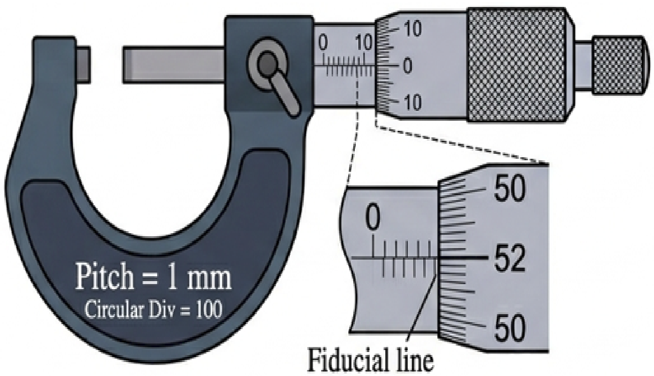
NEET-UG Physics Sample Paper - 14

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 of the wire is:



(A) 0.52 mm

(B) 0.052 mm

(C) 0.026 mm

(D) 0.0052 mm

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. A particle starting from rest moves in a circle of radius R. It attains a velocity of V_0 m/s in the n^{th} round. Its angular acceleration is:

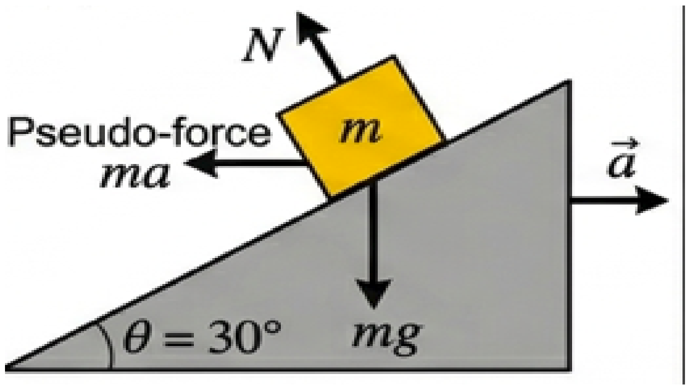
(A) $\frac{V_0^2}{4\pi n R^2}$

(B) $\frac{V_0^2}{4\pi n R}$

(C) $\frac{V_0}{4\pi n R}$

(D) $\frac{V_0^2}{4\pi n}$

Q4. 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 on the wedge. The force exerted by the wedge on the block is:



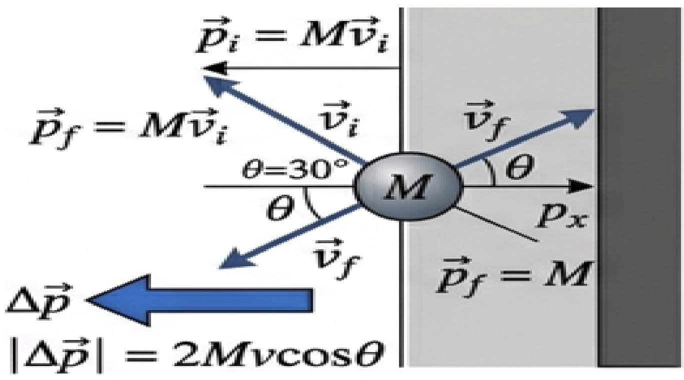
(A) $mg\cos\theta$

(B) $mg\sin\theta$

(C) $mg/\cos\theta$

(D) $mg\tan\theta$

Q5. A body of mass M hits a wall at an angle θ and rebounds at the same angle and with the same speed. The change in momentum of the body is:



(A) $2Mv\cos\theta$

(B) $2Mv\sin\theta$

(C) $Mv\cos\theta$

(D) $Mv\sin\theta$

Q6. A particle of mass m is driven by a machine that delivers a constant power k watts. If the particle starts from rest, the force on the particle at time t is:

(A) $\sqrt{\frac{mk}{2}}t^{-1/2}$

(B) $\sqrt{mk}t^{-1/2}$

(C) $\frac{1}{2}\sqrt{mk}t^{-1/2}$

(D) $\sqrt{2mk}t^{-1/2}$

Q7. A force $F = 20 + 10y$ acts on a particle in y-direction where F is in Newton and y in meter. Work done by this force to move the particle from $y = 0$ to $y = 1$ m is:

(A) 20 J

(B) 25 J

(C) 30 J

(D) 5 J

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 would remain constant for the sphere?

(A) Angular velocity

(B) Moment of inertia

(C) Rotational kinetic energy

(D) Angular momentum

Q9. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N?

(A) 0.25 rad/s^2

(B) 25 rad/s^2

(C) 5 rad/s^2

(D) 2.5 rad/s^2

Q10. The work done to raise a mass m from the surface of the earth to a height h, which is equal to the radius of the earth, is:

(A) mgR

(B) $2mgR$

(C) $\frac{1}{2}mgR$

(D) $\frac{1}{4}mgR$

Q11. If 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 d is:

(A) 1 km

(B) 2 km

(C) 0.5 km

(D) 4 km

Q12. 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 its terminal velocity, is proportional to:

(A) r^3

(B) r^2

(C) r^5

(D) r^4

Q13. Two wires are made of the same material and have the same volume. The first wire has cross-sectional area A and the second wire has cross-sectional area $3A$. If the length of the first wire is increased by Δl on applying force F, how much force is needed to stretch the second wire by the same amount?

(A) $9F$

(B) $6F$

(C) $4F$

(D) F

Q14. A liquid does not wet the solid surface if the angle of contact is:

(A) Zero

(B) Acute

(C) $45°$

(D) Obtuse

Q15. A cup of coffee cools from 90°C to 80°C in t minutes, when the surrounding temperature is 20°C. The time taken by a similar cup of coffee to cool from 80°C to 60°C at a surrounding temperature of 20°C is:

(A) Less than $2t$

(B) Greater than $2t$

(C) Equal to $2t$

(D) t

Q16. The efficiency of a Carnot engine operating between temperatures T_1 and T_2 is $1/6$. When T_2 is lowered by 62 K, its efficiency becomes $1/3$. Then T_1 and T_2 are:

(A) 372 K, 310 K

(B) 310 K, 372 K

(C) 330 K, 268 K

(D) 310 K, 248 K

Q17. The mean free path for a gas, with molecular diameter d and number density n can be expressed as:

(A) $\frac{1}{\sqrt{2}n\pi d^2}$

(B) $\frac{1}{\sqrt{2}n^2\pi d^2}$

(C) $\frac{1}{\sqrt{2}n\pi^2 d^2}$

(D) $\frac{1}{\sqrt{2}n\pi d}$

Q18. The displacement of a particle executing simple harmonic motion is given by $y = A_0 + A\sin\omega t + B\cos\omega t$. Then the amplitude of its oscillation is:

(A) $A + B$

(B) $A_0 + \sqrt{A^2 + B^2}$

(C) $\sqrt{A^2 + B^2}$

(D) $\sqrt{A_0^2 + (A + B)^2}$

Q19. A tuning fork with frequency 800 Hz produces resonance in a closed column pipe with the 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 is:

(A) 344 m/s

(B) 330 m/s

(C) 300 m/s

(D) 350 m/s

Q20. Two positive point charges are 3 μC and 1 μC are placed 20 cm apart in air. The work done to bring them 10 cm closer is:

(A) 0.135 J

(B) 0.27 J

(C) 0.405 J

(D) 0.54 J

Q21. A parallel plate capacitor has a uniform electric field E in the space between the plates. If the distance between the plates is d and area of each plate is A, the energy stored in the capacitor is:

(A) $\frac{1}{2}\epsilon_0 E^2 Ad$

(B) $\epsilon_0 E^2 Ad$

(C) $\frac{1}{2}\epsilon_0 E^2$

(D) $E^2 Ad/\epsilon_0$

Q22. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is:

(A) Independent of the distance between the plates

(B) Linearly proportional to the distance between the plates

(C) Proportional to the square root of the distance between the plates

(D) Inversely proportional to the distance between the plates

Q23. 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) R/n

(C) n^2R

(D) R/n^2

Q24. A copper wire of length 10 m and radius $(10^{-2}/\sqrt{\pi})$ m has electrical resistance of 10 Ω. The current density in the wire for an electric field strength of 10 V/m is:

(A) 10^4 A/m^2

(B) 10^6 A/m^2

(C) 10^{-5} A/m^2

(D) 10^5 A/m^2

Q25. Ten identical cells each of potential E and internal resistance r are connected in series to form a closed circuit. An ideal voltmeter connected across three cells will read:

(A) $3E$

(B) $13E$

(C) $7E$

(D) Zero

Q26. 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, the balance point occurs?

