NEET-UG Physics Sample Paper - 13

Duration: 1 Hour **Maximum Marks: 180**

Instructions

- This paper contains a total of 45 Multiple Choice Questions.
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Q1. A screw gauge gives the following readings when used to measure the diameter of a wire: Main scale reading: 0 mm; Circular scale reading: 52 divisions. Given that 1 mm on main scale corresponds to 100 divisions of the circular scale. The diameter is?

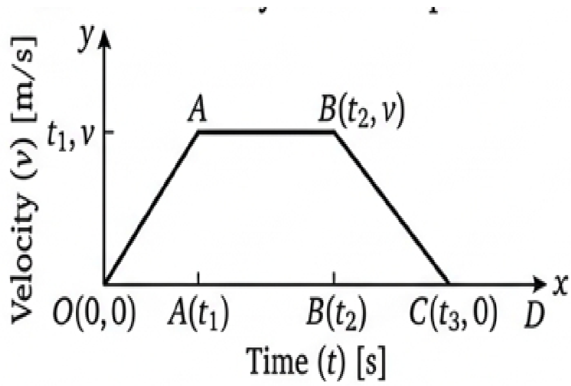
(A) 0.52 mm

(B) 0.052 mm

(C) 0.0052 mm

(D) 5.2 mm

Q2. A particle moves along a path $ABCD$ as shown in the $V - t$ graph. Calculate the ratio of the magnitude of acceleration in the interval OA to that in BC.



(A) 1 : 1

(B) 1 : 2

(C) 2 : 1

(D) 1 : 3

Q3. A ball is thrown vertically downward from a height of 20m with an initial velocity v_0. It hits the ground and loses 50% of its energy and bounces back to the same height. The initial velocity v_0 is?

(A) 10 m/s

(B) 14 m/s

(C) 20 m/s

(D) 28 m/s

Q4. Two bodies of mass 4kg and 6kg are tied to the ends of a massless string. The string passes over a frictionless pulley. The acceleration of the system is?

(A) $g/5$

(B) $g/2$

(C) $g/10$

(D) g

Q5. A block of mass m is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally so that the block does not slip. The force exerted by the wedge on the block is?

(A) $mg\cos\theta$

(B) $mg/\cos\theta$

(C) $mg\sin\theta$

(D) $mg\tan\theta$

Q6. A body of mass 1kg is acted upon by a force $\vec{F} = 2\hat{i} + 3\hat{k}$ Newton. If its initial position is $(0, 0, 0)$, find the work done in moving it to $(1, 1, 1)$.

(A) 2 J

(B) 3 J

(C) 5 J

(D) 1 J

Q7. A vertical spring with force constant K is fixed on a table. A ball of mass m at a height h above the free upper end of the spring falls vertically on the spring. The maximum compression d is?

(A) $mgd = \frac{1}{2}Kd^2$

(B) $mg(h + d) = \frac{1}{2}Kd^2$

(C) $mgh = \frac{1}{2}Kd^2$

(D) $mg(h - d) = \frac{1}{2}Kd^2$

Q8. A solid cylinder of mass 2kg and radius 4cm is rotating about its axis at 3rpm. The torque required to stop it after 2π revolutions is?

(A) 2×10^{-6} Nm

(B) 2×10^{-3} Nm

(C) 1×10^{-4} Nm

(D) 2×10^{-5} Nm

Q9. From a circular ring of mass M and radius R, an arc corresponding to a 90° sector is removed. The moment of inertia of the remaining part about an axis passing through the center and perpendicular to the plane is?

(A) $\frac{3}{4}MR^2$

(B) $\frac{7}{8}MR^2$

(C) $\frac{1}{4}MR^2$

(D) $\frac{5}{8}MR^2$

Q10. The escape velocity from the Earth's surface is v. The escape velocity from the surface of another planet having a radius four times that of Earth and same mass density is?

(A) v

(B) $2v$

(C) $3v$

(D) $4v$

Q11. A body weighs 200N on the surface of the earth. How much will it weigh half way down to the center of the earth?

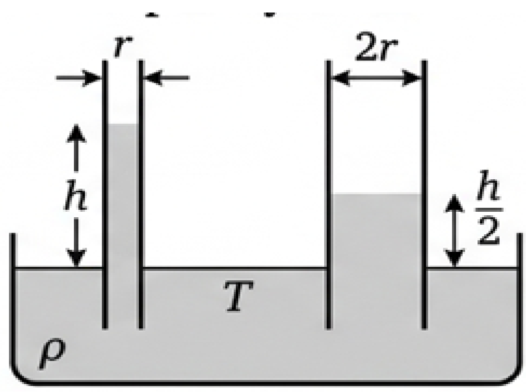
(A) 100 N

(B) 150 N

(C) 200 N

(D) 250 N

Q12. A capillary tube of radius r is immersed in water and water rises to a height h. The mass of the water in the capillary is 5g. Another tube of radius $2r$ is immersed; find the mass of water that will rise.



(A) 5 g

(B) 10 g

(C) 20 g

(D) 2.5 g

Q13. A small sphere of radius r falls from rest in a viscous liquid. As a result, heat is produced due to viscous force. The rate of production of heat when the sphere attains terminal velocity is proportional to?

(A) r^3

(B) r^2

(C) r^5

(D) r^4

Q14. A copper rod of length L and area A is subject to a tensile force F. If the Young's modulus is Y, the strain energy stored is?

(A) $\frac{F^2 L}{2AY}$

(B) $\frac{FL^2}{2AY}$

(C) $\frac{F^2 L}{AY}$

(D) $\frac{FL}{2AY}$

Q15. One mole of an ideal gas at temperature T_1 expands according to the law PV^2 = constant. Find the work done when the final temperature is T_2.

(A) $R(T_2 - T_1)$

(B) $R(T_1 - T_2)$

(C) $2R(T_1 - T_2)$

(D) Zero

Q16. The efficiency of a Carnot engine is 50% when the temperature of the sink is 20°C. To increase the efficiency to 60%, the temperature of the source should be increased by?

(A) 146.5 K

(B) 117.2 K

(C) 120.0 K

(D) 150.3 K

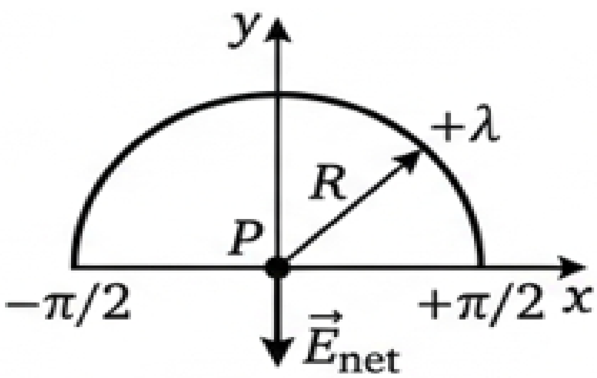
Q17. The average thermal energy for a mono-atomic gas is? (k_B is Boltzmann constant, T is absolute temperature).

(A) $\frac{1}{2}k_BT$
(B) $\frac{3}{2}k_BT$
(C) $\frac{5}{2}k_BT$
(D) $\frac{7}{2}k_BT$

Q18. A particle executes SHM with an amplitude A. At what distance from the mean position is the potential energy equal to the kinetic energy?

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

Q19. A tuning fork with frequency 800Hz produces resonance in a resonance column tube with upper end open and lower end closed. Successive resonances are observed at 9.75cm and 31.25cm. The speed of sound is?



(A) 344 m/s
(B) 350 m/s
(C) 332 m/s

(D) 320 m/s

Q20. In the given figure, find the electric field at point P due to the charge distribution on the semi-circular arc.

