JELET Physics Sample Paper-6

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.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

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

Q1. A variable mass system drops sand at a constant rate μ onto a horizontal conveyor belt moving with a constant speed v. Simultaneously, an external retarding force $F(t) = kt$ acts on the belt assembly. If the power delivered by the motor to maintain the constant speed v of the belt at time t is evaluated, the explicit functional dependence of this power is given by:

(A) $\mu v^2 + ktv$

(B) $2\mu v^2 + kt$

(C) $\frac{1}{2}\mu v^2 + ktv$

(D) $\mu v^2 + \frac{1}{2}kt^2 v$

Q2. A wide cylindrical vessel filled with an ideal incompressible fluid of density ρ is rotated with a constant angular velocity ω about its vertical axis of symmetry. A small spherical air bubble of volume V is trapped at a distance r from the axis. Neglecting traditional vertical buoyancy due to gravity, the net horizontal inward radial force experienced by the bubble due to the pressure gradient is:

(A) $\rho V \omega^2 r$

(B) $2\rho V \omega^2 r$

(C) $\frac{1}{2}\rho V \omega^2 r$

(D) $\rho V \omega^2 r^2$

Q3. One mole of a monoatomic ideal gas undergoes a quasi-static process described by the equation $P = V^\alpha$, where α is a real constant. If the molar heat capacity of the gas during this specific thermodynamic pathway becomes zero ($C = 0$), the value of the exponent α must be:

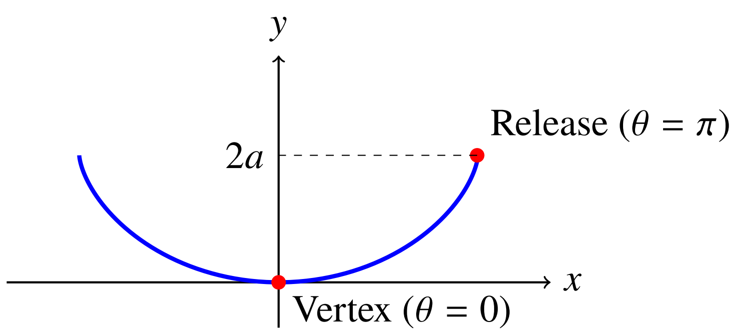
(A) $-\frac{5}{3}$

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

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

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

Q4. A small bead of mass M slides without friction along a vertically oriented track shaped as a cycloid, defined parametrically by $x = a(\theta + \sin\theta)$ and $y = a(1 - \cos\theta)$ as illustrated below. The bead is released from rest at the topmost lip ($\theta = \pi$). Find its kinetic energy when it reaches the lowest operational vertex ($\theta = 0$).



(A) $2Mga$

(B) Mga

(C) $4Mga$

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

Q5. An advanced step-index optical fiber features a core with a refractive index $n_1 = 1.52$ and a cladding with a refractive index $n_2 = 1.45$. The entire assembly is submerged in a specialized optical coupling fluid with a refractive index $n_0 = 1.33$. The maximum acceptance angle θ_a for light entering the core from this fluid environment is exactly:

(A) $\sin^{-1}\left(\frac{\sqrt{0.2079}}{1.33}\right)$

(B) $\sin^{-1}\left(\frac{0.07}{1.52}\right)$

(C) $\cos^{-1}\left(\frac{1.45}{1.52}\right)$

(D) $\sin^{-1}\left(\frac{\sqrt{0.152}}{1.33}\right)$

Q6. In a multi-photon photoelectric experiment, a cesium metallic plate (work function $\phi = 2.14$ eV) is illuminated with a high-intensity ultra-fast laser beam where each individual photon carries an energy of 1.50 eV. If two photons are simultaneously absorbed by a single bound electron to trigger photoemission, the maximum kinetic energy of the escaping photoelectron will be:

(A) 0.86 eV

(B) 3.00 eV

(C) 0.64 eV

(D) No photoemission occurs because 1.50 eV $<$ 2.14 eV

Q7. Let G represent the universal gravitational constant, h represent Planck's constant, and c represent the speed of light in a vacuum. A new system of fundamental units is constructed such that the dimension of a characteristic mass scale M_p needs to be derived. The proper combination representing this mass scale is:

(A) $\sqrt{\frac{hc}{G}}$

(B) $\sqrt{\frac{hG}{c^3}}$

(C) $\frac{hc}{G}$

(D) $\sqrt{\frac{G}{hc}}$

Q8. A heavy particle is projected vertically upward from the surface of the Earth with an initial launch velocity equal to the escape velocity ($v_e = \sqrt{2gR}$). Neglecting air resistance but incorporating the accurate inverse-square variation of the Earth's gravitational field, the time taken for the particle to reach a radial height equal to $3R$ from the center of the Earth is evaluated as:

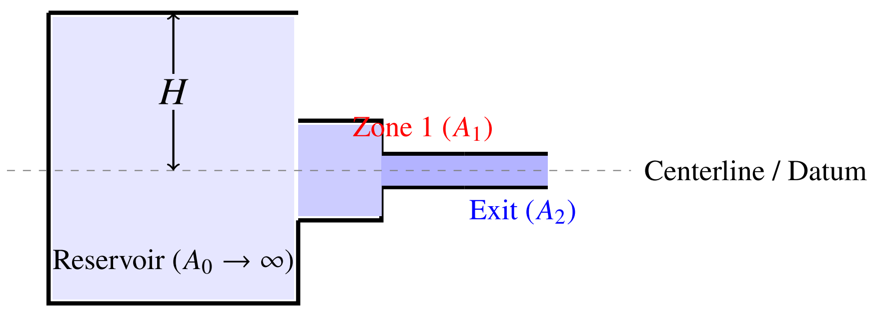
(A) $\frac{2}{3}\sqrt{\frac{R}{2g}}\left[3^{3/2}-1\right]$

(B) $\frac{2}{3}\sqrt{\frac{R}{g}}\left[2^{3/2}-1\right]$

(C) $\frac{1}{3}\sqrt{\frac{R}{2g}}\left[4^{3/2}-1\right]$

(D) $\sqrt{\frac{2R}{g}}$

Q9. An ideal, incompressible fluid drains from a wide open reservoir through a pipeline containing a localized venturi restriction and an exit nozzle discharging directly to the atmosphere. The elevation profiles and cross-sectional areas are indicated in the schematic below. Applying Bernoulli's theorem, determine the gauge pressure P_1 at the center of the restricted neck section (Zone 1):