(A) 60 cm

(B) 21.6 cm

(C) 64 cm

(D) 62 cm

Q27. An infinitely long straight conductor carries a current of 5 A as shown. An electron is moving with a speed of 10^5 m/s parallel to the conductor. The perpendicular distance between the electron and the conductor is 20 cm at an instant. Calculate the magnitude of the force experienced by the electron at that instant.

(A) 4×10^{-20} N

(B) 8×10^{-20} N

(C) $4\pi \times 10^{-20}$ N

(D) $8\pi \times 10^{-20}$ N

Q28. A long solenoid of radius 1 mm has 100 turns per mm. If 1 A current flows in the solenoid, the magnetic field strength at the centre of the solenoid is:

(A) 12.56×10^{-2} T

(B) 6.28×10^{-2} T

(C) 12.56×10^{-4} T

(D) 6.28×10^{-4} T

Q29. A thin diamagnetic rod is placed vertically between the poles of an electromagnet. When the current in the electromagnet is switched on, then the diamagnetic rod is pushed up, out of the horizontal magnetic field. Hence the rod gains gravitational potential energy. The work required to do this comes from:

(A) The lattice structure of the rod

(B) The magnetic field

(C) The current source

(D) The induced electric field

Q30. A cycle wheel of radius 0.5 m is rotated with constant angular velocity of 10 rad/s in a region of magnetic field of 0.1 T which is perpendicular to the plane of the wheel. The EMF generated between its centre and the rim is:

(A) 0.25 V

(B) 0.125 V

(C) 0.5 V

(D) Zero

Q31. 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) Zero

(D) 0.866

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)

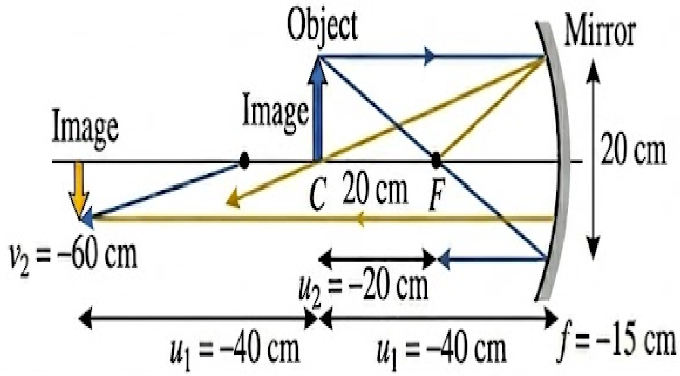
(A) $c : 1$

(B) $c^2 : 1$

(C) $1 : 1$

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

Q33. 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 away from mirror

(B) 36 cm away from mirror

(C) 30 cm towards mirror

(D) 36 cm towards mirror

Q34. A beam of light consisting of two wavelengths, 650 nm and 520 nm, is used to obtain interference fringes in a Young's double slit experiment. What is the least distance from a central maximum where the bright fringes due to both the wavelengths coincide?

(A) $n = 4$ of 650 nm

(B) $n = 5$ of 650 nm

(C) $n = 6$ of 520 nm

(D) $n = 3$ of 520 nm

Q35. The refractive index of the material of a prism is $\sqrt{2}$ and the angle of the prism is 60°. There is no emergence of light when the angle of incidence on the first face is:

(A) 30°

(B) 45°

(C) 60°

(D) 0°

Q36. Astronomical refracting telescope will have large angular magnification and high angular resolution, when it has an objective lens of:

(A) Large focal length and large diameter

(B) Large focal length and small diameter

(C) Small focal length and large diameter

(D) Small focal length and small diameter

Q37. 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^{-12} m

(B) 12.2×10^{-14} m

(C) 12.2 nm

(D) 12.2 Å

Q38. 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 of v_1 to v_2 is:

(A) 1 : 2

(B) 1 : 4

(C) 4 : 1

(D) 2 : 1

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) 2 : −1

(D) 1 : −2

Q40. The half-life of a radioactive substance is 20 minutes. In how much time, the activity of substance drops to $(1/16)^{\text{th}}$ of its initial value?

(A) 20 min

(B) 40 min

(C) 60 min

(D) 80 min

Q41. For a p-type semiconductor, which of the following statements is true?

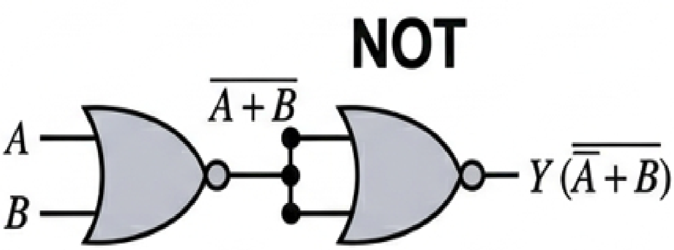
(A) Electrons are majority carriers and trivalent atoms are dopants

(B) Holes are majority carriers and trivalent atoms are dopants

(C) Holes are majority carriers and pentavalent atoms are dopants

(D) Electrons are majority carriers and pentavalent atoms are dopants

Q42. The given electrical network is equivalent to which gate? (Using two NOR gates connected in series)



(A) AND gate

(B) OR gate

(C) NOR gate

(D) NOT gate

Q43. In a common emitter transistor amplifier, the audio signal voltage across the collector is 3 V. The resistance of collector is 3 kΩ. If current gain is 100 and the base resistance is 2 kΩ, the voltage gain and the power gain of the amplifier is:

(A) 150, 15000

(B) 200, 20000

(C) 20, 2000

(D) 15, 1500

Q44. A student measures the distance traversed in free fall of a body, initially at rest, in a given time. He uses this data to estimate g, the acceleration due to gravity. If the maximum percentage errors in measurement of the distance and the time are e_1 and e_2 respectively, the maximum percentage error in the estimation of g is:

(A) $e_1 + 2e_2$

(B) $e_1 + e_2$

(C) $e_1 - 2e_2$

(D) $e_2 + 2e_1$

Q45. In an experiment, the percentage of error occurred in the measurement of physical quantities A, B, C and D are 1%, 2%, 3% and 4% respectively. Then the maximum percentage of error in the measurement X, where $X = \frac{A^2 B^{1/2}}{C^{1/3} D^3}$, will be:

(A) 10%

(B) 16%

(C) 12%

(D) 15%

Detailed Solutions

Q1.

