JEECUP Group A Physics Sample Paper – 20

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 body starts from rest and moves with a uniform acceleration of 2 m/s^2. The displacement of the body in the 5^{th} second of its motion is:

(A) 5 m

(B) 9 m

(C) 10 m

(D) 25 m

Q2. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 40 cm. The power of the combined lens system will be:

(A) $+2.5$ D

(B) -2.5 D

(C) $+5.0$ D

(D) -1.25 D

Q3. A hydraulic press works on the principle of transmission of fluid pressure uniformly in all directions. This foundational law of fluid mechanics is known as:

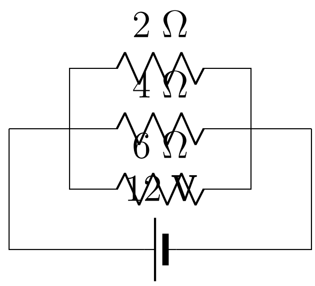
(A) Archimedes' Principle

(B) Bernoulli's Principle

(C) Pascal's Law

(D) Hooke's Law

Q4. Three resistors of resistances $2\ \Omega$, $4\ \Omega$, and $6\ \Omega$ are connected in parallel. If this combination is connected across a 12 V battery of negligible internal resistance, the total current drawn from the battery is:



(A) 2 A

(B) 6 A

(C) 11 A

(D) 12 A

Q5. A bullet of mass 20 g moving with a speed of 100 m/s penetrates a static sand bag and comes to rest in 0.05 seconds. The average retarding force exerted by the sand bag on the bullet is:

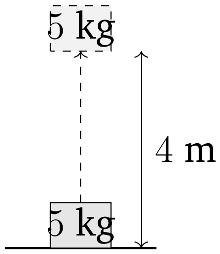
(A) 20 N

(B) 40 N

(C) 100 N

(D) 200 N

Q6. A block of mass 5 kg is raised vertically through a height of 4 meters. If the acceleration due to gravity $g = 10$ m/s^2, the work done by the lifting force is:



(A) 20 J

(B) 50 J

(C) 200 J

(D) 0 J

Q7. At what temperature do the Celsius scale and the Fahrenheit scale read the exact same numerical value?

(A) 40°

(B) -40°

(C) 32°

(D) -100°

Q8. A radioactive isotope has an initial mass of 80 g. If its half-life period is 15 days, the mass of the remaining undecayed isotope left after 45 days will be:

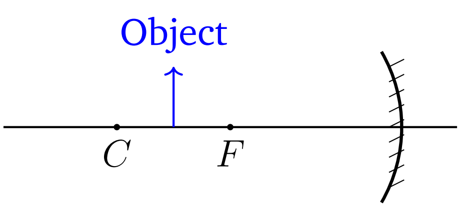
(A) 40 g

(B) 20 g

(C) 10 g

(D) 5 g

Q9. An object is placed at a distance of 15 cm in front of a concave mirror of focal length 10 cm. The nature and position of the image formed will be:



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

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

(C) Real, inverted and at 6 cm in front of the mirror

(D) Virtual, erect and at 6 cm behind the mirror

Q10. A sound wave traveling through air has a frequency of 4 kHz and a wavelength of 8.5 cm. The velocity of this sound wave in air is:

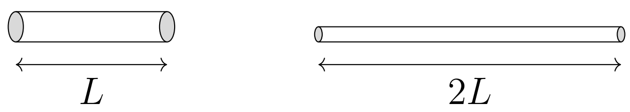
(A) 34 m/s

(B) 340 m/s

(C) 3400 m/s

(D) 34000 m/s

Q11. A cylindrical wire of length L and resistance R is uniformly stretched to double its original length without altering its mass or density. The new electrical resistance of the stretched wire will become:



(A) $2R$

(B) $4R$

(C) $R/2$

(D) $R/4$

Q12. An electric motor of power rating 2 kW operates daily for 5 hours. The total electrical energy consumed by the motor in a standard billing month of 30 days is:

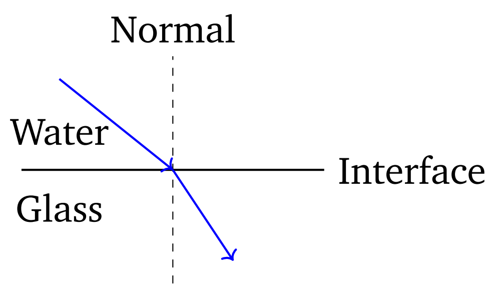
(A) 10 kWh

(B) 60 kWh

(C) 300 kWh

(D) 600 kWh

Q13. When a ray of light travels obliquely from water into a dense glass block, the ray behaves in which of the following ways?



