

WBJEE Physics Sample Paper-2

Duration: 60 Minutes

Maximum Marks: 50

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Sections**.
- **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 dimensional formula for the coefficient of thermal conductivity is:

- (A) $[MLT^{-3}\theta^{-1}]$
- (B) $[ML^2T^{-3}\theta^{-1}]$
- (C) $[MLT^{-2}\theta^{-1}]$
- (D) $[ML^2T^{-2}\theta^{-1}]$

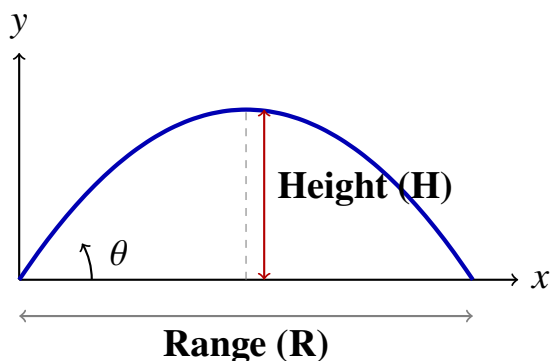
Q2. The density of a cube is measured by measuring its mass and the length of its sides. If the maximum errors in the measurement of mass and length are 3% and 2% respectively, the maximum error in the measurement of density is:

- (A) 5%
- (B) 7%



- (C) 9%
(D) 12%

Q3. A projectile is fired at an angle of 30° with the horizontal. The ratio of its maximum height to its horizontal range is:



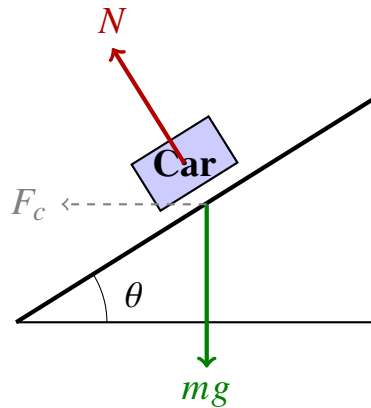
For a fixed launch angle, the height-to-range ratio is constant.

- (A) $1 : \sqrt{3}$
(B) $1 : 4\sqrt{3}$
(C) $\sqrt{3} : 4$
(D) $1 : 3$
- Q4.** A particle moves along a straight line such that its displacement x at any time t is given by $x = t^3 - 6t^2 + 3t + 4$ metres. The velocity of the particle when its acceleration is zero is:
- (A) 3 m/s
(B) -12 m/s
(C) 42 m/s
(D) -9 m/s
- Q5.** A block of mass 5 kg is placed on a rough horizontal surface ($\mu = 0.6$). A horizontal force of 20 N is applied to the block. The frictional force acting on the block is:
- (A) 30 N



- (B) 20 N
- (C) 10 N
- (D) Zero

Q6. A car of mass 1000 kg negotiates a banked curve of radius 90 m on a frictionless road. If the banking angle is 45° , the speed of the car is:



Normal force component provides the necessary centripetal force.

- (A) 20 m/s
- (B) 30 m/s
- (C) 5 m/s
- (D) 10 m/s

Q7. A spring of force constant k is cut into two equal halves. The force constant of each half is:

- (A) $k/2$
- (B) k
- (C) $2k$
- (D) $4k$

Q8. A uniform thin rod of mass M and length L is bent into a semi-circle. The moment of inertia of this semi-circle about an axis passing through its center and perpendicular to its plane is:



- (A) $ML^2/2\pi^2$
- (B) ML^2/π^2
- (C) $ML^2/4\pi^2$
- (D) $2ML^2/\pi^2$

Q9. The height at which the acceleration due to gravity becomes $g/9$ (where g is the acceleration due to gravity on the surface of the earth) in terms of the radius of the earth R is:

- (A) $R/2$
- (B) $2R$
- (C) $3R$
- (D) $4R$

Q10. Two wires A and B are of the same material. Their lengths are in the ratio $1 : 2$ and diameters are in the ratio $2 : 1$. If they are stretched by the same force, the ratio of their increase in length will be:

- (A) $2 : 1$
- (B) $1 : 4$
- (C) $1 : 8$
- (D) $8 : 1$

Q11. A spherical drop of water has radius 1 mm . If the surface tension of water is $70 \times 10^{-3} \text{ N/m}$, the difference of pressure between inside and outside of the spherical drop is:

- (A) 140 N/m^2
- (B) 70 N/m^2
- (C) 35 N/m^2
- (D) 280 N/m^2

Q12. If the temperature of an ideal gas is increased from 27°C to 927°C , the root mean square (RMS) speed of its molecules becomes:



- (A) Twice
- (B) Half
- (C) Four times
- (D) Three times

Q13. In an isothermal process, the internal energy of an ideal gas:

- (A) Increases
- (B) Decreases
- (C) Remains constant
- (D) First increases then decreases

Q14. The equation of a simple harmonic wave is given by $y = 3 \sin \frac{\pi}{2}(50t - x)$, where x and y are in metres and t is in seconds. The ratio of maximum particle velocity to the wave velocity is:

- (A) 2π
- (B) $3\pi/2$
- (C) 3π
- (D) 6π

Q15. An observer moves towards a stationary source of sound with a speed $1/5$ th of the speed of sound. The percentage increase in the apparent frequency is:

- (A) 5%
- (B) 20%
- (C) 10%
- (D) 50%

Q16. Two point charges $+9e$ and $+e$ are kept 16 cm apart. At what distance from $+9e$ charge should a third charge q be placed so that the system is in equilibrium?

