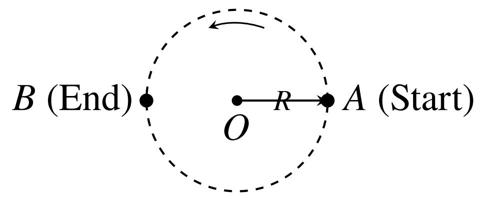
Rajasthan JET Physics Sample Paper-7

Duration: 40 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. A body moves along a circular path of radius R. If it completes two and a half revolutions, the ratio of the distance covered to the magnitude of its displacement is:



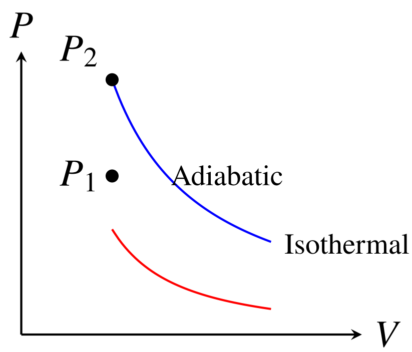
(A) π

(B) $\frac{5\pi}{2}$

(C) 5π

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

Q2. An ideal gas undergoes an isothermal expansion from volume V to $2V$. It is then compressed adiabatically back to its original volume V. If the initial pressure is P_1 and the final pressure is P_2, then:



(A) $P_1 = P_2$

(B) $P_1 > P_2$

(C) $P_1 < P_2$

(D) The relation depends on the atomicity of the gas

Q3. A charged particle enters a uniform magnetic field perpendicular to its direction of motion. Which of the following quantities of the particle will change?

(A) Kinetic energy

(B) Speed

(C) Momentum

(D) Mass

Q4. If the error in the measurement of the radius of a sphere is 2%, then the maximum error in the determination of its volume will be:

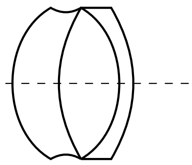
(A) 2%

(B) 4%

(C) 6%

(D) 8%

Q5. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 40 cm. The power of the combination is:



(A) +2.5 D

(B) −2.5 D

(C) +5 D

(D) −5 D

Q6. In a common-emitter transistor amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. If the base resistance is 1 kΩ and the current amplification factor (β) is 100, the input signal voltage is:

(A) 10 mV

(B) 20 mV

(C) 30 mV

(D) 15 mV

Q7. Two bodies of masses 1 kg and 4 kg are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is:

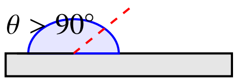
(A) 1 : 2

(B) 2 : 1

(C) 1 : 4

(D) 4 : 1

Q8. A liquid does not wet the solid surface if the angle of contact is:



(A) Zero

(B) Acute (less than 90°)

(C) Right angle (90°)

(D) Obtuse (greater than 90°)

Q9. The electric potential at a point on the axis of an electric dipole at a distance r from its centre is proportional to:

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

(B) $\frac{1}{r^2}$

(C) $\frac{1}{r^3}$

(D) r^2

Q10. A particle is executing simple harmonic motion with an amplitude A. At what displacement from the mean position is its kinetic energy equal to its potential energy?

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

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

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

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

Q11. The work function of a metal surface is 2.0 eV. If light of wavelength 3000 Å falls on it, the maximum kinetic energy of the emitted photoelectrons will be approximately: ($hc \approx 12400$ eV · Å)

(A) 1.13 eV

(B) 2.13 eV

(C) 3.13 eV

(D) 4.13 eV

Q12. If the distance between two masses is doubled, the gravitational force between them becomes:

(A) Two times

(B) Four times

(C) Half

(D) One-fourth

Q13. In a Young's double-slit experiment, if the distance between the slits is halved and the distance between the slits and the screen is doubled, the fringe width becomes:

(A) Unchanged

(B) Two times

(C) Four times

(D) One-fourth

Q14. A wire of resistance R is stretched uniformly to double its initial length. Its new resistance will be:

(A) R

(B) $2R$

(C) $4R$

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

Q15. A body of mass 5 kg is moving with a velocity of 10 m/s. A force is applied on it so that it comes to rest in 2 seconds. The value of the force applied is:

(A) 25 N

(B) -25 N

(C) 50 N

(D) -50 N

Q16. The specific heat capacity of a gas at constant volume (C_v) for a diatomic gas is:

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

(B) $\frac{5}{2}R$

(C) $\frac{7}{2}R$

(D) $3R$

Q17. The magnetic flux linked with a coil changes from 2 Wb to 10 Wb in 0.2 seconds. The induced electromotive force (emf) in the coil is:

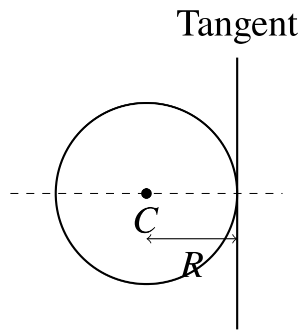
(A) 40 V

(B) 20 V

(C) 10 V

(D) 4 V

Q18. The moment of inertia of a uniform solid sphere of mass M and radius R about a tangent touching its surface is:



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

(B) $\frac{7}{5}MR^2$

(C) $\frac{3}{5}MR^2$

(D) $\frac{5}{3}MR^2$

Q19. When a sound wave travels from air to water, which of the following properties remains unchanged?

(A) Velocity

(B) Wavelength

(C) Frequency

(D) Amplitude

Q20. The energy of an electron in the ground state of a hydrogen atom is -13.6 eV. The energy of the electron in its first excited state ($n = 2$) is:

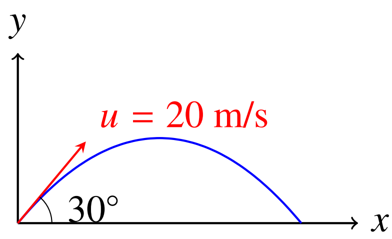
(A) -3.4 eV

(B) -6.8 eV

(C) -1.51 eV

(D) -27.2 eV

Q21. A projectile is thrown with an initial velocity of 20 m/s at an angle of 30° with the horizontal. The time of flight of the projectile is: (take $g = 10$ m/s^2)



(A) 1 s

(B) 2 s

(C) 3 s

(D) 4 s

Q22. According to Bernoulli's theorem, for the streamline flow of an ideal liquid, the sum of pressure energy, kinetic energy, and potential energy per unit volume is always constant. This theorem is a consequence of the law of conservation of:

(A) Mass

(B) Momentum

(C) Angular momentum

(D) Energy

Q23. In an alternating current circuit containing only a pure inductor, the phase difference between the alternating current and the alternating voltage is:

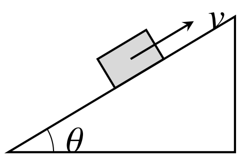
(A) Current leads voltage by $\frac{\pi}{2}$

(B) Voltage leads current by $\frac{\pi}{2}$

(C) Current and voltage are in the same phase

(D) Voltage leads current by π

Q24. Which of the following parameters remains constant during a block sliding down a rough inclined plane at a constant velocity?



