UPCATET Physics Sample Paper-8

Duration: 45 Minutes **Maximum Marks: 200**

Instructions

- This paper contains **50** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **−1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. A uniform solid cylinder of mass M and radius R is pulled on a rough horizontal surface by a horizontal force F applied at its top-most point. If the cylinder rolls without slipping, the acceleration of its center of mass is:

(A) $\frac{2F}{3M}$

(B) $\frac{4F}{3M}$

(C) $\frac{F}{M}$

(D) $\frac{3F}{4M}$

Q2. In a certain region of space, the electric potential is given by $V(x, y, z) = 2x^2y - 3yz$. The magnitude of the electric field intensity (in V/m) at the point $(1, -1, 2)$ is:

(A) $\sqrt{17}$

(B) $\sqrt{21}$

(C) $\sqrt{33}$

(D) $\sqrt{41}$

Q3. A light ray is incident normally on one face of an equilateral glass prism of refractive index $\mu = \sqrt{2}$. The angle of deviation of the ray as it emerges from the prism is:

(A) 30°

(B) 45°

(C) 60°

(D) The ray undergoes total internal reflection and cannot emerge.

Q4. An ideal gas expands from volume V_1 to V_2 via three different processes: isothermal, adiabatic, and isobaric. Let W_{iso}, W_{adia}, and W_{bar} be the work done by the gas respectively. If $V_2 > V_1$, which of the following is correct?

(A) $W_{\text{bar}} > W_{\text{iso}} > W_{\text{adia}}$

(B) $W_{\text{bar}} > W_{\text{adia}} > \text{W}_{\text{iso}}$

(C) $W_{\text{adia}} > W_{\text{iso}} > W_{\text{bar}}$

(D) $W_{\text{iso}} > W_{\text{bar}} > W_{\text{adia}}$

Q5. When light of wavelength λ is incident on a photosensitive surface, the stopping potential is V_0. When the light of wavelength 2λ is incident on the same surface, the stopping potential becomes $V_0/3$. The threshold wavelength for this surface is:

(A) 3λ

(B) 4λ

(C) 5λ

(D) 6λ

Q6. A steel wire of length 2 m and cross-sectional area 1 mm^2 is stretched by a force of 100 N. If Young's modulus of steel is 2×10^{11} N/m^2, the elastic potential energy stored in the wire is:

(A) 0.05 J

(B) 0.10 J

(C) 0.25 J

(D) 0.50 J

Q7. A particle is projected from the ground with an initial velocity u at an angle θ with the horizontal. At the highest point of its trajectory, the radius of curvature of its path is:

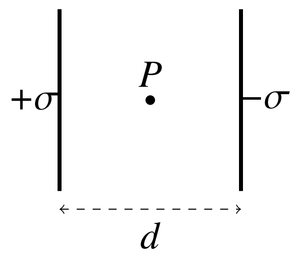
(A) $\frac{u^2 \sin^2\theta}{g}$

(B) $\frac{u^2 \cos^2\theta}{g}$

(C) $\frac{u^2}{g}$

(D) $\frac{u^2 \cos^2\theta}{g \sin\theta}$

Q8. Two parallel large thin metal sheets carry charge densities $+\sigma$ and $-\sigma$ respectively on their inner surfaces. With reference to the TikZ diagram below, find the magnitude of the net electric field at point P located exactly midway between the plates:



(A) Zero

(B) $\frac{\sigma}{2\varepsilon_0}$

(C) $\frac{\sigma}{\varepsilon_0}$

(D) $\frac{2\sigma}{\varepsilon_0}$

Q9. In a Young's double-slit experiment, the intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ being the wavelength of light used) is I. If I_0 denotes the maximum intensity, then $\frac{I}{I_0}$ is equal to:

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

(B) $\frac{\sqrt{3}}{2}$

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

(D) $\frac{1}{4}$

Q10. A metallic sphere is covered with a thick layer of insulating material. The inner radius of the insulation is R and the outer radius is $2R$. Heat is generated inside the sphere at a constant rate. In the steady-state, the temperature gradient $\frac{dT}{dr}$ inside the insulating layer at a distance r $(R < r < 2R)$ from the center varies as:

(A) $\propto r$

(B) $\propto \frac{1}{r}$

(C) $\propto \frac{1}{r^2}$

(D) $\propto r^2$

Q11. The half-life of a radioactive substance is 20 minutes. The time interval between 20% decay and 80% decay of the substance is approximately:

(A) 20 min

(B) 40 min

(C) 30 min

(D) 25 min

Q12. A glass capillary tube of radius r is submerged vertically in water. The water rises up to a height h in it. If the entire apparatus is kept inside an elevator accelerating downwards with an acceleration $a = \frac{g}{3}$, the new height of the water column in the capillary tube becomes:

(A) $\frac{2h}{3}$

(B) $\frac{3h}{2}$

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

(D) $3h$

Q13. A body of mass m is dropped from a height $h = R$ above the surface of the Earth, where R is the radius of the Earth. The speed with which the body hits the surface of the Earth (neglecting air resistance, with g being acceleration due to gravity at the surface) is:

(A) $\sqrt{2gh}$

(B) $\sqrt{gh}$

(C) $\sqrt{1.5gh}$

(D) $\sqrt{0.5gh}$

Q14. An alternating voltage source given by $V = 200\sin(100t)$ V is connected across a series combination of a resistor $R = 30\ \Omega$ and an inductor $L = 0.4$ H. The peak value of the current flowing in the circuit is:

(A) 4 A

(B) $4\sqrt{2}$ A

(C) 2.8 A

(D) 5 A

Q15. A convex lens of focal length $f = 20$ cm in air is immersed completely in a liquid of refractive index $\mu_l = 1.63$. If the refractive index of the glass lens is $\mu_g = 1.5$, the lens will behave as a:

(A) Converging lens of shorter focal length

(B) Converging lens of longer focal length

(C) Diverging lens of longer focal length

(D) Diverging lens of shorter focal length

Q16. Two absolute thermodynamic scales A and B have triple points of water defined to be 200 A and 350 B. What is the relation between the temperatures T_A and T_B?

(A) $T_A = \frac{4}{7}T_B$

(B) $T_A = \frac{7}{4}T_B$

(C) $T_A = T_B + 150$

(D) $T_A = \frac{2}{3}T_B$

Q17. The truth table shown below corresponds to which of the following logic gates?

Input A	Input B	Output Y
0	0	1
0	1	0
1	0	0
1	1	0

(A) NAND

(B) NOR

(C) XOR

(D) XNOR

Q18. A large open tank filled with water has a small hole at a depth h below the water surface. If the area of the hole is A and the top surface area of the tank is infinitely large, the rate of volume flow of water escaping the hole is:

(A) $A\sqrt{gh}$

(B) $A\sqrt{2gh}$

(C) $2A\sqrt{gh}$

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

Q19. A particle moves along a straight line such that its displacement at any time t is given by $s = t^3 - 6t^2 + 9t + 4$ meters. The velocity of the particle when its acceleration becomes zero is:

(A) -3 m/s

(B) 3 m/s

(C) Zero

(D) -9 m/s

Q20. Two long parallel wires separated by a distance d carry equal currents I flowing in opposite directions. The magnetic field at a point midway between the two wires has a magnitude of:

(A) Zero

(B) $\frac{\mu_0 I}{\pi d}$

(C) $\frac{2\mu_0 I}{\pi d}$

(D) $\frac{\mu_0 I}{2\pi d}$

Q21. A thin equiconvex lens has a focal length f. If it is cut into two equal halves along its principal axis, the focal length of each half will be:

(A) f

(B) $2f$

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

(D) Infinite

Q22. During an adiabatic process, the pressure of a fixed mass of a diatomic gas ($\gamma = 1.4$) is found to be proportional to the cube of its absolute temperature. This implies that:

(A) The process is physically impossible for a diatomic gas

(B) The gas must be performing negative work

(C) The statement contains an error as $P \propto T^{3.5}$ for diatomic gases

(D) The gas is behaving as a monoatomic structure instead

Q23. The Bohr radius of the hydrogen atom in the ground state is a_0. The de Broglie wavelength of an electron revolving in the second excited state ($n = 3$) of a hydrogen atom is:

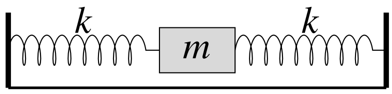
(A) $3\pi a_0$

(B) $6\pi a_0$

(C) $9\pi a_0$

(D) $2\pi a_0$

Q24. The block has mass m and lies on a smooth horizontal floor. It is connected to two identical relaxed springs of stiffness k. The time period of small horizontal oscillations of the block is:



(A) $2\pi\sqrt{\frac{m}{k}}$

(B) $2\pi\sqrt{\frac{m}{2k}}$

(C) $2\pi\sqrt{\frac{2m}{k}}$

(D) $2\pi\sqrt{\frac{m}{4k}}$

Q25. A force $\vec{F} = 3\hat{i} + 4\hat{j}$ N acts on a particle changing its position vector from $\vec{r}_1 = 2\hat{i} + \hat{j}$ m to $\vec{r}_2 = 4\hat{i} + 5\hat{j}$ m. The total work done by the force on the particle is:

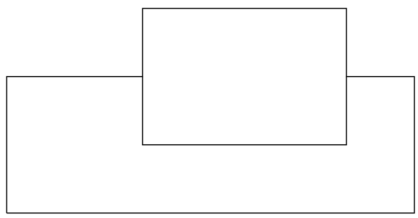
(A) 10 J

(B) 22 J

(C) 24 J

(D) 32 J

Q26. In the circuit shown below, the three resistors are connected to an ideal battery of EMF $E = 12$ V. Find the magnitude of the current passing through the 6 Ω resistor:



(A) 1.0 A

(B) 1.33 A

(C) 2.0 A

(D) 0.67 A

Q27. A astronomical telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. The magnifying power of this telescope for viewing distant objects in normal adjustment is:

(A) 24

(B) 28

(C) 35

(D) 70

Q28. A cyclic process performed on one mole of an ideal gas is plotted on a $P - V$ diagram. If the path forms a perfect circle of radius R centered at some point on the domain, then the total net heat absorbed by the gas during one complete clockwise cycle is:

(A) Zero

(B) πR^2

(C) Dependent on the scales used on the P and V axes

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

Q29. In a forward-biased $p - n$ junction diode, the width of the depletion region:

(A) Increases

(B) Decreases

(C) Remains exactly unchanged

(D) First increases then drops sharply to zero

Q30. A bubble of air escapes from the bottom of a lake to its surface. As it rises up, its radius doubles. If the atmospheric pressure equals the pressure exerted by a water column of depth H, the depth of the lake is:

(A) $2H$

(B) $4H$

(C) $7H$

(D) $8H$

Q31. A particle of mass m is moving in a horizontal circle of radius r under the action of a centripetal force given by $F = -\frac{k}{r^2}$, where k is a constant. The total mechanical energy of the particle (taking potential energy to be zero at infinity) is:

(A) $-\frac{k}{2r}$

(B) $\frac{k}{2r}$

(C) $-\frac{k}{r}$

(D) $\frac{k}{r}$

Q32. A variable capacitor is connected across a constant DC voltage source V. If its capacitance is slowly doubled from C to $2C$, the change in energy stored inside the capacitor is:

(A) $\frac{1}{2}CV^2$

(B) CV^2

(C) $2CV^2$

(D) Zero

Q33. Two coherent light waves of intensities I and $4I$ superimpose to form an interference pattern. The ratio of maximum to minimum intensity observed in the fringes is:

(A) 5 : 3

(B) 9 : 1

(C) 4 : 1

(D) 25 : 9

Q34. Fifty grams of ice at 0°C is mixed with fifty grams of water at 80°C in a well-insulated calorimeter. The final temperature of the mixture at thermal equilibrium will be (take latent heat of fusion of ice = 80 cal/g):

(A) 40°C

(B) 20°C

(C) 0°C

(D) 10°C

Q35. The binding energy per nucleon for a nucleus $A(M, Z)$ is usually maximum around which mass number range?

(A) $A < 20$

(B) $40 < A < 70$

(C) $100 < A < 140$

(D) $A > 200$

Q36. Two small drops of mercury, each of radius R, coalesce to form a single larger drop under isothermal conditions. If the surface tension of mercury is T, the energy released during this amalgamation process is:

(A) $4\pi R^2 T(2 - 2^{2/3})$

(B) $4\pi R^2 T(2^{1/3} - 1)$

(C) $8\pi R^2 T$

(D) $2\pi R^2 T(2^{2/3} - 1)$

Q37. A projectile is fired with an initial velocity of $\vec{v} = 6\hat{i} + 8\hat{j}$ m/s from a flat plain land, where $\hat{j}$ points vertically upwards. Taking $g = 10$ m/s^2, the horizontal range of the projectile is:

(A) 4.8 m

(B) 9.6 m

(C) 12.4 m

(D) 19.2 m

Q38. An electron is moving with a constant speed v along a circular path of radius r around a fixed nucleus. This circulating charge creates an effective magnetic dipole moment at the center equal to:

(A) evr

(B) $\frac{1}{2}evr$

(C) $\frac{ev}{2\pi r}$

(D) $2\pi evr$

Q39. A thin convergent lens creates a sharp real image of an object on a screen placed at a distance D away from the object. If the lens is moved to another unique position, it forms another clear image on the screen. If the separation between these two positions of the lens is x, the focal length of the lens is:

(A) $\frac{D^2-x^2}{4D}$

(B) $\frac{D^2+x^2}{4D}$

(C) $\frac{D-x}{4}$

(D) $\frac{D^2-x^2}{2D}$

Q40. An ideal gas heat engine operates in a Carnot cycle between temperatures 227°C and 127°C. It absorbs 6×10^4 cal of heat at the higher temperature. The amount of heat converted into useful mechanical work is:

(A) 1.2×10^4 cal

(B) 2.4×10^4 cal

(C) 3.6×10^4 cal

(D) 4.8×10^4 cal

Q41. The energy of a photon is equal to the kinetic energy of a fast-moving proton. Let λ_1 be the de Broglie wavelength of the proton and λ_2 be the wavelength of the photon. The ratio $\frac{\lambda_1}{\lambda_2}$ is proportional to (c being speed of light, E being energy):

(A) $E^{1/2}$

(B) $E^{-1/2}$

(C) E

(D) E^2

Q42. A uniform metal rod of mass M and length L is cross-sectionally fixed at one end and hangs vertically. If the density of the metal is ρ and Young's modulus is Y, the elongation of the rod due to its own weight is:

(A) $\frac{\rho g L^2}{2Y}$

(B) $\frac{\rho g L^2}{Y}$

(C) $\frac{MgL}{2Y}$

(D) $\frac{2\rho g L^2}{Y}$

Q43. A block of mass M is placed on a rough horizontal surface with a coefficient of static friction μ_s. A force P is applied at an angle θ above the horizontal. The minimum magnitude of P required to budge the block along the surface is:

(A) $\frac{\mu_s M g}{\cos\theta+\mu_s \sin\theta}$

(B) $\frac{\mu_s M g}{\cos\theta-\mu_s \sin\theta}$

(C) $\frac{\mu_s M g}{\sin\theta+\mu_s \cos\theta}$

(D) $\mu_s M g$

Q44. A small current element $d\vec{l} = \Delta x\hat{i}$ is placed at the origin and carries a heavy current I. The magnetic field induction vector $d\vec{B}$ at a position point $(0, y, 0)$ on the y-axis is directed along:

(A) $+\hat{j}$

(B) $-\hat{i}$

(C) $+\hat{k}$

(D) $-\hat{k}$

Q45. In a single-slit diffraction experiment, the width of the slit is halved. As a consequence, the width of the central diffraction maximum becomes:

(A) Halved and its peak intensity becomes double

(B) Doubled and its peak intensity becomes four times

(C) Doubled and its peak intensity becomes one-fourth

(D) Halved and its peak intensity becomes one-fourth

Q46. According to the kinetic theory of gases, the root-mean-square speed of molecules of an ideal gas at an absolute temperature T is v_{rms}. If the temperature is raised to $4T$ while the volume is kept constant, the new root-mean-square speed is:

(A) $2v_{\text{rms}}$

(B) $4v_{\text{rms}}$

(C) v_{rms}

(D) $1.414v_{\text{rms}}$

Q47. A Zener diode is primarily used in electronics circuits as a device for:

(A) Full-wave rectification

(B) Current amplification

(C) Voltage regulation

(D) Producing electromagnetic oscillations

Q48. A viscous liquid flows through a cylindrical pipe of internal radius r and length l under a constant pressure head difference P. If the radius is reduced to $\frac{r}{2}$ while keeping P and l identical, the volume of liquid flowing out per second changes by a factor of:

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

(B) $\frac{1}{4}$

(C) $\frac{1}{8}$

(D) $\frac{1}{16}$

Q49. A bullet of mass m moving with velocity v strikes and gets embedded inside a stationary wooden block of mass M hanging via a long light string. The fractional loss of mechanical energy during this impact is given by:

(A) $\frac{m}{M+m}$

(B) $\frac{M}{M+m}$

(C) $\frac{M-m}{M+m}$

(D) $\frac{m}{M}$

Q50. A charge q is placed exactly at the center of one of the open circular faces of a straight cylinder of radius R and length L. The net electric flux passing through the curved surface of this cylinder is:

(A) $\frac{q}{\varepsilon_0}$

(B) $\frac{q}{2\varepsilon_0}$

(C) $\frac{q}{4\varepsilon_0}$

(D) Zero

Detailed Solutions

Q1.

Solution

Concept:
When a cylinder rolls without slipping on a rough horizontal surface, both linear acceleration a and angular acceleration α are present, connected by the rolling condition $a = \alpha R$. The friction force f prevents slipping and acts at the contact point.