(A) Bends away from the normal line because glass is optically rarer than water

(B) Bends toward the normal line because glass is optically denser than water

(C) Continues completely straight without any deviation from its original path

(D) Suffers total internal reflection back into the water at all incident angles

Q14. An ideal engine absorbs 1000 J of heat energy from a high-temperature reservoir and rejects 600 J of heat to a low-temperature sink during each cycle. The efficiency of this heat engine is:

(A) 40%

(B) 60%

(C) 66.7%

(D) 100%

Q15. A body of mass 2 kg is dropped from the top of a tower of height 45 m. Using $g = 10$ m/s^2 and neglecting air resistance, the kinetic energy of the body just as it strikes the ground is:

(A) 90 J

(B) 450 J

(C) 900 J

(D) 1800 J

Q16. During a nuclear β^- (beta minus) decay process from an unstable atomic nucleus, which of the following internal structural changes occurs?

(A) A proton converts into a neutron, releasing a positron

(B) A neutron converts into a proton, emitting an electron

(C) Two protons and two neutrons are ejected together as a packet

(D) The high-energy nuclear state drops purely via electromagnetic photon emission

Q17. Two bodies of masses 1 kg and 4 kg are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta ($p_1 : p_2$) is:

(A) $1 : 2$

(B) $2 : 1$

(C) $1 : 4$

(D) $1 : 16$

Q18. An electric bulb filament is designed to draw a steady current of 0.5 A from a household circuit line. The total number of electrons flowing through a cross-section of this filament in a duration of 10 minutes is closest to:

(A) 3×10^{20}

(B) 1.875×10^{21}

(C) 3.125×10^{18}

(D) 1.875×10^{19}

Q19. The fundamental phenomena of "Beats" is heard in acoustics when two sound waves traveling in the same direction superimpose. This occurs specifically when the two waves have:

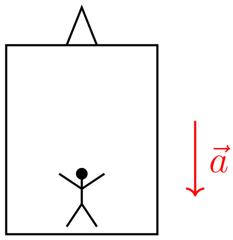
(A) Exactly equal frequencies and equal amplitudes

(B) Slightly different frequencies but nearly equal amplitudes

(C) Widely different frequencies and perpendicular vibrations

(D) Identical wavelengths but a phase difference of exactly $180°$

Q20. A person standing on a sensitive weighing scale inside a lift notices that the scale reading is significantly less than their actual weight. This observation implies that the lift is currently:



(A) Moving upwards with a uniform velocity

(B) Moving downwards with a uniform velocity

(C) Accelerating upwards uniformly

(D) Accelerating downwards uniformly

Q21. How much heat energy must be supplied to completely transform 20 g of pure ice at $0°$C into liquid water at the same temperature of $0°$C? [Take latent heat of fusion of ice $= 80$ cal/g]

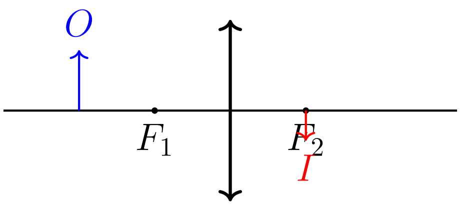
(A) 4 cal

(B) 160 cal

(C) 1600 cal

(D) 100 cal

Q22. An object is placed vertically at a distance of 30 cm along the principal axis of a thin converging lens of focal length 10 cm. The linear magnification (m) produced by the lens is:



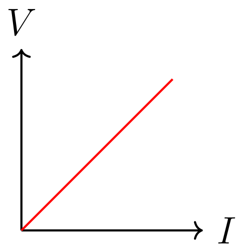
(A) -0.5

(B) $+0.5$

(C) -2.0

(D) $+2.0$

Q23. According to Ohm's Law, a graph plotted between the potential difference (V) across a metallic conductor and the current (I) flowing through it at a constant temperature yields a:



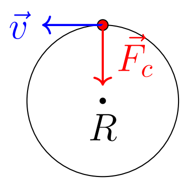
(A) Parabolic curve passing through the origin

(B) Straight line passing through the origin

(C) Hyperbolic curve asymptotic to both axes

(D) Horizontal straight line parallel to the current axis

Q24. A particle moves along a perfectly circular path of radius R with a constant speed v. The total work done on the particle by the centripetal force during one complete revolution is equal to:



(A) $\frac{mv^2}{R} \cdot (2\pi R)$

(B) mv^2

(C) $\frac{1}{2}mv^2$

(D) Zero

Q25. The absolute refractive index of a certain transparent medium is given as 1.5. If the speed of light in vacuum is 3×10^8 m/s, the speed of light when traveling through this medium is:

(A) 1.5×10^8 m/s

(B) 2.0×10^8 m/s

(C) 4.5×10^8 m/s

(D) 2.5×10^8 m/s

Detailed Solutions

Q1.

Solution

Concept: The displacement of an object moving with a uniform acceleration in the n^{th} second of its motion is determined using the specific equation for kinematic intervals: $S_n = u + \frac{a}{2}(2n - 1)$, where u represents the initial velocity, a signifies the constant acceleration, and n denotes the particular second under consideration.