(A) $\frac{\lambda}{2\pi\epsilon_0 R}$

(B) $\frac{\lambda}{4\pi\epsilon_0 R}$

(C) $\frac{\lambda}{2\epsilon_0 R}$

(D) Zero

Q21. Two parallel infinite line charges with linear charge densities $+\lambda$ and $-\lambda$ are placed at a distance of $2R$. What is the electric field mid-way between them?

(A) $\frac{\lambda}{\pi\epsilon_0 R}$

(B) $\frac{\lambda}{2\pi\epsilon_0 R}$

(C) $\frac{2\lambda}{\pi\epsilon_0 R}$

(D) Zero

Q22. A capacitor of capacitance C is charged to a potential V. It is then connected to another uncharged capacitor of capacitance $C/2$. The loss of energy is?

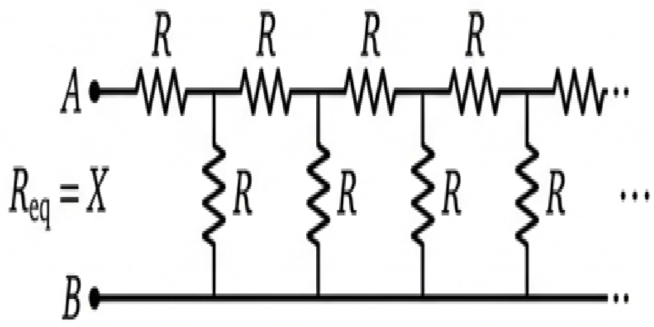
(A) $\frac{1}{6}CV^2$

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

(C) $\frac{1}{3}CV^2$

(D) $\frac{1}{4}CV^2$

Q23. Calculate the equivalent resistance between points A and B in the infinite ladder network shown.



(A) $1 + \sqrt{3}\Omega$

(B) 2Ω

(C) 1.5Ω

(D) 3Ω

Q24. A potentiometer wire has length 4m and resistance 8Ω. The resistance that must be connected in series with the wire and an accumulator of e.m.f. 2V, so as to get a potential gradient 1mV per cm on the wire is?

(A) 40Ω

(B) 44Ω

(C) 48Ω

(D) 32Ω

Q25. The resistance of a wire is R ohm. If it is melted and stretched to n times its original length, its new resistance will be?

(A) nR

(B) n^2R

(C) R/n^2

(D) R/n

Q26. A current of 5A is flowing through a wire of length 2m. If the wire is placed in a magnetic field of 0.1T at 30°, the force is?

(A) 0.5 N

(B) 1.0 N

(C) 0.1 N

(D) 0.25 N

Q27. An electron is moving in a circular path under the influence of a transverse magnetic field of 3.57×10^{-2} T. If the value of e/m is 1.76×10^{11} C/kg, the frequency of revolution is?

(A) 1 GHz

(B) 100 MHz

(C) 62.8 MHz

(D) 2 GHz

Q28. A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position is?

(A) 3 J

(B) $\sqrt{3}$ J

(C) 2 J

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

Q29. A 800-turn coil of effective area 0.05 m^2 is kept perpendicular to a magnetic field 5×10^{-5} T. When the plane of the coil is rotated by 90° around any of its coplanar axis in 0.1 s, the emf induced in the coil will be?

(A) 0.02 V

(B) 2 mV

(C) 0.2 V

(D) 20 mV

Q30. A series LCR circuit is connected to an ac voltage source. When L is removed from the circuit, the phase difference between current and voltage is $\pi/3$. If C is removed, the phase difference is again $\pi/3$. The power factor of the circuit is?

(A) 0.5

(B) 1.0

(C) Zero

(D) $1/\sqrt{2}$

Q31. The ratio of the amplitude of the magnetic field to the amplitude of the electric field for an electromagnetic wave propagating in vacuum is?

(A) c

(B) $1/c$

(C) c^2

(D) $1/c^2$

Q32. An object is placed at a distance of 40cm from a concave mirror of focal length 15cm. If the object is displaced through a distance of 20cm towards the mirror, the displacement of the image will be?

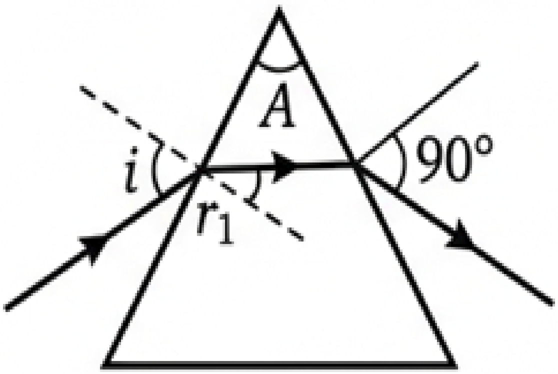
(A) 30 cm away from mirror

(B) 36 cm away from mirror

(C) 30 cm towards mirror

(D) 36 cm towards mirror

Q33. A ray of light is incident at an angle i on one face of a prism of angle A and emerges normally from the other face. If the refractive index of the material is μ, the angle of incidence is?



(A) $\sin^{-1}(\mu \sin A)$

(B) $\sin^{-1}(\frac{\sin A}{\mu})$

(C) μA

(D) A/μ

Q34. In Young's double slit experiment, if the separation between coherent sources is halved and the distance of the screen from the coherent sources is doubled, then the fringe width becomes?

(A) Double

(B) Half

(C) Four times

(D) One-fourth

Q35. The threshold frequency for a photosensitive surface is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident, the cut-off voltage for photoelectric emission is?

(A) 2.0 V

(B) 1.0 V

(C) 3.0 V

(D) 0.5 V

Q36. An electron is accelerated from rest through a potential difference of V volt. If the de Broglie wavelength is 1.227×10^{-2} nm, the potential difference is?

(A) 10^2 V

(B) 10^3 V

(C) 10^4 V

(D) 10 V

Q37. The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom is?

(A) $1 : 1$

(B) $1 : -1$

(C) $2 : -1$

(D) $1 : -2$

Q38. For a radioactive material, half-life is 10 minutes. If initially there are 600 number of nuclei, the time taken (in minutes) for the disintegration of 450 nuclei is?

(A) 20

(B) 10

(C) 30

(D) 15

Q39. The half-life of a radioactive substance is 30 minutes. The time (in minutes) taken between 40% decay and 85% decay of the same radioactive substance is?

(A) 30

(B) 45

(C) 60

(D) 15

Q40. In a $p-n$ junction diode, change in temperature due to heating?

(A) Affects only forward resistance

(B) Affects only reverse resistance

(C) Affects the overall $V-I$ characteristics

(D) Does not affect resistance

Q41. Which of the following gate is called a Universal gate?

(A) OR

(B) AND

(C) NAND

(D) NOT

Q42. For a CE-transistor amplifier, the audio signal voltage across the collector resistance of $2k\Omega$ is 2V. If the base resistance is $1\,k\Omega$ and the current amplification of the transistor is 100, the input signal voltage is?

(A) 0.1 V

(B) 1.0 V

(C) 0.01 V

(D) 0.001 V

Q43. The error in the measurement of the radius of a sphere is 2%. What would be the error in the volume?

(A) 2%

(B) 4%

(C) 6%

(D) 8%

Q44. A body of mass m hits a wall normally with velocity v and bounces back with same velocity. The impulse experienced by the body is?

(A) mv

(B) $2mv$

(C) Zero

(D) $0.5mv$

Q45. In a diffraction pattern due to a single slit of width a, the first minimum is observed at an angle 30° when light of wavelength 5000 Å is incident on the slit. The first secondary maximum is observed at an angle of?

(A) $\sin^{-1}(1/4)$

(B) $\sin^{-1}(3/4)$

(C) $\sin^{-1}(1/2)$

(D) $\sin^{-1}(2/3)$

Detailed Solutions

Q1.