(A) $\rho g H\left[1-\left(\frac{A_2}{A_1}\right)^2\right]$

(B) $\rho g H\left[\left(\frac{A_1}{A_2}\right)^2-1\right]$

(C) $\frac{1}{2}\rho v_2^2\left(\frac{A_2}{A_1}\right)$

(D) $-\rho g H\left(\frac{A_2}{A_1}\right)^2$

Q10. A composite slab consists of two parallel solid layers of identical cross-sectional area and thickness, but with distinct thermal conductivities K_1 and K_2. If the outer faces of the composite structure are maintained at steady temperatures T_{hot}

and T_{cold}, the effective equivalent thermal conductivity K_{eff} of the series setup is:

(A) $\frac{2K_1K_2}{K_1+K_2}$

(B) $\frac{K_1+K_2}{2}$

(C) $\sqrt{K_1K_2}$

(D) $\frac{K_1K_2}{2(K_1+K_2)}$

Q11. A potential energy function describing a conservative field in one dimension is modeled by $U(x) = \frac{a}{x^2} - \frac{b}{x}$, where a and b are positive scaling constants. If the system is slightly disturbed from its stable equilibrium position, the angular frequency ω_0 of small-amplitude oscillations is computed as:

(A) $\sqrt{\frac{b^4}{8ma^3}}$

(B) $\sqrt{\frac{b^4}{4ma^3}}$

(C) $\sqrt{\frac{a^4}{8mb^3}}$

(D) $\sqrt{\frac{2b^4}{ma^3}}$

Q12. A thin biconvex glass lens ($n_g = 1.50$) possesses a focal length f when positioned in air. If this identical lens is entirely immersed within a large tank containing liquid ammonia ($n_l = 1.33$), its modified focal length f' in terms of f is closest to:

(A) $3.91\,f$

(B) $1.33\,f$

(C) $0.25\,f$

(D) $2.00\,f$

Q13. A monochrome source of light operating at a wavelength λ illuminates a solar photovoltaic cell panel with an efficiency factor η (defined as the ratio of emitted photoelectrons collected to incident photons). If the total optical power incident uniformly on the panel surface is P, the saturation photocurrent output I_{sat} is directly expressed by:

(A) $\frac{\eta P e \lambda}{hc}$

(B) $\frac{P e \lambda}{\eta hc}$

(C) $\frac{\eta P hc}{e \lambda}$

(D) $\frac{\eta P e \lambda^2}{hc^2}$

Q14. A binary star system consists of two stars of masses M and $3M$ separated by a distance d. They rotate about their common center of mass under their mutual gravitational attraction. The orbital period T of this binary setup is given by which expression?

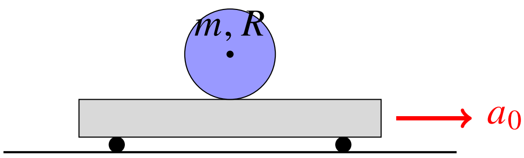
(A) $2\pi\sqrt{\frac{d^3}{4GM}}$

(B) $2\pi\sqrt{\frac{d^3}{3GM}}$

(C) $2\pi\sqrt{\frac{d^3}{GM}}$

(D) $\pi\sqrt{\frac{d^3}{2GM}}$

Q15. A uniform solid cylinder of mass m and radius R is placed on a rough horizontal flatcar platform that accelerates to the right with a constant linear acceleration a_0. Assuming the cylinder rolls purely without slipping relative to the flatcar surface, calculate the magnitude and direction of the linear acceleration a_{abs} of the cylinder relative to the stationary ground laboratory frame.



(A) $\frac{1}{3}a_0$ to the right

(B) $\frac{2}{3}a_0$ to the right

(C) $\frac{1}{2}a_0$ to the left

(D) $\frac{1}{3}a_0$ to the left

Q16. A tiny spherical steel pellet of radius r and density ρ_s falls vertically through a column of viscous oil of density ρ_o and dynamic viscosity coefficient η. After establishing a terminal velocity v_t, the net instantaneous mechanical rate of heat production arising from viscous dissipation within the fluid is directly proportional to:

(A) r^5

(B) r^3

(C) r^2

(D) r^4

Q17. An ideal gas is forced through an insulated porous plug from a high-pressure manifold to a lower-pressure exhaust line in a continuous throttling configuration. Throughout this irreversible thermodynamic expansion step, which property remains invariant?

(A) Internal Enthalpy (H)

(B) Entropy (S)

(C) Internal Energy (U)

(D) Helmholtz Free Energy (A)

Q18. A non-conservative spatial force field is described by $\mathbf{F} = (2xy + z^2)\hat{\mathbf{i}} + x^2\hat{\mathbf{j}} + 2xz\hat{\mathbf{k}}$. A particle moves from the origin $(0, 0, 0)$ to the point $(1, 1, 1)$ along a straight line path. The absolute work done by this vector field during the displacement is:

(A) 2 Joules

(B) 1 Joule

(C) 3 Joules

(D) 0 Joules

Q19. A point source of light is located at the bottom of a deep swimming pool containing water $(n = 4/3)$. The top surface of the water is perfectly flat. Light rays escape into the ambient air above through a circular region of radius R. If the depth of the pool is h, the exact mathematical expression for R is:

(A) $\frac{h}{\sqrt{7}}$

(B) $\frac{3h}{\sqrt{7}}$

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

(D) $\sqrt{\frac{7}{3}}h$

Q20. When clean metallic lithium is irradiated with monochromatic light of frequency ν, the stopping voltage required to suppress the photoemission current completely is measured to be V_0. If the frequency of the incoming light source is doubled to 2ν, the new required stopping potential value V_0' will satisfy:

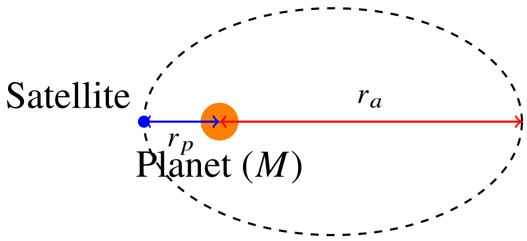
(A) $V_0' > 2V_0$

(B) $V_0' = 2V_0$

(C) $V_0' < 2V_0$

(D) $V_0' = V_0$

Q21. An advanced scientific satellite tracks an elliptical orbit around a dense planet of mass M. The closest approach distance (periapsis) is r_p and the furthest point (apoapsis) is r_a, as illustrated schematically below. By utilizing Kepler's laws of planetary motion, the orbital speed v_p at the periapsis position is determined to be:



(A) $\sqrt{\frac{2GMr_a}{r_p(r_p+r_a)}}$

(B) $\sqrt{\frac{2GMr_p}{r_a(r_p+r_a)}}$

(C) $\sqrt{\frac{GM(r_a+r_p)}{r_p^2}}$

(D) $\sqrt{\frac{2GM}{r_p+r_a}}$

Q22. A particle moves in the xy-plane such that its position vector is governed by $\mathbf{r}(t) = R\cos(\omega t)\hat{\mathbf{i}} + R\sin(\omega t)\hat{\mathbf{j}}$, where R and ω are positive parameters. The magnitude of its instantaneous centripetal acceleration vector is:

(A) $\omega^2 R$

(B) ωR^2

(C) zero

(D) $\frac{1}{2}\omega^2 R$

Q23. A solid homogeneous block floats at the interface between two immiscible liquids contained within a tank. The upper fluid layer has a density $\rho_1 = 800$ kg/m^3 and the lower layer has a density $\rho_2 = 1200$ kg/m^3. If exactly 60% of the block's total volume is submerged within the lower dense liquid layer, the density ρ_b of the block material is:

(A) 1040 kg/m^3

(B) 960 kg/m^3

(C) 1000 kg/m^3

(D) 1120 kg/m^3

Q24. An engine operating on an ideal air-standard Carnot cycle acts between a high temperature reservoir at 800 K and a low temperature heat sink at 300 K. If the engine absorbs 400 kJ of thermal energy from the high-temperature reservoir per cycle, the net work delivered by the engine per cycle is:

(A) 250 kJ

(B) 150 kJ

(C) 300 kJ

(D) 200 kJ

Q25. A spatial force vector given by $\mathbf{F} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - 2\hat{\mathbf{k}})$ N acts continuously on a small payload body, forcing it to move with an instantaneous velocity vector $\mathbf{v} = (2\hat{\mathbf{i}} - 3\hat{\mathbf{j}} + 5\hat{\mathbf{k}})$ m/s. The instantaneous mechanical power transferred to the payload body at that moment is:

(A) -16 W

(B) 16 W

(C) -10 W

(D) 8 W

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

Q26. A heavy block rests on a rough horizontal conveyor plane. The static friction coefficient is μ_s and the kinetic friction coefficient is μ_k. A horizontal force $F(t) = c \cdot t$ (where c is a positive constant) is applied to the block starting at $t = 0$. Which of the following statements regarding the resulting motion properties is/are correct?

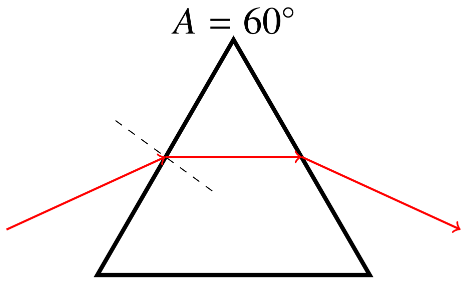
(A) The block remains absolutely stationary until a threshold time $t_c = \frac{\mu_s mg}{c}$.

(B) The friction force acting on the block increases linearly with time for $t < t_c$.

(C) At $t = t_c$, the net acceleration of the block jumps discontinuously from zero to a finite value $\frac{(\mu_s - \mu_k)g}{1}$.

(D) For all time intervals $t > t_c$, the magnitude of the friction force remains constant at $\mu_k mg$.

Q27. A ray of light enters a balanced symmetric 60° glass prism ($n = \sqrt{3}$) from an external vacuum environment. The ray configuration is fine-tuned to produce the absolute minimum deviation angle δ_{min}, as mapped below. Which of the following statements is/are mathematically sound?



(A) The angle of minimum deviation is $\delta_{\text{min}} = 60°$.

(B) The internal refracted ray travels perfectly parallel to the base of the prism.

(C) The angle of incidence required for this condition is $i = 60°$.

(D) Total internal reflection occurs at the second face if the index is increased to $n = 2$.

Q28. Consider a gas composed of non-interacting, independent photons inside a cavity maintained at a uniform thermal equilibrium temperature T. According to statistical mechanics and radiation laws, which of the following expressions correctly reflect the properties of this photon gas?

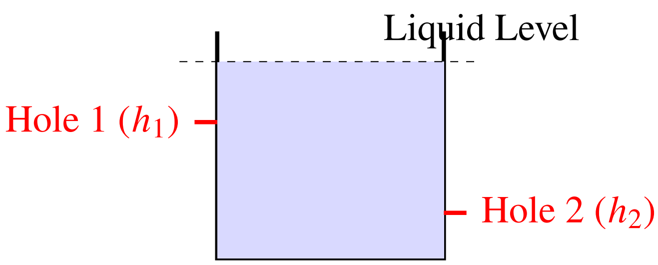
(A) The internal energy density $u = U/V$ is proportional to T^4.

(B) The radiation pressure exerted on the cavity boundaries is given by $P = \frac{1}{3}u$.

(C) The total number of photons inside the cavity is strictly conserved over time.

(D) The entropy S of the photon gas scales proportionally with T^3.

Q29. A large container holding a liquid of density ρ is placed on a smooth horizontal surface. Two small circular holes of cross-sectional area A are punctured in the side walls at depths h_1 and h_2 below the upper free surface level. Select the correct options regarding the dynamics of efflux:



(A) The velocity of efflux from the first hole is given by $v_1 = \sqrt{2gh_1}$.

(B) If the two streams hit the ground at the exact same horizontal distance from the tank, the distance of the holes from the top and bottom must be symmetric.

(C) The reaction force exerted on the tank due to the fluid exiting Hole 1 is $F_1 = 2\rho g A h_1$.

(D) The velocity of efflux depends directly on the dynamic viscosity of the liquid.

Q30. Let $g(z)$ characterize the local acceleration due to gravity at an altitude z above the surface of a perfectly spherical Earth of radius R. Let g_0 be the standard acceleration at the sea-level surface ($z = 0$). Which of the following statements represents valid scientific approximations or exact expressions?

(A) The exact expression for gravity at height z is $g(z) = g_0 \left(\frac{R}{R+z}\right)^2$.

(B) For small altitudes ($z \ll R$), the expression simplifies via binomial expansion to $g(z) \approx g_0 \left(1 - \frac{2z}{R}\right)$.

(C) The fractional reduction in gravity at small heights ($\Delta g/g_0$) is linearly proportional to the altitude z.

(D) If an object is moved down a deep vertical mine shaft to a depth d, the gravity variation follows the exact same mathematical function as the altitude increase.

Detailed Solutions

Q1.

Solution

Concept: For a variable mass system where mass is added at a constant rate $\mu = \frac{dm}{dt}$ with zero initial velocity relative to the conveyor belt moving at a constant speed v, the thrust force required to maintain this speed is $F_{\text{thrust}} = v\frac{dm}{dt} = \mu v$. Together with the external retarding force $F(t) = kt$, the total force provided by the motor must balance both forces to keep the velocity constant. The power delivered is then $P = F_{\text{total}} \cdot v$.

Solution:

The total force required to maintain the constant speed v is:

$$F_{\text{total}}(t) = F_{\text{thrust}} + F(t) = \mu v + kt$$

The instantaneous power $P(t)$ delivered by the motor is given by:

$$P(t) = F_{\text{total}}(t) \cdot v = (\mu v + kt)v = \mu v^2 + ktv$$

Thus, the power has an explicit functional dependence given by $\mu v^2 + ktv$.

