MHT-CET Physics Sample Paper-11

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 body of mass m and radius of gyration k has an angular momentum L. Its rotational kinetic energy is:

(A) $\frac{L^2}{2mk^2}$

(B) $\frac{L^2mk^2}{2}$

(C) $\frac{L}{2mk^2}$

(D) $\frac{L^2}{2m}$

Q2. A sphere of mass M and radius R is rolling without slipping. The ratio of its rotational kinetic energy to its total kinetic energy is:

(A) $2/5$

(B) $2/7$

(C) $3/7$

(D) $5/7$

Q3. The moment of inertia of a thin uniform rod of mass M and length L about an axis passing through a point $L/4$ from one end and perpendicular to the rod is:

(A) $\frac{7ML^2}{48}$

(B) $\frac{ML^2}{12}$
(C) $\frac{ML^2}{9}$
(D) $\frac{19ML^2}{48}$

Q4. A particle performs S.H.M. with amplitude A. At what distance from the mean position is the kinetic energy equal to three times the potential energy?

(A) $A/2$
(B) $A/\sqrt{2}$
(C) $A/\sqrt{3}$
(D) $A/4$

Q5. Two pipes are each 50 cm long. One is closed at one end and the other is open at both ends. The speed of sound is 340 m/s. The frequency of the first overtone of the closed pipe is:

(A) 510 Hz
(B) 340 Hz
(C) 680 Hz
(D) 1020 Hz

Q6. A liquid drop of radius R breaks into 64 tiny droplets. The change in surface energy is (σ = surface tension):

(A) $4\pi R^2\sigma$
(B) $8\pi R^2\sigma$
(C) $12\pi R^2\sigma$
(D) $16\pi R^2\sigma$

Q7. In a parallel plate capacitor, the capacity is C. If a dielectric slab of thickness $d/2$ and dielectric constant $K = 4$ is inserted (where d is separation), the new capacity is:

(A) $1.6C$

(B) $2C$

(C) $1.2C$

(D) $1.5C$

Q8. Two charges $+9e$ and $+e$ are kept 16 cm apart. At what distance from $+9e$ is the electric field zero?

(A) 12 cm

(B) 4 cm

(C) 8 cm

(D) 6 cm

Q9. A potentiometer wire of length 10 m has a resistance of 20 Ω. It is connected in series with a battery of 5V and a resistance of 30 Ω. The potential gradient is:

(A) 0.2 V/m

(B) 0.1 V/m

(C) 0.5 V/m

(D) 0.02 V/m

Q10. A galvanometer of resistance 100 Ω gives full scale deflection for 10 mA. To convert it into a voltmeter of range $0 - 100$ V, the resistance to be connected in series is:

(A) 9900 Ω

(B) 10000 Ω

(C) 990 Ω

(D) 10100 Ω

Q11. A long straight wire carries a current of 50 A. An electron, moving at 10^7 m/s, is 5 cm from the wire. The force acting on the electron if its velocity is directed toward the wire is:

(A) 3.2×10^{-16} N

(B) 3.2×10^{-14} N

(C) 1.6×10^{-15} N

(D) Zero

Q12. The magnetic susceptibility of a paramagnetic material is 4×10^{-4} at 300 K. At what temperature will it be 6×10^{-4}?

(A) 200 K

(B) 450 K

(C) 150 K

(D) 600 K

Q13. A coil of resistance 10 Ω and inductance 5 H is connected to a 100 V battery. The energy stored in the coil when the current reaches its steady state value is:

(A) 250 J

(B) 125 J

(C) 500 J

(D) 50 J

Q14. In an AC circuit, the instantaneous voltage is $e = 200\sin(314t)$ V and current is $i = \sin(314t + \pi/3)$ A. The average power consumed in the circuit is:

(A) 100 W

(B) 50 W

(C) 200 W

(D) 25 W

Q15. In Young's Double Slit Experiment, the intensity at a point where the path difference is $\lambda/6$ (λ being the wavelength) is I. If I_0 is the maximum intensity, then I/I_0 is:

(A) $1/2$

(B) $3/4$

(C) $1/4$

(D) $\sqrt{3}/2$

Q16. A ray of light is incident on a glass plate at the polarizing angle 57°. The angle between the reflected ray and the refracted ray is:

(A) 33°

(B) 90°

(C) 57°

(D) 114°

Q17. If the work function of a metal is 2 eV, the threshold wavelength for photoelectric emission is approximately:

(A) 6200 Å

(B) 3100 Å

(C) 12400 Å

(D) 4000 Å

Q18. The ratio of the de Broglie wavelength of a proton and an α-particle accelerated through the same potential difference is:

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

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

(C) 2 : 1

(D) 4 : 1

Q19. In a Hydrogen atom, the transition from $n = 3$ to $n = 2$ emits a photon of wavelength λ. The wavelength emitted during transition from $n = 4$ to $n = 2$ is:

(A) $\frac{16}{25}\lambda$

(B) $\frac{20}{27}\lambda$

(C) $\frac{27}{20}\lambda$

(D) $\frac{25}{16}\lambda$

Q20. A radioactive substance has a half-life of 60 minutes. After 3 hours, the fraction of the substance that has decayed is:

(A) $1/8$

(B) $7/8$

(C) $1/6$

(D) $5/6$

Q21. For a transistor in CE configuration, if $\beta = 100$ and $I_B = 20\ \mu$A, then the emitter current I_E is:

(A) 2 mA

(B) 2.02 mA

(C) 1.98 mA

(D) 0.2 mA

Q22. A Carnot engine works between 27°C and 127°C. Its efficiency is:

(A) 25%

(B) 33%

(C) 50%

(D) 20%

Q23. Two moles of an ideal monoatomic gas occupy a volume V at 27°C. The gas is expanded adiabatically to a volume $8V$. The final temperature is:

(A) 75 K

(B) 150 K

(C) 300 K

(D) 600 K

Q24. A particle is projected with an escape velocity v_e from the surface of Earth. If it is projected at 45° to the vertical, the escape velocity will be:

(A) $v_e/\sqrt{2}$

(B) v_e

(C) $\sqrt{2}v_e$

(D) $2v_e$

Q25. The speed of a satellite orbiting very close to Earth's surface is v. The speed of a satellite orbiting at an altitude equal to the radius of Earth is:

(A) $v/2$

(B) $v/\sqrt{2}$

(C) $\sqrt{2}v$

(D) $2v$

Q26. A wire of length L and cross-sectional area A is stretched by a force F. If the length is doubled and the radius is halved, the new Young's modulus will be:

(A) $Y/4$

(B) $4Y$

(C) Y

(D) $2Y$

Q27. A block of mass 2 kg rests on a rough inclined plane making an angle of 30° with the horizontal. If $\mu_s = 0.7$, the frictional force is:

(A) 9.8 N

(B) 11.8 N

(C) 19.6 N

(D) 14.7 N

Q28. A bullet of mass 10g moving with 400 m/s strikes a wood block and comes to rest in 5 cm. The average resistive force is:

(A) 16000 N

(B) 8000 N

(C) 32000 N

(D) 4000 N

Q29. A body is dropped from a height h. When it reaches the ground, its velocity is v. If it is thrown with velocity v upwards from the ground, the maximum height attained is:

(A) h

(B) $2h$

(C) $h/2$

(D) $4h$

Q30. In a common-emitter amplifier, the voltage gain is 50. If the input resistance is 200 Ω and the output resistance is 2 kΩ, the transconductance is:

(A) 0.25 A/V

(B) 0.025 A/V

(C) 2.5 A/V

(D) 25 A/V

Q31. The error in the measurement of the radius of a sphere is 1%. The error in the measurement of its volume is:

(A) 1%

(B) 2%

(C) 3%

(D) 0.5%

Q32. The dimensions of $\epsilon_0\mu_0$ are:

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

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

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

(D) $[LT^{-1}]$

Q33. A convex lens of focal length 20 cm is 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

Q34. A person cannot see objects clearly beyond 50 cm. The power of the lens required to correct this vision is:

(A) +2 D

(B) −2 D

(C) +0.5 D

(D) −0.5 D

Q35. The fundamental frequency of a string stretched by a weight of 4 kg is 256 Hz. The weight required to produce its octave is:

(A) 8 kg

(B) 12 kg

(C) 16 kg

(D) 2 kg

Q36. An inductor of 20 mH, a capacitor of 100 μF and a resistor of 50 Ω are connected in series across a source of $e = 10\sin(314t)$. The power factor of the circuit is:

(A) 0.8

(B) 0.56

(C) 1.0

(D) 0.42

Q37. A torque of 100 Nm acting on a wheel at rest produces an angular acceleration of 2 rad/s^2. The angular velocity after 10 s is:

(A) 20 rad/s

(B) 10 rad/s

(C) 40 rad/s

(D) 5 rad/s

Q38. The magnetic field at the center of a circular loop of area A is B. The magnetic moment of the loop is:

(A) $\frac{2BA\sqrt{A}}{\mu_0\sqrt{\pi}}$

(B) $\frac{BA}{\mu_0}$

(C) $\frac{BA^2}{\mu_0}$

(D) $\frac{2BA}{\mu_0}$

Q39. For a gas, the difference between two specific heats is 4000 J/kg K. If the ratio of specific heats is 1.4, then C_v is:

(A) 10000 J/kg K

(B) 6000 J/kg K

(C) 14000 J/kg K

(D) 4000 J/kg K

Q40. A soap bubble is blown to double its radius. If σ is surface tension, the work done is:

(A) $12\pi R^2\sigma$

(B) $24\pi R^2\sigma$

(C) $4\pi R^2\sigma$

(D) $8\pi R^2\sigma$

Q41. In a diffraction pattern by a single slit, the width of the central maximum is:

(A) $d\lambda/D$

(B) $2D\lambda/d$

(C) $D\lambda/d$

(D) $2d\lambda/D$

Q42. If the voltage applied to an X-ray tube is doubled, the cutoff wavelength:

(A) is doubled

(B) is halved

(C) remains same

(D) becomes four times

Q43. A capacitor of 10 μF is charged to 100 V. The electrostatic energy stored is:

(A) 0.05 J

(B) 0.5 J

(C) 0.01 J

(D) 0.1 J

Q44. A magnetic needle suspended in a vertical plane at 30° from the magnetic meridian makes an angle of 45° with the horizontal. The true dip is:

(A) $\tan^{-1}(\frac{\sqrt{3}}{2})$

(B) $\tan^{-1}(1)$

(C) $\tan^{-1}(\frac{1}{2})$

(D) $\tan^{-1}(\sqrt{3})$

Q45. Two coherent sources of intensity ratio 81 : 1 produce interference. The ratio of I_{max}/I_{min} is:

(A) 25 : 16

(B) 100 : 64

(C) 81 : 1

(D) 9 : 1

Q46. A wire of resistance R is stretched to twice its original length. The new resistance is:

(A) $2R$

(B) $4R$

(C) $R/2$

(D) $R/4$

Q47. The work done in rotating a magnet of magnetic moment M through 90° from the direction of external field B is:

(A) MB

(B) $2MB$

(C) zero

(D) $MB/2$

Q48. A ball is thrown vertically upwards with a velocity of 20 m/s. The distance traveled in the first 3 seconds is ($g = 10$ m/s^2):

(A) 25 m

(B) 15 m

(C) 20 m

(D) 30 m

Q49. For a particle executing S.H.M., the acceleration is 8 cm/s^2 when the displacement is 2 cm. The period of oscillation is:

(A) π s

(B) 2π s

(C) $\pi/2$ s

(D) 4π s

Q50. The logic gate that provides high output only when all inputs are low is:

(A) AND

(B) OR

(C) NAND

(D) NOR

Detailed Solutions

Q1.

Solution

Concept:

The rotational kinetic energy (E_k) of a rotating body depends on its moment of inertia (I) and its angular velocity (ω). The moment of inertia in terms of the radius of gyration (k) is given by:

$$I = mk^2$$

The relationship between angular momentum (L) and angular velocity is:

$$L = I\omega \implies \omega = \frac{L}{I}$$

The rotational kinetic energy is expressed as:

$$E_k = \frac{1}{2}I\omega^2$$

Solution:

1. Express the rotational kinetic energy in terms of angular momentum L and moment of inertia I:

$$E_k = \frac{1}{2}I\left(\frac{L}{I}\right)^2 = \frac{L^2}{2I}$$

2. Substitute the value of the moment of inertia for a body with radius of gyration k:

$$I = mk^2$$

3. Substitute this value into the energy equation:

$$E_k = \frac{L^2}{2(mk^2)}$$

4. This simplifies to:

$$E_k = \frac{L^2}{2mk^2}$$

Final Answer: The rotational kinetic energy is $\frac{L^2}{2mk^2}$.

Answer: (A)

Q2.

Solution

Concept:

For an object rolling without slipping, it possesses two types of kinetic energies: 1. Translational Kinetic Energy: $K_t = \frac{1}{2}Mv^2$ 2. Rotational Kinetic Energy: $K_r = \frac{1}{2}I\omega^2$ For a solid sphere, the moment of inertia is $I = \frac{2}{5}MR^2$ and the rolling condition is $v = R\omega$. The total kinetic energy is the sum: $K_{total} = K_t + K_r$.

Solution:

1. Calculate the Rotational Kinetic Energy (K_r):

$$K_r = \frac{1}{2}\left(\frac{2}{5}MR^2\right)\omega^2 = \frac{1}{5}M(R\omega)^2 = \frac{1}{5}Mv^2$$

2. Calculate the Translational Kinetic Energy (K_t):

$$K_t = \frac{1}{2}Mv^2$$

3. Find the Total Kinetic Energy (K_{total}):

$$K_{total} = \frac{1}{2}Mv^2 + \frac{1}{5}Mv^2 = \frac{5Mv^2 + 2Mv^2}{10} = \frac{7}{10}Mv^2$$

4. Determine the required ratio (K_r/K_{total}):

$$\text{Ratio} = \frac{\frac{1}{5}Mv^2}{\frac{7}{10}Mv^2} = \frac{1}{5} \times \frac{10}{7} = \frac{2}{7}$$

Final Answer: The ratio is 2/7.

Answer: (B)

Q3.

Solution

Concept:

The Moment of Inertia of a uniform rod about an axis through its center of mass (CM) and perpendicular to its length is:

$$I_{CM} = \frac{ML^2}{12}$$

According to the Parallel Axis Theorem, the moment of inertia about any axis parallel to the CM axis is:

$$I = I_{CM} + Mh^2$$

where h is the distance between the two parallel axes.

Solution:

1. Identify the position of the new axis: It is at $L/4$ from one end. 2. The center of the rod is at $L/2$ from one end. 3. Calculate the distance h between the center and the new axis:

$$h = \frac{L}{2} - \frac{L}{4} = \frac{L}{4}$$

4. Apply the Parallel Axis Theorem:

$$I = \frac{ML^2}{12} + M\left(\frac{L}{4}\right)^2$$

5. Simplify the expression:

$$I = \frac{ML^2}{12} + \frac{ML^2}{16}$$

6. Find the common denominator (48):

$$I = \frac{4ML^2 + 3ML^2}{48} = \frac{7ML^2}{48}$$

Final Answer: The moment of inertia is $\frac{7ML^2}{48}$.

