JEECUP Group A Physics Sample Paper-10

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 real object is placed at a distance of 15 cm from a concave mirror along its principal axis. A crisp real image is formed at a distance of 30 cm in front of the mirror. If the object is now shifted by an additional distance of 5 cm further away from the mirror, calculate the displacement magnitude and direction of the newly formed real image.

(A) Shifts 10 cm towards the mirror

(B) Shifts 10 cm away from the mirror

(C) Shifts 5 cm towards the mirror

(D) Shifts 5 cm away from the mirror

Q2. A thin biconvex lens with equal radii of curvature ($R_1 = R_2 = 20$ cm) is split vertically down its symmetric center plane into two identical planoconvex halves. If the original whole lens had a optical power rating of +5 Diopters in air, find the individual optical power (P') of each separated planoconvex piece.

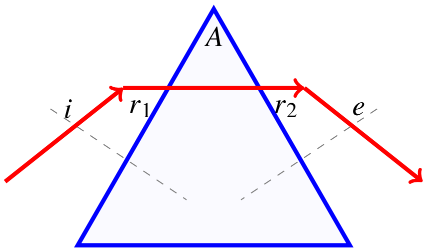
(A) +5.0 D

(B) +10.0 D

(C) +2.5 D

(D) +1.25 D

Q3. A ray of monochromatic light is incident at an angle i on one face of a glass prism having an equilateral cross-section (Prism angle $A = 60°$). The light ray passes symmetrically through the internal glass matrix as shown below. If the minimum angle of deviation recorded by the system is $\delta_m = 30°$, determine the absolute refractive index (μ) of this prism material:



(A) $\mu = 1.5$

(B) $\mu = \sqrt{2}$

(C) $\mu = \sqrt{3}$

(D) $\mu = 1.33$

Q4. A light pointer illuminates a tiny specimen embedded inside a solid cylinder blocks of transparent resin material ($\mu = 1.414$). Calculate the minimum configuration angle of incidence (i) at which light migrating internally can fully hit the boundary and escape into the ambient air environment ($\mu_{\text{air}} = 1.0$) without triggering total internal reflection.

(A) $i < 30°$

(B) $i < 45°$

(C) $i > 45°$

(D) $i < 60°$

Q5. A compound scientific microscope features an objective lens component providing a linear magnification factor of $m_o = -5.0$. If the accompanying eyepiece assembly yields an angular magnifying power rating of $m_e = +6.0$ when adjusted for normal distinct vision tracking, evaluate the total combined instrumental magnifying power (M) of this system.

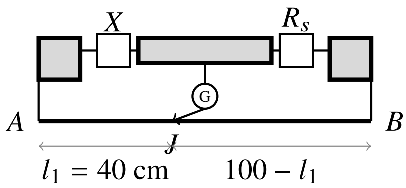
(A) $+1.0$

(B) −11.0

(C) −30.0

(D) +30.0

Q6. A DC diagnostic circuit network loop is connected to a balanced meter bridge layout setup as presented below. A uniform resistance slide wire of total length $L = 100$ cm matches its null calibration balance indicator point at a distance of $l_1 = 40$ cm from left terminal A. If the standard reference resistor block holds a value of $R_s = 12\ \Omega$, deduce the exact resistance value of the unknown test resistor component X:



(A) $X = 18\ \Omega$

(B) $X = 8\ \Omega$

(C) $X = 6\ \Omega$

(D) $X = 24\ \Omega$

Q7. A dense cylindrical metallic wire has an initial resistance of $R_0 = 4\ \Omega$. This wire is mechanically stretched uniformly to double its original length ($L' = 2L_0$) while keeping its material mass density constant. Calculate the new resistance (R') of this stretched wire section.

(A) $8\ \Omega$

(B) $16\ \Omega$

(C) $32\ \Omega$

(D) $4\ \Omega$

Q8. A micro-galvanometer movement has an internal resistance of $G = 100\ \Omega$ and shows full-scale deflection for a current of $I_g = 1$ mA. Determine the value of the series resistance (R_h) that must be added to convert this instrument into a high-range voltmeter reading up to 10 Volts.

(A) $9,900\ \Omega$

(B) $10,100\ \Omega$

(C) $9,000\ \Omega$

(D) $10,000\ \Omega$

Q9. An industrial electric heater unit has three identical internal heating resistor coils. When all three elements are wired together in parallel across a constant line voltage source V, they deliver a heating rate power output of $W_p = 900$ Watts. If the coils are re-wired into a strict series chain loop layout across the same voltage source, calculate the new combined power output (W_s).