Solution:

(a) Let f be the friction force acting in the forward direction. The net horizontal force equation is:

$$F + f = Ma$$

(b) Torque about the center of mass is provided by F and f in opposite directions:

$$\tau = F \cdot R - f \cdot R = I\alpha$$

(c) For a solid cylinder, the moment of inertia is $I = \frac{1}{2}MR^2$. Since it rolls without slipping, $\alpha = \frac{a}{R}$. Substituting these gives:

$$F - f = \frac{1}{2}Ma$$

(d) Adding the force equation and the torque equation eliminates f:

$$2F = \frac{3}{2}Ma$$

(e) Solving for the acceleration of the center of mass yields:

$$a = \frac{4F}{3M}$$

Final Answer: 4F$_{\overline{3M}}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:
The electric field vector $\vec{E}$ is related to the electric potential V through the negative gradient operator: $\vec{E} = -\nabla V = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$.

Solution:

(a) Given the potential function $V(x, y, z) = 2x^2y - 3yz$, find the partial derivatives with respect to each coordinate axis.

(b) Differentiating V gives the components of the field:

$$\frac{\partial V}{\partial x} = 4xy \implies E_x = -4xy$$

$$\frac{\partial V}{\partial y} = 2x^2 - 3z \implies E_y = -(2x^2 - 3z)$$

$$\frac{\partial V}{\partial z} = -3y \implies E_z = 3y$$

(c) Evaluate these components at the specified coordinates $(1, -1, 2)$:

$$E_x = -4(1)(-1) = 4$$

$$E_y = -(2(1)^2 - 3(2)) = -(-4) = 4$$

$$E_z = 3(-1) = -3$$

(d) The electric field vector at this point is $\vec{E} = 4\hat{i} + 4\hat{j} - 3\hat{k}$.

(e) Calculate the magnitude of the field:

$$|\vec{E}| = \sqrt{4^2 + 4^2 + (-3)^2} = \sqrt{16 + 16 + 9} = \sqrt{41}\text{ V/m}$$

Final Answer: $\sqrt{41}$

Answer: (D)

Go Back to Question 2

Q3.

Solution

Concept:
When a light ray enters a prism normally, it travels undeviated through the first surface. At the second surface, it hits at an angle of incidence equal to the prism angle, where it obeys Snell's law or undergoes total internal reflection if the angle exceeds the critical angle.

Solution:

(a) Since the ray is incident normally on the first face, the angle of incidence is 0° and the angle of refraction inside is also 0°.

(b) For an equilateral prism, the angle of the prism is $A = 60^\circ$. The relation between internal angles gives $r_1 + r_2 = A$, so the angle of incidence at the second face is $r_2 = 60^\circ$.

(c) Find the critical angle θ_c for the glass-air interface:

$$\sin\theta_c = \frac{1}{\mu} = \frac{1}{\sqrt{2}} \implies \theta_c = 45^\circ$$

(d) Compare the internal angle of incidence with the critical angle. Since $r_2 = 60^\circ > 45^\circ$, the incident angle is greater than the critical angle.

(e) Therefore, the light ray undergoes total internal reflection at the second face and cannot emerge from it into the air.

Final Answer: The ray undergoes total internal reflection and cannot emerge.

Answer: (D)

Go Back to Question 3

Q4.

Solution

Concept:

Work done by a gas during expansion from volume V_1 to V_2 is represented by the area under the process curve on a pressure-volume $(P - V)$ diagram. Comparing the slopes of the paths establishes the relative magnitudes of work done.

Solution:

(a) For an isobaric expansion, pressure remains constant at its initial value, maintaining the highest path on the diagram.

(b) For isothermal and adiabatic paths starting from the same initial state, the adiabatic curve is steeper because its pressure drops faster due to temperature loss ($P \propto V^{-\gamma}$ compared to $P \propto V^{-1}$).

(c) Plotting all three expansions to the same final volume V_2 shows that the isobaric line lies on top, followed by the isothermal curve, with the adiabatic curve at the bottom.

(d) Since work done corresponds directly to the area under each curve, the areas rank in the exact same order as the curves.

(e) Thus, the relationship between the work done in these three processes is:

$$W_{\text{bar}} > W_{\text{iso}} > W_{\text{adia}}$$

Final Answer: $\mathrm{W}_{\text{bar}} > W_{\text{iso}} > W_{\text{adia}}$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:
Einstein's photoelectric equation relates the energy of incident photons to the stopping potential and the threshold frequency of the surface: $eV_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$, where λ_0 is the threshold wavelength.
Solution:

(a) Set up the equation for the first case with wavelength λ and stopping potential V_0:

$$eV_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} \quad \text{— (Equation 1)}$$

(b) Set up the equation for the second case with wavelength 2λ and stopping potential $\frac{V_0}{3}$:

$$\frac{eV_0}{3} = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0} \quad \text{— (Equation 2)}$$

(c) Multiply Equation 2 by 3 to equate the left-hand sides:

$$eV_0 = \frac{3hc}{2\lambda} - \frac{3hc}{\lambda_0}$$

(d) Equate this expression to Equation 1:

$$\frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{3hc}{2\lambda} - \frac{3hc}{\lambda_0}$$

(e) Cancel hc from both sides and rearrange the terms to solve for λ_0:

$$\frac{3}{\lambda_0} - \frac{1}{\lambda_0} = \frac{3}{2\lambda} - \frac{1}{\lambda}$$

$$\frac{2}{\lambda_0} = \frac{1}{2\lambda} \implies \lambda_0 = 4\lambda$$

Final Answer: 4λ

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:
Elastic potential energy U stored in a stretched wire under an axial load can be computed using the formula $U = \frac{1}{2} \cdot \text{Force} \cdot \text{Elongation}$, or equivalently $U = \frac{F^2 L}{2AY}$ by utilizing Hooke's law.
Solution:

(a) Convert all given quantities into standard SI units: length $L = 2$ m, force $F = 100$ N, Young's modulus $Y = 2 \times 10^{11}$ N/m^2, and area $A = 1$ mm$^2 = 1 \times 10^{-6}$ m^2.

(b) Recall the relation for elongation ΔL from Hooke's Law:

$$\Delta L = \frac{FL}{AY}$$

(c) Substitute ΔL into the potential energy formula:

$$U = \frac{1}{2} F \Delta L = \frac{F^2 L}{2AY}$$

(d) Insert the numerical values into the equation:

$$U = \frac{(100)^2 \times 2}{2 \times (1 \times 10^{-6}) \times (2 \times 10^{11})}$$

(e) Simplify the expression step by step:

$$U = \frac{20000}{4 \times 10^5} = \frac{2}{40} = 0.05 \text{ J}$$

Final Answer: 0.05 J

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:
The radius of curvature R_c of any trajectory is determined by the relationship between the tangential velocity v and the normal component of acceleration a_n, given by the expression $R_c = \frac{v^2}{a_n}$.

Solution:

(a) A particle is launched with velocity u at an angle θ. At the highest point of its parabolic flight, the vertical component of velocity becomes zero.

(b) The remaining horizontal component of velocity is constant throughout the motion:

$$v = u\cos\theta$$

(c) The only acceleration acting on the projectile is gravity g, which points vertically downward.

(d) At the highest point, the velocity vector is purely horizontal, meaning the downward acceleration due to gravity is perpendicular to the direction of motion ($a_n = g$).

(e) Substitute the horizontal velocity and normal acceleration into the radius of curvature formula:

$$R_c = \frac{(u\cos\theta)^2}{g} = \frac{u^2\cos^2\theta}{g}$$

Final Answer: u$^2\cos^2\theta\frac{}{g}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
An infinite thin sheet of uniform charge density creates a uniform electric field of magnitude $E = \frac{\sigma}{2\varepsilon_0}$. The total electric field at any point is found by taking the vector sum of fields from individual sheets.

Solution:

(a) Point P lies in the region between a positively charged plate ($+\sigma$) on the left and a negatively charged plate ($-\sigma$) on the right.