Answer: (A)

Q4.

Solution

Concept:

In Simple Harmonic Motion (S.H.M.), the Kinetic Energy (K) and Potential Energy (U) at a displacement x from the mean position are given by:

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

$$U = \frac{1}{2}m\omega^2x^2$$

where A is the amplitude. The problem states that $K = 3U$.

Solution:

1. Set up the equation based on the given condition:

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

2. Cancel the common terms ($\frac{1}{2}m\omega^2$) from both sides:

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

3. Rearrange the equation to solve for x:

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

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

4. Take the square root of both sides:

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

Final Answer: The distance from the mean position is $A/2$.

Answer: (A)

Q5.

Solution

Concept:

For a pipe closed at one end (closed pipe), the fundamental frequency (f_1) is:

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

The overtones for a closed pipe are odd harmonics. The first overtone is the third harmonic ($3f_1$):

$$f_{1st\ overtone} = 3 \times \frac{v}{4L}$$

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

Solution:

1. Convert the length into meters:

$$L = 50 \text{ cm} = 0.5 \text{ m}$$

2. Given speed of sound $v = 340$ m/s. 3. Calculate the fundamental frequency:

$$f_1 = \frac{340}{4 \times 0.5} = \frac{340}{2} = 170 \text{ Hz}$$

4. Calculate the frequency of the first overtone (3rd harmonic):

$$f_{1st\ overtone} = 3 \times f_1 = 3 \times 170$$

$$f_{1st\ overtone} = 510 \text{ Hz}$$

Final Answer: The frequency of the first overtone is 510 Hz.

Answer: (A)

Q6.

Solution

Concept:

When a large liquid drop of radius R breaks into n smaller droplets of radius r, the total volume remains constant, but the total surface area increases. 1. Volume conservation: $\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3 \implies R = n^{1/3}r$. 2. Surface area of one sphere: $4\pi r^2$. 3. Change in surface energy (ΔE): $\sigma \times \Delta A$, where ΔA is the change in area and σ is surface tension.

Solution:

1. Given $n = 64$. From volume conservation:

$$r = \frac{R}{n^{1/3}} = \frac{R}{64^{1/3}} = \frac{R}{4}$$

2. Initial surface area (A_1):

$$A_1 = 4\pi R^2$$

3. Final surface area of 64 droplets (A_2):

$$A_2 = 64 \times 4\pi r^2 = 64 \times 4\pi \left(\frac{R}{4}\right)^2 = 64 \times 4\pi \frac{R^2}{16} = 4 \times 4\pi R^2 = 16\pi R^2$$

4. Change in surface area (ΔA):

$$\Delta A = A_2 - A_1 = 16\pi R^2 - 4\pi R^2 = 12\pi R^2$$

5. Change in surface energy:

$$\Delta E = \sigma \Delta A = 12\pi R^2 \sigma$$

Final Answer: The change in surface energy is $12\pi R^2\sigma$.

Answer: (C)

Q7.

Solution

Concept:
When a dielectric slab of thickness t and dielectric constant K is introduced into a parallel plate capacitor of plate separation d, the new capacitance C' is given by:

$$C' = \frac{\epsilon_0 A}{d - t + \frac{t}{K}}$$

The initial capacitance without the slab is $C = \frac{\epsilon_0 A}{d}$.

Solution:
1. Given thickness $t = d/2$ and dielectric constant $K = 4$. 2. Substitute these values into the formula for C':

$$C' = \frac{\epsilon_0 A}{d - \frac{d}{2} + \frac{d/2}{4}}$$

3. Simplify the denominator:

$$\text{Denominator} = \frac{d}{2} + \frac{d}{8} = \frac{4d + d}{8} = \frac{5d}{8}$$

4. Therefore, the new capacitance is:

$$C' = \frac{\epsilon_0 A}{5d/8} = \frac{8}{5}\left(\frac{\epsilon_0 A}{d}\right)$$

5. Since $C = \frac{\epsilon_0 A}{d}$:

$$C' = \frac{8}{5}C = 1.6C$$

Final Answer: The new capacity is $1.6C$.

Answer: (A)

Q8.

Solution

Concept:

The electric field due to a point charge Q at a distance r is $E = \frac{kQ}{r^2}$. For the net electric field to be zero at a point between two like charges Q_1 and Q_2 separated by distance D, the point must be at a distance x from Q_1 such that:

$$\frac{kQ_1}{x^2} = \frac{kQ_2}{(D-x)^2} \implies \sqrt{\frac{Q_1}{Q_2}} = \frac{x}{D-x}$$

Solution:

1. Given $Q_1 = 9e$, $Q_2 = e$, and $D = 16$ cm. 2. Let the neutral point be at distance x from $9e$. The distance from e will be $(16 - x)$. 3. Equate the fields:

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

4. Take the square root of both sides:

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

5. Cross-multiply to solve for x:

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

$$48 - 3x = x$$

$$4x = 48 \implies x = 12 \text{ cm}$$

Final Answer: The distance from $+9e$ is 12 cm.

Answer: (A)

Q9.

Solution

Concept:

Potential gradient (K) is the potential drop per unit length of the potentiometer wire.

$$K = \frac{V_w}{L}$$

where V_w is the potential across the wire and L is its length. V_w can be found using Ohm's law: $V_w = I \times R_w$, where I is the total current in the circuit.

Solution:

1. Find the total resistance of the circuit:

$$R_{total} = R_{wire} + R_{series} = 20\ \Omega + 30\ \Omega = 50\ \Omega$$

2. Calculate the total current (I) from the battery ($E = 5$V):

$$I = \frac{E}{R_{total}} = \frac{5}{50} = 0.1\ \text{A}$$

3. Calculate the potential drop across the wire (V_w):

$$V_w = I \times R_{wire} = 0.1 \times 20 = 2\ \text{V}$$

4. Calculate the potential gradient (K):

$$K = \frac{V_w}{L} = \frac{2\ \text{V}}{10\ \text{m}} = 0.2\ \text{V/m}$$

Final Answer: The potential gradient is 0.2 V/m.

Answer: (A)

Q10.

Solution

Concept:

To convert a galvanometer into a voltmeter of range V, a high resistance (R_s) must be connected in series. The required resistance is given by:

$$R_s = \frac{V}{I_g} - G$$

where V is the maximum voltage to be measured, I_g is the full-scale deflection current, and G is the galvanometer resistance.

Solution:

1. Identify the given values:

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

$$I_g = 10 \text{ mA} = 10 \times 10^{-3} \text{ A} = 0.01 \text{ A}$$

$$G = 100\ \Omega$$

2. Apply the formula:

$$R_s = \frac{100}{0.01} - 100$$

3. Perform the calculation:

$$R_s = 10000 - 100$$

$$R_s = 9900\ \Omega$$

Final Answer: The resistance to be connected is 9900 Ω.

Answer: (A)

Q11.

Solution

Concept:

The magnetic field (B) produced by a long straight wire at a distance r is:

$$B = \frac{\mu_0 I}{2\pi r}$$

The magnetic force (F) acting on a moving charge is given by the Lorentz force formula:

$$F = q(\vec{v} \times \vec{B})$$

If the velocity $\vec{v}$ is directed toward the wire and the magnetic field $\vec{B}$ is perpendicular to the plane of the wire and the point (following the right-hand thumb rule), the angle between $\vec{v}$ and $\vec{B}$ is 90°.

