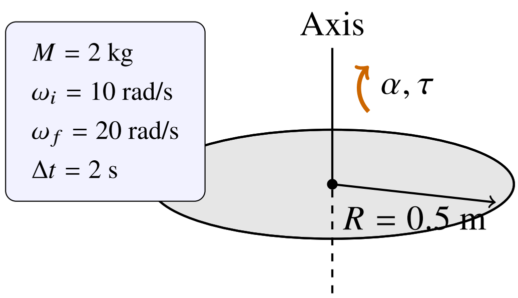
MHT-CET Physics Sample Paper-17

Duration: 45 Minutes **Maximum Marks: 50**

Instructions

- This paper contains a total of **50** Multiple Choice Questions.
- Each correct answer carries **+1 marks**.
- No negative marking for incorrect questions.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.
- No marks will be deducted for questions that are left unattempted.

Q1. A circular disc of mass 2 kg and radius 0.5 m is rotating about an axis passing through its center and perpendicular to its plane. If the angular velocity changes from 10 rad/s to 20 rad/s in 2 seconds, the torque acting on the disc is:



(A) 1.25 N m

(B) 2.5 N m

(C) 0.625 N m

(D) 5.0 N m

Q2. A body of mass m is suspended from a vertical spring of force constant k. The body is pulled down by a distance x and released. The maximum speed of the body during SHM is:

(A) $x\sqrt{k/m}$

(B) $x\sqrt{m/k}$

(C) kx^2/m

(D) $\sqrt{kx/m}$

Q3. Three charges each of $+q$ are placed at the corners of an equilateral triangle of side a. The electrostatic potential energy of the system is:

(A) $\frac{3q^2}{4\pi\epsilon_0 a}$

(B) $\frac{q^2}{4\pi\epsilon_0 a}$

(C) $\frac{\sqrt{3}q^2}{4\pi\epsilon_0 a}$

(D) $\frac{3q^2}{8\pi\epsilon_0 a}$

Q4. In a potentiometer experiment, the balancing length is 250 cm for a cell of emf 1.5 V. If the cell is shunted by a resistance of 10Ω, the balancing length becomes 200 cm. The internal resistance of the cell is:

(A) 2.5Ω

(B) 2.0Ω

(C) 1.25Ω

(D) 5.0Ω

Q5. A proton enters a uniform magnetic field of 0.5 T with a velocity of 2×10^7 m/s at an angle of $30°$ to the field. The magnetic force acting on the proton is ($q_p = 1.6 \times 10^{-19}$ C):

(A) 0.8×10^{-12} N

(B) 1.6×10^{-12} N

(C) 0.4×10^{-12} N

(D) 3.2×10^{-12} N

Q6. The magnetic flux linked with a coil is given by $\phi = 5t^2 + 3t + 16$ mWb. The induced emf in the coil at $t = 4$ s is:

(A) 43 mV

(B) 40 mV

(C) 23 mV

(D) 10 mV

Q7. In a Young's Double Slit Experiment, the ratio of maximum to minimum intensity in the interference pattern is 25 : 9. The ratio of the amplitudes of the two waves is:

(A) 5 : 3

(B) 4 : 1

(C) 8 : 1

(D) 2 : 1

(E) 4 : 1

Q8. The pressure of an ideal gas is increased by 25% isothermally. The volume of the gas will decrease by:

(A) 25%

(B) 20%

(C) 15%

(D) 50%

Q9. A radioactive substance has a half-life of 10 days. The time taken for 75% of the substance to decay is:

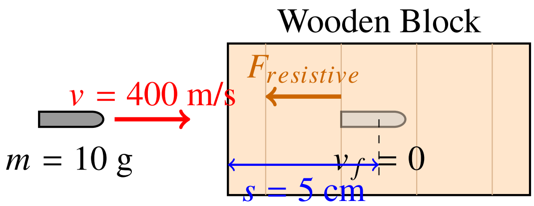
(A) 20 days

(B) 15 days

(C) 30 days

(D) 40 days

Q10. A bullet of mass 10 g moving with a velocity of 400 m/s strikes a wooden block and comes to rest after penetrating 5 cm. The average resistive force exerted by the block is:



(A) 16000 N

(B) 8000 N

(C) 4000 N

(D) 32000 N

Q11. The work done in blowing a soap bubble of radius R is W. The work done in blowing a bubble of radius $2R$ of the same solution is:

(A) $2W$

(B) $4W$

(C) $\sqrt{2}W$

(D) $8W$

Q12. The escape velocity of a body from the Earth is 11.2 km/s. If a body is projected with a velocity twice the escape velocity, the velocity of the body at infinite distance is:

(A) 11.2 km/s

(B) $11.2 \times \sqrt{3}$ km/s

(C) 22.4 km/s

(D) Zero

Q13. A wire of length L and resistance R is stretched so that its length becomes $2L$ and its area of cross-section is halved. The new resistance of the wire will be:

(A) $4R$

(B) $2R$

(C) $R/4$

(D) $8R$

Q14. The threshold wavelength for a metal is 5000 Å. If light of wavelength 4000 Å is incident on it, the maximum kinetic energy of photoelectrons is ($h = 6.6 \times 10^{-34}$ Js):

(A) 0.62 eV

(B) 1.24 eV

(C) 3.1 eV

(D) 0.31 eV

Q15. In a common emitter amplifier, the current gain is 50. If the collector current changes by 2.5 mA, the change in base current is:

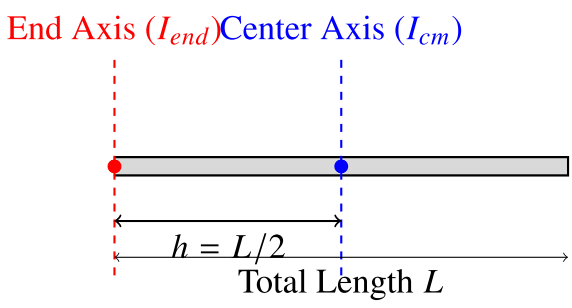
(A) 50μA

(B) 25μA

(C) 100μA

(D) 125μA

Q16. The moment of inertia of a uniform thin rod of mass M and length L about an axis passing through its center and perpendicular to its length is I. The moment of inertia of the same rod about an axis passing through one of its ends and perpendicular to its length is:



(A) $2I$

(B) $3I$

(C) $4I$

(D) $6I$

Q17. A mass m is attached to a spring of force constant k. If the mass is doubled and the force constant is halved, the frequency of oscillation becomes:

(A) Twice the original

(B) Half of the original

(C) Four times the original

(D) One-fourth of the original

Q18. Two capacitors of capacities 3μF and 6μF are connected in series across a 12 V battery. The potential difference across the 3μF capacitor is:

(A) 4 V

(B) 8 V

(C) 6 V

(D) 12 V

Q19. A current of 2 A flows through a circular coil of radius 10 cm having 50 turns. The magnetic induction at the center of the coil is ($\mu_0 = 4\pi \times 10^{-7}$ T m/A):

(A) $2\pi \times 10^{-4}$ T

(B) $4\pi \times 10^{-4}$ T

(C) $1\pi \times 10^{-4}$ T

(D) $2\pi \times 10^{-3}$ T

Q20. An alternating voltage $e = 200\sin(100\pi t)$ V is applied to a pure resistance of 50Ω. The rms current in the circuit is:

(A) 4 A

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

(C) 2 A

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

Q21. In a diffraction pattern due to a single slit of width d, the first minimum is observed at an angle 30° when light of wavelength 5000 Å is used. The width of the slit is:

(A) 1.0×10^{-6} m

(B) 2.0×10^{-6} m

(C) 0.5×10^{-6} m

(D) 1.25×10^{-6} m

Q22. A Carnot engine works between temperatures 600 K and 300 K. Its efficiency is:

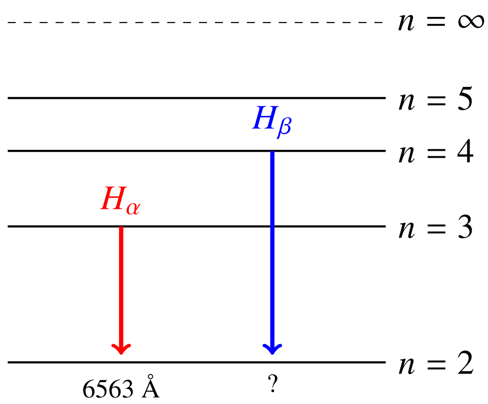
(A) 25%

(B) 50%

(C) 75%

(D) 100%

Q23. The wavelength of the first line of the Balmer series is 6563 Å. The wavelength of the second line of the Balmer series will be:



Balmer Series (Visible Spectrum)

(A) 4861 Å

(B) 4102 Å

(C) 1215 Å

(D) 3646 Å

Q24. A particle is projected with a velocity u at an angle of 45° with the horizontal. The ratio of the maximum height reached to the horizontal range is:

(A) 1 : 4

(B) 1 : 2

(C) 1 : 1

(D) 2 : 1

Q25. A force $\vec{F} = (2\hat{i} + 3\hat{j} + 4\hat{k})$ N acts on a body and displaces it from $(1, 1, 1)$ m to $(2, 3, 5)$ m. The work done is:

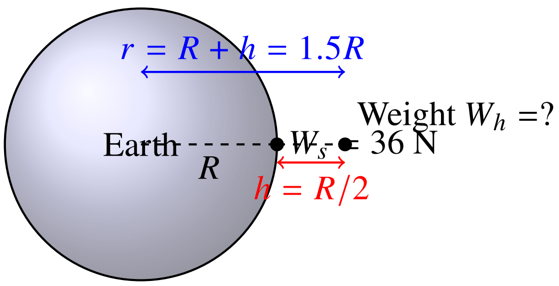
(A) 24 J

(B) 10 J

(C) 20 J

(D) 34 J

Q26. The weight of a body on the surface of the Earth is 36 N. At a height equal to half the radius of the Earth, its weight will be:



(A) 18 N

(B) 16 N

(C) 9 N

(D) 12 N

Q27. A liquid drops from a capillary tube of radius r. If the surface tension of the liquid is T, the weight of the drop is approximately:

(A) $\pi r T$

(B) $2\pi rT$

(C) $4\pi rT$

(D) $\pi r^2 T$

Q28. The dimensions of universal gravitational constant G are:

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

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

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

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

Q29. For a transistor, the relation between current gains α and β is:

(A) $\beta = \frac{\alpha}{1-\alpha}$

(B) $\alpha = \frac{\beta}{1-\beta}$

(C) $\alpha\beta = 1$

(D) $\beta = \frac{\alpha}{1+\alpha}$

Q30. In an adiabatic process, the pressure of a gas is proportional to the cube of its absolute temperature. The value of γ (C_p/C_v) for the gas is:

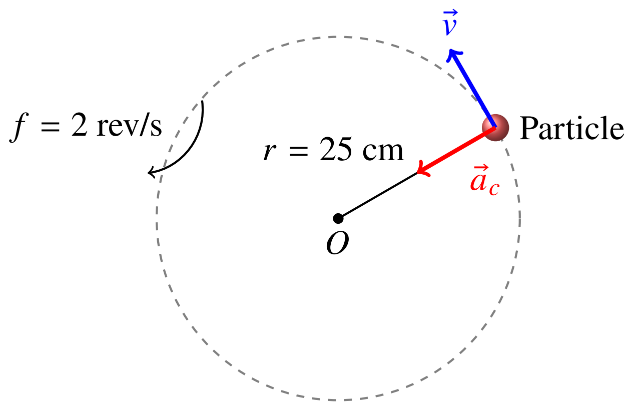
(A) $3/2$

(B) $4/3$

(C) $5/3$

(D) $7/5$

Q31. A particle moves in a circle of radius 25 cm at two revolutions per second. The acceleration of the particle in m/s^2 is:



(A) π^2

(B) $8\pi^2$

(C) $4\pi^2$

(D) $2\pi^2$

Q32. In an electromagnetic wave, the electric field vector $\vec{E}$ and magnetic field vector $\vec{B}$ are:

(A) Parallel to each other

(B) Perpendicular to each other

(C) At an angle of 45°

(D) Randomly oriented

Q33. The self-inductance of a solenoid of length L, area of cross-section A and total number of turns N is:

(A) $\mu_0 N^2 A/L$

(B) $\mu_0 NA/L$

(C) $\mu_0 N^2 L/A$

(D) $\mu_0 NAL$

Q34. Two point charges $+9e$ and $+e$ are kept 16 cm apart. At what distance from $+9e$ charge the electric field is zero?

(A) 12 cm

(B) 4 cm

(C) 8 cm

(D) 6 cm

Q35. A wire of resistance 4Ω is bent into a circle. The effective resistance between two points at the ends of any diameter is:

(A) 4Ω

(B) 2Ω

(C) 1Ω

(D) 8Ω

Q36. The magnetic susceptibility of a paramagnetic material varies with absolute temperature T as:

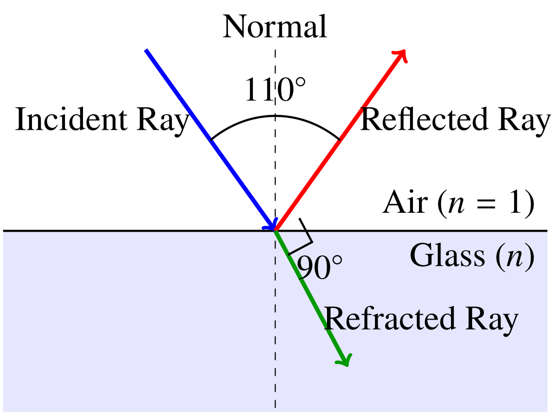
(A) $\chi \propto T$

(B) $\chi \propto 1/T$

(C) $\chi \propto e^T$

(D) χ is independent of T

Q37. A ray of light is incident on a glass plate at a polarizing angle. The angle between the incident ray and the reflected ray is 110°. The angle of refraction is:



(A) 35°

(B) 55°

(C) 20°

(D) 90°

Q38. An ideal gas heat engine operates in a Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cal at the higher temperature. The amount of heat converted into work is:

(A) 1.2×10^4 cal

(B) 4.8×10^4 cal

(C) 3.5×10^4 cal

(D) 2.4×10^4 cal

Q39. 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

Q40. Two projectiles are fired at angles 30° and 60° with the horizontal with the same velocity. The ratio of their horizontal ranges is:

(A) 1 : 1

(B) 1 : 2

(C) 1 : 3

(D) $\sqrt{3} : 1$

Q41. A spring of force constant k is cut into two equal halves. The force constant of each half is:

(A) $k/2$

(B) k

(C) $2k$

(D) $4k$

Q42. The work done in increasing the voltage of a capacitor from 5 V to 10 V is W. The work done in increasing it from 10 V to 15 V will be:

(A) W

(B) $1.67W$

(C) $2W$

(D) $3W$

Q43. A liquid rises to a height of 5 cm in a glass capillary tube. If the area of cross-section of the tube is reduced to $1/4$th, the rise of liquid will be:

(A) 10 cm

(B) 20 cm

(C) 2.5 cm

(D) 5 cm

Q44. The speed of sound in oxygen at STP is v. If the helium gas is used at STP, the speed of sound will be:

(A) Greater than v

(B) Smaller than v

(C) Equal to v

(D) Zero

Q45. The logic gate which gives high output only when both inputs are low is:

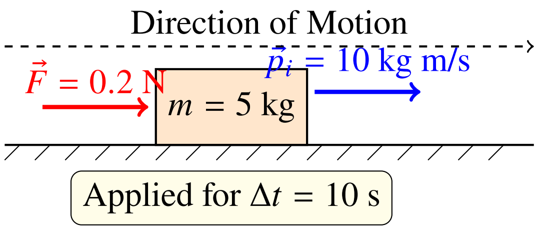
(A) OR

(B) AND

(C) NOR

(D) NAND

Q46. A body of mass 5 kg is moving with a momentum of 10 kg m/s. A force of 0.2 N acts on it in the direction of motion for 10 seconds. The increase in its kinetic energy is:



(A) 4.4 J

(B) 2.2 J

(C) 8.8 J

(D) 10 J

Q47. The fundamental frequency of a closed organ pipe of length L is f. The fundamental frequency of an open organ pipe of the same length is:

(A) $f/2$

(B) $2f$

(C) f

(D) $4f$

Q48. An electron moves in a circular path of radius r with a constant speed v in a perpendicular magnetic field B. If the speed is doubled and magnetic field is halved, the radius will become:

(A) r

(B) $2r$

(C) $4r$

(D) $r/4$

Q49. The energy equivalent of 1 atomic mass unit (amu) is approximately:

(A) 931.5 MeV

(B) 931.5 keV

(C) 9.315 MeV

(D) 0.931 MeV

Q50. A body of mass M hits a wall normally with a velocity v and bounces back with the same velocity. The change in momentum is:

(A) Mv

(B) $2Mv$

(C) Zero

(D) $-Mv$

Detailed Solutions

Q1.