- (A) 12 cm



- (B) 4 cm
- (C) 8 cm
- (D) 10 cm

Q17. The capacitance of a parallel plate capacitor becomes $4/3$ times its original value when a dielectric slab of thickness $t = d/2$ is inserted between the plates (where d is the separation). The dielectric constant of the slab is:

- (A) 2
- (B) 4
- (C) 3
- (D) 1.5

Q18. A wire of resistance R is stretched to double its length. The new resistance is:

- (A) $2R$
- (B) $4R$
- (C) $R/2$
- (D) $R/4$

Q19. A magnetic needle is kept in a non-uniform magnetic field. It experiences:

- (A) A force but not a torque
- (B) A torque but not a force
- (C) Both a force and a torque
- (D) Neither a force nor a torque

Q20. At a certain place, the horizontal component of the earth's magnetic field is B_0 and the angle of dip is 45° . The total intensity of the field at that place is:

- (A) B_0
- (B) $\sqrt{2}B_0$
- (C) $2B_0$



(D) $B_0/\sqrt{2}$

Q21. The peak value of an alternating current is $5\sqrt{2}$ A. Its RMS value is:

- (A) 5 A
- (B) 10 A
- (C) $5\sqrt{2}$ A
- (D) 2.5 A

Q22. Which of the following has the minimum wavelength?

- (A) X-rays
- (B) Ultraviolet rays
- (C) Gamma rays
- (D) Cosmic rays

Q23. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 40 cm. The power of the combination is:

- (A) +2.5 D
- (B) -2.5 D
- (C) +5.0 D
- (D) -5.0 D

Q24. In Young's double slit experiment, if the width of the slits are in the ratio 4 : 9, the ratio of maximum to minimum intensity in the interference pattern is:

- (A) 25 : 1
- (B) 16 : 81
- (C) 9 : 4
- (D) 4 : 9

Q25. The de-Broglie wavelength of an electron accelerated through a potential difference of 100 V is approximately:



- (A) 12.27 Å
- (B) 1.227 Å
- (C) 0.1227 Å
- (D) 122.7 Å

Q26. When a hydrogen atom emits a photon in going from $n = 5$ to $n = 1$, its recoil speed is nearly:

- (A) 10^{-4} m/s
- (B) 2×10^{-2} m/s
- (C) 4 m/s
- (D) 8×10^2 m/s

Q27. For a common emitter amplifier, the audio signal voltage across the collector resistance $2 \text{ k}\Omega$ is 2 V. If the current amplification factor is 100 and the base resistance is $1 \text{ k}\Omega$, the input signal voltage is:

- (A) 10 mV
- (B) 20 mV
- (C) 30 mV
- (D) 15 mV

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Category 2: Multi-Correct (2 Marks Each)

Q28. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_c is varying with time t as $a_c = k^2 r t^2$, where k is a constant. Which of the following is/are correct?

- (A) The velocity of the particle is $v = krt$.
- (B) The tangential force acting on the particle is mk^2r^2t .
- (C) The power delivered to the particle by the forces is mk^2r^2t .
- (D) The tangential acceleration is kr .



- Q29.** A solid sphere is rotating about an axis passing through its center. If the radius of the sphere expands due to heating, then:
- (A) Its angular momentum remains constant.
 - (B) Its angular velocity decreases.
 - (C) Its moment of inertia increases.
 - (D) Its rotational kinetic energy increases.
- Q30.** A capillary tube of radius r is immersed in water and water rises in it to a height h . The mass of water in the capillary tube is M . If the radius of the tube is doubled, then:
- (A) The height of the water level becomes $h/2$.
 - (B) The mass of water in the tube becomes $2M$.
 - (C) The potential energy of water in the tube becomes double.
 - (D) The mass of water in the tube remains M .

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

- Q31.** During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_p/C_v for the gas is:
- (A) $3/2$
 - (B) $4/3$
 - (C) $5/3$
 - (D) $7/5$
- Q32.** A heat engine operates between a cold reservoir at temperature $T_2 = 300$ K and a hot reservoir at temperature T_1 . It takes 200 J of heat from the hot reservoir and delivers 120 J of heat to the cold reservoir in a cycle. Which of the following is/are correct?



- (A) The efficiency of the engine is 40%.
- (B) The temperature of the hot reservoir is 500 K.
- (C) The work done per cycle is 80 J.
- (D) If it were a Carnot engine, the efficiency would be higher for the same T_1 and T_2 .

