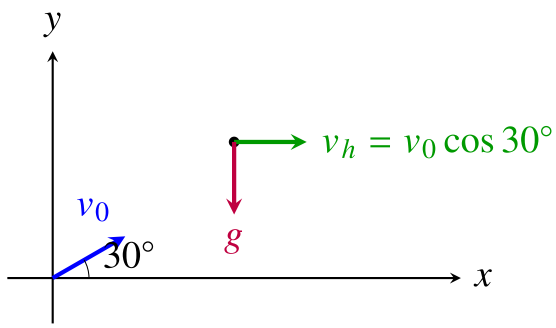
AIIMS Paramedical Physics Sample Paper – 12

Duration: 30 Minutes **Maximum Marks: 30**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct Answer), modelled on the Physics portion of **AIIMS Paramedical** entrance.
- Each correct answer carries **+1 mark**. A penalty of $-\frac{1}{3}$ **mark** is deducted for each incorrect answer. Unattempted questions carry **0 marks** (no negative marking).
- Only **one** option is correct. Choose carefully.
- Syllabus level:**Class 11 & 12 NCERT Physics**
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Q1. A projectile is fired from the ground with an initial velocity of 20 m/s at an angle of 30° with the horizontal. If the acceleration due to gravity is 10 m/s^2, the radius of curvature of its trajectory at the highest point is:



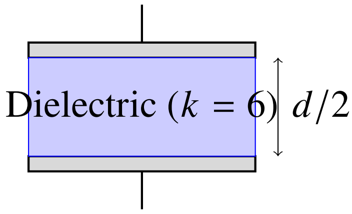
(A) 30 m

(B) 40 m

(C) 15 m

(D) 20 m

Q2. A parallel-plate capacitor with air between the plates has a capacitance of 8 μF. What will be the capacitance if the distance between the plates is reduced by half, and the space between them is completely filled with a medium of dielectric constant $k = 6$?



(A) 24 μF

(B) 48 μF

(C) 96 μF

(D) 12 μF

Q3. In a photoelectric effect experiment, when light of wavelength λ is incident on a photosensitive surface, the stopping potential is V. If the wavelength is changed to 2λ, the stopping potential becomes $V/3$. The threshold wavelength for this surface is:

(A) 4λ

(B) 3λ

(C) 1.5λ

(D) 2.5λ

Q4. An ideal gas undergoes a thermodynamic process where its pressure P varies with volume V as $P = k/V^2$, where k is a positive constant. If the gas expands from an initial volume V_0 to a final volume $2V_0$, the work done by the gas is:

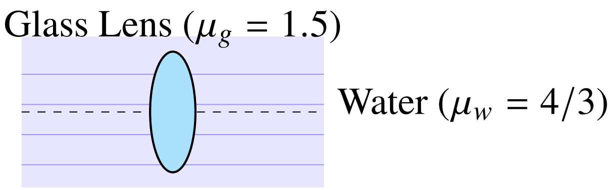
(A) $\frac{k}{V_0}$

(B) $\frac{k}{2V_0}$

(C) $\frac{2k}{V_0}$

(D) $k \ln 2$

Q5. A convex lens of focal length 20 cm in air is immersed completely in water ($\mu_w = 4/3$). If the refractive index of the glass of the lens is $\mu_g = 1.5$, its focal length in water will become:



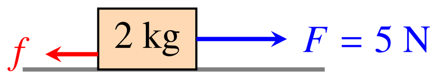
(A) 40 cm

(B) 80 cm

(C) 20 cm

(D) 10 cm

Q6. A block of mass 2 kg is placed on a rough horizontal surface having a coefficient of static friction $\mu_s = 0.4$ and kinetic friction $\mu_k = 0.3$. A horizontal force of 5 N is applied to the block. The frictional force acting on the block is (Take $g = 10$ m/s^2):



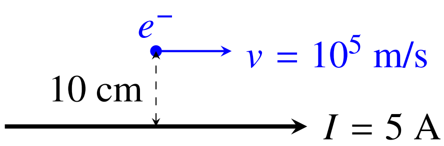
(A) 6 N

(B) 8 N

(C) 5 N

(D) 0 N

Q7. A long straight wire carries a current of 5 A. An electron is moving parallel to the wire at a distance of 10 cm from it, with a velocity of 10^5 m/s in the direction of the current. The magnitude of the magnetic force experienced by the electron is:



(A) 1.6×10^{-19} N

(B) 3.2×10^{-19} N

(C) 1.6×10^{-20} N

(D) 0 N

Q8. In a Young's double-slit experiment, the slit separation is doubled and the distance between the slits and the screen is halved. The original fringe width w changes to a new fringe width w'. The ratio w'/w is:

(A) 1 : 4

(B) 4 : 1

(C) 1 : 2

(D) 1 : 1

Q9. The half-life of a radioactive substance is 20 minutes. The time interval between the stages of 33% decay and 67% decay for this substance is approximately:

(A) 40 minutes

(B) 10 minutes

(C) 20 minutes

(D) 30 minutes

Q10. A body of mass 0.5 kg travels in a straight line with a velocity $v = ax^{3/2}$ where $a = 5\ \mathrm{m^{-1/2}s^{-1}}$. The work done by the net force during its displacement from $x = 0$ to $x = 2$ m is:

(A) 50 J

(B) 10 J

(C) 25 J

(D) 100 J

Q11. Five identical conducting plates each of area A are fixed parallel to each other with equidistant spacing d. The plates are connected alternately to the terminals of a battery of potential difference V. The equivalent capacitance of the system is:

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

(B) $\frac{2\varepsilon_0 A}{d}$

(C) $\frac{4\varepsilon_0 A}{d}$

(D) $\frac{5\varepsilon_0 A}{d}$

Q12. Two absolute scales of temperature 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) $T_A = \frac{2}{3}T_B$

Q13. A particle executes simple harmonic motion along a straight line. If its kinetic energy is three times its potential energy at a certain displacement x from the mean position, then the ratio of x to the amplitude A of the motion is:

(A) $1 : 2$

(B) $1 : \sqrt{2}$

(C) $\sqrt{3} : 2$

(D) $1 : 4$

Q14. The wavelength of the first line of the Lyman series for a hydrogen atom is λ. The wavelength of the first line of the Balmer series for the same atom will be:

(A) $\frac{5}{27}\lambda$

(B) $\frac{27}{5}\lambda$

(C) $\frac{9}{4}\lambda$

(D) $\frac{4}{9}\lambda$

Q15. A circular loop of radius R carries a current I. The magnetic field at the center of the loop is B_0. At what distance along the axis from the center of the loop will the magnetic field drop to $B_0/8$?