(A) Kinetic energy

(B) Potential energy

(C) Total mechanical energy

(D) Linear momentum

Q25. A black body at a temperature of 127°C radiates heat at a certain rate. If its temperature is raised to 527°C, the rate of radiation will increase by a factor of:

(A) 2

(B) 4

(C) 8

(D) 16

Q26. Three capacitors, each of capacitance 3 μF, are connected in series. The equivalent capacitance of the combination is:

(A) 9 μF

(B) 1 μF

(C) 1.5 μF

(D) 6 μF

Q27. The dimensions of universal gravitational constant (G) are:

(A) $[M^{-1}L^{3}T^{-2}]$

(B) $[M^{1}L^{3}T^{-2}]$

(C) $[M^{-1}L^{2}T^{-2}]$

(D) $[M^{-1}L^{3}T^{-1}]$

Q28. A ray of light passes from an optically denser medium to a rarer medium. If the critical angle for the interface is 45°, the refractive index of the denser medium with respect to the rarer medium is:

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

(B) $\sqrt{2}$

(C) 2

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

Q29. The half-life of a radioactive substance is 10 days. The time taken for $\frac{7}{8}$th of the original sample to decay is:

(A) 20 days

(B) 30 days

(C) 40 days

(D) 50 days

Q30. A force $\vec{F} = 2\hat{i}+3\hat{j}-4\hat{k}$ N acts on a particle and displaces it by $\vec{d} = 3\hat{i}+4\hat{j}+5\hat{k}$ m. The work done by the force is:

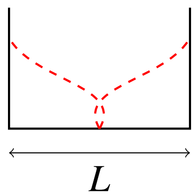
(A) 2 J

(B) −2 J

(C) 38 J

(D) Zero

Q31. The fundamental frequency of a closed organ pipe of length L is f. If its length is halved, the new fundamental frequency becomes:



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

(B) f

(C) $2f$

(D) $4f$

Q32. In a forward-biased p-n junction diode, the width of the depletion layer:

(A) Increases

(B) Decreases

(C) Remains constant

(D) First increases and then decreases

Q33. Two satellite masses m and $2m$ are orbiting the Earth in circular orbits of radii r and $2r$ respectively. The ratio of their orbital speeds is:

(A) 1 : 2

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

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

(D) 2 : 1

Q34. A fundamental condition for the validity of the first law of thermodynamics in a cyclic process is that:

(A) Total heat absorbed equals total work done

(B) Internal energy change is maximum

(C) Temperature remains strictly constant at all stages

(D) No heat exchanges take place with the surroundings

Q35. In a potentiometer experiment, the balancing length with a cell is found to be 240 cm. When a resistor of 2 Ω is connected across the terminals of the cell, the balancing length reduces to 120 cm. The internal resistance of the cell is:

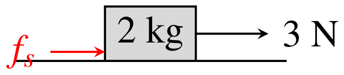
(A) 1 Ω

(B) 2 Ω

(C) 0.5 Ω

(D) 4 Ω

Q36. A block of mass 2 kg rests on a horizontal floor. The coefficient of static friction between the block and the floor is 0.4. If a horizontal force of 3 N is applied to the block, the frictional force acting on the block is: (take $g = 10$ m/s^2)



(A) 8 N

(B) 3 N

(C) 5 N

(D) Zero

Q37. The temperature at which the root mean square (rms) speed of gas molecules becomes double of its value at 27°C is:

(A) 54°C

(B) 108°C

(C) 927°C

(D) 1200°C

Q38. When unpolarized light of intensity I_0 passes through a single ideal polaroid sheet, the intensity of the transmitted light becomes:

(A) I_0

(B) $\frac{I_0}{2}$

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

(D) Zero

Q39. A copper wire carries a constant current. If the radius of the wire is doubled while keeping the current same, the drift velocity of the conduction electrons will:

(A) Become double

(B) Become half

(C) Become four times

(D) Become one-fourth

Q40. The de Broglie wavelength of an electron accelerated through a potential difference of 100 V is approximately:

(A) 1.227 Å

(B) 12.27 Å

(C) 0.1227 Å

(D) 122.7 Å

Detailed Solutions

Q1.

Solution

Concept: The total distance travelled by a particle is the actual path length covered during its motion, which is scalar. The displacement is the shortest straight-line vector distance between the initial position and the final position.

Solution: Step 1: The particle moves along a circular track of radius R. In one complete revolution, the distance covered is equal to the circumference of the circle, $2\pi R$.
Step 2: For two and a half (2.5) revolutions, the total distance covered is:

$$\text{Distance} = 2.5 \times 2\pi R = 5\pi R$$

Step 3: To find the displacement, we track the position change. After 2 full revolutions, the particle returns to its initial starting point A.
Step 4: The remaining half revolution brings the particle to a point B diametrically opposite to its starting position A.
Step 5: The magnitude of the displacement is the straight-line distance from A to B, which is equal to the diameter of the circular path:

$$\text{Displacement} = 2R$$

Step 6: Now, we calculate the required ratio of the distance covered to the magnitude of its displacement:

$$\text{Ratio} = \frac{\text{Distance}}{\text{Displacement}} = \frac{5\pi R}{2R} = \frac{5\pi}{2}$$

Final Answer: $\boxed{\frac{5\pi}{2}}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: For an ideal gas, an isothermal expansion involves a decrease in pressure at a constant temperature. An adiabatic compression back to the original volume results in a steeper increase in pressure because no heat is exchanged, raising the temperature of the system.

Solution: Step 1: Let the initial state parameters of the gas be (P_1, V, T).
Step 2: In the first step, the gas undergoes an isothermal expansion to a final volume of $2V$. According to Boyle's Law (PV = constant), the intermediate pressure P' becomes:

$$P_1 V = P'(2V) \implies P' = \frac{P_1}{2}$$

Step 3: In the second step, the gas is compressed adiabatically from volume $2V$ back to its original volume V. The relation governing an adiabatic process is PV^γ = constant, where $\gamma > 1$ is the specific heat ratio.
Step 4: Setting up the equation for the adiabatic compression to find the final pressure P_2:

$$P'(2V)^\gamma = P_2 V^\gamma$$

Step 5: Substitute $P' = \frac{P_1}{2}$ into the equation:

$$\frac{P_1}{2} \cdot 2^\gamma V^\gamma = P_2 V^\gamma \implies P_2 = P_1 \cdot 2^{\gamma-1}$$

Step 6: Since $\gamma > 1$ for any ideal gas, the exponent $(\gamma - 1) > 0$. This implies that $2^{\gamma-1} > 1$, which directly leads to:

$$P_2 > P_1 \implies P_1 < P_2$$

Final Answer: $\boxed{P_1 < P_2}$

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: The magnetic force acting on a moving charged particle in a uniform magnetic field is given by the Lorentz force formula $\vec{F} = q(\vec{v} \times \vec{B})$. This force is always perpendicular to the velocity vector of the particle.