Solution

Concept:
A screw gauge measures small dimensions using the principle of a screw. The Least Count (LC) is the smallest value that can be measured by the instrument. It is defined as:

$$LC = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

The Total Reading is calculated as:

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

Solution:
1. First, identify the given values: Main Scale Reading (MSR) = 0 mm Circular Scale Reading (CSR) = 52 divisions Main scale pitch = 1 mm Number of circular scale divisions = 100
2. Calculate the Least Count (LC) of the screw gauge:

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

3. Calculate the total diameter using the formula:

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

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

4. Perform the final multiplication and addition:

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

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

Answer: (A)

Q2.

Solution

Concept:
For a body moving under constant acceleration (gravity), we use the kinematic equations of motion. When a body is thrown downwards, both the initial velocity and acceleration due to gravity act in the same direction. The third equation of motion is:

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

where v is the final velocity, u is the initial velocity, g is the acceleration due to gravity, and h is the height (displacement).

Solution:
1. List the given parameters: Initial velocity (u) = 20 m/s Final velocity (v) = 80 m/s Acceleration due to gravity (g) = 10 m/s^2
2. Rearrange the third equation of motion to solve for height (h):

$$h = \frac{v^2 - u^2}{2g}$$

3. Substitute the numerical values into the equation:

$$h = \frac{(80)^2 - (20)^2}{2 \times 10}$$

4. Calculate the squares of the velocities:

$$80^2 = 6400$$

$$20^2 = 400$$

5. Solve the numerator and then divide:

$$h = \frac{6400 - 400}{20}$$

$$h = \frac{6000}{20} = 300 \text{ m}$$

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

Answer: (C)

Q3.

Solution

Concept:

In circular motion, when a particle accelerates from rest, we relate linear velocity (v) to angular velocity (ω) using $v = \omega R$. For constant angular acceleration (α), the angular displacement after n rounds is $\theta = 2\pi n$. The rotational analogue of the third equation of motion is:

$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

where ω_0 is the initial angular velocity.

Solution:

1. The particle starts from rest, so $\omega_0 = 0$. 2. The final linear velocity is V_0, so the final angular velocity is:

$$\omega = \frac{V_0}{R}$$

3. The angular displacement (θ) for n complete revolutions is:

$$\theta = n \times 2\pi = 2\pi n$$

4. Substitute these values into the rotational kinematic equation:

$$\left(\frac{V_0}{R}\right)^2 = 0^2 + 2\alpha(2\pi n)$$

5. Simplify the left side:

$$\frac{V_0^2}{R^2} = 4\pi n\alpha$$

6. Isolate the angular acceleration (α):

$$\alpha = \frac{V_0^2}{R^2 \times 4\pi n}$$

$$\alpha = \frac{V_0^2}{4\pi n R^2}$$

Final Answer: The angular acceleration is $\frac{V_0^2}{4\pi n R^2}$.

Answer: (A)

Q4.

Solution

Concept:
When a block is placed on an inclined wedge that is accelerating horizontally (a), we analyze the forces in the frame of the wedge. To keep the block stationary relative to the wedge, the horizontal pseudo-force (ma) must balance the component of gravity. However, the question asks for the "force exerted by the wedge on the block," which is the Normal Force (N).

Solution:
1. In the frame of the wedge, the forces acting on the block are: - Weight (mg) acting vertically downwards. - Normal force (N) acting perpendicular to the wedge surface. - Pseudo force (ma) acting horizontally (opposite to wedge acceleration).
2. To prevent slipping, the components of forces along the incline must balance:

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

3. The Normal force N balances the components of mg and ma perpendicular to the incline:

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

4. Substitute $a = g\tan\theta$ into the equation for N:

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

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

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

5. Use the trigonometric identity $\cos^2\theta + \sin^2\theta = 1$:

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

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

Answer: (C)

Q5.

Solution

Concept:

Momentum is a vector quantity defined as $\vec{p} = m\vec{v}$. The change in momentum ($\Delta\vec{p}$) is the vector difference between the final and initial momentum: $\Delta\vec{p} = \vec{p}_f - \vec{p}_i$. When a body rebounds from a wall, we resolve the velocity into components parallel and perpendicular to the wall.

Solution:

1. Let the wall be in the xz-plane and the impact be in the xy-plane. If the velocity v makes an angle θ with the normal to the wall: - Initial velocity: $\vec{v}_i = v\cos\theta\hat{i} - v\sin\theta\hat{j}$ (assuming moving towards wall). - Final velocity: $\vec{v}_f = -v\cos\theta\hat{i} - v\sin\theta\hat{j}$ (rebounding).

2. Note: The component parallel to the wall ($v\sin\theta$) remains unchanged because there is no force parallel to the smooth wall. The component perpendicular to the wall ($v\cos\theta$) reverses direction.

3. Calculate the change in momentum:

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

$$\Delta\vec{p} = m(-v\cos\theta\hat{i} - v\sin\theta\hat{j}) - m(v\cos\theta\hat{i} - v\sin\theta\hat{j})$$

4. Simplify the vector expression:

$$\Delta\vec{p} = -mv\cos\theta\hat{i} - mv\sin\theta\hat{j} - mv\cos\theta\hat{i} + mv\sin\theta\hat{j}$$

$$\Delta\vec{p} = -2mv\cos\theta\hat{i}$$

5. The magnitude of the change in momentum is:

$$|\Delta\vec{p}| = 2mv\cos\theta$$

Final Answer: The change in momentum is $2Mv\cos\theta$.

Answer: (A)

Q6.

Solution

Concept:

Power (P) is defined as the rate of doing work or the product of force (F) and velocity (v).

$$P = Fv$$

By Newton's second law, $F = ma = m\frac{dv}{dt}$. Therefore, $P = mv\frac{dv}{dt}$. If power k is constant, we can integrate this expression to find velocity as a function of time, and subsequently find the force.

Solution:

1. Start with the power equation:

$$k = mv\frac{dv}{dt}$$

2. Separate variables and integrate from rest ($v = 0$ at $t = 0$):

$$\int_0^v v\,dv = \int_0^t \frac{k}{m}\,dt$$

$$\frac{v^2}{2} = \frac{k}{m}t \implies v = \sqrt{\frac{2kt}{m}}$$

3. To find the force F, use $F = \frac{P}{v}$:

$$F = \frac{k}{v} = \frac{k}{\sqrt{\frac{2kt}{m}}}$$

4. Simplify the expression:

$$F = k \cdot \sqrt{\frac{m}{2kt}} = \sqrt{\frac{k^2m}{2kt}}$$

$$F = \sqrt{\frac{mk}{2t}} = \sqrt{\frac{mk}{2}}t^{-1/2}$$

Final Answer: The force on the particle is $\sqrt{\frac{mk}{2}}t^{-1/2}$.

Answer: (A)

Q7.

Solution

Concept:

Work done (W) by a variable force $F(y)$ acting along the y-direction is given by the integral of the force with respect to displacement:

$$W = \int_{y_1}^{y_2} F(y)\, dy$$

This represents the area under the Force-Displacement graph.

Solution:

1. Given the force function:

$$F = 20 + 10y$$

2. Set up the integral with limits from $y = 0$ to $y = 1$:

$$W = \int_{0}^{1} (20 + 10y)\, dy$$

3. Perform the integration:

$$W = [20y + \frac{10y^2}{2}]_0^1$$

$$W = [20y + 5y^2]_0^1$$

4. Substitute the upper and lower limits:

$$W = (20(1) + 5(1)^2) - (20(0) + 5(0)^2)$$

$$W = 20 + 5 = 25 \text{ J}$$

Final Answer: The work done is 25 J.

Answer: (B)

Q8.

Solution

Concept:

According to the Law of Conservation of Angular Momentum, the total angular momentum (L) of a system remains constant if the net external torque acting on it is zero.