(A) $R\sqrt{3}$

(B) $3R$

(C) $R\sqrt{2}$

(D) $2R$

Q16. A mass m attached to a light spring oscillates horizontally with a frequency f. If the mass is increased to $4m$, the new frequency of horizontal oscillation becomes:

(A) $2f$

(B) $f/2$

(C) $4f$

(D) $f/4$

Q17. In a meter bridge experiment, the null point is obtained at a distance of 40 cm from the left end when a standard resistance of 12 Ω is connected in the right gap. The value of the unknown resistance in the left gap is:

(A) 8 Ω

(B) 18 Ω

(C) 6 Ω

(D) 24 Ω

Q18. Liquid water of mass 100 g at 0°C is mixed with 100 g of water at 80°C in a calorimeter of negligible heat capacity. The final steady temperature of the mixture is:

(A) 40°C

(B) 30°C

(C) 50°C

(D) 60°C

Q19. An object is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. The nature and magnification of the image formed are:

(A) Real, inverted, and -2

(B) Virtual, erect, and $+2$

(C) Real, inverted, and -0.5

(D) Virtual, erect, and $+0.5$

Q20. When a block of mass M is suspended from a uniform vertical steel wire of length L and area of cross-section A, the elongation produced is ΔL. If the same mass is suspended from another vertical steel wire of length $2L$ and radius doubled, the new elongation will be:

(A) ΔL

(B) $2\Delta L$

(C) $\Delta L/2$

(D) $\Delta L/4$

Q21. A galvanometer of resistance 50 Ω gives a full-scale deflection for a current of 2 mA. To convert it into a voltmeter capable of measuring up to 10 V, the resistance to be connected in series with it is:

(A) 4950 Ω

(B) 5000 Ω

(C) 4900 Ω

(D) 5050 Ω

Q22. If the mass number of a nucleus increases from $A_1 = 27$ to $A_2 = 125$, the ratio of their nuclear radii R_1/R_2 is:

(A) 3 : 5

(B) 9 : 25

(C) 27 : 125

(D) 5 : 3

Q23. An engine operating between two heat reservoirs at temperatures 27°C and 327°C has an efficiency equal to 80% of a perfectly reversible Carnot engine working between the same limits. The actual efficiency of this engine is:

(A) 40%

(B) 50%

(C) 60%

(D) 32%

Q24. A particle moves along the x-axis such that its position x at any time t is given by $x = 2t^3 - 9t^2 + 12t + 4$ (where x is in meters and t is in seconds). The velocity of the particle when its acceleration becomes zero is:

(A) -1.5 m/s

(B) -3 m/s

(C) 3 m/s

(D) 0 m/s

Q25. A ray of light passes through an equilateral glass prism such that the angle of incidence is equal to the angle of emergence. If the angle of emergence is $3/4$ times the angle of the prism, the angle of minimum deviation is:

(A) 30°

(B) 45°

(C) 60°

(D) 15°

Q26. A current of 3 A flows through a circular coil of 100 turns and radius 5 cm. The magnetic dipole moment associated with this coil is approximately:

(A) $2.36\ \mathrm{A \cdot m^2}$

(B) $4.71\ \mathrm{A \cdot m^2}$

(C) $0.24\ \mathrm{A \cdot m^2}$

(D) $23.6\ \mathrm{A \cdot m^2}$

Q27. A body is dropped from a high tower. If it covers a distance of 35 m during the last second of its motion before hitting the ground, the total height of the tower is (Take $g = 10$ m/s^2):

(A) 45 m

(B) 80 m

(C) 60 m

(D) 100 m

Q28. The binding energy per nucleon for a nuclei X^{200} is 7.4 MeV. It fissions into two fragments Y^{100}, each with a binding energy per nucleon of 8.2 MeV. The total energy released during this fission process is:

(A) 160 MeV

(B) 80 MeV

(C) 240 MeV

(D) 320 MeV

Q29. A step-up transformer operates on a 220 V line and supplies a current of 2 A to a load. If the ratio of the primary to secondary turns is 1 : 25 and the efficiency of the transformer is 100%, the primary current is:

(A) 50 A

(B) 25 A

(C) 0.08 A

(D) 12.5 A

Q30. A transverse wave traveling along a string is described by the equation $y(x,t) = 0.05\sin(20x - 4t)$, where x and y are in meters and t is in seconds. The maximum transverse speed of any particle on the string is:

(A) 0.2 m/s

(B) 5 m/s

(C) 0.05 m/s

(D) 4 m/s

Detailed Solutions

Q1.

Solution

Concept: The trajectory of a projectile is a parabolic path. At the highest point of its flight, the vertical component of its velocity becomes zero, leaving only the horizontal component active. The acceleration acting on the projectile at this peak is purely due to gravity, which acts perpendicular to the horizontal velocity vector. The radius of curvature ρ can be determined using the formula for centripetal acceleration, where $a_n = \frac{v^2}{\rho}$.

Solution: Step 1: Write down the given values from the problem. The initial velocity of the projectile is $v_0 = 20$ m/s and the angle of projection with the horizontal is $\theta = 30^\circ$. The acceleration due to gravity is $g = 10$ m/s^2.

Step 2: Find the velocity of the projectile at its highest point. The horizontal velocity remains constant throughout the motion because there is no horizontal acceleration. Thus, the velocity at the maximum height is given by:

$$v_h = v_0 \cos\theta$$

$$v_h = 20 \times \cos 30^\circ = 20 \times \frac{\sqrt{3}}{2} = 10\sqrt{3} \text{ m/s}$$

Step 3: Identify the normal component of acceleration at the highest point. At the peak, the velocity vector is purely horizontal, and the acceleration due to gravity g acts vertically downwards. Therefore, the entire gravitational acceleration is perpendicular to the direction of motion, meaning $a_n = g = 10$ m/s^2. Step 4: Relate the normal acceleration to the radius of curvature. The centripetal acceleration formula gives:

$$g = \frac{v_h^2}{\rho}$$

Step 5: Substitute the value of the horizontal velocity into the equation to compute the radius of curvature ρ:

$$\rho = \frac{(10\sqrt{3})^2}{10}$$

$$\rho = \frac{100 \times 3}{10} = 30 \text{ m}$$

Final Answer: 30 m

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: The capacitance of a parallel-plate capacitor filled with air is given by $C_0 = \frac{\varepsilon_0 A}{d}$. When a dielectric material with a dielectric constant k is inserted between the plates, and the physical dimensions like the separation distance are modified, the new capacitance can be calculated using the generalized formula $C = \frac{k\varepsilon_0 A}{d'}$, where d' represents the modified distance between the plates.

Solution: Step 1: Note the initial configuration. The initial capacitance with air between the plates is given as $C_0 = 8\ \mu$F. The expression for this initial state is:

$$C_0 = \frac{\varepsilon_0 A}{d} = 8\ \mu\text{F}$$

Step 2: Analyze the changes made to the capacitor system. The separation distance between the two conducting plates is reduced by half, which means the new distance becomes $d' = \frac{d}{2}$.