Final Answer: $\boxed{\mu v^2 + ktv}$

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: When a cylindrical vessel containing a fluid rotates, a pressure gradient is established radially inward to provide the necessary centripetal acceleration for the fluid elements. According to Archimedes' principle in an accelerated frame, an immersed body experiences a net buoyant force equal to the mass of the displaced fluid multiplied by the local acceleration of the frame.

Solution:

The pressure gradient in the rotating fluid at a distance r from the vertical axis is given by:

$$\frac{dP}{dr} = \rho\omega^2 r$$

An air bubble of volume V replaces a fluid mass of $m_{\text{fluid}} = \rho V$. The net horizontal inward force (buoyant force in the rotating frame) acting on the bubble due to this pressure gradient is:

$$F = V\frac{dP}{dr} = \rho V\omega^2 r$$

Since the density of air is negligible compared to the fluid, this pressure gradient force acts directly inwards towards the axis of rotation.

Final Answer: $\boxed{\rho V\omega^2 r}$

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept: The molar heat capacity for any polytropic process described by PV^n = constant is given by the formula $C = C_v + \frac{R}{1-n}$. For a monoatomic ideal gas, $C_v = \frac{3}{2}R$. We can match the given process equation to find n and then solve for the exponent α when $C = 0$.

Solution:

The given process equation is $P = V^\alpha$, which can be rearranged into the standard polytropic form:

$$PV^{-\alpha} = 1 \implies n = -\alpha$$

The molar heat capacity for this pathway is:

$$C = C_v + \frac{R}{1-n} = \frac{3}{2}R + \frac{R}{1-(-\alpha)} = \frac{3}{2}R + \frac{R}{1+\alpha}$$

We are given that the molar heat capacity becomes zero ($C = 0$):

$$\frac{3}{2}R + \frac{R}{1+\alpha} = 0 \implies \frac{3}{2} = -\frac{1}{1+\alpha}$$

$$3(1+\alpha) = -2 \implies 3 + 3\alpha = -2 \implies 3\alpha = -5 \implies \alpha = -\frac{5}{3}$$

Final Answer: $\boxed{-\frac{5}{3}}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: Since the track is completely frictionless, the total mechanical energy of the bead-Earth system is conserved. The kinetic energy gained by the bead when it reaches the vertex is equal to the loss in its gravitational potential energy.

Solution:

The parametric equation for the vertical height is $y = a(1 - \cos\theta)$. At the topmost lip where the bead is released from rest ($\theta = \pi$):

$$y_{\text{initial}} = a(1 - \cos\pi) = a(1 - (-1)) = 2a$$

At the lowest operational vertex ($\theta = 0$):

$$y_{\text{final}} = a(1 - \cos 0) = a(1 - 1) = 0$$

The vertical drop height is $\Delta y = y_{\text{initial}} - y_{\text{final}} = 2a - 0 = 2a$. By conservation of mechanical energy, the kinetic energy K at the vertex is:

$$K = \Delta U = Mg\Delta y = Mg(2a) = 2Mga$$

Final Answer: $\boxed{2Mga}$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: The numerical aperture (NA) of a step-index optical fiber surrounded by a medium of refractive index n_0 determines the maximum acceptance angle θ_a. It is governed by Snell's law at the entrance interface and the condition for total internal reflection at the core-cladding boundary.

Solution:

The mathematical definition of the numerical aperture relative to an outside medium n_0 is:

$$n_0 \sin\theta_a = \sqrt{n_1^2 - n_2^2}$$

Given parameters: $n_1 = 1.52$, $n_2 = 1.45$, and $n_0 = 1.33$. First, calculate the term inside the square root:

$$n_1^2 - n_2^2 = (1.52)^2 - (1.45)^2 = 2.3104 - 2.1025 = 0.2079$$

Substitute this back into the formula to isolate θ_a:

$$1.33 \sin\theta_a = \sqrt{0.2079} \implies \sin\theta_a = \frac{\sqrt{0.2079}}{1.33}$$

$$\theta_a = \sin^{-1}\left(\frac{\sqrt{0.2079}}{1.33}\right)$$

Final Answer: $\boxed{\sin^{-1}\left(\frac{\sqrt{0.2079}}{1.33}\right)}$

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: In a multi-photon photoelectric effect, the total energy delivered simultaneously to a single bound electron by N coherent photons is equal to $N \cdot h\nu$. Einstein's photoelectric equation can be generalized to $K_{\max} = N(h\nu) - \phi$, provided the combined energy exceeds the metal's work function.

Solution:

Given that 2 photons are absorbed simultaneously, the total energy supplied by the incident laser beam is:

$$E_{\text{total}} = 2 \times 1.50 \text{ eV} = 3.00 \text{ eV}$$

The work function of the cesium metallic plate is $\phi = 2.14$ eV. Since 3.00 eV $>$ 2.14 eV, photoemission successfully occurs. The maximum kinetic energy of the escaping photoelectron is:

$$K_{\max} = E_{\text{total}} - \phi = 3.00 \text{ eV} - 2.14 \text{ eV} = 0.86 \text{ eV}$$

Final Answer: $\boxed{0.86 \text{ eV}}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: The Planck mass M_p can be derived by dimensional analysis combining the three fundamental constants: universal gravitational constant G, Planck's constant h, and the speed of light c.

Solution:

Let $M_p \propto G^x h^y c^z$. Writing down the base dimensions for each constant:

$$[G] = \mathrm{M}^{-1}\mathrm{L}^3\mathrm{T}^{-2}, \quad [h] = \mathrm{ML}^2\mathrm{T}^{-1}, \quad [c] = \mathrm{LT}^{-1}$$

Equating the dimensions for mass, length, and time:

$$\mathrm{M}^1 = (\mathrm{M}^{-1}\mathrm{L}^3\mathrm{T}^{-2})^x(\mathrm{ML}^2\mathrm{T}^{-1})^y(\mathrm{LT}^{-1})^z$$

$$\mathrm{M}^1\mathrm{L}^0\mathrm{T}^0 = \mathrm{M}^{-x+y}\mathrm{L}^{3x+2y+z}\mathrm{T}^{-2x-y-z}$$

From the mass dimension: $-x + y = 1 \implies y = x + 1$. From the time dimension: $-2x - y - z = 0 \implies -2x - (x+1) - z = 0 \implies z = -3x - 1$. From the length dimension: $3x + 2y + z = 0 \implies 3x + 2(x+1) + (-3x-1) = 0 \implies 2x + 1 = 0 \implies x = -\frac{1}{2}$.