(A) 300 W

(B) 100 W

(C) 2700 W

(D) 900 W

Q10. A 5 meter long potentiometer wire exhibits a total uniform structural resistance of 10 Ω. It is driven by a steady storage accumulator of EMF 2.0 V connected in series with an adjustable external resistance box value of 30 Ω. Calculate the resulting potential gradient (k) along the wire.

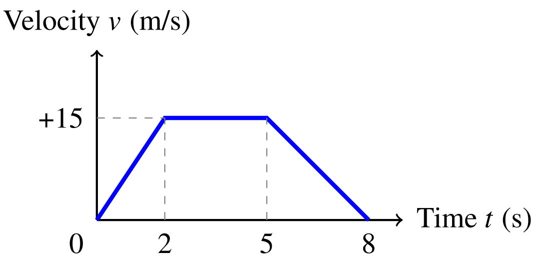
(A) 0.40 V/m

(B) 0.10 V/m

(C) 0.08 V/m

(D) 0.20 V/m

Q11. An automated optical speed trap logs the rectilinear displacement profile of an object. Based on the velocity-time ($v - t$) performance graph shown below, compute the net deceleration magnitude (a) during the final phase of motion from $t = 5$ s to $t = 8$ s:



(A) 3.0 m/s^2

(B) 5.0 m/s^2

(C) 2.5 m/s^2

(D) 7.5 m/s^2

Q12. A projectile weapon discharges a test capsule from ground level with an initial velocity vector profile given by $\vec{v}_0 = 15\hat{i} + 20\hat{j}$ in units of m/s ($\hat{j}$ directed vertically upward). Calculate the total time of flight (T) of the projectile over a flat terrain grid. [Take $g = 10$ m/s^2].

(A) 2.0 seconds

(B) 4.0 seconds

(C) 3.0 seconds

(D) 1.5 seconds

Q13. A heavy automated machine gun mechanism fires bullets of mass $m_b = 40$ grams at a constant operational rate of 5 rounds per second. If the muzzle ejection velocity of each bullet has a magnitude of $v_b = 700$ m/s, calculate the continuous average horizontal force (F) required to hold the weapon chassis stationary.

(A) 140 N

(B) 280 N

(C) 70 N

(D) 35 N

Q14. A static heavy storage module block of mass $M = 10$ kg is situated on a rough horizontal warehouse floor where the static coefficient of friction is $\mu_s = 0.5$ and the kinetic coefficient of friction is $\mu_k = 0.4$. If an external horizontal towing force of $F_{\text{tow}} = 45$ N is applied to the side of the module, find the magnitude of the actual friction force (f) generated at the floor interface. [Take $g = 10$ m/s^2].

(A) 50 N

(B) 40 N

(C) 45 N

(D) 0 N

Q15. A localized variable force described by the linear positional function $F(x) = (10 + 3x^2)$ N acts on a dynamic test block moving along a straight corridor path. Calculate the net structural work done (W) by this force field on the block during its displacement from the origin point $x = 0$ m to a final coordinate position of $x = 4$ m.

(A) 64 Joules

(B) 104 Joules

(C) 40 Joules

(D) 84 Joules

Q16. A solid steel sphere of mass $m = 2$ kg is dropped from rest from an initial height of $H = 20$ m onto a soft sand patch. If the sphere penetrates into the sand down to a depth of $d = 0.5$ m before coming to a complete stop, calculate the average resisting force (F_{res}) exerted by the sand matrix. [Take $g = 10$ m/s^2].

(A) 800 N

(B) 820 N

(C) 400 N

(D) 1600 N

Q17. An electric pumping engine operates at a fixed mechanical efficiency rating of $\eta = 80\%$. If the engine lifts a volume of water equivalent to a mass of $M = 240$ kg vertically upward through a structural height of 10 meters in a time frame of exactly 10 seconds at a uniform speed, calculate the minimum electrical input power (P_{input}) drawn by the motor system. [Take $g = 10$ m/s^2].

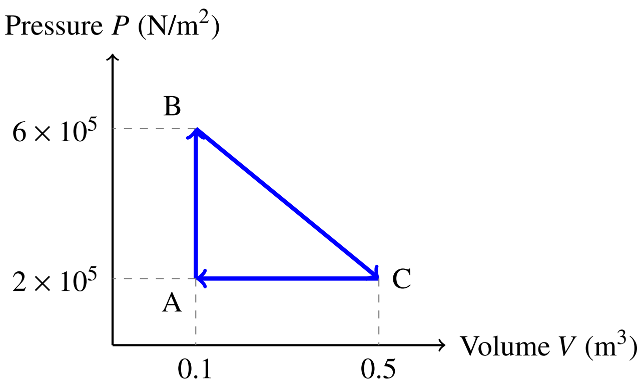
(A) 2400 W

(B) 1920 W

(C) 3000 W

(D) 3600 W

Q18. An ideal gas engine system goes through a closed cyclic thermodynamic sequence plotted on the pressure-volume ($P - V$) indicator chart below. Calculate the exact net mechanical work done (W_{net}) by the gas over a single complete clockwise loop path running $A \to B \to C \to A$:



(A) 1.6×10^5 Joules

(B) 8.0×10^4 Joules

(C) 4.0×10^4 Joules

(D) 1.2×10^5 Joules

Q19. A composite engineering heat sink rod is formed by joining a brass segment and a steel segment end-to-end. Both component segments have identical linear lengths and cross-sectional areas. The thermal conductivity coefficient of the brass segment is exactly double that of the steel segment ($\kappa_{brass} = 2\kappa_{steel}$). If the outer brass face is kept at a steady temperature of +90°C and the outer steel face is held at 0°C, compute the steady-state temperature (T_{junc}) at their shared interface junction.

(A) 45°C

(B) 60°C

(C) 30°C

(D) 50°C

Q20. A calibration technician marks a non-standard custom scale thermometer labeled X. This device records the freezing point of water at $-10°$X and index tracks the boiling steam point at $+140°$X. If a chemical fluid batch records a value of +50°X on this thermometer scale, calculate its true equivalent temperature in standard degrees Celsius (°C).

(A) 35.0°C

(B) 40.0°C

(C) 30.0°C

(D) 42.5°C

Q21. An acoustic organ pipe has a length of $L = 85$ cm and is closed at one end. If the velocity of sound in the air column is $v = 340$ m/s, calculate the fundamental resonant frequency (f_1) excited within this closed pipe structure.

(A) 100 Hz

(B) 200 Hz

(C) 400 Hz

(D) 50 Hz

Q22. A high-speed train sounding its warning whistle at a fixed frequency of $f_0 =$ 480 Hz speeds directly towards a stationary passenger standing on a transit platform at a uniform velocity of $v_s = 30$ m/s. If the speed of sound propagation in the air is exactly $v = 330$ m/s, calculate the apparent frequency (f') heard by the passenger.

(A) 436.4 Hz

(B) 528.0 Hz

(C) 512.6 Hz

(D) 440.0 Hz

Q23. A laboratory tracking instrument isolates an unstable radioactive tracer element sample. The diagnostic computer logs that the radioactive alpha activity rate drops to exactly $\frac{1}{16}$th of its original starting count value over an elapsed time period of $t = 24$ hours. Determine the individual half-life (τ) of this isotope material.

(A) 8.0 hours

(B) 6.0 hours

(C) 4.8 hours

(D) 12.0 hours

Q24. A heavy radioactive parent nucleus of Uranium denoted as ${}_{92}U^{235}$ undergoes a continuous series of spontaneous radioactive decay steps. If the final stable configuration reached at the end of the decay cascade chain is tracked as the isotope Lead ${}_{82}Pb^{207}$, calculate the exact counts of alpha (α) particles and beta-minus (β^-) particles ejected during this decay chain.

(A) $7\,\alpha$ and $4\,\beta^-$

(B) $8\,\alpha$ and $6\,\beta^-$

(C) $7\,\alpha$ and $5\,\beta^-$

(D) $6\,\alpha$ and $4\,\beta^-$

Q25. An incompressible, non-viscous chemical fluid flows under steady streamline conditions through a non-uniform horizontal pipe conduit line. At a wide section point, the pipe cross-sectional area is $A_1 = 40$ cm^2 and the fluid velocity is $v_1 = 3$ m/s. Calculate the fluid velocity (v_2) at a narrower section down the line where the cross-sectional area is reduced to $A_2 = 15$ cm^2.

(A) 5.0 m/s

(B) 8.0 m/s

(C) 6.0 m/s

(D) 1.125 m/s

Detailed Solutions

Q1.

Solution

Concept: The spherical mirror formula relates the object distance u, image distance v, and focal length f:

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

Using sign conventions, distances in front of a concave mirror are negative.

