WBJEE Physics Sample Paper-3

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Categories**.
- **Section A (Q1–Q30):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section B (Q31–Q35):** Each correct answer carries **+2 marks**. Incorrect answer: **−0.5** marks. Only **one** correct option.
- **Section C (Q36–Q40):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section A - 30 Questions × 1 Mark Each (Negative Marking: −0.25) [Single Correct]

Q1. The velocity of a particle is given by $v = at + \frac{b}{t+c}$. If v is in m/s and t is in seconds, the dimensions of a, b, and c are:

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

(B) $[L^2], [T], [LT^{-1}]$

(C) $[LT^{-2}], [LT^{-1}], [T]$

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

Q2. In a measurement, the percentage errors in X, Y, and Z are 1%, 2%, and 3% respectively. If $A = \frac{X^2Y}{\sqrt{Z}}$, the maximum percentage error in A is:

(A) 4.5%

(B) 5.5%

(C) 6.0%

(D) 7.5%

Q3. A particle moves along a straight line such that its displacement s at any time t is given by $s = t^3 - 6t^2 + 3t + 4$ meters. The velocity when the acceleration is zero is:

(A) $3m/s$

(B) $-12m/s$

(C) $-9m/s$

(D) $2m/s$

Q4. A projectile is fired at an angle of 45° with the horizontal. Elevation angle of the projectile at its highest point as seen from the point of projection is:

(A) 45°

(B) 60°

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

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

Q5. A block of mass $5kg$ is held against a vertical wall by applying a horizontal force of $100N$. If $\mu_s = 0.5$, the frictional force acting on the block is ($g = 10m/s^2$):

(A) $100N$

(B) $50N$

(C) $25N$

(D) $10N$

Q6. A car rounds an unbanked curve of radius $50m$. If the coefficient of friction is 0.4, the maximum speed with which the car can take the corner without skidding is:

(A) $10m/s$

(B) $14.1m/s$

(C) $20m/s$

(D) $5m/s$

Q7. A force $F = (2\hat{i} + 3\hat{j})N$ acts on a particle moving it from $(0, 0)$ to $(2, 2)$ meters. The work done by the force is:

(A) $5J$

(B) $10J$

(C) $12J$

(D) $15J$

Q8. A solid sphere of mass M and radius R rolls without slipping on a horizontal surface. The ratio of its rotational kinetic energy to its total kinetic energy is:

(A) $2/5$

(B) $2/7$

(C) $5/7$

(D) $1/2$

Q9. The acceleration due to gravity at a height h above the Earth's surface is $g/4$. The value of h in terms of Earth's radius R is:

(A) $R/2$

(B) R

(C) $2R$

(D) $\sqrt{2}R$

Q10. Two wires of the same material and length have radii r and $2r$. If they are stretched by the same force, the ratio of their internal energy stored is:

(A) $1 : 2$

(B) $4 : 1$

(C) $1 : 4$

(D) 16 : 1

Q11. A spherical drop of water of radius $1mm$ is broken into 10^6 identical drops. If surface tension of water is $72 \times 10^{-3} N/m$, the work done is nearly:

(A) $7.2 \times 10^{-6} J$

(B) $8.9 \times 10^{-5} J$

(C) $9.0 \times 10^{-3} J$

(D) $0.9 \times 10^{-4} J$

Q12. In an isothermal process, the volume of an ideal gas is halved. The pressure of the gas:

(A) Remains constant

(B) Is halved

(C) Is doubled

(D) Increases four times

Q13. One mole of a monoatomic gas ($\gamma = 5/3$) is mixed with one mole of a diatomic gas ($\gamma = 7/5$). The value of γ for the mixture is:

(A) 1.40

(B) 1.50

(C) 1.53

(D) 1.67

Q14. The displacement of a particle in SHM is $x = 5\sin(20\pi t + \pi/3)$. The first time the particle comes to rest is at $t =$:

(A) $1/120s$

(B) $1/60s$

(C) $1/30s$

(D) $1/20s$

Q15. A source of sound of frequency $600Hz$ is moving towards a stationary observer with a speed of $30m/s$. If speed of sound is $330m/s$, the frequency heard by the observer is:

(A) $660Hz$

(B) $550Hz$

(C) $630Hz$

(D) $700Hz$

Q16. Two point charges $+4q$ and $+q$ are placed $30cm$ apart. At what distance from $+4q$ is the net electric field zero?

(A) $10cm$

(B) $20cm$

(C) $15cm$

(D) $25cm$

Q17. The capacitance of a parallel plate capacitor is $10\mu F$. If a dielectric slab of $K = 2$ is inserted to fill half the distance between the plates, the new capacitance is:

(A) $15\mu F$

(B) $20\mu F$

(C) $13.3\mu F$

(D) $6.6\mu F$

Q18. A wire of resistance 10Ω is stretched to thrice its original length. The new resistance is:

(A) 30Ω

(B) 90Ω

(C) $10/9\Omega$

(D) 60Ω

Q19. A circular coil of radius R carries a current I. The magnetic field at the center is B. At what distance on the axis from the center will the field be $B/8$?

(A) $R\sqrt{3}$

(B) $2R$

(C) $R/\sqrt{3}$

(D) $3R$

Q20. At a certain place, the horizontal component of Earth's magnetic field is $\sqrt{3}$ times the vertical component. The angle of dip at that place is:

(A) $30°$

(B) $60°$

(C) $45°$

(D) $0°$

Q21. A square loop of side $10cm$ enters a magnetic field $B = 0.1T$ with velocity $2m/s$ perpendicular to the field. The induced emf is:

(A) $0.01V$

(B) $0.02V$

(C) $0.1V$

(D) $0.2V$

Q22. The ratio of the speed of an electromagnetic wave in vacuum to its speed in a medium of refractive index 1.5 is:

(A) 1 : 1.5

(B) 1.5 : 1

(C) 2.25 : 1

(D) 1 : 2.25

Q23. An object is placed $20cm$ in front of a concave mirror of focal length $15cm$. The image formed is:

(A) Real, inverted and magnified

(B) Virtual, erect and magnified

(C) Real, inverted and diminished

(D) Virtual, erect and diminished

Q24. In Young's Double Slit Experiment, the fringe width is $0.4mm$. If the whole apparatus is immersed in water ($n = 4/3$), the new fringe width is:

(A) $0.3mm$

(B) $0.4mm$

(C) $0.53mm$

(D) $0.2mm$

Q25. The stopping potential for a metal surface is $1.2V$ when light of wavelength λ is incident. If light of wavelength 2λ is used, the stopping potential becomes $0.4V$. The threshold wavelength is:

(A) 3λ

(B) 4λ

(C) 5λ

(D) 1.5λ

Q26. In a hydrogen atom, the transition from $n = 3$ to $n = 2$ emits a photon of wavelength λ. The wavelength emitted during transition from $n = 4$ to $n = 2$ is:

(A) $(20/27)\lambda$

(B) $(27/20)\lambda$

(C) $(3/4)\lambda$

(D) $(9/16)\lambda$

Q27. The half-life of a radioactive substance is 20 minutes. The time taken for the activity to drop to $1/16$th of its initial value is:

(A) 40 min

(B) 60 min

(C) 80 min

(D) 100 min

Q28. For a common-emitter amplifier, the current gain $\beta = 100$. If the base current changes by $20\mu A$, the change in collector current is:

(A) $2mA$

(B) $0.2mA$

(C) $20mA$

(D) $200\mu A$

Q29. A truck and a car are moving with the same kinetic energy on a straight road. Their engines are simultaneously switched off. Which one will stop at a shorter distance?

