a thin spherical lens. We apply the standard lens formula, which states $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, where f is the focal length, v is the image distance, and u is the object distance. A concave lens is a diverging lens, and its focal length is always taken as negative. It always forms a virtual image on the same side as the object, meaning the image distance v must also be negative.

Solution: Step 1: Write down the given numbers with their proper signs according to the Cartesian sign convention. Focal length of the concave lens, $f = -20$ cm Image distance, $v = -10$ cm (since a concave lens forms a virtual image on the object side)

Step 2: Substitute these values into the lens formula:

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

$$\frac{1}{-20} = \frac{1}{-10} - \frac{1}{u}$$

$$-\frac{1}{20} = -\frac{1}{10} - \frac{1}{u}$$

Step 3: Rearrange the terms to isolate the unknown variable fraction $\frac{1}{u}$ on one side:

$$\frac{1}{u} = -\frac{1}{10} + \frac{1}{20}$$

Step 4: Find a common denominator to compute the fraction subtraction:

$$\frac{1}{u} = \frac{-2+1}{20}$$

$$\frac{1}{u} = -\frac{1}{20}$$

$$u = -20 \text{ cm}$$

The negative sign indicates that the object is placed in front of the lens. The magnitude of the object distance is 20 cm.

Final Answer: 20 cm

Answer: (A) Go Back to Question 12

Q13.

Solution

Concept: This problem involves combining electrical resistors in both parallel and series configurations. When n identical resistors each of resistance R are connected in parallel, their equivalent resistance R_p is given by $R_p = \frac{R}{n}$. When resistors are connected in series, their individual resistances are directly added to get the total equivalent resistance ($R_s = R_p + R_{\text{series}}$).

Solution: Step 1: Analyze the first part of the circuit network. There are three identical resistors connected in parallel, each having a value of $R = 12\ \Omega$. The number of resistors is $n = 3$.

Step 2: Calculate the equivalent resistance R_p of this parallel combination using the parallel combination rule:

$$\frac{1}{R_p} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} = \frac{3}{12} = \frac{1}{4}$$

$$R_p = 4\ \Omega$$

Alternatively, using the shorthand for identical resistors: $R_p = \frac{12}{3} = 4\ \Omega$.

Step 3: Analyze the second part of the circuit. This parallel combination group (which acts as a single resistor of $4\ \Omega$) is connected in series with another resistor of value $R_{\text{series}} = 4\ \Omega$.

Step 4: Find the final total equivalent resistance R_{eq} of the entire combination by adding the series values:

$$R_{\text{eq}} = R_p + R_{\text{series}}$$

$$R_{\text{eq}} = 4\ \Omega + 4\ \Omega = 8\ \Omega$$

The equivalent resistance of the complete network is $8\ \Omega$.

Final Answer: $8\ \Omega$

Answer: (A) Go Back to Question 13

Q14.

Solution

Concept: Work done W by a constant force F displacing an object by a distance d is defined mathematically as the dot product of the force vector and the displacement vector. The formula is written as $W = F \cdot d \cdot \cos\theta$, where θ is the angle between the direction of the force and the direction of displacement. We can determine the value of θ by isolating $\cos\theta$ and using inverse trigonometric relationships.

Solution: Step 1: Write down the known values given in the problem statement. Magnitude of the applied force, $F = 50$ N Displacement of the block, $d = 5$ m Total work done by the force, $W = 125$ J

Step 2: Use the mathematical formula for mechanical work done:

$$W = F \cdot d \cdot \cos\theta$$

Step 3: Substitute the given numerical values into the equation:

$$125 = 50 \cdot 5 \cdot \cos\theta$$

$$125 = 250 \cdot \cos\theta$$

Step 4: Solve for $\cos\theta$ by dividing both sides by 250:

$$\cos\theta = \frac{125}{250}$$

$$\cos\theta = \frac{1}{2}$$

Step 5: Determine the value of the angle θ whose cosine value is $\frac{1}{2}$:

$$\theta = \cos^{-1}\left(\frac{1}{2}\right) = 60^\circ$$

Hence, the angle between the direction of force and the direction of motion is 60°.

Final Answer: 60°

Answer: (C) Go Back to Question 14

Q15.