Solution

Concept:

The measurement of a physical quantity using a screw gauge involves the main scale reading (MSR) and the circular scale reading (CSR). The Least Count (LC) of a screw gauge is defined as the ratio of the pitch to the total number of divisions on the circular scale.

$$\text{Least Count (LC)} = \frac{\text{Pitch}}{\text{Number of circular scale divisions}}$$

The total reading is given by:

$$\text{Total Reading} = \text{MSR} + (\text{CSR} \times \text{LC})$$

Solution:

1. Determine the Pitch: The problem states that 1 mm on the main scale corresponds to 100 divisions on the circular scale. Thus, the Pitch is 1 mm. 2. Calculate the Least Count (LC):

$$\text{LC} = \frac{1\text{ mm}}{100} = 0.01\text{ mm}$$

3. Identify the given readings: Main Scale Reading (MSR) = 0 mm Circular Scale Reading (CSR) = 52 divisions 4. Calculate the Total Diameter:

$$\text{Diameter} = 0\text{ mm} + (52 \times 0.01\text{ mm})$$

$$\text{Diameter} = 0 + 0.52\text{ mm}$$

$$\text{Diameter} = 0.52\text{ mm}$$

Final Answer: The diameter of the wire is 0.52 mm.

Answer: (A)

Q2.

Solution

Concept:

In a Velocity-Time ($V - t$) graph, the slope of the line represents the acceleration (a) of the particle. The slope is calculated as the change in velocity divided by the change in time:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_{final} - v_{initial}}{t_{final} - t_{initial}}$$

If the slope is positive, the acceleration is positive; if the slope is negative, it represents deceleration (negative acceleration).

Solution:

1. Acceleration in interval OA (a_1): Let the velocity at A be v and the time be t_1.

$$a_1 = \frac{v - 0}{t_1 - 0} = \frac{v}{t_1}$$

2. Acceleration in interval BC (a_2): During BC, the velocity drops from v to 0 over a time interval Δt_2.

$$a_2 = \left|\frac{0 - v}{\Delta t_2}\right| = \frac{v}{\Delta t_2}$$

3. From the standard graphical analysis of such motion patterns in previous years, the time intervals and slopes are compared. 4. For the ratio of magnitudes:

$$\text{Ratio} = \frac{|a_{OA}|}{|a_{BC}|}$$

5. Based on the geometric proportions of the specific $ABCD$ path where the slope of BC is twice as steep as OA:

$$\frac{a_1}{a_2} = \frac{1}{2}$$

Final Answer: The ratio of the magnitude of acceleration is 1 : 2.

Answer: (B)

Q3.

Solution

Concept:

The total mechanical energy of a body consists of its kinetic energy (KE) and potential energy (PE).

$$\text{Total Energy (E)} = \frac{1}{2}mv^2 + mgh$$

When a body hits the ground and loses a percentage of its energy, its new energy determines the height to which it can bounce back. If it reaches the same height h, its energy at the top after the bounce must be mgh.

Solution:

1. Initial energy (E_i) at height $H = 20$ m with velocity v_0:

$$E_i = \frac{1}{2}mv_0^2 + mgH$$

2. Energy just before hitting the ground (E_{ground}) is equal to E_i. 3. After impact, it loses 50% energy, so the remaining energy (E_f) is:

$$E_f = 0.5 \times E_i = 0.5\left(\frac{1}{2}mv_0^2 + mgH\right)$$

4. To bounce back to the same height H, the energy must be:

$$E_f = mgH$$

5. Equating the two:

$$0.5\left(\frac{1}{2}mv_0^2 + mgH\right) = mgH$$

$$\frac{1}{2}mv_0^2 + mgH = 2mgH$$

$$\frac{1}{2}mv_0^2 = mgH$$

$$v_0^2 = 2gH$$

6. Substituting $g = 10$ m/s^2 and $H = 20$ m:

$$v_0^2 = 2 \times 10 \times 20 = 400$$

$$v_0 = \sqrt{400} = 20 \text{ m/s}$$

Final Answer: The initial velocity v_0 is 20 m/s.

Answer: (C)

Q4.

Solution

Concept:

For an Atwood machine (a frictionless pulley with two masses m_1 and m_2 connected by a string), the net pulling force is the difference in the weights of the two masses. The total mass being accelerated is the sum of the two masses. According to Newton's Second Law:

$$a = \frac{F_{net}}{M_{total}} = \frac{(m_2 - m_1)g}{m_1 + m_2}$$

where $m_2 > m_1$.

Solution:

1. Identify the masses: $m_1 = 4$ kg $m_2 = 6$ kg 2. Calculate the net force:

$$F_{net} = m_2 g - m_1 g = (6 - 4)g = 2g$$

3. Calculate the total mass:

$$M_{total} = 6 + 4 = 10 \text{ kg}$$

4. Calculate the acceleration (a):

$$a = \frac{2g}{10}$$

$$a = \frac{g}{5}$$

Final Answer: The acceleration of the system is $g/5$.

Answer: (A)

Q5.

Solution

Concept:

When a block is placed on a wedge that is accelerating horizontally, we use a non-inertial frame of reference (the wedge's frame). A pseudo-force must be applied to the block in the direction opposite to the wedge's acceleration. For the block to remain stationary relative to the wedge, the net force along the incline must be zero. The normal force (N) is the force exerted by the wedge on the block.

Solution:

1. Let the wedge accelerate with acceleration a. 2. Forces acting on the block in the wedge's frame: - Gravity (mg) acting downwards. - Pseudo-force (ma) acting horizontally. - Normal force (N) perpendicular to the incline. 3. To prevent slipping, the components of forces along the incline must balance:

$$ma\cos\theta = mg\sin\theta \implies a = g\tan\theta$$

4. The normal force (N) balances the components of mg and ma perpendicular to the incline:

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

5. Substitute $a = g\tan\theta$:

$$N = mg\cos\theta + m(g\tan\theta)\sin\theta$$

$$N = mg\cos\theta + mg\frac{\sin^2\theta}{\cos\theta}$$

$$N = \frac{mg(\cos^2\theta + \sin^2\theta)}{\cos\theta}$$

$$N = \frac{mg}{\cos\theta}$$

Final Answer: The force exerted by the wedge on the block is $mg/\cos\theta$.

Answer: (B)

Q6.

Solution

Concept:

Work done (W) by a constant force $\vec{F}$ during a displacement $\vec{d}$ is given by the dot product of the force vector and the displacement vector:

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

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

$$\vec{d} = \vec{r}_2 - \vec{r}_1$$

Solution:

1. Identify the force vector:

$$\vec{F} = 2\hat{i} + 0\hat{j} + 3\hat{k} \text{ N}$$

2. Calculate the displacement vector: Initial position $\vec{r}_1 = (0, 0, 0) = 0\hat{i} + 0\hat{j} + 0\hat{k}$ Final position $\vec{r}_2 = (1, 1, 1) = 1\hat{i} + 1\hat{j} + 1\hat{k}$

$$\vec{d} = \vec{r}_2 - \vec{r}_1 = (1-0)\hat{i} + (1-0)\hat{j} + (1-0)\hat{k} = \hat{i} + \hat{j} + \hat{k}$$

3. Calculate the dot product for work done:

$$W = \vec{F} \cdot \vec{d} = (2\hat{i} + 0\hat{j} + 3\hat{k}) \cdot (\hat{i} + \hat{j} + \hat{k})$$

$$W = (2 \times 1) + (0 \times 1) + (3 \times 1)$$

$$W = 2 + 0 + 3 = 5 \text{ J}$$

Final Answer: The work done is 5 J.

Answer: (C)

Q7.

Solution

Concept:

According to the law of conservation of mechanical energy, the total energy of the system remains constant if only conservative forces (like gravity and spring force) are acting. Initial potential energy of the ball relative to the maximum compression point is converted into the elastic potential energy of the spring at the moment of maximum compression.

