JELET Physics Sample Paper-5

Duration: 35 Minutes **Maximum Marks: 35**

Instructions

- This paper contains **30** Multiple Choice Questions divided into **2 Sections**.
- **Section A (Q1–Q25):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section B (Q26–Q30):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section–A — 25 Questions × 1 Mark Each
(Negative Marking: −0.25) [Single Correct]

Q1. A dimensional analysis is performed on a hypothetical physical quantity $X = \frac{A^2\sqrt{B}}{C^3}$, where the percentage errors in the measurement of A, B, and C are 1.5%, 4.0%, and 2.0% respectively. What is the maximum percentage error in the estimation of X?

(A) 7.5%

(B) 11.0%

(C) 5.0%

(D) 9.5%

Q2. Consider a block of mass m sliding down a rough inclined plane making an angle θ with the horizontal. The coefficient of kinetic friction between the block and the plane is $\mu_k = \tan\theta$. If the block is given an initial velocity v_0 down the incline, what will be the nature of its subsequent motion?

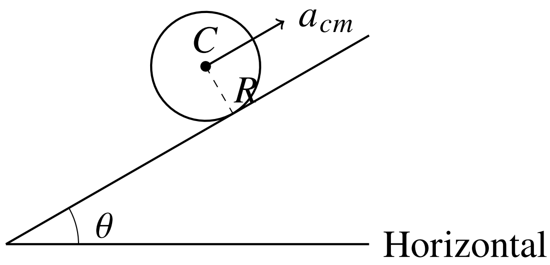
(A) It will accelerate down the incline with an acceleration of $g \sin\theta$.

(B) It will decelerate uniformly and eventually come to rest.

(C) It will continue to move down the incline with a constant velocity v_0.

(D) It will move down with a continuously increasing velocity but zero acceleration.

Q3. A uniform solid cylinder of mass M and radius R rolls without slipping down a rough track as illustrated below. Which of the following expressions correctly gives its absolute linear acceleration down the incline?



(A) $g \sin\theta$

(B) $\frac{2}{3} g \sin\theta$

(C) $\frac{1}{2} g \sin\theta$

(D) $\frac{5}{7} g \sin\theta$

Q4. A water tank is filled up to a height H. A small orifice is punched at a depth h below the free surface of water. To achieve the maximum horizontal range R_{max} on the ground level where the base of the tank rests, what should be the precise location of the orifice?

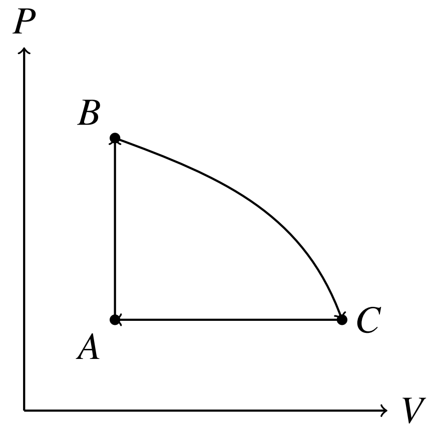
(A) $h = \frac{H}{4}$

(B) $h = \frac{H}{3}$

(C) $h = \frac{H}{2}$

(D) $h = \frac{2H}{3}$

Q5. An ideal gas undergoes a thermodynamic process depicted by the $P - V$ diagram below. The process paths form a closed cyclic loop $A \rightarrow B \rightarrow C \rightarrow A$. If the network done by the system during one complete cycle is 150 J, and the heat rejected during path $C \to A$ is 40 J while path $B \to C$ is adiabatic, determine the total heat supplied during the path $A \to B$.



(A) 110 J

(B) 190 J

(C) 150 J

(D) 230 J

Q6. A potential energy function for a conservative particle moving along the x-axis is given as $U(x) = \frac{\alpha}{x^2} - \frac{\beta}{x}$, where α and β are positive dimensional constants. Find the position of stable equilibrium for this particle.

(A) $x = \frac{\alpha}{\beta}$

(B) $x = \frac{2\alpha}{\beta}$

(C) $x = \frac{\beta}{2\alpha}$

(D) $x = \sqrt{\frac{\alpha}{\beta}}$

Q7. A ray of light traveling in a dense glass medium of refractive index $n_1 = \sqrt{2}$ approaches a boundary with a rarer outer cladding medium of refractive index $n_2 = 1.0$. If the angle of incidence is steadily increased to exactly 45°, which phenomenon occurs at the interface?

(A) Total transmission into the cladding with zero reflection.

(B) Grazing emergence along the boundary interface (critical state).

(C) Normal refraction with an angle of refraction equal to 30°.

(D) Total internal reflection back into the glass medium.

Q8. In a photoelectric effect setup, when monochromatic light of wavelength λ is incident on a clean metallic surface, the stopping potential is observed to be V_0. When light of wavelength 2λ is incident on the exact same surface, the stopping potential drops to $V_0/4$. What is the threshold wavelength λ_0 of this metal?

(A) 3λ

(B) 4λ

(C) 2.5λ

(D) 5λ

Q9. A simple pendulum is suspended from the ceiling of an elevator cabin. If the elevator accelerates vertically upwards with a constant magnitude $a = g/3$, what is the ratio of the new time period of oscillation T' to the original time period T when the elevator was stationary?

(A) $\sqrt{\frac{3}{4}}$

(B) $\sqrt{\frac{4}{3}}$

(C) $\frac{3}{4}$

(D) $\frac{1}{2}$

Q10. An incompressible, non-viscous fluid flows through a non-uniform horizontal pipe network. At a section where the cross-sectional radius is R, the flow velocity is measured to be v. What will be the linear flow velocity at an downstream segment where the pipe radius reduces to $R/3$?

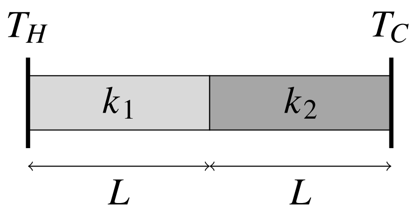
(A) $3v$

(B) $9v$

(C) $\frac{v}{3}$

(D) $\frac{v}{9}$

Q11. A composite bar is formed by joining two distinct metallic rods of identical lengths and identical cross-sectional areas in a series configuration, as shown below. The thermal conductivities of the two rods are k_1 and k_2 respectively. If the open ends are maintained at steady temperatures T_H and T_C, what is the effective thermal conductivity (k_{eq}) of this composite network?



(A) $\frac{k_1+k_2}{2}$

(B) $\frac{2k_1k_2}{k_1+k_2}$

(C) $\sqrt{k_1k_2}$

(D) $\frac{k_1k_2}{k_1+k_2}$

Q12. A variable force $F = (3x^2 + 2x - 5)$ N acts on a small particle of mass 2 kg, causing it to displace along the x-axis from an initial position $x = 0$ m to a final position $x = 2$ m. Compute the total change in kinetic energy of the particle over this interval.