Solution

Concept: Radioactive beta minus (β^-) decay is a nuclear process that occurs in neutron-rich unstable nuclei. During this decay, a neutron inside the parent nucleus transforms into a proton, an electron (emitted as a β^- particle), and an electron antineutrino ($\bar{\nu}_e$). The transmutation equation can be written as:

$$^{A}_{Z}\mathrm{X} \longrightarrow ^{A}_{Z+1}\mathrm{Y} + ^{0}_{-1}\mathrm{e} + \bar{\nu}_e$$

Conservation laws require both mass number and total charge to be conserved.

Solution: Step 1: Analyze the transformation at the nucleon level. In a β^- decay, the fundamental change taking place within the nucleus is:

$$\text{neutron (n)} \longrightarrow \text{proton (p)} + \text{electron } (\mathrm{e}^-) + \text{antineutrino } (\bar{\nu}_e)$$

Step 2: Evaluate the change in the total number of nucleons (Mass Number, A). Since one neutron disappears but one new proton is created, the total number of protons plus neutrons remains completely unchanged. Therefore, the mass number A stays constant ($\Delta A = 0$).

Step 3: Evaluate the change in the number of protons (Atomic Number, Z). A new proton is added to the nucleus as a product of the neutron transformation. Consequently, the total number of protons inside the nucleus increases by exactly 1, meaning the atomic number increases by 1 ($\Delta Z = +1$).

Step 4: Synthesize the findings. During a β^- decay process, the atomic number increases by 1 while the total mass number remains exactly the same.

Final Answer: The atomic number increases by 1 while the mass number remains the same

Answer: (B) Go Back to Question 15

Q16.

Solution

Concept: The basic wave equation relates the speed of a wave (v), its frequency (f), and its wavelength (λ). This relationship is expressed by the fundamental formula $v = f \cdot \lambda$. Frequency represents the number of wave cycles that pass a fixed point per unit of time, and its SI unit is Hertz (Hz). To solve for the frequency, the formula can be rearranged as $f = \frac{v}{\lambda}$, ensuring all inputs are converted to SI units.

Solution: Step 1: Identify the given physical parameters from the text. Velocity of the sound wave, $v = 340$ m/s Wavelength of the sound wave, $\lambda = 20$ cm

Step 2: Convert the wavelength from centimeters to meters to maintain standard SI units:

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

Step 3: Use the wave equation to isolate the frequency term:

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

Step 4: Substitute the numerical values into the rearranged equation:

$$f = \frac{340}{0.2}$$

To simplify, multiply both the numerator and the denominator by 10:

$$f = \frac{3400}{2} = 1700 \text{ Hz}$$

Thus, the frequency of the sound wave is 1700 Hz.

Final Answer: 1700 Hz

Answer: (A) **Go Back to Question 16**

Q17.

Solution

Concept: This problem describes a body moving with constant acceleration. We use uniform linear kinematics equations. The parameters involved are initial velocity u, final velocity v, time interval t, and displacement s. A useful equation that bypasses finding the acceleration explicitly is the average velocity formula for distance: $s = \left(\frac{u+v}{2}\right)t$. Alternatively, one can find acceleration using $a = \frac{v-u}{t}$ and then calculate distance via $s = ut + \frac{1}{2}at^2$.

Solution: Step 1: Extract and convert all given quantities into proper SI units. The car starts from rest, so its initial velocity $u = 0$ m/s. The final velocity is given as $v = 72$ km/h. Convert this to meters per second by multiplying by $\frac{5}{18}$:

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

The total time interval is $t = 10$ seconds.

Step 2: Method 1 - Find the uniform acceleration a first:

$$a = \frac{v-u}{t} = \frac{20-0}{10} = 2 \text{ m/s}^2$$

Step 3: Compute the distance s traveled during these 10 seconds using the second equation of motion:

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

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

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

Step 4: Method 2 - Verify using the average velocity approach:

$$s = \left(\frac{u+v}{2}\right) \times t = \left(\frac{0+20}{2}\right) \times 10 = 10 \times 10 = 100 \text{ m}$$

Both analytical pathways yield the same result. The total distance covered is 100 m.

Final Answer: 100 m

Answer: (B) Go Back to Question 17

Q18.

