NEET-UG Physics Sample Paper-9

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

Instructions

- This paper contains a total of **45** Multiple Choice Questions.
- Each correct answer carries **+5 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Q1. The error in the measurement of the radius of a sphere is 2%. What would be the error in the volume of the sphere?

(A) 8%

(B) 2%

(C) 4%

(D) 6%

Q2. A ball is thrown vertically downward with a velocity of 20 m/s from the top of a tower. It hits the ground after some time with a velocity of 80 m/s. The height of the tower is ($g = 10$ m/s^2):

(A) 340 m

(B) 320 m

(C) 300 m

(D) 360 m

Q3. The displacement x of a particle varies with time t as $x = ae^{-\alpha t} + be^{\beta t}$. The velocity of the particle will:

(A) Go on decreasing with time

(B) Be independent of α and β

(C) Drop to zero when $\alpha = \beta$

(D) Go on increasing with time

Q4. A block of mass m is placed on a smooth inclined wedge ABC of inclination θ. The wedge is given an acceleration a towards the right. The relation between a and θ for the block to remain stationary relative to the wedge is:

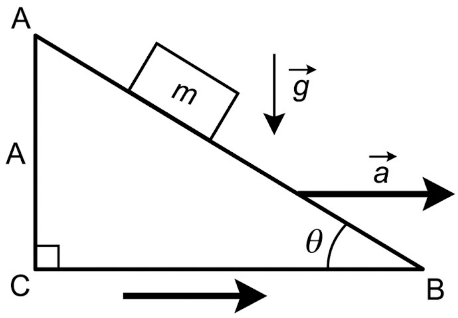


Fig. 1

(A) $a = g/\text{cosec}\,\theta$

(B) $a = g/\sin\theta$

(C) $a = g\cos\theta$

(D) $a = g\tan\theta$

Q5. A rigid ball of mass m strikes a rigid wall at 60° and gets reflected without loss of speed. The value of impulse imparted by the wall on the ball is:

(A) mv

(B) $2mv$

(C) $mv/2$

(D) $mv/3$

Q6. A body of mass 1 kg begins to move under the action of a time-dependent force $\mathbf{F} = (2t\hat{i} + 3t^2\hat{j})$ N. What power is developed by the force at time t?

(A) $(2t^2 + 3t^4)$ W

(B) $(2t^3 + 3t^4)$ W

(C) $(2t^3 + 3t^5)$ W

(D) $(2t + 3t^3)$ W

Q7. A mass m is attached to a thin wire and whirled in a vertical circle. The wire is most likely to break when:

(A) The mass is at the highest point

(B) The wire is horizontal

(C) The mass is at the lowest point

(D) Inclined at an angle of 60° from vertical

Q8. A solid sphere is rotating freely about its symmetry axis in free space. The radius of the sphere is increased keeping its mass same. Which of the following physical quantities remains constant?

(A) Angular velocity

(B) Moment of inertia

(C) Rotational kinetic energy

(D) Angular momentum

Q9. Three objects, a solid sphere, a thin circular disk, and a circular ring, each have the same mass M and radius R. They all spin with the same angular speed ω about their own symmetry axes. The amounts of work (W) required to bring them to rest would satisfy:

(A) $W_{\text{ring}} > W_{\text{disk}} > W_{\text{sphere}}$

(B) $W_{\text{sphere}} > W_{\text{disk}} > W_{\text{ring}}$

(C) $W_{\text{disk}} > W_{\text{sphere}} > W_{\text{ring}}$

(D) $W_{\text{ring}} > W_{\text{sphere}} > W_{\text{disk}}$

Q10. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then:

(A) $d = 1$ km

(B) $d = \frac{3}{2}$ km

(C) $d = 2$ km

(D) $d = \frac{1}{2}$ km

Q11. A Kepler's law states that the square of the period of revolution (T) of a planet around the sun is proportional to the third power of average distance r. If masses of sun and planet are M and m respectively, then as per Newton's law of gravitation T^2 is proportional to:

(A) r^3

(B) $r^{7/2}$

(C) $r^{3/2}$

(D) r^3 (Independent of m)

Q12. The bulk modulus of a spherical object is B. If it is subjected to uniform pressure p, the fractional decrease in radius is:

(A) p/B

(B) $B/3p$

(C) $3p/B$

(D) $p/3B$

Q13. Two small spherical metal balls, having equal masses, are made from materials of densities ρ_1 and ρ_2 ($\rho_1 = 8\rho_2$) and have radii of 1 mm and 2 mm respectively. They are made to fall vertically (from rest) in a viscous medium whose coefficient of viscosity equals η and whose density is $0.1\rho_2$. The ratio of their terminal velocities would be:

(A) $79/36$

(B) $79/72$

(C) $19/36$

(D) $39/72$

Q14. A small soap bubble of radius r is placed inside a large soap bubble of radius R. The excess pressure inside the smaller bubble is:

(A) $4T(1/r + 1/R)$

(B) $4T/r$

(C) $4T/R$

(D) $4T(1/r - 1/R)$

Q15. A sample of 0.1 g of water at 100°C and normal pressure (1.013×10^5 N/m^2) requires 54 cal of heat energy to convert to steam at 100°C. If the volume of the steam produced is 167.1 cc, the change in internal energy of the sample is:

(A) 208.7 J

(B) 42.2 J

(C) 84.5 J

(D) 201.2 J

Q16. The efficiency of a Carnot engine operating with reservoir temperatures of 100°C and -23°C is:

(A) 33%

(B) 25%

(C) 50%

(D) 10%

Q17. The ratio of the specific heats $C_p/C_v = \gamma$ in terms of degrees of freedom (n) is given by:

(A) $(1 + n/2)$

(B) $(1 + 2/n)$

(C) $(1 + n/3)$

(D) $(1 + 1/n)$

Q18. A particle executes linear simple harmonic motion with an amplitude of 3 cm. When the particle is at 2 cm from the mean position, the magnitude of its velocity is equal to that of its acceleration. Its time period in seconds is:

(A) $\sqrt{5}/\pi$

(B) $4\pi/\sqrt{5}$

(C) $2\pi/\sqrt{3}$

(D) $\sqrt{5}/2\pi$

Q19. A tuning fork with frequency 800 Hz produces resonance in a resonance column tube with upper end open and lower end closed by water surface. Successive resonances are observed at lengths 9.75 cm, 31.25 cm and 52.75 cm. The speed of sound in air is:

(A) 344 m/s

(B) 172 m/s

(C) 516 m/s

(D) 250 m/s

Q20. A spherical conductor of radius 10 cm has a charge of 3.2×10^{-7} C distributed uniformly. What is the magnitude of electric field at a point 15 cm from the centre of the sphere? ($\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2)

(A) 1.28×10^4 N/C

(B) 1.28×10^5 N/C

(C) 1.28×10^6 N/C

(D) 1.28×10^7 N/C

Q21. Two metal spheres, one of radius R and the other of radius $2R$ respectively have the same surface charge density σ. They are brought in contact and separated. What will be the new surface charge densities on them?