(b) The positive plate creates an electric field $\vec{E}_+$ directed away from itself, which points to the right:

$$E_+ = \frac{\sigma}{2\varepsilon_0} \quad \text{(Rightward)}$$

(c) The negative plate creates an electric field $\vec{E}_-$ directed toward itself, which also points to the right:

$$E_- = \frac{\sigma}{2\varepsilon_0} \quad \text{(Rightward)}$$

(d) Since both field vectors point in the same direction, their magnitudes add up directly at point P:

$$E_{\text{net}} = E_+ + E_- = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

(e) Simplifying the sum gives the net field magnitude midway between the plates:

$$E_{\text{net}} = \frac{\sigma}{\varepsilon_0}$$

Final Answer: $\sigma \frac{}{\varepsilon_0}$

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept:
In a Young's double-slit experiment, the resultant intensity I at a point depends on the phase difference ϕ between interfering waves, given by the formula $I = I_0 \cos^2\left(\frac{\phi}{2}\right)$, where I_0 is the maximum intensity.
Solution:

(a) The relationship between the path difference Δx and the phase difference ϕ is given by:

$$\phi = \frac{2\pi}{\lambda}\Delta x$$

(b) Substitute the given path difference $\Delta x = \frac{\lambda}{6}$ into the equation:

$$\phi = \frac{2\pi}{\lambda}\left(\frac{\lambda}{6}\right) = \frac{\pi}{3}$$

(c) Use the intensity formula with the calculated phase difference:

$$I = I_0 \cos^2\left(\frac{\phi}{2}\right) = I_0 \cos^2\left(\frac{\pi}{6}\right)$$

(d) Recall that $\cos\left(\frac{\pi}{6}\right) = \frac{\sqrt{3}}{2}$. Square this value:

$$\cos^2\left(\frac{\pi}{6}\right) = \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4}$$

(e) Substitute back to find the ratio of intensity to maximum intensity:

$$\frac{I}{I_0} = \frac{3}{4}$$

Final Answer: $3_{\overline{4}}$

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept:
In a steady-state thermal system, the rate of heat flow Q through any concentric spherical shell within the insulation layer must be constant and equal to the total heat generated inside the core.
Solution:

(a) Consider a spherical shell of radius r inside the insulating layer ($R < r < 2R$). The rate of radial heat conduction is governed by Fourier's Law:

$$Q = -kA\frac{dT}{dr}$$

(b) The surface area of a spherical shell at distance r from the center is $A = 4\pi r^2$.

(c) Substitute the expression for area into Fourier's law equation:

$$Q = -k(4\pi r^2)\frac{dT}{dr}$$

(d) Rearrange the terms to isolate the radial temperature gradient $\frac{dT}{dr}$:

$$\frac{dT}{dr} = -\frac{Q}{4\pi k r^2}$$

(e) Since Q, k, and π are constant parameters in the steady-state condition, the temperature gradient is inversely proportional to the square of the distance:

$$\frac{dT}{dr} \propto \frac{1}{r^2}$$

Final Answer: $\propto \frac{1}{r^2}$

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:
Radioactive decay follows first-order kinetics, meaning the rate of disintegration depends on the number of active nuclei remaining. The half-life describes the fixed time required for half of any given quantity of a radioactive sample to undergo decay.
Solution:

(a) Let N_0 be the initial number of radioactive nuclei. When 20% of the substance has decayed, the number of surviving active nuclei is $N_1 = 0.80N_0$.

(b) When 80% of the substance has decayed, the number of surviving active nuclei drops to $N_2 = 0.20N_0$.

(c) According to the radioactive decay law, the ratio of surviving nuclei at these two states is given by $N_2 = N_1 e^{-\lambda t}$, where λ is the decay constant and t is the elapsed time interval.

(d) Substituting the expressions yields $0.20N_0 = 0.40N_0 e^{-\lambda t}$ divided by two, or simply $\frac{0.20}{0.80} = e^{-\lambda t}$, which simplifies to $\frac{1}{4} = \left(\frac{1}{2}\right)^2 = e^{-\lambda t}$.

(e) Since a reduction to one-half takes one half-life, a reduction to one-fourth corresponds exactly to two half-lives. Given a half-life of 20 minutes, the required time interval is $2 \times 20 = 40$ minutes.

Final Answer: 40 min

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:
The height of a liquid column in a glass capillary tube is governed by the balancing of surface tension forces against the weight of the lifted liquid. This balance is affected by changes in effective gravitational acceleration.

Solution:

(a) The standard formula for capillary ascent is $h = \frac{2T\cos\theta}{r\rho g}$, where g represents the effective acceleration due to gravity acting on the system.

(b) When the entire elevator apparatus accelerates downwards with a vertical linear acceleration $a = \frac{g}{3}$, an upward inertial pseudo-force acts on the liquid.

(c) The modified effective acceleration due to gravity inside the downward moving frame becomes $g_{\text{eff}} = g - a = g - \frac{g}{3} = \frac{2g}{3}$.

(d) Since surface tension T, contact angle θ, radius r, and density ρ remain unchanged, the new height h' varies inversely with the effective gravity.

(e) Setting up the inverse proportion yields $h' = h\left(\frac{g}{g_{\text{eff}}}\right) = h\left(\frac{g}{2g/3}\right) = \frac{3h}{2}$.

Final Answer: 3h$_2$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:

For large distances above the Earth surface, the gravitational force is variable rather than constant. The velocity of a falling body must be calculated using the law of conservation of mechanical energy with variable gravitational potential energy.

Solution:

(a) Let M be the mass of the Earth and R be its radius. The initial distance of the body from the center of the Earth is $r_1 = R + h = R + R = 2R$.

(b) The initial mechanical energy of the dropped body consists purely of gravitational potential energy, given by $E_i = -\frac{GMm}{2R}$.

(c) Upon striking the surface of the Earth, its distance from the center is $r_2 = R$, and its final mechanical energy is $E_f = -\frac{GMm}{R} + \frac{1}{2}mv^2$.

(d) Equating initial and final mechanical energies yields $-\frac{GMm}{2R} = -\frac{GMm}{R} + \frac{1}{2}mv^2$, which simplifies to $\frac{1}{2}mv^2 = \frac{GMm}{2R}$.

(e) Canceling mass m gives $v = \sqrt{\frac{GM}{R}}$. Since the surface gravitational acceleration is $g = \frac{GM}{R^2}$, substituting $GM = gR^2$ gives $v = \sqrt{gR}$, which is $\sqrt{gh}$ because $h = R$.

Final Answer: $\sqrt{gh}$

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:
In an alternating current series circuit containing a resistor and an inductor, the total opposition to alternating current is called impedance. The peak current is the ratio of the peak voltage to this circuit impedance.

Solution:

(a) The alternating voltage equation is given as $V = 200\sin(100t)$, establishing the peak voltage $V_0 = 200$ V and angular frequency $\omega = 100$ rad/s.

(b) The inductive reactance X_L of the inductor is calculated using the relationship $X_L = \omega L = 100 \times 0.4 = 40\ \Omega$.

(c) The total electrical impedance Z of the series combination is given by the formula $Z = \sqrt{R^2 + X_L^2}$.

(d) Substituting the resistance $R = 30\ \Omega$ and $X_L = 40\ \Omega$ yields $Z = \sqrt{30^2 + 40^2} = \sqrt{900 + 1600} = \sqrt{2500} = 50\ \Omega$.

(e) The peak current value I_0 flowing through the circuit is determined by $I_0 = \frac{V_0}{Z} = \frac{200}{50} = 4$ A.

Final Answer: 4 A

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:
The behavior and focal length of an optical lens immersed in a fluid medium depends on the ratio of the refractive index of the lens material to the refractive index of the surrounding liquid.

Solution:

(a) According to the lens maker formula, the focal length in air satisfies $\frac{1}{f_a} = \left(\frac{\mu_g}{\mu_a} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$. Since $\mu_g = 1.5$ and $\mu_a = 1.0$, this factor is positive.

(b) When immersed in the liquid, the modified formula becomes $\frac{1}{f_l} = \left(\frac{\mu_g}{\mu_l} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

(c) Substituting the values $\mu_g = 1.5$ and $\mu_l = 1.63$ reveals that the refractive ratio is $\frac{1.5}{1.63} < 1$, making the term $\left(\frac{\mu_g}{\mu_l} - 1\right)$ negative.

(d) The negative sign indicates that the nature of the lens is inverted, turning the originally converging convex lens into a diverging lens.

(e) Since the absolute numerical difference $|\frac{1.5}{1.63} - 1| = 0.08$ is much smaller than $|\frac{1.5}{1.0} - 1| = 0.5$, the focal length magnitude increases significantly, resulting in a longer focal length.

Final Answer: Diverging lens of longer focal length

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept:
Absolute thermodynamic temperature scales are linearly proportional to each other, anchored to a standard reference state. The standard reference state chosen internationally is the triple point of water, defined as 273.16 K.

Solution:

(a) Let T_{tr} be the absolute temperature of the triple point of water. For scale A, $T_{tr} = 200$ A, and for scale B, $T_{tr} = 350$ B.

(b) Since both scales are absolute thermodynamic scales, their temperature values are directly proportional to the Kelvin scale and to each other, meaning $T_A \propto T_B$.

(c) A given temperature measured on both scales satisfies the constant ratio relation $\frac{T_A}{T_{A,tr}} = \frac{T_B}{T_{B,tr}}$.

(d) Substituting the fixed values for the triple point into the ratio equation gives $\frac{T_A}{200} = \frac{T_B}{350}$.

(e) Solving for T_A yields $T_A = \frac{200}{350}T_B$, which reduces by dividing by fifty to the linear equation $T_A = \frac{4}{7}T_B$.

Final Answer: $T_A = \frac{4}{7}T_B$

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept:
Digital logic gates are characterized by truth tables that define output states for all binary input combinations. Analyzing output conditions reveals the underlying boolean operation.
Solution:

(a) Let us look at the provided output column Y for the input pairs (A, B).