(A) The car

(B) The truck

(C) Both will stop at the same distance

(D) Depends on the coefficient of friction only

Q30. The dimensions of magnetic permeability μ_0 are:

(A) $[MLT^{-2}A^{-2}]$

(B) $[MLT^{-1}A^{-1}]$

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

(D) $[MLT^{-2}A^{-1}]$

Section B - 5 Questions $\times$ 2 Mark Each
(Negative Marking: -0.5) [Single Correct]

Q31. A bullet of mass m moving with velocity v strikes a block of mass M suspended by a string of length L and gets embedded in it. The minimum value of v so that the block completes a vertical circle is:

(A) $\frac{m+M}{m}\sqrt{5gL}$

(B) $\frac{M}{m}\sqrt{5gL}$

(C) $\sqrt{5gL}$

(D) $\frac{m+M}{M}\sqrt{2gL}$

Q32. A uniform rod of mass M and length L is pivoted at one end and released from a horizontal position. The angular velocity of the rod when it becomes vertical is:

(A) $\sqrt{g/L}$

(B) $\sqrt{2g/L}$

(C) $\sqrt{3g/L}$

(D) $\sqrt{6g/L}$

Q33. A liquid rises to a height of $10cm$ in a capillary tube. If the tube is tilted by $60°$ with the vertical, the length of the liquid column in the tube will be:

(A) $10cm$

(B) $20cm$

(C) $5cm$

(D) $10\sqrt{3}cm$

Q34. An ideal heat engine operates between $227°C$ and $127°C$. It absorbs $6 \times 10^4 J$ of heat at higher temperature. The amount of heat converted into work is:

(A) $1.2 \times 10^4 J$

(B) $2.4 \times 10^4 J$

(C) $3.6 \times 10^4 J$

(D) $4.8 \times 10^4 J$

Q35. In an LCR series circuit, $R = 10\Omega$, $L = 2mH$ and $C = 5\mu F$. The Q-factor of the circuit is:

(A) 2

(B) 20

(C) 10

(D) 1

Section C - 5 Questions × 2 Marks Each
(No Negative Marking) [One or More Correct]

Q36. For an ideal gas undergoing an adiabatic process:

(A) PV^{γ} = constant

(B) $TV^{\gamma-1}$ = constant

(C) $P^{1-\gamma}T^{\gamma}$ = constant

(D) $\Delta Q = 0$

Q37. A particle is executing SHM. At the mean position:

(A) Displacement is zero.

(B) Acceleration is maximum.

(C) Velocity is maximum.

(D) Potential energy is minimum.

Q38. In a capacitor-resistor (RC) charging circuit:

(A) The current decreases exponentially with time.

(B) The charge on the capacitor increases exponentially with time.

(C) After one time constant, the charge is approximately 63% of maximum.

(D) The voltage across the resistor is constant.

Q39. According to Bohr's model of the hydrogen atom:

(A) Angular momentum is quantized.

(B) Force between nucleus and electron is kZe^2/r^2.

(C) Kinetic energy of electron is proportional to $1/n^2$.

(D) Total energy of electron is positive.

Q40. Which of the following statements are true for a p-n junction diode?

(A) In forward bias, the depletion layer width decreases.

(B) In reverse bias, the barrier height increases.

(C) Drift current is due to majority carriers.

(D) Diffusion current flows from p to n side.

Detailed Solutions

Q1.

Solution

Concept:
The principle of Homogeneity of Dimensions states that the dimensions of each term in a physical equation must be the same. For an equation $v = A + B + C$, the dimensions of v must match the dimensions of A, B, and C individually. Additionally, physical quantities can only be added or subtracted if they have identical dimensions.

Solution:
Step 1: Analyze the given equation $v = at + \frac{b}{t+c}$. Here, v represents velocity with dimensions $[LT^{-1}]$ and t represents time with dimensions $[T]$.

Step 2: Examine the term $(t + c)$ in the denominator. Since c is added to time t, by the principle of homogeneity, c must have the same dimensions as t.
$[c] = [T]$

Step 3: Analyze the first term at. The dimensions of at must be equal to the dimensions of velocity v.
$[at] = [LT^{-1}]$
$[a][T] = [LT^{-1}]$
$[a] = [LT^{-2}]$

Step 4: Analyze the second term $\frac{b}{t+c}$. The dimensions of this entire term must also match the dimensions of velocity v.
$\left[\frac{b}{t+c}\right] = [LT^{-1}]$
Since the denominator $(t + c)$ has dimensions of $[T]$, we have:
$\frac{[b]}{[T]} = [LT^{-1}]$
$[b] = [LT^{-1}] \times [T] = [L]$

Step 5: Consolidating the results, we find:
$[a] = [LT^{-2}]$
$[b] = [L]$
$[c] = [T]$
Comparing these results with the given options, we find they match option (A).

Final Answer: $\boxed{[LT^{-2}], [L], [T]}$

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept:

When a physical quantity is calculated from the product or quotient of other measured quantities, the maximum relative error is the sum of the relative errors of the individual quantities multiplied by their respective powers. For a quantity $A = X^a Y^b Z^{-c}$, the maximum fractional error is given by $\frac{\Delta A}{A} = |a|\frac{\Delta X}{X} + |b|\frac{\Delta Y}{Y} + |c|\frac{\Delta Z}{Z}$.

Solution:

Step 1: Write the given expression for A in terms of powers:

$A = \frac{X^2 Y}{\sqrt{Z}} = X^2 Y Z^{-1/2}$

Step 2: Express the relative error in A using the general formula for error propagation. We take the absolute values of the powers because we are calculating the maximum possible error.

$\frac{\Delta A}{A} = 2\left(\frac{\Delta X}{X}\right) + 1\left(\frac{\Delta Y}{Y}\right) + \frac{1}{2}\left(\frac{\Delta Z}{Z}\right)$

Step 3: Convert the relative error equation into percentage error by multiplying the entire expression by 100:

$\left(\frac{\Delta A}{A} \times 100\right) = 2\left(\frac{\Delta X}{X} \times 100\right) + 1\left(\frac{\Delta Y}{Y} \times 100\right) + \frac{1}{2}\left(\frac{\Delta Z}{Z} \times 100\right)$

Step 4: Substitute the given percentage errors for X, Y, and Z into the equation:

Percentage error in $X = 1\%$

Percentage error in $Y = 2\%$

Percentage error in $Z = 3\%$

Maximum % error in $A = 2(1\%) + 1(2\%) + \frac{1}{2}(3\%)$

Step 5: Perform the arithmetic calculation:

Maximum % error in $A = 2\% + 2\% + 1.5\%$

Maximum % error in $A = 5.5\%$

Final Answer: 5.5%

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:

In rectilinear kinematics, velocity v is the first derivative of displacement s with respect to time t, and acceleration a is the first derivative of velocity v with respect to time t. To find the velocity at a specific condition (like zero acceleration), we must differentiate the displacement function twice and solve for time.

Solution:

Step 1: Given the displacement equation:

$s = t^3 - 6t^2 + 3t + 4$

Step 2: Find the velocity v by differentiating s with respect to t:

$v = \frac{ds}{dt} = \frac{d}{dt}(t^3 - 6t^2 + 3t + 4)$

$v = 3t^2 - 12t + 3$

Step 3: Find the acceleration a by differentiating v with respect to t:

$a = \frac{dv}{dt} = \frac{d}{dt}(3t^2 - 12t + 3)$

$a = 6t - 12$

Step 4: Set the acceleration to zero as per the condition given in the problem:

$6t - 12 = 0$

$6t = 12$

$t = 2$ seconds

Step 5: Substitute the value of $t = 2$ back into the velocity equation found in Step 2:

$v(2) = 3(2)^2 - 12(2) + 3$

$v(2) = 12 - 24 + 3$

$v(2) = -9m/s$

Final Answer: $\boxed{-9m/s}$

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept:
The elevation angle (ϕ) of a projectile at its highest point as seen from the point of projection is the angle made by the line joining the origin $(0,0)$ to the peak $(R/2, H)$ with the horizontal. This is different from the angle of projection (θ). We use the formulas for Maximum Height (H) and Horizontal Range (R).