Solution

Concept:

The torque (τ) acting on a rotating body is given by the product of its moment of inertia (I) and angular acceleration (α):

$$\tau = I\alpha$$

For a circular disc rotating about its center, the moment of inertia is $I = \frac{1}{2}mR^2$. The angular acceleration is the rate of change of angular velocity: $\alpha = \frac{\omega_f - \omega_i}{t}$.

Solution:

1. Calculate the moment of inertia (I) of the disc:

$$I = \frac{1}{2} \times 2 \text{ kg} \times (0.5 \text{ m})^2 = 1 \times 0.25 = 0.25 \text{ kg m}^2$$

2. Calculate the angular acceleration (α):

$$\alpha = \frac{20 \text{ rad/s} - 10 \text{ rad/s}}{2 \text{ s}} = \frac{10}{2} = 5 \text{ rad/s}^2$$

3. Calculate the torque (τ):

$$\tau = I\alpha = 0.25 \text{ kg m}^2 \times 5 \text{ rad/s}^2 = 1.25 \text{ N m}$$

Final Answer: The torque acting on the disc is 1.25 N m.

Answer: (A)

Q2.

Solution

Concept:
In Simple Harmonic Motion (SHM) of a spring-mass system, the angular frequency (ω) is given by:

$$\omega = \sqrt{\frac{k}{m}}$$

The maximum speed (v_{max}) occurs as the body passes through the mean position and is given by the product of the amplitude (A) and the angular frequency:

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

Solution:
1. The distance x the body is pulled down from the equilibrium position represents the amplitude A of the oscillation. 2. The expression for angular frequency is:

$$\omega = \sqrt{\frac{k}{m}}$$

3. Substitute the values into the maximum speed formula:

$$v_{max} = x \times \sqrt{\frac{k}{m}}$$

Final Answer: The maximum speed is $x\sqrt{k/m}$.

Answer: (A)

Q3.

Solution

Concept:

The electrostatic potential energy (U) of a system of point charges is the sum of the potential energies of all unique pairs of charges. For a pair of charges q_1 and q_2 separated by distance r:

$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

Solution:

1. In an equilateral triangle of side a, there are 3 charges (q, q, q) and 3 identical pairs. 2. The potential energy for one pair is:

$$U_{pair} = \frac{1}{4\pi\epsilon_0}\frac{q^2}{a}$$

3. The total potential energy of the system is:

$$U_{total} = 3 \times U_{pair} = 3 \times \left(\frac{1}{4\pi\epsilon_0}\frac{q^2}{a}\right) = \frac{3q^2}{4\pi\epsilon_0 a}$$

Final Answer: The total potential energy is $\frac{3q^2}{4\pi\epsilon_0 a}$.

Answer: (A)

Q4.

Solution

Concept:

The internal resistance (r) of a cell measured using a potentiometer is given by the formula:

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

where l_1 is the balancing length on open circuit, l_2 is the balancing length when the cell is shunted by external resistance R.

Solution:

1. Given values: $l_1 = 250$ cm, $l_2 = 200$ cm, and $R = 10\Omega$. 2. Substitute these into the internal resistance formula:

$$r = 10 \times \left(\frac{250}{200} - 1\right)$$

3. Simplify the ratio:

$$r = 10 \times (1.25 - 1) = 10 \times 0.25$$

4. Calculate final value:

$$r = 2.5\Omega$$

Final Answer: The internal resistance is 2.5Ω.

Answer: (A)

Q5.

Solution

Concept:
The magnetic force (F) acting on a moving charge q in a magnetic field B is given by:

$$F = qvB\sin(\theta)$$

where v is the velocity and θ is the angle between the velocity vector and the magnetic field vector.
Solution:
1. Identify the given values: $q = 1.6 \times 10^{-19}$ C $v = 2 \times 10^7$ m/s $B = 0.5$ T $\theta = 30°$ 2. Substitute into the force formula:

$$F = (1.6 \times 10^{-19}) \times (2 \times 10^7) \times (0.5) \times \sin(30°)$$

3. Knowing $\sin(30°) = 0.5$:

$$F = (1.6 \times 10^{-19}) \times (2 \times 10^7) \times (0.5) \times (0.5)$$

4. Calculate:

$$F = 1.6 \times 10^{-12} \times 1 \times 0.5 = 0.8 \times 10^{-12}\ \text{N}$$

Final Answer: The force is 0.8×10^{-12} N.

Answer: (A)

Q6.

Solution

Concept:

According to Faraday's Law of Electromagnetic Induction, the magnitude of the induced electromotive force (emf) in a circuit is equal to the time rate of change of magnetic flux through the circuit:

$$e = \frac{d\phi}{dt}$$

If the flux ϕ is given as a function of time t, we find the derivative of the function with respect to t to determine the emf at any specific instant.

Solution:

1. The given equation for magnetic flux is:

$$\phi = 5t^2 + 3t + 16 \text{ mWb}$$

2. Differentiate the flux with respect to time to find the induced emf (e):

$$e = \frac{d}{dt}(5t^2 + 3t + 16)$$

$$e = (10t + 3) \text{ mV}$$

3. To find the emf at $t = 4$ s, substitute the value of t into the expression:

$$e = 10(4) + 3$$

$$e = 40 + 3 = 43 \text{ mV}$$

Final Answer: The induced emf at $t = 4$ s is 43 mV.

Answer: (A)

Q7.

Solution

Concept:

In wave interference, the intensity (I) is proportional to the square of the amplitude (A). The maximum intensity (I_{max}) occurs when waves interfere constructively, and minimum intensity (I_{min}) occurs during destructive interference:

$$I_{max} \propto (A_1 + A_2)^2$$

$$I_{min} \propto (A_1 - A_2)^2$$

Therefore, the ratio of intensities is related to the amplitudes by:

$$\frac{I_{max}}{I_{min}} = \left(\frac{A_1 + A_2}{A_1 - A_2}\right)^2$$

Solution:

1. Given the ratio of intensities:

$$\frac{I_{max}}{I_{min}} = \frac{25}{9}$$

2. Taking the square root of both sides:

$$\frac{A_1 + A_2}{A_1 - A_2} = \sqrt{\frac{25}{9}} = \frac{5}{3}$$

3. Apply cross-multiplication to solve for the relationship between A_1 and A_2:

$$3(A_1 + A_2) = 5(A_1 - A_2)$$

$$3A_1 + 3A_2 = 5A_1 - 5A_2$$

4. Rearrange the terms:

$$3A_2 + 5A_2 = 5A_1 - 3A_1$$

$$8A_2 = 2A_1$$

5. The ratio of amplitudes is:

$$\frac{A_1}{A_2} = \frac{8}{2} = \frac{4}{1}$$

Final Answer: The ratio of the amplitudes is 4 : 1.

Answer: (B)

Q8.

Solution

Concept:

For an isothermal process (constant temperature) of an ideal gas, Boyle's Law states that the product of pressure (P) and volume (V) remains constant:

$$P_1 V_1 = P_2 V_2$$

This implies that pressure and volume are inversely proportional ($V \propto 1/P$).