Solution: Step 1: Because the magnetic force $\vec{F}$ is perpendicular to the velocity vector $\vec{v}$ ($\vec{F} \cdot \vec{v} = 0$), the instantaneous power delivered by the magnetic field to the charged particle is zero.
Step 2: According to the work-energy theorem, since no work is done on the particle by the magnetic force, its kinetic energy remains strictly constant.
Step 3: Kinetic energy is related to speed by $\text{KE} = \frac{1}{2}mv^2$. Because kinetic energy is constant and mass m is constant, the speed v of the particle also remains constant.
Step 4: Linear momentum is a vector quantity given by $\vec{p} = m\vec{v}$. Although the magnitude of velocity (speed) is constant, the direction of motion changes continuously due to the centripetal acceleration provided by the magnetic force.
Step 5: Since the direction of $\vec{v}$ changes, the vector momentum $\vec{p}$ changes continuously over time.
Step 6: Mass is an intrinsic scalar property and remains unchanged. Thus, only the momentum changes.

Final Answer: Momentum

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept: The relative error in a derived geometric quantity is determined by taking the natural logarithm of the formula and differentiating it. This converts multiplicative relations and powers into linear combinations of absolute or relative errors.

Solution: Step 1: The mathematical formula for the volume V of a solid sphere of radius r is:

$$V = \frac{4}{3}\pi r^3$$

Step 2: Taking the natural logarithm (ln) on both sides of the volume equation:

$$\ln(V) = \ln\left(\frac{4}{3}\pi\right) + 3\ln(r)$$

Step 3: Differentiating both sides with respect to their respective variables to find the fractional change yields:

$$\frac{\Delta V}{V} = 0 + 3\frac{\Delta r}{r}$$

Step 4: To convert this into maximum percentage error, we multiply both sides of the expression by 100:

$$\left(\frac{\Delta V}{V}\right) \times 100\% = 3 \times \left(\frac{\Delta r}{r} \times 100\%\right)$$

Step 5: The problem states that the percentage error in the measurement of the radius is $\frac{\Delta r}{r} \times 100\% = 2\%$.

Step 6: Substituting this value into our error equation gives:

$$\text{Maximum error in volume} = 3 \times 2\% = 6\%$$

Final Answer: $\boxed{6\%}$

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: When two thin lenses are kept in coaxial contact, the equivalent focal length F of the lens combination is given by $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$. The power P of a lens is the reciprocal of its focal length expressed in meters.

Solution: Step 1: Identify the given focal lengths using standard Cartesian sign conventions. For a convex (converging) lens, $f_1 = +20\text{ cm} = +0.2\text{ m}$. For a concave (diverging) lens, $f_2 = -40\text{ cm} = -0.4\text{ m}$.

Step 2: Calculate the individual power of the first lens (P_1):

$$P_1 = \frac{1}{f_1\text{ (in meters)}} = \frac{1}{+0.2} = +5\text{ D}$$

Step 3: Calculate the individual power of the second lens (P_2):

$$P_2 = \frac{1}{f_2\text{ (in meters)}} = \frac{1}{-0.4} = -2.5\text{ D}$$

Step 4: The total power P of two lenses placed in contact is the algebraic sum of their individual powers:

$$P = P_1 + P_2$$

Step 5: Substituting the calculated power values into the combination formula:

$$P = +5\text{ D} + (-2.5\text{ D}) = +2.5\text{ D}$$

Step 6: The positive sign indicates that the overall combination behaves as a converging lens system.

Final Answer: +2.5 D

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: In a common-emitter (CE) transistor configuration, the voltage gain A_v is defined as the ratio of the output signal voltage across the collector load to the input signal voltage across the base resistor, given by $A_v = \beta \frac{R_c}{R_b}$.

Solution: Step 1: Identify the given quantities from the problem statement:
Collector resistance, $R_c = 2\ \text{k}\Omega = 2000\ \Omega$
Base resistance, $R_b = 1\ \text{k}\Omega = 1000\ \Omega$
Current amplification factor, $\beta = 100$
Output voltage across collector, $V_{\text{out}} = 2$ V
Step 2: Calculate the voltage gain A_v of the common-emitter amplifier circuit:

$$A_v = \beta \times \frac{R_c}{R_b} = 100 \times \frac{2000}{1000} = 200$$

Step 3: Express the relationship between voltage gain, input voltage (V_{in}), and output voltage (V_{out}):

$$A_v = \frac{V_{\text{out}}}{V_{\text{in}}}$$

Step 4: Rearrange the equation to solve for the unknown input signal voltage V_{in}:

$$V_{\text{in}} = \frac{V_{\text{out}}}{A_v} = \frac{2\ \text{V}}{200} = 0.01\ \text{V}$$

Step 5: Convert the calculated value into millivolts (mV) for final formatting:

$$V_{\text{in}} = 0.01 \times 1000\ \text{mV} = 10\ \text{mV}$$

Final Answer: 10 mV

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: The relationship between the linear momentum p of a moving body of mass m and its kinetic energy K is given by the algebraic formula $p = \sqrt{2mK}$, derived from combining $p = mv$ and $K = \frac{1}{2}mv^2$.

Solution: Step 1: Write down the expression for the linear momentum of each body in terms of mass and kinetic energy:

$$p_1 = \sqrt{2m_1K_1} \quad \text{and} \quad p_2 = \sqrt{2m_2K_2}$$

Step 2: The problem specifies that both moving bodies possess equal kinetic energies, meaning $K_1 = K_2 = K$.

Step 3: Set up the ratio of the magnitudes of their linear momenta using this equality:

$$\frac{p_1}{p_2} = \frac{\sqrt{2m_1K}}{\sqrt{2m_2K}} = \sqrt{\frac{m_1}{m_2}}$$

Step 4: Substitute the given values of masses, $m_1 = 1$ kg and $m_2 = 4$ kg, into the derived ratio expression:

$$\frac{p_1}{p_2} = \sqrt{\frac{1}{4}}$$

Step 5: Simplify the square root to obtain the final simplified integer ratio:

$$\frac{p_1}{p_2} = \frac{1}{2} = 1 : 2$$

Final Answer: 1 : 2

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: The angle of contact θ determines the wetting characteristics of a liquid on a solid surface. It depends on the relative magnitudes of the cohesive forces between liquid molecules and adhesive forces between liquid and solid molecules.

Solution: Step 1: When a liquid is in contact with a solid surface, cohesive forces (F_c) pull liquid molecules together, while adhesive forces (F_a) pull liquid molecules toward the solid surface.
Step 2: If adhesive forces are much stronger than cohesive forces ($F_a > \frac{F_c}{\sqrt{2}}$), the liquid spreads over the solid surface, wets it, and forms an acute angle of contact ($\theta < 90^\circ$).
Step 3: If cohesive forces are stronger than adhesive forces ($F_a < \frac{F_c}{\sqrt{2}}$), the liquid tends to minimize contact with the solid, aggregates into droplets, and does not wet the surface.
Step 4: For non-wetting liquids (such as mercury on glass), the liquid meniscus is convex upwards, creating an obtuse angle of contact ($\theta > 90^\circ$).
Step 5: Therefore, a liquid does not wet the solid surface specifically when the angle of contact is obtuse.