(A) 4 J

(B) 12 J

(C) 2 J

(D) 8 J

Q13. A thin biconvex lens made of glass ($n_g = 1.5$) has a focal length f when measured in air. If this lens is completely immersed inside a transparent chemical liquid whose refractive index is exactly equal to 1.25, its new focal length inside the liquid (f_L) will satisfy which relation?

(A) $f_L = 2.5f$

(B) $f_L = 1.5f$

(C) $f_L = 2.0f$

(D) $f_L = 4.0f$

Q14. According to Kepler's Third Law of Planetary Motion, the square of the orbital period T of a planet revolving in an elliptical path around the Sun is directly proportional to the cube of its semi-major axis a. If a newly discovered exoplanet orbits at an average distance from its parent star that is exactly 4 times the earth-sun distance, what will be its orbital period in equivalent Earth years?

(A) 4 years

(B) 8 years

(C) 16 years

(D) 64 years

Q15. A spherical solid ball of radius r is dropped into a deeply extended column of a highly viscous liquid fluid. The ball accelerates initially but eventually achieves a constant terminal velocity v_t. Which of the following graphical options correctly captures the dependence of this terminal velocity v_t on the radius r of the falling sphere?

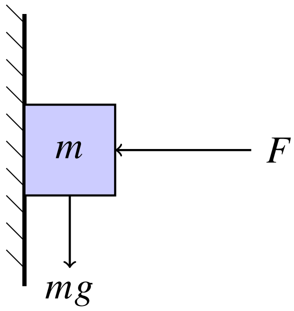
(A) $v_t \propto \frac{1}{r}$

(B) $v_t \propto r$

(C) $v_t \propto r^2$

(D) $v_t \propto r^{3/2}$

Q16. A block of mass $m = 5$ kg is held completely stationary against a rough vertical wall by applying a purely horizontal normal compressive force F, as modeled in the structural schematic below. The static friction coefficient between the vertical surface and the block is $\mu_s = 0.4$. Taking $g = 10$ m/s^2, what is the minimum magnitude of the horizontal force F required to prevent the block from slipping down?



(A) 50 N

(B) 125 N

(C) 20 N

(D) 100 N

Q17. An ideal monoatomic gas expands at a constant operating pressure P_0 from an initial state volume V_0 to a final volume $2V_0$. What fraction of the total heat energy supplied to the gas system during this isobaric process is converted directly into external work?

(A) $\frac{2}{5}$

(B) $\frac{3}{5}$

(C) $\frac{2}{3}$

(D) $\frac{1}{3}$

Q18. A particle moves in a perfect circle of radius $R = 2.0$ m with a time-dependent speed given by $v(t) = 2t$ m/s. Determine the total magnitude of the net absolute acceleration of the particle at the instant $t = 1.0$ s.

(A) 2 m/s^2

(B) $2\sqrt{2}$ m/s^2

(C) 4 m/s^2

(D) $\sqrt{5}$ m/s^2

Q19. A block of mass M is connected to a horizontal ideal spring of stiffness constant k. The system is pulled to an initial displacement amplitude X_0 from its equilibrium configuration along a frictionless floor and released from rest. What is the instantaneous speed of the mass block when it passes through a position exactly halfway ($x = X_0/2$) towards the equilibrium center?

(A) $\frac{1}{2}\sqrt{\frac{k}{M}}X_0$

(B) $\frac{\sqrt{3}}{2}\sqrt{\frac{k}{M}}X_0$

(C) $\frac{3}{4}\sqrt{\frac{k}{M}}X_0$

(D) $\sqrt{\frac{k}{2M}}X_0$

Q20. A U-tube containing mercury is open to the atmosphere at both ends. Water is poured into one arm until the vertical height of the water column is 13.6 cm. Given that the specific gravity of mercury is 13.6 and that of water is 1.0, what is the resulting vertical shift or height differential between the free mercury levels in the two arms?

(A) 13.6 cm

(B) 1.0 cm

(C) 0.5 cm

(D) 2.0 cm

Q21. A highly sensitive photon counter registers that a specific solar photovoltaic test cell absorbs monochromatic radiation of a certain frequency, ejecting electrons via photoemission. If the total intensity of the incoming light beam is doubled without altering its frequency, what happens to the maximum kinetic energy of the emitted photoelectrons and the total saturation photocurrent?

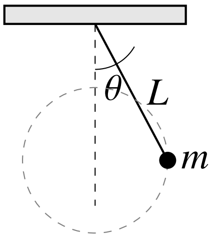
(A) The maximum kinetic energy doubles, and the photocurrent remains unchanged.

(B) The maximum kinetic energy remains unchanged, and the photocurrent doubles.

(C) Both the maximum kinetic energy and the photocurrent are doubled.

(D) The maximum kinetic energy doubles, and the photocurrent quadruples.

Q22. A small body of mass m is suspended at the end of a light string of length L, creating a conical pendulum. The body revolves in a horizontal circle with a uniform angular velocity ω, such that the string maintains a steady angle θ relative to the vertical line as diagrammed below. Find the expression for the tension T within the string.



(A) $mg\cos\theta$

(B) $\frac{mg}{\cos\theta}$

(C) $mg\tan\theta$

(D) $\frac{mg}{\sin\theta}$

Q23. A solid copper cylinder of mass m at an initial high temperature of 100°C is dropped into an insulated calorimeter containing water at 20°C. The thermal capacity of the calorimeter vessel itself is negligible. If the system reaches a final steady thermal equilibrium at 30°C, determine the ratio of the mass of water to the mass of the copper cylinder. (Take specific heat of copper = 0.1 cal/g°C, specific heat of water = 1.0 cal/g°C).

(A) 0.7

(B) 1.4

(C) 0.35

(D) 2.1

Q24. An open vessel contains water filled up to a height h. A tiny hole is made at the bottom plate of the container. If Pascal's law and Bernoulli's equation are valid for this ideal drainage scenario, what is the initial velocity of efflux of water escaping from the bottom opening?

(A) $\sqrt{gh}$

(B) $\sqrt{2gh}$

(C) $2\sqrt{gh}$

(D) $\frac{1}{2}\sqrt{2gh}$

Q25. A light ray enters one end of a long, straight optical fiber core of refractive index $n_1 = 1.50$ surrounded by a protective cladding of refractive index $n_2 = 1.41$. What is the maximum angle of incidence θ_{max} at the air-core interface for which the light ray will be completely guided down the fiber by undergoing total internal reflection at the core-cladding boundary?