Solution:
Step 1: Recall the standard formulas for a projectile fired with velocity u at an angle θ:
Maximum Height $H = \frac{u^2 \sin^2\theta}{2g}$
Range $R = \frac{2u^2 \sin\theta\cos\theta}{g}$

Step 2: The coordinates of the highest point are $(x, y) = (R/2, H)$. The elevation angle ϕ is given by:
$\tan\phi = \frac{y}{x} = \frac{H}{R/2} = \frac{2H}{R}$

Step 3: Substitute the expressions for H and R into the ratio:
$\tan\phi = 2 \times \left(\frac{u^2\sin^2\theta}{2g}\right) \times \left(\frac{g}{2u^2\sin\theta\cos\theta}\right)$
$\tan\phi = \frac{\sin\theta}{2\cos\theta} = \frac{1}{2}\tan\theta$

Step 4: Given the angle of projection $\theta = 45°$:
$\tan\phi = \frac{1}{2}\tan(45°)$
$\tan\phi = \frac{1}{2} \times 1 = \frac{1}{2}$

Step 5: Solve for ϕ using the inverse tangent function:
$\phi = \tan^{-1}(1/2)$

Final Answer: $\boxed{\tan^{-1}(1/2)}$

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept:
For a block held against a vertical wall, the applied horizontal force (F) acts as the Normal Force (N). Friction (f) acts vertically upwards to oppose the weight (mg) of the block. Static friction is a self-adjusting force that ranges from 0 to a maximum value of $f_{max} = \mu_s N$. If $mg \le \mu_s N$, the block remains stationary and $f = mg$.

Solution:
Step 1: Identify the forces acting on the block of mass $m = 5kg$.
Weight $(W) = mg = 5 \times 10 = 50N$ (acting downwards).
Horizontal applied force $(F) = 100N$.

Step 2: The horizontal force F pushes the block against the wall, so the Normal reaction N from the wall is:
$N = F = 100N$

Step 3: Calculate the maximum available static frictional force (f_{max}):
$f_{max} = \mu_s N = 0.5 \times 100 = 50N$

Step 4: Compare the weight of the block with the maximum static friction.
Weight $W = 50N$
Max Friction $f_{max} = 50N$

Step 5: Because the block is in equilibrium (or at the verge of sliding), the actual frictional force f acting on the block must exactly balance its weight:
$f = W = 50N$
Therefore, the frictional force acting is $50N$ upwards.

Final Answer: $\boxed{50N}$

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:

When a car travels along an unbanked circular path, the necessary centripetal force is provided entirely by the static friction between the tires and the road surface. For the car to navigate the turn without skidding, the required centripetal force must be less than or equal to the maximum available static frictional force.

Solution:

Step 1: Identify the forces acting on the car. The centripetal force required for circular motion is $F_c = \frac{mv^2}{R}$, where m is mass, v is velocity, and R is the radius of the curve.

Step 2: The maximum static frictional force f_{max} is given by the formula $f_{max} = \mu_s N$. For a car on a level, unbanked road, the normal force N is equal to the weight of the car, mg.

$f_{max} = \mu_s mg$

Step 3: Set the required centripetal force equal to the maximum frictional force to find the limiting speed v_{max}:

$\frac{mv_{max}^2}{R} = \mu_s mg$

Step 4: Simplify the equation by canceling the mass m from both sides and solving for v_{max}:

$v_{max}^2 = \mu_s Rg$

$v_{max} = \sqrt{\mu_s Rg}$

Step 5: Substitute the given values into the equation ($R = 50m$, $\mu_s = 0.4$, $g = 10m/s^2$):

$v_{max} = \sqrt{0.4 \times 50 \times 10}$

$v_{max} = \sqrt{200}$

$v_{max} = 10\sqrt{2} \approx 14.14m/s$

Thus, the maximum speed to avoid skidding is approximately $14.1m/s$.

Final Answer: $\boxed{14.1m/s}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:

Work done by a constant force is defined as the dot product of the force vector and the displacement vector. If the force $\vec{F} = F_x\hat{i} + F_y\hat{j}$ and the displacement $\vec{d} = \Delta x\hat{i} + \Delta y\hat{j}$, then the work W is calculated as $W = \vec{F} \cdot \vec{d} = F_x\Delta x + F_y\Delta y$.

Solution:

Step 1: Identify the given force vector:
$\vec{F} = (2\hat{i} + 3\hat{j})N$

Step 2: Calculate the displacement vector $\vec{d}$ by subtracting the initial position from the final position:
Initial position $\vec{r_1} = (0\hat{i} + 0\hat{j})m$
Final position $\vec{r_2} = (2\hat{i} + 2\hat{j})m$
$\vec{d} = \vec{r_2} - \vec{r_1} = (2-0)\hat{i} + (2-0)\hat{j} = (2\hat{i} + 2\hat{j})m$

Step 3: Apply the dot product formula to find the work done:
$W = \vec{F} \cdot \vec{d} = (2\hat{i} + 3\hat{j}) \cdot (2\hat{i} + 2\hat{j})$

Step 4: Perform the scalar multiplication for each component:
$W = (2 \times 2) + (3 \times 2)$
$W = 4 + 6$
$W = 10J$

Step 5: Conclude that the total energy transferred to the particle by this force over the given displacement is 10 Joules. This scalar quantity represents the work done regardless of the path taken, as the force is constant.

Final Answer: $\boxed{10J}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
A body in rolling motion without slipping possesses both translational kinetic energy (K_t) and rotational kinetic energy (K_r). The total kinetic energy (K_{total}) is the sum of these two. For a solid sphere, the moment of inertia about its center of mass is $I = \frac{2}{5}MR^2$, and the rolling condition relates linear velocity to angular velocity by $v = \omega R$.

Solution:
Step 1: Express the translational kinetic energy:
$K_t = \frac{1}{2}Mv^2$

Step 2: Express the rotational kinetic energy using the moment of inertia for a solid sphere:
$K_r = \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{2}{5}MR^2\right)\left(\frac{v}{R}\right)^2$
$K_r = \frac{1}{2} \times \frac{2}{5}Mv^2 = \frac{1}{5}Mv^2$

Step 3: Calculate the total kinetic energy:
$K_{total} = K_t + K_r = \frac{1}{2}Mv^2 + \frac{1}{5}Mv^2$
$K_{total} = \left(\frac{5+2}{10}\right)Mv^2 = \frac{7}{10}Mv^2$

Step 4: Determine the ratio of rotational kinetic energy to total kinetic energy:
Ratio $= \frac{K_r}{K_{total}} = \frac{\frac{1}{5}Mv^2}{\frac{7}{10}Mv^2}$

Step 5: Simplify the fraction:
Ratio $= \frac{1}{5} \times \frac{10}{7} = \frac{2}{7}$
This means that for a solid sphere, exactly $2/7$ of its total energy is stored in rotation, while $5/7$ is translational.

Final Answer: $\boxed{2/7}$

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
The acceleration due to gravity at a height h above the Earth's surface is given by the formula $g' = g\left(\frac{R}{R+h}\right)^2$, where g is the acceleration at the surface and R is the Earth's radius. This formula is derived from the law of universal gravitation, accounting for the increased distance from the Earth's center.

Solution:
Step 1: State the given condition from the problem:
$g' = \frac{g}{4}$

Step 2: Substitute the formula for g' into the given condition:
$g\left(\frac{R}{R+h}\right)^2 = \frac{g}{4}$

Step 3: Cancel g from both sides and take the square root of both sides to simplify the equation:
$\left(\frac{R}{R+h}\right)^2 = \frac{1}{4}$
$\frac{R}{R+h} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

Step 4: Solve the resulting linear equation for h:
$2R = R + h$
$2R - R = h$
$h = R$

Step 5: Conclude that at a height equal to the Earth's radius, the force of gravity (and thus the acceleration) drops to one-fourth of its surface value because the distance from the center of the Earth has doubled ($2R$).

Final Answer: $\boxed{R}$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:

The elastic potential energy (internal energy) stored in a stretched wire is given by $U = \frac{1}{2} \times \text{Force} \times \text{Extension}$. Since $Y = \frac{F/A}{\Delta L/L}$, we can write $\Delta L = \frac{FL}{AY}$. Substituting this into the energy formula gives $U = \frac{F^2L}{2AY}$. For wires of the same material and length subjected to the same force, the energy stored is inversely proportional to the cross-sectional area A.

