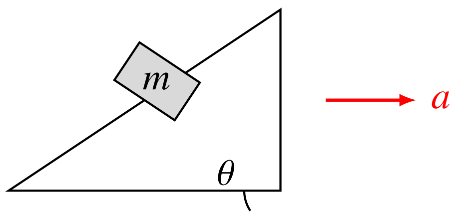
KIITEE Physics Sample Paper – 8

Duration: 50 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct Answer), modelled on the Physics portion of **KIITEE** entrance.
- Each correct answer carries **+4 marks**. There is −1 **mark per wrong answer;** unattempted questions score **0**.
- Only **one** option is correct. Choose carefully.
- Syllabus level: **Class 11 & 12 (10+2) Physics — Mechanics,Heat & Thermodynamics, Electrodynamics, Optics and Modern Physics.**
- The test is computer based. Personal calculators, log tables, mobile phones, and other electronic gadgets are strictly prohibited.

Q1. A block of mass m is placed on a smooth wedge of inclination θ, which is accelerating horizontally to the right with an acceleration a. If the block remains stationary relative to the wedge, the magnitude of a must be:



(A) $g \sin\theta$

(B) $g \cos\theta$

(C) $g \tan\theta$

(D) $g \cot\theta$

Q2. A parallel-plate capacitor with air between the plates has a capacitance C. If the distance between the plates is halved and a dielectric medium of dielectric constant $K = 4$ is introduced to completely fill the space, the new capacitance becomes:

(A) $2C$

(B) $4C$

(C) $8C$

(D) $16C$

Q3. In a Young's double-slit experiment, the slit separation is doubled and the distance between the slits and the screen is halved. The fringe width changes by a factor of:

(A) 4

(B) 2

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

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

Q4. The half-life of a radioactive sample is 4 hours. If the initial mass of the sample is 64 g, the mass of the sample remaining undecayed after 20 hours will be:

(A) 1 g

(B) 2 g

(C) 4 g

(D) 8 g

Q5. An ideal gas undergoes a thermodynamic process where its pressure P varies with volume V as $P = kV^2$, where k is a constant. If the volume changes from V_0 to $2V_0$, the work done by the gas is:

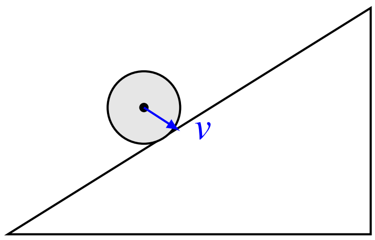
(A) $\frac{7}{3}kV_0^3$

(B) $\frac{8}{3}kV_0^3$

(C) $3kV_0^3$

(D) $\frac{1}{3}kV_0^3$

Q6. A solid sphere and a solid cylinder of the same mass and radius roll down the same inclined plane from rest without slipping. The ratio of their linear accelerations, $a_{\text{sphere}} : a_{\text{cylinder}}$, is:



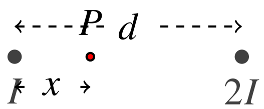
(A) 14 : 15

(B) 15 : 14

(C) 5 : 4

(D) 4 : 5

Q7. Two long, parallel wires separated by a distance d carry currents I and $2I$ in the same direction. The magnetic field is zero at a distance x from the wire carrying current I. The value of x is:



(A) $\frac{d}{3}$

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

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

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

Q8. A particle executes simple harmonic motion with an amplitude A. At what displacement from the mean position is its kinetic energy equal to three times its potential energy?

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

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

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

(D) $\frac{\sqrt{3}A}{2}$

Q9. When light of wavelength λ is incident on a photosensitive surface, the stopping potential is V. If the surface is illuminated with light of wavelength 2λ, the stopping potential becomes V_0. The threshold wavelength for the surface is:

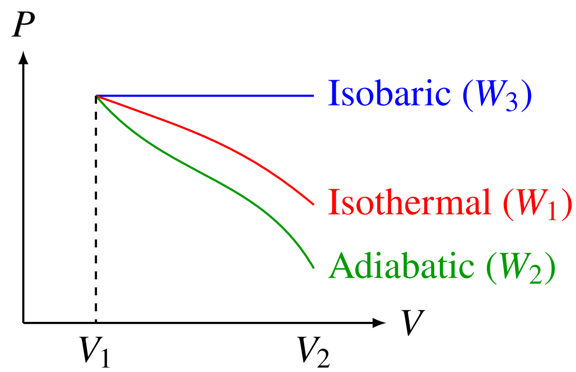
(A) $\frac{2\lambda V}{V-V_0}$

(B) $\frac{\lambda(V-2V_0)}{V-V_0}$

(C) $\frac{\lambda V}{V-2V_0}$

(D) $\frac{2\lambda(V-V_0)}{V-2V_0}$

Q10. An ideal gas expands from volume V_1 to V_2 via three different processes: isothermal, adiabatic, and isobaric. Let W_1, W_2, and W_3 be the work done respectively. If $V_2 > V_1$, then the correct order of work done is:



(A) $W_3 > W_1 > W_2$

(B) $W_1 > W_2 > W_3$

(C) $W_3 > W_2 > W_1$

(D) $W_2 > W_1 > W_3$

Q11. A body of mass 2 kg is moving under the influence of a central force field. Its potential energy is given by $U(r) = 3r^2 + 4$, where r is the distance from the origin. If the body moves in a circular orbit of radius 2 m, its speed must be:

(A) $\sqrt{6}$ m/s

(B) $2\sqrt{3}$ m/s

(C) 6 m/s

(D) 12 m/s

Q12. A resistor of 10 Ω, an inductor of reactance 20 Ω, and a capacitor of reactance 10 Ω are connected in series across an AC source of voltage $V = 100\sqrt{2}\sin(\omega t)$ V. The power factor of the circuit is:

$$V = 100\sqrt{2}\sin(\omega t)\ \text{V}$$

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

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

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

(D) 1

Q13. A ray of light is incident at an angle of 60° on one face of an equilateral glass prism of refractive index $\sqrt{3}$. The angle of deviation produced by the prism is:

(A) 30°

(B) 45°

(C) 60°

(D) 90°

Q14. In a hydrogen-like atom, the energy of an electron in the n-th orbit is given by $E_n = -\frac{54.4}{n^2}$ eV. The atomic number Z of this atom is:

(A) 1

(B) 2

(C) 3

(D) 4

Q15. The efficiency of a Carnot engine working between temperatures T_1 and T_2 ($T_1 > T_2$) is η. If both the source and sink temperatures are increased by 100 K, the new efficiency η' will satisfy:

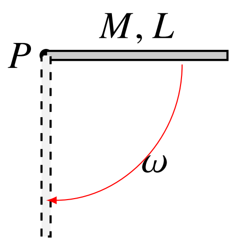
(A) $\eta' > \eta$

(B) $\eta' < \eta$

(C) $\eta' = \eta$

(D) $\eta' = 2\eta$

Q16. A uniform rod of mass M and length L is pivoted smoothly at one end. It is released from a horizontal position. The angular velocity of the rod when it passes through the vertical position is:



(A) $\sqrt{\frac{g}{L}}$

(B) $\sqrt{\frac{2g}{L}}$

(C) $\sqrt{\frac{3g}{L}}$

(D) $\sqrt{\frac{6g}{L}}$

Q17. A charging current of 2.0 A flows into a parallel-plate capacitor with circular plates of radius 10 cm. The displacement current between the plates in the region enclosed by the plates is:

(A) 0.5 A

(B) 1.0 A

(C) 2.0 A

(D) 4.0 A

Q18. A wave pulse traveling along a string is described by the equation $y(x,t) = \frac{0.05}{2+(x-4t)^2}$, where x and y are in meters and t is in seconds. The speed and direction of the wave are:

(A) 2 m/s in the $+x$ direction

(B) 4 m/s in the $+x$ direction

(C) 2 m/s in the $-x$ direction

(D) 4 m/s in the $-x$ direction

Q19. The configuration of common-emitter amplifier has a current gain $\beta = 100$. If the collector current changes by 2 mA, the corresponding change in the base current will be:

(A) 20 μA

(B) 50 μA

(C) 200 μA

(D) 2 mA

Q20. Two absolute temperature 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) $T_A = \frac{2}{3}T_B$

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

Q21. A particle of mass m is projected with a velocity $v = kv_e$ from the surface of the Earth, where v_e is the escape velocity and $k < 1$. The maximum height reached by the particle from the center of the Earth is (R is the radius of the Earth):

(A) $\frac{R}{1-k^2}$

(B) $\frac{R}{k^2}$

(C) $R(1 - k^2)$

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

Q22. A wire of resistance R is stretched uniformly to twice its original length. It is then cut into two equal halves, and these halves are connected in parallel across a battery. The equivalent resistance of the parallel combination is:

(A) $\frac{R}{4}$

(B) $\frac{R}{2}$

(C) R

(D) $2R$

Q23. In an astronomical telescope, the focal lengths of the objective and objective lens are 100 cm and 5 cm respectively. For normal adjustment, the distance between the two lenses is:

(A) 95 cm

(B) 105 cm

(C) 500 cm

(D) 20 cm

Q24. The de Broglie wavelength of an electron accelerated from rest through a potential difference of V volts is λ. If the potential difference is increased to $4V$, the new de Broglie wavelength becomes:

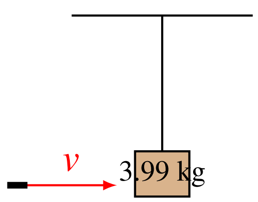
(A) 2λ

(B) 4λ

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

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

Q25. A bullet of mass 10 g moving horizontally with a velocity of 400 m/s strikes a wood block of mass 3.99 kg suspended by a long inextensible string. The bullet gets embedded in the block. The vertical height to which the block rises is (take $g = 10$ m/s^2):