(A) $\sin^{-1}(0.30)$

(B) $\sin^{-1}(0.51)$

(C) $\sin^{-1}(0.15)$

(D) $\sin^{-1}(0.85)$

Section–B — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q26. A rigid object of mass M is rotating about a fixed reference axis with a time-varying angular velocity $\omega(t)$. A net external torque $\tau(t)$ acts on the system. Which of the following statements regarding the rotational dynamics of this object are fundamentally correct?

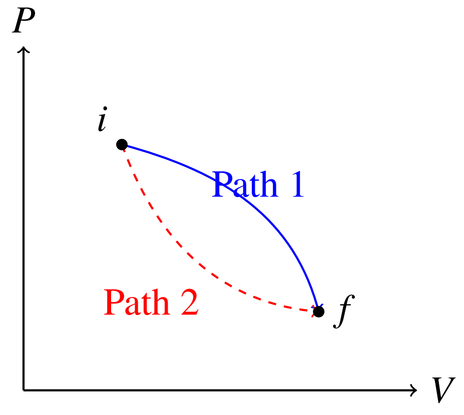
(A) The rotational kinetic energy is given by $K_{rot} = \frac{1}{2}I\omega^2$, where I is the moment of inertia about that specific axis.

(B) The rate of change of angular momentum $\frac{dL}{dt}$ is equal to the net external torque τ.

(C) If the net external torque acting on the system is zero, its total angular momentum must remain conserved in both magnitude and direction.

(D) The linear acceleration of any particle at a distance r from the rotation axis has only a tangential component given by $a_t = r\frac{d\omega}{dt}$.

Q27. A thermodynamic system contains an enclosed sample of an ideal gas. The system transitions from an initial equilibrium state i to a final state f via two alternative physical pathways, Path 1 and Path 2, as shown in the $P - V$ diagram below. Which of the following parameters must have identical values for both Path 1 and Path 2?



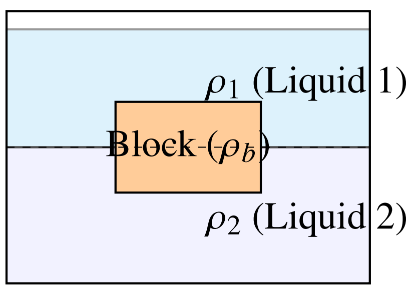
(A) The total net heat exchange, ΔQ, between the gas and the external surroundings.

(B) The net mechanical work done, ΔW, by the expanding gas.

(C) The absolute change in the internal energy, $\Delta U = U_f - U_i$, of the system.

(D) The total change in temperature, $\Delta T = T_f - T_i$, of the ideal gas.

Q28. A solid rectangular block of density ρ_b is floating at the horizontal interface between two immiscible liquids contained in a stationary vat. The upper liquid has a density ρ_1 and the lower liquid has a density ρ_2, such that $\rho_1 < \rho_b < \rho_2$. The block is partially submerged in both layers, as illustrated in the schematic below. Which of the following conclusions are true according to fluid mechanics and buoyancy principles?



(A) The total upward buoyant force exerted on the block equals the total downward gravitational force acting on it.

(B) The fraction of the block's volume submerged in the lower liquid increases if the density ρ_2 is increased.

(C) The fraction of the block's volume submerged in the lower liquid is given by $\frac{V_2}{V} = \frac{\rho_b - \rho_1}{\rho_2 - \rho_1}$.

(D) If the entire container accelerates upward with an acceleration a, the fraction of the block submerged in each liquid will change significantly.

Q29. A light block of mass m is pushed against a horizontal ideal spring of spring constant k, compressing it by a distance x, and is placed on a rough horizontal track. When released, the spring drives the block across the surface. The coefficient of kinetic friction between the block and the track surface is μ_k. Which of the following statements match the conservation of energy and work-energy principles for this scenario?

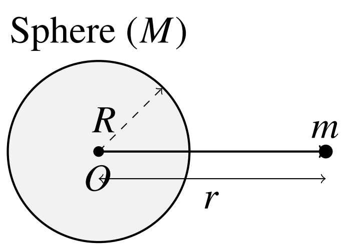
(A) The mechanical energy initially stored as elastic potential energy in the compressed spring is $U_s = \frac{1}{2}kx^2$.

(B) The total work done by the force of kinetic friction as the block slides a total distance d across the track is given by $W_f = -\mu_k mgd$.

(C) The maximum kinetic energy attained by the block occurs exactly at the instant it detaches from the spring when the spring returns to its natural uncompressed length.

(D) The total thermal energy generated and dissipated into the track and surroundings during the complete sliding phase is equal to the magnitude of work done by friction.

Q30. A point mass m is placed at a distance r from the center of a perfectly uniform solid sphere of mass M and radius R. Let F_g denote the magnitude of the gravitational attraction force exerted on the point mass, and g denote the local acceleration due to gravity. Which of the following assertions are correct?



(A) For all external points ($r > R$), the gravitational force satisfies $F_g = \frac{GMm}{r^2}$, treating the entire sphere as a point mass at its center.

(B) For all internal points ($r < R$), the gravitational force is strictly zero due to shell-theory cancellation.

(C) For all internal points ($r < R$), the gravitational force varies linearly with distance from the center, i.e., $F_g = \frac{GMmr}{R^3}$.

(D) The acceleration due to gravity g reaches its absolute maximum value precisely at the surface of the solid sphere ($r = R$).

Detailed Solutions

Q1.

Solution

Concept: Error propagation analyzes how uncertainties in individual measurements affect the calculated uncertainty of a combination function. For a power-product relation, fractional errors combine linearly weighted by their absolute exponents.

Solution:

(a) Given the physical relation $X = \frac{A^2\sqrt{B}}{C^3}$, we take the natural logarithm on both sides to separate individual variables: $\ln X = 2\ln A + \frac{1}{2}\ln B - 3\ln C$.

(b) Differentiating both sides to find small fractional variations yields the differential relation: $\frac{dX}{X} = 2\frac{dA}{A} + \frac{1}{2}\frac{dB}{B} - 3\frac{dC}{C}$.

(c) To compute the worst-case maximum absolute fractional error, all individual negative variations must accumulate constructively, turning minus signs into plus signs: $\frac{\Delta X}{X} = 2\left(\frac{\Delta A}{A}\right) + \frac{1}{2}\left(\frac{\Delta B}{B}\right) + 3\left(\frac{\Delta C}{C}\right)$.

(d) Substitute the given independent percentage error values ($\frac{\Delta A}{A} \times 100\% = 1.5\%$, $\frac{\Delta B}{B} \times 100\% = 4.0\%$, $\frac{\Delta C}{C} \times 100\% = 2.0\%$) directly into the error formula.

(e) This calculation yields the total percentage error: $\frac{\Delta X}{X} \times 100\% = 2(1.5\%) + \frac{1}{2}(4.0\%) + 3(2.0\%) = 3.0\% + 2.0\% + 6.0\% = 11.0\%$.