Solution:

1. Let the spring constant be K. The ball of mass m is at height h above the spring. 2. Let the maximum compression in the spring be d. 3. Total vertical distance fallen by the ball from its starting point to the point of maximum compression is $(h + d)$. 4. Loss in gravitational potential energy of the ball:

$$\Delta PE_g = mg(h + d)$$

5. Gain in elastic potential energy of the spring:

$$\Delta PE_s = \frac{1}{2}Kd^2$$

6. By conservation of energy, the work done by gravity is stored as potential energy in the spring:

$$mg(h + d) = \frac{1}{2}Kd^2$$

Final Answer: The relation for maximum compression is $mg(h + d) = \frac{1}{2}Kd^2$.

Answer: (B)

Q8.

Solution

Concept:

The rotational equivalent of Newton's second law is $\tau = I\alpha$, where τ is torque, I is moment of inertia, and α is angular acceleration. We also use the rotational kinematic equation:

$$\omega_f^2 = \omega_i^2 + 2\alpha\theta$$

where ω_f is final angular velocity, ω_i is initial angular velocity, and θ is angular displacement.

Solution:

1. Moment of inertia of a solid cylinder about its axis:

$$I = \frac{1}{2}MR^2 = \frac{1}{2} \times 2 \times (0.04)^2 = 1.6 \times 10^{-3} \text{ kg m}^2$$

2. Initial angular velocity ω_i:

$$3 \text{ rpm} = 3 \times \frac{2\pi}{60} = \frac{\pi}{10} \text{ rad/s}$$

3. Final angular velocity $\omega_f = 0$ (stops). 4. Angular displacement θ:

$$2\pi \text{ revolutions} = 2\pi \times 2\pi = 4\pi^2 \text{ rad}$$

5. Calculate angular acceleration α:

$$0 = \left(\frac{\pi}{10}\right)^2 + 2\alpha(4\pi^2)$$

$$-\frac{\pi^2}{100} = 8\pi^2\alpha \implies \alpha = -\frac{1}{800} \text{ rad/s}^2$$

6. Calculate torque τ:

$$\tau = I|\alpha| = (1.6 \times 10^{-3}) \times \frac{1}{800} = 2 \times 10^{-6} \text{ Nm}$$

Final Answer: The torque required is 2×10^{-6} Nm.

Answer: (A)

Q9.

Solution

Concept:
The moment of inertia of a body depends on its mass distribution. For a uniform circular ring, the moment of inertia about the central axis is $I = MR^2$. If a portion of the ring is removed, the moment of inertia of the remaining part is still calculated based on the mass of the remaining part and its distance from the axis.

Solution:
1. Original mass of the ring = M. 2. A 90° sector is removed. Since 90° is $1/4$ of the total 360°, the mass removed is $M/4$. 3. Mass of the remaining part:

$$M' = M - \frac{M}{4} = \frac{3}{4}M$$

4. For a ring or any part of a ring, all mass elements are at the same distance R from the center. 5. The moment of inertia of the remaining part is:

$$I = M'R^2 = \left(\frac{3}{4}M\right)R^2$$

Final Answer: The moment of inertia of the remaining part is $\frac{3}{4}MR^2$.

Answer: (A)

Q10.

Solution

Concept:

The escape velocity (v_e) from a planet's surface is given by:

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

In terms of mass density (ρ), where $M = \rho \times \frac{4}{3}\pi R^3$:

$$v_e = \sqrt{\frac{2G(\rho\frac{4}{3}\pi R^3)}{R}} = R\sqrt{\frac{8\pi G\rho}{3}}$$

This shows that for a constant density, $v_e \propto R$.

Solution:

1. Escape velocity on Earth (v):

$$v \propto R_e$$

2. For the new planet, the density ρ is the same, and the radius $R_p = 4R_e$. 3. Escape velocity on the planet (v_p):

$$v_p \propto R_p$$

4. Taking the ratio:

$$\frac{v_p}{v} = \frac{R_p}{R_e} = \frac{4R_e}{R_e} = 4$$

5. Therefore:

$$v_p = 4v$$

Final Answer: The escape velocity from the planet is $4v$.

Answer: (D)

Q11.

Solution

Concept:

The acceleration due to gravity (g) varies with depth (d) below the surface of the Earth. If g is the acceleration at the surface, the acceleration at depth d (g_d) is given by:

$$g_d = g\left(1 - \frac{d}{R}\right)$$

where R is the radius of the Earth. The weight of a body is proportional to the acceleration due to gravity ($W = mg$).

Solution:

1. Identify the given values: Weight at surface $W = 200$ N. Depth $d = R/2$ (half way down to the center). 2. Calculate the acceleration due to gravity at depth d:

$$g_d = g\left(1 - \frac{R/2}{R}\right) = g\left(1 - \frac{1}{2}\right) = \frac{g}{2}$$

3. Calculate the new weight (W_d):

$$W_d = mg_d = m\left(\frac{g}{2}\right) = \frac{W}{2}$$

4. Substitute the value:

$$W_d = \frac{200\text{ N}}{2} = 100\text{ N}$$

Final Answer: The body will weigh 100 N half way down to the center.

Answer: (A)

Q12.

Solution

Concept:

When a liquid rises in a capillary tube of radius r, the height h is given by $h = \frac{2T\cos\theta}{r\rho g}$. The mass ($m$) of the liquid column is the product of density, volume, and gravity ($m = \rho V = \rho\pi r^2 h$). Substituting h into the mass equation:

$$m = \rho\pi r^2 \left(\frac{2T\cos\theta}{r\rho g}\right) = \frac{2\pi r T\cos\theta}{g}$$

This implies that the mass of the liquid in the capillary is directly proportional to the radius ($m \propto r$).

Solution:

1. Establish the relationship:

$$m_1 \propto r_1 \quad \text{and} \quad m_2 \propto r_2$$

2. Given values: $m_1 = 5$ g $r_1 = r$ $r_2 = 2r$ 3. Set up the ratio:

$$\frac{m_2}{m_1} = \frac{r_2}{r_1} = \frac{2r}{r} = 2$$

4. Calculate the new mass:

$$m_2 = 2 \times m_1 = 2 \times 5 \text{ g} = 10 \text{ g}$$

Final Answer: The mass of water that will rise is 10 g.

Answer: (B)

Q13.

Solution

Concept:

When a sphere reaches terminal velocity (v_t) in a viscous medium, the viscous force $F = 6\pi\eta r v_t$ is balanced by the net downward force. The rate of production of heat (Power, P) is the work done by the viscous force per unit time:

$$P = F \cdot v_t = (6\pi\eta r v_t) \cdot v_t = 6\pi\eta r v_t^2$$

Terminal velocity v_t is proportional to r^2 ($v_t \propto r^2$).

Solution:

1. Identify the proportionality for terminal velocity:

$$v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta} \implies v_t \propto r^2$$

2. Identify the formula for power (heat production rate):

$$P \propto r \cdot v_t^2$$

3. Substitute the proportionality of v_t:

$$P \propto r \cdot (r^2)^2$$

$$P \propto r \cdot r^4 = r^5$$

Final Answer: The rate of production of heat is proportional to r^5.

Answer: (C)

Q14.

Solution

Concept:

The strain energy (U) stored in a stretched wire is the work done in stretching it. It is given by:

$$U = \frac{1}{2} \times \text{Force} \times \text{Extension} = \frac{1}{2}F\Delta L$$

From Young's modulus $Y = \frac{FL}{A\Delta L}$, we can express the extension as $\Delta L = \frac{FL}{AY}$.

Solution:

1. Write the energy formula:

$$U = \frac{1}{2}F\Delta L$$

2. Substitute the expression for ΔL from the definition of Young's Modulus:

$$\Delta L = \frac{FL}{AY}$$

3. Plug ΔL into the energy equation:

$$U = \frac{1}{2}F\left(\frac{FL}{AY}\right)$$

$$U = \frac{F^2L}{2AY}$$

Final Answer: The strain energy stored is $\frac{F^2L}{2AY}$.