Solution:

1. Let the initial pressure be P and initial volume be V. 2. The pressure is increased by 25%, so the new pressure (P') is:

$$P' = P + 0.25P = 1.25P = \frac{5}{4}P$$

3. Using Boyle's Law:

$$P \times V = P' \times V'$$

$$P \times V = \left(\frac{5}{4}P\right) \times V'$$

4. Solve for the new volume V':

$$V' = \frac{4}{5}V = 0.8V$$

5. The decrease in volume is $V - V' = V - 0.8V = 0.2V$. 6. Percentage decrease in volume:

$$\text{Decrease } \% = \left(\frac{0.2V}{V}\right) \times 100 = 20\%$$

Final Answer: The volume of the gas will decrease by 20%.

Answer: (B)

Q9.

Solution

Concept:

Radioactive decay follows an exponential law. The amount of substance remaining after n half-lives is given by:

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

where $n = \frac{t}{T_{1/2}}$. If 75% of the substance has decayed, then 25% of the substance remains.

Solution:

1. Given that 75% has decayed, the remaining amount N is:

$$N = N_0 - 0.75N_0 = 0.25N_0 = \frac{1}{4}N_0$$

2. Express the remaining amount in terms of powers of $1/2$:

$$\frac{N_0}{4} = N_0 \left(\frac{1}{2}\right)^n$$

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

3. This shows that $n = 2$ half-lives have passed. 4. Total time t is:

$$t = n \times T_{1/2} = 2 \times 10 \text{ days} = 20 \text{ days}$$

Final Answer: The time taken is 20 days.

Answer: (A)

Q10.

Solution

Concept:
The work-energy theorem states that the work done by the resistive force (F) is equal to the change in kinetic energy of the bullet. Alternatively, we can use the third equation of motion to find acceleration and then use Newton's second law:

$$v^2 = u^2 + 2as$$

$$F = m \times a$$

Solution:
1. Identify the given values in SI units: Mass $m = 10$ g $= 0.01$ kg Initial velocity $u = 400$ m/s Final velocity $v = 0$ m/s (rest) Displacement $s = 5$ cm $= 0.05$ m 2. Use the kinematic equation to find acceleration (a):

$$0^2 = (400)^2 + 2 \times a \times 0.05$$

$$0 = 160000 + 0.1a$$

$$a = -\frac{160000}{0.1} = -1600000 \text{ m/s}^2$$

3. Calculate the magnitude of the average resistive force:

$$F = m \times |a|$$

$$F = 0.01 \text{ kg} \times 1600000 \text{ m/s}^2$$

$$F = 16000 \text{ N}$$

Final Answer: The average resistive force is 16000 N.

Answer: (A)

Q11.

Solution

Concept:
The work done (W) in blowing a soap bubble is equal to the increase in its surface energy. Since a soap bubble has two free surfaces (inner and outer), the work done is given by:

$$W = T \times 2 \times \Delta A$$

where T is the surface tension and ΔA is the change in surface area. For a bubble of radius R, the initial area is zero and the final area is $4\pi R^2$. Thus:

$$W = 8\pi R^2 T$$

This shows that $W \propto R^2$.

Solution:

1. For the first bubble with radius R, the work done is:

$$W_1 = 8\pi R^2 T = W$$

2. For the second bubble with radius $2R$, the work done W_2 is:

$$W_2 = 8\pi (2R)^2 T$$

3. Expand the square term:

$$W_2 = 8\pi (4R^2) T = 4 \times (8\pi R^2 T)$$

4. Substitute W from the first step:

$$W_2 = 4W$$

Final Answer: The work done in blowing a bubble of radius $2R$ is $4W$.

Answer: (B)

Q12.

Solution

Concept:

When a body is projected from the Earth's surface with a velocity v greater than the escape velocity v_e, it will move to infinity. By the Law of Conservation of Energy, the total energy at the surface must equal the total energy at infinity.

$$\frac{1}{2}mv^2 - \frac{GMm}{R} = \frac{1}{2}mv_\infty^2 + 0$$

Since $\frac{1}{2}mv_e^2 = \frac{GMm}{R}$, the equation becomes:

$$v_\infty = \sqrt{v^2 - v_e^2}$$

Solution:

1. Given that the projection velocity is twice the escape velocity:

$$v = 2v_e$$

2. Substitute v into the energy conservation formula for velocity at infinity (v_∞):

$$v_\infty = \sqrt{(2v_e)^2 - v_e^2}$$

3. Simplify the expression under the square root:

$$v_\infty = \sqrt{4v_e^2 - v_e^2} = \sqrt{3v_e^2}$$

4. Therefore:

$$v_\infty = v_e\sqrt{3}$$

5. Substitute the known value of $v_e = 11.2$ km/s:

$$v_\infty = 11.2 \times \sqrt{3} \text{ km/s}$$

Final Answer: The velocity at infinite distance is $11.2 \times \sqrt{3}$ km/s.

Answer: (B)

Q13.

Solution

Concept:
The resistance (R) of a wire is given by the formula:

$$R = \rho \frac{L}{A}$$

where ρ is the resistivity, L is the length, and A is the cross-sectional area. When a wire is stretched, its volume ($V = L \times A$) remains constant.

Solution:
1. Initial resistance is $R = \rho \frac{L}{A}$. 2. New length $L' = 2L$. 3. New area $A' = A/2$. 4. Calculate the new resistance R' using the new dimensions:

$$R' = \rho \frac{L'}{A'} = \rho \frac{2L}{A/2}$$

5. Simplify the fraction:

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

6. Substitute the initial resistance R:

$$R' = 4R$$

Final Answer: The new resistance of the wire will be $4R$.

Answer: (A)

Q14.

Solution

Concept:

According to Einstein's Photoelectric Equation, the maximum kinetic energy (K_{max}) of a photoelectron is given by:

$$K_{max} = E - \phi_0$$

where E is the energy of the incident photon and ϕ_0 is the work function (threshold energy) of the metal. $E = \frac{hc}{\lambda}$ and $\phi_0 = \frac{hc}{\lambda_0}$. A useful shortcut for hc is ≈ 12400 eV Å.

Solution:

1. Calculate the energy of the incident photon (E) for $\lambda = 4000$ Å:

$$E = \frac{12400}{4000} = 3.1 \text{ eV}$$

2. Calculate the work function (ϕ_0) for threshold wavelength $\lambda_0 = 5000$ Å:

$$\phi_0 = \frac{12400}{5000} = 2.48 \text{ eV}$$

3. Calculate the maximum kinetic energy:

$$K_{max} = E - \phi_0 = 3.1 \text{ eV} - 2.48 \text{ eV}$$

$$K_{max} = 0.62 \text{ eV}$$

Final Answer: The maximum kinetic energy is 0.62 eV.

Answer: (A)

Q15.

Solution

Concept:

In a transistor, the current gain in common emitter configuration (β) is defined as the ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B):

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

This parameter indicates how much the output current is amplified relative to the input current.

Solution:

1. Given values: $\beta = 50$ and $\Delta I_C = 2.5\text{ mA} = 2.5 \times 10^{-3}$ A. 2. Rearrange the formula to solve for ΔI_B:

$$\Delta I_B = \frac{\Delta I_C}{\beta}$$

3. Substitute the values:

$$\Delta I_B = \frac{2.5\text{ mA}}{50} = 0.05\text{ mA}$$

4. Convert the answer to microamperes (μA):

$$\Delta I_B = 0.05 \times 1000\mu\text{A} = 50\mu\text{A}$$

Final Answer: The change in base current is 50μA.

Answer: (A)

Q16.

Solution

Concept:

The Parallel Axis Theorem states that the moment of inertia of a body about any axis (I_{any}) is equal to the moment of inertia about a parallel axis passing through the center of mass (I_{cm}) plus the product of the mass (M) and the square of the distance (h) between the two axes:

$$I_{any} = I_{cm} + Mh^2$$

Solution:

1. For a thin rod of length L, the moment of inertia about the center is given as I:

$$I = I_{cm} = \frac{1}{12}ML^2$$

2. To find the moment of inertia about the end, the distance from the center to the end is $h = L/2$.
3. Apply the Parallel Axis Theorem:

$$I_{end} = I_{cm} + M(L/2)^2$$

$$I_{end} = I + \frac{1}{4}ML^2$$

4. Since $ML^2 = 12I$, substitute this into the equation:

$$I_{end} = I + \frac{1}{4}(12I) = I + 3I = 4I$$

Final Answer: The moment of inertia about the end is $4I$.