Step 3: Factor in the addition of the dielectric medium. The entire space between the plates is completely filled with a material having a dielectric constant of $k = 6$.

Step 4: Write down the expression for the modified capacitance C' using the new physical parameters:

$$C' = \frac{k\varepsilon_0 A}{d'} = \frac{k\varepsilon_0 A}{\left(\frac{d}{2}\right)}$$

Step 5: Rearrange the algebraic fraction and substitute the original values to calculate the final value:

$$C' = 2k\left(\frac{\varepsilon_0 A}{d}\right)$$

$$C' = 2 \times 6 \times C_0$$

$$C' = 12 \times 8\ \mu\text{F} = 96\ \mu\text{F}$$

Final Answer: $\boxed{96\ \mu\text{F}}$

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: Einstein's photoelectric equation relates the maximum kinetic energy of emitted photoelectrons to the energy of incident photons and the work function of the metal surface. The equation can be formulated in terms of wavelength λ and stopping potential V as $eV = \frac{hc}{\lambda} - \phi$, where $\phi = \frac{hc}{\lambda_0}$ represents the work function, and λ_0 is the threshold wavelength below which no photoemission occurs.

Solution: Step 1: Set up the first equation for the initial case where the incident light wavelength is λ and the stopping potential is V:

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

Step 2: Set up the second equation for the modified case where the incident light wavelength becomes 2λ and the corresponding stopping potential drops to $\frac{V}{3}$:

$$e\left(\frac{V}{3}\right) = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0} \quad \text{— (Equation 2)}$$

Step 3: Multiply Equation 2 by 3 on both sides to eliminate the fraction on the left-hand side, making it easier to solve simultaneously:

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

Step 4: Equate Equation 1 and Equation 3 since both expressions are equal to the term eV:

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

Step 5: Cancel the common constant term hc from all terms in the equation and gather like variables together:

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

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

$$\lambda_0 = 4\lambda$$

Final Answer: $\boxed{4\lambda}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: The work done by an ideal gas during a quasi-static expansion or compression process can be derived by integrating the pressure P with respect to volume V over the given limits. The general mathematical relation is $W = \int_{V_i}^{V_f} P\,dV$, where V_i represents the initial volume boundaries and V_f represents the final volume boundaries of the system.

Solution: Step 1: State the relationship between pressure and volume as provided in the question:

$$P = \frac{k}{V^2}$$

Step 2: Identify the limits of integration for the volume expansion. The gas expands from its starting volume $V_i = V_0$ to its expanded final volume $V_f = 2V_0$.

Step 3: Substitute the pressure function into the work integral formula:

$$W = \int_{V_0}^{2V_0} \frac{k}{V^2}\,dV$$

Step 4: Factor out the positive constant k and carry out the integration with respect to the variable V:

$$W = k\int_{V_0}^{2V_0} V^{-2}\,dV = k\left[\frac{V^{-1}}{-1}\right]_{V_0}^{2V_0} = k\left[-\frac{1}{V}\right]_{V_0}^{2V_0}$$

Step 5: Apply the upper and lower integration limits to find the net work done by the expanding gas:

$$W = -k\left(\frac{1}{2V_0} - \frac{1}{V_0}\right)$$

$$W = -k\left(-\frac{1}{2V_0}\right) = \frac{k}{2V_0}$$

Final Answer: $\boxed{\frac{k}{2V_0}}$

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: According to the Lens Maker's Formula, the focal length of a thin lens depends on the refractive index of the lens material relative to the surrounding medium, as well as the radii of curvature of its two surfaces. The equation is expressed as $\frac{1}{f} = \left(\frac{\mu_{\text{lens}}}{\mu_{\text{medium}}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$. By comparing the focal length in air with the focal length in liquid, the modified parameters can be found.

Solution: Step 1: Write down the Lens Maker's Formula for the lens when it is surrounded by air ($\mu_{\text{air}} = 1$):

$$\frac{1}{f_a} = (\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Given $f_a = 20$ cm and $\mu_g = 1.5$:

$$\frac{1}{20} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0.5\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{— (Equation 1)}$$

Step 2: Write down the equation for the lens when it is completely immersed in water ($\mu_w = 4/3$):

$$\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Step 3: Substitute the known refractive index values into the equation for the water medium:

$$\frac{1}{f_w} = \left(\frac{1.5}{4/3} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{3/2}{4/3} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{9}{8} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{8}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{— (Equation 2)}$$

Step 4: Divide Equation 1 by Equation 2 to eliminate the geometric factor containing the geometric parameters R_1 and R_2:

$$\frac{f_w}{20} = \frac{0.5}{1/8} = 0.5 \times 8 = 4$$

Step 5: Compute the final value of the focal length when immersed in water:

$$f_w = 4 \times 20 = 80 \text{ cm}$$

Final Answer: 80 cm

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: When a force is applied to a block placed on a rough surface, the static frictional force matches the applied external force up to a maximum threshold value known as the limiting friction, $f_L = \mu_s N$. If the applied force is less than or equal to this limiting friction, the object remains completely stationary, and the self-adjusting static friction balances the applied force exactly.

Solution: Step 1: Calculate the normal reaction force N acting on the block from the supporting horizontal surface. Since there is no vertical movement, the normal force balances the weight:

$$N = mg = 2\text{ kg} \times 10\text{ m/s}^2 = 20\text{ N}$$

Step 2: Determine the maximum limiting static frictional force f_L that the surface can exert to prevent sliding:

$$f_L = \mu_s N = 0.4 \times 20\text{ N} = 8\text{ N}$$

Step 3: Compare the applied horizontal force F with the computed limiting friction value f_L. The applied force is given as $F = 5$ N.

Step 4: Since $F \leq f_L$ (5 N < 8 N), the force applied is insufficient to overcome the static resistance of the contact surfaces, meaning the block does not accelerate and remains at rest.

Step 5: Because the block is stationary, the static friction behaves as a self-adjusting force and opposes the tendency of motion by exactly matching the applied force. Therefore:

$$f = F = 5\text{ N}$$

Final Answer: $\boxed{\text{5 N}}$

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept: A long straight current-carrying conductor establishes a surrounding magnetic field given by Ampere's Law: $B = \frac{\mu_0 I}{2\pi r}$. A moving charged particle moving through an external magnetic field experiences a magnetic Lorentz force expressed by the vector relation $\vec{F} = q(\vec{v} \times \vec{B})$, whose magnitude is calculated as $F = qvB\sin\theta$.