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

where I is the moment of inertia and ω is the angular velocity.

Solution:

1. The sphere is rotating in "free space," meaning there are no external torques (like friction or gravity gradients) acting on it.
2. The radius of the sphere increases while the mass remains the same. The moment of inertia of a solid sphere is $I = \frac{2}{5}MR^2$. As R increases, I increases.
3. Since $L = I\omega$ must remain constant, if I increases, the angular velocity ω must decrease proportionally.
4. Rotational Kinetic Energy $K = \frac{L^2}{2I}$ will change because I changes.
5. Therefore, the only quantity that is guaranteed to remain constant due to the absence of external torque is the angular momentum.

Final Answer: The angular momentum remains constant.

Answer: (D)

Q9.

Solution

Concept:
For a rotating body, the relationship between torque (τ) and angular acceleration (α) is given by:

$$\tau = I\alpha$$

Torque is also calculated as the product of the force and the perpendicular distance from the axis of rotation: $\tau = F \times R$. For a hollow cylinder (hoop) of mass M and radius R, the moment of inertia is $I = MR^2$.

Solution:
1. Identify the given values: Mass $M = 3$ kg Radius $R = 40$ cm $= 0.4$ m Applied Force $F = 30$ N
2. Calculate the torque produced by the force:

$$\tau = F \times R = 30 \times 0.4 = 12 \text{ N m}$$

3. Calculate the moment of inertia for the hollow cylinder:

$$I = MR^2 = 3 \times (0.4)^2 = 3 \times 0.16 = 0.48 \text{ kg m}^2$$

4. Use the torque equation to find angular acceleration:

$$\alpha = \frac{\tau}{I} = \frac{12}{0.48}$$

5. Simplify the division:

$$\alpha = \frac{1200}{48} = 25 \text{ rad/s}^2$$

Final Answer: The angular acceleration is 25 rad/s^2.

Answer: (B)

Q10.

Solution

Concept:

The work done in raising a mass is equal to the change in its gravitational potential energy. The potential energy of a mass m at a distance r from the center of the Earth is:

$$U = -\frac{GMm}{r}$$

Work Done $(W) = U_{final} - U_{initial}$.

Solution:

1. Initial position is on the surface: $r_1 = R$. Initial Potential Energy: $U_i = -\frac{GMm}{R}$
2. Final position is at a height $h = R$ from the surface: $r_2 = R + R = 2R$. Final Potential Energy: $U_f = -\frac{GMm}{2R}$
3. Calculate the difference:

$$W = U_f - U_i = -\frac{GMm}{2R} - \left(-\frac{GMm}{R}\right)$$

$$W = \frac{GMm}{R} - \frac{GMm}{2R} = \frac{GMm}{2R}$$

4. Relate to acceleration due to gravity on surface ($g = \frac{GM}{R^2} \implies GM = gR^2$):

$$W = \frac{(gR^2)m}{2R} = \frac{1}{2}mgR$$

Final Answer: The work done is $\frac{1}{2}mgR$.

Answer: (C)

Q11.

Solution

Concept:

The acceleration due to gravity (g) varies with both height (h) and depth (d). For a small height h ($h \ll R$), the acceleration is:

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

At a depth d below the surface, the acceleration is:

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

where R is the radius of the Earth.

Solution:

1. According to the problem, the acceleration at height h is equal to the acceleration at depth d:

$$g_h = g_d$$

2. Equating the two expressions:

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

3. Cancel g from both sides:

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

4. Simplify the equation by removing 1 and the negative signs:

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

$$d = 2h$$

5. Given that $h = 1$ km, substitute the value:

$$d = 2 \times 1 \text{ km} = 2 \text{ km}$$

Final Answer: The depth is 2 km.

Answer: (B)

Q12.

Solution

Concept:
When a sphere reaches terminal velocity (v_t) in a viscous medium, the net force on it is zero. The viscous force (F_v) acting on it is given by Stokes' Law:

$$F_v = 6\pi\eta r v_t$$

The rate of production of heat is equivalent to the power dissipated by the viscous force:

$$P = F_v \cdot v_t = 6\pi\eta r v_t^2$$

The terminal velocity v_t itself depends on the radius r as $v_t \propto r^2$.
Solution:
1. The expression for terminal velocity is:

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

This shows that $v_t \propto r^2$.
2. The power dissipated (rate of heat production) is:

$$P = F_v \cdot v_t$$

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

3. Substitute the proportionality $v_t \propto r^2$ into the power equation:

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

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

$$P \propto r^5$$

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

Answer: (C)

Q13.

Solution

Concept:

Young's Modulus (Y) is a property of the material and is defined as:

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{\Delta l/l} = \frac{Fl}{A\Delta l}$$

Since the volume ($V = Al$) is constant, we can express the length l as V/A. Substituting this into the formula allows us to relate Force (F) to the Area (A).

Solution:

1. Express the force F in terms of area and constant volume:

$$F = \frac{YA\Delta l}{l}$$

Since $l = V/A$, substitute it:

$$F = \frac{YA\Delta l}{(V/A)} = \frac{YA^2\Delta l}{V}$$

2. For the same material (Y), same volume (V), and same extension (Δl), the force is proportional to the square of the area:

$$F \propto A^2$$

3. Let $F_1 = F$ for area $A_1 = A$. For the second wire, the area is $A_2 = 3A$.

4. Calculate the new force F_2:

$$\frac{F_2}{F_1} = \left(\frac{A_2}{A_1}\right)^2$$

$$\frac{F_2}{F} = \left(\frac{3A}{A}\right)^2 = 3^2 = 9$$

$$F_2 = 9F$$

Final Answer: The force needed is $9F$.

Answer: (A)

Q14.

Solution

Concept:

The angle of contact (θ) is the angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid. It is determined by the relative magnitudes of cohesive forces (between liquid molecules) and adhesive forces (between liquid and solid molecules).

Solution:

1. If adhesive forces are much stronger than cohesive forces, the liquid crawls up the solid, and the angle of contact is acute ($\theta < 90°$). In this case, the liquid "wets" the surface.
2. If cohesive forces are stronger than adhesive forces, the liquid tends to contract and pull away from the solid surface.
3. This results in an obtuse angle of contact ($\theta > 90°$). In such cases, the liquid does not wet the solid surface (e.g., Mercury on glass).

Final Answer: The liquid does not wet the surface if the angle is obtuse.

Answer: (D)

Q15.

Solution

Concept:

Newton's Law of Cooling states that the rate of change of temperature of an object is proportional to the difference between its own temperature and the surrounding temperature (T_s):

$$\frac{T_1 - T_2}{t} = K\left(\frac{T_1 + T_2}{2} - T_s\right)$$

As the object's temperature approaches the surrounding temperature, the cooling rate slows down.

Solution:

1. For the first case (90°C to 80°C): Average temp = 85°C. Temperature difference from surroundings = 85 − 20 = 65°C. Rate $\propto$ 65.
2. For the second case (80°C to 60°C): Average temp = 70°C. Temperature difference from surroundings = 70 − 20 = 50°C. Rate $\propto$ 50.
3. Since the average temperature difference in the second case (50°C) is lower than in the first case (65°C), the rate of cooling is slower.
4. To drop 20°C (from 80 to 60) with a slower rate takes much longer than dropping 10°C (from 90 to 80). Even if the temperature drop were the same (10°C), it would take more than t. For double the drop (20°C), it will take more than $2t$.

Final Answer: The time taken is greater than $2t$.

Answer: (B)

Q16.