Final Answer: 11.0%

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: The motion of an object along a rough inclined surface is governed by the vector sum of its component of gravitational weight acting parallel to the incline and the opposing kinetic friction force.

Solution:

(a) Consider the component of gravity pulling the mass block downward parallel to the inclined ramp, which is expressed as $F_{\parallel} = mg\sin\theta$.

(b) The normal contact force exerted by the rough incline on the block acts perpendicular to the surface, counterbalancing the component of gravity: $N = mg\cos\theta$.

(c) Kinetic friction opposes relative sliding motion along the plane and is calculated using the relation: $f_k = \mu_k N = \mu_k mg\cos\theta$.

(d) Substituting the given critical value for the dynamic friction coefficient, $\mu_k = \tan\theta = \frac{\sin\theta}{\cos\theta}$, the kinetic friction force simplifies directly to: $f_k = \left(\frac{\sin\theta}{\cos\theta}\right) mg\cos\theta = mg\sin\theta$.

(e) Balancing forces along the incline shows that the net driving force is zero ($F_{\parallel} - f_k = 0$). By Newton's first law, with no net force, the block maintains its initial velocity v_0 without accelerating or decelerating.

Final Answer: It will continue to move down the incline with a constant velocity v_0.

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: Rigid body rolling without slipping down an incline requires both linear acceleration of the center of mass and angular acceleration about the center, coupled via the non-slip condition.

Solution:

(a) The parallel component of gravity pulls the cylinder downward ($mg \sin\theta$), while static friction f_s acts upward along the plane to cause rotation, giving: $mg \sin\theta - f_s = ma_{cm}$.

(b) Torque about the center of mass is produced exclusively by static friction: $\tau = f_s R = I\alpha$, where I is the rotational moment of inertia.

(c) For a uniform solid cylinder, the moment of inertia about its central longitudinal axis is given by the geometric formula: $I = \frac{1}{2}MR^2$.

(d) The condition for rolling without slipping dictates a strict physical link between linear and rotational kinematics at the contact point: $a_{cm} = R\alpha$.

(e) Substituting these relations into the torque equation yields $f_s = \frac{1}{2}ma_{cm}$. Inserting this friction expression back into the linear force equation gives $mg \sin\theta - \frac{1}{2}ma_{cm} = ma_{cm}$, which simplifies to $a_{cm} = \frac{2}{3}g \sin\theta$.

Final Answer: $2\frac{}{3g \sin\theta}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: The velocity of efflux from an orifice is determined by Torricelli's law, and the subsequent path follows a standard parabolic trajectory under horizontal projectile motion.

Solution:

(a) By Torricelli's theorem, the horizontal exit velocity v of water escaping from an orifice at a depth h below the free top surface is: $v = \sqrt{2gh}$.

(b) The vertical distance remaining for the fluid jet to fall before hitting the ground line at the base of the tank is given by: $y = H - h$.

(c) Using the kinematic equation for a horizontal projectile with zero initial vertical velocity ($y = \frac{1}{2}gt^2$), the total time of flight is: $t = \sqrt{\frac{2(H-h)}{g}}$.

(d) The horizontal range R covered by the water stream is the product of horizontal exit speed and flight time: $R = v \cdot t = \sqrt{2gh} \cdot \sqrt{\frac{2(H-h)}{g}} = 2\sqrt{h(H-h)}$.

(e) To maximize R, differentiate the expression inside the square root with respect to h and equate to zero ($\frac{d}{dh}(Hh - h^2) = H - 2h = 0$), which yields $h = \frac{H}{2}$.

Final Answer: h = H$_{2}$

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: The cyclic process is analyzed using the First Law of Thermodynamics, which states that the total change in internal energy over any complete closed thermodynamic loop is zero.

Solution:

(a) For a complete thermodynamic cycle ($A \to B \to C \to A$), the initial and final states are identical, meaning the net internal energy change is zero: $\Delta U_{net} = 0$.

(b) Applying the cyclic version of the First Law of Thermodynamics connects total work and total heat: $Q_{net} = W_{net}$, where $W_{net} = 150$ J.

(c) The total net heat exchange is the sum of the heat values across the three individual segments: $Q_{net} = Q_{AB} + Q_{BC} + Q_{CA}$.

(d) We are given that segment $B \to C$ is an adiabatic process, meaning no heat is exchanged with the surroundings: $Q_{BC} = 0$ J.

(e) The system rejects heat during segment $C \to A$, so this value enters the equation as a negative quantity: $Q_{CA} = -40$ J. Substituting these values into the energy balance gives $150 = Q_{AB} + 0 - 40$, which resolves to $Q_{AB} = 190$ J.

Final Answer: 190 J

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: A particle is in mechanical equilibrium when the net conservative force acting on it is zero. Stable equilibrium requires that the potential energy function is at a local minimum.

Solution:

(a) The conservative force acting on a particle along the x-axis is related to the spatial derivative of its potential energy function: $F(x) = -\frac{dU}{dx}$.

(b) Differentiating the given function $U(x) = \alpha x^{-2} - \beta x^{-1}$ gives the force equation: $F(x) = -\left(-2\alpha x^{-3} + \beta x^{-2}\right) = \frac{2\alpha}{x^3} - \frac{\beta}{x^2}$.

(c) To locate equilibrium configurations, set the force expression to zero: $\frac{2\alpha}{x^3} - \frac{\beta}{x^2} = 0 \implies \frac{2\alpha}{x^3} = \frac{\beta}{x^2}$, which simplifies to the position coordinate $x = \frac{2\alpha}{\beta}$.

(d) To confirm stability, find the second derivative of potential energy: $\frac{d^2U}{dx^2} = \frac{d}{dx}\left(-\frac{2\alpha}{x^3} + \frac{\beta}{x^2}\right) = \frac{6\alpha}{x^4} - \frac{2\beta}{x^3}$.

(e) Evaluating this second derivative at $x = \frac{2\alpha}{\beta}$ yields a positive value ($\frac{\beta^4}{8\alpha^3} > 0$), confirming that this position represents a stable minimum point.

Final Answer: x = $2\alpha_{\overline{\beta}}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: Snell's law governs refraction at a boundary between media of different refractive indices. Total internal reflection occurs when light travels from a denser to a rarer medium and exceeds the critical angle.

Solution:

(a) The critical angle θ_c for an interface between two media is the angle of incidence that results in a refraction angle of 90° into the rarer medium.

(b) Using Snell's law, this condition is expressed as: $\sin\theta_c = \frac{n_2}{n_1}$, where n_1 is the denser medium and n_2 is the rarer medium.