Answer: (C)

Q17.

Solution

Concept:

The frequency (f) of a spring-mass system is the reciprocal of the time period (T). The formula for frequency is:

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

where k is the force constant and m is the mass.

Solution:

1. Let the initial frequency be $f_1 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$. 2. According to the problem, the new mass $m' = 2m$ and the new force constant $k' = k/2$. 3. The new frequency f_2 is:

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{k/2}{2m}} = \frac{1}{2\pi}\sqrt{\frac{k}{4m}}$$

4. Simplify the square root:

$$f_2 = \frac{1}{2} \times \left(\frac{1}{2\pi}\sqrt{\frac{k}{m}}\right)$$

5. Substitute f_1:

$$f_2 = \frac{1}{2}f_1$$

Final Answer: The frequency of oscillation becomes half of the original.

Answer: (B)

Q18.

Solution

Concept:

When capacitors are connected in series, the charge (Q) on each capacitor is the same. The potential difference (V) across a capacitor is $V = Q/C$. For two capacitors C_1 and C_2 in series across voltage V_{total}, the voltage V_1 across C_1 is:

$$V_1 = V_{total} \times \frac{C_2}{C_1 + C_2}$$

(Note the inverse relationship: higher voltage across the smaller capacitor).

Solution:

1. Given $C_1 = 3\mu$F, $C_2 = 6\mu$F, and $V_{total} = 12$ V. 2. We need to find the potential difference across the 3μF capacitor (V_1):

$$V_1 = 12 \times \frac{6}{3+6}$$

3. Simplify the fraction:

$$V_1 = 12 \times \frac{6}{9} = 12 \times \frac{2}{3}$$

4. Calculate the result:

$$V_1 = 8 \text{ V}$$

Final Answer: The potential difference across the 3μF capacitor is 8 V.

Answer: (B)

Q19.

Solution

Concept:

The magnetic induction (B) at the center of a circular coil of N turns carrying current I and having radius R is given by:

$$B = \frac{\mu_0 N I}{2R}$$

Solution:

1. Identify the given parameters: $N = 50$, $I = 2$ A, $R = 10$ cm $= 0.1$ m, $\mu_0 = 4\pi \times 10^{-7}$ T m/A.
2. Substitute the values into the formula:

$$B = \frac{(4\pi \times 10^{-7}) \times 50 \times 2}{2 \times 0.1}$$

3. Simplify the numerator and denominator:

$$B = \frac{4\pi \times 10^{-7} \times 100}{0.2}$$

$$B = \frac{4\pi \times 10^{-5}}{0.2}$$

4. Calculate the final value:

$$B = 20\pi \times 10^{-5} = 2\pi \times 10^{-4} \text{ T}$$

Final Answer: The magnetic induction is $2\pi \times 10^{-4}$ T.

Answer: (A)

Q20.

Solution

Concept:

For an alternating voltage given by $e = E_0 \sin(\omega t)$, the rms voltage is $E_{rms} = E_0/\sqrt{2}$. According to Ohm's Law for a purely resistive AC circuit, the rms current (I_{rms}) is:

$$I_{rms} = \frac{E_{rms}}{R}$$

Solution:

1. From the equation $e = 200\sin(100\pi t)$, the peak voltage $E_0 = 200$ V. 2. Calculate the rms voltage:

$$E_{rms} = \frac{200}{\sqrt{2}} = 100\sqrt{2} \text{ V}$$

3. Use the resistance $R = 50\Omega$ to find the rms current:

$$I_{rms} = \frac{100\sqrt{2}}{50}$$

4. Calculate:

$$I_{rms} = 2\sqrt{2} \text{ A}$$

Final Answer: The rms current is $2\sqrt{2}$ A.

Answer: (B)

Q21.

Solution

Concept:

In Fraunhofer diffraction at a single slit, the condition for the n^{th} minimum is given by the relation:

$$d \sin\theta = n\lambda$$

where d is the width of the slit, θ is the angle of diffraction, n is the order of the minimum ($n = 1, 2, 3 \ldots$), and λ is the wavelength of light used.

Solution:

1. For the first minimum, we set $n = 1$. 2. The given values are: $\theta = 30^\circ$ and $\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m $= 5 \times 10^{-7}$ m. 3. Substitute these values into the formula:

$$d \sin(30^\circ) = 1 \times (5 \times 10^{-7})$$

4. Since $\sin(30^\circ) = 0.5$ or $1/2$:

$$d \times (0.5) = 5 \times 10^{-7}$$

5. Solve for d:

$$d = \frac{5 \times 10^{-7}}{0.5} = 10 \times 10^{-7} \text{ m}$$

$$d = 1.0 \times 10^{-6} \text{ m}$$

Final Answer: The width of the slit is 1.0×10^{-6} m.

Answer: (A)

Q22.

Solution

Concept:

The efficiency (η) of a Carnot engine (a theoretical ideal thermodynamic cycle) depends only on the absolute temperatures of the hot reservoir (source, T_1) and the cold reservoir (sink, T_2). It is given by:

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100\%$$

Temperatures must always be in Kelvin.

Solution:

1. Identify the given temperatures: Source $T_1 = 600$ K and Sink $T_2 = 300$ K. 2. Apply the efficiency formula:

$$\eta = \left(1 - \frac{300}{600}\right) \times 100\%$$

3. Simplify the fraction:

$$\eta = (1 - 0.5) \times 100\%$$

4. Calculate the percentage:

$$\eta = 0.5 \times 100\% = 50\%$$

Final Answer: The efficiency of the Carnot engine is 50%.

Answer: (B)

Q23.

Solution

Concept:

According to the Rydberg formula for the hydrogen spectrum, the wavelength (λ) of the spectral lines is given by:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For the Balmer series, $n_1 = 2$. The first line (H_α) corresponds to $n_2 = 3$. The second line (H_β) corresponds to $n_2 = 4$.

Solution:

1. For the first line ($n_1 = 2, n_2 = 3$):

$$\frac{1}{\lambda_1} = R\left(\frac{1}{4} - \frac{1}{9}\right) = R\left(\frac{5}{36}\right) \implies \lambda_1 = \frac{36}{5R}$$

2. For the second line ($n_1 = 2, n_2 = 4$):

$$\frac{1}{\lambda_2} = R\left(\frac{1}{4} - \frac{1}{16}\right) = R\left(\frac{3}{16}\right) \implies \lambda_2 = \frac{16}{3R}$$

3. Find the ratio:

$$\frac{\lambda_2}{\lambda_1} = \frac{16/3R}{36/5R} = \frac{16}{3} \times \frac{5}{36} = \frac{4 \times 5}{3 \times 9} = \frac{20}{27}$$

4. Calculate λ_2 using $\lambda_1 = 6563$ Å:

$$\lambda_2 = 6563 \times \frac{20}{27} \approx 4861 \text{ Å}$$

Final Answer: The wavelength of the second line is 4861 Å.

Answer: (A)

Q24.

Solution

Concept:

For a projectile projected at an angle θ with velocity u, the maximum height (H) and horizontal range (R) are given by:

$$H = \frac{u^2 \sin^2\theta}{2g}$$

$$R = \frac{u^2 \sin 2\theta}{g} = \frac{2u^2 \sin\theta\cos\theta}{g}$$

The general relationship between height and range is: $\tan\theta = \frac{4H}{R}$.

Solution:

1. Given the angle of projection $\theta = 45^\circ$. 2. Use the relation $\tan\theta = \frac{4H}{R}$:

$$\tan(45^\circ) = \frac{4H}{R}$$

3. Since $\tan(45^\circ) = 1$:

$$1 = \frac{4H}{R}$$

4. Rearrange to find the ratio H/R:

$$\frac{H}{R} = \frac{1}{4}$$

Final Answer: The ratio of maximum height to horizontal range is 1 : 4.

Answer: (A)

Q25.