Solution:

Step 1: Establish the relationship for internal energy U in terms of given constants (Force F, Length L, Young's modulus Y) and the variable (Radius r).

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

Since $A = \pi r^2$, we have $U \propto \frac{1}{r^2}$.

Step 2: Identify the radii of the two wires:

Wire 1 radius = $r_1 = r$

Wire 2 radius = $r_2 = 2r$

Step 3: Set up the ratio of the energy stored in the two wires:

$\frac{U_1}{U_2} = \frac{r_2^2}{r_1^2}$

Step 4: Substitute the values of the radii into the ratio:

$\frac{U_1}{U_2} = \frac{(2r)^2}{r^2}$

$\frac{U_1}{U_2} = \frac{4r^2}{r^2}$

$\frac{U_1}{U_2} = 4$

Step 5: Conclude that the ratio of the internal energy stored is 4 : 1. The thinner wire stores more energy because it undergoes a much larger extension for the same applied force compared to the thicker wire.

Final Answer: 4 : 1

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:
The work done in breaking a larger liquid drop into multiple smaller droplets is equal to the increase in surface energy. This energy change occurs because the total surface area increases while the volume remains constant. The surface energy is given by $U = T \times \Delta A$, where T is the surface tension and ΔA is the change in total surface area.

Solution:
Step 1: Let the radius of the large drop be R and the radius of each small droplet be r. The number of droplets is $n = 10^6$. Since volume is conserved:
$\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$
$R^3 = nr^3 \implies r = \frac{R}{n^{1/3}}$

Step 2: Substitute $n = 10^6$ into the relation:
$r = \frac{1mm}{(10^6)^{1/3}} = \frac{10^{-3}m}{10^2} = 10^{-5}m$

Step 3: Calculate the change in surface area ΔA. The final area is the sum of areas of n droplets, and the initial area is the area of the single large drop:
$\Delta A = n(4\pi r^2) - 4\pi R^2 = 4\pi(nr^2 - R^2)$
Using $nr^3 = R^3$, we can also write $\Delta A = 4\pi R^2(n^{1/3} - 1)$.

Step 4: Substitute the values ($R = 10^{-3}m$, $n^{1/3} = 100$):
$\Delta A = 4 \times 3.14 \times (10^{-3})^2 \times (100 - 1)$
$\Delta A \approx 12.56 \times 10^{-6} \times 99 \approx 1.24 \times 10^{-3}m^2$

Step 5: Calculate the work done $W = T \times \Delta A$:
$W = 72 \times 10^{-3} \times 1.24 \times 10^{-3}$
$W \approx 89.28 \times 10^{-6}J \approx 8.9 \times 10^{-5}J$
Therefore, a significant amount of energy must be supplied to overcome the cohesive forces and create the additional surface area.

Final Answer: $\boxed{8.9 \times 10^{-5}J}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:

In an isothermal process, the temperature of the system remains constant ($\Delta T = 0$). For an ideal gas, the state is governed by Boyle's Law, which states that the product of pressure P and volume V is constant ($PV = \text{constant}$). Consequently, pressure and volume are inversely proportional to each other.

Solution:

Step 1: Write the equation for an isothermal process for an ideal gas:

$P_1V_1 = P_2V_2$

Step 2: Identify the relationship between the initial volume V_1 and the final volume V_2 as given in the problem:

$V_2 = \frac{V_1}{2}$

Step 3: Substitute the value of V_2 into the Boyle's Law equation to solve for the final pressure P_2:

$P_1V_1 = P_2\left(\frac{V_1}{2}\right)$

Step 4: Cancel V_1 from both sides and rearrange the equation:

$P_1 = \frac{P_2}{2}$

$P_2 = 2P_1$

Step 5: Conclude that when the volume of an ideal gas is compressed to half its original size at a constant temperature, the gas molecules collide with the container walls more frequently, resulting in a doubling of the pressure.

Final Answer: Is doubled

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:
The ratio of specific heats (γ) for a mixture of non-reactive ideal gases is determined by the total internal energy change or the effective degrees of freedom. The formula for the adiabatic exponent of a mixture is $\gamma_{mix} = \frac{n_1 C_{p1} + n_2 C_{p2}}{n_1 C_{v1} + n_2 C_{v2}}$, where n is the number of moles and C_p, C_v are the molar heat capacities.

Solution:
Step 1: Identify the heat capacities for the individual gases.
For a monoatomic gas: $C_{v1} = \frac{3}{2}R$, $C_{p1} = \frac{5}{2}R$.
For a diatomic gas: $C_{v2} = \frac{5}{2}R$, $C_{p2} = \frac{7}{2}R$.

Step 2: Given $n_1 = 1$ mole and $n_2 = 1$ mole, calculate the total molar heat capacity at constant volume for the mixture ($C_{v,mix}$):
$C_{v,mix} = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2} = \frac{1(\frac{3}{2}R) + 1(\frac{5}{2}R)}{2} = \frac{4R}{2} = 2R$

Step 3: Calculate the total molar heat capacity at constant pressure for the mixture ($C_{p,mix}$):
$C_{p,mix} = \frac{n_1 C_{p1} + n_2 C_{p2}}{n_1 + n_2} = \frac{1(\frac{5}{2}R) + 1(\frac{7}{2}R)}{2} = \frac{6R}{2} = 3R$

Step 4: Find the ratio $\gamma_{mix} = \frac{C_{p,mix}}{C_{v,mix}}$:
$\gamma_{mix} = \frac{3R}{2R} = 1.50$

Step 5: Verify the result. A monoatomic gas has $\gamma = 1.67$ and a diatomic gas has $\gamma = 1.40$. The mixture's value of 1.50 correctly falls between these two limits, reflecting the combined thermal behavior of both gas types.

Final Answer: 1.50

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:
In Simple Harmonic Motion (SHM), a particle comes to rest at the extreme positions where its velocity is zero. The velocity v is the derivative of displacement x with respect to time t. Alternatively, the particle is at rest when the phase of the sine function in the displacement equation corresponds to the points where displacement is maximum ($\pm A$).

Solution:
Step 1: Given the displacement equation:
$x = 5\sin(20\pi t + \pi/3)$

Step 2: Differentiate x with respect to t to find the velocity v:
$v = \frac{dx}{dt} = 5 \times (20\pi)\cos(20\pi t + \pi/3)$
$v = 100\pi\cos(20\pi t + \pi/3)$

Step 3: Set the velocity to zero to find the times when the particle is at rest:
$100\pi\cos(20\pi t + \pi/3) = 0$
$\cos(20\pi t + \pi/3) = 0$

Step 4: The cosine function is zero when its argument is an odd multiple of $\pi/2$. For the first instance of rest, we set the argument to $\pi/2$:
$20\pi t + \pi/3 = \pi/2$

Step 5: Solve for t by rearranging the terms:
$20\pi t = \frac{\pi}{2} - \frac{\pi}{3}$
$20\pi t = \frac{3\pi - 2\pi}{6} = \frac{\pi}{6}$
$t = \frac{1}{6\times20} = \frac{1}{120}s$
Thus, the particle first stops after $1/120$ seconds.

Final Answer: $\boxed{1/120s}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:

The Doppler Effect describes the change in frequency of a wave in relation to an observer who is moving relative to the wave source. When a source moves towards a stationary observer, the observed frequency f' is higher than the emitted frequency f. The formula is $f' = f\left(\frac{v}{v-v_s}\right)$, where v is the speed of sound and v_s is the speed of the source.

Solution:

Step 1: Identify the given parameters:
Emitted frequency $f = 600Hz$
Speed of sound $v = 330m/s$
Speed of source $v_s = 30m/s$ (moving towards the observer)

Step 2: Since the source is moving towards the stationary observer, the effective wavelength decreases, leading to an increase in perceived frequency. Use the specific Doppler formula:
$f' = f\left(\frac{v}{v-v_s}\right)$

Step 3: Substitute the numerical values into the equation:
$f' = 600\left(\frac{330}{330-30}\right)$

Step 4: Perform the subtraction in the denominator and simplify the fraction:
$f' = 600\left(\frac{330}{300}\right)$
$f' = 600 \times 1.1$

Step 5: Calculate the final frequency:
$f' = 660Hz$
The frequency increases by $60Hz$ due to the relative motion of the source towards the observer.