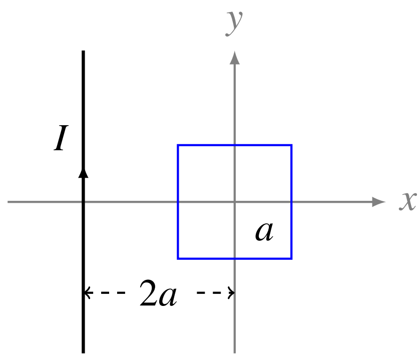
(A) 5 cm

(B) 10 cm

(C) 20 cm

(D) 40 cm

Q26. A square loop of wire of side length a lies in the xy-plane with its center at the origin. A long straight wire carrying a constant current I lies along the line $x = -2a$ parallel to the y-axis. The total magnetic flux passing through the square loop is:



(A) $\frac{\mu_0 I a}{2\pi} \ln(3)$

(B) $\frac{\mu_0 I a}{2\pi} \ln\left(\frac{3}{2}\right)$

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

(D) $\frac{\mu_0 I a}{\pi} \ln\left(\frac{5}{3}\right)$

Q27. The fundamental frequency of a closed organ pipe is equal to the first overtone frequency of an open organ pipe. If the length of the open organ pipe is 60 cm, the length of the closed organ pipe is:

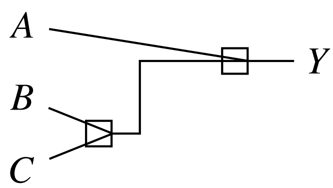
(A) 15 cm

(B) 30 cm

(C) 7.5 cm

(D) 45 cm

Q28. The output Y of the logic circuit shown below is required to be 1. What must be the inputs A, B, and C if the circuit consists of an AND gate receiving inputs from A and the output of an OR gate fed by B and C?



(A) $A = 0, B = 1, C = 1$

(B) $A = 1, B = 0, C = 0$

(C) $A = 1, B = 1, C = 0$

(D) $A = 0, B = 0, C = 1$

Q29. A block of mass m attached to a spring of spring constant k oscillates on a smooth horizontal floor. The block is released from rest at a distance X_0 from the equilibrium position. The average power delivered by the spring to the block during its motion from the extreme position to the equilibrium position is:

(A) $\frac{1}{4}X_0^2\sqrt{mk}$

(B) $\frac{1}{\pi}X_0^2\sqrt{\frac{k^3}{m}}$

(C) $\frac{1}{2\pi}X_0^2\sqrt{\frac{k^3}{m}}$

(D) $\frac{1}{\pi}X_0^2\sqrt{mk}$

Q30. A circular loop of radius R carries a current I. The magnetic dipole moment of the loop is proportional to:

(A) R

(B) R^2

(C) $1/R$

(D) $1/R^2$

Q31. An unpolarized light beam of intensity I_0 is incident on a stack of two polarizing sheets. The transmission axis of the second sheet is oriented at $30°$ relative to the axis of the first sheet. The intensity of the light emerging from the second sheet is:

(A) $\frac{3}{4}I_0$

(B) $\frac{3}{8}I_0$

(C) $\frac{1}{4}I_0$

(D) $\frac{1}{8}I_0$

Q32. In a nuclear reaction, a stable nucleus X absorbs a low-energy neutron and emits an alpha particle, transforming into a Lithium-7 nucleus ($^{7}_{3}$Li). The original nucleus X was:

(A) $^{10}_{5}$B

(B) $^{9}_{4}$Be

(C) $^{12}_{6}$C

(D) $^{11}_{5}$B

Q33. A solid metal sphere of radius R is charged to a potential V. The electrical potential at a distance $R/3$ from the center of the sphere is:

(A) $V/3$

(B) $V/9$

(C) V

(D) $3V$

Q34. 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:

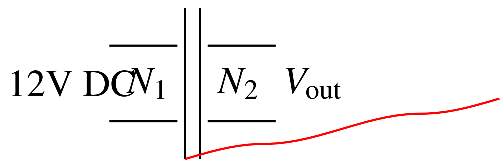
(A) -3 m/s

(B) 3 m/s

(C) -12 m/s

(D) 0 m/s

Q35. A transformer has 500 turns in the primary coil and 1000 turns in the secondary coil. If a 12 V DC battery is connected across the primary coil, the voltage developed across the secondary coil will be:



(A) 24 V

(B) 6 V

(C) 0 V

(D) 12 V

Q36. Two coherent monochromatic light beams of intensities I and $4I$ superimpose. The maximum and minimum possible intensities in the resulting interference pattern are respectively:

(A) $5I$ and $3I$

(B) $9I$ and I

(C) $5I$ and I

(D) $9I$ and $3I$

Q37. The binding energy per nucleon for a deuteron ($^2_1$H) and a helium nucleus ($^4_2$He) are 1.1 MeV and 7.0 MeV respectively. If two deuterons fuse together to form a helium nucleus, the total energy released in the process is:

(A) 23.6 MeV

(B) 25.8 MeV

(C) 28.0 MeV

(D) 30.2 MeV

Q38. One mole of a monoatomic ideal gas ($\gamma = 5/3$) is mixed with one mole of a diatomic ideal gas ($\gamma = 7/5$). The effective value of γ for the mixture is:

(A) 1.50

(B) 1.45

(C) 1.40

(D) 1.60

Q39. A simple pendulum has a time period T_1 when on the surface of the Earth. When taken to a height equal to the radius of the Earth R, its time period becomes T_2. The ratio T_2/T_1 is:

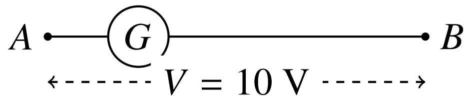
(A) 2

(B) 4

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

(D) $\sqrt{2}$

Q40. A galvanometer of resistance 50 Ω gives full-scale deflection for a current of 2 mA. To convert it into a voltmeter capable of measuring up to 10 V, the resistance that should be connected in series with it is:



(A) 4950 Ω

(B) 5000 Ω

(C) 4500 Ω

(D) 4900 Ω

Detailed Solutions

Q1.

Solution

Concept: When a block is placed on an accelerating wedge, we analyze its motion using a pseudo force in the non-inertial reference frame of the wedge. For the block to remain stationary relative to the wedge, the net force acting on it parallel to the inclined surface must be zero.

Solution: Step 1: Let us observe the block of mass m from the reference frame of the wedge accelerating horizontally to the right with acceleration a. Since this is an accelerating, non-inertial frame of reference, a pseudo force must be applied to the block. The direction of this pseudo force is opposite to the acceleration of the wedge, which means it acts horizontally to the left with a magnitude equal to ma.

Step 2: Let us resolve the forces acting on the block along the inclined surface and perpendicular to it. The real forces acting on the block are the gravitational force mg acting vertically downwards and the normal reaction force N acting perpendicular to the inclined surface of the wedge.

Step 3: Resolving the gravitational force mg along the inclined plane, we get a component $mg\sin\theta$ acting down the incline. Resolving the pseudo force ma along the inclined plane, we get a component $ma\cos\theta$ acting up the incline.

Step 4: For the block to remain completely stationary relative to the wedge, the forces acting along the inclined surface must balance each other perfectly. Therefore, we can equate the two opposing components along the incline:

$$ma\cos\theta = mg\sin\theta$$

Step 5: Simplifying the equation by canceling the mass m from both sides, we get:

$$a\cos\theta = g\sin\theta$$

Dividing both sides by $\cos\theta$, we obtain the required expression for the acceleration:

$$a = g\frac{\sin\theta}{\cos\theta} = g\tan\theta$$

Final Answer: $g\tan\theta$

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept: The capacitance of a parallel-plate capacitor depends directly on the plate area, the dielectric constant of the medium between the plates, and inversely on the separation distance between the plates. The formula is given by $C = \frac{K\epsilon_0 A}{d}$.

Solution: Step 1: Write down the initial capacitance of the parallel-plate capacitor with air between its plates. The dielectric constant for air is $K_{\text{air}} = 1$. Let the plate area be A and the initial plate separation distance be d. The initial capacitance C is expressed as:

$$C = \frac{\epsilon_0 A}{d}$$

Step 2: Identify the modifications made to the capacitor system. According to the problem statement, the distance between the plates is halved, meaning the new distance d' becomes:

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

Additionally, a dielectric material with a dielectric constant $K = 4$ is introduced to fill the entire space between the plates.

Step 3: Substitute the new parameters into the generalized capacitance formula to find the expression for the new capacitance C':

$$C' = \frac{K\epsilon_0 A}{d'} = \frac{4 \cdot \epsilon_0 A}{\left(\frac{d}{2}\right)}$$

Step 4: Simplify the fraction by moving the factor of 2 from the denominator of the denominator to the numerator:

$$C' = 4 \times 2 \times \frac{\epsilon_0 A}{d} = 8\left(\frac{\epsilon_0 A}{d}\right)$$

Step 5: Substitute the initial capacitance C back into the simplified expression to find the final relation:

$$C' = 8C$$

Thus, the capacitance increases by a factor of 8.

Final Answer: $\boxed{8C}$

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: In Young's double-slit experiment, the fringe width β is defined as the distance between two consecutive bright or dark fringes. It depends directly on the wavelength of light λ and the distance to the screen D, and inversely on the slit separation d, according to the formula $\beta = \frac{\lambda D}{d}$.