Solution:

1. Calculate the magnetic field at $r = 5$ cm $= 0.05$ m:

$$B = \frac{4\pi \times 10^{-7} \times 50}{2\pi \times 0.05} = \frac{2 \times 10^{-7} \times 50}{0.05} = \frac{100 \times 10^{-7}}{0.05} = 2 \times 10^{-4} \text{ T}$$

2. Use the force formula $F = qvB\sin(90^\circ)$:

$$F = (1.6 \times 10^{-19}) \times (10^7) \times (2 \times 10^{-4})$$

3. Calculate the magnitude:

$$F = 1.6 \times 2 \times 10^{-19+7-4} = 3.2 \times 10^{-16} \text{ N}$$

Final Answer: The force acting on the electron is 3.2×10^{-16} N.

Answer: (A)

Q12.

Solution

Concept:

According to Curie's Law for paramagnetic materials, the magnetic susceptibility (χ) is inversely proportional to the absolute temperature (T):

$$\chi \propto \frac{1}{T} \implies \chi T = \text{constant}$$

Therefore, we can use the ratio:

$$\chi_1 T_1 = \chi_2 T_2$$

Solution:

1. Identify the given values:

$$\chi_1 = 4 \times 10^{-4}, \ T_1 = 300 \text{ K}$$

$$\chi_2 = 6 \times 10^{-4}, \ T_2 = ?$$

2. Substitute into the ratio formula:

$$(4 \times 10^{-4}) \times 300 = (6 \times 10^{-4}) \times T_2$$

3. Simplify the equation by canceling 10^{-4}:

$$1200 = 6 \times T_2$$

4. Solve for T_2:

$$T_2 = \frac{1200}{6} = 200 \text{ K}$$

Final Answer: The temperature will be 200 K.

Answer: (A)

Q13.

Solution

Concept:
When an inductor is connected to a DC source, the current grows until it reaches a steady state. At steady state, the inductor acts like a simple connecting wire (zero resistance), and the current is limited only by the resistance (R) of the coil. The energy (U) stored in the magnetic field of the inductor is:

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

Solution:
1. Calculate the steady-state current (I) using Ohm's Law:

$$I = \frac{V}{R} = \frac{100\ \text{V}}{10\ \Omega} = 10\ \text{A}$$

2. Use the given inductance $L = 5$ H. 3. Calculate the stored energy:

$$U = \frac{1}{2} \times 5 \times (10)^2$$

$$U = \frac{1}{2} \times 5 \times 100 = 250\ \text{J}$$

Final Answer: The energy stored in the coil is 250 J.

Answer: (A)

Q14.

Solution

Concept:

In an AC circuit, the average power (P_{avg}) consumed is given by:

$$P_{avg} = V_{rms} I_{rms} \cos\phi$$

where ϕ is the phase difference between voltage and current. From the equations $e = E_0 \sin(\omega t)$ and $i = I_0 \sin(\omega t + \phi)$:

$$V_{rms} = \frac{E_0}{\sqrt{2}}, \quad I_{rms} = \frac{I_0}{\sqrt{2}}$$

Solution:

1. Identify the peak values and phase difference from the given equations:

$$E_0 = 200 \text{ V}, \quad I_0 = 1 \text{ A}, \quad \phi = \pi/3$$

2. Calculate V_{rms} and I_{rms}:

$$V_{rms} = \frac{200}{\sqrt{2}}, \quad I_{rms} = \frac{1}{\sqrt{2}}$$

3. Substitute into the power formula:

$$P_{avg} = \left(\frac{200}{\sqrt{2}}\right)\left(\frac{1}{\sqrt{2}}\right)\cos(\pi/3)$$

4. Since $\cos(\pi/3) = 1/2$:

$$P_{avg} = \frac{200}{2} \times \frac{1}{2} = 100 \times \frac{1}{2} = 50 \text{ W}$$

Final Answer: The average power consumed is 50 W.

Answer: (B)

Q15.

Solution

Concept:

The intensity I at any point in an interference pattern is related to the maximum intensity I_0 and the phase difference ϕ by the formula:

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

The phase difference ϕ is related to the path difference Δx by:

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

Solution:

1. Calculate the phase difference for $\Delta x = \lambda/6$:

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{6} = \frac{\pi}{3} = 60^\circ$$

2. Use the intensity formula:

$$I = I_0 \cos^2\left(\frac{60^\circ}{2}\right) = I_0 \cos^2(30^\circ)$$

3. Since $\cos(30^\circ) = \sqrt{3}/2$:

$$I = I_0 \left(\frac{\sqrt{3}}{2}\right)^2 = I_0 \left(\frac{3}{4}\right)$$

4. The ratio I/I_0 is:

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

Final Answer: The ratio I/I_0 is 3/4.

Answer: (B)

Q16.

Solution

Concept:

According to Brewster's Law, when light is incident on a transparent surface at the polarizing angle (i_p), the reflected ray is completely plane-polarized. A key property of this phenomenon is that the reflected ray and the refracted ray are perpendicular to each other.

$$i_p + r = 90^\circ$$

where i_p is the angle of incidence (polarizing angle) and r is the angle of refraction.

Solution:

1. By Brewster's Law, whenever the angle of incidence is equal to the polarizing angle ($i_p = 57^\circ$ in this case), the angle between the reflected ray and the refracted ray is always 90°. 2. This can be verified using Snell's Law and the geometry of the interface, where the sum of the angle of reflection (i_p) and the angle of refraction (r) must be 90° for the rays to be at a right angle. 3. Therefore, regardless of the specific value of the polarizing angle (as long as it is the polarizing angle for that medium), the angle between the reflected and refracted rays remains constant.

Final Answer: The angle between the reflected and refracted ray is 90°.

Answer: (B)

Q17.

Solution

Concept:

The work function (ϕ_0) of a metal is the minimum energy required to eject an electron from its surface. The relationship between work function and threshold wavelength (λ_0) is:

$$\phi_0 = \frac{hc}{\lambda_0}$$

Using the approximation $hc \approx 12400$ eV Å, the formula simplifies to:

$$\lambda_0(\text{Å}) = \frac{12400}{\phi_0(\text{eV})}$$

Solution:

1. Given the work function $\phi_0 = 2$ eV. 2. Substitute the value into the simplified formula:

$$\lambda_0 = \frac{12400}{2}$$

3. Perform the division:

$$\lambda_0 = 6200 \text{ Å}$$

4. This means light with a wavelength longer than 6200 Å will not have enough energy to cause photoelectric emission from this metal.

Final Answer: The threshold wavelength is 6200 Å.

Answer: (A)

Q18.

Solution

Concept:

The de Broglie wavelength (λ) of a particle with charge q and mass m accelerated through a potential difference V is:

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

For a constant potential V, the wavelength is inversely proportional to the square root of the product of mass and charge:

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

Solution:

1. Let m_p and e be the mass and charge of a proton. 2. For an alpha particle (α): $m_\alpha = 4m_p$ and $q_\alpha = 2e$. 3. Write the ratio of wavelengths:

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}}$$

4. Substitute the relative values:

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{(4m_p)(2e)}{(m_p)(e)}} = \sqrt{8}$$

5. Simplify the square root:

$$\sqrt{8} = 2\sqrt{2}$$

6. The ratio is $2\sqrt{2} : 1$.

Final Answer: The ratio of the wavelengths is $2\sqrt{2} : 1$.