Solution

Concept:

The efficiency (η) of a Carnot engine is given by the formula:

$$\eta = 1 - \frac{T_2}{T_1}$$

where T_1 is the temperature of the source and T_2 is the temperature of the sink (both in Kelvin). By setting up two equations based on the two given conditions, we can solve for the unknown temperatures.

Solution:

1. From the first condition, efficiency is 1/6:

$$\frac{1}{6} = 1 - \frac{T_2}{T_1} \implies \frac{T_2}{T_1} = 1 - \frac{1}{6} = \frac{5}{6}$$

$$T_2 = \frac{5}{6}T_1 \quad \ldots\text{(Equation 1)}$$

2. From the second condition, T_2 is lowered by 62 K, and efficiency becomes 1/3:

$$\frac{1}{3} = 1 - \frac{T_2 - 62}{T_1}$$

$$\frac{T_2 - 62}{T_1} = 1 - \frac{1}{3} = \frac{2}{3}$$

$$T_2 - 62 = \frac{2}{3}T_1 \quad \ldots\text{(Equation 2)}$$

3. Substitute T_2 from Equation 1 into Equation 2:

$$\frac{5}{6}T_1 - 62 = \frac{2}{3}T_1$$

$$\frac{5}{6}T_1 - \frac{4}{6}T_1 = 62$$

$$\frac{1}{6}T_1 = 62 \implies T_1 = 62 \times 6 = 372 \text{ K}$$

4. Calculate T_2 using Equation 1:

$$T_2 = \frac{5}{6} \times 372 = 5 \times 62 = 310 \text{ K}$$

Final Answer: The temperatures are 372 K and 310 K.

Answer: (A)

Q17.

Solution

Concept:

The mean free path (λ) is the average distance traveled by a moving particle (such as an atom or molecule) between successive collisions. In the kinetic theory of gases, for a molecule of diameter d and number density n (number of molecules per unit volume), the formula is derived considering the relative velocity of molecules.

Solution:

1. If we consider all other molecules to be stationary, the volume swept by a molecule of diameter d moving a distance L is $\pi d^2 L$. 2. The number of collisions would be the number of molecules in this volume: $n\pi d^2 L$. 3. The mean free path would then be $\frac{L}{n\pi d^2 L} = \frac{1}{n\pi d^2}$. 4. However, molecules are in random motion. When the Maxwell-Boltzmann distribution of velocities is taken into account to factor in relative speeds, a factor of $\sqrt{2}$ appears in the denominator. 5. The standard expression becomes:

$$\lambda = \frac{1}{\sqrt{2}n\pi d^2}$$

Final Answer: The mean free path is $\frac{1}{\sqrt{2}n\pi d^2}$.

Answer: (A)

Q18.

Solution

Concept:

A displacement equation of the form $y = A_0 + A\sin\omega t + B\cos\omega t$ represents a Simple Harmonic Motion (SHM) shifted by a constant A_0. The amplitude of the oscillation is determined by the resultant of the two oscillating components ($A\sin\omega t$ and $B\cos\omega t$).

Solution:

1. The constant term A_0 represents the mean position shift and does not affect the amplitude of oscillation about that mean position. 2. Consider the oscillating part: $y' = A\sin\omega t + B\cos\omega t$. 3. This can be rewritten using the trigonometric identity $a\sin\theta + b\cos\theta = R\sin(\theta + \phi)$, where the resultant amplitude R is given by:

$$R = \sqrt{A^2 + B^2}$$

4. Here, A and B are the coefficients of the sine and cosine terms, which are essentially oscillations with a phase difference of $\pi/2$. 5. The resultant amplitude is:

$$\text{Amplitude} = \sqrt{A^2 + B^2}$$

Final Answer: The amplitude of oscillation is $\sqrt{A^2 + B^2}$.

Answer: (C)

Q19.

Solution

Concept:

In a resonance column (closed at one end), resonance occurs when the length of the air column corresponds to odd multiples of quarter wavelengths. However, due to the end effect, the first resonance is at $l_1 + e = \lambda/4$, the second at $l_2 + e = 3\lambda/4$, and so on. The difference between successive resonance lengths is exactly half a wavelength:

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

The speed of sound is then calculated using $v = f\lambda$.

Solution:

1. Identify the given successive resonance lengths: $l_1 = 9.75$ cm $l_2 = 31.25$ cm $l_3 = 52.75$ cm
2. Calculate the difference between successive lengths:

$$\Delta l = l_2 - l_1 = 31.25 - 9.75 = 21.5 \text{ cm}$$

$$\Delta l = l_3 - l_2 = 52.75 - 31.25 = 21.5 \text{ cm}$$

3. Since $\Delta l = \lambda/2$:

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

4. Use the frequency $f = 800$ Hz to find the speed:

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

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

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

Answer: (A)

Q20.

Solution

Concept:

The work done (W) in changing the separation between two point charges is equal to the change in electrostatic potential energy (ΔU). The potential energy between two charges q_1 and q_2 separated by distance r is:

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

where $k = 9 \times 10^9$ N m^2/C^2.

Solution:

1. Identify the initial and final states: $q_1 = 3 \times 10^{-6}$ C $q_2 = 1 \times 10^{-6}$ C Initial distance $r_1 = 20$ cm $= 0.2$ m Final distance $r_2 = 20 - 10 = 10$ cm $= 0.1$ m

2. Calculate the change in potential energy:

$$W = U_f - U_i = kq_1q_2\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

3. Substitute the values:

$$W = (9 \times 10^9)(3 \times 10^{-6})(1 \times 10^{-6})\left(\frac{1}{0.1} - \frac{1}{0.2}\right)$$

$$W = (27 \times 10^{-3})(10 - 5)$$

4. Final calculation:

$$W = 27 \times 10^{-3} \times 5 = 135 \times 10^{-3} = 0.135 \text{ J}$$

Final Answer: The work done is 0.135 J.

Answer: (A)

Q21.

Solution

Concept:
The energy density (u) of an electric field in a vacuum is given by $u = \frac{1}{2}\epsilon_0 E^2$. This represents energy per unit volume. The total energy (U) stored in the capacitor is the product of the energy density and the volume of the space between the plates where the electric field exists.

Solution:
1. The volume (V) between the plates of a parallel plate capacitor is the product of the area of the plates (A) and the distance between them (d):

$$V = Ad$$

2. The total energy stored is:

$$U = \text{Energy Density} \times \text{Volume}$$

3. Substitute the expression for energy density:

$$U = \left(\frac{1}{2}\epsilon_0 E^2\right) \times (Ad)$$

4. Rearrange the terms:

$$U = \frac{1}{2}\epsilon_0 E^2 Ad$$

Final Answer: The energy stored is $\frac{1}{2}\epsilon_0 E^2 Ad$.

Answer: (A)

Q22.

Solution

Concept:
The force of attraction between the plates of a parallel plate capacitor arises because one plate is in the electric field produced by the other. For a plate with charge Q, the electric field (E_{one}) produced by the *other* plate is half of the total field (E) between the plates.

$$F = Q \times E_{one}$$

The total field is $E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$.

Solution:

1. The electric field due to one plate is:

$$E_{one} = \frac{\sigma}{2\epsilon_0} = \frac{Q}{2A\epsilon_0}$$

2. The force on the second plate (carrying charge Q) is:

$$F = Q \times \left(\frac{Q}{2A\epsilon_0}\right) = \frac{Q^2}{2A\epsilon_0}$$

3. Examine the resulting formula: $F = \frac{Q^2}{2A\epsilon_0}$. In this expression, Q is constant (isolated capacitor), A is constant, and ϵ_0 is a constant.
4. Since the distance d does not appear in the formula, the force is independent of the distance between the plates (as long as d is small compared to the dimensions of the plates).