Solution: Step 1: Write down the formula for the initial fringe width β under the baseline conditions where the slit separation is d and the distance from the slits to the screen is D:

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

Step 2: Analyze the changes given in the problem statement. The slit separation is doubled, which means the new separation d' is:

$$d' = 2d$$

The distance between the slits and the screen is halved, meaning the new distance D' is:

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

Step 3: Set up the equation for the new fringe width β' using the altered values of distance and slit separation:

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

Step 4: Simplify the expression by gathering the numerical constants together:

$$\beta' = \frac{1}{2 \times 2} \times \frac{\lambda D}{d} = \frac{1}{4}\left(\frac{\lambda D}{d}\right)$$

Step 5: Relate the new fringe width to the original fringe width β by substituting the expression from Step 1:

$$\beta' = \frac{1}{4}\beta$$

Therefore, the fringe width changes by a factor of $\frac{1}{4}$.

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

Answer: (D)

Go Back to Question 3

Q4.

Solution

Concept: Radioactive decay follows a statistical exponential decay law. The mass of a remaining undecayed radioactive sample after a certain elapsed time can be calculated using the number of half-lives that have passed, given by the relation $N = N_0 \left(\frac{1}{2}\right)^n$.

Solution: Step 1: Extract the given physical parameters from the question text. The initial mass of the sample M_0 is given as 64 g. The half-life period $T_{1/2}$ of the sample is equal to 4 hours. The total elapsed time t for the decay process is 20 hours.

Step 2: Determine the total number of half-lives, denoted as n, that have occurred during the total elapsed time interval of 20 hours. This is calculated by dividing the total time by the half-life period:

$$n = \frac{t}{T_{1/2}} = \frac{20 \text{ hours}}{4 \text{ hours}} = 5$$

Step 3: Apply the radioactive decay formula that relates the remaining mass M to the initial mass M_0 and the number of elapsed half-lives n:

$$M = M_0 \left(\frac{1}{2}\right)^n$$

Step 4: Substitute the values of $M_0 = 64$ g and $n = 5$ into the equation:

$$M = 64 \times \left(\frac{1}{2}\right)^5$$

Step 5: Evaluate the exponential term and calculate the final remaining mass:

$$\left(\frac{1}{2}\right)^5 = \frac{1}{32}$$

$$M = \frac{64}{32} = 2 \text{ g}$$

Thus, exactly 2 g of the radioactive sample remains undecayed after 20 hours.

Final Answer: 2 g

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: The work done by an ideal gas during a quasi-static thermodynamic process involving a volume change is calculated by integrating the pressure with respect to volume, expressed mathematically as $W = \int P\,dV$ between the initial and final volume limits.

Solution: Step 1: Identify the relation between pressure P and volume V provided for the process. The pressure varies as a function of volume according to the equation:

$$P = kV^2$$

where k is a positive constant. The volume expands from an initial value $V_i = V_0$ to a final value $V_f = 2V_0$.

Step 2: Set up the definitive integral for work done by substituting the given pressure relation into the standard work formula:

$$W = \int_{V_0}^{2V_0} P\,dV = \int_{V_0}^{2V_0} kV^2\,dV$$

Step 3: Perform the integration with respect to V. Since k is a constant, it can be taken outside the integration sign:

$$W = k\left[\frac{V^3}{3}\right]_{V_0}^{2V_0} = \frac{k}{3}\left[V^3\right]_{V_0}^{2V_0}$$

Step 4: Apply the upper and lower limits of integration to evaluate the expression inside the brackets:

$$\left[V^3\right]_{V_0}^{2V_0} = (2V_0)^3 - (V_0)^3 = 8V_0^3 - V_0^3 = 7V_0^3$$

Step 5: Combine the terms to find the total work done by the gas during this expansion process:

$$W = \frac{k}{3}\left(7V_0^3\right) = \frac{7}{3}kV_0^3$$

Final Answer: $\boxed{\frac{7}{3}kV_0^3}$

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: The linear acceleration of a rigid body rolling down an inclined plane without slipping depends on the inclination angle and its mass distribution, described by the acceleration formula $a = \frac{g \sin\theta}{1+\frac{I}{MR^2}}$, where I is the moment of inertia about the center of mass.

Solution: Step 1: State the standard formula for the linear acceleration of a symmetric object rolling down an incline of angle θ without slipping:

$$a = \frac{g \sin\theta}{1+\beta}$$

where $\beta = \frac{I}{MR^2}$ is the dimensionless moment of inertia coefficient for the specific geometric shape.
Step 2: Find the value of β for a solid sphere. The moment of inertia of a solid sphere of mass M and radius R about its central axis is $I_{\text{sphere}} = \frac{2}{5}MR^2$. Therefore, its coefficient is:

$$\beta_{\text{sphere}} = \frac{2}{5}$$

Substitute this into the acceleration formula to find a_{sphere}:

$$a_{\text{sphere}} = \frac{g \sin\theta}{1+\frac{2}{5}} = \frac{g \sin\theta}{\frac{7}{5}} = \frac{5}{7} g \sin\theta$$

Step 3: Find the value of β for a solid cylinder. The moment of inertia of a solid cylinder of mass M and radius R about its longitudinal geometry axis is $I_{\text{cylinder}} = \frac{1}{2}MR^2$. Thus, its coefficient is:

$$\beta_{\text{cylinder}} = \frac{1}{2}$$

Substitute this into the acceleration formula to find a_{cylinder}:

$$a_{\text{cylinder}} = \frac{g \sin\theta}{1+\frac{1}{2}} = \frac{g \sin\theta}{\frac{3}{2}} = \frac{2}{3} g \sin\theta$$

Step 4: Set up the ratio of the linear acceleration of the solid sphere to that of the solid cylinder as requested:

$$\frac{a_{\text{sphere}}}{a_{\text{cylinder}}} = \frac{\frac{5}{7} g \sin\theta}{\frac{2}{3} g \sin\theta} = \frac{\frac{5}{7}}{\frac{2}{3}}$$

Step 5: Simplify the fraction by multiplying the numerator by the reciprocal of the denominator:

$$\frac{a_{\text{sphere}}}{a_{\text{cylinder}}} = \frac{5}{7} \times \frac{3}{2} = \frac{15}{14}$$

Thus, the ratio of their linear accelerations is 15 : 14.
Final Answer: 15 : 14

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The magnitude of the magnetic field produced by a long straight current-carrying wire at a perpendicular distance r is given by Ampere's Law as $B = \frac{\mu_0 I}{2\pi r}$. The net magnetic field due to multiple wires is the vector sum of individual fields.

Solution: Step 1: Analyze the direction of the magnetic fields produced by the two parallel wires. Both wires carry current in the same direction (into or out of the page). By the right-hand grip rule, the magnetic fields produced by the two currents in the region between the wires are in opposite directions. Therefore, a point where the net magnetic field is zero must lie somewhere on the line segment connecting the two wires.

Step 2: Let the point where the net magnetic field is zero be located at a distance x from the first wire carrying current I. Since the total distance separating the two wires is d, the distance of this point from the second wire carrying current $2I$ must be $(d - x)$.

Step 3: Write down the expressions for the magnitudes of the magnetic fields B_1 and B_2 produced by the first and second wires respectively at this specific point:

$$B_1 = \frac{\mu_0 I}{2\pi x}$$

$$B_2 = \frac{\mu_0 (2I)}{2\pi (d - x)}$$

Step 4: Set the two opposing magnetic field magnitudes equal to each other so that they cancel out, yielding a net magnetic field of zero:

$$\frac{\mu_0 I}{2\pi x} = \frac{\mu_0 (2I)}{2\pi (d - x)}$$

Step 5: Cancel out the common factors μ_0, I, and 2π from both sides of the equation to simplify the expression:

$$\frac{1}{x} = \frac{2}{d - x}$$

Cross-multiply to solve for x:

$$d - x = 2x$$

$$d = 3x \implies x = \frac{d}{3}$$

Final Answer: $\boxed{\frac{d}{3}}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: In simple harmonic motion, the total mechanical energy is conserved and shared between kinetic energy and potential energy. The potential energy at displacement x is $PE = \frac{1}{2}kx^2$ and the kinetic energy is $KE = \frac{1}{2}k(A^2 - x^2)$.

Solution: Step 1: Write down the basic formulas for kinetic energy (KE) and potential energy (PE) of a particle performing simple harmonic motion with amplitude A at any displacement x from its mean equilibrium position:

$$PE = \frac{1}{2}kx^2$$

$$KE = \frac{1}{2}k(A^2 - x^2)$$

where k is the force constant of the oscillating system.

Step 2: Use the condition specified in the problem statement, which requires the kinetic energy to be exactly equal to three times the potential energy at the given position:

$$KE = 3 \cdot PE$$

Step 3: Substitute the explicit algebraic expressions for KE and PE from Step 1 into the condition equation:

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

Step 4: Cancel the common factor $\frac{1}{2}k$ from both sides of the equation to simplify the expression:

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

Step 5: Rearrange the algebraic terms to isolate the variable x^2 on one side:

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

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

Taking the square root on both sides to find the positive displacement magnitude x:

$$x = \sqrt{\frac{A^2}{4}} = \frac{A}{2}$$

Final Answer: $\boxed{\frac{A}{2}}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: Einstein's photoelectric equation relates the maximum kinetic energy of emitted photoelectrons (or the stopping potential V) to the incident light frequency (or wavelength λ) and the work function ϕ of the surface via $eV = \frac{hc}{\lambda} - \phi$.

Solution: Step 1: Set up Einstein's photoelectric equation for the first scenario where the incident light wavelength is λ and the stopping potential is measured to be V:

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

where h is Planck's constant, c is the speed of light, and ϕ is the work function of the material.