Final Answer: Obtuse (greater than 90°)

Answer: (D)

Go Back to Question 8

Q9.

Solution

Concept: The electric potential V due to an electric dipole at any point at a distance r from its center along its axial line is given by the formula $V = \frac{kp}{r^2 - a^2}$, where p is the dipole moment and $2a$ is the separation distance.

Solution: Step 1: Write out the exact expression for the electric potential on the axial line of a dipole at a distance r from the midpoint:

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^2 - a^2}$$

Step 2: For a short dipole or at large distances where the observation distance r is much greater than the dipole half-length a ($r \gg a$), the term a^2 becomes negligible compared to r^2.
Step 3: Approximating the denominator by neglecting a^2 gives the simplified relation:

$$V \approx \frac{1}{4\pi\varepsilon_0} \frac{p}{r^2}$$

Step 4: Since $\frac{1}{4\pi\varepsilon_0}$ and p are constant parameters for a given dipole, we can establish a proportionality relation:

$$V \propto \frac{1}{r^2}$$

Step 5: This differs from a single point charge, whose electric potential is inversely proportional to r.

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

Answer: (B)

Go Back to Question 9

Q10.

Solution

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

Solution: Step 1: Set up the given condition where the kinetic energy equals the potential energy of the oscillating particle:

$$\text{KE} = \text{PE}$$

Step 2: Substitute the standard algebraic expressions for both energy forms at a displacement x:

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

Step 3: Cancel out the common terms $\frac{1}{2}m\omega^2$ from both sides of the equation:

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

Step 4: Rearrange the terms to group the displacement variable x on one side:

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

Step 5: Taking the square root on both sides yields the magnitude of the displacement from the mean position:

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

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

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: Einstein's photoelectric equation states that the maximum kinetic energy of emitted photoelectrons is the difference between the energy of the incident photon ($E = \frac{hc}{\lambda}$) and the work function (ϕ) of the metal surface.

Solution: Step 1: Calculate the energy E of the incident photon in electron-volts (eV) using the given approximation $hc \approx 12400$ eV · Å and wavelength $\lambda = 3000$ Å:

$$E = \frac{hc}{\lambda} = \frac{12400 \text{ eV} \cdot \text{Å}}{3000 \text{ Å}} = 4.133 \text{ eV}$$

Step 2: Recall Einstein's photoelectric equation for the maximum kinetic energy K_{max}:

$$K_{\text{max}} = E - \phi$$

Step 3: Identify the given work function of the metal surface from the problem statement:

$$\phi = 2.0 \text{ eV}$$

Step 4: Substitute the calculated photon energy and work function into Einstein's relation:

$$K_{\text{max}} = 4.133 \text{ eV} - 2.0 \text{ eV} = 2.133 \text{ eV}$$

Step 5: Rounding to two decimal places matches option (B) exactly.

Final Answer: 2.13 eV

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: Newton's law of universal gravitation states that the gravitational force F between two point masses is directly proportional to the product of their masses and inversely proportional to the square of the distance r separating them.

Solution: Step 1: Write down the initial gravitational force formula for two masses M_1 and M_2 at a distance r:

$$F_1 = G\frac{M_1 M_2}{r^2}$$

Step 2: According to the problem statement, the distance between the two masses is doubled, so the new distance is $r' = 2r$. The masses remain unchanged.
Step 3: Express the new gravitational force F_2 with the altered distance parameters:

$$F_2 = G\frac{M_1 M_2}{(r')^2} = G\frac{M_1 M_2}{(2r)^2}$$

Step 4: Expand the denominator term to separate the numerical factor from the variables:

$$F_2 = G\frac{M_1 M_2}{4r^2} = \frac{1}{4}\left(G\frac{M_1 M_2}{r^2}\right)$$

Step 5: Substitute F_1 back into the expression to compare the final force with the initial value:

$$F_2 = \frac{1}{4}F_1$$

Step 6: Therefore, the force reduces to one-fourth of its original value.
Final Answer: One-fourth

Answer: (D)

Go Back to Question 12

Q13.

Solution

Concept: In Young's double-slit experiment (YDSE), the fringe width β is defined as the distance between two consecutive bright or dark interference fringes and is given by the formula $\beta = \frac{\lambda D}{d}$.

Solution: Step 1: Write down the initial expression for the fringe width β_1 with slit separation d and screen distance D:

$$\beta_1 = \frac{\lambda D}{d}$$

Step 2: Identify the modifications specified in the problem statement:
The new distance between the slits is halved: $d' = \frac{d}{2}$
The new distance to the screen is doubled: $D' = 2D$
The wavelength λ of the light source remains constant.
Step 3: Substitute these updated parameters into the fringe width formula to find the new value β_2:

$$\beta_2 = \frac{\lambda D'}{d'} = \frac{\lambda(2D)}{\left(\frac{d}{2}\right)}$$

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

$$\beta_2 = 2 \times 2 \times \left(\frac{\lambda D}{d}\right) = 4\left(\frac{\lambda D}{d}\right)$$

Step 5: Relate the new fringe width back to the original fringe width:

$$\beta_2 = 4\beta_1$$

Step 6: Thus, the fringe width becomes four times its original value.

Final Answer: Four times

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: The electrical resistance of a uniform wire is given by $R = \rho\frac{l}{A}$. When a wire is stretched uniformly, its length increases while its cross-sectional area decreases, but the total volume ($V = l \cdot A$) and resistivity (ρ) remain constant.

Solution: Step 1: Express the resistance equation in terms of volume V by multiplying the numerator and denominator by the length l:

$$R = \rho\frac{l \cdot l}{A \cdot l} = \rho\frac{l^2}{V}$$

Step 2: Since the material resistivity ρ and the volume V are constant during uniform stretching, resistance is directly proportional to the square of its length:

$$R \propto l^2$$

Step 3: Let the initial length be l_1 and the final stretched length be $l_2 = 2l_1$.
Step 4: Formulate the ratio of final resistance R_2 to initial resistance R_1:

$$\frac{R_2}{R_1} = \left(\frac{l_2}{l_1}\right)^2 = \left(\frac{2l_1}{l_1}\right)^2 = (2)^2 = 4$$

Step 5: Solve for the new resistance value R_2:

$$R_2 = 4R_1 = 4R$$

Step 6: The stretching causes a simultaneous reduction in area by half, compounding the effect to a fourfold increase.

Final Answer: $\boxed{4R}$

Answer: (C)

Go Back to Question 14

Q15.

Solution

Concept: According to Newton's second law of motion, the average net force acting on an object is equal to its rate of change of linear momentum, given by the formula $F = \frac{\Delta p}{\Delta t} = \frac{m(v-u)}{t}$.