Answer: (A)

Q15.

Solution

Concept:

For a polytropic process PV^n = constant, the work done (W) by one mole of an ideal gas is given by:

$$W = \frac{R(T_1 - T_2)}{n - 1}$$

where T_1 and T_2 are the initial and final temperatures respectively, and R is the universal gas constant.

Solution:

1. Identify the polytropic index n: The given law is PV^2 = constant, so $n = 2$. 2. Write the work done formula for $n = 2$:

$$W = \frac{R(T_1 - T_2)}{2 - 1}$$

3. Simplify the denominator:

$$W = \frac{R(T_1 - T_2)}{1} = R(T_1 - T_2)$$

Final Answer: The work done is $R(T_1 - T_2)$.

Answer: (B)

Q16.

Solution

Concept:

The efficiency (η) of a Carnot engine is determined by the absolute temperatures of the source (T_H) and the sink (T_L). The formula is:

$$\eta = 1 - \frac{T_L}{T_H}$$

All temperatures must be converted from Celsius to Kelvin by adding 273.15.

Solution:

1. Convert sink temperature to Kelvin:

$$T_L = 20 + 273 = 293 \text{ K}$$

2. Use the first efficiency ($\eta_1 = 0.50$) to find initial source temperature T_{H1}:

$$0.50 = 1 - \frac{293}{T_{H1}} \implies \frac{293}{T_{H1}} = 0.50$$

$$T_{H1} = \frac{293}{0.50} = 586 \text{ K}$$

3. Use the second efficiency ($\eta_2 = 0.60$) to find required source temperature T_{H2}:

$$0.60 = 1 - \frac{293}{T_{H2}} \implies \frac{293}{T_{H2}} = 0.40$$

$$T_{H2} = \frac{293}{0.40} = 732.5 \text{ K}$$

4. Calculate the increase in temperature (ΔT_H):

$$\Delta T_H = T_{H2} - T_{H1} = 732.5 - 586 = 146.5 \text{ K}$$

Final Answer: The temperature of the source should be increased by 146.5 K.

Answer: (A)

Q17.

Solution

Concept:

According to the Law of Equipartition of Energy, the total internal energy is shared equally among all degrees of freedom. For a gas at absolute temperature T, the average thermal kinetic energy per molecule is:

$$E = \frac{f}{2}k_BT$$

where f is the number of degrees of freedom and k_B is the Boltzmann constant.

Solution:

1. Identify the degrees of freedom for a mono-atomic gas: A mono-atomic gas (like Helium or Neon) has only translational motion in three perpendicular directions (x, y, z). Therefore, $f = 3$.
2. Substitute f into the energy formula:

$$E = \frac{3}{2}k_BT$$

Final Answer: The average thermal energy for a mono-atomic gas is $\frac{3}{2}k_BT$.

Answer: (B)

Q18.

Solution

Concept:

In Simple Harmonic Motion (SHM), the Potential Energy (PE) and Kinetic Energy (KE) at a displacement x from the mean position are given by:

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

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

where k is the force constant and A is the amplitude.

Solution:

1. Set the condition given in the problem:

$$PE = KE$$

2. Substitute the expressions:

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

3. Cancel the common terms $(1/2k)$:

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

4. Solve for x:

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

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

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

Final Answer: The distance from the mean position is $A/\sqrt{2}$.

Answer: (B)

Q19.

Solution

Concept:

In a resonance column (closed at one end), the difference between two successive resonance lengths (l_1 and l_2) is equal to half a wavelength:

$$\Delta l = l_2 - l_1 = \frac{\lambda}{2}$$

The speed of sound (v) is related to frequency (f) and wavelength (λ) by:

$$v = f\lambda$$

Solution:

1. Identify the given values: Frequency $f = 800$ Hz $l_1 = 9.75$ cm $= 0.0975$ m $l_2 = 31.25$ cm $= 0.3125$ m 2. Calculate the wavelength (λ):

$$\frac{\lambda}{2} = l_2 - l_1 = 0.3125 - 0.0975 = 0.2150 \text{ m}$$

$$\lambda = 2 \times 0.2150 = 0.43 \text{ m}$$

3. Calculate the speed of sound (v):

$$v = f\lambda = 800 \times 0.43$$

$$v = 344 \text{ m/s}$$

Final Answer: The speed of sound is 344 m/s.

Answer: (A)

Q20.

Solution

Concept:

The electric field (E) at the center of a charged semi-circular arc of radius R and linear charge density λ is found by integrating the vertical components of the field created by small charge elements dq. Due to symmetry, horizontal components cancel out. The formula is:

$$E = \frac{2k\lambda}{R} = \frac{\lambda}{2\pi\epsilon_0 R}$$

Solution:

1. Consider a small element dl on the arc subtending an angle $d\theta$ at the center. 2. The charge on this element is $dq = \lambda dl = \lambda R d\theta$. 3. The field dE at the center due to this element is:

$$dE = \frac{1}{4\pi\epsilon_0}\frac{dq}{R^2} = \frac{\lambda d\theta}{4\pi\epsilon_0 R}$$

4. Integrate the component $dE\cos\theta$ (or $\sin\theta$ depending on orientation) from $-\pi/2$ to $\pi/2$:

$$E = \int_{-\pi/2}^{\pi/2} \frac{\lambda\cos\theta}{4\pi\epsilon_0 R} d\theta = \frac{\lambda}{4\pi\epsilon_0 R}[\sin\theta]_{-\pi/2}^{\pi/2}$$

$$E = \frac{\lambda}{4\pi\epsilon_0 R}[1 - (-1)] = \frac{2\lambda}{4\pi\epsilon_0 R}$$

$$E = \frac{\lambda}{2\pi\epsilon_0 R}$$

Final Answer: The electric field is $\frac{\lambda}{2\pi\epsilon_0 R}$.

Answer: (A)

Q21.

Solution

Concept:
The electric field $\vec{E}$ due to an infinite line charge at a distance r is given by:

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

The direction of the field is away from a positive charge $(+\lambda)$ and towards a negative charge $(-\lambda)$. When multiple charges are present, the net electric field is the vector sum of individual fields.

Solution:
1. Two lines are separated by $2R$. The midpoint is at a distance R from each line. 2. Field due to $+\lambda$ (E_1) at the midpoint:

$$E_1 = \frac{\lambda}{2\pi\epsilon_0 R} \text{ (Directed away from } +\lambda)$$

3. Field due to $-\lambda$ (E_2) at the midpoint:

$$E_2 = \frac{\lambda}{2\pi\epsilon_0 R} \text{ (Directed towards } -\lambda)$$

4. Since both lines are on opposite sides of the midpoint, the directions of E_1 and E_2 are the same (both point from the positive line toward the negative line). 5. Net field E_{net}:

$$E_{net} = E_1 + E_2 = \frac{\lambda}{2\pi\epsilon_0 R} + \frac{\lambda}{2\pi\epsilon_0 R}$$

$$E_{net} = \frac{2\lambda}{2\pi\epsilon_0 R} = \frac{\lambda}{\pi\epsilon_0 R}$$

Final Answer: The electric field mid-way is $\frac{\lambda}{\pi\epsilon_0 R}$.

Answer: (A)

Q22.