(b) For inputs $A = 0$ and $B = 0$, the output is $Y = 1$. This indicates that a low state at both inputs produces a high output state.

(c) For inputs $A = 0$ and $B = 1$, the output drops to $Y = 0$.

(d) For inputs $A = 1$ and $B = 0$, the output remains at $Y = 0$.

(e) For inputs $A = 1$ and $B = 1$, the output remains at $Y = 0$.

(f) This logic output matches the boolean expression $Y = \overline{A + B}$, which represents an OR operation followed by an inverter, defining a NOR gate.

Final Answer: NOR

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept:
The flow of an ideal fluid from an open container is governed by Torricelli's law of efflux, derived from Bernoulli's equation for conservation of energy in fluid dynamics.
Solution:

(a) Consider a point on the top surface of the liquid and another point inside the escaping stream at the small hole.

(b) Since the top surface area is infinitely large compared to the hole area A, the downward velocity of the top surface is negligible.

(c) Applying Bernoulli's equation, the gauge pressure energy at depth h is entirely converted into kinetic energy of the emerging liquid.

(d) This yields the efflux speed equation $v = \sqrt{2gh}$, which depends solely on the depth below the free surface.

(e) The rate of volume flow, or discharge Q, escaping through the hole is the product of the cross-sectional area and velocity: $Q = Av = A\sqrt{2gh}$.

Final Answer: $\text{A}\sqrt{2gh}$

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:

Kinematic variables are related through calculus operations. Velocity is the first time-derivative of the displacement function, and acceleration is the first time-derivative of the velocity function.

Solution:

(a) The displacement function is given as $s = t^3 - 6t^2 + 9t + 4$. Differentiating once with respect to time yields velocity: $v = \frac{ds}{dt} = 3t^2 - 12t + 9$.

(b) Differentiating the velocity function with respect to time yields the acceleration function: $a = \frac{dv}{dt} = 6t - 12$.

(c) To find when acceleration becomes zero, set the expression to zero: $6t - 12 = 0$, which yields the time solution $t = 2$ seconds.

(d) Substitute this time value back into the velocity equation to find the corresponding velocity.

(e) This calculation yields $v(2) = 3(2)^2 - 12(2) + 9 = 12 - 24 + 9 = -3$ m/s.

Final Answer: -3 m/s

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept:

The magnetic field produced by a long straight current-carrying conductor is determined by the Biot-Savart law. The net field from multiple wires is found using vector addition, with directions given by the right-hand grip rule.

Solution:

(a) Let the two parallel wires be separated by a total distance d. The midway point lies at a perpendicular distance of $r = \frac{d}{2}$ from each wire.

(b) The magnitude of the magnetic field produced by a single long wire carrying current I at distance r is $B_1 = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi(d/2)} = \frac{\mu_0 I}{\pi d}$.

(c) Since the currents flow in opposite directions, applying the right-hand grip rule shows that the magnetic field vectors from both wires point in the same direction at the midway position.

(d) Because the two field vectors are parallel and point in the same direction, they add together constructively.

(e) The net magnetic field magnitude is $B_{\text{net}} = B_1 + B_2 = \frac{\mu_0 I}{\pi d} + \frac{\mu_0 I}{\pi d} = \frac{2\mu_0 I}{\pi d}$.

Final Answer: $2\mu_0 I_{\overline{\pi d}}$

Answer: (C)

Go Back to Question 20

Q21.

Solution

Concept:
The focal length of a glass lens is determined by the curvature of its refractive boundaries and the refractive index of its material relative to the surrounding medium, as described by the lens maker formula.

Solution:

(a) According to the lens maker formula, an equiconvex lens with a refractive index μ and boundary radii of curvature $R_1 = R$ and $R_2 = -R$ satisfies the equation $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{-1}{R}\right) = \frac{2(\mu-1)}{R}$.

(b) Cutting the lens into two equal symmetrical halves along its longitudinal principal axis does not modify the curvature of either external face.

(c) Each separate segment retains its original front radius of curvature $R_1 = R$ and its rear radius of curvature $R_2 = -R$.

(d) Since the geometric radii of curvature and the material refractive index remain unchanged, the power of each half is identical to the whole.

(e) Consequently, the focal length of each half remains exactly equal to f.

Final Answer: f

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept:
Adiabatic thermodynamic transitions for an ideal gas are governed by specific equations relating state variables such as pressure and absolute temperature via the adiabatic index γ.

Solution:

(a) For an ideal gas undergoing an adiabatic process, the relation between pressure P and absolute temperature T is given by $P^{1-\gamma}T^{\gamma}$ = constant, which translates to $P \propto T^{\frac{\gamma}{\gamma-1}}$.

(b) For a standard diatomic gas molecule, the ratio of specific heats is defined as $\gamma = 1.4 = \frac{7}{5}$.

(c) Substituting this index value into the theoretical exponent yields $P \propto T^{\frac{1.4}{1.4-1}} = T^{\frac{1.4}{0.4}} = T^{3.5}$.

(d) However, the problem statement states that the pressure is directly proportional to the cube of the absolute temperature, meaning $P \propto T^3$.

(e) Matching the observed exponent to the formula requires $\frac{\gamma}{\gamma-1} = 3$, which simplifies to $\gamma = 1.5$. This indicates that the internal degrees of freedom have changed, meaning the gas behaves as a monoatomic structure instead under these specific conditions.

Final Answer: The gas is behaving as a monoatomic structure instead

Answer: (D)

Go Back to Question 22

Q23.

Solution

Concept:
Bohr's atomic quantization postulate restricts electron orbits to states where the orbital angular momentum matches integer multiples of Dirac's constant. This links the orbit geometry directly to the de Broglie wavelength.

Solution:

(a) Bohr's angular momentum quantization condition is expressed mathematically as $mvr_n = \frac{nh}{2\pi}$, which can be rewritten as $2\pi r_n = n\left(\frac{h}{mv}\right)$.

(b) According to the de Broglie hypothesis, the wavelength associated with a moving electron is $\lambda = \frac{h}{mv}$. Substituting this yields $2\pi r_n = n\lambda$.

(c) For a hydrogenic atom, the radius of the n-th stationary circular orbit scales quadratically with the quantum number such that $r_n = n^2 a_0$.

(d) The problem specifies the second excited state, which corresponds to the principal quantum number $n = 3$. The radius is therefore $r_3 = 3^2 a_0 = 9a_0$.

(e) Substituting these values into the circumference relation gives $2\pi(9a_0) = 3\lambda$. Solving for the wavelength yields $\lambda = \frac{18\pi a_0}{3} = 6\pi a_0$.

Final Answer: $6\pi a_0$

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept:
The natural time period of a simple harmonic oscillator depends on the mass of the block and the total effective stiffness of the attached spring combination.
Solution:

(a) Let the mass block m shift horizontally by a small linear displacement x toward the right-hand side.

(b) This horizontal displacement compresses the right spring by a distance x, creating a leftward restoring force equal to kx.

(c) Simultaneously, this movement elongates the left spring by the same distance x, creating an additional leftward restoring force equal to kx.

(d) The net restoring force acting on the mass block is the sum of these two parallel forces: $F_{\text{net}} = -kx - kx = -2kx$.

(e) Comparing this to the standard spring law equation $F = -k_{\text{eff}}x$ reveals the effective system stiffness is $k_{\text{eff}} = 2k$. The system period is therefore $T = 2\pi\sqrt{\frac{m}{k_{\text{eff}}}} = 2\pi\sqrt{\frac{m}{2k}}$.

Final Answer: $2\pi\sqrt{\frac{m}{2k}}$

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept:
The mechanical work done by a constant vector force during a spatial translation is calculated as the scalar dot product of the force vector and the net linear displacement vector.
Solution:

(a) The constant vector force acting on the particle is given by the expression $\vec{F} = 3\hat{i} + 4\hat{j}$ N.

(b) The spatial translation of the particle shifts its position from $\vec{r}_1 = 2\hat{i} + \hat{j}$ m to $\vec{r}_2 = 4\hat{i} + 5\hat{j}$ m.

(c) The net linear displacement vector $\Delta\vec{r}$ is calculated as $\vec{r}_2 - \vec{r}_1 = (4-2)\hat{i} + (5-1)\hat{j} = 2\hat{i} + 4\hat{j}$ m.

(d) The total mechanical work done is determined by evaluating the dot product: $W = \vec{F} \cdot \Delta\vec{r} = (3\hat{i} + 4\hat{j}) \cdot (2\hat{i} + 4\hat{j})$.

(e) Computing the components gives $W = (3 \times 2) + (4 \times 4) = 6 + 16 = 22$ J.

Final Answer: 22 J

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:
Direct current circuit networks containing combinations of parallel and series resistors can be analyzed by calculating the total equivalent resistance to determine branch currents.

Solution:

(a) Analyze the parallel branch containing the 3 Ω and 6 Ω resistors. Their equivalent resistance is $R_p = \frac{3\times6}{3+6} = \frac{18}{9} = 2\ \Omega$.