Final Answer: $\boxed{660Hz}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:

The net electric field at a point due to a system of charges is the vector sum of the individual fields. For the net field to be zero at a point between two like charges, the magnitudes of the fields produced by both charges must be equal and their directions must be opposite. This point is known as the neutral point.

Solution:

Step 1: Let the two charges be $q_1 = +4q$ and $q_2 = +q$, separated by a distance $r = 30cm$. Let the neutral point be at a distance x from the charge $+4q$. Consequently, the distance from the charge $+q$ will be $(30 - x)$.

Step 2: Write the expression for the electric field magnitude produced by each charge at distance x:

$E_1 = \frac{k(4q)}{x^2}$

$E_2 = \frac{kq}{(30-x)^2}$

Step 3: Set $E_1 = E_2$ for the net field to be zero:

$\frac{k(4q)}{x^2} = \frac{kq}{(30-x)^2}$

Step 4: Simplify the equation by canceling k and q, then take the square root of both sides:

$\frac{4}{x^2} = \frac{1}{(30-x)^2}$

$\frac{2}{x} = \frac{1}{30-x}$

Step 5: Solve for x by cross-multiplication:

$2(30 - x) = x$

$60 - 2x = x$

$3x = 60$

$x = 20cm$

The null point is located $20cm$ from the larger charge and $10cm$ from the smaller charge.

Final Answer: $\boxed{20cm}$

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:

When a dielectric slab is inserted into a capacitor, the capacitance increases. If the slab fills only a portion of the thickness, the setup acts like two capacitors in series. The capacitance of a parallel plate capacitor is $C = \frac{\epsilon_0 A}{d}$. With a slab of thickness t and dielectric constant K, the new capacitance is $C' = \frac{\epsilon_0 A}{(d-t)+t/K}$.

Solution:

Step 1: Given the initial capacitance $C = \frac{\epsilon_0 A}{d} = 10\mu F$.

Step 2: A dielectric slab of $K = 2$ is inserted to fill half the distance, so $t = d/2$. Identify the new expression for capacitance:

$C' = \frac{\epsilon_0 A}{(d-d/2)+(d/2)/K}$

Step 3: Substitute $K = 2$ and simplify the denominator:

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

$C' = \frac{\epsilon_0 A}{3d/4} = \frac{4}{3}\left(\frac{\epsilon_0 A}{d}\right)$

Step 4: Substitute the initial value of C into the expression:

$C' = \frac{4}{3} \times 10\mu F$

$C' = 13.33\mu F$

Step 5: Alternatively, viewing this as two capacitors in series: C_1 (air) with distance $d/2$ and C_2 (dielectric) with distance $d/2$.

$C_1 = 2C = 20\mu F$

$C_2 = K(2C) = 2 \times 20 = 40\mu F$

$C_{eq} = \frac{C_1 C_2}{C_1+C_2} = \frac{20\times 40}{60} = \frac{800}{60} = 13.3\mu F$.

Final Answer: $\boxed{13.3\mu F}$

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept:

When a wire is stretched, its length increases while its volume remains constant. Resistance R is given by $\rho\frac{L}{A}$. Since volume $V = A \times L$ is constant, as L increases, A must decrease proportionally ($A = V/L$). Substituting this into the resistance formula shows that R is proportional to the square of the length ($R \propto L^2$).

Solution:

Step 1: Start with the formula for resistance $R = \rho\frac{L}{A}$. Multiply numerator and denominator by L to express it in terms of volume:

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

Step 2: Since resistivity ρ and volume V are constant during stretching, we establish the ratio:

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

Step 3: According to the problem, the wire is stretched to thrice its original length, so $L_2 = 3L_1$.

$\frac{R_2}{10} = \left(\frac{3L_1}{L_1}\right)^2$

Step 4: Calculate the square:

$\frac{R_2}{10} = 3^2 = 9$

Step 5: Solve for the new resistance R_2:

$R_2 = 10 \times 9 = 90\Omega$

The resistance increases ninefold because the length triples and the cross-sectional area simultaneously reduces to one-third of its original value.

Final Answer: $\boxed{90\Omega}$

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:

The magnetic field at a distance x on the axis of a circular current-carrying coil of radius R is given by $B_x = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$. At the center ($x = 0$), the field is $B_0 = \frac{\mu_0 I}{2R}$. By comparing these two expressions, we can find the distance x where the field is a specific fraction of the center field.

Solution:

Step 1: Write the ratio of the axial field to the center field:

$\frac{B_x}{B_0} = \frac{R^3}{(R^2+x^2)^{3/2}}$

Step 2: Given that the axial field is 1/8 of the center field ($B_x = B/8$ and $B_0 = B$):

$\frac{1}{8} = \frac{R^3}{(R^2+x^2)^{3/2}}$

Step 3: Take the cube root of both sides of the equation:

$\left(\frac{1}{8}\right)^{1/3} = \left(\frac{R^3}{(R^2+x^2)^{3/2}}\right)^{1/3}$

$\frac{1}{2} = \frac{R}{(R^2+x^2)^{1/2}}$

Step 4: Square both sides to eliminate the square root:

$\frac{1}{4} = \frac{R^2}{R^2+x^2}$

$R^2 + x^2 = 4R^2$

Step 5: Solve for x:

$x^2 = 3R^2$

$x = R\sqrt{3}$

Thus, at a distance of $\sqrt{3}$ times the radius along the axis, the magnetic intensity drops to one-eighth of its maximum value.

Final Answer: $\boxed{R\sqrt{3}}$

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept:

The angle of dip (θ) at a point on the Earth's surface is the angle that the total magnetic field vector makes with the horizontal direction. It is related to the horizontal component (B_H) and vertical component (B_V) of the Earth's magnetic field by the trigonometric relation $\tan\theta = \frac{B_V}{B_H}$.

Solution:

Step 1: Identify the relationship provided in the problem statement:

$B_H = \sqrt{3}B_V$

Step 2: Use the standard formula for the angle of dip:

$\tan\theta = \frac{B_V}{B_H}$

Step 3: Substitute the expression for B_H from Step 1 into the formula:

$\tan\theta = \frac{B_V}{\sqrt{3}B_V}$

Step 4: Simplify the fraction by canceling B_V:

$\tan\theta = \frac{1}{\sqrt{3}}$

Step 5: Find the angle θ whose tangent is $1/\sqrt{3}$:

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

$\theta = 30^\circ$

The magnetic field at this location is tilted 30 degrees below or above the horizontal plane.

Final Answer: $\boxed{30^\circ}$

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept:
Motional electromotive force (emf) is induced in a conductor when it moves through a magnetic field. For a straight conductor of length L moving with velocity v perpendicular to a uniform magnetic field B, the induced emf is given by $\epsilon = Blv$. For a square loop, only the sides that cut the magnetic flux lines contribute to the net induced emf.

Solution:
Step 1: Identify the given physical parameters.
Side of the square loop $l = 10cm = 0.1m$
Magnetic field $B = 0.1T$
Velocity $v = 2m/s$

Step 2: When the loop is entering the field, one side of the square is within the field and moving perpendicular to the flux lines. This side acts as a source of emf.

Step 3: Apply the formula for motional emf:
$\epsilon = Blv$

Step 4: Substitute the values into the equation:
$\epsilon = 0.1 \times 0.1 \times 2$
$\epsilon = 0.01 \times 2$

Step 5: Calculate the final result:
$\epsilon = 0.02V$
Once the loop is fully inside the uniform field, the induced emfs in the opposite sides cancel each other out, resulting in a net emf of zero. However, while entering, the induced emf is $0.02V$.