(A) $\sigma_1 = 5/6\sigma, \sigma_2 = 5/2\sigma$

(B) $\sigma_1 = 5/3\sigma, \sigma_2 = 5/6\sigma$

(C) $\sigma_1 = 4/3\sigma, \sigma_2 = 2/3\sigma$

(D) $\sigma_1 = 2/3\sigma, \sigma_2 = 4/3\sigma$

Q22. The capacitance of a parallel plate capacitor with air as medium is 6 μF. With the introduction of a dielectric medium, the capacitance becomes 30 μF. The permittivity of the medium is:

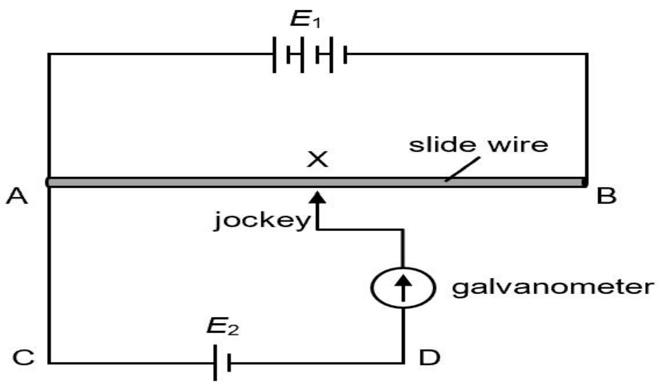
(A) $0.44 \times 10^{-10}\ C^2/Nm^2$

(B) $1.77 \times 10^{-12}\ C^2/Nm^2$

(C) $5.00\ \ C^2/Nm^2$

(D) $0.44 \times 10^{-13}\ C^2/Nm^2$

Q23. In a potentiometer circuit, a cell of EMF 1.5 V gives balance point at 36 cm length of wire. If another cell of EMF 2.5 V replaces the first cell, then at what length of the wire will the balance point occur?



(A) 60 cm

(B) 64 cm

(C) 62 cm

(D) 66 cm

Q24. The color code of a resistance is: Yellow, Violet, Brown, Gold. The values of resistance and tolerance are:

(A) 470Ω, 5%

(B) 47Ω, 10%

(C) $4.7k\Omega$, 5%

(D) 470Ω, 10%

Q25. A set of n equal resistors, each of resistance R, when connected in series have an effective resistance X. When they are connected in parallel, the effective resistance is Y. The relation between X and Y is:

(A) $X = n^2Y$

(B) $Y = n^2X$

(C) $X = nY$

(D) $Y = nX$

Q26. The Wheatstone bridge shown in the figure is balanced. If the positions of the cell and the galvanometer are interchanged, the bridge will:

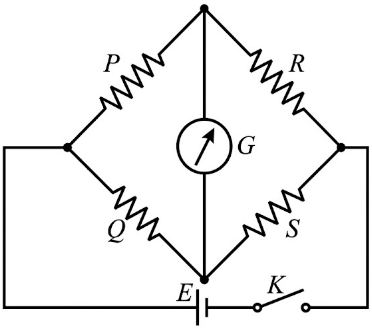


Fig. 1

(A) Remain balanced

(B) Not remain balanced

(C) Show deflection in one direction

(D) Show zero deflection only at high voltage

Q27. A long solenoid of 50 cm length having 100 turns carries a current of 2.5 A. The magnetic field at the centre of the solenoid is:

(A) 6.28×10^{-4} T

(B) 3.14×10^{-4} T

(C) 6.28×10^{-5} T

(D) 3.14×10^{-5} T

Q28. An electron is moving in a circular orbit of radius r with a frequency ν. The magnetic dipole moment that can be associated with the electron is:

(A) $\pi e \nu r^2$

(B) $\frac{\pi e r^2}{\nu}$

(C) $\frac{\nu e r^2}{\pi}$

(D) $2\pi evr^2$

Q29. If the susceptibility of dia-, para- and ferro-magnetic materials are χ_d, χ_p, χ_f respectively, then:

(A) $\chi_d < 0, \chi_p > 0, \chi_f \gg 1$

(B) $\chi_d > 0, \chi_p > 0, \chi_f > 1$

(C) $\chi_d < 0, \chi_p < 0, \chi_f < 0$

(D) $\chi_d > 0, \chi_p < 0, \chi_f \gg 1$

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 instead C is removed from the circuit, the phase difference is again $\pi/3$ between current and voltage. The power factor of the circuit is:

(A) 0.5

(B) 1.0

(C) -1.0

(D) zero

Q31. An inductor 20 mH, a capacitor 100 μF and a resistor 50 Ω are connected in series across a source of emf $V = 10\sin 314t$. The power loss in the circuit is:

(A) 0.79 W

(B) 0.43 W

(C) 2.74 W

(D) 1.13 W

Q32. The ratio of contributions made by the electric field and magnetic field components to the intensity of an electromagnetic wave is (c = speed of electromagnetic waves):

(A) $c : 1$

(B) $1 : 1$

(C) $1 : c$

(D) $1 : c^2$

Q33. A ray is incident at an angle of incidence i on one surface of a small angle prism (with angle of prism A) and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ, then the angle of incidence is nearly equal to:

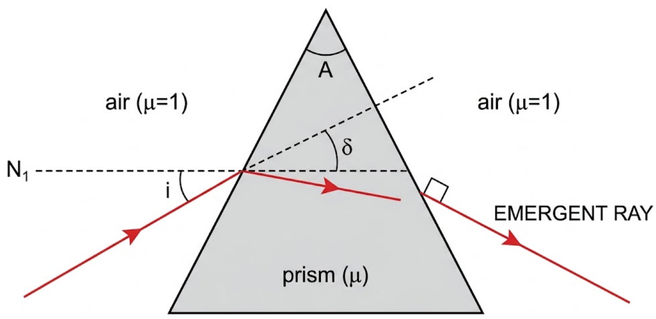


Fig. 1

(A) $A/2\mu$

(B) $2A/\mu$

(C) μA

(D) $\mu A/2$

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 refractive index of the material of a prism is $\sqrt{2}$ and the angle of the prism is $60°$. What is the angle of minimum deviation?

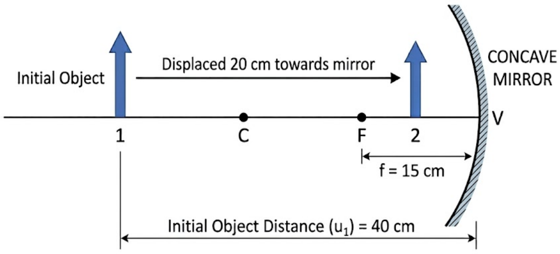
(A) $45°$

(B) $30°$

(C) 37°

(D) 60°

Q36. An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be:



(A) 30 cm towards the mirror

(B) 36 cm away from the mirror

(C) 30 cm away from the mirror

(D) 36 cm towards the mirror

Q37. When the light of frequency $2\nu_0$ (where ν_0 is threshold frequency) is incident on a metal plate, the maximum velocity of electrons emitted is v_1. When the frequency of the incident radiation is increased to $5\nu_0$, the maximum velocity of electrons emitted from the same plate is v_2. The ratio v_1/v_2 is:

(A) 1 : 2

(B) 1 : 4

(C) 4 : 1

(D) 2 : 1

Q38. An electron is accelerated through a potential difference of 10,000 V. Its de Broglie wavelength is (nearly) ($m_e = 9 \times 10^{-31}$ kg):

(A) 12.2×10^{-13} m

(B) 12.2×10^{-12} m

(C) 12.2×10^{-14} m

(D) 12.2×10^{-11} m

Q39. 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) 1 : -2

(D) 2 : -1

Q40. 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) 15

(B) 30

(C) 45

(D) 60

Q41. 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 of p-n junction

Q42. For a transistor action, which of the following statements is correct?