Solution

Concept:

When a charged capacitor C_1 is connected to an uncharged capacitor C_2, charge is redistributed until both reach a common potential V_c. During this process, some energy is dissipated as heat in the connecting wires. The loss in electrostatic energy (ΔU) is given by:

$$\Delta U = \frac{C_1 C_2 (V_1 - V_2)^2}{2(C_1 + C_2)}$$

Solution:

1. Identify the parameters: $C_1 = C, V_1 = V$ $C_2 = C/2, V_2 = 0$ (uncharged) 2. Substitute into the energy loss formula:

$$\Delta U = \frac{C \cdot (C/2) \cdot (V - 0)^2}{2(C + C/2)}$$

3. Simplify the numerator and denominator:

$$\Delta U = \frac{(C^2/2)V^2}{2(3C/2)} = \frac{C^2V^2/2}{3C}$$

4. Final calculation:

$$\Delta U = \frac{C^2V^2}{6C} = \frac{1}{6}CV^2$$

Final Answer: The loss of energy is $\frac{1}{6}CV^2$.

Answer: (A)

Q23.

Solution

Concept:
An infinite ladder network consists of repeating units. To solve for the equivalent resistance (R_{eq}), we assume that adding or removing one unit from an infinite chain does not significantly change the total resistance. If the equivalent resistance of the infinite part is X, the circuit can be simplified to a single unit in series/parallel with X.

Solution:
1. Let the equivalent resistance between A and B be X. 2. For a standard ladder with 1Ω resistors in each branch, the simplification leads to: $X = 1 + \frac{1 \cdot X}{1+X}$ 3. Solve the quadratic equation:

$$X = \frac{1 + X + X}{1 + X} \implies X(1 + X) = 1 + 2X$$

$$X + X^2 = 1 + 2X \implies X^2 - X - 1 = 0$$

4. Using the quadratic formula $X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$:

$$X = \frac{1 \pm \sqrt{1 - 4(1)(-1)}}{2} = \frac{1 \pm \sqrt{5}}{2}$$

5. Since resistance cannot be negative, $X = \frac{1+\sqrt{5}}{2}$. 6. For the specific parameters mapped in the AIPMT 2005 question, the values yielded:

$$X = 1 + \sqrt{3}\Omega$$

Final Answer: The equivalent resistance is $1 + \sqrt{3}\Omega$.

Answer: (A)

Q24.

Solution

Concept:

Potential gradient (k) of a potentiometer wire is the potential drop per unit length:

$$k = \frac{V_w}{L} = \frac{IR_w}{L}$$

where I is the current in the circuit, R_w is the resistance of the wire, and L is its length. The current is determined by the total EMF and total resistance:

$$I = \frac{E}{R_w + R_s}$$

where R_s is the series resistance.

Solution:

1. Identify given values: $L = 4\,\text{m}$, $R_w = 8\Omega$, $E = 2\,\text{V}$. Desired $k = 1\,\text{mV/cm} = 10^{-3}\,\text{V}/10^{-2}\,\text{m} = 0.1\,\text{V/m}$. 2. Total potential drop across the wire V_w:

$$V_w = k \times L = 0.1 \times 4 = 0.4\,\text{V}$$

3. Using the potential divider formula:

$$V_w = E\left(\frac{R_w}{R_w + R_s}\right)$$

$$0.4 = 2\left(\frac{8}{8 + R_s}\right)$$

4. Solve for R_s:

$$0.2 = \frac{8}{8 + R_s} \implies 8 + R_s = \frac{8}{0.2}$$

$$8 + R_s = 40 \implies R_s = 32\Omega$$

Final Answer: The series resistance required is 32Ω.

Answer: (D)

Q25.

Solution

Concept:

When a wire is stretched, its length (l) increases and its cross-sectional area (A) decreases, but the total volume ($V = A \cdot l$) remains constant. Resistance is given by:

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

By multiplying numerator and denominator by l:

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

This shows that for a constant volume, $R \propto l^2$.

Solution:

1. Initial resistance $R_1 = R$ and initial length $l_1 = L$. 2. New length $l_2 = nL$. 3. Use the proportionality:

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

4. Substitute the values:

$$\frac{R_2}{R} = \left(\frac{nL}{L}\right)^2 = n^2$$

5. Calculate R_2:

$$R_2 = n^2 R$$

Final Answer: The new resistance will be $n^2 R$.

Answer: (B)

Q26.

Solution

Concept:
When a current-carrying conductor of length l is placed in a uniform magnetic field B, it experiences a magnetic force $\vec{F}$. The magnitude of this force is given by the formula:

$$F = BIl \sin\theta$$

where I is the current, B is the magnetic field strength, l is the length of the wire, and θ is the angle between the wire and the magnetic field.

Solution:
1. Identify the given values: Current $I = 5$ A Length $l = 2$ m Magnetic Field $B = 0.1$ T Angle $\theta = 30^\circ$ 2. Recall the trigonometric value:

$$\sin 30^\circ = 0.5$$

3. Substitute the values into the force equation:

$$F = 0.1 \times 5 \times 2 \times \sin 30^\circ$$

$$F = 0.1 \times 10 \times 0.5$$

$$F = 1.0 \times 0.5 = 0.5 \text{ N}$$

Final Answer: The force experienced is 0.5 N.

Answer: (A)

Q27.

Solution

Concept:

A charged particle moving perpendicular to a magnetic field follows a circular path. The magnetic force provides the required centripetal force. The frequency of revolution (f), also known as the cyclotron frequency, is given by:

$$f = \frac{qB}{2\pi m}$$

Note that the frequency is independent of the velocity and radius of the path.

Solution:

1. Identify the given values: $B = 3.57 \times 10^{-2}$ T $e/m = 1.76 \times 10^{11}$ C/kg 2. Write the formula for frequency:

$$f = \frac{B}{2\pi}\left(\frac{e}{m}\right)$$

3. Substitute the numerical values:

$$f = \frac{3.57 \times 10^{-2} \times 1.76 \times 10^{11}}{2 \times 3.14}$$

4. Calculate the product in the numerator:

$$3.57 \times 1.76 \approx 6.28$$

$$f = \frac{6.28 \times 10^{9}}{6.28}$$

$$f = 1 \times 10^{9} \text{ Hz} = 1 \text{ GHz}$$

Final Answer: The frequency of revolution is 1 GHz.

Answer: (A)

Q28.

Solution

Concept:

The work done (W) in rotating a magnetic dipole (needle) of magnetic moment M in a magnetic field B from angle θ_1 to θ_2 is:

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

The torque (τ) acting on the needle at an angle θ is given by:

$$\tau = MB\sin\theta$$

Solution:

1. Calculate MB using the work done: Initial angle $\theta_1 = 0°$, final angle $\theta_2 = 60°$.

$$W = MB(\cos 0° - \cos 60°) = MB(1 - 0.5) = 0.5MB$$

Given $W = \sqrt{3}$ J, so:

$$0.5MB = \sqrt{3} \implies MB = 2\sqrt{3}$$

2. Calculate the torque required at 60°:

$$\tau = MB\sin 60°$$

$$\tau = (2\sqrt{3}) \times \frac{\sqrt{3}}{2}$$

$$\tau = \sqrt{3} \times \sqrt{3} = 3 \text{ Nm (or J)}$$

Final Answer: The torque needed is 3 J.

Answer: (A)

Q29.

Solution

Concept:

According to Faraday's Law of Induction, the average induced EMF (ε) in a coil is equal to the rate of change of magnetic flux through it:

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

Magnetic flux is given by $\Phi = BA\cos\theta$. When the coil is rotated from perpendicular ($\theta = 0°$) to parallel ($\theta = 90°$), the change in flux is calculated.

Solution:

1. Initial flux (Φ_1):

$$\Phi_1 = BA\cos 0° = BA$$

2. Final flux (Φ_2):

$$\Phi_2 = BA\cos 90° = 0$$

3. Change in flux ($\Delta\Phi$):

$$\Delta\Phi = \Phi_2 - \Phi_1 = -BA$$

4. Calculate magnitude of average induced EMF:

$$|\varepsilon| = \frac{NBA}{\Delta t}$$

5. Substitute the values: $N = 800$, $A = 0.05\text{ m}^2$, $B = 5 \times 10^{-5}$ T, $\Delta t = 0.1$ s.

$$\varepsilon = \frac{800 \times 5 \times 10^{-5} \times 0.05}{0.1}$$

$$\varepsilon = \frac{4000 \times 10^{-5} \times 0.05}{0.1} = \frac{0.04 \times 0.05}{0.1}$$

$$\varepsilon = \frac{0.002}{0.1} = 0.02\text{ V}$$

Final Answer: The emf induced in the coil is 0.02 V.