Solution: Step 1: Calculate the magnitude of the magnetic field B produced by the wire carrying a current $I = 5$ A at a perpendicular separation distance of $r = 10$ cm $= 0.1$ m:

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 5}{2\pi \times 0.1}$$

$$B = \frac{2 \times 10^{-7} \times 5}{0.1} = \frac{10^{-6}}{0.1} = 10^{-5}\ \text{T}$$

Step 2: Determine the vector direction of the magnetic field using the Right-Hand Grip Rule. For a current flowing along the wire, the field lines form concentric circles around it. At the position of the electron, the magnetic field lines point perpendicular to the plane containing the wire and the electron path.

Step 3: Analyze the angle θ between the electron's velocity vector $\vec{v}$ and the magnetic field vector $\vec{B}$. Since the velocity is parallel to the wire and the magnetic field is perpendicular to the plane of the velocity and position vectors, the angle is exactly $\theta = 90^\circ$.

Step 4: Write down the values for the remaining physical quantities. The charge of an electron is $q = 1.6 \times 10^{-19}$ C and its speed is given as $v = 10^5$ m/s.

Step 5: Compute the magnitude of the magnetic Lorentz force using the formula:

$$F = qvB\sin 90^\circ = (1.6 \times 10^{-19}) \times (10^5) \times (10^{-5}) \times 1$$

$$F = 1.6 \times 10^{-19}\ \text{N}$$

Final Answer: $\boxed{1.6 \times 10^{-19}\ \text{N}}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: In Young's Double Slit Experiment (YDSE), the spatial separation between consecutive bright or dark interference fringes on a screen is termed the fringe width, denoted by w. The algebraic relation for the fringe width is defined by $w = \frac{\lambda D}{d}$, where λ is the wavelength of the light source, D is the distance from the double slits to the screen, and d is the distance separating the two slits.

Solution: Step 1: Write down the expression for the original fringe width based on the initial system dimensions:

$$w = \frac{\lambda D}{d}$$

Step 2: Identify the transformations applied to the experimental setup. The slit separation distance is doubled, which translates to a new value $d' = 2d$.

Step 3: Account for the change in the position of the screen. The distance between the slits and the observation screen is halved, giving a new distance parameter $D' = \frac{D}{2}$.

Step 4: Substitute these updated parameters into the fringe width equation to derive the modified value w':

$$w' = \frac{\lambda D'}{d'} = \frac{\lambda\left(\frac{D}{2}\right)}{2d}$$

$$w' = \frac{1}{4}\left(\frac{\lambda D}{d}\right)$$

Step 5: Relate the new fringe width to the original value and express it as a simple mathematical ratio:

$$w' = \frac{1}{4}w \implies \frac{w'}{w} = \frac{1}{4}$$

Thus, the required ratio is 1 : 4.

Final Answer: $\boxed{1:4}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 8

Q9.

Solution

Concept: Radioactive decay follows first-order kinetics, governed by the exponential law $N(t) = N_0 e^{-\lambda_d t}$, where $N(t)$ is the amount of active radioactive nuclei remaining at time t. Alternatively, this can be modeled using the concept of half-life $T_{1/2}$, where the remaining fraction of active material after n half-lives is given by $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$.

Solution: Step 1: Understand what the percentages mean in terms of remaining nuclei. When a substance has reached a stage of 33% decay, the fraction of active radioactive nuclei left intact is:

$$N_1 = 100\% - 33\% = 67\% = 0.67N_0$$

Step 2: Analyze the second milestone state. When the radioactive sample has undergone 67% cumulative decay, the fraction of intact nuclei remaining unreacted is:

$$N_2 = 100\% - 67\% = 33\% = 0.33N_0$$

Step 3: Examine the ratio of the remaining nuclei between these two observation points:

$$\frac{N_2}{N_1} = \frac{0.33N_0}{0.67N_0} \approx \frac{1}{2}$$

Step 4: Notice that the quantity of radioactive active nuclei drops to exactly half of its value during the transition from the first stage to the second stage (67% reduces to approximately 33%).

Step 5: By definition, the time taken for a radioactive sample to decrease to half of its current value is equal to exactly one half-life. Since the half-life $T_{1/2}$ of this material is 20 minutes, the time interval is:

$$\Delta t = T_{1/2} = 20 \text{ minutes}$$

Final Answer: $\boxed{\text{20 minutes}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 9

Q10.

Solution

Concept: The Work-Energy Theorem states that the net work done by all the forces acting on a body is equal to the change in its kinetic energy. Mathematically, $W_{\text{net}} = \Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$, where v_i and v_f represent the velocities at the initial and final spatial coordinates.

Solution: Step 1: Write down the given expression for velocity as a function of position x:

$$v = ax^{3/2} \quad \text{where } a = 5\ \text{m}^{-1/2}\text{s}^{-1}$$

Step 2: Determine the initial velocity v_i at the initial position $x_i = 0$ m:

$$v_i = 5 \times (0)^{3/2} = 0 \text{ m/s}$$

Step 3: Determine the final velocity v_f at the final position $x_f = 2$ m:

$$v_f = 5 \times (2)^{3/2} = 5 \times \sqrt{2^3} = 5 \times 2\sqrt{2} = 10\sqrt{2} \text{ m/s}$$

Step 4: Use the mathematical expression from the Work-Energy Theorem to calculate the work done, substituting the mass value $m = 0.5$ kg:

$$W = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

$$W = \frac{1}{2} \times 0.5 \times \left[(10\sqrt{2})^2 - 0^2\right]$$

Step 5: Evaluate the arithmetic terms to find the final numerical value of the work done on the body:

$$W = \frac{1}{4} \times [100 \times 2] = \frac{200}{4} = 50 \text{ J}$$

Final Answer: 50 J

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: A multi-plate capacitor system containing n identical parallel plates arranged symmetrically with alternate electrical connections can be modeled as a parallel combination of $(n-1)$ individual identical capacitors. The equivalent capacitance of m capacitors connected in parallel configuration is the direct sum of their individual values, $C_{eq} = m \times C_0$.

Solution: Step 1: Identify the parameters of a single constituent parallel-plate capacitor unit formed by any two adjacent overlapping plates. The capacitance is:

$$C_0 = \frac{\varepsilon_0 A}{d}$$

Step 2: Count the total number of parallel plates in the given network. Here, $n = 5$ identical conducting plates.

Step 3: Analyze the alternate wiring configuration. Plates 1, 3, and 5 are tied together to one terminal (say, B), while plates 2 and 4 are joined to the opposite electrical terminal (say, A).

Step 4: Determine the number of active capacitive spaces created between these plates. Each adjacent pair forms a separate functioning capacitor. With 5 plates, there are $n - 1 = 5 - 1 = 4$ separate dielectric fields.