Solution: Step 1: Extract the given physical parameters from the problem statement. The body starts its motion from rest, which directly implies that its initial velocity is zero, so $u = 0$ m/s. The uniform linear acceleration is explicitly given as $a = 2$ m/s^2.

Step 2: Identify the time interval parameter. The question specifically demands the calculation of the linear displacement during the 5^{th} second of its trajectory. Therefore, we set the integer value $n = 5$.

Step 3: Substitute these verified values into the kinematic relation for the n^{th} second displacement:

$$S_5 = 0 + \frac{2}{2}(2 \times 5 - 1)$$

Step 4: Perform the algebraic simplification within the brackets first, which yields $(10 - 1) = 9$. Multiplying this by the pre-factor $\frac{2}{2} = 1$ leads directly to the precise evaluation of the distance traversed.

$$S_5 = 1 \times 9 = 9 \text{ m}$$

Step 5: Compare the evaluated displacement with the given choices. The calculated value matches option (B).

Final Answer: 9 m

Answer: (B) Go Back to Question 1

Q2.

Solution

Concept: When two thin optical lenses are placed in close contact with each other, the net power of the combined coaxial system is equal to the algebraic sum of the individual powers of the constituent lenses, expressed mathematically as $P = P_1 + P_2$. The power of a lens is inversely proportional to its focal length measured in meters, satisfying the relation $P = \frac{1}{f(\text{in meters})}$.

Solution: Step 1: Convert the focal lengths of both individual lenses from centimeters to SI units of meters. For the first lens, which is a convex (converging) lens, the focal length is positive:

$$f_1 = +20 \text{ cm} = +0.2 \text{ m}$$

For the second lens, which is a concave (diverging) lens, the focal length is defined as negative according to standard Cartesian sign convention:

$$f_2 = -40 \text{ cm} = -0.4 \text{ m}$$

Step 2: Calculate the optical power of the individual convex lens (P_1) using the reciprocal formula:

$$P_1 = \frac{1}{+0.2} = +5.0 \text{ D}$$

Step 3: Calculate the optical power of the individual concave lens (P_2) ensuring the negative sign is retained:

$$P_2 = \frac{1}{-0.4} = -2.5 \text{ D}$$

Step 4: Apply the combination principle to determine the total net power (P) of the compound lens alignment:

$$P = P_1 + P_2 = +5.0 \text{ D} + (-2.5 \text{ D}) = +2.5 \text{ D}$$

The resulting system behaves as a net converging lens.

Final Answer: $+2.5$ D

Answer: (A) Go Back to Question 2

Q3.

Solution

Concept: The fundamental operation of heavy hydraulic machinery is governed by the principles of hydrostatic pressure distribution in an enclosed, incompressible fluid system. According to fluid mechanics, an external pressure applied to any point of a confined fluid is transmitted completely undiminished to every single portion of the fluid and onto the walls of the containing vessel.

Solution: Step 1: Analyze the functional mechanics of a standard hydraulic press. It consists of two pistons of unequal cross-sectional areas connected via a fluid-filled conduit. A small force applied on a smaller area generates a pressure.

Step 2: Relate this operational setup to the underlying theoretical laws of physics. The core requirement is that the static fluid pressure remains completely uniform at the same horizontal level throughout the connected system.

Step 3: Evaluate the scientific definitions of the listed choices. Archimedes' principle deals entirely with buoyant forces and fluid displacement, while Bernoulli's principle governs dynamic fluid flow and energy conservation along a streamline. Hooke's law relates stress and strain in elastic solid bodies.

Step 4: Match the pressure transmission characteristic with Pascal's Law, which states that change in pressure applied to an enclosed fluid is transmitted undiminished to every point. Therefore, hydraulic lifting mechanisms are a direct application of Pascal's Law.

Final Answer: Pascal's Law

Answer: (C) Go Back to Question 3

Q4.

Solution

Concept: For an electrical network containing several resistors connected in a parallel configuration, the reciprocal of the total equivalent resistance (R_p) is equal to the sum of the reciprocals of the individual resistances. This is mathematically formulated as $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. Once the equivalent resistance is determined, Ohm's law ($I = \frac{V}{R_p}$) is applied to find the total current.

Solution: Step 1: Identify the individual values of the resistances from the given circuit layout. We have $R_1 = 2\ \Omega$, $R_2 = 4\ \Omega$, and $R_3 = 6\ \Omega$ arranged in parallel across a constant potential difference of $V = 12$ V.

Step 2: Set up the algebraic reciprocal equation to calculate the equivalent net resistance of this parallel network:

$$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{4} + \frac{1}{6}$$

Step 3: Find the least common multiple (LCM) of the denominators (2, 4, and 6), which is 12. Re-write the fractions with the common denominator and sum them up:

$$\frac{1}{R_p} = \frac{6+3+2}{12} = \frac{11}{12}\ \Omega^{-1}$$

Taking the reciprocal gives the equivalent resistance: $R_p = \frac{12}{11}\ \Omega$.