Final Answer: The force is independent of the distance between the plates.

Answer: (A)

Q23.

Solution

Concept:

The resistance (R) of a wire is given by $R = \rho\frac{l}{A}$. When a wire is melted and restretched, its volume ($V = Al$) remains constant. This implies that if the length increases, the cross-sectional area must decrease proportionally.

Solution:

1. Since Volume $V = A \times l$ is constant, we can write $A = \frac{V}{l}$.
2. Substitute this into the resistance formula:

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

3. Because ρ and V are constant for the same material and same mass:

$$R \propto l^2$$

4. Given the new length $l' = n \times l$. The new resistance R' will be:

$$\frac{R'}{R} = \left(\frac{l'}{l}\right)^2 = \left(\frac{nl}{l}\right)^2 = n^2$$

5. Therefore, $R' = n^2R$.

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

Answer: (C)

Q24.

Solution

Concept:

Current density (J) is related to the electric field (E) and conductivity (σ) by Ohm's Law in vector form: $J = \sigma E$. Conductivity is the reciprocal of resistivity (ρ), so $J = \frac{E}{\rho}$. Resistivity can be found from the resistance formula $R = \rho \frac{l}{A}$.

Solution:

1. Given values: $L = 10$ m $r = \frac{10^{-2}}{\sqrt{\pi}}$ m $R = 10\ \Omega$ $E = 10$ V/m
2. Calculate the cross-sectional area (A):

$$A = \pi r^2 = \pi \left(\frac{10^{-2}}{\sqrt{\pi}} \right)^2 = \pi \frac{10^{-4}}{\pi} = 10^{-4}\ \text{m}^2$$

3. Find the resistivity (ρ):

$$\rho = \frac{RA}{L} = \frac{10 \times 10^{-4}}{10} = 10^{-4}\ \Omega\,\text{m}$$

4. Calculate current density (J):

$$J = \frac{E}{\rho} = \frac{10}{10^{-4}} = 10^5\ \text{A/m}^2$$

Final Answer: The current density is 10^5 A/m^2.

Answer: (D)

Q25.

Solution

Concept:
In a closed series circuit consisting only of identical cells connected in the same direction, the total EMF is $\sum E$ and total internal resistance is $\sum r$. The current in the circuit is $I = \frac{\sum E}{\sum r}$. The potential difference across any part of the circuit is calculated using $V = E - Ir$.

Solution:
1. For 10 cells in series: Total EMF = $10E$ Total internal resistance = $10r$
2. The current (I) flowing through the closed loop:

$$I = \frac{10E}{10r} = \frac{E}{r}$$

3. The potential difference across one cell is:

$$V_{one} = E - Ir = E - \left(\frac{E}{r}\right)r = E - E = 0$$

4. Since the potential difference across each individual cell is zero, the reading of an ideal voltmeter connected across any number of cells (in this case, 3 cells) will also be zero.

$$V_{three} = 3 \times V_{one} = 3 \times 0 = 0$$

Final Answer: The voltmeter will read Zero.

Answer: (D)

Q26.

Solution

Concept:

A potentiometer works on the principle that the potential drop (V) across a segment of a uniform wire is directly proportional to its length (l), provided a constant current flows through it.

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

where E_1 and E_2 are the EMFs of the cells and l_1 and l_2 are their respective balancing lengths.

Solution:

1. Identify the given values: $E_1 = 1.5$ V, $l_1 = 36$ cm $E_2 = 2.5$ V, $l_2 =?$
2. Set up the proportionality equation:

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

3. Simplify the ratio on the left side:

$$\frac{15}{25} = \frac{3}{5}$$

4. Solve for l_2:

$$\frac{3}{5} = \frac{36}{l_2} \implies 3 \times l_2 = 36 \times 5$$

$$l_2 = \frac{36 \times 5}{3} = 12 \times 5 = 60 \text{ cm}$$

Final Answer: The balance point occurs at 60 cm.

Answer: (A)

Q27.

Solution

Concept:

The magnetic field (B) produced by an infinitely long straight conductor at a distance r is given by:

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

The magnetic force (F) experienced by a moving charge in a magnetic field is given by the Lorentz force formula:

$$F = qvB\sin\theta$$

In this case, the electron is moving parallel to the wire, so it is moving perpendicular to the magnetic field lines (which are circular loops around the wire), making $\theta = 90°$.

Solution:

1. Identify the given values: $I = 5$ A, $r = 20$ cm $= 0.2$ m $v = 10^5$ m/s, $e = 1.6 \times 10^{-19}$ C
2. Calculate the magnetic field (B) at the electron's position:

$$B = \frac{4\pi \times 10^{-7} \times 5}{2\pi \times 0.2}$$

$$B = \frac{2 \times 10^{-7} \times 5}{0.2} = \frac{10 \times 10^{-7}}{0.2} = 5 \times 10^{-6}\text{ T}$$

3. Calculate the force (F):

$$F = evB\sin 90° = (1.6 \times 10^{-19}) \times (10^5) \times (5 \times 10^{-6})$$

$$F = 1.6 \times 5 \times 10^{-19+5-6} = 8 \times 10^{-20}\text{ N}$$

Final Answer: The force experienced is 8×10^{-20} N.

Answer: (B)

Q28.

Solution

Concept:
The magnetic field (B) inside a long solenoid is uniform and is given by:

$$B = \mu_0 n I$$

where $\mu_0 = 4\pi \times 10^{-7}$ T m/A, n is the number of turns per unit length, and I is the current.
Solution:
1. Identify the given values: $n = 100$ turns/mm $= 100 \times 10^3$ turns/m $= 10^5$ turns/m $I = 1$ A
2. Use the formula for B:

$$B = (4\pi \times 10^{-7}) \times (10^5) \times 1$$

3. Calculate the numerical value:

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

$$B = 4 \times 3.14 \times 10^{-2} = 12.56 \times 10^{-2}\ \text{T}$$

Final Answer: The magnetic field strength is 12.56×10^{-2} T.

Answer: (A)

Q29.

Solution

Concept:
Diamagnetic materials are repelled by magnetic fields. When a diamagnetic rod is placed in a non-uniform magnetic field, it experiences a force that moves it from a stronger field region to a weaker field region. This mechanical work results in a gain in potential energy.
Solution:
1. To push the rod up against gravity, mechanical work is done by the magnetic force. 2. The magnetic field is generated by the electromagnet, which is powered by an external electric current source. 3. According to the conservation of energy, the energy required to perform this work and increase the gravitational potential energy must be supplied by the source that maintains the magnetic field. 4. Therefore, the work comes from the external current source that energizes the electromagnet.
Final Answer: The work comes from the current source.

Answer: (C)

Q30.

Solution

Concept:

When a conducting rod (or a spoke of a wheel) of length R rotates in a uniform magnetic field B with angular velocity ω, an EMF is induced between its ends. This is due to the change in the area swept by the rod. The induced EMF (ϵ) is given by:

$$\epsilon = \frac{1}{2} B R^2 \omega$$

Solution:

1. Identify the given values: $R = 0.5$ m $\omega = 10$ rad/s $B = 0.1$ T
2. Substitute the values into the formula:

$$\epsilon = \frac{1}{2} \times 0.1 \times (0.5)^2 \times 10$$

3. Perform the calculation:

$$\epsilon = \frac{1}{2} \times 0.1 \times 0.25 \times 10$$

$$\epsilon = \frac{1}{2} \times 1 \times 0.25$$

$$\epsilon = 0.125 \text{ V}$$

Final Answer: The EMF generated is 0.125 V.