Solution

Concept: This problem is solved using the Principle of Calorimetry, which is based on the law of conservation of energy. In an isolated system, when two substances at different temperatures are mixed, the heat lost by the hotter body must be exactly equal to the heat gained by the colder body, assuming no heat is exchanged with the surroundings. The formula for heat exchange is $Q = mc\Delta T$, where m is the mass, c is the specific heat capacity, and ΔT is the change in temperature.

Solution: Step 1: Define the variables for both liquids. For Liquid A: Mass $= m$, Initial Temperature $T_A = 20°$C, Specific Heat Capacity $= C_A$. For Liquid B: Mass $= m$ (since masses are equal), Initial Temperature $T_B = 40°$C, Specific Heat Capacity $= C_B$. Final equilibrium temperature of the mixture, $T = 32°$C. Step 2: Identify which liquid gains heat and which liquid loses heat. Since $T_A < T < T_B$, Liquid A is colder and will gain heat, while Liquid B is hotter and will lose heat. Step 3: Write down the expression for the heat gained by Liquid A as its temperature rises from $20°$C to $32°$C:

$$Q_{\text{gained}} = m \cdot C_A \cdot (T - T_A) = m \cdot C_A \cdot (32 - 20) = m \cdot C_A \cdot 12$$

Step 4: Write down the expression for the heat lost by Liquid B as its temperature falls from $40°$C to $32°$C:

$$Q_{\text{lost}} = m \cdot C_B \cdot (T_B - T) = m \cdot C_B \cdot (40 - 32) = m \cdot C_B \cdot 8$$

Step 5: Apply the principle of calorimetry, equating heat gained to heat lost:

$$Q_{\text{gained}} = Q_{\text{lost}}$$

$$m \cdot C_A \cdot 12 = m \cdot C_B \cdot 8$$

Since the mass m is the same on both sides and non-zero, it cancels out:

$$12 \cdot C_A = 8 \cdot C_B$$

Rearrange this equation to find the ratio $\frac{C_A}{C_B}$:

$$\frac{C_A}{C_B} = \frac{8}{12} = \frac{2}{3}$$

Thus, the ratio of their specific heat capacities is $2 : 3$.

Final Answer: $2 : 3$

Answer: (A) Go Back to Question 18

Q19.

Solution

Concept: This question deals with the thermal and physical phase changes of water, specifically looking at its density profile during a phase change. Most substances contract when changing from a liquid to a solid, making their solid phase denser than their liquid phase. However, water exhibits an anomalous behavior. Due to hydrogen bonding, ice forms an open cage-like crystalline structure that occupies more volume than the same mass of liquid water. Density is inversely proportional to volume for a constant mass ($\rho = \frac{m}{V}$).

Solution: Step 1: Analyze the physical state change described. A given mass m of ice at $0°C$ is melting into liquid water at the same temperature, $0°C$.

Step 2: Compare the volumes of the two phases. Because of the cage-like open molecular structure of ice, the volume of a given mass of ice (V_{ice}) is greater than the volume of the same mass of liquid water (V_{water}) at $0°C$.

$$V_{\text{ice}} > V_{\text{water}}$$

Step 3: Evaluate how this volume reduction affects density. Since the mass m remains perfectly conserved during the phase transition, we use the density relation $\rho = \frac{m}{V}$. A reduction in volume means that the molecules pack more closely together in the liquid state.

Step 4: Since $V_{\text{water}} < V_{\text{ice}}$, it follows that:

$$\rho_{\text{water}} > \rho_{\text{ice}}$$

Therefore, when ice melts into water at $0°C$, the density of the substance increases.

Final Answer: Increases

Answer: (B) Go Back to Question 19

Q20.

Solution

Concept: The electrical resistance R of a uniform wire depends on its resistivity ρ, its length l, and its cross-sectional area A. The relationship is given by $R = \rho\frac{l}{A}$. For a wire with a circular cross-section of radius r, the area is $A = \pi r^2$. Substituting this into the resistance formula gives $R = \rho\frac{l}{\pi r^2}$. For two wires made of the same material (copper), the resistivity ρ is identical, and the ratio of resistances can be expressed in terms of their length and radius ratios.