Solution:

In the first case, the real object distance is $u_1 = -15$ cm and the real image distance is $v_1 = -30$ cm. Substituting into the mirror formula to find the focal length f:

$$\frac{1}{f} = \frac{1}{-30} + \frac{1}{-15} = \frac{-1-2}{30} = \frac{-3}{30} = -\frac{1}{10} \implies f = -10 \text{ cm}$$

When the object is shifted by an additional distance of 5 cm further away from the mirror, the new object distance becomes:

$$u_2 = -(15+5) = -20 \text{ cm}$$

Now, substituting u_2 and f back into the mirror formula to determine the new image position v_2:

$$\frac{1}{-10} = \frac{1}{v_2} + \frac{1}{-20} \implies \frac{1}{v_2} = -\frac{1}{10} + \frac{1}{20} = \frac{-2+1}{20} = -\frac{1}{20} \implies v_2 = -20 \text{ cm}$$

The image moves from its initial position of -30 cm to a new position of -20 cm. The displacement magnitude is:

$$|\Delta v| = |v_2 - v_1| = |-20-(-30)| = 10 \text{ cm}$$

Since the value changed from 30 cm to 20 cm in front of the mirror, the image shifts towards the mirror.

Final Answer: Shifts 10 cm towards the mirror

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: The lens-maker's formula for a thin biconvex lens in air is:

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

For an equiconvex lens with $R_1 = +R$ and $R_2 = -R$:

$$P = (\mu - 1)\left(\frac{1}{R} - \left(-\frac{1}{R}\right)\right) = \frac{2(\mu - 1)}{R}$$

When split vertically down its center symmetric plane, each resulting half is a planoconvex lens with surfaces $R'_1 = +R$ and $R'_2 = \infty$.

Solution:

The power of each planoconvex piece (P') becomes:

$$P' = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) = \frac{\mu - 1}{R}$$

Comparing this to the original power P:

$$P' = \frac{P}{2}$$

Given that the original power rating of the whole lens is $P = +5$ Diopters:

$$P' = \frac{+5\text{ D}}{2} = +2.5\text{ Diopters}$$

Final Answer: $\boxed{+2.5\text{ D}}$

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: For a glass prism at the minimum deviation position, the light ray passes symmetrically through the crystal matrix. The refractive index μ is related to the prism angle A and the minimum angle of deviation δ_m by the prism formula:

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Solution:
Given an equilateral cross-section, the prism angle is $A = 60^\circ$. The minimum angle of deviation is $\delta_m = 30^\circ$. Substituting these values into the formula:

$$\mu = \frac{\sin\left(\frac{60^\circ+30^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)} = \frac{\sin(45^\circ)}{\sin(30^\circ)}$$

Using standard values $\sin(45^\circ) = \frac{1}{\sqrt{2}}$ and $\sin(30^\circ) = \frac{1}{2}$:

$$\mu = \frac{1/\sqrt{2}}{1/2} = \frac{2}{\sqrt{2}} = \sqrt{2}$$

Final Answer: $\boxed{\mu = \sqrt{2}}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: Total internal reflection (TIR) occurs when a light ray traveling from an optically denser medium to a rarer medium hits the interface boundary at an angle of incidence greater than the critical angle θ_c. The critical angle is given by Snell's law:

$$\sin\theta_c = \frac{\mu_{\text{rarer}}}{\mu_{\text{denser}}}$$

To escape into the ambient medium without triggering total internal reflection, the angle of incidence i must be strictly less than the critical angle ($i < \theta_c$).

Solution:

Given the resin medium refractive index $\mu_{\text{denser}} = 1.414 = \sqrt{2}$ and ambient air $\mu_{\text{rarer}} = 1.0$:

$$\sin\theta_c = \frac{1.0}{\sqrt{2}} \implies \theta_c = 45^\circ$$

Thus, for the light to escape the boundary into the air, the incident condition is:

$$i < 45^\circ$$

Final Answer: $\boxed{i < 45^\circ}$

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: The total linear magnifying power (M) of a compound scientific microscope is equal to the product of the linear magnification of the objective lens element (m_o) and the angular magnifying power of the eyepiece assembly (m_e):

$$M = m_o \times m_e$$

Solution:

Given parameters: $m_o = -5.0$ and $m_e = +6.0$. Multiplying these factors together yields:

$$M = (-5.0) \times (+6.0) = -30.0$$

Final Answer: $\boxed{-30.0}$

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: A meter bridge operates on the principle of a balanced Wheatstone bridge. When the galvanometer indicates zero current at a null balance point, the ratio of resistances in the two parallel branches is equal:

$$\frac{X}{R_s} = \frac{l_1}{100 - l_1}$$

Solution:

Given that the balancing length from left terminal A is $l_1 = 40$ cm, the remaining segment of the uniform slide wire is $100 - l_1 = 100 - 40 = 60$ cm. The reference resistance block is $R_s = 12\ \Omega$. Substituting these values into the balance condition formula:

$$\frac{X}{12} = \frac{40}{60} = \frac{2}{3}$$

Solving for the unknown test resistor component X:

$$X = 12 \times \frac{2}{3} = 4 \times 2 = 8\ \Omega$$

Final Answer: $\boxed{X = 8\ \Omega}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The electrical resistance of a uniform conductor is given by:

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

When a wire is stretched mechanically, its volume ($V = A \cdot L$) stays completely constant. Therefore, cross-sectional area A is inversely proportional to the length ($A = \frac{V}{L}$). Substituting this into the resistance formula gives:

$$R = \rho \frac{L^2}{V} \implies R \propto L^2$$

Solution:
Since the wire length is stretched uniformly to double its original value ($L' = 2L_0$), the resistance scales by the square of the extension factor:

$$\frac{R'}{R_0} = \left(\frac{L'}{L_0}\right)^2 = (2)^2 = 4$$

Given the initial base resistance $R_0 = 4\ \Omega$:

$$R' = 4 \times 4\ \Omega = 16\ \Omega$$

Final Answer: $\boxed{16\ \Omega}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: To convert a micro-galvanometer into a voltmeter of range V, a large multiplier resistance (R_h) must be connected in series with the instrument coil. The total resistance of the series loop is given by Ohm's law:

$$R_{\text{total}} = G + R_h = \frac{V}{I_g} \implies R_h = \frac{V}{I_g} - G$$

Solution:
Given data: internal coil resistance $G = 100\ \Omega$, full-scale deflection current $I_g = 1$ mA $= 10^{-3}$ A, and target high-voltage limit $V = 10$ V. Substituting these quantities into the conversion equation:

$$R_h = \frac{10}{10^{-3}} - 100 = 10,000 - 100 = 9,900\ \Omega$$

Final Answer: $\boxed{9,900\ \Omega}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The power output dissipated across an equivalent electrical network resistance connected to a constant voltage line source V is given by Joule's heating formula:

$$W = \frac{V^2}{R_{\text{eq}}}$$

Solution:
Let each of the three identical heating resistor coils have a resistance of R. When connected in parallel, the total equivalent resistance R_p is:

$$R_p = \frac{R}{3}$$

The corresponding parallel power output W_p is given as 900 W:

$$W_p = \frac{V^2}{R_p} = \frac{V^2}{R/3} = \frac{3V^2}{R} = 900\text{ W} \implies \frac{V^2}{R} = 300\text{ W}$$

When the three coils are re-wired into a strict series chain loop layout, the new equivalent resistance R_s is:

$$R_s = R + R + R = 3R$$

The series power output W_s can then be calculated:

$$W_s = \frac{V^2}{R_s} = \frac{V^2}{3R} = \frac{1}{3}\left(\frac{V^2}{R}\right)$$

Substituting the value of $\frac{V^2}{R} = 300$ W:

$$W_s = \frac{300}{3} = 100\text{ Watts}$$

Final Answer: 100 W

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: The potential gradient (k) along a potentiometer slide wire is the potential drop per unit length across the wire:

$$k = \frac{V_w}{L}$$

The voltage drop across the wire (V_w) is determined by treating the driver accumulator circuit loop as a simple series voltage divider:

$$V_w = I \cdot R_w = \left(\frac{E}{R_w + R_{\text{ext}}}\right) R_w$$

Solution:
Given parameters: wire length $L = 5$ m, wire resistance $R_w = 10\ \Omega$, accumulator EMF $E = 2.0$ V, and series external resistance box value $R_{\text{ext}} = 30\ \Omega$. First, find the total current I flowing through the circuit:

$$I = \frac{2.0}{10 + 30} = \frac{2.0}{40} = 0.05 \text{ A}$$

Next, calculate the static voltage drop V_w along the potentiometer wire:

$$V_w = I \cdot R_w = 0.05 \times 10 = 0.5 \text{ V}$$

Finally, compute the resulting potential gradient k:

$$k = \frac{V_w}{L} = \frac{0.5 \text{ V}}{5 \text{ m}} = 0.10 \text{ V/m}$$

Final Answer: $\boxed{0.10 \text{ V/m}}$

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: On a velocity-time $(v - t)$ performance graph, the linear acceleration or deceleration magnitude during any phase equals the absolute value of the slope of the velocity curve line segment:

$$a = \left|\frac{\Delta v}{\Delta t}\right| = \left|\frac{v_f - v_i}{t_f - t_i}\right|$$

.