(A) Base, emitter and collector regions should have same size.

(B) Both emitter junction as well as the collector junction are forward biased.

(C) The base region must be very thin and lightly doped.

(D) Base, emitter and collector regions should have same doping concentrations.

Q43. Which of the following gate is called a Universal gate?

(A) OR gate

(B) AND gate

(C) NAND gate

(D) NOT gate

Q44. In a screw gauge, the zero of the circular scale lies 4 divisions below the line of graduation when the gaps are closed. The pitch of the screw is 1 mm and there are 100 divisions on the circular scale. While measuring the diameter of a wire, the linear scale reads 2 mm and the circular scale reads 45 divisions. The corrected diameter of the wire is:

(A) 2.49 mm

(B) 2.41 mm

(C) 2.50 mm

(D) 2.45 mm

Q45. In the measurement of the speed of sound by resonance column method, the first resonance is obtained at L_1 and second resonance at L_2. The end correction is:

(A) $(L_2 - 3L_1)/2$

(B) $(L_2 - L_1)/2$

(C) $(L_2 - 2L_1)/2$

(D) $(3L_1 - L_2)/2$

Detailed Solutions

Q1.

Solution

Concept: The volume V of a sphere is related to its radius r by the formula $V = \frac{4}{3}\pi r^3$. According to the theory of errors, if a quantity V depends on r as $V = kr^n$, the relative error is given by:

$$\frac{\Delta V}{V} = n\frac{\Delta r}{r}$$

For a sphere, $n = 3$.
Solution: Given: The percentage error in the measurement of radius:

$$\frac{\Delta r}{r} \times 100 = 2\%$$

The formula for the volume of a sphere is:

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

The percentage error in volume is given by:

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

Substituting the given value:

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

Final Answer: The error in the volume of the sphere is 6%.

Answer: (D)

Q2.

Solution

Concept: For motion under constant acceleration (gravity), we use the third equation of motion:

$$v^2 = u^2 + 2gh$$

where: - v is the final velocity - u is the initial velocity - g is the acceleration due to gravity - h is the displacement (height of the tower)

Solution:

Given: - Initial velocity, $u = 20$ m/s - Final velocity, $v = 80$ m/s - Acceleration, $g = 10$ m/s^2

Applying the formula:

$$v^2 = u^2 + 2gh$$

Substitute the values:

$$(80)^2 = (20)^2 + 2(10)(h)$$

$$6400 = 400 + 20h$$

Rearrange to solve for h:

$$20h = 6400 - 400$$

$$20h = 6000$$

$$h = \frac{6000}{20}$$

$$h = 300 \text{ m}$$

Final Answer: The height of the tower is 300 m.

Answer: (C)

Q3.

Solution

Concept: The velocity v of a particle is the first derivative of its displacement x with respect to time t. To determine if the velocity increases or decreases, we calculate the acceleration a_{acc}, which is the derivative of velocity. If $a_{acc} > 0$, the velocity increases with time.

Solution: Given the displacement equation:

$$x = ae^{-\alpha t} + be^{\beta t}$$

Differentiating with respect to t to find the velocity (v):

$$v = \frac{dx}{dt} = -a\alpha e^{-\alpha t} + b\beta e^{\beta t}$$

To find the nature of the velocity change, calculate the acceleration (a_{acc}):

$$a_{acc} = \frac{dv}{dt} = \frac{d}{dt}(-a\alpha e^{-\alpha t} + b\beta e^{\beta t})$$

$$a_{acc} = a\alpha^2 e^{-\alpha t} + b\beta^2 e^{\beta t}$$

Since all individual terms ($a, b, \alpha^2, \beta^2, e^{-\alpha t}, e^{\beta t}$) are positive, the sum is positive:

$$a_{acc} > 0$$

Because the acceleration is positive for all values of t, the velocity of the particle **goes on increasing with time**.

Final Answer: The velocity of the particle will go on increasing with time.

Answer: (D)

Q4.

Solution

Concept: To keep the block stationary relative to an accelerating wedge, the net force along the incline in the wedge's frame must be zero. This involves balancing the component of the real force (gravity) with the component of the pseudo force. - Component of gravity down the incline: $mg\sin\theta$ - Component of pseudo force (ma) up the incline: $ma\cos\theta$

Solution:

In the frame of the wedge accelerating to the right with acceleration a, the block experiences a pseudo force $F_p = ma$ directed to the left.

For the block to be stationary relative to the wedge, the forces parallel to the inclined surface must be in equilibrium:

$$\sum F_{\text{parallel}} = 0$$

The component of gravity acting down the slope is $mg\sin\theta$. The component of the horizontal pseudo force acting up the slope is $ma\cos\theta$.

Equating the two components:

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

Dividing both sides by $m\cos\theta$:

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

$$a = g\tan\theta$$

Final Answer: The relation between a and θ is $a = g\tan\theta$.

Answer: (D)

Q5.

Solution

Concept: Impulse (J) is defined as the change in momentum (Δp). When a ball strikes a wall and reflects, only the component of velocity perpendicular to the wall changes.
If the angle of incidence θ is measured with the normal:

$$J = \Delta p = m(v_f - v_i)$$

The component parallel to the wall remains constant, while the component perpendicular to the wall reverses direction.
Solution: Assuming the 60° angle is with the normal to the wall: - Initial velocity perpendicular to wall: $v_{ix} = v\cos 60^\circ$ - Final velocity perpendicular to wall: $v_{fx} = -v\cos 60^\circ$
The change in momentum (Impulse) is:

$$J = |m(v_{fx} - v_{ix})| = |m(-v\cos 60^\circ - v\cos 60^\circ)|$$

$$J = 2mv\cos 60^\circ$$

Substituting $\cos 60^\circ = \frac{1}{2}$:

$$J = 2mv\left(\frac{1}{2}\right) = mv$$

Final Answer: The value of impulse imparted is mv.

Answer: (A)

Q6.

Solution

Concept: Power (P) is the dot product of the force vector ($\vec{F}$) and the velocity vector ($\vec{v}$):

$$P = \vec{F} \cdot \vec{v}$$

Velocity is obtained by integrating acceleration ($\vec{a} = \vec{F}/m$) with respect to time.
Solution: Given $m = 1$ kg and $\vec{F} = 2t\hat{i} + 3t^2\hat{j}$: 1. Find Acceleration:

$$\vec{a} = \frac{\vec{F}}{m} = 2t\hat{i} + 3t^2\hat{j}$$

2. Find Velocity (integrating from $t = 0$):

$$\vec{v} = \int \vec{a}\, dt = \int (2t\hat{i} + 3t^2\hat{j})\, dt = t^2\hat{i} + t^3\hat{j}$$

3. Calculate Power:

$$P = \vec{F} \cdot \vec{v} = (2t\hat{i} + 3t^2\hat{j}) \cdot (t^2\hat{i} + t^3\hat{j})$$

$$P = (2t \times t^2) + (3t^2 \times t^3) = 2t^3 + 3t^5$$

Final Answer: Power developed is $(2t^3 + 3t^5)$ W.

Answer: (C)

Q7.