Step 4: Utilize Ohm's law to determine the total current (I) drawn from the external 12 V chemical battery source:

$$I = \frac{V}{R_p} = \frac{12}{\left(\frac{12}{11}\right)} = 12 \times \frac{11}{12} = 11\ \text{A}$$

Final Answer: 11 A

Answer: (C) Go Back to Question 4

Q5.

Solution

Concept: According to 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 its linear momentum. This can be expressed using the dynamic equation $F = \frac{\Delta p}{\Delta t} = \frac{m(v-u)}{t}$, where m is the mass, u is the initial velocity, v is the final velocity, and t is the deceleration time interval.

Solution: Step 1: Convert all given quantities into standard SI units. The mass of the high-velocity bullet is given in grams and must be transformed into kilograms:

$$m = 20\text{ g} = \frac{20}{1000}\text{ kg} = 0.02\text{ kg}$$

Step 2: Record the initial and final states of motion. The initial velocity right before impacting the sand bag is $u = 100$ m/s. Since the bullet penetrates the target and eventually comes to a complete rest, its final velocity is $v = 0$ m/s. The interaction time is $t = 0.05$ seconds.

Step 3: Substitute these values into the average retarding force expression:

$$F = \frac{0.02 \times (0 - 100)}{0.05}$$

Step 4: Simplify the numerator and complete the division to find the magnitude of the force:

$$F = \frac{-2}{0.05} = -40\text{ N}$$

The negative sign confirms that the force is resistive and opposes the direction of motion. The absolute magnitude of the retarding force is 40 N.

Final Answer: 40 N

Answer: (B) Go Back to Question 5

Q6.

Solution

Concept: The work done by an external force in lifting a body vertically upward at a constant speed is equal to the change in the gravitational potential energy of the body-Earth system. The formula for the work done against gravity is defined as $W = mgh$, where m is the mass of the block, g is the acceleration due to gravity, and h is the vertical displacement.

Solution: Step 1: Identify the variables provided in the problem statement. The mass of the block is $m = 5$ kg, the height through which it is raised is $h = 4$ meters, and the acceleration due to gravity is specified as $g = 10\ \text{m/s}^2$.

Step 2: Since the lifting force acts vertically upward and the displacement is also vertically upward, the angle θ between the force vector and the displacement vector is $0°$. Thus, the work done is positive:

$$W = F \cdot h \cdot \cos(0°) = F \cdot h$$

Step 3: To lift the mass, the minimum external force required must balance the downward weight of the object, meaning $F = mg$. Substitute this expression into the work equation:

$$W = mgh$$

Step 4: Calculate the numerical value by multiplying the individual parameters:

$$W = 5\ \text{kg} \times 10\ \text{m/s}^2 \times 4\ \text{m} = 200\ \text{J}$$

The total mechanical work done by the lifting agent is 200 Joules.

Final Answer: 200 J

Answer: (C) Go Back to Question 6

Q7.

Solution

Concept: The relationship between the Celsius temperature scale (C) and the Fahrenheit temperature scale (F) is governed by a linear conversion formula derived from their respective freezing and boiling reference points. The standard formula linking these two thermal scales is given by: $\frac{C}{5} = \frac{F-32}{9}$.

Solution: Step 1: The problem requires finding a unique temperature condition where both scales display the exact same numerical value. Let us assume this common numerical temperature value is represented by the variable x, such that $C = F = x$.

Step 2: Substitute the variable x in place of both C and F in the standard conversion formula:

$$\frac{x}{5} = \frac{x-32}{9}$$

Step 3: Perform cross-multiplication to eliminate the fractions and set up a linear algebraic equation:

$$9x = 5(x - 32)$$

Step 4: Expand the right side of the equation and rearrange all terms containing x to one side to isolate the variable:

$$9x = 5x - 160$$

$$9x - 5x = -160$$

$$4x = -160$$

Step 5: Divide both sides by 4 to solve for x:

$$x = \frac{-160}{4} = -40$$

Thus, at -40°, both the Celsius and Fahrenheit thermometers indicate identical readings.

Final Answer: -40°

Answer: (B) Go Back to Question 7

Q8.

Solution

Concept: Radioactive decay follows a first-order kinetic process where the mass of the remaining undecayed radioactive isotope after a certain elapsed time can be calculated using the half-life expression: $N = N_0\left(\frac{1}{2}\right)^n$. Here, N_0 represents the initial mass, N is the final remaining mass, and n represents the total number of half-life periods that have elapsed.

Solution: Step 1: Extract the given data from the problem text. The initial mass of the isotope is $N_0 = 80$ g, the half-life period is $T_{1/2} = 15$ days, and the total time of decay is $t = 45$ days.

Step 2: Determine the total number of half-life cycles (n) that occur within the given 45-day timeframe:

$$n = \frac{t}{T_{1/2}} = \frac{45}{15} = 3 \text{ cycles}$$

Step 3: Apply the remaining mass formula using the calculated value of $n = 3$:

$$N = 80 \times \left(\frac{1}{2}\right)^3$$

Step 4: Calculate the value of the fractional exponential component, $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$. Substitute this back into the expression to determine the final mass:

$$N = 80 \times \frac{1}{8} = 10 \text{ g}$$

Therefore, after 45 days, 10 g of the undecayed substance remains.