Solution

Concept:
Work done (W) by a constant force $\vec{F}$ during a displacement $\vec{d}$ is calculated using the dot product:

$$W = \vec{F} \cdot \vec{d}$$

The displacement vector $\vec{d}$ is the difference between the final position vector ($\vec{r}_2$) and the initial position vector ($\vec{r}_1$).

Solution:
1. Identify the force vector: $\vec{F} = 2\hat{i} + 3\hat{j} + 4\hat{k}$. 2. Calculate the displacement vector $\vec{d}$:

$$\vec{d} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$$

$$\vec{d} = (2 - 1)\hat{i} + (3 - 1)\hat{j} + (5 - 1)\hat{k} = 1\hat{i} + 2\hat{j} + 4\hat{k}$$

3. Calculate the dot product for work done:

$$W = \vec{F} \cdot \vec{d} = (2)(1) + (3)(2) + (4)(4)$$

4. Sum the components:

$$W = 2 + 6 + 16 = 24 \text{ J}$$

Final Answer: The total work done is 24 J.

Answer: (A)

Q26.

Solution

Concept:

The acceleration due to gravity (g_h) at a height h above the Earth's surface is given by the formula:

$$g_h = g\left(\frac{R}{R+h}\right)^2$$

where g is the acceleration due to gravity on the surface and R is the radius of the Earth. The weight of a body is $W = mg$, so the weight at height h is $W_h = mg_h$.

Solution:

1. Given the initial weight $W = 36$ N and height $h = R/2$. 2. Substitute the value of h into the gravity formula:

$$g_h = g\left(\frac{R}{R+R/2}\right)^2 = g\left(\frac{R}{3R/2}\right)^2$$

3. Simplify the expression inside the parentheses:

$$g_h = g\left(\frac{2}{3}\right)^2 = g\left(\frac{4}{9}\right)$$

4. Since weight is proportional to gravity, the new weight W_h is:

$$W_h = W \times \frac{4}{9} = 36 \times \frac{4}{9}$$

5. Calculate the final value:

$$W_h = 4 \times 4 = 16 \text{ N}$$

Final Answer: The weight of the body at the given height will be 16 N.

Answer: (B)

Q27.

Solution

Concept:
When a liquid drop is formed at the end of a capillary tube, it is supported by the force of surface tension acting along the circumference of the tube. Just before the drop detaches, the downward force (weight of the drop) is balanced by the upward force due to surface tension:

$$W \approx F_{surface\ tension}$$

The vertical component of the surface tension force acting around the circle of contact is $T \times (2\pi r)$.
Solution:
1. The surface tension T acts along the length of the circumference of the tube of radius r. 2. Total upward force exerted by surface tension is $F = T \times 2\pi r$. 3. At the moment the drop is about to fall, its weight W is approximately equal to this force:

$$W \approx 2\pi rT$$

4. This relationship assumes the contact angle is zero and the drop is hemispherical at the point of detachment.
Final Answer: The weight of the drop is approximately $2\pi rT$.

Answer: (B)

Q28.

Solution

Concept:

According to Newton's Law of Universal Gravitation, the force F between two masses m_1 and m_2 separated by distance r is:

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

To find the dimensions of G, we rearrange the formula:

$$G = \frac{Fr^2}{m_1 m_2}$$

Solution:

1. Substitute the dimensions of each quantity: Force $[F] = [M^1 L^1 T^{-2}]$ Distance $[r^2] = [L^2]$ Mass $[m_1 m_2] = [M^2]$ 2. Place them into the formula for G:

$$[G] = \frac{[M^1 L^1 T^{-2}][L^2]}{[M^2]}$$

3. Combine the terms:

$$[G] = [M^{1-2} L^{1+2} T^{-2}]$$

$$[G] = [M^{-1} L^3 T^{-2}]$$

Final Answer: The dimensions of G are $[M^{-1} L^3 T^{-2}]$.

Answer: (A)

Q29.

Solution

Concept:

The current gain α (common base) is the ratio of collector current to emitter current (I_C/I_E). The current gain β (common emitter) is the ratio of collector current to base current (I_C/I_B). Since $I_E = I_B + I_C$, these two gains are mathematically related.

Solution:

1. Start with the definition of α:

$$\alpha = \frac{I_C}{I_E} = \frac{I_C}{I_B + I_C}$$

2. Divide the numerator and denominator by I_B:

$$\alpha = \frac{I_C/I_B}{1 + I_C/I_B}$$

3. Substitute $I_C/I_B = \beta$:

$$\alpha = \frac{\beta}{1+\beta}$$

4. To express β in terms of α, rearrange the equation:

$$\alpha(1+\beta) = \beta$$

$$\alpha + \alpha\beta = \beta \implies \alpha = \beta(1-\alpha)$$

$$\beta = \frac{\alpha}{1-\alpha}$$

Final Answer: The relationship is $\beta = \frac{\alpha}{1-\alpha}$.

Answer: (A)

Q30.

Solution

Concept:

In an adiabatic process, the relationship between pressure (P) and temperature (T) is given by:

$$P^{1-\gamma}T^{\gamma} = \text{constant} \quad \text{or} \quad P \propto T^{\frac{\gamma}{\gamma-1}}$$

where γ is the ratio of specific heats (C_p/C_v).

Solution:

1. The problem states that P is proportional to the cube of temperature:

$$P \propto T^3$$

2. Compare this with the standard adiabatic relation $P \propto T^{\frac{\gamma}{\gamma-1}}$:

$$\frac{\gamma}{\gamma-1} = 3$$

3. Solve for γ:

$$\gamma = 3(\gamma - 1)$$

$$\gamma = 3\gamma - 3$$

4. Rearrange the terms:

$$2\gamma = 3$$

$$\gamma = 3/2$$

Final Answer: The value of γ for the gas is $3/2$.

Answer: (A)

Q31.

Solution

Concept:

For a particle performing uniform circular motion, the centripetal acceleration (a_c) is given by:

$$a_c = \omega^2 r$$

where ω is the angular velocity and r is the radius. The angular velocity ω is related to frequency (f) by the relation $\omega = 2\pi f$.

Solution:

1. Given values: $r = 25$ cm $= 0.25$ m and frequency $f = 2$ rev/s. 2. Calculate angular velocity (ω):

$$\omega = 2\pi \times f = 2\pi \times 2 = 4\pi \text{ rad/s}$$

3. Substitute ω and r into the acceleration formula:

$$a_c = (4\pi)^2 \times 0.25$$

4. Simplify the expression:

$$a_c = 16\pi^2 \times 0.25$$

$$a_c = 16\pi^2 \times \frac{1}{4} = 4\pi^2 \text{ m/s}^2$$

Final Answer: The acceleration of the particle is $4\pi^2$ m/s^2.

Answer: (C)

Q32.

Solution

Concept:

Electromagnetic (EM) waves are transverse waves consisting of oscillating electric ($\vec{E}$) and magnetic ($\vec{B}$) fields. A fundamental property of EM waves is that the electric field, the magnetic field, and the direction of wave propagation are all mutually perpendicular to each other.

Solution:

1. In a vacuum or any isotropic medium, the cross product $\vec{E} \times \vec{B}$ gives the direction of propagation (Poynting vector). 2. This mathematical relationship implies that the angle between the electric field vector $\vec{E}$ and the magnetic field vector $\vec{B}$ must be 90°. 3. Therefore, $\vec{E}$ and $\vec{B}$ are perpendicular to each other.

Final Answer: The vectors $\vec{E}$ and $\vec{B}$ are perpendicular to each other.

Answer: (B)

Q33.

Solution

Concept:
Self-inductance (L) is a measure of a circuit's ability to oppose changes in current. For a long solenoid, the magnetic field B inside is $\mu_0 n I$, where $n = N/L$. The total flux Φ linked with the solenoid is $N \times B \times A$. Self-inductance is defined as $L = \Phi/I$.

Solution:

1. Magnetic field inside the solenoid:

$$B = \mu_0 \left(\frac{N}{L}\right) I$$

2. Total flux linked with N turns:

$$\Phi = N \times B \times A = N \times \left(\mu_0 \frac{N}{L} I\right) \times A$$

3. Simplify the flux expression:

$$\Phi = \frac{\mu_0 N^2 A I}{L}$$

4. Find self-inductance:

$$L = \frac{\Phi}{I} = \frac{\mu_0 N^2 A}{L}$$

Final Answer: The self-inductance is $\mu_0 N^2 A/L$.