Solution

Concept: In a vertical circle, the tension (T) in the wire provides the centripetal force while opposing or being aided by the component of weight (mg). The wire is most likely to break where the tension is maximum. - At the lowest point: $T - mg = \frac{mv^2}{r} \implies T = \frac{mv^2}{r} + mg$ - At the highest point: $T + mg = \frac{mv^2}{r} \implies T = \frac{mv^2}{r} - mg$
Solution:
The tension is maximum at the lowest point for two reasons: 1. The weight mg acts in the opposite direction to the centripetal force, so the wire must pull harder to maintain the circle. 2. By the law of conservation of energy, the velocity v is at its maximum at the lowest point, which further increases the required centripetal force ($\frac{mv^2}{r}$).
Since $T_{bottom} = \frac{mv_{max}^2}{r} + mg$ is the peak tension during the cycle, the wire is most likely to break here.
Final Answer: The mass is at the lowest point.

Answer: (C)

Q8.

Solution

Concept: For an object rotating in free space with no external torques acting upon it, the total angular momentum (L) of the system must remain constant.

$$L = I\omega = \text{constant}$$

Solution:
As the radius (R) of the solid sphere increases while mass (M) remains the same: 1. The moment of inertia ($I = \frac{2}{5}MR^2$) increases. 2. To conserve angular momentum ($L = I\omega$), the angular velocity (ω) must decrease. 3. Since I and ω change, the rotational kinetic energy ($K = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$) also changes (it decreases).
Because there is no external torque in free space, **angular momentum** is the only quantity that remains constant.
Final Answer: Angular momentum remains constant.

Answer: (D)

Q9.

Solution

Concept: According to the work-energy theorem for rotation, the work (W) required to bring a rotating object to rest is equal to its initial rotational kinetic energy (K_{rot}):

$$W = \Delta K = \frac{1}{2}I\omega^2$$

Given that the mass M, radius R, and angular speed ω are the same for all objects, the work required is directly proportional to the moment of inertia (I).
Solution: Compare the moments of inertia (I) for the three shapes about their symmetry axes: 1. **Circular Ring:** $I_{ring} = MR^2$ 2. **Circular Disk:** $I_{disk} = \frac{1}{2}MR^2 = 0.5\,MR^2$ 3. **Solid Sphere:** $I_{sphere} = \frac{2}{5}MR^2 = 0.4\,MR^2$
Ordering the moments of inertia:

$$I_{ring} > I_{disk} > I_{sphere}$$

Since $W \propto I$, the work required to bring them to rest follows the same order:

$$W_{ring} > W_{disk} > W_{sphere}$$

Final Answer: The relationship is $W_{ring} > W_{disk} > W_{sphere}$.

Answer: (A)

Q10.

Solution

Concept: The acceleration due to gravity varies with height (h) and depth (d): - Above the surface ($h \ll R$): $g_h = g\left(1 - \frac{2h}{R}\right)$ - Below the surface: $g_d = g\left(1 - \frac{d}{R}\right)$ where R is the radius of the Earth.
Solution:
Given that $g_h = g_d$ at $h = 1$ km:

$$g\left(1 - \frac{2h}{R}\right) = g\left(1 - \frac{d}{R}\right)$$

$$1 - \frac{2h}{R} = 1 - \frac{d}{R}$$

$$\frac{2h}{R} = \frac{d}{R}$$

$$d = 2h$$

Substituting $h = 1$ km:

$$d = 2(1 \text{ km}) = 2 \text{ km}$$

Final Answer: The depth is $d = 2$ km.

Answer: (C)

Q11.

Solution

Concept: For a planet of mass m orbiting a sun of mass M, the gravitational force provides the necessary centripetal force for circular motion:

$$F_g = F_c \implies \frac{GMm}{r^2} = m\omega^2 r$$

where $\omega = \frac{2\pi}{T}$ is the angular velocity and T is the time period.
Solution: Substituting for ω in the force equation:

$$\frac{GMm}{r^2} = m\left(\frac{4\pi^2}{T^2}\right)r$$

Rearranging to solve for T^2:

$$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$$

The term in the bracket consists of constants (G is the universal gravitational constant and M is the mass of the sun). This shows that $T^2 \propto r^3$. Importantly, the mass of the planet m cancels out, making the proportionality independent of the planet's mass.
Final Answer: T^2 is proportional to r^3 (Independent of m).

Answer: (D)

Q12.

Solution

Concept: Bulk modulus (B) is defined as the ratio of hydraulic stress (pressure p) to volumetric strain ($\frac{\Delta V}{V}$):

$$B = \frac{p}{\Delta V/V} \implies \frac{\Delta V}{V} = \frac{p}{B}$$

For a sphere, the fractional change in volume is mathematically related to the fractional change in radius.

Solution:

The volume of a sphere is $V = \frac{4}{3}\pi r^3$. Taking the natural log and differentiating (or using the power rule for errors/fractions):

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

$$\frac{dV}{V} = 3\frac{dr}{r}$$

Substitute this into the bulk modulus relation:

$$3\frac{\Delta r}{r} = \frac{p}{B}$$

Solving for the fractional decrease in radius ($\frac{\Delta r}{r}$):

$$\frac{\Delta r}{r} = \frac{p}{3B}$$

Final Answer: The fractional decrease in radius is $p/3B$.

Answer: (D)

Q13.

Solution

Concept: The terminal velocity (v_t) of a spherical body falling through a viscous medium is given by:

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

where: - r is the radius of the ball - ρ is the density of the ball - σ is the density of the medium - η is the coefficient of viscosity

Solution:

Given: - Ball 1: $r_1 = 1$ mm, $\rho_1 = 8\rho_2$ - Ball 2: $r_2 = 2$ mm, $\rho_2 = \rho_2$ - Medium density: $\sigma = 0.1\rho_2$
Ratio of terminal velocities:

$$\frac{v_1}{v_2} = \frac{r_1^2(\rho_1 - \sigma)}{r_2^2(\rho_2 - \sigma)}$$

Substituting the values:

$$\frac{v_1}{v_2} = \frac{(1)^2(8\rho_2 - 0.1\rho_2)}{(2)^2(\rho_2 - 0.1\rho_2)}$$

$$\frac{v_1}{v_2} = \frac{1 \times 7.9\rho_2}{4 \times 0.9\rho_2}$$

$$\frac{v_1}{v_2} = \frac{7.9}{3.6} = \frac{79}{36}$$

Final Answer: The ratio of terminal velocities is 79/36.

Answer: (A)

Q14.

Solution

Concept: A soap bubble has two surfaces (inner and outer), so the excess pressure relative to its immediate surroundings is $\Delta P = \frac{4T}{r}$. If a bubble is placed inside another bubble, the total excess pressure inside the smaller bubble is the sum of the excess pressures of both bubbles.

Solution:

1. Let P_{out} be the atmospheric pressure outside the large bubble. 2. The pressure inside the large bubble (radius R) is:

$$P_{large} = P_{out} + \frac{4T}{R}$$

3. The small bubble (radius r) is inside the large bubble. Its excess pressure relative to the medium inside the large bubble is $\frac{4T}{r}$. 4. Therefore, the absolute pressure inside the smaller bubble is:

$$P_{small} = P_{large} + \frac{4T}{r} = P_{out} + \frac{4T}{R} + \frac{4T}{r}$$

5. The excess pressure inside the smaller bubble relative to the atmosphere is:

$$\Delta P_{total} = P_{small} - P_{out} = \frac{4T}{R} + \frac{4T}{r}$$

$$\Delta P_{total} = 4T\left(\frac{1}{r} + \frac{1}{R}\right)$$

Final Answer: The excess pressure is $4T(1/r + 1/R)$.