Solution: Step 1: State the given ratios from the problem. Ratio of lengths of the two copper wires: $\frac{l_1}{l_2} = \frac{1}{2}$ Ratio of radii of the two copper wires: $\frac{r_1}{r_2} = \frac{2}{1}$

Step 2: Set up the resistance expressions for both wires using the formula $R = \frac{\rho l}{\pi r^2}$:

$$R_1 = \frac{\rho l_1}{\pi r_1^2} \quad \text{and} \quad R_2 = \frac{\rho l_2}{\pi r_2^2}$$

Step 3: Formulate the ratio of their resistances, $\frac{R_1}{R_2}$. Since both wires are made of copper, the resistivity constant ρ and the mathematical constant π cancel out:

$$\frac{R_1}{R_2} = \frac{\frac{\rho l_1}{\pi r_1^2}}{\frac{\rho l_2}{\pi r_2^2}} = \left(\frac{l_1}{l_2}\right) \times \left(\frac{r_2}{r_1}\right)^2$$

Step 4: Substitute the given numerical ratios into this structural ratio equation:

$$\frac{R_1}{R_2} = \left(\frac{1}{2}\right) \times \left(\frac{1}{2}\right)^2$$

$$\frac{R_1}{R_2} = \frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$$

Thus, the ratio of their electrical resistances $R_1 : R_2$ is equal to $1 : 8$.

Final Answer: 1 : 8

Answer: (B) Go Back to Question 20

Q21.

Solution

Concept: Power is defined as the rate at which work is done or energy is transferred ($P = \frac{W}{t}$). When a pump lifts water against gravity through a vertical height h, the work done by the pump is equal to the gain in gravitational potential energy of the water ($W = mgh$). Therefore, the power required can be expressed as $P = \frac{mgh}{t}$, where m is the mass of water lifted, g is the acceleration due to gravity, and t is the time taken.

Solution: Step 1: Identify and format the parameters given in the problem statement into SI units. Mass of water lifted, $m = 600$ kg Time duration, $t = 1$ minute $= 60$ seconds Depth of the well (height), $h = 20$ m Acceleration due to gravity, $g = 10$ m/s^2

Step 2: Calculate the total work done W by the engine in lifting the water. This work goes entirely into increasing the gravitational potential energy of the water mass:

$$W = mgh$$

$$W = 600 \text{ kg} \times 10 \text{ m/s}^2 \times 20 \text{ m}$$

$$W = 120,000 \text{ Joules}$$

Step 3: Compute the mechanical power output P by dividing the total work done by the time interval in seconds:

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

$$P = \frac{120,000 \text{ J}}{60 \text{ s}}$$

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

Step 4: Convert the power output from Watts to kilowatts (kW) for the final response matching:

$$P = \frac{2000}{1000} \text{ kW} = 2.0 \text{ kW}$$

The power of the engine is 2.0 kW.

Final Answer: 2.0 kW

Answer: (B) **Go Back to Question 21**

Q22.

Solution

Concept: This problem involves the reflection of light by a concave mirror. The position and nature of the image formed depend on the location of the object along the principal axis. Rays of light originating from an object placed exactly at the principal focus (F) of a concave mirror travel parallel to the principal axis before hitting the mirror. According to the laws of reflection, rays that are parallel to the principal axis pass through the focus after reflection, and conversely, rays coming from the focus become parallel to the principal axis after reflection.

Solution: Step 1: Visualize or sketch the ray diagram for an object situated at the focus of a concave mirror. Let a point object or the tip of an object be at F.

Step 2: Trace at least two sample light rays. A first ray starting from the object travels parallel to the principal axis, hits the mirror surface, and reflects back through the principal focus F.

Step 3: Trace a second ray that passes through or aligns with the center of curvature C. This ray strikes the mirror normally (90° to the surface tangent) and reflects back along its own path, passing through C.

Step 4: Examine the reflected rays. Both reflected rays emerge parallel to each other on the object side of the mirror. In Euclidean geometry, parallel lines do not intersect at any finite distance, but they are conceptually defined to meet at infinity.

Step 5: Conclude the image characteristics. Because the parallel reflected rays meet at infinity, the image is formed at infinity. The image will be real, inverted, and highly magnified.

Final Answer: At infinity

Answer: (C) Go Back to Question 22

Q23.