(c) Substituting the given refractive index values ($n_1 = \sqrt{2}$ and $n_2 = 1.0$) into the equation gives: $\sin\theta_c = \frac{1.0}{\sqrt{2}}$.

(d) Taking the inverse sine of this value determines the exact critical angle for this glass-cladding boundary: $\theta_c = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$.

(e) Because the actual angle of incidence is given as exactly 45°, it matches the critical angle ($\theta = \theta_c$). Under this condition, the light ray does not cross into the cladding but emerges parallel to the interface, a state known as grazing emergence.

Final Answer: Grazing emergence along the boundary interface (critical state).

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The photoelectric effect is described by Einstein's equation, which balances the incident photon energy between overcoming the metal's work function and providing kinetic energy to the emitted electron.

Solution:

(a) Einstein's photoelectric equation relates stopping potential V to wavelength λ and threshold wavelength λ_0 as: $eV = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$.

(b) For the first wavelength λ, the stopping potential is V_0. This gives our first equation: $eV_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$.

(c) For the second wavelength 2λ, the observed stopping potential drops to $V_0/4$, giving our second equation: $e\left(\frac{V_0}{4}\right) = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0}$.

(d) Multiply the entire second equation by 4 to align the left-hand terms: $eV_0 = \frac{4hc}{2\lambda} - \frac{4hc}{\lambda_0} = \frac{2hc}{\lambda} - \frac{4hc}{\lambda_0}$.

(e) Equating the two expressions for eV_0 gives: $\frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{2hc}{\lambda} - \frac{4hc}{\lambda_0}$. Simplifying this equation by grouping like terms leads to $\frac{3hc}{\lambda_0} = \frac{hc}{\lambda}$, which yields $\lambda_0 = 3\lambda$.

Final Answer: 3λ

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The period of a simple pendulum depends on the local effective acceleration field experienced within its frame of reference. An accelerating frame introduces a fictional inertial force.

Solution:

(a) The fundamental time period of a simple pendulum of length L in a stationary inertial frame is given by: $T = 2\pi\sqrt{\frac{L}{g}}$.

(b) When the elevator accelerates vertically upward with acceleration a, an observer inside experiences an downward pseudo-force of magnitude ma.

(c) This upward acceleration increases the effective gravitational field strength experienced by the pendulum bob: $g_{eff} = g + a$.

(d) Substituting the given acceleration value $a = \frac{g}{3}$ into the relation gives the effective field: $g_{eff} = g + \frac{g}{3} = \frac{4}{3}g$.

(e) The new time period of oscillation inside the moving cabin is $T' = 2\pi\sqrt{\frac{L}{g_{eff}}} = 2\pi\sqrt{\frac{L}{(4/3)g}}$. Taking the ratio of T' to T yields $\frac{T'}{T} = \sqrt{\frac{g}{g_{eff}}} = \sqrt{\frac{3}{4}}$.

Final Answer: $\sqrt{\frac{3}{4}}$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: The equation of continuity governs steady, incompressible fluid flow, stating that the total mass flow rate through any cross-section of a continuous pipe remains constant.

Solution:

(a) For an incompressible fluid, volume conservation requires that the product of the cross-sectional area and fluid velocity remains constant at all points: $A_1 v_1 = A_2 v_2$.

(b) Modeling the non-uniform pipe network with circular cross-sections, the area expression in terms of radius R is given by: $A = \pi R^2$.

(c) At the first section, the cross-sectional area is $A_1 = \pi R^2$ and the measured flow velocity is $v_1 = v$.

(d) At the downstream section, the radius is reduced to $R_2 = \frac{R}{3}$, so its cross-sectional area becomes: $A_2 = \pi \left(\frac{R}{3}\right)^2 = \frac{\pi R^2}{9} = \frac{A_1}{9}$.

(e) Substitute these areas into the continuity equation: $A_1 v = \left(\frac{A_1}{9}\right) v_2$. Solving for the downstream velocity yields $v_2 = 9v$, showing that fluid speed increases to compensate for the narrower channel.

Final Answer: 9v

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: The conductive transfer of heat through materials arranged sequentially in a series setup is governed by Fourier's law, where the total thermal resistance is the sum of the individual resistances.

Solution:

(a) The configuration describes a steady-state thermal conduction setup where the rate of heat flow through both adjacent metallic rods remains identical throughout the process.

(b) The individual thermal resistance R of a conductor depends on its spatial dimensions and properties, given by the formula: $R = \frac{L}{kA}$.

(c) For two distinct rods connected in series, the total equivalent thermal resistance is the linear sum of their parts: $R_{eq} = R_1 + R_2$.

(d) Expressing the overall combined segment with an effective length of $2L$, we substitute the individual parameters: $\frac{2L}{k_{eq}A} = \frac{L}{k_1 A} + \frac{L}{k_2 A}$.

(e) Eliminating the common geometric factors L and A gives $\frac{2}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} = \frac{k_1+k_2}{k_1 k_2}$, which simplifies to $k_{eq} = \frac{2k_1 k_2}{k_1+k_2}$.

Final Answer: $2\text{k}_1 k_2 \overline{k_1+k_2}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The work-energy theorem establishes that the net mechanical work done on a body by a variable external force is equal to the resulting net change in its total kinetic energy.

Solution:

(a) According to the work-energy theorem, the change in kinetic energy ΔK matches the spatial integration of the net force function acting parallel to motion.

(b) We formulate the definite integral of the non-uniform force $F(x)$ over the bounds from the initial coordinate to the final destination: $W = \int_{x_i}^{x_f} F(x)\,dx$.

(c) Substituting the explicit force function and the given boundaries into our framework yields the expression: $\Delta K = \int_0^2 (3x^2 + 2x - 5)\,dx$.

(d) Finding the analytical antiderivative of this polynomial expression term by term results in the following function: $\left[x^3 + x^2 - 5x\right]_0^2$.

(e) Evaluating this function at the upper bound of two meters gives $(8 + 4 - 10) = 2$, while the lower bound contributes zero, yielding a net energy change of 2 J.

Final Answer: 2 J

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept: The optical power and focusing properties of a spherical glass lens immersed within an external medium are dictated quantitatively by the lens-maker's formula.

Solution:

(a) The lens-maker's equation relates the focal property to relative refractive indices: $\frac{1}{f} = \left(\frac{n_{lens}}{n_{medium}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, where R values are surface radii.

(b) For the initial state in an air medium where $n_{medium} = 1.0$, the expression simplifies directly to: $\frac{1}{f} = (1.5 - 1) \cdot K = 0.5 \cdot K$.

(c) When the assembly is fully submerged inside the chemical liquid, the local surrounding index changes to 1.25, yielding: $\frac{1}{f_L} = \left(\frac{1.50}{1.25} - 1\right) \cdot K$.