Answer: (A)

Q15.

Solution

Concept: According to the First Law of Thermodynamics, the change in internal energy (ΔU) is given by:

$$\Delta U = \Delta Q - \Delta W$$

where ΔQ is the heat supplied and ΔW is the work done by the system ($P\Delta V$).

Solution: 1. **Convert Heat (ΔQ) to Joules:** Given $\Delta Q = 54$ cal. Since 1 cal = 4.184 J:

$$\Delta Q = 54 \times 4.184 = 225.94 \text{ J}$$

2. **Calculate Work Done (ΔW):** The volume of water (0.1 g) is negligible compared to the volume of steam. $\Delta V = 167.1$ cc $= 167.1 \times 10^{-6}$ m^3.

$$\Delta W = P\Delta V = (1.013 \times 10^5) \times (167.1 \times 10^{-6})$$

$$\Delta W \approx 16.93 \text{ J}$$

3. **Calculate Internal Energy Change (ΔU):**

$$\Delta U = 225.94 - 16.93 = 209.01 \text{ J}$$

Rounding to the nearest provided option:

$$\Delta U \approx 208.7 \text{ J}$$

Final Answer: The change in internal energy is 208.7 J.

Answer: (A)

Q16.

Solution

Concept: The efficiency (η) of a Carnot engine depends solely on the absolute temperatures (in Kelvin) of the hot reservoir (T_H) and the cold reservoir (T_C):

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

Solution:

1. **Convert Temperatures to Kelvin:** - $T_H = 100°C = 100 + 273 = 373$ K - $T_C = -23°C = -23 + 273 = 250$ K
2. **Calculate Efficiency:**

$$\eta = 1 - \frac{250}{373}$$

$$\eta = \frac{373 - 250}{373} = \frac{123}{373}$$

$$\eta \approx 0.3297$$

3. **Convert to Percentage:**

$$\eta \approx 33\%$$

Final Answer: The efficiency is 33%.

Answer: (A)

Q17.

Solution

Concept: For an ideal gas, the molar specific heat at constant volume (C_v) and constant pressure (C_p) can be expressed in terms of the degrees of freedom (n): - $C_v = \frac{n}{2}R$ - $C_p = C_v + R = \left(\frac{n}{2} + 1\right) R$ The ratio of specific heats is defined as $\gamma = \frac{C_p}{C_v}$.

Solution: Substituting the expressions for C_p and C_v into the ratio:

$$\gamma = \frac{\left(\frac{n}{2} + 1\right) R}{\frac{n}{2}R}$$

Dividing each term in the numerator by the denominator:

$$\gamma = \frac{\frac{n}{2}}{\frac{n}{2}} + \frac{1}{\frac{n}{2}}$$

$$\gamma = 1 + \frac{2}{n}$$

Final Answer: The ratio γ is given by $(1 + 2/n)$.

Answer: (B)

Q18.

Solution

Concept: For a particle in simple harmonic motion (SHM): - Velocity magnitude: $v = \omega\sqrt{A^2 - x^2}$ - Acceleration magnitude: $a = \omega^2 x$ where A is amplitude, x is displacement, and $\omega = \frac{2\pi}{T}$ is angular frequency.

Solution:

Given: - Amplitude $A = 3$ cm - Displacement $x = 2$ cm - Condition: $|v| = |a|$

Equating the expressions:

$$\omega\sqrt{A^2 - x^2} = \omega^2 x$$

Dividing by ω (since $\omega \neq 0$):

$$\sqrt{3^2 - 2^2} = \omega(2)$$

$$\sqrt{9-4} = 2\omega \implies \sqrt{5} = 2\omega$$

$$\omega = \frac{\sqrt{5}}{2}$$

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

$$\frac{2\pi}{T} = \frac{\sqrt{5}}{2}$$

$$T = \frac{4\pi}{\sqrt{5}}$$

Final Answer: The time period is $4\pi/\sqrt{5}$ seconds.

Answer: (B)

Q19.

Solution

Concept: In a resonance column tube (closed at one end), successive resonances occur at lengths $l_1, l_2, l_3, \ldots$. The difference between any two successive resonance lengths is equal to half a wavelength ($\lambda/2$):

$$\Delta l = l_{n+1} - l_n = \frac{\lambda}{2}$$

The speed of sound (v) is then calculated using the relation $v = f\lambda$.

Solution: Given: - Frequency (f) = 800 Hz - Resonance lengths: $l_1 = 9.75$ cm, $l_2 = 31.25$ cm, $l_3 = 52.75$ cm

Calculate the common difference (Δl):

$$\Delta l = 31.25 - 9.75 = 21.5 \text{ cm}$$

$$\Delta l = 52.75 - 31.25 = 21.5 \text{ cm}$$

Since $\Delta l = \frac{\lambda}{2}$:

$$\frac{\lambda}{2} = 21.5 \text{ cm} \implies \lambda = 43 \text{ cm} = 0.43 \text{ m}$$

Calculate the speed of sound:

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

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

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

Answer: (A)

Q20.

Solution

Concept: For a uniformly charged spherical conductor, the electric field at a point outside the sphere ($r > R$) is calculated as if the entire charge were concentrated at the center:

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

where r is the distance from the center.

Solution:

Given: - Charge (q) = 3.2×10^{-7} C - Distance from center (r) = 15 cm = 0.15 m - Radius (R) = 10 cm (Note: since $r > R$, we use the point charge formula) - $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2

Substituting into the formula:

$$E = 9 \times 10^9 \times \frac{3.2 \times 10^{-7}}{(0.15)^2}$$

$$E = \frac{28.8 \times 10^2}{0.0225}$$

$$E = \frac{2880}{0.0225} = 1.28 \times 10^5 \text{ N/C}$$

Final Answer: The magnitude of the electric field is 1.28×10^5 N/C.

Answer: (B)

Q21.

Solution

Concept: When two conducting spheres are brought into contact, charge flows until they reach a common potential ($V_1 = V_2$). The total charge is conserved. - Initial charge $q = \sigma \times$ Area - Common potential $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$ implies the final charges q' are proportional to the radii: $\frac{q_1'}{q_2'} = \frac{R_1}{R_2}$.
Solution: 1. **Initial Total Charge (Q_{total}):**

$$q_1 = \sigma(4\pi R^2), \quad q_2 = \sigma(4\pi(2R)^2) = \sigma(16\pi R^2)$$

$$Q_{total} = 4\pi R^2\sigma + 16\pi R^2\sigma = 20\pi R^2\sigma$$

2. **Final Charge Distribution:** Upon contact, the charges q_1' and q_2' redistribute such that:

$$\frac{q_1'}{R} = \frac{q_2'}{2R} \implies q_2' = 2q_1'$$

$$q_1' + 2q_1' = 20\pi R^2\sigma \implies 3q_1' = 20\pi R^2\sigma \implies q_1' = \frac{20}{3}\pi R^2\sigma$$

$$q_2' = \frac{40}{3}\pi R^2\sigma$$

3. **New Surface Charge Densities:**

$$\sigma_1 = \frac{q_1'}{4\pi R^2} = \frac{\frac{20}{3}\pi R^2\sigma}{4\pi R^2} = \frac{5}{3}\sigma$$

$$\sigma_2 = \frac{q_2'}{4\pi(2R)^2} = \frac{\frac{40}{3}\pi R^2\sigma}{16\pi R^2} = \frac{40}{48}\sigma = \frac{5}{6}\sigma$$

Final Answer: The new densities are $\sigma_1 = 5/3\sigma$ and $\sigma_2 = 5/6\sigma$.