Step 2: Set up the equation for the second scenario where the incident light wavelength is doubled to 2λ and the observed stopping potential is V_0:

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

Step 3: We eliminate the work function ϕ to find a relationship for $\frac{hc}{\lambda}$. Subtract Equation 2 from Equation 1:

$$e(V - V_0) = \left(\frac{hc}{\lambda} - \phi\right) - \left(\frac{hc}{2\lambda} - \phi\right)$$

$$e(V - V_0) = \frac{hc}{\lambda} - \frac{hc}{2\lambda} = \frac{hc}{2\lambda}$$

This implies that:

$$\frac{hc}{\lambda} = 2e(V - V_0) \quad \text{— (Equation 3)}$$

Step 4: Substitute the expression for $\frac{hc}{\lambda}$ from Equation 3 back into Equation 1 to find the work function ϕ in terms of potentials:

$$eV = 2e(V - V_0) - \phi$$

$$\phi = 2eV - 2eV_0 - eV = e(V - 2V_0)$$

Step 5: The threshold wavelength λ_0 is defined by the relation $\phi = \frac{hc}{\lambda_0}$. Therefore, $\lambda_0 = \frac{hc}{\phi}$. Substitute the values of hc from Equation 3 ($hc = 2e\lambda(V - V_0)$) and ϕ:

$$\lambda_0 = \frac{2e\lambda(V - V_0)}{e(V - 2V_0)} = \frac{2\lambda(V - V_0)}{V - 2V_0}$$

Final Answer: $\boxed{\frac{2\lambda(V - V_0)}{V - 2V_0}}$

Answer: (D)

Go Back to Question 9

Q10.

Solution

Concept: The work done by a gas during an expansion process is represented by the area under the curve on a Pressure-Volume (P-V) diagram. By comparing the slopes and paths of isobaric, isothermal, and adiabatic lines, we can determine the relative work done.

Solution: Step 1: Understand that during gas expansion from an initial volume V_1 to a larger final volume V_2, the work done $W = \int P\, dV$ corresponds directly to the total area bounded under the process curve down to the volume axis.

Step 2: Analyze the isobaric process (constant pressure). The pressure remains at its maximum initial value throughout the expansion. Thus, the curve is a horizontal straight line at the highest level, enclosing the maximum possible rectangular area underneath it. Hence, W_3 is the largest.

Step 3: Analyze the isothermal expansion (constant temperature). The pressure drops as volume increases according to $P \propto \frac{1}{V}$. The curve slopes downwards, but maintains a higher profile than the adiabatic curve because heat is absorbed to maintain temperature.

Step 4: Analyze the adiabatic expansion (no heat exchange). The pressure drops much more steeply according to $P \propto \frac{1}{V^\gamma}$, where $\gamma > 1$. Because it falls rapidly, the adiabatic curve lies completely below the isothermal curve on the P-V plane. Thus, it encloses the smallest area.

Step 5: Compare the areas under the three curves visually or mathematically. The area under the isobaric line is the greatest, followed by the isothermal curve, and the area under the adiabatic curve is the smallest. Therefore, the exact sequence of work done is:

$$W_3 > W_1 > W_2$$

Final Answer: $\boxed{W_3 > W_1 > W_2}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: A conservative central force is related to the potential energy function by the derivative $F(r) = -\frac{dU}{dr}$. For a body moving in a steady circular orbit, this attractive radial force provides the necessary centripetal force $\frac{mv^2}{r}$.

Solution: Step 1: Given the potential energy function $U(r) = 3r^2 + 4$, find the expression for the radial force acting on the body by taking the negative derivative of the potential energy with respect to distance r:

$$F(r) = -\frac{dU}{dr} = -\frac{d}{dr}(3r^2 + 4) = -6r$$

The negative sign indicates that the force is attractive, directed towards the origin. The magnitude of the force is $6r$.

Step 2: For a body of mass m to maintain a stable circular orbit of radius r with a constant tangential speed v, the magnitude of the central force must equal the required centripetal force:

$$|F(r)| = \frac{mv^2}{r}$$

Step 3: Equate the force magnitude obtained in Step 1 to the centripetal force expression:

$$6r = \frac{mv^2}{r}$$

Step 4: Substitute the given numerical constants into the balance equation. The mass of the body $m = 2$ kg, and the radius of the circular orbit $r = 2$ m:

$$6(2) = \frac{2 \cdot v^2}{2}$$

Step 5: Simplify the equation to solve for the orbital speed v:

$$12 = v^2$$

$$v = \sqrt{12} = \sqrt{4 \times 3} = 2\sqrt{3} \text{ m/s}$$

Final Answer: $2\sqrt{3}$ m/s

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The power factor of an alternating current (AC) series circuit is defined as $\cos\phi = \frac{R}{Z}$, where R is the net resistance and Z is the total impedance of the circuit given by $Z = \sqrt{R^2 + (X_L - X_C)^2}$.

Solution: Step 1: Extract the given electrical parameters from the circuit details. The resistance $R = 10\ \Omega$, the inductive reactance $X_L = 20\ \Omega$, and the capacitive reactance $X_C = 10\ \Omega$.

Step 2: Calculate the total impedance Z of the series LCR circuit using the standard vector impedance formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Step 3: Substitute the numerical values into the impedance equation and compute the result:

$$Z = \sqrt{10^2 + (20 - 10)^2}$$

$$Z = \sqrt{10^2 + 10^2} = \sqrt{100 + 100} = \sqrt{200} = 10\sqrt{2}\ \Omega$$

Step 4: Recall the definition of the power factor for an AC circuit, which is the cosine of the phase angle ϕ between voltage and current:

$$\text{Power Factor} = \cos\phi = \frac{R}{Z}$$

Step 5: Substitute the value of resistance $R = 10\ \Omega$ and total impedance $Z = 10\sqrt{2}\ \Omega$ into the power factor equation:

$$\cos\phi = \frac{10}{10\sqrt{2}} = \frac{1}{\sqrt{2}}$$

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

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: The deviation δ produced by a triangular prism is given by the formula $\delta = i_1 + i_2 - A$, where i_1 is the initial angle of incidence, i_2 is the angle of emergence from the second face, and A is the refracting angle of the prism.

Solution: Step 1: Identify the parameters of the equilateral prism. An equilateral prism has a refracting angle $A = 60^\circ$. The refractive index of the glass material is $\mu = \sqrt{3}$, and the angle of incidence on the first face is $i_1 = 60^\circ$.

Step 2: Apply Snell's law at the first refracting face to find the angle of refraction r_1:

$$1 \cdot \sin i_1 = \mu \cdot \sin r_1$$

$$\sin 60^\circ = \sqrt{3} \cdot \sin r_1 \implies \frac{\sqrt{3}}{2} = \sqrt{3} \cdot \sin r_1$$

$$\sin r_1 = \frac{1}{2} \implies r_1 = 30^\circ$$

Step 3: Use the geometric relationship between the prism angle A and the internal refraction angles r_1 and r_2 to find r_2:

$$r_1 + r_2 = A \implies 30^\circ + r_2 = 60^\circ \implies r_2 = 30^\circ$$

Step 4: Apply Snell's law at the second face to determine the angle of emergence i_2:

$$\mu \cdot \sin r_2 = 1 \cdot \sin i_2$$

$$\sqrt{3} \cdot \sin 30^\circ = \sin i_2 \implies \sqrt{3} \cdot \frac{1}{2} = \sin i_2$$

$$\sin i_2 = \frac{\sqrt{3}}{2} \implies i_2 = 60^\circ$$

Step 5: Calculate the total angle of deviation δ using the values computed for i_1, i_2, and A:

$$\delta = i_1 + i_2 - A = 60^\circ + 60^\circ - 60^\circ = 60^\circ$$

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

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: The energy of an electron in the n-th orbit of a hydrogen-like atom is given by the Bohr formula $E_n = -13.6\frac{Z^2}{n^2}$ eV, where Z is the atomic number representing the number of protons in the nucleus.

Solution: Step 1: Write down the general expression for the quantized energy levels of a hydrogen-like single-electron system according to the Bohr model:

$$E_n = -13.6\frac{Z^2}{n^2}\text{ eV}$$

Step 2: Compare this theoretical equation with the specific empirical equation provided in the problem statement:

$$E_n = -\frac{54.4}{n^2}\text{ eV}$$

Step 3: Equate the coefficients of the $\frac{1}{n^2}$ terms from both expressions since they must represent identical physical quantities:

$$-13.6Z^2 = -54.4$$

Step 4: Solve for Z^2 by dividing both sides of the equation by -13.6:

$$Z^2 = \frac{-54.4}{-13.6}$$

$$Z^2 = 4$$

Step 5: Take the positive square root to find the atomic number Z, which must be a positive integer:

$$Z = \sqrt{4} = 2$$

The atomic number $Z = 2$ corresponds to a singly ionized Helium atom (He^+).

Final Answer: 2

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: The efficiency of a perfectly reversible Carnot thermal engine depends solely on the absolute temperatures of the heat source (T_1) and the heat sink (T_2), given by the expression $\eta = 1 - \frac{T_2}{T_1}$.

Solution: Step 1: State the expression for the baseline efficiency η of the Carnot engine operating between the source temperature T_1 and sink temperature T_2:

$$\eta = 1 - \frac{T_2}{T_1}$$

Step 2: Define the new temperatures after both are increased by a constant value $\Delta T = 100$ K. The new source temperature is $T_1' = T_1 + 100$ and the new sink temperature is $T_2' = T_2 + 100$. Write the expression for the modified efficiency η':

$$\eta' = 1 - \frac{T_2 + 100}{T_1 + 100}$$

Step 3: To determine whether η' is greater than or less than η, we must compare the fractions $\frac{T_2}{T_1}$ and $\frac{T_2+100}{T_1+100}$. Let us analyze the effect of adding a positive constant to both the numerator and denominator of a fraction less than 1.