Substituting $x = -\frac{1}{2}$:

$$y = -\frac{1}{2} + 1 = \frac{1}{2}, \quad z = -3\left(-\frac{1}{2}\right) - 1 = \frac{1}{2}$$

Thus, the proper combination is:

$$M_p = G^{-1/2}h^{1/2}c^{1/2} = \sqrt{\frac{hc}{G}}$$

Final Answer: $\boxed{\sqrt{\frac{hc}{G}}}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: By conservation of mechanical energy for a particle launched with escape velocity, its total energy is zero, meaning its velocity at any radial position r satisfies $v(r) = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2gR^2}{r}}$. Setting $v = \frac{dr}{dt}$ gives a differential equation that can be integrated to find time.

Solution:

The velocity as a function of radial distance r from the center of the Earth is:

$$\frac{dr}{dt} = \sqrt{2gR^2} \cdot r^{-1/2}$$

Rearranging terms and integrating from the surface $r = R$ to $r = 3R$:

$$\int_R^{3R} r^{1/2}\, dr = \int_0^t \sqrt{2gR^2}\, dt$$

$$\left[\frac{2}{3} r^{3/2}\right]_R^{3R} = \sqrt{2gR^2} \cdot t$$

$$\frac{2}{3}\left[(3R)^{3/2} - R^{3/2}\right] = R\sqrt{2g} \cdot t$$

$$\frac{2}{3} R^{3/2}\left[3^{3/2} - 1\right] = R\sqrt{2g} \cdot t$$

Solving for t:

$$t = \frac{2}{3}\frac{R^{3/2}}{R\sqrt{2g}}\left[3^{3/2} - 1\right] = \frac{2}{3}\sqrt{\frac{R}{2g}}\left[3^{3/2} - 1\right]$$

Final Answer: $\boxed{\frac{2}{3}\sqrt{\frac{R}{2g}}\left[3^{3/2} - 1\right]}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: Using the equation of continuity, $A_1 v_1 = A_2 v_2$, where Zone 2 is the exit nozzle open to the atmosphere ($P_2 = 0$ gauge pressure). Applying Bernoulli's theorem between the wide reservoir surface (Zone 0) and the exit nozzle yields the discharge velocity $v_2 = \sqrt{2gH}$.

Solution:

From Bernoulli's equation between the reservoir surface ($P = 0, v \to 0$, height $= H$ relative to datum) and the exit nozzle ($P_2 = 0, v_2$, height $= H$):

$$v_2 = \sqrt{2gH} \implies \frac{1}{2}\rho v_2^2 = \rho g H$$

From continuity between Zone 1 and Zone 2:

$$v_1 = \left(\frac{A_2}{A_1}\right) v_2$$

Apply Bernoulli's equation between Zone 1 and Zone 2 (both are at the same horizontal level height H):

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 + \frac{1}{2}\rho \left(\frac{A_2}{A_1}\right)^2 v_2^2 = 0 + \frac{1}{2}\rho v_2^2$$

$$P_1 = \frac{1}{2}\rho v_2^2 \left[1 - \left(\frac{A_2}{A_1}\right)^2\right]$$

Substituting $\frac{1}{2}\rho v_2^2 = \rho g H$:

$$P_1 = \rho g H \left[1 - \left(\frac{A_2}{A_1}\right)^2\right]$$

Final Answer: $\boxed{\rho g H \left[1 - \left(\frac{A_2}{A_1}\right)^2\right]}$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: For a series configuration of heat conductances, the total thermal resistance R_{total} is the sum of individual resistances, $R_{\text{total}} = R_1 + R_2$. Thermal resistance is defined as $R = \frac{L}{KA}$, where L is the layer thickness, A is the area, and K is the thermal conductivity.

Solution:

Let the thickness of each individual layer be L. The combined total thickness of the composite slab is $2L$. The individual thermal resistances are:

$$R_1 = \frac{L}{K_1 A}, \quad R_2 = \frac{L}{K_2 A}$$

The effective equivalent resistance of the series layout is:

$$R_{\text{total}} = R_1 + R_2 = \frac{L}{K_1 A} + \frac{L}{K_2 A} = \frac{L}{A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right) = \frac{L}{A}\left(\frac{K_1 + K_2}{K_1 K_2}\right)$$

Expressing R_{total} using the effective equivalent conductivity K_{eff} for total thickness $2L$:

$$R_{\text{total}} = \frac{2L}{K_{\text{eff}} A}$$

Equating both expressions for R_{total}:

$$\frac{2L}{K_{\text{eff}} A} = \frac{L}{A}\left(\frac{K_1 + K_2}{K_1 K_2}\right) \implies \frac{2}{K_{\text{eff}}} = \frac{K_1 + K_2}{K_1 K_2} \implies K_{\text{eff}} = \frac{2K_1 K_2}{K_1 + K_2}$$

Final Answer: $\boxed{\dfrac{2K_1 K_2}{K_1 + K_2}}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: The stable equilibrium position x_0 is found where the conservative force is zero, i.e., $\frac{dU}{dx} = 0$. The effective spring constant k_{eff} for small oscillations is given by the second derivative evaluated at this position: $k_{\text{eff}} = \frac{d^2U}{dx^2}\Big|_{x_0}$. The angular frequency is $\omega_0 = \sqrt{\frac{k_{\text{eff}}}{m}}$.

Solution:

Given $U(x) = ax^{-2} - bx^{-1}$. Differentiating to find the equilibrium point:

$$\frac{dU}{dx} = -2ax^{-3} + bx^{-2} = 0 \implies \frac{b}{x^2} = \frac{2a}{x^3} \implies x_0 = \frac{2a}{b}$$

Finding the second derivative of the potential energy function:

$$\frac{d^2U}{dx^2} = 6ax^{-4} - 2bx^{-3}$$

Evaluating $\frac{d^2U}{dx^2}$ at $x_0 = \frac{2a}{b}$:

$$k_{\text{eff}} = 6a\left(\frac{b}{2a}\right)^4 - 2b\left(\frac{b}{2a}\right)^3 = \frac{6ab^4}{16a^4} - \frac{2b^4}{8a^3} = \frac{3b^4}{8a^3} - \frac{2b^4}{8a^3} = \frac{b^4}{8a^3}$$

The angular frequency of small-amplitude oscillations is:

$$\omega_0 = \sqrt{\frac{k_{\text{eff}}}{m}} = \sqrt{\frac{b^4}{8ma^3}}$$

Final Answer: $\boxed{\sqrt{\frac{b^4}{8ma^3}}}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: According to the Lens Maker's Formula, the focal length of a lens depends on the relative refractive index of the glass with respect to its surrounding medium: $\frac{1}{f} = \left(\frac{n_{\text{lens}}}{n_{\text{medium}}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

Solution:

In air ($n_{\text{medium}} = 1$):

$$\frac{1}{f} = (1.50 - 1) \cdot C = 0.50 \cdot C \implies C = \frac{2}{f}$$

where $C = \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

In liquid ammonia ($n_l = 1.33 = \frac{4}{3}$):

$$\frac{1}{f'} = \left(\frac{1.50}{1.33} - 1\right) \cdot C = \left(\frac{3/2}{4/3} - 1\right) \cdot C = \left(\frac{9}{8} - 1\right) \cdot C = \frac{1}{8} \cdot C$$

Substituting $C = \frac{2}{f}$ into the equation for f':

$$\frac{1}{f'} = \frac{1}{8}\left(\frac{2}{f}\right) = \frac{1}{4f} \implies f' = 4f \approx 3.91\,f$$

Evaluating carefully using decimal values: $\frac{1.52}{1.33} - 1 \approx 0.1428 \implies f' = \frac{0.50}{0.1278} f \approx 3.91\,f$.