Answer: (B)

Q22.

Solution

Concept: The capacitance of a parallel plate capacitor increases when a dielectric is introduced: $C_m = KC_0$, where K is the dielectric constant. The permittivity of the medium is $\epsilon = K\epsilon_0$.

Solution: 1. **Find the Dielectric Constant (K):**

$$K = \frac{C_{medium}}{C_{air}} = \frac{30\,\mu\text{F}}{6\,\mu\text{F}} = 5$$

2. **Calculate Permittivity (ϵ):** Using $\epsilon_0 = 8.854 \times 10^{-12}\ \text{C}^2/\text{Nm}^2$:

$$\epsilon = K\epsilon_0 = 5 \times (8.854 \times 10^{-12})$$

$$\epsilon = 44.27 \times 10^{-12}\ \text{C}^2/\text{Nm}^2$$

$$\epsilon \approx 0.44 \times 10^{-10}\ \text{C}^2/\text{Nm}^2$$

Final Answer: The permittivity of the medium is $0.44 \times 10^{-10}\ \text{C}^2/\text{Nm}^2$.

Answer: (A)

Q23.

Solution

Concept: In a potentiometer, the EMF (E) of a cell is directly proportional to the balancing length (l) of the wire, provided the potential gradient remains constant:

$$E \propto l \implies \frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Solution:

Given: - $E_1 = 1.5$ V - $l_1 = 36$ cm - $E_2 = 2.5$ V

We need to find l_2:

$$\frac{1.5}{2.5} = \frac{36}{l_2}$$

$$l_2 = 36 \times \left(\frac{2.5}{1.5}\right)$$

$$l_2 = 36 \times \left(\frac{5}{3}\right)$$

$$l_2 = 12 \times 5 = 60 \text{ cm}$$

Final Answer: The balance point will occur at 60 cm.

Answer: (A)

Q24.

Solution

Concept: The resistance value is determined using the standard color code chart (BBROY of Great Britain...): 1. First band: First digit 2. Second band: Second digit 3. Third band: Multiplier (10^n) 4. Fourth band: Tolerance

Solution:

According to the color code: - **Yellow:** 4 (First digit) - **Violet:** 7 (Second digit) - **Brown:** 1 (Multiplier is 10^1) - **Gold:** ±5% (Tolerance)

Calculating the resistance:

$$R = (47 \times 10^1)\,\Omega \pm 5\%$$

$$R = 470\,\Omega \pm 5\%$$

Final Answer: The value of resistance and tolerance is 470 Ω, 5%.

Answer: (A)

Q25.

Solution

Concept: For n equal resistors of resistance R: 1. In **series connection**, the effective resistance is the sum of individual resistances:

$$R_{series} = R_1 + R_2 + \cdots + R_n$$

2. In **parallel connection**, the reciprocal of the effective resistance is the sum of the reciprocals:

$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

Solution:
Given that all n resistors are equal (R): 1. **Series Resistance (X):**

$$X = R + R + \ldots \text{ up to } n \text{ times} = nR$$

$$\implies R = \frac{X}{n} \quad \text{—(Eq. 1)}$$

2. **Parallel Resistance (Y):**

$$\frac{1}{Y} = \frac{1}{R} + \frac{1}{R} + \ldots \text{ up to } n \text{ times} = \frac{n}{R}$$

$$\implies Y = \frac{R}{n} \quad \text{—(Eq. 2)}$$

3. **Finding the relation between X and Y:** Substitute the value of R from Eq. 1 into Eq. 2:

$$Y = \frac{(X/n)}{n}$$

$$Y = \frac{X}{n^2}$$

$$\implies X = n^2 Y$$

Final Answer: The relation between X and Y is $X = n^2 Y$.

Answer: (A)

Q26.

Solution

Concept: A Wheatstone bridge is balanced when the ratio of the resistances in the four arms satisfies the condition:

$$\frac{P}{Q} = \frac{R}{S}$$

In this state, the potential at the two terminals of the galvanometer is equal, so no current flows through it. According to the **Principle of Conjugate Arms**, the positions of the source (cell) and the detector (galvanometer) can be interchanged without affecting the balance condition of the bridge.

Solution:

1. In the initial balanced state, the current through the galvanometer is zero because the bridge satisfies the resistance ratio. 2. When the cell and galvanometer are interchanged, the galvanometer is now connected across the other pair of opposite junctions. 3. The new balance condition mathematically remains the same (the products of opposite arm resistances remain equal, i.e., $PS = RQ$). 4. Consequently, no current will flow through the galvanometer in its new position either.

Thus, the bridge **remains balanced**.

Final Answer: The bridge will remain balanced.

Answer: (A)

Q27.

Solution

Concept: The magnetic field (B) at the center of a long solenoid is given by the formula:

$$B = \mu_0 n I$$

where: - μ_0 is the permeability of free space ($4\pi \times 10^{-7}$ T · m/A) - n is the number of turns per unit length (N/L) - I is the current

Solution:

Given: - Total turns (N) = 100 - Length (L) = 50 cm = 0.5 m - Current (I) = 2.5 A

1. Calculate n (turns per meter):

$$n = \frac{N}{L} = \frac{100}{0.5} = 200 \text{ turns/m}$$

2. Calculate B:

$$B = (4\pi \times 10^{-7}) \times 200 \times 2.5$$

$$B = (4\pi \times 10^{-7}) \times 500$$

$$B = 2000\pi \times 10^{-7} = 2\pi \times 10^{-4} \text{ T}$$

Substituting $\pi \approx 3.14$:

$$B = 2 \times 3.14 \times 10^{-4} = 6.28 \times 10^{-4} \text{ T}$$

Final Answer: The magnetic field at the centre is 6.28×10^{-4} T.

Answer: (A)

Q28.

Solution

Concept: A circulating charge behaves like a current loop. The magnetic dipole moment (μ) of a current loop is given by:

$$\mu = IA$$

where I is the equivalent current and A is the area of the orbit (πr^2).

Solution:

1. Find the equivalent current (I): Current is the charge per unit time. For an electron with charge e and frequency ν:

$$I = \frac{e}{T} = e\nu$$

(since frequency $\nu = 1/T$)

2. Calculate the Area (A): For a circular orbit of radius r:

$$A = \pi r^2$$

3. Calculate Magnetic Dipole Moment (μ):

$$\mu = IA = (e\nu)(\pi r^2)$$

$$\mu = \pi e \nu r^2$$

Final Answer: The magnetic dipole moment is $\pi e \nu r^2$.

Answer: (A)

Q29.

Solution

Concept: Magnetic susceptibility (χ) measures how a material becomes magnetized in an applied magnetic field. * **Diamagnetic:** Opposes the external field; susceptibility is small and negative. * **Paramagnetic:** Weakly attracted to the external field; susceptibility is small and positive. * **Ferromagnetic:** Strongly attracted and easily magnetized; susceptibility is very large and positive.