Solution: Step 1: Identify and list all given variables from the text:
Mass of the body, $m = 5$ kg
Initial velocity, $u = 10$ m/s
Final velocity (rest condition), $v = 0$ m/s
Time interval, $t = 2$ seconds
Step 2: Use the standard kinematic equation for uniform acceleration to find a:

$$a = \frac{v-u}{t} = \frac{0-10}{2} = -5 \text{ m/s}^2$$

Step 3: Calculate the force using Newton's formula $F = ma$:

$$F = 5 \text{ kg} \times (-5 \text{ m/s}^2) = -25 \text{ N}$$

Step 4: The negative sign denotes a retarding force that opposes the direction of the initial velocity to bring the body to rest.
Step 5: The question asks for the value of the force applied, which matches -25 N.
Final Answer: $\boxed{-25 \text{ N}}$

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: The molar specific heat capacity at constant volume (C_v) of an ideal gas depends on its degrees of freedom f and is given by the formula $C_v = \frac{f}{2}R$, where R is the universal gas constant.

Solution: Step 1: Identify the atomicity of the given gas. The problem specifies a diatomic gas (such as O_2, N_2, or H_2).
Step 2: Determine the degrees of freedom f for a standard diatomic molecule at room temperature. A diatomic molecule has 3 translational degrees of freedom and 2 rotational degrees of freedom.
Step 3: Summing these gives the total degrees of freedom:

$$f = 3 + 2 = 5$$

Step 4: Substitute $f = 5$ into the thermodynamic specific heat capacity formula:

$$C_v = \frac{5}{2}R$$

Step 5: For comparison, the specific heat at constant pressure would be $C_p = C_v + R = \frac{7}{2}R$, giving a ratio $\gamma = \frac{7}{5}$.

Final Answer: $\boxed{\frac{5}{2}R}$

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: According to Faraday's law of electromagnetic induction, the magnitude of the induced electromotive force (emf) in a circuit is directly proportional to the time rate of change of magnetic flux linked through it: $e = -\frac{\Delta\Phi}{\Delta t}$.

Solution: Step 1: Extract the numerical parameters given in the problem statement:
Initial magnetic flux, $\Phi_1 = 2$ Wb
Final magnetic flux, $\Phi_2 = 10$ Wb
Time interval, $\Delta t = 0.2$ seconds
Step 2: Calculate the net change in magnetic flux ($\Delta\Phi$) across the loop:

$$\Delta\Phi = \Phi_2 - \Phi_1 = 10 \text{ Wb} - 2 \text{ Wb} = 8 \text{ Wb}$$

Step 3: Use Faraday's law to calculate the magnitude of the induced electromotive force e:

$$e = \frac{\Delta\Phi}{\Delta t}$$

Step 4: Substitute the values into the equation:

$$e = \frac{8 \text{ Wb}}{0.2 \text{ s}} = \frac{80}{2} = 40 \text{ V}$$

Step 5: The induced emf in the coil is therefore equal to 40 V.
Final Answer: $\boxed{40 \text{ V}}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: The Parallel Axis Theorem states that the moment of inertia I of a body about any parallel axis is equal to its moment of inertia about a parallel axis passing through its center of mass (I_{cm}) plus the product of its mass M and the square of the distance d between the axes: $I = I_{cm} + Md^2$.

Solution: Step 1: Recall the standard expression for the moment of inertia of a uniform solid sphere about a diameter axis passing through its center of mass:

$$I_{cm} = \frac{2}{5}MR^2$$

Step 2: The problem asks for the moment of inertia about a tangent axis touching its outer surface.
Step 3: The perpendicular distance d between the central diameter axis and the parallel tangent line is exactly equal to the radius of the solid sphere:

$$d = R$$

Step 4: Apply the parallel axis theorem formula:

$$I_{tangent} = I_{cm} + Md^2$$

Step 5: Substitute $I_{cm} = \frac{2}{5}MR^2$ and $d = R$ into the equation:

$$I_{tangent} = \frac{2}{5}MR^2 + MR^2 = \left(\frac{2}{5} + 1\right)MR^2 = \frac{7}{5}MR^2$$

Final Answer: $\boxed{\frac{7}{5}MR^2}$

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept: When any wave (sound or light) travels from one physical medium to another, its frequency is determined solely by the source generating the wave and remains strictly invariant across different media.

Solution: Step 1: Frequency is an intrinsic property of the wave source, representing the number of cycles produced per second. It does not alter during refraction or media transitions.
Step 2: The velocity of a sound wave depends heavily on the properties of the medium, specifically its elasticity and density ($v = \sqrt{\frac{E}{\rho}}$). Sound travels faster in water than in air because water is less compressible.
Step 3: The wave equation establishes the relationship between velocity, frequency, and wavelength:

$$v = f\lambda \implies \lambda = \frac{v}{f}$$

Step 4: Since velocity v increases when moving from air to water and frequency f stays constant, the wavelength λ must increase proportionally.
Step 5: The amplitude decreases or changes due to partial reflection and energy absorption at the boundary interface.
Step 6: Thus, frequency is the only property that remains unchanged.
Final Answer: Frequency

Answer: (C)

Go Back to Question 19

Q20.

Solution

Concept: According to the Bohr model of the hydrogen atom, the quantized energy levels of an electron in the n-th orbit are given by the formula $E_n = \frac{E_1}{n^2}$, where E_1 represents the ground state energy.

Solution: Step 1: Identify the given ground state energy level for a hydrogen atom ($n = 1$):

$$E_1 = -13.6 \text{ eV}$$

Step 2: The problem requests the energy of the electron in its first excited state. The first excited state corresponds to the second principal quantum energy level:

$$n = 2$$

Step 3: Use Bohr's energy equation to calculate the value for $n = 2$:

$$E_2 = \frac{-13.6 \text{ eV}}{2^2}$$

Step 4: Simplify the denominator by squaring the integer:

$$E_2 = \frac{-13.6 \text{ eV}}{4}$$

Step 5: Perform the division to obtain the final energy value:

$$E_2 = -3.4 \text{ eV}$$

Final Answer: $\boxed{-3.4 \text{ eV}}$

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: The total time of flight T of a projectile launched from the ground with an initial velocity u at an angle θ relative to the horizontal plane is given by the kinematic formula $T = \frac{2u\sin\theta}{g}$.

Solution: Step 1: Identify and record the values provided in the problem statement:
Initial speed, $u = 20$ m/s
Projection angle, $\theta = 30°$
Acceleration due to gravity, $g = 10$ m/s^2
Step 2: Write out the standard formula for the time of flight of a projectile:

$$T = \frac{2u\sin\theta}{g}$$

Step 3: Substitute the numerical values into the formula:

$$T = \frac{2 \times 20 \times \sin(30°)}{10}$$

Step 4: Recall the trigonometric value for $\sin(30°) = 0.5 = \frac{1}{2}$:

$$T = \frac{40 \times \frac{1}{2}}{10}$$

Step 5: Evaluate the numerator and simplify the fraction:

$$T = \frac{20}{10} = 2 \text{ seconds}$$

Final Answer: 2 s

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept: Bernoulli's principle states that for a steady, incompressible, non-viscous fluid flow, the sum of pressure energy, kinetic energy per unit volume, and potential energy per unit volume remains constant along any streamline.