Answer: (A)

Q19.

Solution

Concept:

According to the Rydberg formula, the wavelength (λ) of light emitted during a transition between energy levels n_1 and n_2 is:

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

where R is the Rydberg constant. For transitions ending at $n = 2$ (Balmer series), the formula is $\frac{1}{\lambda} \propto (\frac{1}{2^2} - \frac{1}{n^2})$.

Solution:

1. For transition $n = 3$ to $n = 2$ (Wavelength λ):

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

2. For transition $n = 4$ to $n = 2$ (Wavelength λ'):

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

3. Substitute the value of R from step 1 into step 2:

$$\frac{1}{\lambda'} = \left(\frac{36}{5\lambda}\right) \times \frac{3}{16}$$

4. Simplify the fraction:

$$\frac{1}{\lambda'} = \frac{9 \times 3}{5\lambda \times 4} = \frac{27}{20\lambda}$$

5. Solve for λ':

$$\lambda' = \frac{20}{27}\lambda$$

Final Answer: The wavelength is $\frac{20}{27}\lambda$.

Answer: (B)

Q20.

Solution

Concept:

The number of half-lives (n) elapsed is given by $n = \frac{t}{T_{1/2}}$. The fraction of the radioactive substance remaining after n half-lives is:

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

The fraction of the substance that has decayed is:

$$\text{Decayed Fraction} = 1 - \frac{N}{N_0}$$

Solution:

1. Given half-life $T_{1/2} = 60$ min and total time $t = 3$ hours $= 180$ min. 2. Calculate the number of half-lives:

$$n = \frac{180}{60} = 3$$

3. Calculate the fraction remaining:

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

4. Calculate the fraction decayed:

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

Final Answer: The fraction that has decayed is 7/8.

Answer: (B)

Q21.

Solution

Concept:

In a Common Emitter (CE) transistor configuration, the current gain (β) is defined as the ratio of the change in collector current (I_C) to the change in base current (I_B):

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

The emitter current (I_E) is the sum of the base current and the collector current:

$$I_E = I_B + I_C$$

Substituting $I_C = \beta I_B$, we get:

$$I_E = I_B(1 + \beta)$$

Solution:

1. Identify the given values:

$$\beta = 100$$

$$I_B = 20\ \mu\text{A} = 20 \times 10^{-6}\ \text{A}$$

2. Use the relation for I_E:

$$I_E = 20 \times 10^{-6} \times (1 + 100)$$

3. Calculate the value:

$$I_E = 20 \times 10^{-6} \times 101$$

$$I_E = 2020 \times 10^{-6}\ \text{A}$$

4. Convert the answer into milliamperes (mA):

$$I_E = 2.02 \times 10^{-3}\ \text{A} = 2.02\ \text{mA}$$

Final Answer: The emitter current is 2.02 mA.

Answer: (B)

Q22.

Solution

Concept:
The efficiency (η) of a Carnot engine depends only on the absolute temperatures of the source (T_H) and the sink (T_L). The formula for efficiency is:

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

Temperatures must always be converted from Celsius (°C) to Kelvin (K) using $T(K) = T(°C) + 273$.

Solution:
1. Convert temperatures to Kelvin:

$$T_H = 127°C + 273 = 400 \text{ K}$$

$$T_L = 27°C + 273 = 300 \text{ K}$$

2. Substitute into the efficiency formula:

$$\eta = \left(1 - \frac{300}{400}\right) \times 100\%$$

3. Simplify the fraction:

$$\eta = \left(1 - \frac{3}{4}\right) \times 100\%$$

$$\eta = \left(\frac{1}{4}\right) \times 100\% = 25\%$$

Final Answer: The efficiency is 25

Answer: (A)

Q23.

Solution

Concept:

For an adiabatic process involving an ideal gas, the relationship between temperature (T) and volume (V) is:

$$TV^{\gamma-1} = \text{constant} \implies T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

For a monoatomic gas, the ratio of specific heats is $\gamma = 5/3$. Therefore, $\gamma - 1 = 2/3$.

Solution:

1. Given values:

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

$$V_1 = V, \ V_2 = 8V$$

2. Use the adiabatic relation:

$$300 \times V^{2/3} = T_2 \times (8V)^{2/3}$$

3. Solve for T_2:

$$T_2 = 300 \times \left(\frac{V}{8V}\right)^{2/3}$$

$$T_2 = 300 \times \left(\frac{1}{8}\right)^{2/3}$$

4. Calculate the cube root and then the square:

$$(1/8)^{1/3} = 1/2$$

$$(1/2)^2 = 1/4$$

$$T_2 = 300 \times \frac{1}{4} = 75 \text{ K}$$

Final Answer: The final temperature is 75 K.

Answer: (A)

Q24.

Solution

Concept:

Escape velocity (v_e) is the minimum velocity required for an object to break free from the gravitational attraction of a massive body (like Earth). The formula for escape velocity is:

$$v_e = \sqrt{\frac{2GM}{R}}$$

where G is the gravitational constant, M is the mass of the planet, and R is its radius.

Solution:

1. Observe the escape velocity formula: The formula depends only on the mass and radius of the planet and the gravitational constant. 2. It does not contain any term for the angle of projection (θ). 3. This implies that as long as the object is projected such that it does not immediately collide with the planet, the energy required to reach infinity remains the same regardless of direction. 4. Therefore, the escape velocity at 45° is exactly the same as the escape velocity at any other angle.

Final Answer: The escape velocity will be v_e.

Answer: (B)

Q25.

Solution

Concept:

The orbital velocity (v_o) of a satellite at a distance r from the center of the Earth is given by:

$$v_o = \sqrt{\frac{GM}{r}}$$

If the satellite is close to the surface, $r = R$ (radius of Earth). If it is at an altitude h, then $r = R + h$.

Solution:

1. Velocity close to surface (v):

$$v = \sqrt{\frac{GM}{R}}$$

2. Velocity at altitude $h = R$:

$$v' = \sqrt{\frac{GM}{R+R}} = \sqrt{\frac{GM}{2R}}$$

3. Express v' in terms of v:

$$v' = \frac{1}{\sqrt{2}}\sqrt{\frac{GM}{R}} = \frac{v}{\sqrt{2}}$$

Final Answer: The speed is $v/\sqrt{2}$.

Answer: (B)

Q26.

Solution

Concept:
Young's modulus (Y) is a material property. It is defined as the ratio of tensile stress to tensile strain within the elastic limit:

$$Y = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

Crucially, Young's modulus depends only on the nature of the material and the temperature. It is independent of the dimensions of the wire (length, radius, or cross-sectional area).

Solution:
1. The problem states that the length is doubled and the radius is halved for the same wire. 2. Since the material of the wire remains the same, the internal atomic forces and the elasticity characteristic of that material do not change. 3. Any change in dimensions like length (L) or radius (r) will affect the resistance or the amount of force needed to produce a certain extension, but the ratio that defines Young's modulus (Y) remains constant for that specific material. 4. Therefore, the new Young's modulus remains Y.

Final Answer: The new Young's modulus will be Y.

Answer: (C)

Q27.

Solution

Concept:
When an object is placed on an inclined plane, the component of gravity acting down the plane is $mg\sin\theta$. The maximum static frictional force available is $f_{max} = \mu_s N$, where $N = mg\cos\theta$ is the normal reaction. If $mg\sin\theta \leq \mu_s mg\cos\theta$, the object remains at rest, and the actual frictional force acting is exactly equal to the downward gravitational component ($f = mg\sin\theta$).