Step 4: Since $T_1 > T_2$, the ratio $\frac{T_2}{T_1} < 1$. Mathematically, adding the same positive quantity to both the numerator and denominator of a fraction less than 1 increases the total value of the fraction:

$$\frac{T_2 + 100}{T_1 + 100} > \frac{T_2}{T_1}$$

Step 5: Multiply by -1 on both sides (which reverses the inequality sign) and add 1 to both sides:

$$-\frac{T_2 + 100}{T_1 + 100} < -\frac{T_2}{T_1}$$

$$1 - \frac{T_2 + 100}{T_1 + 100} < 1 - \frac{T_2}{T_1} \implies \eta' < \eta$$

Final Answer: $\boxed{\eta' < \eta}$

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: For a rigid body rotating about a fixed axis, we apply the Law of Conservation of Mechanical Energy. The loss in gravitational potential energy of the center of mass equals the gain in rotational kinetic energy, $\Delta PE = \frac{1}{2}I\omega^2$.

Solution: Step 1: Determine the location of the center of mass of the uniform rod and its initial potential energy. The rod has a mass M and length L, so its center of mass lies exactly at its geometric midpoint, at a distance of $\frac{L}{2}$ from the pivot. Initially, the rod is held horizontally.

Step 2: When the rod swings down to the vertical position, the center of mass drops by a vertical height equal to $h = \frac{L}{2}$. Calculate the total loss in gravitational potential energy (ΔPE):

$$\Delta PE = Mgh = Mg\left(\frac{L}{2}\right)$$

Step 3: Find the rotational kinetic energy of the rod at the vertical position. The moment of inertia I of a uniform rod of mass M and length L pivoted at one of its extreme ends is:

$$I = \frac{1}{3}ML^2$$

The rotational kinetic energy gained is given by $KE_{\text{rot}} = \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{1}{3}ML^2\right)\omega^2 = \frac{1}{6}ML^2\omega^2$.

Step 4: Equate the loss in potential energy to the gain in rotational kinetic energy according to energy conservation:

$$Mg\left(\frac{L}{2}\right) = \frac{1}{6}ML^2\omega^2$$

Step 5: Cancel the mass M and one factor of length L from both sides, and solve for the angular velocity ω:

$$\frac{g}{2} = \frac{1}{6}L\omega^2 \implies \omega^2 = \frac{6g}{2L} = \frac{3g}{L}$$

$$\omega = \sqrt{\frac{3g}{L}}$$

Final Answer: $\boxed{\sqrt{\frac{3g}{L}}}$

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept: According to Maxwell's generalization of Ampere's Law, the displacement current I_d created by a time-varying electric field between the plates of a capacitor is always equal in magnitude to the conduction current I_c flowing through the connecting wires, ensuring continuity of current.

Solution: Step 1: Understand the principle of continuity of current established by Maxwell. A conduction current I_c represents the actual flow of physical charge carriers along a conducting wire leading to a capacitor plate. This current stops at the surface of the plate.

Step 2: Inside the gap between the plates of the capacitor, there are no physical charge carriers to conduct electric current. Instead, the accumulating charge on the plates produces a time-varying electric field $\vec{E}$ within the gap space.

Step 3: Maxwell defined the displacement current I_d in terms of the rate of change of the electric flux Φ_e through a surface between the plates as:

$$I_d = \epsilon_0 \frac{d\Phi_e}{dt}$$

Step 4: By applying Gauss's Law and considering the complete area enclosed by the circular parallel plates, the total displacement current generated inside the dielectric gap must perfectly match the external conduction current feeding the plates at every instant to preserve Kirchhoff's Current Law:

$$I_d = I_c$$

Step 5: Given that the external charging conduction current I_c is specified as 2.0 A, the total displacement current I_d within the region enclosed between the plates is also exactly 2.0 A. The radius of the plates is extra information.

Final Answer: 2.0 A

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept: A one-dimensional progressive wave or moving pulse can be represented mathematically by any function of the form $y(x,t) = f(x \mp vt)$. The constant v represents the speed of propagation, and the sign determines the direction along the axis.

Solution: Step 1: Examine the mathematical function given for the traveling wave pulse on the string:

$$y(x,t) = \frac{0.05}{2 + (x - 4t)^2}$$

Step 2: Identify the core variable combination inside the function that depends on both space x and time t. We notice that the expression contains the specific binomial linear term:

$$(x - 4t)$$

Step 3: Compare this term directly with the standard mathematical form for a non-dispersive wave pulse moving with speed v, which is represented generally as $(x - vt)$ or $(vt - x)$.

Step 4: By comparing the terms $(x - 4t)$ and $(x - vt)$, we can immediately deduce the numerical value of the wave propagation velocity v:

$$v = 4 \text{ m/s}$$

Step 5: Determine the direction of propagation from the sign connecting the space and time variables. A negative sign in the combination $(x - vt)$ indicates that the wave profile translates towards the positive x-direction as time increases. Thus, the speed is 4 m/s in the $+x$ direction.

Final Answer: 4 m/s in the $+x$ direction

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept: In a common-emitter transistor amplifier configuration, the alternating current gain β is defined as the ratio of the change in collector current ΔI_c to the corresponding change in base current ΔI_b, expressed as $\beta = \frac{\Delta I_c}{\Delta I_b}$.

Solution: Step 1: State the definition of the common-emitter current amplification factor β, which relates small variations in the output collector current to small variations in the input base current:

$$\beta = \frac{\Delta I_c}{\Delta I_b}$$

Step 2: Identify the given numerical values from the problem description. The current gain coefficient is $\beta = 100$. The change in the collector current is given as $\Delta I_c = 2 \text{ mA} = 2 \times 10^{-3}$ A.

Step 3: Rearrange the current gain formula to isolate the unknown variable, which is the change in the base current ΔI_b:

$$\Delta I_b = \frac{\Delta I_c}{\beta}$$

Step 4: Substitute the given values into the rearranged equation to compute the change in base current:

$$\Delta I_b = \frac{2 \text{ mA}}{100} = 0.02 \text{ mA}$$

Step 5: Convert the calculated value from milliamperes (mA) to microamperes (μA) to match the standard units used in the options:

$$\Delta I_b = 0.02 \times 10^{-3} \text{ A} = 20 \times 10^{-6} \text{ A} = 20 \ \mu\text{A}$$

Final Answer: $\boxed{20 \ \mu\text{A}}$

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept: An absolute thermodynamic temperature scale is defined linearly with respect to a single fixed reference point, usually chosen as the triple point of water (273.16 K). The ratio of temperature readings on two such scales is equal to the ratio of their defined triple point values.

Solution: Step 1: Understand that for any absolute temperature scales A and B, the temperature reading is directly proportional to the physical thermodynamic state, starting from absolute zero (0 K). Therefore, we can write:

$$T_A = k_A \cdot T \quad \text{and} \quad T_B = k_B \cdot T$$

where T is the absolute temperature in Kelvin, and k_A, k_B are scale constants.

Step 2: Use the triple point of water as the common physical baseline reference. Let T_{tr} be the absolute temperature of the triple point of water. According to the definitions given:

$$\text{On Scale } A : T_{A,\text{tr}} = 200 \text{ A}$$

$$\text{On Scale } B : T_{B,\text{tr}} = 350 \text{ B}$$

Step 3: Since both values correspond to the exact same physical thermal state (T_{tr}), the ratio of any arbitrary temperature T_A to its triple point must equal the ratio of the corresponding temperature T_B to its triple point:

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

Step 4: Isolate T_A to find the explicit algebraic relationship expressing T_A as a function of T_B:

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

Step 5: Simplify the fraction by dividing both the numerator and the denominator by their greatest common divisor, which is 50:

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

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

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: The maximum height reached by a projectile launched vertically from a planetary body can be found using the Law of Conservation of Mechanical Energy. The total energy at the surface must equal the total potential energy at the highest point where the velocity becomes zero.

Solution: Step 1: Write down the total mechanical energy E_i of the particle of mass m at the surface of the Earth (at distance $r = R$ from the center). The escape velocity from the surface is defined as $v_e = \sqrt{\frac{2GM}{R}}$. The launch velocity is $v = kv_e = k\sqrt{\frac{2GM}{R}}$.

$$E_i = KE_i + PE_i = \frac{1}{2}mv^2 - \frac{GMm}{R}$$

Step 2: Substitute the expression for v into the initial energy equation:

$$E_i = \frac{1}{2}m\left(k^2\frac{2GM}{R}\right) - \frac{GMm}{R} = k^2\frac{GMm}{R} - \frac{GMm}{R} = -\frac{GMm}{R}(1 - k^2)$$

Step 3: Let the maximum distance reached by the particle from the center of the Earth be $r_{\max}$. At this peak position, the particle momentarily comes to rest, so its kinetic energy is zero ($KE_f = 0$). The final total energy E_f is entirely potential:

$$E_f = -\frac{GMm}{r_{\max}}$$

Step 4: Equate the initial and final total mechanical energies since gravity is a conservative force field ($E_i = E_f$):

$$-\frac{GMm}{R}(1 - k^2) = -\frac{GMm}{r_{\max}}$$

Step 5: Cancel the common negative sign and the factor GMm from both sides to solve for $r_{\max}$:

$$\frac{1 - k^2}{R} = \frac{1}{r_{\max}} \implies r_{\max} = \frac{R}{1 - k^2}$$

Final Answer: $\boxed{\frac{R}{1 - k^2}}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: When a wire is stretched uniformly, its volume remains constant. This causes the cross-sectional area to decrease as length increases. Resistance is given by $R = \rho\frac{L}{A}$. Combining identical resistors in parallel reduces the net equivalent resistance.