Final Answer: 10 g

Answer: (C) Go Back to Question 8

Q9.

Solution

Concept: The positioning and characteristics of images formed by spherical mirrors are determined using the standard mirror formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$, alongside the sign convention rules where distances measured in the direction of incident light are positive, and those opposite are negative.

Solution: Step 1: Identify the parameters and assign signs. For a concave mirror, the focal length lies in front of the reflecting surface, making it negative: $f = -10$ cm. The object is also placed in front of the mirror, so $u = -15$ cm.

Step 2: Rearrange the spherical mirror equation to solve explicitly for the image distance parameter (v):

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

Step 3: Substitute the signed values into the rearranged equation:

$$\frac{1}{v} = \frac{1}{-10} - \frac{1}{-15} = -\frac{1}{10} + \frac{1}{15}$$

Step 4: Find the common denominator for 10 and 15, which is 30, and solve for v:

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

$$v = -30 \text{ cm}$$

Step 5: Interpret the negative sign of v. A negative image distance implies that the image is formed at a distance of 30 cm in front of the mirror. Images formed in front of a concave mirror are always real and inverted.

Final Answer: Real, inverted and at 30 cm in front of the mirror

Answer: (B) Go Back to Question 9

Q10.

Solution

Concept: The wave propagation speed (v) for any periodic wave phenomenon is uniquely governed by the fundamental wave equation, which states that velocity is equal to the mathematical product of its frequency (ν or f) and its spatial wavelength (λ). The equation is written as $v = f\lambda$.

Solution: Step 1: Analyze the given wave parameters and convert them into standard SI units to prevent calculation errors. The frequency is provided in kilohertz:

$$f = 4 \text{ kHz} = 4 \times 10^3 \text{ Hz} = 4000 \text{ Hz}$$

The spatial wavelength is given in centimeters and must be converted to meters:

$$\lambda = 8.5 \text{ cm} = \frac{8.5}{100} \text{ m} = 0.085 \text{ m}$$

Step 2: Apply the wave equation to compute the linear velocity of the acoustic wave through the air medium:

$$v = f\lambda = 4000 \times 0.085$$

Step 3: Perform the final numerical multiplication:

$$v = 4 \times 85 = 340 \text{ m/s}$$

The velocity matches the standard speed of sound in air under normal atmospheric conditions.

Final Answer: 340 m/s

Answer: (B) Go Back to Question 10

Q11.

Solution

Concept: The electrical resistance of a uniform conductor is directly proportional to its length and inversely proportional to its cross-sectional area, given by $R = \rho\frac{L}{A}$. When a wire is stretched uniformly, its total volume ($V = A \cdot L$) must remain constant because mass and density do not change.

Solution: Step 1: Express the initial resistance of the wire as $R_1 = \rho\frac{L_1}{A_1} = R$, where ρ is the material resistivity, $L_1 = L$ is the initial length, and A_1 is the initial cross-sectional area.

Step 2: Establish the relationships for the stretched state. The final length is given as twice the original length: $L_2 = 2L$. Since the volume must remain constant ($A_1L_1 = A_2L_2$), we can determine the new area A_2:

$$A_1 \cdot L = A_2 \cdot (2L) \implies A_2 = \frac{A_1}{2}$$

Step 3: Set up the formula for the modified final resistance (R_2) using the new geometric parameters:

$$R_2 = \rho\frac{L_2}{A_2} = \rho\frac{2L}{\left(\frac{A_1}{2}\right)}$$

Step 4: Simplify the fraction by moving the denominator factor to the numerator:

$$R_2 = \rho\frac{4L}{A_1} = 4\left(\rho\frac{L}{A_1}\right) = 4R$$

Stretching the wire to double its length increases its resistance by a factor of 4.

Final Answer: $4R$

Answer: (B) Go Back to Question 11

Q12.

Solution

Concept: Electrical energy consumption (E) is defined as the total power rating (P) of an electrical appliance multiplied by the total operational time duration (t) for which it is kept active. The standard commercial unit for billing purposes is the kilowatt-hour (kWh), where $E(\text{in kWh}) = P(\text{in kW}) \times t(\text{in hours})$.

Solution: Step 1: Identify the power specification of the electric motor from the problem statement. The power rating is already expressed in kilowatts, so $P = 2$ kW.

Step 2: Calculate the daily operational time. The motor runs for 5 hours every single day. Therefore, the daily energy consumption is:

$$E_{\text{daily}} = 2\text{ kW} \times 5\text{ hours} = 10\text{ kWh}$$

Step 3: Determine the total operational time across the entire billing cycle. The question specifies a standard month comprising 30 days. Multiply the daily energy expenditure by 30:

$$E_{\text{total}} = E_{\text{daily}} \times 30 = 10\text{ kWh/day} \times 30\text{ days}$$

$$E_{\text{total}} = 300\text{ kWh}$$

Final Answer: 300 kWh

Answer: (C) Go Back to Question 12

Q13.