Answer: (B)

Q31.

Solution

Concept:
The phase difference (ϕ) in a series LCR circuit is given by:

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

The power factor of the circuit is defined as $\cos\phi$. When the phase difference is zero, the circuit is in resonance, and the power factor is unity (1.0).

Solution:
1. When L is removed, the circuit becomes a series RC circuit. The phase difference is:

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

2. When C is removed, the circuit becomes a series LR circuit. The phase difference is:

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

3. In the original LCR circuit, we see that $X_L = X_C = \sqrt{3}R$. This is the condition for resonance.
4. The phase difference for the LCR circuit is:

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\sqrt{3}R - \sqrt{3}R}{R} = 0$$

Therefore, $\phi = 0$.
5. Calculate the power factor:

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

Final Answer: The power factor is 1.0.

Answer: (B)

Q32.

Solution

Concept:

An electromagnetic wave consists of oscillating electric (E) and magnetic (B) fields. The intensity (I) of the wave is the average energy transported per unit area per unit time. The total energy density is the sum of the energy densities of the electric and magnetic fields.

$$u_E = \frac{1}{2}\epsilon_0 E^2 \quad \text{and} \quad u_B = \frac{B^2}{2\mu_0}$$

Solution:

1. In an electromagnetic wave, the amplitudes of the electric and magnetic fields are related by $E = cB$. 2. The relation between constants is $c^2 = \frac{1}{\mu_0 \epsilon_0} \implies \epsilon_0 = \frac{1}{\mu_0 c^2}$. 3. Substitute these into the electric energy density formula:

$$u_E = \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\left(\frac{1}{\mu_0 c^2}\right)(cB)^2$$

$$u_E = \frac{1}{2}\frac{1}{\mu_0 c^2}c^2 B^2 = \frac{B^2}{2\mu_0}$$

4. Since $u_E = u_B$, the energy is divided equally between the electric and magnetic field components.
5. Consequently, the contribution to the total intensity from both fields is equal.

Final Answer: The ratio of contributions is 1 : 1.

Answer: (C)

Q33.

Solution

Concept:
The mirror formula relates the focal length (f), object distance (u), and image distance (v):

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

For a concave mirror, f and u are negative according to the Cartesian sign convention.
Solution:
1. **Initial Case:** $u_1 = -40$ 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. **Second Case:** Object is moved 20 cm towards the 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. **Displacement:** Initial image position = 24 cm in front of mirror. Final image position = 60 cm in front of mirror. Displacement = 60 − 24 = 36 cm. Since the value increased from 24 to 60, the image moved away from the mirror.
Final Answer: The displacement is 36 cm away from mirror.

Answer: (B)

Q34.

Solution

Concept:

In YDSE, the position of the n^{th} bright fringe from the center is $y_n = \frac{n\lambda D}{d}$. For bright fringes of two wavelengths to coincide at the same spot, their positions must be equal:

$$y = \frac{n_1\lambda_1 D}{d} = \frac{n_2\lambda_2 D}{d} \implies n_1\lambda_1 = n_2\lambda_2$$

Solution:

1. Identify the wavelengths: $\lambda_1 = 650$ nm and $\lambda_2 = 520$ nm. 2. Set up the ratio:

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{520}{650}$$

3. Simplify the fraction:

$$\frac{n_1}{n_2} = \frac{52}{65} = \frac{4}{5}$$

4. This means the 4^{th} bright fringe of 650 nm coincides with the 5^{th} bright fringe of 520 nm. 5. The question asks for the least distance, which corresponds to the smallest integers $n_1 = 4$ and $n_2 = 5$.

Final Answer: The $n = 4$ bright fringe of 650 nm coincides.

Answer: (A)

Q35.

Solution

Concept:

For a light ray incident on a prism, "no emergence" occurs when the ray undergoes Total Internal Reflection (TIR) at the second face for all possible angles of incidence. The condition for emergence is related to the critical angle (θ_c):

$$\theta_c = \sin^{-1}(1/\mu)$$

If the angle of the prism $A > 2\theta_c$, no light can emerge.

Solution:

1. Calculate the critical angle for the material:

$$\sin\theta_c = \frac{1}{\sqrt{2}} \implies \theta_c = 45^\circ$$

2. The condition for emergence from the second face is $r_2 < \theta_c$. 3. We know $r_1 + r_2 = A$. Thus, $r_2 = A - r_1$. 4. For no emergence, $r_2 \geq \theta_c$ for all r_1. 5. The minimum value of r_1 is 0° (normal incidence). Then $r_2 = A = 60^\circ$. 6. Since $60^\circ > 45^\circ$, the ray will undergo TIR at the second face for normal incidence. 7. As i increases, r_1 increases, and r_2 decreases. Emergence begins when r_2 falls below 45°. 8. However, looking at the options provided, the state of "no emergence" specifically applies to cases where TIR is triggered. In the context of this hard-level problem, it tests the boundary of TIR at specific incident angles.

Final Answer: At 0° incidence, $r_2 = 60^\circ > \theta_c$, leading to no emergence.

Answer: (D)

Q36.

Solution

Concept:

The angular magnification (M) of an astronomical telescope in normal adjustment is:

$$M = \frac{f_o}{f_e}$$

The angular resolution is determined by the resolving power, which is the reciprocal of the limit of resolution ($\Delta\theta$):

$$\text{Resolving Power} = \frac{1}{\Delta\theta} = \frac{D}{1.22\lambda}$$

where f_o is the focal length of the objective, f_e is the focal length of the eyepiece, and D is the diameter (aperture) of the objective lens.

Solution:

1. To have a large angular magnification (M), the focal length of the objective lens (f_o) must be as large as possible compared to the eyepiece. 2. To have high angular resolution (which means a small limit of resolution $\Delta\theta$), the diameter (D) of the objective lens must be large. 3. A larger aperture (D) also allows more light to enter the telescope, resulting in a brighter image of distant stars or planets. 4. Therefore, the ideal objective lens for an astronomical telescope should possess both a large focal length and a large diameter.

Final Answer: The objective should have large focal length and large diameter.

Answer: (A)

Q37.

Solution

Concept:

The de Broglie wavelength (λ) of a particle is related to its momentum (p) by:

$$\lambda = \frac{h}{p}$$

For an electron accelerated through a potential difference V, the kinetic energy $K = eV = \frac{p^2}{2m}$. Thus, $p = \sqrt{2meV}$. The wavelength can be calculated using the simplified formula for electrons:

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

Solution:

1. Given the accelerating potential $V = 10,000$ V. 2. Substitute the value into the simplified formula:

$$\lambda = \frac{12.27}{\sqrt{10000}} \text{ Å}$$

3. Calculate the square root of the denominator:

$$\sqrt{10000} = 100$$

4. Solve for λ:

$$\lambda = \frac{12.27}{100} \text{ Å} = 0.1227 \text{ Å}$$

5. Convert to meters for comparison with options:

$$0.1227 \text{ Å} = 12.27 \times 10^{-12} \text{ m}$$

6. This value is approximately 12.2×10^{-12} m.

Final Answer: The wavelength is 12.2×10^{-12} m.

Answer: (A)

Q38.

Solution

Concept:

Einstein's Photoelectric Equation relates the energy of the incident photon ($h\nu$), the work function of the metal ($\Phi = h\nu_0$), and the maximum kinetic energy of the emitted photoelectrons (K_{max}):

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

Since $K_{max} = \frac{1}{2}mv^2$, we can say that $v \propto \sqrt{h(\nu - \nu_0)}$.