Solution:

From the graph, during the final deceleration phase from $t_i = 5$ s to $t_f = 8$ s, the velocity drops linearly from an initial value of $v_i = 15$ m/s down to a complete halt $v_f = 0$ m/s. Calculating the slope magnitude over this time window:

$$a = \left|\frac{0 - 15}{8 - 5}\right| = \left|\frac{-15}{3}\right| = 5.0 \text{ m/s}^2$$

Final Answer: $\boxed{5.0 \text{ m/s}^2}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: For a ballistic projectile launched with an initial velocity vector $\vec{v}_0 = v_x\hat{i} + v_y\hat{j}$, the total time of flight T over flat ground depends entirely on the vertical velocity component v_y opposing gravitational acceleration g:

$$T = \frac{2v_y}{g}$$

Solution:

From the given initial velocity vector profile $\vec{v}_0 = 15\hat{i} + 20\hat{j}$, we isolate the vertical velocity scalar component:

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

Substituting $v_y = 20$ m/s and $g = 10$ m/s^2 into the time of flight formula:

$$T = \frac{2 \times 20}{10} = \frac{40}{10} = 4.0 \text{ seconds}$$

Final Answer: $\boxed{4.0 \text{ seconds}}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: According to Newton's second law of motion expressed in terms of linear momentum, the average mechanical force F exerted by the weapon mechanism equals the rate of change of momentum of the ejected ammunition system:

$$F = \frac{\Delta p}{\Delta t} = n \cdot m_b \cdot v_b$$

where n is the operational firing rate in rounds per second, m_b is the mass of a single bullet, and v_b is the muzzle exit velocity.

Solution:

Given metrics: $n = 5$ rounds/sec, bullet mass $m_b = 40$ grams $= 0.04$ kg, and muzzle velocity $v_b = 700$ m/s. Substituting these quantities into the force formulation:

$$F = 5 \times 0.04 \times 700 = 0.2 \times 700 = 140 \text{ Newtons}$$

Final Answer: $\boxed{140 \text{ N}}$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: The static friction force acts as a self-adjusting resisting mechanism until it hits its maximum limiting threshold value $f_{s,\max}$:

$$f_{s,\max} = \mu_s N = \mu_s M g$$

If the horizontally applied force F_{tow} is smaller than or equal to this threshold ($F_{\text{tow}} \leq f_{s,\max}$), the body remains entirely in static equilibrium, and the active resisting force matches the applied towing force exactly ($f = F_{\text{tow}}$).

Solution:

Given details: mass $M = 10$ kg, static coefficient $\mu_s = 0.5$, kinetic coefficient $\mu_k = 0.4$, and $g = 10$ m/s^2. First, evaluate the maximum limiting static friction barrier:

$$f_{s,\max} = 0.5 \times (10 \times 10) = 0.5 \times 100 = 50 \text{ N}$$

The applied horizontal towing force is $F_{\text{tow}} = 45$ N. Since the applied push (45 N) is strictly below the minimum threshold required to initiate sliding breakdown (50 N), the storage module block stays static. The matching resisting friction force is:

$$f = F_{\text{tow}} = 45 \text{ Newtons}$$

Final Answer: $\boxed{45 \text{ N}}$

Answer: (C)

Go Back to Question 14

Q15.

Solution

Concept: The mechanical work done W by a position-dependent variable force along a one-dimensional trajectory is calculated using the definite integral of the force function over the displacement interval:

$$W = \int_{x_i}^{x_f} F(x)\,dx$$

Solution:
Given the force profile $F(x) = 10 + 3x^2$, we integrate between the position bounds $x_i = 0$ m and $x_f = 4$ m:

$$W = \int_0^4 (10 + 3x^2)\,dx = \left[10x + x^3\right]_0^4$$

Evaluating the polynomial expression at the upper bound limit $x = 4$:

$$W = (10(4) + (4)^3) - (0) = 40 + 64 = 104 \text{ Joules}$$

Final Answer: $\boxed{104 \text{ Joules}}$

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: By applying the generalized Work-Energy Theorem, the net mechanical work done by all participating forces on the sphere is equal to its total change in kinetic energy (ΔK). Since the sphere starts from rest and finishes at rest, $\Delta K = 0$:

$$W_{\text{net}} = W_{\text{gravity}} + W_{\text{sand}} = 0$$

The gravitational force performs positive work as the object falls through the total vertical distance $(H + d)$, while the average resisting sand force F_{res} works in opposition over the penetration depth d:

$$mg(H + d) - F_{\text{res}} \cdot d = 0 \implies F_{\text{res}} = \frac{mg(H + d)}{d}$$

Solution:
Given values: mass $m = 2$ kg, release height $H = 20$ m, penetration path $d = 0.5$ m, and $g = 10$ m/s^2. Substituting these parameters into the work equation balance:

$$F_{\text{res}} = \frac{2 \times 10 \times (20 + 0.5)}{0.5} = \frac{20 \times 20.5}{0.5} = 40 \times 20.5 = 820 \text{ Newtons}$$