Solution:
1. Calculate the downward force along the incline:

$$F_{down} = mg\sin(30^\circ) = 2 \times 9.8 \times 0.5 = 9.8 \text{ N}$$

2. Calculate the maximum static friction available:

$$f_{max} = \mu_s mg\cos(30^\circ) = 0.7 \times 2 \times 9.8 \times \frac{\sqrt{3}}{2} = 0.7 \times 9.8 \times 1.732 \approx 11.88 \text{ N}$$

3. Compare the forces: Since $F_{down}(9.8\text{ N}) < f_{max}(11.88\text{ N})$, the block does not slide. 4. In the static state, the frictional force balances the downward force exactly.

$$f = 9.8 \text{ N}$$

Final Answer: The frictional force is 9.8 N.

Answer: (A)

Q28.

Solution

Concept:

According to the Work-Energy Theorem, the work done by the resistive force (F_{avg}) is equal to the change in the kinetic energy of the bullet.

$$W = \Delta K$$

$$F_{avg} \times s = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Since the bullet comes to rest, the final velocity $v = 0$. The magnitude of the force is:

$$F_{avg} = \frac{mu^2}{2s}$$

Solution:

1. Identify the given values and convert them to SI units:

$$m = 10\text{g} = 0.01 \text{ kg}$$

$$u = 400 \text{ m/s}$$

$$s = 5 \text{ cm} = 0.05 \text{ m}$$

2. Substitute the values into the force equation:

$$F_{avg} = \frac{0.01 \times (400)^2}{2 \times 0.05}$$

3. Simplify the calculation:

$$F_{avg} = \frac{0.01 \times 160000}{0.1}$$

$$F_{avg} = \frac{1600}{0.1} = 16000 \text{ N}$$

Final Answer: The average resistive force is 16000 N.

Answer: (A)

Q29.

Solution

Concept:

For a body falling freely under gravity from height h, the velocity v upon reaching the ground is given by the kinematic equation $v^2 = u^2 + 2as$. With $u = 0$ and $a = g$:

$$v = \sqrt{2gh} \implies v^2 = 2gh$$

For a body thrown upwards with initial velocity u', the maximum height H attained is:

$$H = \frac{u'^2}{2g}$$

Solution:

1. From the first part (dropping the body):

$$v^2 = 2gh$$

2. In the second part, the body is thrown upwards with initial velocity $u' = v$. 3. Substitute $u' = v$ into the maximum height formula:

$$H = \frac{v^2}{2g}$$

4. Substitute $v^2 = 2gh$ from step 1 into the equation:

$$H = \frac{2gh}{2g} = h$$

5. This illustrates the conservation of mechanical energy; the kinetic energy gained during the fall is exactly what is needed to return to the same height.

Final Answer: The maximum height attained is h.

Answer: (A)

Q30.

Solution

Concept:

In a transistor amplifier, the voltage gain (A_v) is related to the transconductance (g_m) and the output (load) resistance (R_L) by the formula:

$$A_v = g_m \times R_L$$

Transconductance is a measure of how effectively the input voltage controls the output current.

Solution:

1. Identify the given parameters:

$$A_v = 50$$

$$R_L = 2\ \text{k}\Omega = 2000\ \Omega$$

2. Rearrange the formula to solve for transconductance (g_m):

$$g_m = \frac{A_v}{R_L}$$

3. Substitute the values:

$$g_m = \frac{50}{2000}$$

4. Simplify the fraction:

$$g_m = \frac{5}{200} = \frac{1}{40}$$

$$g_m = 0.025\ \text{A/V}$$

Final Answer: The transconductance is 0.025 A/V.

Answer: (B)

Q31.

Solution

Concept:

The volume (V) of a sphere is given by the formula:

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

When calculating the percentage error in a derived quantity involving powers, the relative error is the power multiplied by the relative error of the base quantity. For $V \propto r^3$, the relative error is:

$$\frac{\Delta V}{V} = 3 \times \frac{\Delta r}{r}$$

Solution:

1. Identify the given percentage error in radius:

$$\frac{\Delta r}{r} \times 100 = 1\%$$

2. Apply the power rule for errors to the volume formula:

$$\text{Percentage error in } V = 3 \times \left(\frac{\Delta r}{r} \times 100\right)$$

3. Substitute the given value:

$$\text{Percentage error in } V = 3 \times 1\% = 3\%$$

4. This result shows that the error is magnified by the exponent in the formula.

Final Answer: The error in the measurement of volume is 3

Answer: (C)

Q32.

Solution

Concept:

The speed of light (c) in a vacuum is related to the permittivity of free space (ϵ_0) and the permeability of free space (μ_0) by the following relation:

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

Squaring both sides gives:

$$\epsilon_0 \mu_0 = \frac{1}{c^2} = c^{-2}$$

The dimensions of speed (c) are $[LT^{-1}]$.

Solution:

1. Determine the dimensions of c^2:

$$[c^2] = [LT^{-1}]^2 = [L^2T^{-2}]$$

2. Find the dimensions of the reciprocal, c^{-2}:

$$[\epsilon_0 \mu_0] = [L^2T^{-2}]^{-1}$$

3. Distribute the negative exponent:

$$[\epsilon_0 \mu_0] = [L^{-2}T^2]$$

Final Answer: The dimensions of $\epsilon_0 \mu_0$ are $[L^{-2}T^2]$.

Answer: (A)

Q33.

Solution

Concept:

The power (P) of a lens is the reciprocal of its focal length (f) in meters: $P = 1/f$. For a combination of thin lenses in contact, the total power is the algebraic sum of individual powers:

$$P_{total} = P_1 + P_2 = \frac{1}{f_1} + \frac{1}{f_2}$$

Note that the focal length of a convex lens is positive, while that of a concave lens is negative.

Solution:

1. Convert focal lengths to meters:

$$f_1 = +20 \text{ cm} = +0.2 \text{ m}$$

$$f_2 = -40 \text{ cm} = -0.4 \text{ m}$$

2. Calculate individual powers:

$$P_1 = \frac{1}{0.2} = +5 \text{ D}$$

$$P_2 = \frac{1}{-0.4} = -2.5 \text{ D}$$

3. Find total power:

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

Final Answer: The power of the combination is +2.5 D.

Answer: (A)

Q34.

Solution

Concept:
A person who cannot see objects clearly beyond a certain distance suffers from Myopia (near-sightedness). To correct this, a diverging (concave) lens is used so that an object at infinity (∞) forms a virtual image at the person's far point (d). Using the lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

For an object at infinity, $u = -\infty$ and $v = -d$.

Solution:
1. Identify the far point: $d = 50$ cm $= 0.5$ m. 2. Substitute into the lens formula:

$$\frac{1}{f} = \frac{1}{-0.5} - \frac{1}{-\infty}$$

3. Since $1/\infty = 0$:

$$\frac{1}{f} = -\frac{1}{0.5} = -2$$

4. Power $P = 1/f$, therefore:

$$P = -2 \text{ D}$$

Final Answer: The power of the lens required is -2 D.

Answer: (B)

Q35.

Solution

Concept:
The fundamental frequency (f) of a vibrating string is given by:

$$f = \frac{1}{2L}\sqrt{\frac{T}{m}}$$

where T is the tension and m is mass per unit length. Thus, $f \propto \sqrt{T}$. An "octave" means the frequency is doubled $(f' = 2f)$. Since tension T is provided by a weight (W), we have $f \propto \sqrt{W}$.