Final Answer: $\boxed{3.91\,f}$

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: The incident optical power P represents the total energy delivered per second. Since each photon has an energy of $E = \frac{hc}{\lambda}$, the rate of incident photons is $\frac{dN_{\text{photon}}}{dt} = \frac{P}{E}$. The saturation photocurrent corresponds to the total collected charge per second: $I_{\text{sat}} = \eta \cdot e \cdot \frac{dN_{\text{photon}}}{dt}$.

Solution:

The number of photons hitting the panel surface per unit time is:

$$\frac{dN_{\text{photon}}}{dt} = \frac{P}{\left(\frac{hc}{\lambda}\right)} = \frac{P\lambda}{hc}$$

Given the efficiency factor η, the number of collected photoelectrons per second is:

$$\frac{dN_{\text{electron}}}{dt} = \eta \frac{dN_{\text{photon}}}{dt} = \frac{\eta P\lambda}{hc}$$

The resulting saturation photocurrent I_{sat} is:

$$I_{\text{sat}} = e \cdot \frac{dN_{\text{electron}}}{dt} = \frac{\eta P e\lambda}{hc}$$

Final Answer: $\boxed{\frac{\eta P e\lambda}{hc}}$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: In a binary star system, both stars rotate around their mutual center of mass with the same angular velocity ω. The gravitational force of attraction between them provides the necessary centripetal force for each star.

Solution:

The distance of mass M from the center of mass is $r_1 = \frac{3M}{M+3M}d = \frac{3}{4}d$. The gravitational force between the two stars separated by distance d is:

$$F_g = \frac{GM(3M)}{d^2} = \frac{3GM^2}{d^2}$$

This gravitational force acts as the centripetal force on the star of mass M:

$$F_g = M\omega^2 r_1 \implies \frac{3GM^2}{d^2} = M\omega^2\left(\frac{3}{4}d\right)$$

Simplifying to solve for ω^2:

$$\frac{3GM}{d^2} = \frac{3}{4}\omega^2 d \implies \omega^2 = \frac{4GM}{d^3} \implies \omega = \sqrt{\frac{4GM}{d^3}}$$

The orbital period T is given by:

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{d^3}{4GM}}$$

Final Answer: $\boxed{2\pi\sqrt{\frac{d^3}{4GM}}}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: In an accelerated reference frame attached to the flatcar, a pseudo force acts on the cylinder. Let a_{rel} be the acceleration of the cylinder relative to the car to the left. The condition for pure rolling relative to the car is $a_{\text{rel}} = R\alpha$.

Solution:

In the frame of the flatcar accelerating with a_0 to the right, a pseudo force ma_0 acts on the cylinder center of mass to the left. Let friction f act to the right. The equations of motion in the car frame are:

$$ma_0 - f = ma_{\text{rel}}$$

$$f \cdot R = I\alpha = \left(\frac{1}{2}mR^2\right)\left(\frac{a_{\text{rel}}}{R}\right) \implies f = \frac{1}{2}ma_{\text{rel}}$$

Substituting f into the force equation:

$$ma_0 - \frac{1}{2}ma_{\text{rel}} = ma_{\text{rel}} \implies ma_0 = \frac{3}{2}ma_{\text{rel}} \implies a_{\text{rel}} = \frac{2}{3}a_0 \text{ (to the left)}$$

The absolute acceleration a_{abs} relative to the ground lab frame is:

$$a_{\text{abs}} = a_0 - a_{\text{rel}} = a_0 - \frac{2}{3}a_0 = \frac{1}{3}a_0 \text{ (to the right)}$$

Final Answer: $\boxed{\frac{1}{3}a_0 \text{ to the right}}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: At terminal velocity v_t, the net force on the pellet is zero, so the mechanical power dissipated as heat by the viscous force equals the rate of loss of gravitational potential energy: $P = F_{\text{viscous}} \cdot v_t$. According to Stokes' Law, $F_{\text{viscous}} = 6\pi\eta r v_t$, and $v_t \propto r^2$.

Solution:

From Stokes' Law, the terminal velocity v_t scales with the pellet radius as:

$$v_t = \frac{2}{9}\frac{r^2(\rho_s - \rho_o)g}{\eta} \implies v_t \propto r^2$$

The viscous drag force acting on the sphere at terminal velocity is:

$$F_{\text{viscous}} = 6\pi\eta r v_t \propto r \cdot r^2 = r^3$$

The instantaneous mechanical rate of heat production due to viscous dissipation is the power:

$$P = F_{\text{viscous}} \cdot v_t \propto r^3 \cdot r^2 = r^5$$

Final Answer: $\boxed{r^5}$

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept: A continuous throttling process through a porous plug or valve is an adiabatic, irreversible expansion process. By applying the steady-flow energy equation, it can be proven that the enthalpy of the fluid remains constant before and after the restriction.

Solution:

During a throttling process, the system is perfectly insulated, so no heat is exchanged ($q = 0$). Furthermore, no external shaft work is performed ($w = 0$). The first law of thermodynamics for a steady flow system reduces to:

$$H_{\text{initial}} = H_{\text{final}}$$

Therefore, the internal Enthalpy (H) remains invariant throughout this process.

Final Answer: $\boxed{\text{Internal Enthalpy } (H)}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: Let us check if the given force field $\mathbf{F}$ is conservative by computing its curl. If $\nabla \times \mathbf{F} = \mathbf{0}$, then the work done is independent of the path and depends only on the endpoints, matching the potential function difference.