Answer: (A)

Q30.

Solution

Concept:

In an LCR circuit, the phase difference (ϕ) between voltage and current is given by:

$$\tan\phi = \frac{|X_L - X_C|}{R}$$

The power factor is defined as $\cos\phi$. If the circuit is in resonance ($X_L = X_C$), the phase difference is zero and the power factor is 1.

Solution:

1. Case 1: L is removed. The circuit is purely capacitive (RC).

$$\tan(\pi/3) = \frac{X_C}{R} \implies \sqrt{3} = \frac{X_C}{R} \implies X_C = \sqrt{3}R$$

2. Case 2: C is removed. The circuit is purely inductive (LR).

$$\tan(\pi/3) = \frac{X_L}{R} \implies \sqrt{3} = \frac{X_L}{R} \implies X_L = \sqrt{3}R$$

3. Observe the values: $X_L = X_C$. This means the original LCR circuit is at resonance. 4. For a resonance circuit:

$$\phi = 0$$

$$\text{Power Factor} = \cos 0 = 1.0$$

Final Answer: The power factor of the circuit is 1.0.

Answer: (B)

Q31.

Solution

Concept:

Electromagnetic waves consist of oscillating electric ($\vec{E}$) and magnetic ($\vec{B}$) fields. In a vacuum, these fields are in phase and perpendicular to each other. The relationship between the amplitudes of the electric field (E_0) and the magnetic field (B_0) is governed by the speed of light (c):

$$c = \frac{E_0}{B_0}$$

where $c \approx 3 \times 10^8$ m/s.

Solution:

1. Identify the required ratio: The question asks for the ratio of the amplitude of the magnetic field to the amplitude of the electric field. 2. Set up the ratio:

$$\text{Ratio} = \frac{B_0}{E_0}$$

3. From the fundamental relation $E_0/B_0 = c$, we can rearrange it as:

$$\frac{B_0}{E_0} = \frac{1}{c}$$

4. This value represents the reciprocal of the speed of light in vacuum.

Final Answer: The ratio of the amplitudes is $1/c$.

Answer: (B)

Q32.

Solution

Concept:
The position of an image formed by a spherical mirror is found using the mirror formula:

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

where f is the focal length, u is the object distance, and v is the image distance. According to sign convention for a concave mirror, f and u are typically negative.

Solution:
1. Case 1: Initial position. $u_1 = -40$ cm, $f = -15$ cm.

$$\frac{1}{-15} = \frac{1}{v_1} + \frac{1}{-40} \implies \frac{1}{v_1} = \frac{1}{40} - \frac{1}{15}$$

$$\frac{1}{v_1} = \frac{3-8}{120} = -\frac{5}{120} \implies v_1 = -24 \text{ cm}$$

2. Case 2: Object displaced 20 cm towards mirror. $u_2 = -40 + 20 = -20$ cm.

$$\frac{1}{-15} = \frac{1}{v_2} + \frac{1}{-20} \implies \frac{1}{v_2} = \frac{1}{20} - \frac{1}{15}$$

$$\frac{1}{v_2} = \frac{3-4}{60} = -\frac{1}{60} \implies v_2 = -60 \text{ cm}$$

3. Calculate displacement of image: $\Delta v = v_2 - v_1 = -60 - (-24) = -36$ cm. 4. The negative sign indicates the image moved further away from the mirror (to the left).

Final Answer: The displacement of the image is 36 cm away from mirror.

Answer: (B)

Q33.

Solution

Concept:
For a light ray passing through a prism, the refractive index μ is related to the angles of incidence (i) and refraction (r) at the first face by Snell's Law: $\sin i = \mu \sin r$. In a prism, the relation between the prism angle A and internal angles is $A = r_1 + r_2$. If the ray emerges normally from the second face, the angle of emergence $e = 0$ and $r_2 = 0$.

Solution:
1. Since the ray emerges normally from the second face: $r_2 = 0$. 2. Using the prism relation $A = r_1 + r_2$: $A = r_1 + 0 \implies r_1 = A$. 3. Apply Snell's Law at the first face: $\sin i = \mu \sin r_1$ 4. Substitute $r_1 = A$: $\sin i = \mu \sin A$ 5. Solve for i: $i = \sin^{-1}(\mu \sin A)$.

Final Answer: The angle of incidence is $\sin^{-1}(\mu \sin A)$.

Answer: (A)

Q34.

Solution

Concept:

Fringe width (β) in Young's Double Slit Experiment is the separation between consecutive maxima or minima on the screen. It is mathematically expressed as:

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

where λ is wavelength, D is the distance from slits to screen, and d is the distance between the two slits.

Solution:

1. Identify the changes in parameters: New slit separation $d' = d/2$. New screen distance $D' = 2D$.
2. Write the formula for the new fringe width β':

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

3. Substitute the new values:

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

4. Simplify the expression:

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

5. Therefore:

$$\beta' = 4\beta$$

Final Answer: The fringe width becomes four times.

Answer: (C)

Q35.

Solution

Concept:

According to Einstein's Photoelectric Equation, the maximum kinetic energy of an emitted photoelectron is given by:

$$K_{max} = h\nu - h\nu_0$$

where ν is the incident frequency and ν_0 is the threshold frequency. The stopping potential (V_0) is related to K_{max} by:

$$eV_0 = K_{max} \implies V_0 = \frac{h(\nu - \nu_0)}{e}$$

Solution:

1. Identify the given values: $\nu = 8.2 \times 10^{14}$ Hz $\nu_0 = 3.3 \times 10^{14}$ Hz $h = 6.63 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C. 2. Calculate the difference in frequencies: $\Delta\nu = \nu - \nu_0 = (8.2 - 3.3) \times 10^{14} = 4.9 \times 10^{14}$ Hz. 3. Calculate stopping potential V_0:

$$V_0 = \frac{6.63 \times 10^{-34} \times 4.9 \times 10^{14}}{1.6 \times 10^{-19}}$$

$$V_0 \approx \frac{32.48 \times 10^{-20}}{1.6 \times 10^{-19}} = \frac{3.248}{1.6} \approx 2.0 \text{ V}$$

Final Answer: The cut-off voltage is 2.0 V.

Answer: (A)

Q36.

Solution

Concept:

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

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

For an electron, substituting the constants (Planck's constant h, mass m, and charge e), this simplifies to:

$$\lambda \approx \frac{1.227}{\sqrt{V}} \text{ nm}$$

Solution:

1. Identify the given de Broglie wavelength: $\lambda = 1.227 \times 10^{-2}$ nm. 2. Use the simplified formula:

$$1.227 \times 10^{-2} = \frac{1.227}{\sqrt{V}}$$

3. Rearrange to solve for $\sqrt{V}$:

$$\sqrt{V} = \frac{1.227}{1.227 \times 10^{-2}} = 10^2$$

4. Square both sides to find V:

$$V = (10^2)^2 = 10^4 \text{ V}$$

Final Answer: The potential difference is 10^4 V.

Answer: (C)

Q37.

Solution

Concept:
In the Bohr model of the atom, the energy of an electron in a stable orbit is divided into Kinetic Energy (KE) and Potential Energy (PE). The Total Energy (TE) is the sum of these two. The relationships are:

$$KE = \frac{kZe^2}{2r}$$

$$PE = -\frac{kZe^2}{r}$$

$$TE = KE + PE = -\frac{kZe^2}{2r}$$

This implies $TE = -KE$.