Final Answer: $\boxed{0.02V}$

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept:

The refractive index (n) of a medium is defined as the ratio of the speed of light (or any electromagnetic wave) in a vacuum (c) to its speed in that specific medium (v). This relationship is expressed as $n = c/v$. This value is always greater than or equal to 1 because the speed of light is maximum in a vacuum.

Solution:

Step 1: Write the definition of the refractive index:

$n = \frac{\text{Speed in vacuum (c)}}{\text{Speed in medium (v)}}$

Step 2: Identify the given refractive index for the medium:

$n = 1.5$

Step 3: Express the ratio requested in the question, which is the ratio of speed in vacuum to speed in the medium:

$\text{Ratio} = \frac{c}{v}$

Step 4: From the definition in Step 1, it is clear that this ratio is exactly equal to the refractive index n.

$\text{Ratio} = 1.5$

Step 5: Convert this numerical value into a standard ratio format:

$\text{Ratio} = 1.5 : 1$

Alternatively, this can be written as $3 : 2$. Comparing this with the provided options, $1.5 : 1$ is the correct representation.

Final Answer: $\boxed{1.5 : 1}$

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept:

For a concave mirror, the nature and position of the image depend on the position of the object relative to the focal point (F) and the center of curvature (C). If an object is placed between C and F (where $C = 2f$), the image formed is real, inverted, and magnified, located beyond C.

Solution:

Step 1: Identify the mirror parameters.

Focal length $f = 15cm$

Center of curvature $C = 2f = 30cm$

Object distance $u = 20cm$ (placed in front of the mirror)

Step 2: Compare the object position with the key points.

Since $15cm < 20cm < 30cm$, the object is located between the focus and the center of curvature.

Step 3: Use the mirror formula to find the image distance v:

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

Using sign convention: $u = -20$, $f = -15$

$\frac{1}{v} + \frac{1}{-20} = \frac{1}{-15}$

$\frac{1}{v} = \frac{1}{20} - \frac{1}{15} = \frac{3-4}{60} = -\frac{1}{60}$

$v = -60cm$

Step 4: Calculate the magnification m:

$m = -\frac{v}{u} = -\frac{-60}{-20} = -3$

Step 5: Interpret the results. The negative sign for v indicates a real image formed in front of the mirror. The negative sign for m indicates the image is inverted. Since $|m| > 1$, the image is magnified.

Final Answer: Real, inverted and magnified

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept:
In Young's Double Slit Experiment, the fringe width (β) is given by $\beta = \frac{\lambda D}{d}$, where λ is the wavelength, D is the distance to the screen, and d is the slit separation. When the experiment is immersed in a medium of refractive index n, the wavelength changes to $\lambda' = \lambda/n$, while D and d remain constant.

Solution:
Step 1: Express the initial fringe width in air:
$\beta_{air} = \frac{\lambda D}{d} = 0.4mm$

Step 2: Express the new fringe width in water:
$\beta_{water} = \frac{\lambda' D}{d} = \frac{(\lambda/n)D}{d}$

Step 3: Relate the two fringe widths:
$\beta_{water} = \frac{\beta_{air}}{n}$

Step 4: Substitute the given values ($n = 4/3$ for water):
$\beta_{water} = \frac{0.4}{4/3}$

Step 5: Perform the calculation:
$\beta_{water} = 0.4 \times \frac{3}{4}$
$\beta_{water} = 0.1 \times 3 = 0.3mm$
The reduction in fringe width occurs because the wavelength of light decreases when it enters a denser medium.

Final Answer: $\boxed{0.3mm}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:
Einstein's photoelectric equation relates the stopping potential V_0 to the incident light frequency and the work function ϕ. It is given by $eV_0 = \frac{hc}{\lambda} - \phi$. By setting up equations for two different wavelengths, we can eliminate the work function and solve for the threshold wavelength λ_0 (where $\phi = hc/\lambda_0$).

Solution:
Step 1: Set up the equations for the two cases given.
Case 1: $e(1.2) = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$
Case 2: $e(0.4) = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0}$

Step 2: Multiply Case 2 by 3 to match the voltage of Case 1:
$e(1.2) = \frac{3hc}{2\lambda} - \frac{3hc}{\lambda_0}$

Step 3: Equate the two expressions for $e(1.2)$:
$\frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{3hc}{2\lambda} - \frac{3hc}{\lambda_0}$

Step 4: Cancel hc and rearrange the terms to isolate λ_0:
$\frac{3}{\lambda_0} - \frac{1}{\lambda_0} = \frac{3}{2\lambda} - \frac{1}{\lambda}$
$\frac{2}{\lambda_0} = \frac{3-2}{2\lambda}$
$\frac{2}{\lambda_0} = \frac{1}{2\lambda}$

Step 5: Solve for λ_0:
$\lambda_0 = 4\lambda$
This means the maximum wavelength that can cause electron emission from this metal is four times the initial wavelength used.

Final Answer: $\boxed{4\lambda}$

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:

The wavelength (λ) of radiation emitted during an electronic transition in a hydrogen atom is given by the Rydberg formula: $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$, where R is the Rydberg constant, n_i is the initial orbit, and n_f is the final orbit. By comparing the wavelengths of two different transitions, we can find the ratio between them.

Solution:

Step 1: Write the equation for the first transition from $n = 3$ to $n = 2$:

$\frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{1}{4} - \frac{1}{9}\right)$

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

$\lambda_1 = \frac{36}{5R}$ (Given as λ)

Step 2: Write the equation for the second transition from $n = 4$ to $n = 2$:

$\frac{1}{\lambda_2} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = R\left(\frac{1}{4} - \frac{1}{16}\right)$

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

$\lambda_2 = \frac{16}{3R}$

Step 3: Relate λ_2 to λ_1 by dividing the two expressions:

$\frac{\lambda_2}{\lambda_1} = \frac{16/3R}{36/5R} = \frac{16}{3} \times \frac{5}{36}$

Step 4: Simplify the resulting fraction:

$\frac{\lambda_2}{\lambda} = \frac{4\times5}{3\times9} = \frac{20}{27}$

Step 5: Solve for λ_2:

$\lambda_2 = \frac{20}{27}\lambda$

The wavelength for the $4 \rightarrow 2$ transition is shorter than the $3 \rightarrow 2$ transition because the energy difference is greater.

Final Answer: $\boxed{(20/27)\lambda}$

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept:

Radioactive decay follows an exponential law where the activity (A) after time t is given by $A = A_0(1/2)^n$, where n is the number of half-lives that have passed. The number of half-lives is calculated as $n = t/T_{1/2}$, where $T_{1/2}$ is the half-life period.

Solution:

Step 1: Identify the given information.
Half-life $T_{1/2} = 20$ minutes.
Final activity $A = \frac{1}{16}A_0$.

Step 2: Use the relation for the fraction of activity remaining:
$\frac{A}{A_0} = \left(\frac{1}{2}\right)^n$
$\frac{1}{16} = \left(\frac{1}{2}\right)^n$

Step 3: Express $1/16$ as a power of $1/2$ to find the number of half-lives:
$\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$
$n = 4$

Step 4: Calculate the total time t using the value of n:
$t = n \times T_{1/2}$
$t = 4 \times 20$

Step 5: Perform the multiplication:
$t = 80$ minutes.
After 80 minutes, the substance has undergone four successive reductions by half, leaving only 6.25% of the original activity.

Final Answer: $\boxed{80 \text{ min}}$

Answer: (C)

Go Back to Question 27

Q28.

Solution

Concept:

In a Common Emitter (CE) configuration of a transistor, the current gain (β) is defined as the ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B). This is expressed by the formula $\beta = \frac{\Delta I_C}{\Delta I_B}$. This parameter quantifies the amplification capability of the transistor.