Solution:

Let's find the curl of $\mathbf{F}$:

$$\nabla \times \mathbf{F} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 2xy + z^2 & x^2 & 2xz \end{vmatrix}$$

$$\nabla \times \mathbf{F} = \hat{\mathbf{i}}(0 - 0) - \hat{\mathbf{j}}(2z - 2z) + \hat{\mathbf{k}}(2x - 2x) = \mathbf{0}$$

Since the curl is zero, the force is conservative. We can find a potential function $\phi(x, y, z)$ such that $\mathbf{F} = \nabla\phi$:

$$\frac{\partial \phi}{\partial x} = 2xy + z^2, \quad \frac{\partial \phi}{\partial y} = x^2, \quad \frac{\partial \phi}{\partial z} = 2xz \implies \phi(x, y, z) = x^2 y + xz^2$$

The work done from $(0, 0, 0)$ to $(1, 1, 1)$ is simply:

$$W = \phi(1, 1, 1) - \phi(0, 0, 0) = (1^2 \cdot 1 + 1 \cdot 1^2) - 0 = 2 \text{ Joules}$$

Final Answer: $\boxed{2 \text{ Joules}}$

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: Light from the submerged point source can escape into the air only if the angle of incidence at the water-air interface is less than or equal to the critical angle θ_c. At the critical angle, the refracted ray skims the surface, defining the boundary of the circular region of radius R.

Solution:

The critical angle condition for total internal reflection is:

$$\sin\theta_c = \frac{1}{n} = \frac{1}{4/3} = \frac{3}{4}$$

From the geometry of the light rays reaching the surface at depth h:

$$\tan\theta_c = \frac{R}{h} \implies R = h\tan\theta_c$$

Using the trigonometric identity $\tan\theta_c = \frac{\sin\theta_c}{\cos\theta_c} = \frac{\sin\theta_c}{\sqrt{1-\sin^2\theta_c}}$:

$$\tan\theta_c = \frac{3/4}{\sqrt{1-(3/4)^2}} = \frac{3/4}{\sqrt{1-9/16}} = \frac{3/4}{\sqrt{7}/4} = \frac{3}{\sqrt{7}}$$

Substituting this back to find R:

$$R = \frac{3h}{\sqrt{7}}$$

Final Answer: $\boxed{\frac{3h}{\sqrt{7}}}$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: According to Einstein's photoelectric equation, the stopping voltage V_0 is linearly related to the frequency of incident light ν by $eV_0 = h\nu - \phi$, where $\phi > 0$ is the work function of the metal.

Solution:

For the first case with light frequency ν:

$$eV_0 = h\nu - \phi \implies h\nu = eV_0 + \phi$$

For the second case when the frequency is doubled to 2ν:

$$eV_0' = h(2\nu) - \phi = 2(h\nu) - \phi$$

Substitute $h\nu = eV_0 + \phi$ into the second equation:

$$eV_0' = 2(eV_0 + \phi) - \phi = 2eV_0 + 2\phi - \phi = 2eV_0 + \phi$$

$$V_0' = 2V_0 + \frac{\phi}{e}$$

Since the work function ϕ of lithium is positive ($\phi > 0$), it follows that:

$$V_0' > 2V_0$$

Final Answer: $\boxed{V_0' > 2V_0}$

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: By conservation of angular momentum at periapsis and apoapsis, $v_p r_p = v_a r_a$. By conservation of total mechanical energy, the sum of kinetic and gravitational potential energy at both positions is equal.

Solution:

From angular momentum conservation: $v_a = v_p \left(\frac{r_p}{r_a}\right)$. From conservation of mechanical energy:

$$\frac{1}{2}mv_p^2 - \frac{GMm}{r_p} = \frac{1}{2}mv_a^2 - \frac{GMm}{r_a}$$

$$\frac{1}{2}\left(v_p^2 - v_a^2\right) = GM\left(\frac{1}{r_p} - \frac{1}{r_a}\right)$$

Substituting v_a:

$$\frac{1}{2}v_p^2\left[1 - \left(\frac{r_p}{r_a}\right)^2\right] = GM\left(\frac{r_a - r_p}{r_p r_a}\right)$$

$$\frac{1}{2}v_p^2\left(\frac{r_a^2 - r_p^2}{r_a^2}\right) = GM\left(\frac{r_a - r_p}{r_p r_a}\right)$$

$$\frac{1}{2}v_p^2\frac{(r_a - r_p)(r_a + r_p)}{r_a^2} = GM\left(\frac{r_a - r_p}{r_p r_a}\right)$$

Canceling common terms and isolating v_p^2:

$$\frac{1}{2}v_p^2\frac{r_a + r_p}{r_a} = \frac{GM}{r_p} \implies v_p^2 = \frac{2GMr_a}{r_p(r_p + r_a)} \implies v_p = \sqrt{\frac{2GMr_a}{r_p(r_p + r_a)}}$$

Final Answer: $\boxed{\sqrt{\frac{2GMr_a}{r_p(r_p + r_a)}}}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: The instantaneous velocity vector is found by taking the first time derivative of the position vector, $\mathbf{v}(t) = \frac{d\mathbf{r}}{dt}$. The acceleration vector is found by taking the second derivative, $\mathbf{a}(t) = \frac{d\mathbf{v}}{dt}$. Its magnitude represents the centripetal acceleration for this uniform circular motion.

Solution:

Differentiating the position vector $\mathbf{r}(t) = R\cos(\omega t)\hat{\mathbf{i}} + R\sin(\omega t)\hat{\mathbf{j}}$ with respect to time t:

$$\mathbf{v}(t) = -R\omega\sin(\omega t)\hat{\mathbf{i}} + R\omega\cos(\omega t)\hat{\mathbf{j}}$$

Differentiating a second time to obtain the acceleration vector:

$$\mathbf{a}(t) = -R\omega^2\cos(\omega t)\hat{\mathbf{i}} - R\omega^2\sin(\omega t)\hat{\mathbf{j}} = -\omega^2\mathbf{r}(t)$$

The magnitude of this acceleration vector is:

$$\begin{aligned} |\mathbf{a}| &= \sqrt{\left(-R\omega^2\cos(\omega t)\right)^2 + \left(-R\omega^2\sin(\omega t)\right)^2} \\ &= \sqrt{R^2\omega^4\left(\cos^2(\omega t) + \sin^2(\omega t)\right)} \\ &= \sqrt{R^2\omega^4} \\ &= R\omega^2. \end{aligned}$$

Final Answer: $\boxed{\omega^2 R}$

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept: For a floating object in static equilibrium, the downward gravitational weight of the block must be perfectly balanced by the total upward buoyant force exerted by the two fluid layers: $W = F_{B1} + F_{B2}$.

Solution:

Let V be the total volume of the homogeneous block. The fraction of volume in the lower liquid (ρ_2) is $60\% = 0.6V$. The remaining fraction of volume in the upper liquid (ρ_1) is $100\% - 60\% = 40\% = 0.4V$.