Answer: (A)

Q34.

Solution

Concept:

The electric field at a point due to a charge q at distance r is $E = \frac{kq}{r^2}$. For the total electric field to be zero between two like charges, the fields produced by both charges must be equal in magnitude and opposite in direction. If x is the distance from q_1, then $r - x$ is the distance from q_2.

$$\frac{q_1}{x^2} = \frac{q_2}{(r-x)^2} \implies \sqrt{\frac{q_1}{q_2}} = \frac{x}{r-x}$$

Solution:

1. Given $q_1 = 9e$, $q_2 = e$, and $r = 16$ cm. 2. Let the distance from $9e$ charge be x. 3. Set up the equilibrium equation:

$$\frac{9e}{x^2} = \frac{e}{(16-x)^2}$$

4. Take the square root of both sides:

$$\frac{3}{x} = \frac{1}{16-x}$$

5. Cross-multiply and solve for x:

$$3(16-x) = x$$

$$48 - 3x = x \implies 4x = 48$$

$$x = 12 \text{ cm}$$

Final Answer: The electric field is zero at a distance of 12 cm from the $+9e$ charge.

Answer: (A)

Q35.

Solution

Concept:
When a uniform wire of resistance R is bent into a circle, any two diametrically opposite points divide the wire into two semi-circular paths. Each path has a length half of the original length, and since $R \propto L$, each semi-circular part has half the total resistance.

Solution:
1. Total resistance of the wire $R = 4\Omega$. 2. When bent into a circle, the two semi-circular arcs between two ends of a diameter act as two resistors in parallel. 3. Resistance of each semi-circular arc:

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

4. Calculate the effective resistance R_p in parallel:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2} + \frac{1}{2} = 1$$

$$R_p = 1\Omega$$

Final Answer: The effective resistance is 1Ω.

Answer: (C)

Q36.

Solution

Concept:
Curie's Law states that the magnetic susceptibility (χ) of a paramagnetic material is inversely proportional to its absolute temperature (T):

$$\chi = \frac{C}{T}$$

where C is the Curie constant. This relationship exists because increasing temperature enhances thermal agitation, which opposes the alignment of atomic magnetic dipoles with the external magnetic field.

Solution:
1. Paramagnetic materials possess permanent magnetic dipoles that are randomly oriented due to thermal motion. 2. When an external field is applied, these dipoles tend to align. 3. As temperature T increases, the thermal energy $k_B T$ increases, making it harder for the dipoles to remain aligned. 4. Therefore, susceptibility (χ) decreases as temperature increases, following the inverse relation:

$$\chi \propto \frac{1}{T}$$

Final Answer: The magnetic susceptibility varies as $\chi \propto 1/T$.

Answer: (B)

Q37.

Solution

Concept:

Brewster's Law states that when light is incident at the polarizing angle (i_p), the reflected ray and the refracted ray are perpendicular to each other (90°). The angle of incidence is equal to the angle of reflection ($i = r_{reflected}$).

Solution:

1. The problem states the angle between the incident ray and the reflected ray is 110°. 2. Since the angle of incidence equals the angle of reflection:

$$i_p + r_{reflected} = 110^\circ \implies 2i_p = 110^\circ \implies i_p = 55^\circ$$

3. According to Brewster's condition, the reflected ray is perpendicular to the refracted ray ($r_{refracted}$):

$$r_{reflected} + 90^\circ + r_{refracted} = 180^\circ$$

4. Alternatively, use the relation $i_p + r_{refracted} = 90^\circ$:

$$55^\circ + r_{refracted} = 90^\circ$$

$$r_{refracted} = 90^\circ - 55^\circ = 35^\circ$$

Final Answer: The angle of refraction is 35°.

Answer: (A)

Q38.

Solution

Concept:

For a Carnot cycle, the ratio of heat exchanged is proportional to the ratio of absolute temperatures:

$$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

The work done (W) by the engine is the difference between the heat absorbed (Q_1) and the heat rejected (Q_2):

$$W = Q_1 - Q_2 = Q_1\left(1 - \frac{T_2}{T_1}\right)$$

Solution:

1. Convert temperatures to Kelvin: $T_1 = 227 + 273 = 500$ K $T_2 = 127 + 273 = 400$ K 2. Given heat absorbed $Q_1 = 6 \times 10^4$ cal. 3. Calculate efficiency (η):

$$\eta = 1 - \frac{400}{500} = 1 - 0.8 = 0.2$$

4. Calculate work done (W):

$$W = \eta \times Q_1 = 0.2 \times (6 \times 10^4)$$

$$W = 1.2 \times 10^4 \text{ cal}$$

Final Answer: The amount of heat converted into work is 1.2×10^4 cal.

Answer: (A)

Q39.

Solution

Concept:
The de Broglie wavelength (λ) of an electron accelerated through a potential difference V is given by the formula:

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

Substituting the constants (mass and charge of electron, Planck's constant), the simplified formula becomes:

$$\lambda \approx \sqrt{\frac{150}{V}}\ \text{Å} \quad \text{or} \quad \lambda \approx \frac{12.27}{\sqrt{V}}\ \text{Å}$$

Solution:
1. Given potential difference $V = 100$ V. 2. Use the simplified formula:

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

3. Calculate the square root:

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

Final Answer: The de Broglie wavelength is approximately 1.227 Å.

Answer: (A)

Q40.

Solution

Concept:
The horizontal range (R) of a projectile is given by:

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

Projectiles have the same horizontal range for complementary angles of projection (angles that sum to 90°), provided the initial velocity is the same.
Solution:
1. The given angles are $\theta_1 = 30°$ and $\theta_2 = 60°$. 2. Observe that $\theta_1 + \theta_2 = 30° + 60° = 90°$. 3. Check the calculation: For 30°: $R_1 = \frac{u^2 \sin(60°)}{g} = \frac{u^2}{g}\frac{\sqrt{3}}{2}$ For 60°: $R_2 = \frac{u^2 \sin(120°)}{g} = \frac{u^2}{g}\frac{\sqrt{3}}{2}$ 4. Since $R_1 = R_2$, the ratio is 1 : 1.
Final Answer: The ratio of their horizontal ranges is 1 : 1.

Answer: (A)

Q41.

Solution

Concept:

The force constant (k) of a spring is inversely proportional to its length (L). This relationship is defined by:

$$k \propto \frac{1}{L} \quad \text{or} \quad kL = \text{constant}$$

When a spring is cut into parts, each part becomes stiffer than the original long spring.

Solution:

1. Let the original spring have length L and force constant k. 2. When the spring is cut into two equal halves, the length of each half becomes $L' = L/2$. 3. Using the relation $k'L' = kL$:

$$k'\left(\frac{L}{2}\right) = kL$$

4. Solve for k':

$$k' = 2k$$

Final Answer: The force constant of each half is $2k$.

Answer: (C)

Q42.

Solution

Concept:

The work done (W) in charging a capacitor or increasing its voltage is equal to the change in electrostatic potential energy stored in it. The energy (U) stored in a capacitor of capacitance C at voltage V is:

$$U = \frac{1}{2}CV^2$$

Work done for a change from V_1 to V_2 is $W = \frac{1}{2}C(V_2^2 - V_1^2)$.

Solution:

1. For the first case (5 V to 10 V):

$$W = \frac{1}{2}C(10^2 - 5^2) = \frac{1}{2}C(100 - 25) = \frac{75}{2}C$$

2. For the second case (10 V to 15 V):

$$W' = \frac{1}{2}C(15^2 - 10^2) = \frac{1}{2}C(225 - 100) = \frac{125}{2}C$$

3. Find the relationship between W' and W:

$$\frac{W'}{W} = \frac{125}{75} = \frac{5}{3} \approx 1.67$$

4. Therefore:

$$W' = 1.67W$$

Final Answer: The work done will be $1.67W$.

Answer: (B)

Q43.