(d) Simplifying the relative index fraction gives $\frac{6}{5} - 1 = 0.2$, which means the modified focal inverse is: $\frac{1}{f_L} = 0.2 \cdot K$.

(e) Dividing the first relation by the second relation cancels out the geometric curvature constant K: $\frac{f_L}{f} = \frac{0.5}{0.2} = 2.5 \implies f_L = 2.5f$.

Final Answer: $f_L = 2.5f$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: Kepler's third law of planetary motion establishes a fixed mathematical power-law dependency between the temporal orbital period of a celestial body and its average orbital radius.

Solution:

(a) Kepler's third law states that the square of the periodic time T is proportional to the cube of the semi-major axis distance a: $T^2 \propto a^3$.

(b) We can establish a direct ratio comparison between the properties of the discovered exoplanet and our baseline planet Earth: $\left(\frac{T_{exo}}{T_{earth}}\right)^2 = \left(\frac{a_{exo}}{a_{earth}}\right)^3$.

(c) The user details specify that the average orbital distance of this exoplanet is exactly four times the distance of Earth: $\frac{a_{exo}}{a_{earth}} = 4$.

(d) Substituting this parameter into the comparative ratio yields the following relationship: $\left(\frac{T_{exo}}{T_{earth}}\right)^2 = (4)^3 = 64$.

(e) Taking the square root on both sides to solve for the final orbital period provides: $T_{exo} = \sqrt{64} \cdot T_{earth} = 8 \cdot (1 \text{ Earth year}) = 8$ years.

Final Answer: 8 years

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: A solid object falling freely inside a dense viscous medium experiences a counter-balancing hydrodynamic drag described by Stokes' law, eventually leading to a steady terminal velocity.

Solution:

(a) At terminal velocity v_t, the net gravitational force matches the sum of the upward buoyant force and the viscous drag: $F_g = F_b + F_d$.

(b) Expressing the net downward force using mass and volume parameters for a sphere of radius r gives: $F_g - F_b = \frac{4}{3}\pi r^3(\rho_{ball} - \rho_{fluid})g$.

(c) According to Stokes' law, the resistive retarding force acting on a moving spherical body is given by: $F_d = 6\pi\eta r v_t$.

(d) Equating these two forces reflects the dynamic balance state at terminal speed: $6\pi\eta r v_t = \frac{4}{3}\pi r^3(\rho_{ball} - \rho_{fluid})g$.

(e) Solving for the velocity variable gives the relation: $v_t = \frac{2r^2(\rho_{ball}-\rho_{fluid})g}{9\eta}$. This proves that the terminal velocity is proportional to the square of the radius.

Final Answer: $\mathrm{v}_t \propto r^2$

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept: To prevent a solid object from slipping down a vertical boundary, the maximum available static friction force must balance the downward pull of gravity.

Solution:

(a) The downward force acting on the block is its gravitational weight, which is calculated as follows: $W = mg = 5 \text{ kg} \times 10 \text{ m/s}^2 = 50 \text{ N}$.

(b) The horizontal external force F compresses the block against the wall, creating an equal and opposite normal reaction force: $N = F$.

(c) The upward static friction force f_s prevents downward slipping, meaning the system satisfies equilibrium along the vertical axis when: $f_s = mg = 50 \text{ N}$.

(d) The maximum threshold value for static friction that a surface can provide is governed by the normal force: $f_{s,max} = \mu_s N = \mu_s F$.

(e) To ensure stability without slipping, the maximum available friction must be greater than or equal to the weight: $\mu_s F \geq mg \implies 0.4 \cdot F \geq 50 \text{ N} \implies F \geq 125 \text{ N}$.

Final Answer: 125 N

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: The allocation of heat energy during an isobaric expansion of an ideal gas is determined by its specific heat capacities under the first law of thermodynamics.

Solution:

(a) For an ideal monoatomic gas, the constant-volume specific heat is $C_v = \frac{3}{2}R$ and the constant-pressure specific heat is $C_p = \frac{5}{2}R$.

(b) The total heat energy supplied to the gas during an isobaric process depends on temperature change: $Q = nC_p\Delta T = n\left(\frac{5}{2}R\right)\Delta T$.

(c) The change in internal energy during this process depends on the constant-volume specific heat: $\Delta U = nC_v\Delta T = n\left(\frac{3}{2}R\right)\Delta T$.

(d) According to the first law of thermodynamics, the external work done during this expansion is the difference: $W = Q - \Delta U = nR\Delta T$.

(e) The fraction of heat converted into work is the ratio of work to total heat: $\frac{W}{Q} = \frac{nR\Delta T}{(5/2)nR\Delta T} = \frac{2}{5}$.

Final Answer: $2_{\overline{5}}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: A particle undergoing non-uniform circular motion experiences both a tangential acceleration component from changing speed and a centripetal acceleration component from changing direction.

Solution:

(a) The tangential acceleration component a_t reflects the rate of change of linear speed, found by differentiating the velocity function: $a_t = \frac{dv}{dt} = \frac{d}{dt}(2t) = 2\ \text{m/s}^2$.

(b) Next, we determine the instantaneous linear speed of the particle at the specified time parameter by evaluating $v(t)$ at $t = 1.0$ s: $v = 2(1.0) = 2$ m/s.

(c) The radial centripetal acceleration component a_c depends on this instantaneous speed and the path radius: $a_c = \frac{v^2}{R} = \frac{2^2}{2.0} = 2\ \text{m/s}^2$.

(d) Because these two acceleration vector components act perpendicular to each other, their net total magnitude is found using the Pythagorean theorem.

(e) Calculating the net total acceleration yields: $a_{net} = \sqrt{a_t^2 + a_c^2} = \sqrt{2^2 + 2^2} = \sqrt{8} = 2\sqrt{2}\ \text{m/s}^2$.

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

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept: For an ideal mass-spring system on a frictionless floor, the total mechanical energy—the sum of kinetic energy and elastic potential energy—remains conserved.

Solution:

(a) The total mechanical energy of the system is determined by its maximum displacement amplitude X_0: $E_{total} = \frac{1}{2}kX_0^2$.

(b) At any intermediate position coordinate x, this total energy is shared between kinetic and potential forms: $\frac{1}{2}kX_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$.

(c) We evaluate the state of the system at the specified halfway position by substituting $x = \frac{X_0}{2}$ into the energy balance equation.

(d) This substitution gives: $\frac{1}{2}kX_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}k\left(\frac{X_0}{2}\right)^2 \implies \frac{1}{2}kX_0^2 = \frac{1}{2}mv^2 + \frac{1}{8}kX_0^2$.

(e) Rearranging terms isolates the kinetic energy component: $\frac{1}{2}mv^2 = \frac{3}{8}kX_0^2 \implies v^2 = \frac{3k}{4M}X_0^2$, which simplifies to $v = \frac{\sqrt{3}}{2}\sqrt{\frac{k}{M}}X_0$.