Step 5: Since every individual field is bounded between a plate connected to terminal A and a plate connected to terminal B, all 4 capacitors are connected in a parallel network across terminals A and B. Thus:

$$C_{eq} = 4 \times C_0 = \frac{4\varepsilon_0 A}{d}$$

Final Answer: $\boxed{\frac{4\varepsilon_0 A}{d}}$

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept: An absolute thermodynamic temperature scale is anchored linearly to a fundamental physical reference, typically chosen as the triple point of water, which is defined globally as 273.16 K on the Kelvin scale. For any two arbitrary absolute scales A and B, the structural ratios of their measured temperatures to their respective triple point values must be equal: $\frac{T_A}{T_{A,\text{tr}}} = \frac{T_B}{T_{B,\text{tr}}}$.

Solution: Step 1: Write down the given reference values for the triple point of water on both custom temperature scales. For scale A, $T_{A,\text{tr}} = 200$ A, and for scale B, $T_{B,\text{tr}} = 350$ B.

Step 2: Use the fundamental property of absolute temperature scales, which states that value readings on any absolute scale are directly proportional to each other since they both share a common zero point at absolute zero:

$$\frac{T_A}{T_{A,\text{tr}}} = \frac{T_B}{T_{B,\text{tr}}}$$

Step 3: Substitute the given triple point numerical constants into the proportionality equation:

$$\frac{T_A}{200} = \frac{T_B}{350}$$

Step 4: Solve the algebraic equation for T_A to express it in terms of T_B:

$$T_A = \frac{200}{350} T_B$$

Step 5: Reduce the fraction to its lowest terms by dividing the numerator and denominator by their greatest common divisor, 50:

$$T_A = \frac{4}{7} T_B$$

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

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: For a particle executing simple harmonic motion (SHM) with an amplitude A and angular frequency ω, the kinetic energy (K) and potential energy (U) at any arbitrary displacement x from the central equilibrium position are given by the equations $K = \frac{1}{2}m\omega^2(A^2 - x^2)$ and $U = \frac{1}{2}m\omega^2x^2$.

Solution: Step 1: State the constraint equation given in the problem statement, which relates kinetic and potential energy:

$$K = 3U$$

Step 2: Substitute the algebraic formulas for both kinetic energy and potential energy into this constraint equation:

$$\frac{1}{2}m\omega^2(A^2 - x^2) = 3\left(\frac{1}{2}m\omega^2x^2\right)$$

Step 3: Cancel the common multiplier $\frac{1}{2}m\omega^2$ from both sides of the expression to simplify the equation:

$$A^2 - x^2 = 3x^2$$

Step 4: Group the terms involving the displacement variable x onto one side of the equation:

$$A^2 = 3x^2 + x^2$$

$$A^2 = 4x^2$$

Step 5: Take the square root on both sides to find the relationship between displacement and amplitude, and then compute their ratio:

$$A = 2x \implies \frac{x}{A} = \frac{1}{2}$$

Thus, the ratio is 1 : 2.

Final Answer: $\boxed{1 : 2}$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: The wavelengths of the spectral lines emitted by a hydrogen atom during electron transitions are calculated using the Rydberg formula: $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, where R is the Rydberg constant, n_1 is the lower energy level, and n_2 is the higher energy level. By taking the ratio of the formulas for different transitions, the unknown wavelength can be determined.

Solution: Step 1: Analyze the first line of the Lyman series. The first line corresponds to an electronic transition from the $n_2 = 2$ energy level to the $n_1 = 1$ base level. Write its Rydberg equation:

$$\frac{1}{\lambda_L} = \frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = R\left(1 - \frac{1}{4}\right) = \frac{3R}{4} \quad \text{— (Equation 1)}$$

Step 2: Analyze the first line of the Balmer series. The first line of this series corresponds to an electronic transition from the $n_2 = 3$ level to the $n_1 = 2$ level. Write its Rydberg equation:

$$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{1}{4} - \frac{1}{9}\right) = R\left(\frac{9-4}{36}\right) = \frac{5R}{36} \quad \text{— (Equation 2)}$$

Step 3: Divide Equation 1 by Equation 2 to establish a direct relationship between the two wavelengths:

$$\frac{\left(\frac{1}{\lambda}\right)}{\left(\frac{1}{\lambda_B}\right)} = \frac{\left(\frac{3R}{4}\right)}{\left(\frac{5R}{36}\right)}$$

$$\frac{\lambda_B}{\lambda} = \frac{3}{4} \times \frac{36}{5} = \frac{3 \times 9}{5} = \frac{27}{5}$$

Step 4: Solve for the unknown Balmer wavelength λ_B in terms of the given Lyman wavelength value λ:

$$\lambda_B = \frac{27}{5}\lambda$$

Final Answer: $\boxed{\frac{27}{5}\lambda}$

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: The magnetic field produced by a circular current loop of radius R carrying current I at a perpendicular distance x along its central axis is given by the formula $B(x) = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$. At the center of the loop ($x = 0$), this simplifies to $B_0 = \frac{\mu_0 I}{2R}$.

Solution: Step 1: Express the axial magnetic field equation in terms of the center magnetic field intensity value B_0:

$$B(x) = \frac{\mu_0 I}{2R} \times \frac{R^3}{(R^2 + x^2)^{3/2}} = B_0 \frac{R^3}{(R^2 + x^2)^{3/2}}$$

Step 2: Set the axial field expression equal to the target value specified in the problem, which is $\frac{B_0}{8}$:

$$B_0 \frac{R^3}{(R^2 + x^2)^{3/2}} = \frac{B_0}{8}$$

Step 3: Cancel the common factor B_0 from both sides and take the reciprocal of the remaining terms:

$$\frac{(R^2 + x^2)^{3/2}}{R^3} = 8 \implies (R^2 + x^2)^{3/2} = 8R^3$$

Step 4: Take the cube root (raise to the power of $1/3$) on both sides of the equation to simplify the exponent:

$$\left[(R^2 + x^2)^{3/2}\right]^{1/3} = (8R^3)^{1/3}$$

$$(R^2 + x^2)^{1/2} = 2R$$

Step 5: Square both sides to eliminate the radical, then solve for the axial distance variable x:

$$R^2 + x^2 = 4R^2$$

$$x^2 = 3R^2 \implies x = R\sqrt{3}$$

Final Answer: $\boxed{R\sqrt{3}}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: The natural frequency of oscillation f for a mass-spring system moving on a frictionless horizontal surface depends on the spring stiffness constant k and the attached inertia mass m. The relationship is defined by the formula $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, showing that frequency is inversely proportional to the square root of the mass ($f \propto \frac{1}{\sqrt{m}}$).

Solution: Step 1: Write down the mathematical proportional relationship for the frequency of a spring oscillator:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \implies f \propto \frac{1}{\sqrt{m}}$$

Step 2: Identify the baseline case. For an initial mass $m_1 = m$, the frequency is given as $f_1 = f$.

Step 3: Define the parameters for the modified state. The load mass is increased to four times its original value, so the new mass is $m_2 = 4m$. Let the new frequency be f_2.