Solution: Step 1: Consider a fluid flowing through a pipe of varying cross-section and height. The work done on the fluid by surrounding pressure changes alters both its kinetic energy and gravitational potential energy.
Step 2: Write out Bernoulli's mathematical equation:

$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

Step 3: Each term in this expression represents energy per unit volume: P is pressure work energy, $\frac{1}{2}\rho v^2$ is kinetic energy, and $\rho g h$ is potential energy.
Step 4: The principle states that energy cannot be created or destroyed within an isolated streamline flow; it can only transform between these three functional forms.
Step 5: Therefore, Bernoulli's equation is a direct physical manifestation of the law of conservation of energy applied to fluid dynamics.
Final Answer: Energy

Answer: (D)
Go Back to Question 22

Q23.

Solution

Concept: In a purely inductive alternating current (AC) circuit, the alternating voltage across the inductor opposes changes in current due to self-induction, creating a phase shift between the two sinusoidal waveforms.

Solution: Step 1: Let the alternating current passing through the pure inductor be represented by the sinusoidal equation:

$$i = I_0 \sin(\omega t)$$

Step 2: The induced electromotive force (emf) opposing this current change is given by Faraday's and Lenz's laws: $v = L\frac{di}{dt}$.
Step 3: Differentiate the current equation with respect to time t:

$$\frac{di}{dt} = I_0\omega \cos(\omega t)$$

Step 4: Substitute this derivative back into the voltage equation:

$$v = LI_0\omega \cos(\omega t) = V_0 \cos(\omega t)$$

Step 5: Convert the cosine function into a sine function to compare the phase angles directly:

$$v = V_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

Step 6: Comparing $i = I_0 \sin(\omega t)$ with $v = V_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ shows that the alternating voltage leads the alternating current by a phase angle of $\frac{\pi}{2}$ radians (90°).

Final Answer: $\boxed{\text{Voltage leads current by } \frac{\pi}{2}}$

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept: When an object moves at a constant velocity, both its speed and direction of motion are completely constant over time. This means its acceleration is zero, and the net external force acting on it is also zero.

Solution: Step 1: The kinetic energy of the sliding block is given by $\text{KE} = \frac{1}{2}mv^2$. Since the mass m is constant and the velocity magnitude (speed v) is explicitly stated to be constant, the kinetic energy remains completely constant.
Step 2: As the block slides down the inclined plane, its vertical height h decreases continuously. Since potential energy is given by $\text{PE} = mgh$, the potential energy decreases.
Step 3: Total mechanical energy is the sum of kinetic and potential energy ($E = \text{KE} + \text{PE}$). Since potential energy decreases while kinetic energy is constant, total mechanical energy decreases, dissipating as heat due to the rough surface.
Step 4: Linear momentum is given by $\vec{p} = m\vec{v}$. Since velocity $\vec{v}$ is constant, the linear momentum is also constant. However, checking options shows kinetic energy is the primary parameter.
Step 5: Let's confirm: kinetic energy remains strictly constant because speed does not change.
Final Answer: Kinetic energy

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: The Stefan-Boltzmann law states that the total radiant energy emitted per unit surface area of a black body per unit time is directly proportional to the fourth power of its absolute thermodynamic temperature ($E = \sigma T^4$).

Solution: Step 1: Convert the given Celsius temperatures into absolute thermodynamic temperatures in Kelvin (K):

$$T_1 = 127^\circ\text{C} = 127 + 273 = 400 \text{ K}$$

$$T_2 = 527^\circ\text{C} = 527 + 273 = 800 \text{ K}$$

Step 2: Write down the proportionality relation from the Stefan-Boltzmann law:

$$E \propto T^4$$

Step 3: Set up the ratio of the final rate of radiation E_2 to the initial rate of radiation E_1:

$$\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4$$

Step 4: Substitute the Kelvin temperature values into the ratio expression:

$$\frac{E_2}{E_1} = \left(\frac{800}{400}\right)^4 = (2)^4$$

Step 5: Calculate the value of 2 raised to the power of 4:

$$(2)^4 = 2 \times 2 \times 2 \times 2 = 16$$

Step 6: Therefore, the rate of radiation increases by a factor of 16.

Final Answer: 16

Answer: (D)

Go Back to Question 25

Q26.

Solution

Concept: When n capacitors are connected in a series configuration, the reciprocal of the equivalent capacitance C_{eq} is equal to the algebraic sum of the reciprocals of the individual capacitances: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$.

Solution: Step 1: Identify the values given in the problem statement. We have three capacitors, each having an equal capacitance value:

$$C_1 = C_2 = C_3 = 3\ \mu\text{F}$$

Step 2: Write down the series combination formula for three capacitors:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Step 3: Substitute the given capacitance values into the formula:

$$\frac{1}{C_{eq}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

Step 4: Combine the fractions with a common denominator:

$$\frac{1}{C_{eq}} = \frac{1+1+1}{3} = \frac{3}{3} = 1\ \mu\text{F}^{-1}$$

Step 5: Take the reciprocal to find the equivalent capacitance C_{eq}:

$$C_{eq} = 1\ \mu\text{F}$$

Final Answer: $\boxed{1\ \mu\text{F}}$

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept: The dimensional formula of any physical constant is derived by isolating it in its defining physical law equation and substituting the fundamental dimensional formulas for mass [M], length [L], and time [T].

Solution: Step 1: Write down Newton's Law of Universal Gravitation, which defines the force F between two masses m_1 and m_2 separated by a distance r:

$$F = G\frac{m_1 m_2}{r^2}$$

Step 2: Rearrange the algebraic equation to isolate the universal gravitational constant G:

$$G = \frac{F \cdot r^2}{m_1 m_2}$$

Step 3: Substitute the known dimensional formulas for each component variable:
Force, $[F] = [\mathrm{M\,L\,T^{-2}}]$
Distance squared, $[r^2] = [\mathrm{L}^2]$
Mass product, $[m_1 m_2] = [\mathrm{M \cdot M}] = [\mathrm{M}^2]$
Step 4: Substitute these dimensions back into the isolated equation for G:

$$[G] = \frac{[\mathrm{M\,L\,T^{-2}}] \cdot [\mathrm{L}^2]}{[\mathrm{M}^2]}$$

Step 5: Combine the terms by applying basic laws of exponents:

$$[G] = [\mathrm{M}^{1-2} \cdot \mathrm{L}^{1+2} \cdot \mathrm{T}^{-2}] = [\mathrm{M}^{-1}\mathrm{L}^3\mathrm{T}^{-2}]$$

Final Answer: $[\mathrm{M}^{-1}\mathrm{L}^3\mathrm{T}^{-2}]$

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept: The critical angle C is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is exactly 90°. Snell's law relates the critical angle to the relative refractive index by the formula $\mu = \frac{1}{\sin C}$.