Solution

Concept: The phenomenon of refraction occurs due to the change in the propagation velocity of light when passing obliquely from one optical medium to another. According to Snell's Law, when light travels from an optically rarer medium (lower refractive index) to an optically denser medium (higher refractive index), the light ray undergoes deviation and bends toward the normal line.

Solution: Step 1: Identify the optical properties of the two media mentioned in the question. The light ray originates in water and enters a dense glass block.

Step 2: Compare the absolute refractive indices of water and glass. The refractive index of water (μ_w) is approximately 1.33, while the refractive index of typical dense glass (μ_g) is approximately 1.5.

Step 3: Since $\mu_g > \mu_w$, glass is optically denser than water. Therefore, when light crosses the interface obliquely from water into glass, its speed decreases.

Step 4: This reduction in speed causes the refracted ray to deviate toward the normal line drawn perpendicular to the interface at the point of incidence.

Final Answer: Bends toward the normal line because glass is optically denser than water

Answer: (B) Go Back to Question 13

Q14.

Solution

Concept: The thermal efficiency (η) of a heat engine is defined as the ratio of the net mechanical work done (W) by the engine per cycle to the total heat energy absorbed (Q_1) from the high-temperature source. This can be expressed as $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$, where Q_2 represents the heat rejected to the low-temperature sink.

Solution: Step 1: Identify the given thermodynamic energy values. The heat absorbed from the hot reservoir is $Q_1 = 1000$ J. The heat rejected to the cold sink is $Q_2 = 600$ J.

Step 2: Calculate the net useful mechanical work output (W) delivered by the engine during one cycle:

$$W = Q_1 - Q_2 = 1000 \text{ J} - 600 \text{ J} = 400 \text{ J}$$

Step 3: Compute the thermal efficiency fraction by dividing the work done by the initial heat input:

$$\eta = \frac{W}{Q_1} = \frac{400}{1000} = 0.4$$

Step 4: Convert the fractional efficiency value into a percentage by multiplying by 100:

$$\eta = 0.4 \times 100\% = 40\%$$

Final Answer: 40%

Answer: (A) Go Back to Question 14

Q15.

Solution

Concept: According to the law of conservation of mechanical energy, in the absence of dissipative forces like air resistance, the total mechanical energy of an object remains constant. Therefore, when a body is dropped from rest, its initial gravitational potential energy ($U = mgh$) at the top of a tower is completely converted into kinetic energy ($K = \frac{1}{2}mv^2$) right before it strikes the ground.

Solution: Step 1: Collect the data parameters provided: the mass of the falling object is $m = 2$ kg, the height of the tower is $h = 45$ m, and the acceleration due to gravity is $g = 10$ m/s^2. Since the body is dropped from rest, its initial kinetic energy is zero.

Step 2: Equate the kinetic energy gained at the base of the tower to the potential energy lost from the summit:

$$\text{Kinetic Energy}_{\text{final}} = \text{Potential Energy}_{\text{initial}} = mgh$$

Step 3: Substitute the numerical parameters into the energy equivalence equation:

$$\text{Kinetic Energy} = 2 \text{ kg} \times 10 \text{ m/s}^2 \times 45 \text{ m}$$

Step 4: Perform the multiplication to determine the total kinetic energy:

$$\text{Kinetic Energy} = 20 \times 45 = 900 \text{ J}$$

The kinetic energy of the object just before impact is 900 Joules.

Final Answer: 900 J

Answer: (C) **Go Back to Question 15**

Q16.

Solution

Concept: Nuclear beta minus (β^-) decay is a weak nuclear interaction process that occurs in neutron-rich unstable nuclei. To achieve greater stability, an excess subatomic neutron undergoes a transformation inside the nucleus, altering the atomic number while leaving the total mass number unchanged.

Solution: Step 1: Analyze the fundamental reaction that defines a standard beta minus particle emission. A neutron (n) converts into a proton (p), an electron (β^- particle), and an antineutrino ($\bar{\nu}_e$). The reaction is written as:

$$^1_0n \rightarrow ^1_1 p + ^0_{-1} e + \bar{\nu}_e$$

Step 2: Examine the choices to determine which option accurately describes this subatomic process. Option (B) states that a neutron converts into a proton, emitting an electron. This matches our formulation.

Step 3: Verify why other options are incorrect. Option (A) describes beta plus (β^+) decay, option (C) describes alpha (α) particle emission, and option (D) corresponds to gamma (γ) de-excitation. Thus, option (B) is the correct statement.

Final Answer: A neutron converts into a proton, emitting an electron

Answer: (B) Go Back to Question 16

Q17.