Solution: Step 1: Let the initial length of the wire be L and its initial cross-sectional area be A. The baseline resistance is $R = \rho\frac{L}{A}$. When the wire is stretched uniformly to twice its original length, its new length becomes $L' = 2L$.

Step 2: Since the total volume ($V = L \cdot A$) of the wire material must remain invariant during stretching, doubling the length forces the cross-sectional area to be cut in half:

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

Step 3: Calculate the resistance R' of the entire stretched wire using the modified length and area parameters:

$$R' = \rho\frac{L'}{A'} = \rho\frac{2L}{\left(\frac{A}{2}\right)} = 4\left(\rho\frac{L}{A}\right) = 4R$$

Step 4: The stretched wire of total resistance $4R$ is then cut into two equal halves. Since resistance is directly proportional to length, each half will have exactly half of the total resistance:

$$R_1 = R_2 = \frac{4R}{2} = 2R$$

Step 5: These two equal pieces are connected in parallel across a battery. Calculate the final equivalent resistance R_{eq} of this parallel combination:

$$\frac{1}{R_{eq}} = \frac{1}{2R} + \frac{1}{2R} = \frac{2}{2R} = \frac{1}{R} \implies R_{eq} = R$$

Final Answer: $\boxed{R}$

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept: An astronomical telescope in normal adjustment means that the final image is formed at infinity. In this standard operating configuration, the distance between the objective lens and the eyepiece lens (the length of the telescope tube L) is equal to the sum of their focal lengths, $L = f_o + f_e$.

Solution: Step 1: Understand the optical configuration of a simple refracting astronomical telescope adjusted for a relaxed eye (normal adjustment). The parallel rays coming from an object at infinity are focused by the objective lens at its focal plane, forming a real intermediate image.

Step 2: For the final image to be formed at infinity by the eyepiece lens, this intermediate image must lie exactly at the principal focal point of the eyepiece.

Step 3: Therefore, the distance from the objective lens to the intermediate image is equal to the focal length of the objective lens, f_o. Similarly, the distance from the intermediate image to the eyepiece lens is equal to the focal length of the eyepiece, f_e.

Step 4: The total physical length of the telescope tube, denoted as L, is the total distance separating the two lenses along the principal optical axis:

$$L = f_o + f_e$$

Step 5: Identify the given focal lengths from the problem text: $f_o = 100$ cm and $f_e = 5$ cm. Substitute these numerical values into the tube length equation:

$$L = 100 \text{ cm} + 5 \text{ cm} = 105 \text{ cm}$$

Final Answer: 105 cm

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept: The de Broglie wavelength of a non-relativistic particle of mass m and charge e accelerated from rest through an electric potential difference V is inversely proportional to the square root of the potential, expressed by the equation $\lambda = \frac{h}{\sqrt{2meV}}$.

Solution: Step 1: Write down the expression for the initial de Broglie wavelength λ of an electron accelerated through a voltage potential difference V:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

where $K = eV$ is the kinetic energy gained by the electron. Thus, we have:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

Step 2: Identify the functional dependency from this formula. We can see that all parameters except the potential difference are constants. Therefore, the wavelength relates to the voltage as:

$$\lambda \propto \frac{1}{\sqrt{V}}$$

Step 3: Let the potential difference be increased to a new value $V' = 4V$. Write down the expression for the new de Broglie wavelength λ' corresponding to this voltage:

$$\lambda' = \frac{h}{\sqrt{2me(4V)}}$$

Step 4: Factor out the numerical constant from inside the square root in the denominator:

$$\lambda' = \frac{h}{\sqrt{4} \cdot \sqrt{2meV}} = \frac{1}{2}\left(\frac{h}{\sqrt{2meV}}\right)$$

Step 5: Substitute the original wavelength λ into the simplified equation:

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

Thus, the de Broglie wavelength is halved when the accelerating potential is quadrupled.

Final Answer: $\boxed{\frac{\lambda}{2}}$

Answer: (C)

Go Back to Question 24

Q25.

Solution

Concept: This problem involves a two-stage physical process: a completely inelastic collision where linear momentum is conserved, followed by an upward swing where mechanical energy is conserved as kinetic energy converts into gravitational potential energy.

Solution: Step 1: Apply the Law of Conservation of Linear Momentum immediately for the collision stage. Let the mass of the bullet be $m = 10$ g $= 0.01$ kg and its initial velocity be $v = 400$ m/s. Let the mass of the suspended block be $M = 3.99$ kg.

Step 2: Let V' be the common velocity of the combined bullet-block system immediately after the bullet becomes embedded. Equate the initial and final momentum:

$$m \cdot v + M \cdot 0 = (m + M) \cdot V'$$

$$0.01 \times 400 = (0.01 + 3.99) \times V'$$

$$4 = 4.00 \times V' \implies V' = 1 \text{ m/s}$$

Step 3: Apply the Law of Conservation of Mechanical Energy for the subsequent swinging motion of the combined mass. The kinetic energy immediately after the collision is transformed into gravitational potential energy at the maximum height h.

Step 4: Set up the energy conservation equation for the combined mass moving up to height h:

$$\frac{1}{2}(m + M)V'^2 = (m + M)gh$$

Step 5: Cancel the total mass $(m + M)$ from both sides and solve for the vertical height h using $g = 10$ m/s^2:

$$\frac{1}{2}V'^2 = g \cdot h \implies \frac{1}{2}(1)^2 = 10 \cdot h$$

$$0.5 = 10h \implies h = \frac{0.5}{10} = 0.05 \text{ m}$$

Converting to centimeters: $h = 0.05 \times 100$ cm $= 5$ cm.

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

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept: The magnetic flux Φ passing through a surface is given by the surface integral of the magnetic field, $\Phi = \int B\,dA$. Because the magnetic field from a straight wire varies with distance, we integrate over a series of differential strips across the loop area.

Solution: Step 1: Define the coordinate space for the square loop of side length a centered at the origin in the xy-plane. The loop extends from $x = -a/2$ to $x = +a/2$ horizontally, and from $y = -a/2$ to $y = +a/2$ vertically. The current-carrying wire is located at the vertical line $x = -2a$.

Step 2: Consider an infinitesimal vertical strip of the square loop at a coordinate position x, with a width dx and a height equal to the full side length a. The area of this differential strip is $dA = a \cdot dx$.

Step 3: Determine the perpendicular distance r from the long wire at $x = -2a$ to the strip at position x. The distance is:

$$r = x - (-2a) = x + 2a$$

The magnitude of the magnetic field B produced by the wire at this strip is:

$$B(x) = \frac{\mu_0 I}{2\pi(x + 2a)}$$

Step 4: Set up the integral for the total magnetic flux Φ by integrating the differential flux $d\Phi = B \cdot dA$ from the left edge to the right edge of the loop:

$$\Phi = \int_{-a/2}^{a/2} \frac{\mu_0 I}{2\pi(x + 2a)} \cdot a\,dx = \frac{\mu_0 I a}{2\pi} \int_{-a/2}^{a/2} \frac{1}{x + 2a}\,dx$$

Step 5: Perform the integration and evaluate the limits:

$$\Phi = \frac{\mu_0 I a}{2\pi}\Big[\ln(x + 2a)\Big]_{-a/2}^{a/2} = \frac{\mu_0 I a}{2\pi}\left[\ln\left(\frac{a}{2} + 2a\right) - \ln\left(-\frac{a}{2} + 2a\right)\right]$$

$$\Phi = \frac{\mu_0 I a}{2\pi}\left[\ln\left(\frac{5a}{2}\right) - \ln\left(\frac{3a}{2}\right)\right] = \frac{\mu_0 I a}{2\pi}\ln\left(\frac{5}{3}\right)$$

Final Answer: $\boxed{\frac{\mu_0 I a}{2\pi}\ln\left(\frac{5}{3}\right)}$

Answer: (D)

Go Back to Question 26

Q27.

Solution

Concept: The fundamental frequency of an organ pipe closed at one end is $f_c = \frac{v}{4L_c}$. The frequency of the first overtone (which is the second harmonic) of an organ pipe open at both ends is given by $f_o = \frac{2v}{2L_o} = \frac{v}{L_o}$.

Solution: Step 1: Write down the formula for the fundamental frequency f_c of a closed organ pipe of length L_c, where v represents the speed of sound in air:

$$f_c = \frac{v}{4L_c}$$

Step 2: Write down the formula for the frequencies of an open organ pipe. The harmonics are given by $f_n = n\frac{v}{2L_o}$. The first overtone of an open pipe corresponds to the second harmonic ($n = 2$). Therefore, its frequency f_o is:

$$f_o = 2\left(\frac{v}{2L_o}\right) = \frac{v}{L_o}$$

Step 3: According to the condition given in the problem statement, the fundamental frequency of the closed pipe is exactly equal to the first overtone frequency of the open pipe:

$$f_c = f_o$$

Step 4: Substitute the mathematical expressions for both frequencies into the condition equation:

$$\frac{v}{4L_c} = \frac{v}{L_o}$$

Step 5: Cancel the speed of sound v from both sides and rearrange the equation to solve for the length of the closed pipe L_c in terms of the open pipe length $L_o = 60$ cm:

$$\frac{1}{4L_c} = \frac{1}{60} \implies 4L_c = 60 \implies L_c = \frac{60}{4} = 15 \text{ cm}$$

Final Answer: 15 cm

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept: To find the required inputs for a specific logic circuit output, we determine the Boolean logic expression of the circuit. For an AND gate output to be high (1), all of its inputs must simultaneously be high (1).