Solution:

Based on the physical properties of these materials: 1. For diamagnetic materials: $\chi_d < 0$ (negative). 2. For paramagnetic materials: $\chi_p > 0$ (positive, but small). 3. For ferromagnetic materials: $\chi_f \gg 1$ (very large and positive).

Comparing these to the given options, Option (A) correctly identifies all three states.

Final Answer: $\chi_d < 0, \chi_p > 0, \chi_f \gg 1$.

Answer: (A)

Q30.

Solution

Concept: The phase difference ϕ in an LCR circuit is given by:

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

The power factor is defined as $\cos\phi = \frac{R}{Z}$.
Solution:
1. **When L is removed:** The circuit becomes a series RC circuit.

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

2. **When C is removed:** The circuit becomes a series LR circuit.

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

3. **In the original LCR circuit:** Since $X_L = X_C = \sqrt{3}R$, the net reactance is zero:

$$X_{net} = X_L - X_C = 0$$

This indicates the circuit is in a state of **resonance**. In resonance, the phase difference ϕ is 0. 4. **Calculate Power Factor:**

$$\text{Power Factor} = \cos\phi = \cos(0) = 1.0$$

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

Answer: (B)

Q31.

Solution

Concept: In an AC circuit, the average power loss (P_{avg}) occurs only in the resistor and is given by:

$$P_{avg} = V_{rms} I_{rms} \cos\phi = I_{rms}^2 R$$

where $I_{rms} = \frac{V_{rms}}{Z}$ and $Z = \sqrt{R^2 + (X_L - X_C)^2}$.

Solution:

Given: $V = 10\sin(314t) \implies V_0 = 10$ V, $\omega = 314$ rad/s $L = 20$ mH $= 0.02$ H, $C = 100\,\mu$F $= 10^{-4}$ F, $R = 50\,\Omega$

1. **Calculate Reactances:** $X_L = \omega L = 314 \times 0.02 = 6.28\,\Omega$ $X_C = \frac{1}{\omega C} = \frac{1}{314\times10^{-4}} = \frac{10000}{314} \approx 31.85\,\Omega$

2. **Calculate Impedance (Z):** $X_C - X_L = 31.85 - 6.28 = 25.57\,\Omega$ $Z = \sqrt{50^2 + 25.57^2} = \sqrt{2500 + 653.8} = \sqrt{3153.8} \approx 56.16\,\Omega$

3. **Calculate Power Loss:** $V_{rms} = \frac{10}{\sqrt{2}}$ $P_{avg} = \frac{V_{rms}^2}{Z^2} R = \frac{(10/\sqrt{2})^2}{(56.16)^2} \times 50$ $P_{avg} = \frac{50}{3153.8} \times 50 = \frac{2500}{3153.8} \approx 0.792$ W

Final Answer: The power loss in the circuit is 0.79 W.

Answer: (A)

Q32.

Solution

Concept: The intensity of an electromagnetic wave is the average energy flux. The energy density of the electric field is $u_E = \frac{1}{2}\epsilon_0 E^2$ and the energy density of the magnetic field is $u_B = \frac{B^2}{2\mu_0}$.

Solution:

In an electromagnetic wave, the relationship between the peak values of the electric field (E_0) and magnetic field (B_0) is:

$$E_0 = cB_0$$

The average energy densities are:

$$u_E = \frac{1}{4}\epsilon_0 E_0^2 \quad \text{and} \quad u_B = \frac{B_0^2}{4\mu_0}$$

Since $c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$, substituting $B_0 = E_0/c$:

$$u_B = \frac{(E_0/c)^2}{4\mu_0} = \frac{E_0^2}{4\mu_0(1/\mu_0\epsilon_0)} = \frac{1}{4}\epsilon_0 E_0^2$$

This shows that $u_E = u_B$. Because intensity is proportional to energy density ($I = uc$), the contributions made by the electric and magnetic fields are exactly equal.

Final Answer: The ratio is 1 : 1.

Answer: (B)

Q33.

Solution

Concept: For a prism, the relationship between the angles is given by $A = r_1 + r_2$. According to Snell's Law, $n_1 \sin i = n_2 \sin r$. For small angles, $\sin\theta \approx \theta$ (in radians).

Solution:

1. **At the second surface:** The ray emerges normally, which means the angle of emergence $e = 0°$ and the angle of refraction at the second surface $r_2 = 0°$. 2. **Angle of the Prism:** Since $A = r_1 + r_2$ and $r_2 = 0$, we have $r_1 = A$. 3. **At the first surface:** Using Snell's Law:

$$\mu = \frac{\sin i}{\sin r_1}$$

For a small angle prism, i and r_1 are small. Therefore:

$$\mu \approx \frac{i}{r_1}$$

$$i = \mu r_1$$

Substituting $r_1 = A$:

$$i = \mu A$$

Final Answer: The angle of incidence is nearly equal to μA.

Answer: (C)

Q34.

Solution

Concept: In Young's double slit experiment, the fringe width (β) is given by the formula:

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

where: - λ is the wavelength of light - D is the distance between the slits and the screen - d is the separation between the coherent sources (slits)

Solution:

1. **Initial Fringe Width:** $\beta = \frac{\lambda D}{d}$ 2. **New Conditions:** - New distance of screen: $D' = 2D$ - New slit separation: $d' = \frac{d}{2}$ 3. **New Fringe Width (β'):**

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

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

$$\beta' = 4\beta$$

Final Answer: The fringe width becomes four times the original value.

Answer: (C)

Q35.

Solution

Concept: For a prism, the refractive index (μ) is related to the angle of the prism (A) and the angle of minimum deviation (δ_m) by the prism formula:

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Solution:
Given: - $\mu = \sqrt{2}$ - $A = 60°$
Substitute the values into the formula:

$$\sqrt{2} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$\sqrt{2} = \frac{\sin\left(30° + \frac{\delta_m}{2}\right)}{\sin(30°)}$$

Since $\sin(30°) = 1/2$:

$$\sqrt{2} \times \frac{1}{2} = \sin\left(30° + \frac{\delta_m}{2}\right)$$

$$\frac{1}{\sqrt{2}} = \sin\left(30° + \frac{\delta_m}{2}\right)$$

We know that $\sin(45°) = \frac{1}{\sqrt{2}}$, so:

$$45° = 30° + \frac{\delta_m}{2}$$

$$15° = \frac{\delta_m}{2}$$

$$\delta_m = 30°$$

Final Answer: The angle of minimum deviation is 30°.

Answer: (B)

Q36.

Solution

Concept: We use the mirror formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ to find the image positions. By sign convention for a concave mirror, f and u are negative.

Solution:

Given: $f = -15$ cm.

Case 1: $u_1 = -40$ cm

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

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

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

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

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

Displacement of image: The image moved from 24 cm to 60 cm from the mirror.

$$\text{Displacement} = |60 - 24| = 36 \text{ cm}$$

Since the distance increased from the mirror, it moved **away from the mirror**.

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

Answer: (B)

Q37.

Solution

Concept: According to Einstein's photoelectric equation, the maximum kinetic energy (K_{max}) of emitted electrons is given by:

$$K_{max} = h\nu - \phi_0 = h\nu - h\nu_0$$

where ν is the incident frequency, ν_0 is the threshold frequency, and $K_{max} = \frac{1}{2}mv^2$.