Solution: Step 1: Let μ be the refractive index of the optically denser medium with respect to the rarer medium.

Step 2: Write out the mathematical expression relating the refractive index and the critical angle:

$$\mu = \frac{1}{\sin C}$$

Step 3: Identify the given value of the critical angle from the problem statement:

$$C = 45^\circ$$

Step 4: Substitute this angle value into the trigonometric relation:

$$\mu = \frac{1}{\sin(45^\circ)}$$

Step 5: Recall the exact trigonometric value for $\sin(45^\circ) = \frac{1}{\sqrt{2}}$:

$$\mu = \frac{1}{\left(\frac{1}{\sqrt{2}}\right)}$$

Step 6: Simplify the complex fraction to find the final value for the refractive index:

$$\mu = \sqrt{2}$$

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

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept: Radioactive decay follows a first-order exponential law. The fraction of a radioactive substance remaining intact after n half-lives is given by $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$, where N_0 is the initial amount.

Solution: Step 1: The problem states that a fraction equal to $\frac{7}{8}$th of the original sample has decayed.
Step 2: Calculate the remaining fraction of active radioactive nuclei (N) left intact in the sample:

$$\text{Remaining fraction} = 1 - \text{Decayed fraction} = 1 - \frac{7}{8} = \frac{1}{8}$$

Step 3: Express the remaining fraction as a power of $\frac{1}{2}$ to determine the number of elapsed half-lives n:

$$\frac{N}{N_0} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$$

Step 4: Comparing this with the standard formula $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ gives the total number of half-lives:

$$n = 3$$

Step 5: Calculate the total time t required for this decay process using the given half-life value ($T_{1/2} = 10$ days):

$$\text{Total time } t = n \times T_{1/2} = 3 \times 10 \text{ days} = 30 \text{ days}$$

Final Answer: $\boxed{30 \text{ days}}$

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept: Work done W by a constant vector force $\vec{F}$ acting through a vector displacement $\vec{d}$ is a scalar quantity defined by the vector dot product (inner product) expression $W = \vec{F} \cdot \vec{d}$.

Solution: Step 1: Identify the given force and displacement vectors from the problem text:

$$\vec{F} = 2\hat{i} + 3\hat{j} - 4\hat{k}$$

$$\vec{d} = 3\hat{i} + 4\hat{j} + 5\hat{k}$$

Step 2: Set up the mathematical expression for the dot product of two vectors in Cartesian components:

$$W = \vec{F} \cdot \vec{d} = (F_x d_x) + (F_y d_y) + (F_z d_z)$$

Step 3: Substitute the corresponding unit vector coefficients into the dot product formula:

$$W = (2 \times 3) + (3 \times 4) + (-4 \times 5)$$

Step 4: Perform the multiplication for each component term:

$$W = 6 + 12 - 20$$

Step 5: Add and subtract the terms to calculate the final scalar work value:

$$W = 18 - 20 = -2 \text{ Joules}$$

Step 6: The negative work indicates that the force has a component opposing the actual displacement direction.

Final Answer: $\boxed{-2 \text{ J}}$

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept: The fundamental frequency f of a closed organ pipe (closed at one end, open at the other) is determined by its length L and the speed of sound v through the air column, given by the formula $f = \frac{v}{4L}$.

Solution: Step 1: Write down the initial relation for the fundamental frequency f_1 of the pipe with length L:

$$f_1 = f = \frac{v}{4L}$$

Step 2: According to the problem statement, the length of the organ pipe is cut in half, so the new length becomes $L' = \frac{L}{2}$.

Step 3: Formulate the expression for the new fundamental frequency f_2 using this modified length:

$$f_2 = \frac{v}{4L'} = \frac{v}{4\left(\frac{L}{2}\right)}$$

Step 4: Simplify the complex mathematical fraction by moving the factor of 2 to the numerator:

$$f_2 = 2 \times \left(\frac{v}{4L}\right)$$

Step 5: Substitute the original frequency term f back into the expression:

$$f_2 = 2f$$

Step 6: Shortening the column decreases the acoustic wavelength, which doubles the fundamental vibrational frequency.

Final Answer: $\boxed{2f}$

Answer: (C)

Go Back to Question 31

Q32.

Solution

Concept: The depletion layer in a p-n junction diode is formed by immobile ions creating a built-in potential barrier. Applying an external voltage biases this barrier, directly altering the spatial width of the depletion region.

Solution: Step 1: In a p-n junction diode, the depletion region contains uncovered positive donor ions on the n-side and negative acceptor ions on the p-side, which sets up an internal barrier potential pointing from the n-side to the p-side.
Step 2: When the diode is forward-biased, the positive terminal of the external battery is connected to the p-side and the negative terminal to the n-side.
Step 3: This external electric field opposes the internal built-in barrier electric field of the depletion region.
Step 4: The opposing field lowers the potential barrier height and pushes majority carriers (holes from p-side, electrons from n-side) into the depletion zone.
Step 5: This action compresses the layer, causing the total spatial width of the depletion layer to decrease significantly, facilitating current flow.

Final Answer: Decreases

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept: The orbital speed v of a satellite in a circular orbit around a central planet depends solely on the mass of the planet M and the radius of the orbit r. It is given by $v = \sqrt{\frac{GM}{r}}$ and is completely independent of the satellite's own mass.

Solution: Step 1: Write down the general formula for the orbital speed of a satellite revolving around the Earth:

$$v = \sqrt{\frac{GM_e}{r}}$$

Step 2: Note that the masses of the satellites (m and $2m$) do not appear in this formula, meaning they have no effect on the speed.

Step 3: Set up the expressions for the orbital speeds of both satellites based on their orbital radii $r_1 = r$ and $r_2 = 2r$:

$$v_1 = \sqrt{\frac{GM_e}{r}} \quad \text{and} \quad v_2 = \sqrt{\frac{GM_e}{2r}}$$

Step 4: Formulate the ratio of their orbital speeds $\frac{v_1}{v_2}$:

$$\frac{v_1}{v_2} = \frac{\sqrt{\frac{GM_e}{r}}}{\sqrt{\frac{GM_e}{2r}}} = \sqrt{\frac{2r}{r}} = \sqrt{2} = \sqrt{2} : 1$$

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

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept: The first law of thermodynamics is an expression of the law of conservation of energy: $\Delta Q = \Delta U + \Delta W$. For any cyclic thermodynamic process, the system returns exactly to its initial state.

Solution: Step 1: Internal energy U is a thermodynamic state function, meaning its value depends entirely on the current state parameters of the system and not on the historical path taken to reach that state.

Step 2: In a cyclic process, the system undergoes a series of changes but ultimately returns to its initial thermodynamic state.

Step 3: Therefore, the net change in internal energy (ΔU) over one complete cycle is identically zero:

$$\Delta U = 0$$

Step 4: Substitute $\Delta U = 0$ into the mathematical expression of the first law of thermodynamics:

$$\Delta Q = 0 + \Delta W \implies \Delta Q = \Delta W$$

Step 5: This equation demonstrates that the total net heat energy absorbed by the system from the surroundings throughout the cycle is completely converted into net mechanical work done by the system.