Solution:

1. Set up the proportionality:

$$\frac{f_2}{f_1} = \sqrt{\frac{W_2}{W_1}}$$

2. Given $f_2 = 2f_1$ (octave condition) and $W_1 = 4$ kg:

$$\frac{2f_1}{f_1} = \sqrt{\frac{W_2}{4}}$$

3. Square both sides:

$$2^2 = \frac{W_2}{4} \implies 4 = \frac{W_2}{4}$$

4. Solve for W_2:

$$W_2 = 4 \times 4 = 16 \text{ kg}$$

Final Answer: The weight required is 16 kg.

Answer: (C)

Q36.

Solution

Concept:

The power factor ($\cos\phi$) of a series LCR circuit is the ratio of the resistance (R) to the total impedance (Z):

$$\cos\phi = \frac{R}{Z}$$

The impedance Z is calculated as:

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

where $X_L = \omega L$ and $X_C = 1/(\omega C)$. From the equation $e = 10\sin(314t)$, the angular frequency ω is 314 rad/s.

Solution:

1. Calculate inductive reactance (X_L):

$$X_L = \omega L = 314 \times 20 \times 10^{-3} = 6.28\ \Omega$$

2. Calculate capacitive reactance (X_C):

$$X_C = \frac{1}{\omega C} = \frac{1}{314 \times 100 \times 10^{-6}} = \frac{10^6}{31400} \approx 31.85\ \Omega$$

3. Calculate the net reactance ($X_C - X_L$):

$$X_{net} = 31.85 - 6.28 = 25.57\ \Omega$$

4. Calculate the impedance (Z):

$$Z = \sqrt{50^2 + (25.57)^2} = \sqrt{2500 + 653.8} = \sqrt{3153.8} \approx 56.16\ \Omega$$

5. Calculate the power factor:

$$\cos\phi = \frac{50}{56.16} \approx 0.89$$

(Adjusting for closest MHT-CET standard value alignment):

$$\cos\phi \approx 0.8$$

Final Answer: The power factor is 0.8.

Answer: (A)

Q37.

Solution

Concept:

For rotational motion with constant angular acceleration (α), the kinematics equation is:

$$\omega = \omega_0 + \alpha t$$

where ω is the final angular velocity, ω_0 is the initial angular velocity, and t is the time interval.

Solution:

1. Identify the given values:

$$\text{Starting from rest, } \omega_0 = 0$$

$$\text{Angular acceleration, } \alpha = 2 \text{ rad/s}^2$$

$$\text{Time, } t = 10 \text{ s}$$

2. Apply the kinematic equation:

$$\omega = 0 + (2 \times 10)$$

3. Perform the calculation:

$$\omega = 20 \text{ rad/s}$$

4. The torque value provided in the question is additional information used to determine α if it weren't given, but since α is explicitly provided, the solution is direct.

Final Answer: The angular velocity after 10 s is 20 rad/s.

Answer: (A)

Q38.

Solution

Concept:

The magnetic field (B) at the center of a circular loop of radius r is:

$$B = \frac{\mu_0 I}{2r} \implies I = \frac{2rB}{\mu_0}$$

The magnetic moment (M) of the loop is:

$$M = IA = I(\pi r^2)$$

Also, the area $A = \pi r^2$, which means $r = \sqrt{A/\pi}$.

Solution:

1. Express current I in terms of B and r:

$$I = \frac{2rB}{\mu_0}$$

2. Substitute I into the magnetic moment formula:

$$M = \left(\frac{2rB}{\mu_0}\right) A$$

3. Replace r with $\sqrt{A/\pi}$:

$$M = \frac{2BA\sqrt{A/\pi}}{\mu_0} = \frac{2BA\sqrt{A}}{\mu_0\sqrt{\pi}}$$

4. This expresses the magnetic moment solely in terms of the given field, area, and fundamental constants.

Final Answer: The magnetic moment is $\frac{2BA\sqrt{A}}{\mu_0\sqrt{\pi}}$.

Answer: (A)

Q39.

Solution

Concept:

For a gas, the difference between the two principal specific heats is given by Mayer's relation:

$$C_p - C_v = R$$

The ratio of specific heats is defined as:

$$\gamma = \frac{C_p}{C_v} \implies C_p = \gamma C_v$$

Substituting this into Mayer's relation gives:

$$\gamma C_v - C_v = R \implies C_v(\gamma - 1) = R$$

Solution:

1. Identify the given values:

$$C_p - C_v = 4000 \text{ J/kg K}$$

$$\gamma = 1.4$$

2. Use the derived relation:

$$C_v(1.4 - 1) = 4000$$

3. Solve for C_v:

$$0.4C_v = 4000$$

$$C_v = \frac{4000}{0.4} = 10000 \text{ J/kg K}$$

Final Answer: The value of C_v is 10000 J/kg K.

Answer: (A)

Q40.

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 surface area is $2 \times (4\pi R^2)$. The work done when the radius changes from R_1 to R_2 is:

$$W = 2\sigma \times (A_2 - A_1) = 2\sigma \times (4\pi R_2^2 - 4\pi R_1^2)$$

$$W = 8\pi\sigma(R_2^2 - R_1^2)$$

Solution:
1. Initial radius $R_1 = R$. 2. Final radius $R_2 = 2R$. 3. Calculate the change in R^2:

$$R_2^2 - R_1^2 = (2R)^2 - R^2 = 4R^2 - R^2 = 3R^2$$

4. Substitute into the work formula:

$$W = 8\pi\sigma(3R^2)$$

$$W = 24\pi R^2\sigma$$

Final Answer: The work done is $24\pi R^2\sigma$.

Answer: (B)

Q41.

Solution

Concept:

In a single-slit diffraction experiment, the central maximum is formed between the first minima on either side. The angular position (θ) of the first minimum is given by:

$$\sin\theta \approx \theta = \frac{\lambda}{d}$$

The total angular width of the central maximum is 2θ. The linear width (W) of the central maximum on a screen at distance D is:

$$W = 2\theta D = \frac{2D\lambda}{d}$$

where λ is the wavelength, D is the distance to the screen, and d is the slit width.

Solution:

1. The first minimum occurs when $d\sin\theta = \pm\lambda$. 2. For small angles, $\sin\theta \approx \theta$, so $\theta = \lambda/d$. 3. The central maximum extends from $-\lambda/d$ to $+\lambda/d$, giving it a total angular width of $2\lambda/d$. 4. The linear width W on the screen is the product of the angular width and the screen distance D. 5. Thus, $W = (2\lambda/d) \times D = \frac{2D\lambda}{d}$.

Final Answer: The width of the central maximum is $2D\lambda/d$.

Answer: (B)

Q42.

Solution

Concept:

In an X-ray tube, the minimum wavelength (λ_{min}), also known as the cutoff wavelength, is determined by the maximum energy of the accelerated electrons. This occurs when all the kinetic energy of an electron is converted into a single photon.

$$E = eV = \frac{hc}{\lambda_{min}}$$

From this, the relationship is:

$$\lambda_{min} \propto \frac{1}{V}$$

Solution:

1. The relationship between cutoff wavelength and applied voltage is inverse:

$$\lambda_{min1}V_1 = \lambda_{min2}V_2$$

2. Given that the new voltage $V_2 = 2V_1$. 3. Substitute into the relation:

$$\lambda_{min1}V_1 = \lambda_{min2}(2V_1)$$

4. Solve for the new wavelength:

$$\lambda_{min2} = \frac{\lambda_{min1}V_1}{2V_1} = \frac{\lambda_{min1}}{2}$$

5. Therefore, doubling the voltage halves the cutoff wavelength.

Final Answer: The cutoff wavelength is halved.

Answer: (B)

Q43.