Solution:

Step 1: Identify the given values from the problem statement:

Current gain $\beta = 100$

Change in base current $\Delta I_B = 20\mu A = 20 \times 10^{-6} A$

Step 2: Rearrange the β formula to solve for the change in collector current:

$\Delta I_C = \beta \times \Delta I_B$

Step 3: Substitute the numerical values into the equation:

$\Delta I_C = 100 \times (20 \times 10^{-6} A)$

$\Delta I_C = 2000 \times 10^{-6} A$

Step 4: Convert the result into milliamperes (mA) for standard representation:

$\Delta I_C = 2 \times 10^{-3} A$

$\Delta I_C = 2mA$

Step 5: Conclude that a small change in the input base current leads to a significantly larger change in the output collector current, which is the fundamental principle of amplification.

Final Answer: $\boxed{2mA}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept:
According to the Work-Energy Theorem, the work done by the force of friction is equal to the change in kinetic energy (ΔK). If the engines are switched off, the only horizontal force is friction $f = \mu N = \mu mg$. The stopping distance s can be found from the equation $f \times s = K$, where K is the initial kinetic energy.

Solution:
Step 1: Write the work-energy relation for the stopping process:
Work done by friction = Initial Kinetic Energy
$f \times s = K$

Step 2: Substitute the expression for friction $f = \mu mg$:
$(\mu mg) \times s = K$

Step 3: Rearrange the equation to solve for the stopping distance s:
$s = \frac{K}{\mu mg}$

Step 4: Analyze the dependency of s. The problem states both vehicles have the same kinetic energy K. Assuming the coefficient of friction μ and g are the same for both:
$s \propto \frac{1}{m}$

Step 5: Compare the masses of the truck and the car.
Since Mass of truck (M) > Mass of car (m), the stopping distance for the truck will be smaller.
$s_{truck} < s_{car}$
The heavier vehicle (truck) experiences a much larger frictional force for the same kinetic energy, causing it to dissipate its energy over a shorter distance.

Final Answer: The truck

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept:

The dimensions of magnetic permeability (μ_0) can be derived from several physical laws, such as Biot-Savart Law or the force between two parallel current-carrying wires. The force per unit length between two wires is $F/L = \frac{\mu_0 I_1 I_2}{2\pi d}$. We use this relation to isolate the dimensions of μ_0.

Solution:

Step 1: Start with the formula for force between two parallel wires:
$F = \frac{\mu_0 I^2 L}{2\pi d}$

Step 2: Rearrange the formula to solve for μ_0:
$\mu_0 = \frac{2\pi d F}{I^2 L}$

Step 3: Substitute the dimensions of each physical quantity:
Dimensions of Distance $[d] = [L]$
Dimensions of Force $[F] = [MLT^{-2}]$
Dimensions of Current $[I] = [A]$
Dimensions of Length $[L] = [L]$

Step 4: Combine these into the expression for μ_0:
$[\mu_0] = \frac{[L][MLT^{-2}]}{[A]^2[L]}$

Step 5: Simplify the dimensions by canceling the common terms:
$[\mu_0] = [MLT^{-2}A^{-2}]$
This confirms that magnetic permeability involves mass, length, time, and electric current in its fundamental definition.

Final Answer: $\boxed{[MLT^{-2}A^{-2}]}$

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept:

This problem involves two distinct phases: a perfectly inelastic collision and vertical circular motion. First, we use the Principle of Conservation of Linear Momentum to find the velocity of the system immediately after the bullet embeds. Second, we use the Work-Energy Theorem to determine the minimum velocity required at the lowest point for the system to complete a full vertical circle.

Solution:

Step 1: Let v be the initial velocity of the bullet and V be the velocity of the (bullet + block) system immediately after collision. By conservation of momentum:

$mv + M(0) = (m + M)V$

$V = \frac{mv}{m+M}$

Step 2: To complete a vertical circle of radius L, the minimum velocity V_{min} required at the lowest point is $\sqrt{5gL}$. This condition ensures that the string remains taut even at the highest point of the trajectory.

Step 3: Set the velocity after collision V equal to the required minimum velocity:

$\frac{mv}{m+M} = \sqrt{5gL}$

Step 4: Rearrange the equation to solve for the initial velocity v of the bullet:

$v = \left(\frac{m+M}{m}\right)\sqrt{5gL}$

Step 5: This result illustrates that because the collision is inelastic, a significant portion of the bullet's initial kinetic energy is lost as heat, requiring a much higher initial velocity than if the energy were conserved.

Final Answer: $\boxed{\dfrac{m+M}{m}\sqrt{5gL}}$

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept:
The motion of the rod is a pure rotation about a fixed pivot. Since there are no non-conservative forces like friction, we apply the Principle of Conservation of Mechanical Energy. The loss in gravitational potential energy of the rod as its center of mass descends is equal to the gain in its rotational kinetic energy.

Solution:
Step 1: Identify the change in position of the Center of Mass (COM). A uniform rod of length L has its COM at $L/2$. In the horizontal position, the height is $L/2$ relative to the vertical position.

Step 2: Write the energy conservation equation:
Loss in $P.E.$ = Gain in $R.K.E.$
$Mg(\frac{L}{2}) = \frac{1}{2}I\omega^2$

Step 3: Substitute the moment of inertia for a rod pivoted at one end, which is $I = \frac{1}{3}ML^2$:
$Mg\frac{L}{2} = \frac{1}{2}\left(\frac{1}{3}ML^2\right)\omega^2$

Step 4: Simplify the equation by canceling M and one L, then rearrange to solve for ω:
$\frac{gL}{2} = \frac{1}{6}L^2\omega^2$
$\frac{3g}{L} = \omega^2$

Step 5: Take the square root to find the final angular velocity:
$\omega = \sqrt{3g/L}$
This shows the rod's rotation speed depends only on the acceleration due to gravity and the length of the rod.

Final Answer: $\boxed{\sqrt{3g/L}}$

Answer: (C)

Go Back to Question 32

Q33.

Solution

Concept:
When a capillary tube is tilted, the vertical height (h) of the liquid column remains constant to maintain the pressure balance against atmospheric pressure. However, because the tube is at an angle, the actual length (l) of the liquid column along the tube must increase so that its vertical component still equals the original height.

Solution:
Step 1: Let h be the vertical height of the liquid column when the tube is vertical.
$h = 10cm$

Step 2: Let l be the length of the liquid column when the tube is inclined at an angle α with the vertical. The relationship between the vertical height and the slanted length is:
$h = l \cos\alpha$

Step 3: Rearrange the formula to solve for the new length l:
$l = \frac{h}{\cos\alpha}$

Step 4: Substitute the given values ($h = 10cm$ and $\alpha = 60°$):
$l = \frac{10}{\cos 60°}$

Step 5: Use the value $\cos 60° = 1/2$:
$l = \frac{10}{0.5} = 20cm$
Thus, while the vertical height remains $10cm$ to balance the surface tension, the liquid travels $20cm$ along the tilted path of the tube.

Final Answer: $\boxed{20cm}$

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:

An ideal heat engine (Carnot engine) follows the efficiency relation $\eta = 1 - \frac{T_L}{T_H}$, where T_L and T_H are the absolute temperatures of the sink and source respectively. Additionally, efficiency is defined as the ratio of work done (W) to the heat absorbed (Q_H) from the source: $\eta = W/Q_H$.

Solution:

Step 1: Convert the given temperatures from Celsius to Kelvin:
$T_H = 227 + 273 = 500K$
$T_L = 127 + 273 = 400K$

Step 2: Calculate the efficiency of the engine:
$\eta = 1 - \frac{400}{500} = 1 - 0.8 = 0.2$
This means 20% of the absorbed heat is converted into useful work.

Step 3: Use the relationship between work, heat, and efficiency:
$W = \eta \times Q_H$

Step 4: Substitute the given value of heat absorbed $Q_H = 6 \times 10^4 J$:
$W = 0.2 \times (6 \times 10^4 J)$

Step 5: Perform the calculation:
$W = 1.2 \times 10^4 J$
The remaining $4.8 \times 10^4 J$ of energy is exhausted to the sink as waste heat.

Final Answer: $\boxed{1.2 \times 10^4 J}$

Answer: (A)

Go Back to Question 34

Q35.