Solution

Concept: The relationship between the magnitude of the linear momentum (p) of a moving body and its kinetic energy (K) is derived from their fundamental formulas ($p = mv$ and $K = \frac{1}{2}mv^2$). Combining these two expressions yields the equation $p = \sqrt{2mK}$.

Solution: Step 1: Write down the individual expressions for the momentum of both bodies. Let the first body have mass $m_1 = 1$ kg and momentum p_1. Let the second body have mass $m_2 = 4$ kg and momentum p_2. Both objects possess identical kinetic energies, so $K_1 = K_2 = K$.

Step 2: Express the momentum equations for both masses:

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

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

Step 3: Construct the ratio of their momenta ($p_1 : p_2$) by dividing the first expression by the second:

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

Step 4: Substitute the given values of the masses into the simplified ratio equation:

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

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

Final Answer: $1 : 2$

Answer: (A) Go Back to Question 17

Q18.

Solution

Concept: Electric current (I) is defined as the rate of flow of electric charge (Q) across a given cross-section per unit time, expressed as $I = \frac{Q}{t}$. According to the quantization of charge, the total charge is equal to the number of individual electrons (n) multiplied by the elementary charge of a single electron ($e = 1.6 \times 10^{-19}$ C). Combining these principles gives $I = \frac{ne}{t}$.

Solution: Step 1: Convert all given problem parameters into standard SI units. The electrical current is $I = 0.5$ A. The time duration is given in minutes and must be converted to seconds:

$$t = 10 \text{ minutes} = 10 \times 60 \text{ seconds} = 600 \text{ s}$$

Step 2: Calculate the total electric charge (Q) that flows through the filament by rearranging the current formula:

$$Q = I \times t = 0.5 \text{ A} \times 600 \text{ s} = 300 \text{ C}$$

Step 3: Use the charge quantization relation ($Q = ne$) to solve for the total number of electrons (n):

$$n = \frac{Q}{e} = \frac{300}{1.6 \times 10^{-19}}$$

Step 4: Perform the final arithmetic calculation:

$$n = \frac{300}{1.6} \times 10^{19} = 187.5 \times 10^{19} = 1.875 \times 10^{21} \text{ electrons}$$

Final Answer: 1.875×10^{21}

Answer: (B) Go Back to Question 18

Q19.

Solution

Concept: The phenomenon of acoustic beats is an interference pattern that occurs in time rather than in space. It is produced by the superposition of two sound waves traveling in the same direction with slightly different frequencies. The resulting wave exhibits a periodic variation in intensity, and the frequency of these intensity fluctuations is known as the beat frequency.

Solution: Step 1: Understand the mathematical basis of beats. If two acoustic waves have frequencies denoted as f_1 and f_2, their superposition creates a resultant wave whose amplitude varies with a frequency equal to the absolute difference $|f_1 - f_2|$.

Step 2: Evaluate the physical constraints required to hear distinct beats. If the frequencies are identical ($f_1 = f_2$), no beats are produced because the amplitude remains constant over time. If the frequencies are widely different, the fluctuations happen too rapidly for the human ear to resolve.

Step 3: Therefore, to perceive distinct, periodic variations in sound intensity, the two sound waves must have slightly different frequencies but nearly identical amplitudes. This corresponds to option (B).

Final Answer: Slightly different frequencies but nearly equal amplitudes

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: The apparent weight of a person inside a moving lift is determined by the normal reaction force (N) exerted by the weighing scale platform on the person. This normal force can be evaluated by applying Newton's Second Law of Motion within an accelerating frame of reference using pseudo-forces, or within an inertial frame.

Solution: Step 1: Write down the force balance equation for a person of mass m inside a lift. The true weight acting vertically downward is mg. The normal force acting vertically upward is N.

Step 2: Analyze the condition where the lift moves with a uniform velocity. In this case, the acceleration is zero ($a = 0$), which means the scale reads the true weight ($N = mg$). This eliminates options (A) and (B).

Step 3: Analyze the condition where the lift accelerates upward with a uniform acceleration a. The equation of motion is $N - mg = ma \implies N = m(g + a)$. Here, the apparent weight is greater than the true weight. This eliminates option (C).

Step 4: Analyze the condition where the lift accelerates downward with a uniform acceleration a. The equation of motion becomes $mg - N = ma \implies N = m(g - a)$. In this scenario, the normal force N is less than mg, meaning the scale reading is less than the actual weight. This matches option (D).

Final Answer: Accelerating downwards uniformly

Answer: (D) Go Back to Question 20

Q21.

Solution

Concept: When a substance changes its physical phase at a constant temperature, the thermal energy required is known as latent heat. For the transition from solid ice to liquid water at the melting point, the quantity of heat required (Q) is given by the formula $Q = m \cdot L_f$, where m represents the mass of the substance and L_f represents the latent heat of fusion.

Solution: Step 1: Identify the given thermal parameters. The mass of the pure ice to be melted is $m = 20$ g. The phase change occurs at a constant temperature of $0°$C. The latent heat of fusion of ice is given as $L_f = 80$ cal/g.