Solution:

1. **Case 1:** Incident frequency $\nu = 2\nu_0$

$$\frac{1}{2}mv_1^2 = h(2\nu_0) - h\nu_0 = h\nu_0 \quad \text{—(Eq. 1)}$$

2. **Case 2:** Incident frequency $\nu = 5\nu_0$

$$\frac{1}{2}mv_2^2 = h(5\nu_0) - h\nu_0 = 4h\nu_0 \quad \text{—(Eq. 2)}$$

3. **Finding the ratio:** Divide Eq. 1 by Eq. 2:

$$\frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{h\nu_0}{4h\nu_0}$$

$$\frac{v_1^2}{v_2^2} = \frac{1}{4} \implies \frac{v_1}{v_2} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Final Answer: The ratio v_1/v_2 is $1:2$.

Answer: (A)

Q38.

Solution

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

$$\lambda = \frac{h}{\sqrt{2meV}} \approx \frac{12.27}{\sqrt{V}} \text{ Å}$$

where 1 Å = 10^{-10} m.

Solution:

Given: $V = 10,000$ V $= 10^4$ V.

Using the shortcut formula:

$$\lambda = \frac{12.27}{\sqrt{10^4}} \text{ Å}$$

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

$$\lambda = 0.1227 \text{ Å}$$

Convert to meters:

$$\lambda = 0.1227 \times 10^{-10} \text{ m}$$

$$\lambda = 12.27 \times 10^{-12} \text{ m}$$

Comparing with the options, Option (B) is the closest value.

Final Answer: The de Broglie wavelength is (nearly) 12.2×10^{-12} m.

Answer: (B)

Q39.

Solution

Concept: In the Bohr model of the hydrogen atom, the potential energy (U), kinetic energy (K), and total energy (E) of an electron are related by the following ratios:

$$K = -E$$

$$U = 2E$$

$$E = K + U$$

These relationships are derived from the balance of electrostatic attraction and centripetal force.

Solution:

The total energy E of an electron in the n^{th} orbit is negative (indicating a bound state):

$$E = -\frac{me^4}{8\epsilon_0^2 n^2 h^2}$$

The kinetic energy K is always positive:

$$K = \frac{me^4}{8\epsilon_0^2 n^2 h^2}$$

Therefore, $K = -E$. To find the ratio of kinetic energy to total energy:

$$\frac{K}{E} = \frac{K}{-K} = \frac{1}{-1}$$

Final Answer: The ratio is 1 : -1.

Answer: (A)

Q40.

Solution

Concept: The amount of a radioactive substance remaining (N) is given by the formula:

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

where N_0 is the initial amount, t is the time elapsed, and $T_{1/2}$ is the half-life.

Solution:

Given: $T_{1/2} = 30$ minutes.

1. **At 40% decay:** The amount remaining is $N_1 = 100\% - 40\% = 60\%$ of N_0. 2. **At 85% decay:** The amount remaining is $N_2 = 100\% - 85\% = 15\%$ of N_0.

3. **Relation between N_1 and N_2:**

$$\frac{N_2}{N_1} = \frac{15\%}{60\%} = \frac{1}{4} = \left(\frac{1}{2}\right)^2$$

This means the substance has gone through **2 half-lives** to get from 60% remaining to 15% remaining.

4. **Calculate Time:**

$$\text{Time} = n \times T_{1/2}$$

$$\text{Time} = 2 \times 30 \text{ minutes} = 60 \text{ minutes}$$

Final Answer: The time taken is 60 minutes.

Answer: (D)

Q41.

Solution

Concept: In a semiconductor, the concentration of charge carriers (electrons and holes) is highly dependent on temperature. As temperature increases, more covalent bonds break, creating more electron-hole pairs. This affects the conductivity and the potential barrier of the p-n junction.

Solution: Temperature affects several parameters of a diode: 1. **Reverse Saturation Current (I_0):** This current approximately doubles for every 10°C rise in temperature. 2. **Knee Voltage (V_γ):** The barrier potential decreases as temperature increases (typically by 2 mV/°C). 3. **Resistance:** Both forward and reverse resistances change as the carrier concentration shifts. Because both the forward and reverse regions of the graph shift and change slope with temperature, the **overall V-I characteristics** are affected.

Final Answer: Temperature change affects the overall V-I characteristics.

Answer: (C)

Q42.

Solution

Concept: A Bipolar Junction Transistor (BJT) consists of three regions: Emitter, Base, and Collector. For the transistor to function effectively (especially in the active region), specific physical and doping requirements must be met.

Solution:

Let's evaluate the requirements for transistor action: * **Size:** The Collector is the largest (to dissipate heat), the Emitter is medium-sized, and the **Base is the thinnest**. * **Doping:** The Emitter is the most heavily doped, the Collector is moderately doped, and the **Base is lightly doped**. * **Biasing:** For normal active operation, the emitter-base junction is forward biased, and the collector-base junction is reverse biased.

A thin, lightly doped base ensures that most charge carriers injected from the emitter pass through to the collector with minimal recombination in the base region.

Final Answer: The base region must be very thin and lightly doped.

Answer: (C)

Q43.

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. In digital electronics, there are two primary universal gates: **NAND** and **NOR**.

Solution:

* **OR, AND, and NOT** are known as basic gates. They cannot individually perform all logic operations. * The **NAND** gate (and the NOR gate) can be combined in various ways to replicate the functions of all other logic gates.

Final Answer: NAND gate is called a Universal gate.

Answer: (C)

Q44.

Solution

Concept: The measurement in a screw gauge is calculated as:

$$\text{Total Reading} = \text{Main Scale Reading (MSR)} + (\text{Circular Scale Reading (CSR)} \times \text{Least Count})$$

The **Corrected Reading** = Observed Reading − Zero Error.

Solution: 1. **Calculate Least Count (LC):**

$$\text{LC} = \frac{\text{Pitch}}{\text{Number of Divisions}} = \frac{1 \text{ mm}}{100} = 0.01 \text{ mm}$$

2. **Determine Zero Error:** The zero of the circular scale is 4 divisions **below** the reference line. This is a **positive zero error**.

$$\text{Zero Error} = +4 \times 0.01 = +0.04 \text{ mm}$$

3. **Calculate Observed Reading:**

$$\text{Observed} = 2 \text{ mm} + (45 \times 0.01 \text{ mm}) = 2.45 \text{ mm}$$

4. **Calculate Corrected Diameter:**

$$\text{Corrected} = 2.45 - (+0.04) = 2.41 \text{ mm}$$

Final Answer: The corrected diameter is 2.41 mm.

Answer: (B)

Q45.

Solution

Concept: In a resonance column, the antinode is formed slightly above the open end of the tube. This distance is called the **end correction (e)**. The effective lengths for resonance are: - First resonance: $L_1 + e = \frac{\lambda}{4}$ - Second resonance: $L_2 + e = \frac{3\lambda}{4}$

Solution:

From the first equation: $\lambda = 4(L_1 + e)$ From the second equation: $\lambda = \frac{4}{3}(L_2 + e)$

Equating the two expressions for λ:

$$4(L_1 + e) = \frac{4}{3}(L_2 + e)$$

Multiply both sides by 3:

$$3L_1 + 3e = L_2 + e$$

$$2e = L_2 - 3L_1$$

$$e = \frac{L_2 - 3L_1}{2}$$

Final Answer: The end correction is $(L_2 - 3L_1)/2$.

Answer: (A)

Answer Key

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