(b) This parallel combination is connected in series with the remaining 4 Ω resistor, making the total equivalent resistance of the network $R_{\text{eq}} = 4 + 2 = 6\ \Omega$.

(c) The total electrical current delivered by the ideal 12 V battery source is $I_{\text{total}} = \frac{E}{R_{\text{eq}}} = \frac{12}{6} = 2$ A.

(d) The potential drop across the parallel section is calculated using Ohm's law: $V_p = I_{\text{total}} \times R_p = 2\text{ A} \times 2\ \Omega = 4$ V.

(e) The current passing through the specific 6 Ω branch resistor is the branch voltage divided by its resistance: $I_6 = \frac{V_p}{6} = \frac{4}{6} = 0.67$ A.

Final Answer: 0.67 A

Answer: (D)

Go Back to Question 26

Q27.

Solution

Concept:
The angular magnification of a standard astronomical telescope configured in normal adjustment is determined by the ratio of the focal length of the objective lens to that of the eyepiece lens.
Solution:

(a) Normal adjustment signifies that the telescope is focused to form the final virtual image at an infinite distance, which minimizes eye strain for the observer.

(b) Under these conditions, the parallel rays from a distant target focus at the focal point of the objective lens, which coincides with the focal point of the eyepiece.

(c) The mathematical formula for angular magnification under normal adjustment is given by $m = \frac{f_o}{f_e}$.

(d) The problem states the objective focal length is $f_o = 140$ cm and the eyepiece focal length is $f_e = 5.0$ cm.

(e) Substituting these values into the ratio gives $m = \frac{140}{5.0} = 28$.

Final Answer: 28

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:
The first law of thermodynamics states that the net heat absorbed during a cyclic process equals the net mechanical work performed, which corresponds to the area enclosed by the loop on a pressure-volume plot.

Solution:

(a) For any closed thermodynamic cycle, the net change in internal energy is zero because it is a state function: $\Delta U = 0$.

(b) According to the first law of thermodynamics, the total net heat absorbed matches the work performed: $Q_{net} = W_{net}$.

(c) The net mechanical work performed equals the geometric area enclosed within the closed loop on the $P - V$ diagram.

(d) Although the path is described as a circle of radius R, the coordinates of the two axes represent entirely different physical quantities with different units.

(e) Consequently, calculating a geometric circle area as πR^2 is physically meaningless without defining the scale factors of the pressure and volume axes. The value depends entirely on the chosen coordinate scaling.

Final Answer: Dependent on the scales used on the P and V axes

Answer: (C)

Go Back to Question 28

Solution

Concept:
The depletion region at a p-n semiconductor junction forms due to the diffusion of mobile majority charge carriers across the interface, creating an internal potential barrier.
Solution:

(a) In an isolated p-n junction, majority holes from the p-type side and electrons from the n-type side diffuse across the boundary, leaving behind fixed uncompensated donor and acceptor ions.

(b) These immobile ions create an internal space-charge field and a built-in potential barrier that opposes further carrier diffusion.

(c) Applying an external forward-bias voltage means connecting the positive terminal to the p-type side and the negative terminal to the n-type side.

(d) This external electric field directly opposes the built-in internal potential barrier at the junction interface.

(e) This reduction reduces the repulsive force on the majority carriers, causing the width of the depletion region to decrease and allowing current to flow easily.

Final Answer: Decreases

Answer: (B)

Go Back to Question 29

Q29.

Solution

Concept:

Assuming constant temperature, the behavior of an rising air bubble is governed by Boyle's ideal gas law, where the internal volume varies inversely with the surrounding hydrostatic pressure.

Solution:

(a) Let the total depth of the lake be d. The absolute pressure acting on the air bubble at the bottom of the lake is $P_1 = P_0 + \rho g d$.

(b) The problem states the atmospheric pressure matches a water column of height H, so $P_0 = \rho g H$. Substituting this gives $P_1 = \rho g H + \rho g d = \rho g(H + d)$.

(c) At the surface of the lake, the hydrostatic pressure is zero, so the absolute pressure acting on the bubble is simply atmospheric pressure: $P_2 = P_0 = \rho g H$.

(d) As the bubble rises, its radius doubles from R to $2R$. Since volume scales with the cube of the radius, the volume increases by a factor of $2^3 = 8$, meaning $V_2 = 8V_1$.

(e) Applying Boyle's law $P_1V_1 = P_2V_2$ gives $\rho g(H + d)V_1 = \rho g H(8V_1)$. Canceling shared terms leaves $H + d = 8H$, which simplifies to $d = 7H$.

Final Answer: 7H

Answer: (C)

Go Back to Question 30

Q30.

Solution

Concept:
The total mechanical energy of a bound orbiting particle is the scalar sum of its kinetic energy and its gravitational or electrostatic potential energy. The relationship between these energy types is governed by the centripetal force equation.
Solution:

(a) The particle moves in a stable circular trajectory under a central centripetal force of magnitude $F = \frac{k}{r^2}$.

(b) Equating this conservative force to the standard mechanical expression for centripetal force yields $\frac{mv^2}{r} = \frac{k}{r^2}$, which simplifies directly to $mv^2 = \frac{k}{r}$.

(c) The kinetic energy K of the orbiting particle is defined as $\frac{1}{2}mv^2$. Substituting the force relation gives $K = \frac{k}{2r}$.

(d) The potential energy U is found by integrating the conservative force function from an infinite reference distance: $U = -\int_{\infty}^{r} \left(-\frac{k}{r'^2}\right) dr' = -\frac{k}{r}$.

(e) The total mechanical energy E is the sum of these components: $E = K + U = \frac{k}{2r} - \frac{k}{r} = -\frac{k}{2r}$.

Final Answer: -k$\overline{2r}$

Answer: (A)

Go Back to Question 31

Q31.

Solution

Concept:
The electrostatic potential energy stored in a charged capacitor depends on its configuration parameters and its electrical connection status, which determines whether voltage or charge remains constant.

Solution:

(a) The variable capacitor is permanently connected across a constant direct current voltage source, meaning the potential difference V across its plates remains constant.

(b) The initial electrostatic energy E_i stored in the device with initial capacitance C is given by the standard equation $E_i = \frac{1}{2}CV^2$.

(c) The system configuration changes slowly, doubling the capacitance parameter to a final value of $C' = 2C$.

(d) The final electrostatic energy E_f stored in the modified device is calculated as $E_f = \frac{1}{2}C'V^2 = \frac{1}{2}(2C)V^2 = CV^2$.

(e) The net change in stored electrostatic energy ΔE is the difference between the final and initial states: $\Delta E = E_f - E_i = CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$.

Final Answer: $1_{\overline{2CV^2}}$

Answer: (A)

Go Back to Question 32

Q32.

Solution

Concept:
The distribution of intensity in an optical interference pattern depends on the principle of linear superposition of coherent wave amplitudes, which creates alternating maximum and minimum regions.

Solution:

(a) The intensities of the two individual mixing coherent light waves are given as $I_1 = I$ and $I_2 = 4I$.

(b) The electric field wave amplitude is directly proportional to the square root of intensity, yielding $A_1 = \sqrt{I}$ and $A_2 = \sqrt{4I} = 2\sqrt{I}$.

(c) Maximum intensity I_{max} occurs during fully constructive interference, where amplitudes add: $I_{max} = (A_1 + A_2)^2 = (\sqrt{I} + 2\sqrt{I})^2 = (3\sqrt{I})^2 = 9I$.

(d) Minimum intensity I_{min} occurs during fully destructive interference, where amplitudes subtract: $I_{min} = (A_2 - A_1)^2 = (2\sqrt{I} - \sqrt{I})^2 = (\sqrt{I})^2 = I$.

(e) The numeric ratio of maximum to minimum intensity observed within the fringe boundaries is calculated as $\frac{I_{max}}{I_{min}} = \frac{9I}{I} = \frac{9}{1}$.

Final Answer: 9:1

Answer: (B)

Go Back to Question 33

Q33.

Solution

Concept:
Thermal mixing calculations inside an isolated system are governed by the principle of calorimetry, which states that total heat lost by warm components must equal total heat gained by cold components.

Solution:

(a) Let us evaluate the thermal energy available from cooling the liquid water sample from its initial temperature down to the freezing point: $Q_{\text{lost}} = mw \cdot s \cdot \Delta T = 50 \cdot 1 \cdot (80 - 0) = 4000$ calories.

(b) Now compute the thermal energy required to completely melt the entire ice sample at its freezing point: $Q_{\text{melt}} = m_{\text{ice}} \cdot L_f = 50 \cdot 80 = 4000$ calories.

(c) The thermal energy released by cooling the liquid water to 0°C matches the energy needed to melt all the ice.

(d) This exact matching means all the ice melts into liquid water at the freezing point, and no extra energy remains to raise the temperature.

(e) Consequently, the entire system reaches a stable state of thermal equilibrium consisting entirely of liquid water at a final temperature of 0°C.

Final Answer: 0°C

Answer: (C)

Go Back to Question 34

Q34.