Final Answer: $\sqrt{3}\frac{}{2\sqrt{\frac{k}{M}}X_0}$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: In a connected fluid column at rest, hydrostatic pressure must balance at any horizontal reference line drawn through the same continuous liquid.

Solution:

(a) We establish a reference level at the horizontal interface where the water column meets the underlying mercury layer.

(b) The downward hydrostatic pressure exerted by the water column of height h_w is given by the expression: $P_{water} = \rho_{water} \cdot g \cdot h_w$.

(c) This pressure must be balanced by an equal column of mercury of height h_m in the opposing arm: $P_{mercury} = \rho_{mercury} \cdot g \cdot h_m$.

(d) Equating these two hydrostatic pressures and canceling gravity yields: $\rho_{water} \cdot h_w = \rho_{mercury} \cdot h_m \implies h_m = \left(\frac{\rho_{water}}{\rho_{mercury}}\right) h_w$.

(e) Substituting the given values ($h_w = 13.6$ cm and specific gravity ratio = 13.6) gives: $h_m = \frac{1.0}{13.6} \times 13.6 \text{ cm} = 1.0 \text{ cm}$.

Final Answer: 1.0 cm

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept: The photoelectric effect shows that the kinetic energy of emitted electrons depends on light frequency, while the electrical photocurrent depends directly on light intensity.

Solution:

(a) According to Einstein's photoelectric equation, the maximum kinetic energy is given by $K_{max} = h\nu - \phi$, where ν represents frequency and ϕ is the work function.

(b) Since the operating frequency of the incoming beam remains completely unchanged, the maximum kinetic energy of the individual emitted electrons stays identical.

(c) Light intensity measures the number of photons hitting the metallic plate per unit time rather than changing the packet energy.

(d) Doubling the intensity doubles the total number of target photons hitting the surface, which causes twice as many electrons to be ejected.

(e) As the rate of photoemission scales linearly with the photon flux, the total saturation photocurrent doubles while maximum kinetic energy remains unchanged.

Final Answer: The maximum kinetic energy remains unchanged, and the photocurrent doubles.

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept: A conical pendulum moves in a steady horizontal circle because the vertical component of the string tension supports the mass weight while the horizontal component provides centripetal force.

Solution:

(a) Let T represent the internal tension vector acting along the string at an inclination angle θ relative to the true vertical axis.

(b) Resolving the tension vector along the vertical direction yields a component equal to $T\cos\theta$ directed upwards.

(c) Because there is no acceleration along the vertical axis, this upward component balances the gravitational force: $T\cos\theta = mg$.

(d) Resolving the tension vector along the horizontal direction yields a component equal to $T\sin\theta$ directed toward the center.

(e) Isolating the string tension variable from the vertical equilibrium equation directly yields the following relationship: $T = \frac{mg}{\cos\theta}$.

Final Answer: mg$\frac{}{\cos\theta}$

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept: The principle of calorimetry states that inside a thermally isolated system, the total heat energy lost by hot components equals the total heat energy gained by cold components.

Solution:

(a) The solid copper cylinder lowers its temperature from 100°C down to 30°C, yielding a thermal change: $\Delta T_{cu} = 100 - 30 = 70$°C.

(b) The total heat energy released by the copper cylinder during this cooling stage is calculated using: $Q_{lost} = m \cdot c_{cu} \cdot \Delta T_{cu} = m \cdot (0.1) \cdot 70$.

(c) The surrounding water sample increases its temperature from 20°C up to 30°C, yielding a thermal change: $\Delta T_w = 30 - 20 = 10$°C.

(d) The total heat energy absorbed by the water column is calculated using: $Q_{gained} = m_w \cdot c_w \cdot \Delta T_w = m_w \cdot (1.0) \cdot 10$.

(e) Equating heat lost to heat gained gives $m \cdot 0.1 \cdot 70 = m_w \cdot 1.0 \cdot 10$, which simplifies to $7m = 10m_w \implies \frac{m_w}{m} = 0.7$.

Final Answer: 0.7

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: Torricelli's law, derived from Bernoulli's principle, states that the speed of a fluid escaping an open orifice matches the speed of an object falling freely from the same height.

Solution:

(a) We choose two reference points: point one at the wide upper free surface of the water tank and point two at the low drainage opening.

(b) Bernoulli's equation states that the total fluid energy along a streamline remains constant: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$.

(c) Since both points open directly to the environment, they share identical atmospheric pressures, canceling out the pressure terms: $P_1 = P_2 = P_{atm}$.

(d) The surface area of the tank is much larger than the tiny hole, meaning the surface water drops at a negligible speed: $v_1 \approx 0$.

(e) Setting the bottom hole as the height baseline ($h_2 = 0$ and $h_1 = h$) simplifies the equation to $\rho g h = \frac{1}{2}\rho v_2^2$, which gives $v_2 = \sqrt{2gh}$.

Final Answer: $\sqrt{2gh}$

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: For an optical fiber to guide light, the internal angle at the core-cladding boundary must be greater than or equal to the critical angle to cause total internal reflection.

Solution:

(a) The critical angle θ_c at the boundary between the internal core and outer cladding satisfies the relation: $\sin\theta_c = \frac{n_2}{n_1} = \frac{1.41}{1.50}$.

(b) Geometry dictates that the internal refraction angle θ_r at the air entry interface matches the critical boundary state through: $\theta_r = 90^\circ - \theta_c$.

(c) This spatial relationship links the trigonometric functions of the angles, changing the sine function into a cosine function: $\sin\theta_r = \cos\theta_c = \sqrt{1-\sin^2\theta_c}$.

(d) Applying Snell's law at the initial air-to-core boundary interface gives: $1.0 \cdot \sin\theta_{max} = n_1 \cdot \sin\theta_r = n_1 \cdot \sqrt{1-\left(\frac{n_2}{n_1}\right)^2}$.

(e) Simplifying the radical equation yields the acceptance angle formula: $\sin\theta_{max} = \sqrt{n_1^2 - n_2^2} = \sqrt{1.50^2 - 1.41^2} = \sqrt{2.25 - 1.99} \approx 0.51$.

Final Answer: $\sin^{-1}(0.51)$

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept: The mechanics of a rigid body rotating around a fixed frame are governed by rotational analogues of Newton's laws. These principles relate parameters like torque, angular momentum, and kinetic energy through the moment of inertia.