Solution: Step 1: Analyze the structure of the given digital logic circuit. The circuit consists of two connected logic gates: an OR gate and an AND gate. Let us determine the intermediate outputs.

Step 2: The OR gate receives two inputs, labeled B and C. The output of this OR gate can be written using the standard Boolean addition operation as:

$$\text{Output}_{\text{OR}} = B + C$$

Step 3: The final output Y is produced by an AND gate. This AND gate takes two inputs: the primary input line A, and the intermediate output from the OR gate $(B + C)$. Write the complete Boolean expression for Y:

$$Y = A \cdot (B + C)$$

Step 4: The problem specifies that the final output must be high, meaning $Y = 1$. For a logical product (AND operation) to equal 1, both terms multiplying each other must be equal to 1 independently:

$$A = 1 \quad \text{and} \quad (B + C) = 1$$

Step 5: Check the options to find which combination satisfies $A = 1$ and $(B + C) = 1$. Option (C) states $A = 1$, $B = 1$, and $C = 0$. Let us verify the OR condition: $B + C = 1 + 0 = 1$. This satisfies the requirements perfectly.

Final Answer: $\boxed{A = 1, B = 1, C = 0}$

Answer: (C)

Go Back to Question 28

Q29.

Solution

Concept: The average power delivered by a force is defined as the total work done divided by the total time interval taken to perform that work, $P_{avg} = \frac{W}{\Delta t}$. The work done by a spring is found from its potential energy change.

Solution: Step 1: Determine the total work done (W) by the spring force as the block moves from its maximum displacement extreme position $x = X_0$ to its equilibrium position $x = 0$. The work done equals the loss in potential energy stored in the spring:

$$W = \frac{1}{2}kX_0^2 - 0 = \frac{1}{2}kX_0^2$$

Step 2: Determine the time interval Δt required for the block to travel from the extreme position to the equilibrium position. The total time period for one full oscillation of a mass-spring system is $T = 2\pi\sqrt{\frac{m}{k}}$.

Step 3: The motion from an extreme position to the equilibrium position constitutes exactly one-quarter of a full oscillation cycle. Therefore, the time interval is:

$$\Delta t = \frac{T}{4} = \frac{2\pi}{4}\sqrt{\frac{m}{k}} = \frac{\pi}{2}\sqrt{\frac{m}{k}}$$

Step 4: Calculate the average power P_{avg} delivered by the spring using the definition of average power as total work divided by time:

$$P_{avg} = \frac{W}{\Delta t} = \frac{\frac{1}{2}kX_0^2}{\frac{\pi}{2}\sqrt{\frac{m}{k}}}$$

Step 5: Simplify the fraction by canceling the factor of $\frac{1}{2}$ from the numerator and the denominator, and combining the spring constant terms:

$$P_{avg} = \frac{kX_0^2}{\pi\sqrt{\frac{m}{k}}} = \frac{1}{\pi}X_0^2 \cdot k \cdot \sqrt{\frac{k}{m}} = \frac{1}{\pi}X_0^2\sqrt{\frac{k^3}{m}}$$

Final Answer: $\boxed{\frac{1}{\pi}X_0^2\sqrt{\frac{k^3}{m}}}$

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept: The magnetic dipole moment $\vec{M}$ of a current-carrying planar loop is defined as the product of the electric current I flowing through the loop and the vector area $\vec{A}$ enclosed by the boundary loop path, expressed as $M = I \cdot A$.

Solution: Step 1: State the fundamental definition of the magnitude of the magnetic dipole moment M for a single turn of a planar current loop carrying a steady current I:

$$M = I \cdot A$$

where A is the total planar surface area enclosed by the path of the loop.

Step 2: Identify the geometry of the loop given in the problem. The loop is specified to be circular with a radius equal to R.

Step 3: Recall the standard geometric formula for calculating the area of a flat circle of radius R:

$$A = \pi R^2$$

Step 4: Substitute the expression for the circular area into the magnetic dipole moment equation:

$$M = I \cdot (\pi R^2) = (\pi I)R^2$$

Step 5: Analyze the mathematical proportionality of the resulting equation. Since the current I and π are constants, the magnetic dipole moment is directly proportional to the square of the loop radius:

$$M \propto R^2$$

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

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept: When unpolarized light passes through a polarizer, its intensity is halved. When this linearly polarized light passes through a second polarizing sheet (analyzer), its transmitted intensity follows Malus's Law: $I = I_{in}\cos^2\theta$.

Solution: Step 1: Analyze the first stage of the process where an unpolarized light beam of initial intensity I_0 passes through the first polarizing sheet. A perfect polarizing filter blocks all light vibrations perpendicular to its axis, transmitting exactly half of the total incident energy:

$$I_1 = \frac{I_0}{2}$$

The light emerging from this first sheet is now linearly polarized along the direction of its transmission axis.

Step 2: This polarized light of intensity I_1 is now incident on the second polarizing sheet. The transmission axis of the second sheet is oriented at an angle $\theta = 30^\circ$ relative to the polarization direction of the incoming light.

Step 3: Apply Malus's Law to calculate the intensity I_2 of the light beam emerging from the second sheet:

$$I_2 = I_1\cos^2\theta$$

Step 4: Substitute the expression for I_1 from Step 1 and the angle $\theta = 30^\circ$ into Malus's Law:

$$I_2 = \left(\frac{I_0}{2}\right)\cos^2(30^\circ)$$

Step 5: Evaluate the trigonometric term and calculate the final intensity:

$$\cos(30^\circ) = \frac{\sqrt{3}}{2} \implies \cos^2(30^\circ) = \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4}$$

$$I_2 = \frac{I_0}{2} \times \frac{3}{4} = \frac{3}{8}I_0$$

Final Answer: $\boxed{\frac{3}{8}I_0}$

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept: In any nuclear reaction, the total mass number A (total number of nucleons) and the total atomic number Z (total nuclear charge) must be conserved between the initial reactants and the final reaction products.

Solution: Step 1: Represent the nuclear reaction described in the problem statement as a balanced symbolic nuclear equation. Let the unknown target stable nucleus be denoted as ${}^{A}_{Z}X$:

$$ {}^{A}_{Z}X + {}^{1}_{0}\text{n} \longrightarrow {}^{4}_{2}\alpha + {}^{7}_{3}\text{Li} $$

where ${}^{1}_{0}$n represents the absorbed low-energy neutron, and ${}^{4}_{2}\alpha$ represents the emitted alpha particle (a Helium-4 nucleus).

Step 2: Apply the Law of Conservation of Mass Number A by equating the sum of mass numbers on the reactant side to the sum on the product side:

$$ A + 1 = 4 + 7 $$

$$ A + 1 = 11 \implies A = 10 $$

Step 3: Apply the Law of Conservation of Atomic Number Z by equating the sum of nuclear charges on both sides of the reaction equation:

$$ Z + 0 = 2 + 3 $$

$$ Z = 5 $$

Step 4: Identify the element that corresponds to an atomic number $Z = 5$. The element with 5 protons in its nucleus is Boron (B).

Step 5: Combine the determined atomic number and mass number to identify the exact isotope of the original nucleus X. The nucleus is ${}^{10}_{5}$B.

Final Answer: $\boxed{{}^{10}_{5}\text{B}}$

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept: For a charged solid conducting or metal sphere, all excess electric charge resides entirely on its outer surface. Consequently, the electric field inside the conductor is zero, meaning that the electrostatic potential is constant everywhere inside.

Solution: Step 1: Analyze the physical properties of a solid metallic sphere in electrostatic equilibrium. When a charge Q is deposited on a metallic conductor, the charges repel each other and distribute themselves uniformly across the exterior surface to minimize potential energy.

Step 2: Because the charges reside entirely on the surface, Gauss's Law shows that the net electric field $\vec{E}$ at any point inside the sphere ($r < R$) is identically zero:

$$E_{\text{inside}} = 0$$

Step 3: Recall the calculus relationship between the electric field and the electrostatic potential, which is $E = -\frac{dV}{dr}$. Since the internal electric field is zero, the spatial derivative of the potential must be zero:

$$\frac{dV}{dr} = 0 \implies V = \text{constant}$$

Step 4: This constancy means that the electric potential at any internal point from the center up to the surface is exactly equal to the potential at the surface of the sphere. The surface potential is given as V.

Step 5: The point of interest is located at a distance $r = \frac{R}{3}$ from the center. Since $\frac{R}{3} < R$, this point lies inside the metal sphere. Therefore, its potential is equal to the surface value:

$$V_{\text{inside}} = V$$

Final Answer: $\boxed{V}$

Answer: (C)

Go Back to Question 33

Q34.

Solution

Concept: The instantaneous velocity is the first time-derivative of displacement ($v = \frac{ds}{dt}$), and the instantaneous acceleration is the time-derivative of velocity ($a = \frac{dv}{dt}$). We find when acceleration is zero and calculate the velocity at that time.

Solution: Step 1: Given the time-dependent displacement function of the particle moving along a straight line:

$$s(t) = t^3 - 6t^2 + 9t + 4$$

Step 2: Differentiate the displacement function $s(t)$ once with respect to time t using the power rule to find the expression for the instantaneous velocity $v(t)$:

$$v(t) = \frac{ds}{dt} = \frac{d}{dr}(t^3 - 6t^2 + 9t + 4) = 3t^2 - 12t + 9$$

Step 3: Differentiate the velocity function $v(t)$ with respect to time to obtain the expression for the instantaneous linear acceleration $a(t)$:

$$a(t) = \frac{dv}{dt} = \frac{d}{dr}(3t^2 - 12t + 9) = 6t - 12$$

Step 4: Determine the specific time instant t when the acceleration of the particle becomes equal to zero as specified by the problem:

$$a(t) = 0 \implies 6t - 12 = 0 \implies 6t = 12 \implies t = 2 \text{ s}$$

Step 5: Calculate the velocity of the particle at this time instant by substituting $t = 2$ s back into the velocity formula derived in Step 2:

$$v(2) = 3(2)^2 - 12(2) + 9 = 3(4) - 24 + 9 = 12 - 24 + 9 = -3 \text{ m/s}$$

Final Answer: $\boxed{-3 \text{ m/s}}$

Answer: (A)

Go Back to Question 34

Q35.