Solution

Concept:

The Q-factor (Quality factor) of a series LCR circuit measures the sharpness of resonance. It is defined as the ratio of the resonant frequency to the bandwidth. Mathematically, it is expressed in terms of the circuit components as $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$. A higher Q-factor indicates lower energy loss relative to the energy stored.

Solution:

Step 1: Identify the given values for the components:

Resistance $R = 10\Omega$

Inductance $L = 2mH = 2 \times 10^{-3}H$

Capacitance $C = 5\mu F = 5 \times 10^{-6}F$

Step 2: Substitute these values into the Q-factor formula:

$Q = \frac{1}{10}\sqrt{\frac{2\times10^{-3}}{5\times10^{-6}}}$

Step 3: Simplify the expression inside the square root:

$\frac{2\times10^{-3}}{5\times10^{-6}} = \frac{2}{5} \times 10^3 = 0.4 \times 1000 = 400$

Step 4: Calculate the square root:

$\sqrt{400} = 20$

Step 5: Divide by the resistance value:

$Q = \frac{1}{10} \times 20 = 2$

A Q-factor of 2 suggests that the circuit is moderately damped and the resonance peak is not extremely sharp.

Final Answer: $\boxed{2}$

Answer: (A)

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Q36.

Solution

Concept:
An adiabatic process is a thermodynamic transition in which no heat is exchanged between the system and its surroundings ($\Delta Q = 0$). For an ideal gas, this process is governed by Poisson's relations, which link pressure, volume, and temperature using the adiabatic index γ (ratio of specific heats). These relations describe how the internal energy change is solely due to work done.

Solution:
Step 1: The fundamental definition of an adiabatic process is that the system is thermally insulated, meaning:
$\Delta Q = 0$

Step 2: From the first law of thermodynamics ($\Delta Q = \Delta U + W$), since $\Delta Q = 0$, we have $W = -\Delta U$. For an ideal gas, this leads to the relation between pressure and volume:
$PV^{\gamma} = \text{constant}$

Step 3: Using the ideal gas law $PV = nRT$, we can substitute $P = nRT/V$ into the previous equation:
$(nRT/V)V^{\gamma} = \text{constant}$
$TV^{\gamma-1} = \text{constant}$

Step 4: Similarly, substituting $V = nRT/P$ into $PV^{\gamma} = \text{constant}$:
$P(nRT/P)^{\gamma} = \text{constant}$
$P^{1-\gamma}T^{\gamma} = \text{constant}$

Step 5: Reviewing the options provided in the question, all statements (A), (B), (C), and (D) are mathematically and physically correct descriptions of an ideal gas undergoing an adiabatic change.

Final Answer: A, B, C, D (All are correct)

Answer: (A,B,C,D)

Go Back to Question 36

Q37.

Solution

Concept:
In Simple Harmonic Motion (SHM), the mean position is defined as the point where the net restoring force is zero. At this point, the displacement from equilibrium is zero. Because the force is zero, the acceleration is also zero. However, the kinetic energy is at its maximum because the potential energy has been entirely converted into motion.

Solution:
Step 1: Analyze the displacement x. By definition, at the mean position:
$x = 0$

Step 2: Analyze the acceleration a. In SHM, $a = -\omega^2 x$. Substituting $x = 0$:
$a = 0$
Thus, acceleration is minimum (zero), not maximum, at the mean position.

Step 3: Analyze the velocity v. The velocity in SHM is given by $v = \omega\sqrt{A^2 - x^2}$. At $x = 0$:
$v = \omega A$ (Maximum velocity)

Step 4: Analyze the Potential Energy (U). The potential energy is $U = \frac{1}{2}kx^2$. At $x = 0$:
$U = 0$
Since potential energy cannot be negative in this system, zero is its minimum value.

Step 5: Comparing these findings with the options: (A) displacement is zero, (C) velocity is maximum, and (D) potential energy is minimum are all true statements regarding the mean position.

Final Answer: $\boxed{\text{A, C, D}}$

Answer: (A,C,D)

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Q38.

Solution

Concept:

When a capacitor (C) is charged through a resistor (R) by a DC source (V), the charge q and current I vary over time. The time constant $\tau = RC$ determines the rate of charging. The charge grows towards its maximum value $Q_0 = CV$, while the current starts at a maximum and decays toward zero.

Solution:

Step 1: The equation for the instantaneous charge $q(t)$ during charging is:

$q(t) = Q_0(1 - e^{-t/RC})$

This indicates that the charge increases exponentially toward a steady state.

Step 2: The instantaneous current $I(t)$ is the derivative of charge:

$I(t) = \frac{dq}{dt} = \frac{V}{R}e^{-t/RC}$

This shows that the current decreases exponentially from its initial value $I_0 = V/R$.

Step 3: Evaluate the state at $t = \tau = RC$:

$q(RC) = Q_0(1 - e^{-1}) \approx Q_0(1 - 0.37) = 0.63Q_0$

This confirms that the charge reaches approximately 63% of its maximum value after one time constant.

Step 4: Analyze the voltage across the resistor V_R. Since $V_R = I(t)R$:

$V_R = Ve^{-t/RC}$

The voltage across the resistor is not constant; it decreases as the capacitor charges.

Step 5: Based on this analysis, options (A), (B), and (C) are correct statements regarding the RC charging circuit behavior.

Final Answer: A, B, C

Answer: (A,B,C)

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Q39.

Solution

Concept:
Bohr's model of the hydrogen atom introduced the quantization of atomic properties. It assumes electrons move in circular orbits where the centripetal force is provided by the Coulombic attraction of the nucleus. The model successfully explains the stability of atoms and the discrete nature of atomic spectra through specific postulates.

Solution:
Step 1: Bohr's first postulate states that the angular momentum L of an electron is quantized:
$L = n\frac{h}{2\pi}$
where n is an integer. Thus, statement (A) is correct.

Step 2: The model uses the electrostatic force for the circular orbit. For a nucleus of charge Ze and an electron of charge e:
$F = \frac{kZe^2}{r^2}$
Thus, statement (B) is correct.

Step 3: The kinetic energy $K.E.$ of an electron in the n-th orbit is:
$K.E. = \frac{13.6Z^2}{n^2}eV$
This shows $K.E. \propto 1/n^2$, making statement (C) correct.

Step 4: The total energy E of an electron in a bound state is negative:
$E = -\frac{13.6Z^2}{n^2}eV$
A negative total energy indicates that the electron is bound to the nucleus. Therefore, statement (D) is incorrect.

Step 5: The correct physical descriptions within Bohr's framework are found in statements (A), (B), and (C).

Final Answer: A, B, C

Answer: (A,B,C)

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Q40.

Solution

Concept:

A p-n junction diode is formed by joining p-type and n-type semiconductors. The interaction between charge carriers (holes and electrons) creates a depletion region and a built-in potential barrier. The behavior of this barrier changes significantly depending on the polarity of the external voltage applied (biasing).

Solution:

Step 1: Analyze forward bias. When the p-side is connected to the positive terminal, it repels holes toward the junction, and the n-side repels electrons toward the junction. This reduces the width of the depletion layer. Thus, statement (A) is correct.

Step 2: Analyze reverse bias. When the p-side is negative and the n-side is positive, majority carriers are pulled away from the junction. This increases the width of the depletion layer and the height of the potential barrier. Thus, statement (B) is correct.

Step 3: Distinguish between drift and diffusion currents. Diffusion current is caused by the concentration gradient of majority carriers (holes from p to n, electrons from n to p). Thus, statement (D) is correct.

Step 4: Drift current is caused by the electric field in the depletion region acting on minority carriers (holes from n to p, electrons from p to n). Therefore, statement (C) is incorrect because it attributes drift current to majority carriers.

Step 5: Consequently, the scientifically accurate statements regarding the p-n junction are (A), (B), and (D).

Final Answer: A, B, D

Answer: (A,B,D)

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Answer Key

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

Note: Section C (Q36–Q40): One or more correct options may be correct. Full marks only if all correct options are marked. Partial marking is not applicable.