Solution:

(a) Let us evaluate each fundamental assertion step-by-step:

- Statement A: The rotational kinetic energy of a body rotating with angular velocity ω around a specific axis is defined as $K_{rot} = \frac{1}{2}I\omega^2$, where I represents the moment of inertia about that fixed axis. This statement is correct.
- Statement B: According to the rotational form of Newton's second law, the net external torque vector acting on a system equals the time derivative of its angular momentum vector, expressed as $\tau = \frac{dL}{dt}$. This statement is correct.
- Statement C: Integrating the torque law shows that when the net external torque is zero ($\tau = 0$), the rate of change of angular momentum is zero ($\frac{dL}{dt} = 0$). This means total angular momentum L remains completely conserved in both magnitude and direction. This statement is correct.
- Statement D: For a particle at a radius r, the absolute linear acceleration vector contains two perpendicular components: a tangential component $a_t = r\frac{d\omega}{dt}$ and a radial centripetal component $a_c = \omega^2 r$. This statement is incorrect.

(b) Therefore, the fundamentally correct dynamic assertions are given by statements (A), (B), and (C).

Final Answer: A, B, C

Answer: (A,B,C)

Go Back to Question 26

Q27.

Solution

Concept: In classical thermodynamics, state functions depend only on the current equilibrium state of a system, whereas path functions depend on the specific thermodynamic process layout.

Solution:

(a) Let us evaluate each parameters based on path dependency:

- Parameter A: The net heat exchange ΔQ represents energy transferred due to a thermal gradient, which changes depending on the process pathway. It is a path function, so it will differ between Path 1 and Path 2.
- Parameter B: The mechanical work done ΔW is equivalent to the geometric area under the curve on a $P - V$ diagram. Since the paths follow different lines, their enclosed areas differ, making work a path function.
- Parameter C: Internal energy U is a state function that depends solely on state parameters like pressure, volume, and temperature. Because both paths share identical initial state i and final state f, the net difference $\Delta U = U_f - U_i$ must be identical.
- Parameter D: Temperature T is an intrinsic thermodynamic state variable. Since the endpoints i and f are fixed for both paths, the total temperature change $\Delta T = T_f - T_i$ is identical.

(b) Therefore, the parameters that must have identical values are given by statements (C) and (D).

Final Answer: C, D

Answer: (C,D)

Go Back to Question 27

Q28.

Solution

Concept: Archimedes' principle states that a body floating at the interface of immiscible fluids experiences an upward buoyant force equal to the total weight of the displaced fluids.

Solution:

(a) Let us evaluate each mechanical assertion systematically:

- Statement A: For static equilibrium, the net vertical force must be zero. This means the upward buoyant force must balance the downward gravitational force: $F_b = mg$. This statement is correct.
- Statement C: Let V_1 and V_2 be the volumes submerged in Liquid 1 and Liquid 2 respectively. The force balance gives: $\rho_1 V_1 g + \rho_2 V_2 g = \rho_b V g$. Substituting $V_1 = V - V_2$ yields $\rho_1(V - V_2) + \rho_2 V_2 = \rho_b V \implies (\rho_2 - \rho_1)V_2 = (\rho_b - \rho_1)V \implies \frac{V_2}{V} = \frac{\rho_b - \rho_1}{\rho_2 - \rho_1}$. This statement is correct.
- Statement B: From the formula $\frac{V_2}{V} = \frac{\rho_b - \rho_1}{\rho_2 - \rho_1}$, increasing the density ρ_2 increases the denominator, which decreases the submerged fraction $\frac{V_2}{V}$. This statement is incorrect.
- Statement D: If the container accelerates upward at a, gravity is replaced by effective gravity $g_{eff} = g + a$. Since g_{eff} cancels out of the equilibrium equation, the submerged fractions remain unchanged. This statement is incorrect.

(b) Therefore, the mathematically sound conclusions are given by statements (A) and (C).

Final Answer: A, C

Answer: (A,C)

Go Back to Question 28

Q29.

Solution

Concept: The work-energy theorem states that the change in kinetic energy of a block equals the work done by all forces, including the conservative spring force and non-conservative friction.

Solution:

(a) Let us evaluate the thermodynamic and mechanical assertions:

- Statement A: The elastic potential energy stored in an ideal spring compressed by a displacement distance x from its natural rest length is given by $U_s = \frac{1}{2}kx^2$. This statement is correct.
- Statement B: Kinetic friction is a non-conservative force acting opposite to the direction of motion. The work done over a displacement distance d is given by $W_f = \vec{f}_k \cdot \vec{d} = -(\mu_k mg)d$. This statement is correct.
- Statement C: The net force on the block is $F_{net} = kx' - \mu_k mg$, where x' is the instantaneous compression. The maximum kinetic energy occurs when acceleration is zero ($F_{net} = 0$), which happens at a compressed position $x' = \frac{\mu_k mg}{k}$, before the spring returns to its uncompressed length. This statement is incorrect.
- Statement D: According to the conservation of energy, the mechanical energy lost due to friction is converted entirely into thermal energy, meaning the generated heat equals the magnitude of work done by friction. This statement is correct.

(b) Therefore, the statements matching the core energy principles are given by (A), (B), and (D).

Final Answer: A, B, D

Answer: (A,B,D)

Go Back to Question 29

Q30.

Solution

Concept: Newton's law of universal gravitation and the shell theorem describe how the gravitational force exerted by a uniform solid sphere changes depending on the distance from its center.

Solution:

(a) Let us evaluate each gravitational assertion:

- Statement A: According to the shell theorem, a uniform solid sphere exerts an external gravitational force ($r > R$) that treats the entire mass M as if it were concentrated at the center point O: $F_g = \frac{GMm}{r^2}$. This statement is correct.
- Statement B: For internal points ($r < R$), the mass outside radius r exerts no net force, but the inner core mass $M' = M\left(\frac{r}{R}\right)^3$ exerts a non-zero force. This statement is incorrect.
- Statement C: The internal gravitational force ($r < R$) depends only on the inner core mass: $F_g = \frac{GM'm}{r^2} = \frac{G[M(r/R)^3]m}{r^2} = \frac{GMmr}{R^3}$. This shows the force varies linearly with distance from the center. This statement is correct.
- Statement D: The local acceleration due to gravity is $g = \frac{GMr}{R^3}$ for $r \leq R$ and $g = \frac{GM}{r^2}$ for $r \geq R$. Evaluating these formulas shows that g increases linearly inside the sphere and decreases quadratically outside, reaching its maximum value at the surface ($r = R$). This statement is correct.

(b) Therefore, the correct assertions regarding gravitational dynamics are given by (A), (C), and (D).

Final Answer: A, C, D

Answer: (A,C,D)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	B	4	C	5	B
6	B	7	B	8	A	9	A	10	B
11	B	12	C	13	A	14	B	15	C
16	B	17	A	18	B	19	B	20	B
21	B	22	B	23	A	24	B	25	B
26	A,B,C	27	C,D	28	A,C	29	A,B,D	30	A,C,D