Solution

Concept: When an electric current flows through a conductor, electrical energy is converted into thermal energy due to collisions between flowing electrons and the lattice ions of the material. This phenomenon is known as the heating effect of current, governed quantitatively by Joule's Law of Heating. Joule's Law states that the heat H generated in a resistor is directly proportional to the square of the current I, directly proportional to the resistance R, and directly proportional to the time duration t for which the current flows ($H = I^2Rt$).

Solution: Step 1: Write down the mathematical formulation of Joule's Law of Heating:

$$H = I^2 \cdot R \cdot t$$

where H is the heat developed, I is the electric current, R is the electrical resistance of the wire, and t is the time duration of the current flow.

Step 2: Analyze the operational conditions provided in the problem. The question states that a "constant current" flows through a metallic wire. This means that the current I is fixed (I = constant).

Step 3: For a given metallic wire at a stable temperature, its shape, material, and length are fixed, so its resistance R is also a constant parameter (R = constant).

Step 4: Combine the constants in the equation. Since I and R are constants, the term I^2R behaves as a single combined constant factor, let's call it $k = I^2R$. The equation simplifies to:

$$H = k \cdot t \implies H \propto t$$

Step 5: From this proportionality, we deduce that the heat developed in the wire is directly proportional to the first power of the time duration of the current flow.

Final Answer: The time duration of the current flow

Answer: (B) Go Back to Question 23

Q24.

Solution

Concept: This question tests the conceptual understanding of buoyant force, which is explained by Archimedes' Principle. The buoyant force (F_b) acting on an object submerged in a fluid depends on three factors: the volume of the submerged portion of the body (V_{sub}), the density of the fluid (ρ), and the acceleration due to gravity (g). The formula is written as $F_b = V_{\text{sub}} \cdot \rho \cdot g$. The hydrostatic pressure changes with depth, but the buoyant force depends purely on the volume of fluid displaced.

Solution: Step 1: Analyze the motion of the swimmer. As the swimmer jumps into the pool and moves downwards, there are two distinct phases to consider: the partial submersion phase and the complete submersion phase.

Step 2: During the initial entry, as the swimmer enters the water surface, the submerged volume V_{sub} increases from zero until his entire body is under water. During this brief transition, the buoyant force increases because V_{sub} is increasing.

Step 3: Analyze the scenario once the swimmer is completely underwater and continues to swim deeper. In this region, the entire volume of the swimmer's body is fully submerged, so $V_{\text{sub}} = V_{\text{total}} =$ constant.

Step 4: Examine the fluid properties. Water is practically incompressible, meaning its density ρ remains constant at all normal swimming pool depths. The local acceleration due to gravity g is also a constant.

Step 5: Apply these constants to the buoyant force equation. Since V_{sub}, ρ, and g are all constant once he is completely submerged, the buoyant force F_b remains constant, regardless of how deep he goes.

Final Answer: Remains constant once he is completely submerged

Answer: (C) Go Back to Question 24

Q25.

Solution

Concept: This problem distinguishes between two fundamental physical quantities in kinematics: distance and displacement. Distance is a scalar quantity representing the actual path length covered by a moving object. 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 the start point to the end point. In a circular path of radius R, completing any integer number of full revolutions brings the object back to its starting location.

Solution: Step 1: Set up the coordinate geometry or path trajectory. Let the particle start its motion from a point A on a circle of radius R centered at the origin O.

Step 2: Trace the motion of the particle for the given number of revolutions. The total motion consists of two and a half (2.5) revolutions. Break this down into full revolutions and fractional components:

$$\text{Total revolutions} = 2 + 0.5$$

Step 3: Analyze the position after the integer number of revolutions. After completing exactly 1 full revolution, the particle returns to point A. After completing 2 full revolutions, the particle again returns precisely to its initial starting position, point A. At this moment, its net displacement is zero.

Step 4: Analyze the remaining fractional motion. The particle now undergoes an additional half (0.5) revolution starting from point A. A half-revolution covers an angular displacement of π radians $(180°)$. This moves the particle to a position diametrically opposite to its starting point. Let this final position be point B.

Step 5: Determine the straight-line distance between the initial position A and the final position B. Since A and B are diametrically opposite points on a circle of radius R, the distance between them is equal to the length of the diameter of the circle:

$$\text{Displacement} = \text{Distance } AB = \text{Diameter} = 2R$$

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

Final Answer: 2R

Answer: (C) Go Back to Question 25

Answer Key

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