Final Answer: $\boxed{820 \text{ N}}$

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: The mechanical work output power (P_{output}) needed to lift a mass M vertically through a vertical height h in a time t at uniform speed is:

$$P_{\text{output}} = \frac{W}{t} = \frac{Mgh}{t}$$

The system efficiency factor η scales the minimum required electrical input power (P_{input}):

$$P_{\text{input}} = \frac{P_{\text{output}}}{\eta}$$

Solution:
Given specifications: mass $M = 240$ kg, height $h = 10$ m, duration $t = 10$ s, efficiency $\eta = 80\% = 0.8$, and $g = 10$ m/s^2. First, evaluate the target power output generated at the pump column:

$$P_{\text{output}} = \frac{240 \times 10 \times 10}{10} = 2400 \text{ Watts}$$

Next, calculate the total input electrical power drawn by the motor system:

$$P_{\text{input}} = \frac{2400 \text{ W}}{0.8} = 3000 \text{ Watts}$$

Final Answer: 3000 W

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept: On a thermodynamic pressure-volume $(P - V)$ diagram, the net work done W_{net} during a complete closed engine cycle matches the geometric area enclosed inside the loop. For a clockwise path orientation, the net work value is positive.

Solution:

The closed triangular loop forms a right-angled triangle. The length of the horizontal base along the volume axis is:

$$\Delta V = V_C - V_A = 0.5 - 0.1 = 0.4 \text{ m}^3$$

The height of the vertical side along the pressure axis is:

$$\Delta P = P_B - P_A = (6 \times 10^5) - (2 \times 10^5) = 4 \times 10^5 \text{ N/m}^2$$

Calculating the enclosed area of this clockwise engine path loop:

$$W_{net} = \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 0.4 \times (4 \times 10^5) = 0.2 \times (4 \times 10^5) = 8.0 \times 10^4 \text{ Joules}$$

Final Answer: $\boxed{8.0 \times 10^4 \text{ Joules}}$

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept: Under steady-state thermodynamic conditions, the rate of conductive heat transfer (H) passing through a composite structure remains completely uniform across each connected segment layer:

$$H = \frac{\kappa \cdot A \cdot \Delta T}{L}$$

Solution:

Let the interface junction temperature be T_{junc}. The segments have identical lengths (L) and equal cross-sectional areas (A). The thermal conductivities satisfy $\kappa_{\text{brass}} = 2\kappa_{\text{steel}}$. Equating the heat flow rate through the brass segment to that through the steel segment:

$$\frac{\kappa_{\text{brass}} \cdot A \cdot (90 - T_{\text{junc}})}{L} = \frac{\kappa_{\text{steel}} \cdot A \cdot (T_{\text{junc}} - 0)}{L}$$

Substitute $\kappa_{\text{brass}} = 2\kappa_{\text{steel}}$ into the relation:

$$2\kappa_{\text{steel}} \cdot (90 - T_{\text{junc}}) = \kappa_{\text{steel}} \cdot T_{\text{junc}}$$

Canceling out the common structural terms (κ_{steel}):

$$2(90 - T_{\text{junc}}) = T_{\text{junc}} \implies 180 - 2T_{\text{junc}} = T_{\text{junc}}$$

$$180 = 3T_{\text{junc}} \implies T_{\text{junc}} = \frac{180}{3} = 60^\circ\text{C}$$

Final Answer: $\boxed{60^\circ\text{C}}$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: The mathematical relationship used to convert between an arbitrary non-standard temperature scale X and the standard Celsius scale C relies on linear interpolation mapping relative to fixed reference points (Lower Fixed Point, LFP and Upper Fixed Point, UFP):

$$\frac{T_X - \text{LFP}_X}{\text{UFP}_X - \text{LFP}_X} = \frac{T_C - \text{LFP}_C}{\text{UFP}_C - \text{LFP}_C}$$

Solution:

For the standard Celsius scale, $\text{LFP}_C = 0°\text{C}$ and $\text{UFP}_C = 100°\text{C}$. For the custom scale X, we have $\text{LFP}_X = -10°\text{X}$ and $\text{UFP}_X = +140°\text{X}$. Given a diagnostic test value of $T_X = +50°\text{X}$:

$$\frac{50 - (-10)}{140 - (-10)} = \frac{T_C - 0}{100 - 0}$$

$$\frac{60}{150} = \frac{T_C}{100} \implies \frac{2}{5} = \frac{T_C}{100}$$

Solving for T_C:

$$T_C = \frac{2}{5} \times 100 = 2 \times 20 = 40.0°\text{C}$$

Final Answer: $\boxed{40.0°\text{C}}$

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept: For an acoustic organ pipe closed at one end and open at the other, the standing wave boundary conditions require a displacement node at the flat bottom and an antinode at the rim. The fundamental resonant frequency wavelength satisfies $L = \frac{\lambda_1}{4}$, which leads to:

$$f_1 = \frac{v}{4L}$$

Solution:

Given specifications: pipe column length $L = 85$ cm $= 0.85$ m and speed of sound $v = 340$ m/s. Substituting these quantities into the fundamental calculation formula:

$$f_1 = \frac{340}{4 \times 0.85} = \frac{340}{3.40} = 100 \text{ Hz}$$

Final Answer: $\boxed{100 \text{ Hz}}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: According to the acoustic Doppler effect formulation, when a sound source emitting waves at a baseline frequency f_0 travels directly toward a stationary observer, the apparent registered frequency f' increases:

$$f' = f_0 \left(\frac{v}{v - v_s} \right)$$

where v is the wave propagation velocity in air and v_s is the uniform speed of the oncoming source.

Solution:

Given data: baseline whistle frequency $f_0 = 480$ Hz, sound propagation speed $v = 330$ m/s, and approaching train speed $v_s = 30$ m/s. Substituting these metrics into the Doppler equation:

$$f' = 480 \times \left(\frac{330}{330 - 30} \right) = 480 \times \left(\frac{330}{300} \right) = 480 \times 1.1 = 528.0 \text{ Hz}$$

Final Answer: $\boxed{528.0 \text{ Hz}}$

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept: The fraction of remaining active parent nuclei in a radioactive sample after an elapsed time t can be modeled in terms of the number of completed half-life periods n:

$$\frac{N_t}{N_0} = \left(\frac{1}{2} \right)^n, \quad \text{where } n = \frac{t}{\tau}$$

Solution:

The radioactive activity drops to $\frac{1}{16}$th of its starting count value over an elapsed time of $t = 24$ hours. Expressing this remaining fraction as a power of two:

$$\frac{1}{16} = \left(\frac{1}{2} \right)^4 \implies n = 4 \text{ half-lives}$$

Now, utilizing the connection between elapsed time and the half-life period τ:

$$n = \frac{t}{\tau} \implies 4 = \frac{24 \text{ hours}}{\tau} \implies \tau = \frac{24}{4} = 6.0 \text{ hours}$$

Final Answer: $\boxed{6.0 \text{ hours}}$

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept: Let x represent the total count of alpha particles ($_2He^4$) emitted and y represent the total count of beta-minus particles ($_{-1}\beta^0$) ejected during the cascade breakdown chain. Balancing both total atomic mass numbers (A) and atomic proton numbers (Z) ensures stability conservations.

Solution:

The balanced nuclear equation is written as:

$$_{92}U^{235} \longrightarrow _{82}Pb^{207} + x(_2He^4) + y(_{-1}\beta^0)$$

First, isolate and solve for the mass number conservation (A):

$$235 = 207 + 4x \implies 28 = 4x \implies x = 7 \text{ alpha particles}$$

Next, isolate and solve for the total atomic charge number conservation (Z):

$$92 = 82 + 2x - y$$

Substituting the known alpha count $x = 7$ into the atomic charge equation:

$$92 = 82 + 2(7) - y \implies 92 = 82 + 14 - y$$

$$92 = 96 - y \implies y = 96 - 92 = 4 \text{ beta particles}$$

Thus, the decay chain emits exactly $7\,\alpha$ and $4\,\beta^-$ particles.

Final Answer: $\boxed{7\,\alpha \text{ and } 4\,\beta^-}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: For an incompressible, non-viscous fluid undergoing steady streamline flow, the total volume flow rate remains constant along the pipe conduit. This principle is mathematically expressed by the Equation of Continuity:

$$A_1 \cdot v_1 = A_2 \cdot v_2$$

Solution:
Given values: area at wide section $A_1 = 40 \text{ cm}^2$, fluid velocity $v_1 = 3$ m/s, and narrower pipe area cross-section $A_2 = 15 \text{ cm}^2$. Substituting these parameters directly into the continuity equation to isolate v_2:

$$40 \times 3 = 15 \times v_2 \implies 120 = 15 \cdot v_2$$

$$v_2 = \frac{120}{15} = 8.0 \text{ m/s}$$

Final Answer: $\boxed{8.0 \text{ m/s}}$

Answer: (B)

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Answer Key

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