Solution

Concept:
Nuclear stability is measured by the binding energy per nucleon, which represents the average energy needed to separate a single nucleon from a nucleus. This value varies with mass number.
Solution:

(a) Plotting the average binding energy per nucleon against mass number A produces a characteristic curve that reflects the balance between nuclear forces and electrostatic repulsion.

(b) Light nuclei with low mass numbers have a relatively low binding energy per nucleon because a large fraction of their nucleons reside on the nuclear surface.

(c) The curve rises rapidly and reaches its peak in the intermediate mass region, where nuclear packing is most efficient and stable.

(d) The absolute maximum occurs near Iron-56 ($A = 56$), where the binding energy reaches approximately 8.8 MeV per nucleon.

(e) This peak plateau is generally located within the mass number interval $40 < A < 70$, beyond which heavy electrostatic repulsion causes the curve to decrease.

Final Answer: 40 < A < 70

Answer: (B)

Go Back to Question 35

Q35.

Solution

Concept:
Fluid droplets minimize their surface potential energy by reducing their total exposed surface area. When small drops coalesce, the total surface area decreases, releasing energy.
Solution:

(a) Let two liquid mercury droplets, each of radius R, combine to form a single large droplet of radius R'.

(b) Since the fluid volume is conserved during this amalgamation, $\frac{4}{3}\pi R'^3 = 2 \cdot \left(\frac{4}{3}\pi R^3\right)$, which simplifies to $R' = 2^{1/3}R$.

(c) The initial combined surface area of the two separate small droplets is $A_i = 2 \cdot (4\pi R^2) = 8\pi R^2$.

(d) The final surface area of the single large coalesced droplet is $A_f = 4\pi R'^2 = 4\pi(2^{1/3}R)^2 = 4\pi 2^{2/3} R^2$.

(e) The net mechanical energy released matches the reduction in surface potential energy: $\Delta E = T(A_i - A_f) = T(8\pi R^2 - 4\pi 2^{2/3} R^2) = 4\pi R^2 T(2 - 2^{2/3})$.

Final Answer: $4\pi R^2 T(2 - 2^{2/3})$

Answer: (A)

Go Back to Question 36

Q36.

Solution

Concept:
A projectile launched with an initial velocity vector can be analyzed by separating its motion into independent horizontal and vertical components that operate simultaneously.
Solution:

(a) The initial velocity vector is given as $\vec{v} = 6\hat{i} + 8\hat{j}$ m/s, establishing the horizontal velocity component $u_x = 6$ m/s and the vertical component $u_y = 8$ m/s.

(b) The total time of flight T depends entirely on the vertical motion and gravitational acceleration: $T = \frac{2u_y}{g}$.

(c) Substituting the values $u_y = 8$ m/s and $g = 10$ m/s^2 yields a total flight duration of $T = \frac{2\times8}{10} = 1.6$ seconds.

(d) The horizontal range R is the total horizontal distance traveled during this flight time.

(e) Since air resistance is neglected, horizontal velocity remains constant, yielding $R = u_x \cdot T =$ 6 m/s $\times$ 1.6 s = 9.6 meters.

Final Answer: 9.6 m

Answer: (B)

Go Back to Question 37

Q37.

Solution

Concept:
A moving electric charge creates an effective conventional current path. For circular motion, this current loop produces an effective magnetic dipole moment proportional to the loop area.
Solution:

(a) An electron with charge magnitude e moves at a constant speed v along a circular orbit of radius r.

(b) The orbital period T required to complete one full revolution is the circumference divided by the speed: $T = \frac{2\pi r}{v}$.

(c) The effective conventional current I created by this circulating charge is the charge divided by the period: $I = \frac{e}{T} = \frac{ev}{2\pi r}$.

(d) The magnetic dipole moment M produced by a current loop is the product of the current and the enclosed area: $M = I \cdot A$.

(e) The enclosed area is $A = \pi r^2$. Substituting the current expression yields $M = \left(\frac{ev}{2\pi r}\right) \cdot (\pi r^2) = \frac{1}{2} evr$.

Final Answer: $1\frac{}{2evr}$

Answer: (B)

Go Back to Question 38

Q38.

Solution

Concept:
The displacement method is a technique used to determine the focal length of a thin convex lens by measuring how much it must be moved between two distinct imaging positions.
Solution:

(a) Let D be the fixed distance between an object and a screen. A real image forms on the screen if the lens focal length satisfies $f \leq \frac{D}{4}$.

(b) By the principle of optical reversibility, there are two distinct lens positions that project a sharp image onto the screen.

(c) For the first position, let the object distance be u and the image distance be v, so that $u + v = D$. For the second position, these distances swap.

(d) The distance between these two valid lens positions is given as $x = v - u$.

(e) Solving this system of equations yields $v = \frac{D+x}{2}$ and $u = \frac{D-x}{2}$. Substituting these into the standard lens equation gives $f = \frac{uv}{u+v} = \frac{D^2-x^2}{4D}$.

Final Answer: $D^2 - x^2 \frac{}{4D}$

Answer: (A)

Go Back to Question 39

Q39.

Solution

Concept:
The thermal efficiency of an ideal Carnot heat engine represents the fraction of input heat converted into net mechanical work, determined by the operating absolute temperatures.
Solution:

(a) First convert the given Celsius temperatures of the heat reservoirs into absolute Kelvin temperatures.

(b) The high-temperature source is $T_1 = 227°\text{C} + 273.15 = 500$ K, and the low-temperature sink is $T_2 = 127°\text{C} + 273.15 = 400$ K.

(c) The thermodynamic efficiency η of a Carnot engine is calculated as $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{500} = 1 - 0.80 = 0.20$.

(d) Efficiency is also defined as the ratio of net mechanical work performed to the input heat absorbed: $\eta = \frac{W}{Q_1}$.

(e) Substituting the input heat $Q_1 = 6 \times 10^4$ cal yields the net mechanical work: $W = \eta \cdot Q_1 = 0.20 \times (6 \times 10^4) = 1.2 \times 10^4$ calories.

Final Answer: 1.2×10^4 cal

Answer: (A)

Go Back to Question 40

Q40.

Solution

Concept:
The de Broglie wavelength of a material particle depends on its momentum, while the wavelength of a photon relates directly to its electromagnetic energy. Comparing these expressions reveals how their scale ratio scales with energy.

Solution:

(a) The non-relativistic kinetic energy E of a fast-moving proton of mass m is related to its mechanical momentum by $p = \sqrt{2mE}$.

(b) According to the de Broglie relationship, the wavelength associated with this proton is given by $\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$. This demonstrates that $\lambda_1 \propto E^{-1/2}$.

(c) For a photon carrying the exact same energy level E, the relationship is determined by the Planck-Einstein equation $E = \frac{hc}{\lambda_2}$.

(d) Rearranging this electromagnetic equation to solve for the photon wavelength yields $\lambda_2 = \frac{hc}{E}$, which shows that $\lambda_2 \propto E^{-1}$.

(e) Taking the ratio of these two expressions gives $\frac{\lambda_1}{\lambda_2} = \left(\frac{h}{\sqrt{2mE}}\right) \cdot \left(\frac{E}{hc}\right) = \frac{1}{c\sqrt{2m}} \cdot \frac{E}{\sqrt{E}} = \frac{\sqrt{E}}{c\sqrt{2m}}$. Thus, the final ratio is proportional to $E^{1/2}$.

Final Answer: $\mathrm{E}^{1/2}$

Answer: (A)

Go Back to Question 41

Q41.

Solution

Concept:
A heavy hanging vertical rod undergoes mechanical strain due to the distributed force of its own weight. The total deformation is found by integrating the stretching of each infinitesimal segment.
Solution:

(a) Consider a uniform vertical rod of mass M, cross-sectional area A, and total length L suspended securely from its top-most boundary.

(b) Let us analyze an infinitesimal element of length dx located at a distance x measured from the free bottom end of the rod.

(c) The tension force $T(x)$ pulling down on this specific cross-section is equal to the weight of the segment hanging below it: $T(x) = \left(\frac{M}{L}\right) xg$.

(d) Using the definition of Young's modulus, the elongation $d\delta$ of this small segment is expressed as $d\delta = \frac{T(x)dx}{AY} = \frac{Mgxdx}{ALY}$.

(e) Integrating this expression from $x = 0$ to $x = L$ yields the total elongation: $\delta = \int_0^L \frac{Mgxdx}{ALY} = \frac{MgL^2}{2ALY} = \frac{MgL}{2AY}$. Substituting mass in terms of density $M = \rho AL$ yields $\delta = \frac{\rho g L^2}{2Y}$.

Final Answer: $\rho g L^2 \frac{}{2Y}$

Answer: (A)

Go Back to Question 42

Q42.

Solution

Concept:
To induce motion for a stationary block on a rough surface, the horizontal component of the applied force must match or exceed the maximum threshold value of static friction.
Solution:

(a) Let an external pulling force P be applied to a block of mass M at an angle θ measured relative to the flat horizontal plain.