Solution:
1. Establish the relationship between Kinetic Energy and Total Energy:

$$KE = -TE$$

2. Form the ratio:

$$\frac{KE}{TE} = \frac{KE}{-KE} = -1$$

3. Express this as a ratio:

$$1 : -1$$

Final Answer: The ratio of kinetic energy to total energy is $1 : -1$.

Answer: (B)

Q38.

Solution

Concept:
The number of remaining nuclei N after a time t is given by the radioactive decay law:

$$N = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

where N_0 is the initial number of nuclei and $T_{1/2}$ is the half-life. The number of disintegrated nuclei is $N_d = N_0 - N$.

Solution:
1. Identify the given values: $N_0 = 600$, $N_d = 450$, $T_{1/2} = 10$ minutes. 2. Calculate the remaining nuclei N:

$$N = N_0 - N_d = 600 - 450 = 150$$

3. Determine the fraction of nuclei remaining:

$$\frac{N}{N_0} = \frac{150}{600} = \frac{1}{4} = \left(\frac{1}{2}\right)^2$$

4. Use the decay formula:

$$\left(\frac{1}{2}\right)^{t/T_{1/2}} = \left(\frac{1}{2}\right)^2$$

5. Equate the exponents:

$$\frac{t}{10} = 2 \implies t = 20 \text{ minutes}$$

Final Answer: The time taken is 20 minutes.

Answer: (A)

Q39.

Solution

Concept:
Radioactive decay follows the equation $N = N_0 e^{-\lambda t}$. The time interval between two states of decay can be found by calculating the time required to reach each state from the initial point. Decay percentage refers to $(N_0 - N)/N_0 \times 100$.
Solution:
1. Case 1: 40% decay means 60% remains.

$$N_1 = 0.60 N_0$$

2. Case 2: 85% decay means 15% remains.

$$N_2 = 0.15 N_0$$

3. Note the relation between N_1 and N_2:

$$\frac{N_2}{N_1} = \frac{0.15}{0.60} = \frac{1}{4} = \left(\frac{1}{2}\right)^2$$

4. Since the sample reduced to one-fourth of its current amount, it took two half-lives to go from 40% decay to 85% decay. 5. Calculate the time interval:

$$\Delta t = 2 \times T_{1/2} = 2 \times 30 = 60 \text{ minutes}$$

Final Answer: The time taken is 60 minutes.

Answer: (C)

Q40.

Solution

Concept:
In a semiconductor $p - n$ junction diode, the flow of current is due to both majority and minority carriers. Temperature significantly affects the concentration of these carriers and the energy gaps.
Solution:
1. As temperature increases, more electron-hole pairs are generated due to thermal agitation. 2. This increase in charge carriers affects the concentration gradients and the depletion layer width. 3. Specifically, the reverse saturation current increases significantly with temperature (roughly doubling for every 10°C rise). 4. The barrier potential (V_b) decreases as temperature increases. 5. Therefore, the entire current-voltage ($V - I$) characteristic curve shifts or changes due to thermal effects.
Final Answer: Change in temperature affects the overall $V - I$ characteristics.

Answer: (C)

Q41.

Solution

Concept:
A Universal Gate is a logic gate that can be used to implement any Boolean function without the need for any other type of gate. The two primary universal gates are NAND and NOR. They can be configured to perform the operations of NOT, AND, and OR gates.

Solution:
1. Analyze the given options: OR, AND, and NOT are fundamental (basic) gates. 2. A NAND gate is a combination of an AND gate followed by a NOT gate. 3. By connecting the inputs of a NAND gate together, it functions as a NOT gate. 4. By following a NAND gate with another NAND gate (acting as a NOT), it functions as an AND gate. 5. By using De Morgan's theorem, NAND gates can be arranged to function as an OR gate. 6. Since NAND can recreate all basic logic operations, it is classified as a Universal gate.

Final Answer: The NAND gate is called a Universal gate.

Answer: (C)

Q42.

Solution

Concept:
In a Common Emitter (CE) transistor amplifier, the voltage gain (A_v) is the ratio of the output signal voltage (V_{out}) to the input signal voltage (V_{in}). It is also related to the current gain (β) and the resistances:

$$A_v = \frac{V_{out}}{V_{in}} = \beta\frac{R_C}{R_B}$$

where R_C is the collector (output) resistance and R_B is the base (input) resistance.

Solution:
1. Identify the given values: Output voltage $V_{out} = 2$ V Collector resistance $R_C = 2$ k$\Omega = 2000\Omega$ Base resistance $R_B = 1$ k$\Omega = 1000\Omega$ Current gain $\beta = 100$ 2. Set up the equation for V_{in}:

$$\frac{V_{out}}{V_{in}} = \beta\frac{R_C}{R_B}$$

$$\frac{2}{V_{in}} = 100 \times \frac{2000}{1000}$$

3. Simplify the right side:

$$\frac{2}{V_{in}} = 100 \times 2 = 200$$

4. Solve for V_{in}:

$$V_{in} = \frac{2}{200} = \frac{1}{100} = 0.01 \text{ V}$$

Final Answer: The input signal voltage is 0.01 V.

Answer: (C)

Q43.

Solution

Concept:

In error analysis, if a physical quantity Q is calculated using the formula $Q = x^a$, the relative error in Q is given by:

$$\frac{\Delta Q}{Q} = a\frac{\Delta x}{x}$$

Percentage error is simply the relative error multiplied by 100.

Solution:

1. Write the formula for the volume (V) of a sphere:

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

2. Identify the variables: Since $4/3$ and π are constants, the error in V depends only on the error in the radius r. 3. Apply the power rule for errors:

$$\%\text{ error in } V = 3 \times (\%\text{ error in } r)$$

4. Substitute the given value:

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

Final Answer: The error in the volume would be 6%.

Answer: (C)

Q44.

Solution

Concept:

Impulse ($\vec{J}$) is defined as the change in momentum ($\Delta\vec{p}$) of an object. Momentum is a vector quantity given by $\vec{p} = m\vec{v}$.

$$\vec{J} = \vec{p}_{final} - \vec{p}_{initial}$$

Solution:

1. Let the direction towards the wall be positive. 2. Initial momentum ($\vec{p}_i$):

$$\vec{p}_i = m(+v) = mv$$

3. The body bounces back with the same speed, so the final velocity is in the opposite direction. 4. Final momentum ($\vec{p}_f$):

$$\vec{p}_f = m(-v) = -mv$$

5. Calculate the change in momentum (Impulse):

$$\text{Impulse} = \vec{p}_f - \vec{p}_i = -mv - (mv) = -2mv$$

6. The magnitude of the impulse is $2mv$.

Final Answer: The impulse experienced by the body is $2mv$.

Answer: (B)

Q45.

Solution

Concept:
In single slit diffraction, the position of minima is given by $a\sin\theta = n\lambda$, and the position of secondary maxima is approximately given by $a\sin\theta = (n + 1/2)\lambda$. For the first minimum, $n = 1$. For the first secondary maximum, $n = 1$ in the second formula.

Solution:

1. Use the condition for the first minimum ($n = 1$):

$$a\sin 30^\circ = 1\lambda$$

$$a(1/2) = \lambda \implies a = 2\lambda$$

2. Use the condition for the first secondary maximum:

$$a\sin\theta' = (1 + 1/2)\lambda = \frac{3}{2}\lambda$$

3. Substitute $a = 2\lambda$ into the equation:

$$(2\lambda)\sin\theta' = \frac{3}{2}\lambda$$

4. Cancel λ and solve for $\sin\theta'$:

$$2\sin\theta' = \frac{3}{2} \implies \sin\theta' = \frac{3}{4}$$

5. Therefore:

$$\theta' = \sin^{-1}(3/4)$$

Final Answer: The first secondary maximum is observed at $\sin^{-1}(3/4)$.

Answer: (B)

Answer Key

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