Final Answer: Total heat absorbed equals total work done

Answer: (A)

Go Back to Question 34

Q35.

Solution

Concept: The internal resistance r of a cell measured using a linear potentiometer system is given by the standard formula $r = R\left(\frac{l_1}{l_2} - 1\right)$, where l_1 is the open-circuit balancing length and l_2 is the short-circuit balancing length.

Solution: Step 1: Identify and record the values provided in the question:
Open-circuit balancing length (no shunt resistor), $l_1 = 240$ cm
Closed-circuit balancing length (with shunt resistor), $l_2 = 120$ cm
External shunt resistance connected, $R = 2\ \Omega$
Step 2: Write out the potentiometer relation for internal resistance:

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

Step 3: Substitute the numerical experimental values into the formula:

$$r = 2 \times \left(\frac{240}{120} - 1\right)$$

Step 4: Simplify the fractional expression inside the parentheses:

$$\frac{240}{120} = 2 \implies r = 2 \times (2 - 1)$$

Step 5: Calculate the final internal resistance:

$$r = 2 \times 1 = 2\ \Omega$$

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

Answer: (B)

Go Back to Question 35

Q36.

Solution

Concept: Static friction is a self-adjusting force that matches the applied force up to a maximum threshold called the limiting friction ($f_L = \mu_s N$). If the applied force is less than f_L, the body remains stationary, and static friction equals the applied force.

Solution: Step 1: Calculate the normal contact force N acting on the block resting on the horizontal floor:

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

Step 2: Compute the maximum threshold value of static friction, known as the limiting friction force (f_L):

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

Step 3: Compare the externally applied horizontal force ($F = 3$ N) with the calculated limiting friction force ($f_L = 8$ N).
Step 4: Since the applied force is less than the limiting friction (3 N < 8 N), the block will not move and remains in a state of static equilibrium.
Step 5: Because static friction is self-adjusting to prevent relative motion, its value adjusts to exactly balance the applied force:

$$f_s = F = 3 \text{ N}$$

Final Answer: $\boxed{3 \text{ N}}$

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept: The root mean square (rms) speed of gas molecules is given by $v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$, showing that it is directly proportional to the square root of the absolute thermodynamic temperature of the gas ($v_{\text{rms}} \propto \sqrt{T}$).

Solution: Step 1: Convert the initial given temperature from Celsius to Kelvin:

$$T_1 = 27^\circ\text{C} = 27 + 273 = 300 \text{ K}$$

Step 2: Set up the proportionality relation derived from the kinetic theory of gases:

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$$

Step 3: The problem states that the final rms speed becomes double its initial value ($v_2 = 2v_1$), so the speed ratio is:

$$\frac{v_2}{v_1} = 2$$

Step 4: Substitute this ratio into the temperature relation and square both sides to clear the root:

$$2 = \sqrt{\frac{T_2}{300}} \implies 4 = \frac{T_2}{300}$$

Step 5: Solve for the final absolute temperature T_2 in Kelvin:

$$T_2 = 4 \times 300 = 1200 \text{ K}$$

Step 6: Convert the Kelvin value back into Celsius to match the options:

$$t_2 = 1200 - 273 = 927^\circ\text{C}$$

Final Answer: $\boxed{927^\circ\text{C}}$

Answer: (C)

Go Back to Question 37

Q38.

Solution

Concept: Unpolarized light consists of electric field vector oscillations distributed uniformly in all possible transverse directions. An ideal polaroid sheet restricts these oscillations to a single linear transmission axis.

Solution: Step 1: Unpolarized light can be resolved into two mutually perpendicular independent linear polarization components of equal intensity.
Step 2: Let the total initial intensity of the unpolarized beam be I_0. The intensity is split equally between these two components:

$$I_x = \frac{I_0}{2} \quad \text{and} \quad I_y = \frac{I_0}{2}$$

Step 3: When this light passes through an ideal polarizing filter, the component aligned parallel to the transmission axis is fully transmitted.
Step 4: The component oriented perpendicular to the transmission axis is completely absorbed or blocked by the chemical structure of the polaroid.
Step 5: This leaves exactly half of the total initial light energy to emerge as linearly polarized light:

$$I_{\text{transmitted}} = \frac{I_0}{2}$$

Step 6: This result is independent of the orientation angle of the first polaroid sheet.

Final Answer: $\boxed{\frac{I_0}{2}}$

Answer: (B)

Go Back to Question 38

Q39.

Solution

Concept: The electric current I flowing through a conductor is related to the drift velocity v_d of its conduction electrons by the microscopic transport formula $I = nAev_d$, where A is the cross-sectional area.

Solution: Step 1: Isolate the drift velocity v_d in the current expression:

$$v_d = \frac{I}{nAe}$$

Step 2: Express the cross-sectional area A of the cylindrical copper wire in terms of its radius r ($A = \pi r^2$):

$$v_d = \frac{I}{n(\pi r^2)e}$$

Step 3: Since the current I, electron density n, and elementary charge e remain constant, drift velocity is inversely proportional to the square of the wire's radius:

$$v_d \propto \frac{1}{r^2}$$

Step 4: Let the initial radius be r_1 and the new radius be $r_2 = 2r_1$. Set up the velocity ratio:

$$\frac{v_{d2}}{v_{d1}} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{r_1}{2r_1}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

Step 5: Solve for the new drift velocity v_{d2}:

$$v_{d2} = \frac{1}{4}v_{d1}$$

Step 6: Thus, doubling the radius causes the drift velocity to become one-fourth of its original value.

Final Answer: Become one-fourth

Answer: (D)

Go Back to Question 39

Q40.

Solution

Concept: The de Broglie wavelength λ of a material particle is related to its momentum by $\lambda = \frac{h}{p}$. For an electron accelerated from rest through a potential difference V, this simplifies to $\lambda = \frac{12.27}{\sqrt{V}}$ Å.

Solution: Step 1: Write down the convenient formula for the de Broglie wavelength of an electron accelerated through an electric potential V:

$$\lambda = \frac{12.27}{\sqrt{V}} \text{ Å}$$

Step 2: Identify the given accelerating potential difference from the problem:

$$V = 100 \text{ V}$$

Step 3: Substitute the voltage value into the denominator of the wavelength equation:

$$\lambda = \frac{12.27}{\sqrt{100}} \text{ Å}$$

Step 4: Evaluate the square root of 100 in the denominator:

$$\sqrt{100} = 10$$

Step 5: Perform the division by 10 to determine the final value:

$$\lambda = \frac{12.27}{10} \text{ Å} = 1.227 \text{ Å}$$

Step 6: This value matches option (A) exactly, representing typical atomic scale dimensions.

Final Answer: $\boxed{1.227 \text{ Å}}$

Answer: (A)

Go Back to Question 40

Answer Key

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