Solution

Concept: An electrical transformer operates on the principle of Faraday's Law of Electromagnetic Induction, which requires a continually changing magnetic flux to induce a voltage. A steady direct current (DC) source produces a static magnetic field.

Solution: Step 1: Analyze the input source connected across the primary winding of the transformer. The problem states that a 12 V battery is used. A battery delivers a steady, constant direct current (DC).

Step 2: When a steady direct current flows through the primary coil containing $N_1 = 500$ turns, it creates a constant magnetic field inside the ferromagnetic core according to Ampere's Law.

Step 3: This constant magnetic field passes through the secondary coil containing $N_2 = 1000$ turns, establishing a magnetic flux Φ_B. Because the primary current is completely constant over time, this magnetic flux is also constant:

$$\frac{d\Phi_B}{dt} = 0$$

Step 4: According to Faraday's Law of Induction, the electromotive force (voltage) induced across the secondary terminals is proportional to the time rate of change of the magnetic flux linking its turns:

$$V_{\text{secondary}} = -N_2 \frac{d\Phi_B}{dt}$$

Step 5: Substitute the flux derivative value from Step 3 into Faraday's equation:

$$V_{\text{secondary}} = -1000 \times 0 = 0$$

Final Answer: 0 V

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept: When two coherent light waves interfere, the resultant maximum and minimum intensities depend on the individual wave intensities I_1 and I_2 according to the algebraic formulas $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ and $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$.

Solution: Step 1: Identify the given individual intensities of the two coherent monochromatic light beams from the problem statement:

$$I_1 = I \quad \text{and} \quad I_2 = 4I$$

Step 2: Find the square roots of the individual intensities, which are directly proportional to the wave amplitudes:

$$\sqrt{I_1} = \sqrt{I}$$

$$\sqrt{I_2} = \sqrt{4I} = 2\sqrt{I}$$

Step 3: Apply the formula for the maximum intensity I_{max} in the interference pattern, which occurs when the two waves are completely in phase (constructive interference):

$$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = \left(\sqrt{I} + 2\sqrt{I}\right)^2$$

$$I_{max} = \left(3\sqrt{I}\right)^2 = 9I$$

Step 4: Apply the formula for the minimum intensity I_{min} in the interference pattern, which occurs when the two waves are completely out of phase (destructive interference):

$$I_{min} = \left(\sqrt{I_2} - \sqrt{I_1}\right)^2 = \left(2\sqrt{I} - \sqrt{I}\right)^2$$

$$I_{min} = \left(\sqrt{I}\right)^2 = I$$

Step 5: Combine the calculated maximum and minimum values into the requested pair sequence, giving $9I$ and I respectively.

Final Answer: $9I$ and I

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept: The total binding energy of a nucleus is equal to its binding energy per nucleon multiplied by its total mass number A. In a nuclear fusion reaction, the net energy released (Q-value) is equal to the difference between the total binding energy of the final products and that of the initial reactants.

Solution: Step 1: Write out the nuclear equation for the fusion process. Two deuterons ($^2_1$H) combine together to form a single stable Helium nucleus ($^4_2$He):

$$2\left(^2_1\text{H}\right) \longrightarrow ^4_2\text{He}$$

Step 2: Calculate the total binding energy of the initial reactants. Each deuteron contains $A = 2$ nucleons, and its binding energy per nucleon is given as 1.1 MeV. For two deuterons, the initial binding energy is:

$$BE_{\text{initial}} = 2 \times (2 \times 1.1 \text{ MeV}) = 2 \times 2.2 \text{ MeV} = 4.4 \text{ MeV}$$

Step 3: Calculate the total binding energy of the final reaction product. The Helium nucleus contains $A = 4$ nucleons, and its binding energy per nucleon is specified as 7.0 MeV:

$$BE_{\text{final}} = 4 \times 7.0 \text{ MeV} = 28.0 \text{ MeV}$$

Step 4: Determine the net energy released (Q) during this exothermic nuclear fusion process by calculating the increase in total binding energy:

$$Q = BE_{\text{final}} - BE_{\text{initial}}$$

Step 5: Substitute the calculated values into the energy release equation:

$$Q = 28.0 \text{ MeV} - 4.4 \text{ MeV} = 23.6 \text{ MeV}$$

Final Answer: 23.6 MeV

Answer: (A)

Go Back to Question 37

Q38.

Solution

Concept: The effective ratio of specific heats γ_{mix} for a mixture of ideal gases is given by $\gamma_{\text{mix}} = \frac{C_{p,\text{mix}}}{C_{v,\text{mix}}}$, where the total molar heat capacities are the weighted averages of the individual components' capacities.

Solution: Step 1: Determine the molar heat capacities at constant volume for the individual gases. For one mole of a monoatomic gas ($n_1 = 1$), the molar heat capacity is $C_{v1} = \frac{3}{2}R$. For one mole of a diatomic gas ($n_2 = 1$), the capacity is $C_{v2} = \frac{5}{2}R$.

Step 2: Calculate the effective molar heat capacity at constant volume ($C_{v,\text{mix}}$) for the mixture containing a total of $n_1 + n_2 = 2$ moles:

$$C_{v,\text{mix}} = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2} = \frac{1 \cdot \left(\frac{3}{2}R\right) + 1 \cdot \left(\frac{5}{2}R\right)}{1 + 1}$$

$$C_{v,\text{mix}} = \frac{\frac{8}{2}R}{2} = \frac{4R}{2} = 2R$$

Step 3: Use Mayer's relation ($C_p = C_v + R$) to find the effective molar heat capacity at constant pressure ($C_{p,\text{mix}}$) for the gas mixture:

$$C_{p,\text{mix}} = C_{v,\text{mix}} + R = 2R + R = 3R$$

Step 4: Calculate the effective value of the adiabatic index γ_{mix} for the combined mixture by taking the ratio of specific heats:

$$\gamma_{\text{mix}} = \frac{C_{p,\text{mix}}}{C_{v,\text{mix}}} = \frac{3R}{2R} = \frac{3}{2} = 1.50$$

Final Answer: 1.50

Answer: (A)

Go Back to Question 38

Q39.

Solution

Concept: The time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{L}{g}}$. It is inversely proportional to the square root of the local acceleration due to gravity, which varies with altitude above the Earth's surface according to Newton's law of gravitation.

Solution: Step 1: Write down the expression for the time period T_1 of the pendulum on the surface of the Earth, where the local acceleration due to gravity is $g_1 = g$:

$$T_1 = 2\pi\sqrt{\frac{L}{g}}$$

Step 2: Find the local acceleration due to gravity g_2 at a height h equal to the radius of the Earth $(h = R)$. The general gravitational formula for variation with altitude is:

$$g(h) = \frac{GM}{(R+h)^2} = \frac{GM}{(R+R)^2} = \frac{GM}{(2R)^2} = \frac{GM}{4R^2}$$

Since the surface gravity is $g = \frac{GM}{R^2}$, we can write:

$$g_2 = \frac{g}{4}$$

Step 3: Write down the expression for the new time period T_2 of the simple pendulum at this altitude:

$$T_2 = 2\pi\sqrt{\frac{L}{g_2}} = 2\pi\sqrt{\frac{L}{(\frac{g}{4})}}$$

Step 4: Simplify the square root expression by taking the factor of 4 to the numerator and pulling it out of the radical:

$$T_2 = 2\pi\sqrt{\frac{4L}{g}} = 2\cdot\left(2\pi\sqrt{\frac{L}{g}}\right)$$

Step 5: Substitute the original time period T_1 into the equation to find the ratio:

$$T_2 = 2T_1 \implies \frac{T_2}{T_1} = 2$$

Final Answer: $\boxed{2}$

Answer: (A)

Go Back to Question 39

Q40.

Solution

Concept: To convert a galvanometer into a voltmeter capable of measuring up to a maximum voltage V, a large resistance R_s must be connected in series with it. The relationship is governed by Ohm's Law as $V = I_g(G + R_s)$, where G is the galvanometer resistance.

Solution: Step 1: Extract the given physical parameters from the question text. The internal electrical resistance of the galvanometer coil is $G = 50\ \Omega$. The current required for full-scale deflection is $I_g = 2\text{ mA} = 2 \times 10^{-3}$ A. The maximum voltage range to be measured is $V = 10$ V.

Step 2: Understand that when a high series resistance R_s is connected to the galvanometer, the total resistance of the modified device becomes $(G + R_s)$.

Step 3: Apply Ohm's Law for the maximum full-scale voltage deflection condition:

$$V = I_g \cdot (G + R_s)$$

Step 4: Substitute the known numerical values into the equation to solve for the unknown series resistance R_s:

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

Divide both sides by 2×10^{-3}:

$$\frac{10}{2 \times 10^{-3}} = 50 + R_s \implies 5 \times 10^3 = 50 + R_s$$

$$5000 = 50 + R_s$$

Step 5: Isolate R_s by subtracting 50 from both sides:

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

Therefore, a resistance of 4950 Ω must be connected in series with the galvanometer.

Final Answer: 4950 Ω

Answer: (A)

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Answer Key

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