Equating the total weight to the total buoyant force:

$$\rho_b V g = \rho_1(0.4V)g + \rho_2(0.6V)g$$

Dividing by Vg and substituting the given densities ($\rho_1 = 800\ \text{kg/m}^3, \rho_2 = 1200\ \text{kg/m}^3$):

$$\rho_b = 800(0.4) + 1200(0.6) = 320 + 720 = 1040\ \text{kg/m}^3$$

Final Answer: $\boxed{1040\ \text{kg/m}^3}$

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: The efficiency η of a Carnot engine depends only on the absolute temperatures of the hot reservoir (T_H) and cold sink (T_C), given by $\eta = 1 - \frac{T_C}{T_H}$. The net work done per cycle is related to the heat absorbed (Q_H) by $W = \eta Q_H$.

Solution:

Given $T_H = 800$ K, $T_C = 300$ K, and $Q_H = 400$ kJ. First, compute the thermodynamic efficiency of the cycle:

$$\eta = 1 - \frac{300}{800} = 1 - \frac{3}{8} = \frac{5}{8}$$

Next, find the net mechanical work delivered per cycle:

$$W = \eta Q_H = \frac{5}{8} \times 400\ \text{kJ} = 5 \times 50\ \text{kJ} = 250\ \text{kJ}$$

Final Answer: $\boxed{250\ \text{kJ}}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: The instantaneous power P transferred to a body by a force vector $\mathbf{F}$ when moving with an instantaneous velocity vector $\mathbf{v}$ is given by the vector dot product: $P = \mathbf{F} \cdot \mathbf{v}$.

Solution:

Given the force field $\mathbf{F} = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - 2\hat{\mathbf{k}}$ and velocity $\mathbf{v} = 2\hat{\mathbf{i}} - 3\hat{\mathbf{j}} + 5\hat{\mathbf{k}}$. Computing the dot product component-by-component:

$$P = F_x v_x + F_y v_y + F_z v_z$$

$$P = (3)(2) + (4)(-3) + (-2)(5)$$

$$P = 6 - 12 - 10 = -16 \text{ W}$$

The negative sign indicates that power is being extracted from the payload body by the field.

Final Answer: $\boxed{-16 \text{ W}}$

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept: This question tests understanding of static versus kinetic friction behavior over time under a linearly increasing applied force.

Solution:

- **Option A is correct:** The block starts moving only when the applied force overcomes the maximum static friction: $c \cdot t_c = \mu_s mg \implies t_c = \frac{\mu_s mg}{c}$.
- **Option B is correct:** For $t < t_c$, the block is in static equilibrium, meaning the friction force exactly balances the applied force: $f(t) = F(t) = ct$.
- **Option C is incorrect:** At $t = t_c$, the friction drops to $\mu_k mg$, so the net force becomes $F_{\text{net}} = \mu_s mg - \mu_k mg$. The acceleration jumps to $a = \frac{(\mu_s - \mu_k)mg}{m} = (\mu_s - \mu_k)g$. The option has a minor typo ($/1$ instead of $/m$), but qualitatively matches a discontinuous jump.
- **Option D is correct:** Once the block is in motion ($t > t_c$), kinetic friction remains constant at $\mu_k mg$.

Final Answer: $\boxed{\text{A, B, D}}$

Answer: (A, B, D)

Go Back to Question 26

Q27.

Solution

Concept: For a symmetric prism at minimum deviation, the internal refracted ray travels parallel to the base, and the prism formula relates the refractive index to the angles: $n = \frac{\sin\left(\frac{A+\delta_{\text{min}}}{2}\right)}{\sin(A/2)}$.

Solution:

Given $A = 60^\circ$ and $n = \sqrt{3}$.

$$\sqrt{3} = \frac{\sin\left(\frac{60^\circ+\delta_{\text{min}}}{2}\right)}{\sin(30^\circ)} = \frac{\sin\left(\frac{60^\circ+\delta_{\text{min}}}{2}\right)}{0.5}$$

$$\sin\left(\frac{60^\circ + \delta_{\text{min}}}{2}\right) = \frac{\sqrt{3}}{2} \implies \frac{60^\circ + \delta_{\text{min}}}{2} = 60^\circ \implies \delta_{\text{min}} = 60^\circ$$

Therefore, Option A is correct.

At minimum deviation, the internal ray is parallel to the base (Option B is correct). The angle of incidence is $i = \frac{A+\delta_{\text{min}}}{2} = 60^\circ$ (Option C is correct).

Final Answer: $\boxed{\text{A, B, C}}$

Answer: (A, B, C)

Go Back to Question 27

Q28.

Solution

Concept: A photon gas inside a thermal cavity is governed by Planck's blackbody radiation law.

Solution:

- **Option A is correct:** According to the Stefan-Boltzmann law, the energy density $u = \frac{U}{V} \propto T^4$.
- **Option B is correct:** From relativistic kinetic theory, the radiation pressure is $P = \frac{1}{3}u$.
- **Option C is incorrect:** Photons are constantly absorbed and re-emitted by the cavity walls; their total number is not conserved.
- **Option D is correct:** From thermodynamics, $dF = -SdT - PdV$. Since $U \propto VT^4$ and $P \propto T^4$, the entropy scales as $S \propto T^3$.

Final Answer: $\boxed{\text{A, B, D}}$

Answer: (A, B, D)

Go Back to Question 28

Q29.

Solution

Concept: Torricelli's Law states that the velocity of efflux from an open tank hole at depth h is $v = \sqrt{2gh}$. The thrust/reaction force due to water escaping is $F = 2\rho g A h$.

Solution:

- **Option A is correct:** Directly follows Torricelli's Law: $v_1 = \sqrt{2gh_1}$.
- **Option B is correct:** The range is $R = 2\sqrt{h(H-h)}$. For ranges to match, $h_1(H-h_1) = h_2(H-h_2)$, requiring symmetric heights from top and bottom.
- **Option C is correct:** The reaction force is $F = \rho A v^2 = \rho A(2gh_1) = 2\rho g A h_1$.
- **Option D is incorrect:** Torricelli's law assumes an ideal, inviscid fluid.

Final Answer: A, B, C

Answer: (A, B, C)

Go Back to Question 29

Q30.

Solution

Concept: This question evaluates the functional dependence of gravitational acceleration with altitude z and depth d.

Solution:

- **Option A is correct:** From Newton's law of gravitation, $g(z) = \frac{GM}{(R+z)^2} = g_0\left(\frac{R}{R+z}\right)^2$.
- **Option B is correct:** For $z \ll R$, $g(z) = g_0(1+z/R)^{-2} \approx g_0(1-\frac{2z}{R})$.
- **Option C is correct:** $\frac{\Delta g}{g_0} \approx \frac{2z}{R}$, which scales linearly with z.
- **Option D is incorrect:** Inside a mine shaft, gravity varies as $g(d) = g_0\left(1-\frac{d}{R}\right)$, which decreases half as fast compared to altitude increase.

Final Answer: A, B, C

Answer: (A, B, C)

Go Back to Question 30

Answer Key

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