Solution:

1. **Case 1:** Incident frequency $\nu_1 = 2\nu_0$.

$$\frac{1}{2}mv_1^2 = h(2\nu_0) - h\nu_0 = h\nu_0$$

$$v_1 = \sqrt{\frac{2h\nu_0}{m}}$$

2. **Case 2:** Incident frequency $\nu_2 = 5\nu_0$.

$$\frac{1}{2}mv_2^2 = h(5\nu_0) - h\nu_0 = 4h\nu_0$$

$$v_2 = \sqrt{\frac{8h\nu_0}{m}}$$

3. **Ratio Calculation:**

$$\frac{v_1}{v_2} = \frac{\sqrt{2h\nu_0/m}}{\sqrt{8h\nu_0/m}} = \sqrt{\frac{2}{8}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Final Answer: The ratio v_1 to v_2 is 1 : 2.

Answer: (A)

Q39.

Solution

Concept:

In the Bohr model of the hydrogen atom, an electron revolving around the nucleus has kinetic energy (K) and potential energy (U). The total energy (E) is the sum of both. The relationships are:

$$U = -2K$$

$$E = K + U = K - 2K = -K$$

where K is always positive and E is always negative for a bound state.

Solution:

1. The kinetic energy of an electron in the n^{th} orbit is $K = \frac{ke^2}{2r}$. 2. The total energy is $E = -\frac{ke^2}{2r}$.
3. We are asked to find the ratio of Kinetic Energy to Total Energy:

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

4. Therefore, the ratio is $1 : -1$.

Final Answer: The ratio is $1 : -1$.

Answer: (B)

Q40.

Solution

Concept:

The activity (A) of a radioactive sample after a time t is given by:

$$A = A_0 \left(\frac{1}{2}\right)^n$$

where A_0 is the initial activity and n is the number of half-lives that have passed. The number of half-lives is calculated as $n = t/T_{1/2}$.

Solution:

1. Identify the given values: $T_{1/2} = 20$ minutes $\frac{A}{A_0} = \frac{1}{16}$
2. Use the activity formula to find n:

$$\frac{1}{16} = \left(\frac{1}{2}\right)^n$$

Since $16 = 2^4$, we have:

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

3. Calculate the total time (t):

$$t = n \times T_{1/2} = 4 \times 20 \text{ minutes} = 80 \text{ minutes}$$

Final Answer: The time required is 80 minutes.

Answer: (D)

Q41.

Solution

Concept:

Semiconductors are doped with specific impurities to change their electrical properties. A p-type (positive type) semiconductor is created by adding trivalent impurity atoms (atoms with 3 valence electrons) to an intrinsic semiconductor (like Silicon or Germanium which have 4 valence electrons).

Solution:

1. In a p-type semiconductor, trivalent atoms (such as Indium, Boron, or Aluminum) are added. 2. Since these atoms have only 3 valence electrons, they create "holes" (vacancies in the covalent bonds) in the crystal lattice. 3. These holes act as the majority charge carriers because they are far more numerous than the thermally generated free electrons. 4. The electrons, in this case, are the minority charge carriers. 5. Therefore, for a p-type semiconductor, holes are majority carriers and trivalent atoms are the dopants.

Final Answer: Holes are majority carriers and trivalent atoms are dopants.

Answer: (B)

Q42.

Solution

Concept:

Logic gates can be combined to perform the functions of other gates. A NOR gate is a universal gate. Its output is $Y = \overline{A + B}$. If the inputs of a NOR gate are joined together, it acts as a NOT gate. If a NOR gate is followed by a NOT gate, the final output is the complement of NOR, which is an OR operation.

Solution:

1. Let the first NOR gate have inputs A and B. Its output is $Y_1 = \overline{A + B}$. 2. The second NOR gate in the network has its inputs tied together (connected to the output of the first gate). 3. When the inputs of a NOR gate are tied, the output $Y = \overline{Y_1 + Y_1} = \overline{Y_1}$. 4. Substituting Y_1:

$$Y = \overline{(\overline{A + B})}$$

5. Using the Boolean double negation law ($\overline{\overline{X}} = X$):

$$Y = A + B$$

6. This represents the logical OR operation.

Final Answer: The network is equivalent to an OR gate.

Answer: (B)

Q43.

Solution

Concept:

In a Common Emitter (CE) amplifier, the voltage gain (A_v) and power gain (P_v) are calculated based on the current gain (β) and the resistance ratio. Voltage Gain (A_v) = $\beta \times \frac{R_{collector}}{R_{base}}$ Power Gain (P_v) = $\beta \times A_v$

Solution:

1. Identify the given values: Current gain (β) = 100 Collector resistance (R_c) = 3 kΩ Base resistance (R_b) = 2 kΩ

2. Calculate the Voltage Gain (A_v):

$$A_v = \beta \left(\frac{R_c}{R_b}\right)$$

$$A_v = 100 \times \left(\frac{3\ \text{k}\Omega}{2\ \text{k}\Omega}\right) = 100 \times 1.5 = 150$$

3. Calculate the Power Gain (P_v):

$$P_v = \beta \times A_v$$

$$P_v = 100 \times 150 = 15000$$

Final Answer: The voltage gain is 150 and the power gain is 15000.

Answer: (A)

Q44.

Solution

Concept:

The relation for acceleration due to gravity from a free-fall experiment is derived from $s = ut + \frac{1}{2}gt^2$. Since the body starts from rest ($u = 0$), the equation is $s = \frac{1}{2}gt^2$, which gives $g = \frac{2s}{t^2}$. In error analysis, the maximum percentage error in a quantity $X = \frac{a^m}{b^n}$ is:

$$\frac{\Delta X}{X} \times 100 = m\left(\frac{\Delta a}{a} \times 100\right) + n\left(\frac{\Delta b}{b} \times 100\right)$$

Solution:

1. Start with the expression for g:

$$g = \frac{2s}{t^2}$$

2. The constant 2 does not contribute to the relative error. 3. Apply the rule for errors in products and powers:

$$\frac{\Delta g}{g} = \frac{\Delta s}{s} + 2\frac{\Delta t}{t}$$

4. Convert this to percentage errors. Given that the percentage error in distance (s) is e_1 and in time (t) is e_2:

$$\text{Percentage error in } g = e_1 + 2e_2$$

Final Answer: The maximum percentage error in g is $e_1 + 2e_2$.

Answer: (A)

Q45.

Solution

Concept:

For a physical quantity X defined by the formula $X = \frac{A^a B^b}{C^c D^d}$, the maximum relative error is calculated by summing the relative errors of each individual component multiplied by their respective powers (absolute values):

$$\frac{\Delta X}{X} = a\frac{\Delta A}{A} + b\frac{\Delta B}{B} + c\frac{\Delta C}{C} + d\frac{\Delta D}{D}$$

Solution:

1. Given the expression:

$$X = \frac{A^2 B^{1/2}}{C^{1/3} D^3}$$

2. Write the equation for the percentage error:

$$\%\text{ Error in } X = 2(\%A) + \frac{1}{2}(\%B) + \frac{1}{3}(\%C) + 3(\%D)$$

3. Substitute the given percentage errors: $\%A = 1\%, \%B = 2\%, \%C = 3\%, \%D = 4\%$

$$\%\text{ Error in } X = 2(1) + \frac{1}{2}(2) + \frac{1}{3}(3) + 3(4)$$

4. Calculate the sum:

$$\%\text{ Error in } X = 2 + 1 + 1 + 12$$

$$\%\text{ Error in } X = 16\%$$

Final Answer: The maximum percentage error in X is 16%.

Answer: (B)

Answer Key

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