Step 4: Set up a ratio equation comparing the modified state to the original state:

$$\frac{f_2}{f_1} = \sqrt{\frac{m_1}{m_2}}$$

$$\frac{f_2}{f} = \sqrt{\frac{m}{4m}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Step 5: Rearrange the equation to isolate and solve for the new frequency f_2:

$$f_2 = \frac{f}{2}$$

Final Answer: $\boxed{f/2}$

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: A meter bridge operates on the principle of a balanced Wheatstone bridge. When the galvanometer shows zero deflection (null point), the ratio of the resistances in the left and right gaps equals the ratio of the resistances of the corresponding wire segments. The balance condition is given by $\frac{R}{S} = \frac{l}{100-l}$, where l is the balancing length from the left end in centimeters, R is the unknown left-gap resistance, and S is the known right-gap resistance.

Solution: Step 1: Identify the given values from the experimental parameters. The null point is obtained at a distance $l = 40$ cm from the left side. The standard known resistance in the right gap is $S = 12\ \Omega$.

Step 2: Calculate the remaining length of the wire segment on the right-hand side of the balancing jockey:

$$100 - l = 100 - 40 = 60 \text{ cm}$$

Step 3: State the balanced Wheatstone bridge condition equation:

$$\frac{R}{S} = \frac{l}{100 - l}$$

Step 4: Substitute the known numerical values into the balance formula:

$$\frac{R}{12} = \frac{40}{60}$$

Step 5: Simplify the fraction on the right side and solve for the unknown left gap resistance R:

$$\frac{R}{12} = \frac{2}{3}$$

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

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

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: According to the Principle of Calorimetry, when two substances at different temperatures are mixed in an isolated system, the total heat lost by the hotter substance must equal the total heat gained by the colder substance, assuming no thermal energy is exchanged with the surroundings: $Q_{\text{gain}} = Q_{\text{loss}}$. The formula for heat transfer without a phase change is $Q = mc\Delta T$.

Solution: Step 1: Identify the parameters of the two mixing components. The cold water has mass $m_1 = 100$ g at an initial temperature $T_1 = 0°\text{C}$. The hot water has mass $m_2 = 100$ g at an initial temperature $T_2 = 80°\text{C}$. Let T_f be the final equilibrium temperature.

Step 2: Write down the expression for the heat absorbed by the cold water as its temperature rises from 0°C to T_f:

$$Q_{\text{gain}} = m_1 c_w (T_f - T_1) = 100 \times c_w \times (T_f - 0)$$

Step 3: Write down the expression for the heat released by the hot water as its temperature drops from 80°C to T_f:

$$Q_{\text{loss}} = m_2 c_w (T_2 - T_f) = 100 \times c_w \times (80 - T_f)$$

Step 4: Equate the heat gained to the heat lost based on the conservation of energy principle:

$$100 \times c_w \times T_f = 100 \times c_w \times (80 - T_f)$$

Step 5: Cancel the common factors (100 and c_w) from both sides and solve the simple linear equation for T_f:

$$T_f = 80 - T_f$$

$$2T_f = 80 \implies T_f = 40°\text{C}$$

Final Answer: $\boxed{40°\text{C}}$

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: The position of an image formed by a spherical mirror can be found using the mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$. The linear magnification m is given by the ratio of image distance to object distance with a negative sign: $m = -\frac{v}{u}$. Cartesian sign conventions must be strictly applied: distances measured opposite to the incident light are negative.

Solution: Step 1: List the given parameters with their proper signs according to the sign convention. For a concave mirror, the focal length is negative, so $f = -10$ cm. The object is placed in front of the mirror, so $u = -15$ cm.

Step 2: Substitute these values into the mirror formula to find the image distance v:

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

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

Step 3: Find a common denominator to subtract the fractions on the right side:

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

Step 4: Use the value of v to calculate the linear magnification factor m:

$$m = -\frac{v}{u} = -\frac{-30}{-15} = -2$$

Step 5: Interpret the physical meaning of the calculated values. The negative sign of the image distance ($v = -30$ cm) indicates that the image is formed in front of the mirror, meaning it is a real image. The negative sign of the magnification ($m = -2$) confirms that the image is inverted, and its magnitude shows it is twice the size of the object.

Final Answer: $\boxed{\text{Real, inverted, and } -2}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 19

Q20.

Solution

Concept: Hooke's Law states that within the elastic limit, structural elongation is related to the applied load and material dimensions by Young's Modulus: $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{\Delta L/L}$. Rearranging this gives the elongation formula: $\Delta L = \frac{FL}{AY} = \frac{FL}{\pi r^2 Y}$, where $F = Mg$ is the suspended load force, L is the wire length, and r is its cross-sectional radius.

Solution: Step 1: Write down the mathematical relationship for the elongation of a wire under a load, expressing the area in terms of the radius:

$$\Delta L = \frac{(Mg)L}{\pi r^2 Y} \implies \Delta L \propto \frac{L}{r^2}$$

Step 2: Note the initial configuration parameters. For a wire of length $L_1 = L$ and radius $r_1 = r$, the elongation produced by the suspended block is $\Delta L_1 = \Delta L$.

Step 3: Analyze the changed structural parameters of the second wire. The new length is $L_2 = 2L$ and the radius is doubled, so $r_2 = 2r$. The material remains steel, so Young's Modulus Y is unchanged.

Step 4: Formulate a ratio comparing the new elongation ΔL_2 to the original elongation ΔL_1:

$$\frac{\Delta L_2}{\Delta L_1} = \left(\frac{L_2}{L_1}\right) \times \left(\frac{r_1}{r_2}\right)^2$$

$$\frac{\Delta L_2}{\Delta L} = \left(\frac{2L}{L}\right) \times \left(\frac{r}{2r}\right)^2$$

Step 5: Evaluate the arithmetic terms to find the final simplified expression for the new elongation:

$$\frac{\Delta L_2}{\Delta L} = 2 \times \frac{1}{4} = \frac{1}{2} \implies \Delta L_2 = \frac{\Delta L}{2}$$

Final Answer: $\boxed{\Delta L/2}$

Answer: (C)

Go Back to Question 20

Q21.

Solution

Concept: To convert a sensitive galvanometer into a voltmeter capable of measuring larger potentials, a high resistance R must be connected in series with the galvanometer coil. The total equivalent series resistance is $(G+R)$. According to Ohm's Law, the maximum measurable voltage V is reached when the full-scale deflection current I_g flows through the circuit: $V = I_g(G+R)$.

Solution: Step 1: List the given electrical specifications. The internal resistance of the galvanometer coil is $G = 50\ \Omega$. The full-scale deflection current limit is $I_g = 2\text{ mA} = 2 \times 10^{-3}$ A. The target maximum voltage measurement is $V = 10$ V.