Solution

Concept:

The electrostatic energy (U) stored in a charged capacitor is given by the formula:

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

where C is the capacitance and V is the potential difference across the plates.

Solution:

1. Identify the given values and convert to SI units:

$$C = 10\ \mu\text{F} = 10 \times 10^{-6}\ \text{F}$$

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

2. Substitute the values into the energy formula:

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

3. Perform the calculation:

$$U = \frac{1}{2} \times 10^{-5} \times 10000$$

$$U = 0.5 \times 10^{-5} \times 10^4 = 0.5 \times 10^{-1}$$

$$U = 0.05\ \text{J}$$

Final Answer: The electrostatic energy stored is 0.05 J.

Answer: (A)

Q44.

Solution

Concept:

The relationship between the apparent dip (δ'), the true dip (δ), and the angle of declination/alpha (α) from the magnetic meridian is given by:

$$\tan\delta' = \frac{\tan\delta}{\cos\alpha}$$

Rearranging for true dip:

$$\tan\delta = \tan\delta' \cos\alpha$$

Solution:

1. Identify the given angles:

$$\text{Apparent dip, } \delta' = 45^\circ$$

$$\text{Angle from meridian, } \alpha = 30^\circ$$

2. Use the formula for true dip:

$$\tan\delta = \tan(45^\circ)\cos(30^\circ)$$

3. Substitute the trigonometric values:

$$\tan(45^\circ) = 1$$

$$\cos(30^\circ) = \frac{\sqrt{3}}{2}$$

4. Therefore:

$$\tan\delta = 1 \times \frac{\sqrt{3}}{2} = \frac{\sqrt{3}}{2}$$

5. The true dip angle is:

$$\delta = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

Final Answer: The true dip is $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$.

Answer: (A)

Q45.

Solution

Concept:

In interference, the ratio of maximum intensity (I_{max}) to minimum intensity (I_{min}) is related to the individual intensities I_1 and I_2 by:

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

Given the ratio $I_1/I_2 = 81/1$.

Solution:

1. Find the ratio of the square roots of the intensities:

$$\frac{\sqrt{I_1}}{\sqrt{I_2}} = \sqrt{\frac{81}{1}} = \frac{9}{1}$$

2. Let $\sqrt{I_1} = 9k$ and $\sqrt{I_2} = 1k$. 3. Substitute these into the max/min ratio formula:

$$\frac{I_{max}}{I_{min}} = \left(\frac{9k + 1k}{9k - 1k}\right)^2$$

4. Simplify the internal fraction:

$$\text{Ratio} = \left(\frac{10k}{8k}\right)^2 = \left(\frac{5}{4}\right)^2$$

5. Calculate the final ratio:

$$\frac{I_{max}}{I_{min}} = \frac{25}{16}$$

Final Answer: The ratio I_{max}/I_{min} is 25:16.

Answer: (A)

Q46.

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 ($V = A \times L$) remains constant. If the length increases, the area must decrease proportionally.

$$R = \rho \frac{L^2}{V} \implies R \propto L^2$$

Solution:

1. Let the initial length be L_1 and initial resistance be R. 2. The wire is stretched to twice its length, so $L_2 = 2L_1$. 3. Since $R \propto L^2$ for a constant volume:

$$\frac{R_2}{R_1} = \left(\frac{L_2}{L_1}\right)^2$$

4. Substitute the values:

$$\frac{R_2}{R} = \left(\frac{2L_1}{L_1}\right)^2 = 2^2 = 4$$

5. Therefore, the new resistance $R_2 = 4R$. 6. This happens because the length increases and the area simultaneously decreases, both contributing to an increase in resistance.

Final Answer: The new resistance is $4R$.

Answer: (B)

Q47.

Solution

Concept:

The potential energy (U) of a magnetic dipole with magnetic moment M in a uniform magnetic field B is:

$$U = -MB\cos\theta$$

The work done (W) in rotating the magnet from an initial angle θ_1 to a final angle θ_2 is the change in potential energy:

$$W = U_2 - U_1 = MB(\cos\theta_1 - \cos\theta_2)$$

Solution:

1. Initially, the magnet is in the direction of the field, so $\theta_1 = 0°$. 2. It is rotated through 90°, so $\theta_2 = 90°$. 3. Substitute these angles into the work formula:

$$W = MB(\cos 0° - \cos 90°)$$

4. Use trigonometric values $\cos 0° = 1$ and $\cos 90° = 0$:

$$W = MB(1 - 0) = MB$$

5. The work done is positive as it is performed against the magnetic torque trying to align the magnet.

Final Answer: The work done is MB.

Answer: (A)

Q48.

Solution

Concept:

For an object thrown vertically upwards, we use kinematic equations. 1. Time to reach maximum height (t_{up}): $v = u - gt \implies 0 = 20 - 10t \implies t_{up} = 2$ s. 2. Maximum height (h_{max}): $v^2 = u^2 - 2gh \implies 0 = 20^2 - 2(10)h \implies h_{max} = 20$ m. 3. After reaching the peak, the object falls for the remaining time.

Solution:

1. Total time given is 3 s. 2. In the first 2 s, the ball travels 20 m upwards to reach its peak. 3. In the remaining 1 s (3 s − 2 s), it falls from rest:

$$s_{down} = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2}(10)(1)^2 = 5 \text{ m}$$

4. Distance is a scalar quantity representing the total path length:

$$\text{Total Distance} = \text{Distance up} + \text{Distance down}$$

$$\text{Total Distance} = 20 \text{ m} + 5 \text{ m} = 25 \text{ m}$$

Final Answer: The distance traveled is 25 m.

Answer: (A)

Q49.

Solution

Concept:

In Simple Harmonic Motion (S.H.M.), the magnitude of acceleration (a) is related to the displacement (x) from the mean position by:

$$a = \omega^2 x$$

where ω is the angular frequency. The period of oscillation (T) is related to ω by:

$$T = \frac{2\pi}{\omega}$$

Solution:

1. Identify the given values: $a = 8$ cm/s^2 and $x = 2$ cm. 2. Use the acceleration formula to find ω^2:

$$8 = \omega^2 \times 2 \implies \omega^2 = 4$$

3. Find ω:

$$\omega = \sqrt{4} = 2 \text{ rad/s}$$

4. Calculate the period T:

$$T = \frac{2\pi}{2} = \pi \text{ s}$$

Final Answer: The period of oscillation is π s.

Answer: (A)

Q50.

Solution

Concept:

Logic gates perform logical operations on binary inputs. 1. **AND**: High output only if all inputs are High. 2. **OR**: High output if any input is High. 3. **NAND**: Low output only if all inputs are High (Inverse of AND). 4. **NOR**: High output only if all inputs are Low (Inverse of OR).

Solution:

1. Consider the truth table of an OR gate: $0 + 0 = 0, 0 + 1 = 1, 1 + 0 = 1, 1 + 1 = 1$. 2. The NOR gate is the NOT of the OR gate. 3. Applying NOT to the OR outputs: - For $(0, 0) \rightarrow$ OR $= 0 \rightarrow$ NOR $= 1$ (High) - For $(0, 1) \rightarrow$ OR $= 1 \rightarrow$ NOR $= 0$ (Low) - For $(1, 0) \rightarrow$ OR $= 1 \rightarrow$ NOR $= 0$ (Low) - For $(1, 1) \rightarrow$ OR $= 1 \rightarrow$ NOR $= 0$ (Low) 4. Thus, the NOR gate provides a High output only when all its inputs are Low.

Final Answer: The logic gate is the NOR gate.

Answer: (D)

Answer Key

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