Step 2: Since there is no change in temperature during the phase transition, we do not use the specific heat capacity formula ($ms\Delta T$). We apply the latent heat relation directly:

$$Q = m \cdot L_f$$

Step 3: Substitute the numerical values into the phase change equation:

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

Step 4: Perform the final multiplication to determine the total thermal energy in calories:

$$Q = 1600 \text{ cal}$$

Thus, 1600 calories of heat must be supplied to melt the ice completely.

Final Answer: 1600 cal

Answer: (C) Go Back to Question 21

Q22.

Solution

Concept: The position of an image formed by a thin lens is determined using the thin lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$. Once the image distance (v) is found, the linear magnification (m) can be calculated using the relation $m = \frac{v}{u}$.

Solution: Step 1: Apply standard Cartesian sign conventions to the given parameters. For a converging (convex) lens, the focal length is positive: $f = +10$ cm. The object is placed in front of the lens, so the object distance is negative: $u = -30$ cm.

Step 2: Rearrange the thin lens formula to solve for the reciprocal of the image distance ($\frac{1}{v}$):

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

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

$$\frac{1}{v} = \frac{1}{10} + \frac{1}{-30} = \frac{1}{10} - \frac{1}{30}$$

$$\frac{1}{v} = \frac{3-1}{30} = \frac{2}{30} = \frac{1}{15} \implies v = +15 \text{ cm}$$

Step 4: Calculate the linear magnification (m) using the values of v and u:

$$m = \frac{v}{u} = \frac{15}{-30} = -0.5$$

The negative sign indicates that the image is real and inverted.

Final Answer: -0.5

Answer: (A) Go Back to Question 22

Q23.

Solution

Concept: Ohm's Law states that the electric current (I) flowing through a metallic conductor is directly proportional to the potential difference (V) applied across its ends, provided physical conditions such as temperature remain constant. This linear relationship is expressed mathematically as $V = IR$, where the constant of proportionality R represents the electrical resistance.

Solution: Step 1: Analyze the algebraic form of the equation $V = IR$. This expression is structurally identical to the classical equation of a straight line passing through the coordinate origin, $y = mx$, where V is plotted on the vertical y-axis, I is plotted on the horizontal x-axis, and the resistance R represents the constant slope (m) of the line.

Step 2: Evaluate the nature of the graph based on this mathematical structure. Since R is a constant positive value for an ohmic conductor at a fixed temperature, the relationship between V and I is strictly linear.

Step 3: Therefore, a plot of potential difference (V) versus current (I) yields a straight line passing through the origin. This matches option (B).

Final Answer: Straight line passing through the origin

Answer: (B) Go Back to Question 23

Q24.

Solution

Concept: The work done (W) by a force $\vec{F}$ on an object during a displacement $\vec{d}$ is defined by the vector dot product equation $W = \vec{F} \cdot \vec{d} = F \cdot d \cdot \cos(\theta)$, where θ is the angle between the force vector and the instantaneous velocity (or displacement) vector.

Solution: Step 1: Analyze the directional orientation of the vectors in uniform circular motion. The centripetal force ($\vec{F}_c$) always points radially inward toward the center of the circular path.

Step 2: Determine the direction of the displacement. The instantaneous displacement vector (or velocity vector $\vec{v}$) acts tangentially to the circular path at any given point along the trajectory.

Step 3: Evaluate the geometric angle (θ) between the radial centripetal force vector and the tangential displacement vector. Because a radius line and a tangent line are always perpendicular at the point of contact, the angle $\theta = 90°$ at all times.

Step 4: Substitute $\theta = 90°$ into the work equation:

$$W = F_c \cdot d \cdot \cos(90°)$$

Since $\cos(90°) = 0$, the work done by the centripetal force is zero throughout any interval of the motion.

Final Answer: Zero

Answer: (D) Go Back to Question 24

Q25.

Solution

Concept: The absolute refractive index (μ or n) of a transparent optical medium is defined as the ratio of the velocity of light in a vacuum (c) to the velocity of light in that specific medium (v). The relationship is given by the formula: $\mu = \frac{c}{v}$.

Solution: Step 1: Identify the given values from the problem statement. The absolute refractive index of the medium is $\mu = 1.5$. The speed of light in a vacuum is a known constant, given as $c = 3 \times 10^8$ m/s.

Step 2: Rearrange the refractive index equation to solve explicitly for the velocity of light within the medium (v):

$$v = \frac{c}{\mu}$$

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

$$v = \frac{3 \times 10^8}{1.5}$$

Step 4: Perform the division. Since $\frac{3}{1.5} = 2$, the expression simplifies directly to:

$$v = 2.0 \times 10^8 \text{ m/s}$$

Thus, light travels at a speed of 2.0×10^8 m/s through this medium.

Final Answer: 2.0×10^8 m/s

Answer: (B) Go Back to Question 25

Answer Key

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