Step 2: Set up the algebraic equation based on the series circuit conversion formula:

$$V = I_g(G+R)$$

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

$$10 = (2 \times 10^{-3}) \times (50 + R)$$

Step 4: Rearrange the equation to isolate the term containing the unknown series resistor R:

$$50 + R = \frac{10}{2 \times 10^{-3}}$$

$$50 + R = 5 \times 10^{3} = 5000\ \Omega$$

Step 5: Calculate the final value of the required series resistance R:

$$R = 5000 - 50 = 4950\ \Omega$$

Final Answer: $\boxed{4950\ \Omega}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 21

Q22.

Solution

Concept: The physical radius R of an atomic nucleus is directly proportional to the cube root of its total mass number A. This empirical relationship is expressed by the formula $R = R_0 A^{1/3}$, where R_0 is a constant multiplier ($R_0 \approx 1.2$ fm). Consequently, the ratio of the nuclear radii of two different isotopes is given by $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$.

Solution: Step 1: Identify the mass numbers of the two nuclei from the problem description. The initial mass number is $A_1 = 27$ and the second mass number is $A_2 = 125$.

Step 2: Set up the proportional ratio equation for their respective nuclear radii based on the cube root dependency:

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

Step 3: Substitute the given mass values into the ratio expression:

$$\frac{R_1}{R_2} = \left(\frac{27}{125}\right)^{1/3}$$

Step 4: Express the integers inside the brackets as perfect cubes to make evaluating the radical straightforward:

$$27 = 3^3 \quad \text{and} \quad 125 = 5^3$$

$$\frac{R_1}{R_2} = \left(\frac{3^3}{5^3}\right)^{1/3}$$

Step 5: Apply the cube root exponent to find the final simplified ratio:

$$\frac{R_1}{R_2} = \frac{3}{5}$$

Thus, the required ratio is 3 : 5.

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

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 22

Q23.

Solution

Concept: The efficiency of an ideal, perfectly reversible Carnot thermal engine operating between two constant temperature reservoirs depends only on the absolute temperatures of the source (T_H) and the sink (T_C): $\eta_C = 1 - \frac{T_C}{T_H}$. The temperatures must always be converted to the absolute Kelvin scale. The efficiency of a real engine can then be found from its specified relationship to the ideal case.

Solution: Step 1: Convert the given Celsius temperatures of the heat reservoirs into absolute temperatures on the Kelvin scale. For the cold sink reservoir:

$$T_C = 27°\text{C} + 273 = 300 \text{ K}$$

For the hot source reservoir:

$$T_H = 327°\text{C} + 273 = 600 \text{ K}$$

Step 2: Calculate the thermal efficiency of an ideal Carnot engine operating between these absolute limits:

$$\eta_C = 1 - \frac{T_C}{T_H} = 1 - \frac{300}{600}$$

$$\eta_C = 1 - 0.5 = 0.5 \quad \text{or} \quad 50\%$$

Step 3: Read the performance constraint for the actual engine. The problem states that the actual engine's efficiency is equal to 80% of the ideal Carnot efficiency.

Step 4: Set up the multiplication equation to find the actual operating efficiency η_{actual}:

$$\eta_{\text{actual}} = 80\% \text{ of } \eta_C = 0.80 \times \eta_C$$

Step 5: Substitute the computed Carnot efficiency value to get the final result:

$$\eta_{\text{actual}} = 0.80 \times 0.5 = 0.40 \quad \text{or} \quad 40\%$$

Final Answer: 40%

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: Instantaneous velocity is defined mathematically as the first time derivative of the position function, $v = \frac{dx}{dt}$. Similarly, instantaneous acceleration is the first time derivative of the velocity function, or the second time derivative of position, $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$. By finding when acceleration becomes zero, the corresponding time can be substituted back into the velocity function.

Solution: Step 1: State the position function given in the problem statement:

$$x = 2t^3 - 9t^2 + 12t + 4$$

Step 2: Differentiate the position function with respect to time t to find the velocity equation:

$$v = \frac{dx}{dt} = \frac{d}{dt}(2t^3 - 9t^2 + 12t + 4)$$

$$v = 6t^2 - 18t + 12 \quad \text{— (Equation 1)}$$

Step 3: Differentiate the velocity function with respect to time to derive the acceleration expression:

$$a = \frac{dv}{dt} = \frac{d}{dt}(6t^2 - 18t + 12)$$

$$a = 12t - 18 \quad \text{— (Equation 2)}$$

Step 4: Set the acceleration expression equal to zero to find the exact time instant requested:

$$12t - 18 = 0 \implies 12t = 18$$

$$t = \frac{18}{12} = 1.5 \text{ seconds}$$

Step 5: Substitute this time value $t = 1.5$ s back into the velocity equation (Equation 1) to calculate the velocity at that instant:

$$v = 6(1.5)^2 - 18(1.5) + 12$$

$$v = 6(2.25) - 27 + 12$$

$$v = 13.5 - 27 + 12 = -1.5 \text{ m/s}$$

Final Answer: $\boxed{-1.5 \text{ m/s}}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: For a light ray passing through a triangular prism, the relationship connecting the angle of incidence (i), the angle of emergence (e), the angle of the prism (A), and the angle of deviation (δ) is given by the formula $i + e = A + \delta$. Minimum deviation (δ_m) occurs under the symmetric condition where the angle of incidence equals the angle of emergence ($i = e$).

Solution: Step 1: Note the given geometric and optical properties of the prism setup. The prism is described as equilateral, which means its apex angle is $A = 60°$.

Step 2: Apply the condition given in the problem statement, which states that the angle of incidence equals the angle of emergence ($i = e$). This symmetry means the prism is operating at minimum deviation, so $\delta = \delta_m$.

Step 3: Use the given proportional relationship to determine the numerical value of the emergence angle e:

$$e = \frac{3}{4}A = \frac{3}{4} \times 60^\circ = 3 \times 15^\circ = 45^\circ$$

Since $i = e$, the angle of incidence is also $i = 45°$.

Step 4: Substitute these angles into the structural prism equation:

$$i + e = A + \delta_m$$

$$45^\circ + 45^\circ = 60^\circ + \delta_m$$

Step 5: Solve the linear arithmetic equation to find the angle of minimum deviation δ_m:

$$90^\circ = 60^\circ + \delta_m$$

$$\delta_m = 90^\circ - 60^\circ = 30^\circ$$

Final Answer: $\boxed{30^\circ}$

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept: The magnetic dipole moment M_d associated with a planar current-carrying coil containing multiple turns depends on the total number of turns N, the current I flowing through the conductor, and the cross-sectional area A enclosed by a single loop. The vector magnitude is calculated using the formula $M_d = NIA$. For a circular coil, the face area is $A = \pi r^2$.