Solution

Concept:

The height (h) to which a liquid rises in a capillary tube is given by Jurin's Law:

$$h = \frac{2T\cos\theta}{r\rho g}$$

This shows that $h \propto 1/r$. Since the area of cross-section $A = \pi r^2$, we have $r = \sqrt{A/\pi}$, which means $h \propto 1/\sqrt{A}$.

Solution:

1. Initially, $h_1 = 5$ cm with area A_1. 2. The new area is $A_2 = A_1/4$. 3. Using the relation $h_1\sqrt{A_1} = h_2\sqrt{A_2}$:

$$5 \times \sqrt{A_1} = h_2 \times \sqrt{A_1/4}$$

4. Simplify the square root:

$$5 \times \sqrt{A_1} = h_2 \times \frac{\sqrt{A_1}}{2}$$

5. Solve for h_2:

$$h_2 = 5 \times 2 = 10 \text{ cm}$$

Final Answer: The rise of the liquid will be 10 cm.

Answer: (A)

Q44.

Solution

Concept:

The speed of sound (v) in a gas is given by Laplace's correction to the Newton's formula:

$$v = \sqrt{\frac{\gamma RT}{M}}$$

where γ is the adiabatic index, R is the gas constant, T is absolute temperature, and M is the molar mass of the gas.

Solution:

1. Oxygen (O_2) is a diatomic gas ($\gamma = 1.4$, $M = 32$ g/mol). 2. Helium (He) is a monatomic gas ($\gamma = 1.67$, $M = 4$ g/mol). 3. Comparing the two at the same temperature (STP):

$$\frac{v_{He}}{v_{O_2}} = \sqrt{\frac{\gamma_{He}}{M_{He}} \times \frac{M_{O_2}}{\gamma_{O_2}}}$$

4. Substitute values:

$$\frac{v_{He}}{v_{O_2}} = \sqrt{\frac{1.67}{4} \times \frac{32}{1.4}} = \sqrt{1.67 \times \frac{8}{1.4}}$$

5. Since M_{He} is much smaller than M_{O_2} and $\gamma_{He} > \gamma_{O_2}$, the numerator is significantly larger. Thus, $v_{He} > v_{O_2}$.

Final Answer: The speed of sound will be greater than v.

Answer: (A)

Q45.

Solution

Concept:

Logic gates are evaluated based on their Truth Tables. We need to identify which gate yields a "High" output (1) specifically when both inputs are "Low" (0, 0).

Solution:

1. **AND Gate**: Output is 1 only if both inputs are 1. For (0,0), output is 0. 2. **OR Gate**: Output is 1 if at least one input is 1. For (0,0), output is 0. 3. **NAND Gate**: Inverse of AND. For (0,0), output is 1. However, it also gives 1 for (0,1) and (1,0). 4. **NOR Gate**: Inverse of OR. - For (1,1), output is 0. - For (1,0), output is 0. - For (0,1), output is 0. - For (0,0), output is 1. 5. The NOR gate is the only one that gives a high output **only** (exclusively) when all inputs are low.

Final Answer: The logic gate is NOR.

Answer: (C)

Q46.

Solution

Concept:

The Work-Energy Theorem states that the work done by all forces acting on a particle equals the change in its kinetic energy. Work done (W) can also be expressed as the product of force (F) and displacement (s), or by using the impulse-momentum relationship to find the change in velocity.

$$W = \Delta K.E. = \frac{1}{2}m(v^2 - u^2)$$

Solution:

1. Initial momentum $p_1 = mu = 10$ kg m/s. Given mass $m = 5$ kg, the initial velocity is:

$$u = \frac{p_1}{m} = \frac{10}{5} = 2 \text{ m/s}$$

2. Initial Kinetic Energy:

$$K.E._i = \frac{p_1^2}{2m} = \frac{10^2}{2 \times 5} = \frac{100}{10} = 10 \text{ J}$$

3. The force $F = 0.2$ N acts for $t = 10$ s. The change in momentum (Impulse) is:

$$\Delta p = F \times t = 0.2 \times 10 = 2 \text{ kg m/s}$$

4. Final momentum $p_2 = p_1 + \Delta p = 10 + 2 = 12$ kg m/s. 5. Final Kinetic Energy:

$$K.E._f = \frac{p_2^2}{2m} = \frac{12^2}{2 \times 5} = \frac{144}{10} = 14.4 \text{ J}$$

6. Increase in Kinetic Energy:

$$\Delta K.E. = 14.4 \text{ J} - 10 \text{ J} = 4.4 \text{ J}$$

Final Answer: The increase in kinetic energy is 4.4 J.

Answer: (A)

Q47.

Solution

Concept:

Organ pipes produce stationary waves. For a closed organ pipe (closed at one end), the fundamental frequency (f_{closed}) is:

$$f_{closed} = \frac{v}{4L}$$

For an open organ pipe (open at both ends), the fundamental frequency (f_{open}) is:

$$f_{open} = \frac{v}{2L}$$

where v is the speed of sound and L is the length of the pipe.

Solution:

1. We are given that the fundamental frequency of the closed pipe is f:

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

2. The fundamental frequency of an open pipe of the same length is:

$$f_{open} = \frac{v}{2L}$$

3. We can write f_{open} in terms of f:

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

4. Substituting f:

$$f_{open} = 2f$$

Final Answer: The fundamental frequency of the open organ pipe is $2f$.

Answer: (B)

Q48.

Solution

Concept:
When a charged particle moves perpendicular to a uniform magnetic field, it follows a circular path. The magnetic force provides the required centripetal force:

$$qvB = \frac{mv^2}{r} \implies r = \frac{mv}{qB}$$

This indicates that the radius r is directly proportional to the velocity v and inversely proportional to the magnetic field B.

Solution:
1. Initial radius: $r = \frac{mv}{qB}$. 2. The new speed is $v' = 2v$ and the new magnetic field is $B' = B/2$. 3. The new radius r' is:

$$r' = \frac{m(2v)}{q(B/2)}$$

4. Simplify the expression:

$$r' = \frac{2mv}{qB/2} = 4 \times \left(\frac{mv}{qB}\right)$$

5. Therefore:

$$r' = 4r$$

Final Answer: The radius will become $4r$.

Answer: (C)

Q49.

Solution

Concept:
Mass-energy equivalence is given by Einstein's equation $E = mc^2$. An atomic mass unit (amu) is defined as $1/12^{th}$ of the mass of a Carbon-12 atom. When this mass is converted entirely into energy, it results in a specific amount of Mega-electron Volts (MeV).

Solution:
1. 1 amu $\approx 1.66 \times 10^{-27}$ kg. 2. Speed of light $c \approx 3 \times 10^8$ m/s. 3. Energy $E = (1.66 \times 10^{-27}) \times (3 \times 10^8)^2$ Joules. 4. Convert Joules to MeV (where 1 eV $= 1.6 \times 10^{-19}$ J and 1 MeV $= 10^6$ eV):

$$E \text{ (in MeV)} = \frac{1.66 \times 10^{-27} \times 9 \times 10^{16}}{1.6 \times 10^{-13}}$$

5. The calculation yields approximately 931.5 MeV.

Final Answer: The energy equivalent of 1 amu is 931.5 MeV.

Answer: (A)

Q50.

Solution

Concept:
Newton's Second Law in terms of momentum states that Force is the rate of change of momentum. The change in momentum (Δp) is the final momentum minus the initial momentum:

$$\Delta p = \vec{p}_f - \vec{p}_i$$

Velocity is a vector, so direction must be considered.
Solution:
1. Let the direction towards the wall be positive. 2. Initial momentum: $\vec{p}_i = Mv$. 3. Since the body bounces back with the same speed, the final velocity is $-v$. 4. Final momentum: $\vec{p}_f = M(-v) = -Mv$. 5. Change in momentum:

$$\Delta p = \vec{p}_f - \vec{p}_i = -Mv - (Mv) = -2Mv$$

6. The magnitude of the change in momentum is $2Mv$. In most physics problems regarding "change in momentum," the magnitude is requested unless specified otherwise.
Final Answer: The change in momentum is $2Mv$.

Answer: (B)

Answer Key

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