(b) Resolving this force vector gives a horizontal pulling component $P\cos\theta$ and a vertical lifting component $P\sin\theta$.

(c) Balancing the forces acting along the vertical axis yields the normal contact force: $N + P\sin\theta = Mg$, which gives $N = Mg - P\sin\theta$.

(d) The maximum available threshold force of static friction opposing impending slide motion is given by $f_s = \mu_s N = \mu_s(Mg - P\sin\theta)$.

(e) To budge the block, the horizontal pushing force must equal this static friction threshold: $P\cos\theta = \mu_s(Mg - P\sin\theta)$. Rearranging terms to solve for P gives $P = \frac{\mu_s Mg}{\cos\theta+\mu_s\sin\theta}$.

Final Answer: $\mu_s Mg\frac{}{\cos\theta+\mu_s\sin\theta}$

Answer: (A)

Go Back to Question 43

Q43.

Solution

Concept:
The spatial direction of the infinitesimal magnetic field vector produced by a localized current-carrying element is uniquely determined by the Biot-Savart law cross product.
Solution:

(a) According to the fundamental Biot-Savart law, the differential magnetic field vector $d\vec{B}$ generated by a current element is proportional to $d\vec{l} \times \vec{r}$.

(b) The problem states that the current element is positioned at the coordinate origin, directed as $d\vec{l} = \Delta x\hat{i}$.

(c) The target observation point is located on the positive y-axis at $(0, y, 0)$, defining its position vector as $\vec{r} = y\hat{j}$.

(d) To find the spatial orientation of the field vector, evaluate the vector cross product of these two coordinate axes: $\hat{i} \times \hat{j}$.

(e) Following the standard right-hand rule for orthogonal Cartesian systems, the cross product simplifies directly to $\hat{i} \times \hat{j} = +\hat{k}$. Thus, the field vector is directed along $+\hat{k}$.

Final Answer: +

Answer: (C)

Go Back to Question 44

Q44.

Solution

Concept:
The geometric width and central peak intensity of a single-slit Fraunhofer diffraction pattern are governed by wave interference constraints across the aperture width.
Solution:

(a) The angular half-width of the central maximum in a single-slit diffraction setup is given by the formula $\theta = \frac{\lambda}{a}$, where a is the slit width.

(b) When the width of the slit is halved ($a' = \frac{a}{2}$), the angular width becomes $\theta' = \frac{\lambda}{(a/2)} = 2\theta$, meaning the central maximum width doubles.

(c) The peak electric field amplitude at the center of the screen is directly proportional to the area or width of the slit, so $E_0 \propto a$.

(d) Halving the slit width reduces the central wave field amplitude by half: $E_0' = \frac{E_0}{2}$.

(e) Since light intensity is proportional to the square of the field amplitude ($I \propto E_0^2$), the new peak intensity becomes $I' = \left(\frac{E_0}{2}\right)^2 = \frac{I_0}{4}$, which is one-fourth.

Final Answer: Doubled and its peak intensity becomes one-fourth

Answer: (C)

Go Back to Question 45

Q45.

Solution

Concept:
According to the kinetic theory of gases, the root-mean-square velocity of ideal gas molecules reflects their average translational kinetic energy, which depends strictly on absolute temperature.
Solution:

(a) The theoretical expression for the root-mean-square speed of an ideal gas sample is given by $v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$, where M is the molar mass.

(b) This mathematical formula reveals that for a fixed gas species, the speed is directly proportional to the square root of its absolute temperature: $v_{\text{rms}} \propto \sqrt{T}$.

(c) The problem states that the absolute temperature of the system is raised from an initial state T to a final state of $4T$.

(d) Since the container volume is held constant, the molar mass remains unchanged. We can set up the ratio: $v'_{\text{rms}} = \sqrt{\frac{3R(4T)}{M}}$.

(e) Factoring out the numeric constant simplifies the expression to $v'_{\text{rms}} = 2\sqrt{\frac{3RT}{M}} = 2v_{\text{rms}}$. Thus, the new speed is exactly double.

Final Answer: 2v_{rms}

Answer: (A)

Go Back to Question 46

Q46.

Solution

Concept:

A Zener diode is a heavily doped semiconductor device engineered to operate reliably in its reverse breakdown region without sustaining structural damage.

Solution:

(a) When a standard p-n junction diode is reverse-biased, it permits a negligible leakage current until it reaches a destructive breakdown voltage.

(b) In contrast, a Zener diode possesses a highly controlled, sharp reverse breakdown voltage characteristic known as the Zener voltage.

(c) Once the applied reverse voltage exceeds this threshold, the diode enters breakdown, allowing current to rise dramatically while keeping the voltage across it virtually constant.

(d) This unique ability to maintain a steady voltage drop despite fluctuations in current makes it ideal for parallel shunt configurations.

(e) Therefore, the primary application of a Zener diode in electronic circuitry is providing reliable shunt voltage regulation against input variations.

Final Answer: Voltage regulation

Answer: (C)

Go Back to Question 47

Q47.

Solution

Concept:
The laminar flow rate of a viscous fluid through a cylindrical conduit is quantified by Poiseuille's law, which states that flow depends strongly on the internal radius.
Solution:

(a) Poiseuille's equation states that the volume flow rate Q of a fluid with viscosity η through a pipe of length l is $Q = \frac{\pi P r^4}{8\eta l}$.

(b) This formula demonstrates that under a fixed pressure difference P and length l, the volume flow rate scales with the fourth power of the radius: $Q \propto r^4$.

(c) The problem specifies that the internal radius of the pipe is reduced to half its original value, meaning $r' = \frac{r}{2}$.

(d) Substituting this new radius parameter into the proportional relationship yields the modified flow rate: $Q' \propto \left(\frac{r}{2}\right)^4 = \frac{r^4}{16}$.

(e) Comparing the two states shows that the volume of liquid escaping per second decreases by a factor of $\frac{Q'}{Q} = \frac{1}{16}$.

Final Answer: 1_{16}

Answer: (D)

Go Back to Question 48

Q48.

Solution

Concept:
In a perfectly inelastic collision, momentum is conserved but mechanical kinetic energy is lost due to internal deformation and heat generation as the bodies stick together.
Solution:

(a) Let a moving bullet of mass m with velocity v collide with a stationary block of mass M. The initial kinetic energy of the system is $K_i = \frac{1}{2}mv^2$.

(b) Applying the law of conservation of linear momentum yields $mv = (M+m)V_{\text{final}}$, where $V_{\text{final}} = \frac{mv}{M+m}$ is their shared velocity.

(c) The final kinetic energy stored in the combined mass system is calculated as $K_f = \frac{1}{2}(M+m)V_{\text{final}}^2 = \frac{1}{2}(M+m)\left(\frac{mv}{M+m}\right)^2 = \frac{1}{2}\frac{m^2v^2}{M+m}$.

(d) The net loss of kinetic energy during impact is $\Delta K = K_i - K_f = \frac{1}{2}mv^2\left(1 - \frac{m}{M+m}\right) = \frac{1}{2}mv^2\left(\frac{M}{M+m}\right)$.

(e) The fractional loss of mechanical energy is the ratio of this loss to the initial energy: $\frac{\Delta K}{K_i} = \frac{\frac{1}{2}mv^2[M/(M+m)]}{\frac{1}{2}mv^2} = \frac{M}{M+m}$.

Final Answer: M$\overline{M+m}$

Answer: (B)

Go Back to Question 49

Q49.

Solution

Concept:
Gauss's law states that the net electric flux passing through any closed boundary equals the total enclosed net charge divided by the permittivity of free space.
Solution:

(a) Consider a straight cylinder of radius R and length L, with a point charge q positioned at the exact geometric center of one circular flat face.

(b) To exploit system symmetry, construct an identical imaginary cylinder of equal dimensions joined face-to-face at the charge location.

(c) This combined structure forms a single symmetric closed Gaussian surface that completely encloses the point charge q at its center.

(d) According to Gauss's law, the total electric flux emerging through this entire combined surface is $\Phi_{\text{total}} = \frac{q}{\varepsilon_0}$.

(e) By symmetry, exactly half of this total flux passes through each of the two symmetric cylinders, meaning the flux through one cylinder is $\Phi_{\text{cyl}} = \frac{q}{2\varepsilon_0}$. Since field lines from a point charge on the flat face are parallel to it, the flux through that face is zero, meaning all of this flux passes through the curved surface.

Final Answer: $\mathrm{q}_{\overline{2\varepsilon_0}}$

Answer: (B)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	D	3	D	4	A	5	B
6	A	7	B	8	C	9	C	10	C
11	B	12	B	13	B	14	A	15	C
16	A	17	B	18	B	19	A	20	C
21	A	22	D	23	B	24	B	25	B
26	D	27	B	28	C	29	B	30	C
31	A	32	A	33	B	34	C	35	B
36	A	37	B	38	B	39	A	40	A
41	A	42	A	43	A	44	C	45	C
46	A	47	C	48	D	49	B	50	B