Solution: Step 1: List the given values and convert them into standard SI units. The number of wire turns is $N = 100$. The current is $I = 3$ A. The radius of the circular loop is $r = 5$ cm $= 0.05$ m.

Step 2: Calculate the face area A enclosed by a single loop of the circular coil:

$$A = \pi r^2 = \pi \times (0.05)^2 = 0.0025\pi \text{ m}^2$$

Step 3: Substitute the calculated area and the given parameters into the magnetic dipole moment formula:

$$M_d = NIA = 100 \times 3 \times (0.0025\pi)$$

Step 4: Simplify the numeric terms before substituting the decimal value for the mathematical constant π:

$$M_d = 300 \times 0.0025\pi = 0.75\pi \text{ A} \cdot \text{m}^2$$

Step 5: Substitute $\pi \approx 3.1416$ to find the final numerical value:

$$M_d = 0.75 \times 3.1416 = 2.3562 \text{ A} \cdot \text{m}^2 \approx 2.36 \text{ A} \cdot \text{m}^2$$

Final Answer: $\boxed{2.36 \text{ A} \cdot \text{m}^2}$

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept: For an object moving under uniform acceleration from rest ($u = 0$), the displacement covered during a specific n-th second interval of its motion is given by the kinematic formula $S_{nth} = u + \frac{a}{2}(2n - 1)$. Once the total time of flight n is found, the total height can be calculated using the standard displacement formula $H = \frac{1}{2}gt^2$.

Solution: Step 1: Identify the given kinematics parameters. The object is dropped from rest, so its initial velocity is $u = 0$. The acceleration is due to gravity, $a = g = 10$ m/s^2. The distance covered in the final n-th second is $S_{nth} = 35$ m.

Step 2: Substitute these values into the n-th second distance equation to solve for the total duration of the fall n:

$$S_{nth} = 0 + \frac{g}{2}(2n - 1)$$

$$35 = \frac{10}{2}(2n - 1)$$

Step 3: Solve the simplified linear equation to find the value of n:

$$35 = 5(2n - 1) \implies 7 = 2n - 1$$

$$2n = 8 \implies n = 4 \text{ seconds}$$

This means the body takes a total of 4 seconds to reach the ground.

Step 4: Use the total time of flight $t = 4$ s to calculate the total height H of the tower:

$$H = ut + \frac{1}{2}gt^2$$

$$H = 0 \times 4 + \frac{1}{2} \times 10 \times (4)^2$$

Step 5: Evaluate the arithmetic terms to find the final height of the tower:

$$H = 5 \times 16 = 80 \text{ m}$$

Final Answer: $\boxed{80 \text{ m}}$

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept: The total binding energy of a nucleus is equal to its binding energy per nucleon multiplied by its total mass number A: $E_{\text{total}} = \left(\frac{E_B}{A}\right) \times A$. In a nuclear fission reaction, the net energy released (Q-value) is equal to the difference between the total binding energy of the product fragments and the total binding energy of the initial reactant nucleus: $Q = E_{\text{products}} - E_{\text{reactants}}$.

Solution: Step 1: Calculate the total structural binding energy of the initial parent nucleus X^{200} before fission occurs:

$$E_{\text{reactant}} = 200 \times 7.4 \text{ MeV} = 1480 \text{ MeV}$$

Step 2: Note the properties of the fission products. The parent nucleus splits into two identical daughter fragments, each designated as Y^{100}.

Step 3: Calculate the total binding energy for one daughter nucleus Y^{100}:

$$E_{\text{one fragment}} = 100 \times 8.2 \text{ MeV} = 820 \text{ MeV}$$

Step 4: Find the combined total binding energy of both produced daughter fragments:

$$E_{\text{products}} = 2 \times 820 \text{ MeV} = 1640 \text{ MeV}$$

Step 5: Calculate the net energy released (Q-value) during this fission event by subtracting the reactant energy from the product energy:

$$Q = E_{\text{products}} - E_{\text{reactants}}$$

$$Q = 1640 \text{ MeV} - 1480 \text{ MeV} = 160 \text{ MeV}$$

Final Answer: $\boxed{\text{160 MeV}}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: For an ideal electrical transformer with 100% power efficiency, the electrical power supplied to the primary coil equals the electrical power delivered by the secondary coil: $P_p = P_s$, which means $V_p I_p = V_s I_s$. Additionally, the voltage ratio across the coils is directly proportional to their turn ratio: $\frac{V_s}{V_p} = \frac{N_s}{N_p}$. Combining these gives the current relation: $\frac{I_p}{I_s} = \frac{N_s}{N_p}$.

Solution: Step 1: List the given parameters from the problem statement. The primary voltage is $V_p = 220$ V. The secondary output load current is $I_s = 2$ A. The turns ratio between the primary and secondary windings is given as $\frac{N_p}{N_s} = \frac{1}{25}$.

Step 2: State the inverse relationship between the coil current values and their respective number of turns, which is derived from the conservation of power in an ideal transformer:

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Step 3: Invert the given turns ratio to find the value of $\frac{N_s}{N_p}$:

$$\text{Given } \frac{N_p}{N_s} = \frac{1}{25} \implies \frac{N_s}{N_p} = 25$$

Step 4: Substitute this ratio and the secondary current value into the current relationship equation:

$$\frac{I_p}{2} = 25$$

Step 5: Solve for the primary input current I_p:

$$I_p = 25 \times 2 = 50 \text{ A}$$

Final Answer: 50 A

Answer: (A)

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Q30.

Solution

Concept: A particle embedded within a medium transporting a traveling wave executes simple harmonic motion perpendicular or parallel to the direction of wave propagation. For a wave described by the mathematical function $y(x,t) = A\sin(kx - \omega t)$, the instantaneous transverse velocity of a particle is found by taking the partial derivative of displacement with respect to time: $v_p = \frac{\partial y}{\partial t}$. The maximum value of this velocity is given by $v_{\max} = A\omega$.

Solution: Step 1: Write down the given wave equation from the problem statement:

$$y(x,t) = 0.05\sin(20x - 4t)$$

Step 2: Compare this function with the standard wave equation $y(x,t) = A\sin(kx - \omega t)$ to identify the constituent parameters. By direct comparison, the displacement amplitude is $A = 0.05$ m.

Step 3: Identify the angular frequency ω from the time coefficient in the argument of the sine function. This gives $\omega = 4$ rad/s.

Step 4: Recall the expression for the maximum transverse velocity attained by any particle executing simple harmonic motion within the wave path:

$$v_{\max} = A\omega$$

Step 5: Substitute the identified values for amplitude A and angular frequency ω into the expression to compute the maximum speed:

$$v_{\max} = 0.05 \times 4 = 0.2 \text{ m/s}$$

Final Answer: 0.2 m/s

Answer: (A)

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Answer Key

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