Q33. A particle executes SHM with amplitude A . At what displacement from the mean position is:

- (A) Kinetic energy equal to potential energy at $x = A/\sqrt{2}$.
- (B) Velocity half of maximum velocity at $x = \sqrt{3}A/2$.
- (C) Acceleration maximum at $x = A$.
- (D) Potential energy maximum at $x = 0$.

Q34. A parallel plate capacitor is charged and then disconnected from the source. If the distance between the plates is increased:

- (A) The capacitance decreases.
- (B) The potential difference increases.
- (C) The energy stored increases.
- (D) The electric field between the plates remains constant.

Q35. In a potentiometer experiment, the balancing length is l . Which of the following will increase the balancing length?

- (A) Increasing the resistance in the primary circuit.
- (B) Decreasing the resistance in the primary circuit.
- (C) Using a cell of higher EMF in the secondary circuit.
- (D) Increasing the length of the potentiometer wire.

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



- Q36.** For a cell of EMF E and internal resistance r connected to an external resistance R :
- (A) Power delivered to R is maximum when $R = r$.
 - (B) The maximum power is $E^2/4r$.
 - (C) Efficiency is 50% when power is maximum.
 - (D) Terminal voltage is $E/2$ when $R = r$.
- Q37.** A long straight wire carries a current I . A particle of charge q and mass m is projected with velocity v parallel to the wire at a distance d . The force on the particle is:
- (A) Directed towards the wire if q is positive and v is in the direction of I .
 - (B) Zero if v is perpendicular to the wire.
 - (C) $\frac{\mu_0 q v I}{2\pi d}$ in magnitude.
 - (D) Independent of the mass of the particle.
- Q38.** In a series LCR circuit at resonance:
- (A) The impedance is minimum.
 - (B) The current is in phase with the voltage.
 - (C) The voltage across L and C are equal and opposite.
 - (D) The power factor is unity.
- Q39.** In a Young's double slit experiment, if the entire apparatus is immersed in a liquid of refractive index μ :
- (A) The fringe width decreases.
 - (B) The angular fringe width decreases.
 - (C) The central fringe remains at the same position.
 - (D) The wavelength of light decreases.
- Q40.** In a photoelectric effect experiment, if the intensity of incident light is doubled:



- (A) The photoelectric current is doubled.
- (B) The maximum kinetic energy of photoelectrons remains the same.
- (C) The stopping potential remains the same.
- (D) The threshold frequency remains the same.



Detailed Solutions

Q1.

Solution

Concept:

Thermal conductivity represents the property of a material to conduct heat. To find its dimensions, we use the law of heat conduction, which states that the rate of heat flow through a material is proportional to the area of cross-section and the temperature gradient. By isolating the coefficient of thermal conductivity in the heat flow equation, we can substitute the fundamental dimensions of mass, length, time, and temperature to derive the final formula.

Solution:

- The rate of heat flow is given by the formula $dQ/dt = KA(dT/dx)$, where dQ is heat energy, dt is time, K is the coefficient of thermal conductivity, A is area, and dT/dx is the temperature gradient.
- Rearranging for K , we get the expression $K = (dQ \cdot dx)/(dt \cdot A \cdot dT)$. We now substitute the dimensions for each physical quantity involved.
- Heat energy dQ has dimensions of work, which is $[ML^2T^{-2}]$. The thickness dx has dimensions of length $[L]$. Time dt has the dimension $[T]$, area A has $[L^2]$, and temperature difference dT has $[\theta]$.
- Substituting these into the rearranged expression: $K = ([ML^2T^{-2}] \cdot [L])/([T] \cdot [L^2] \cdot [\theta])$.
- Simplifying the powers of L and T , we observe that L^2 in the numerator and denominator cancel out, leaving a single L term. The T in the denominator moves up as T^{-1} , combining with T^{-2} to form T^{-3} .

Final Answer: The dimensional formula is $[MLT^{-3}\theta^{-1}]$.

Answer: (A)

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Q2.

Solution**Concept:**

Error analysis in physics involves determining how uncertainties in individual measurements propagate through a calculation. For quantities related by multiplication or division, the relative errors are additive. When a variable is raised to a power, its relative error is multiplied by that power. Density is defined as the ratio of mass to volume, and for a cube, volume is the third power of the side length.

Solution:

- (a) The formula for the density of a cube is $\rho = m/V$. Since the volume of a cube is given by $V = L^3$, the expression becomes $\rho = m/L^3$.
- (b) According to the principle of error propagation for products and quotients, the maximum relative error in density is the sum of the relative error in mass and the relative error in volume.
- (c) For the volume term L^3 , the relative error is three times the relative error in the side length L . Thus, the total percentage error is expressed as: %error in $\rho =$ %error in $m + 3 \cdot$ (%error in L).
- (d) Substituting the given values from the problem: Maximum error in mass is 3% and maximum error in length is 2%.
- (e) Calculating the final result: $3\% + (3 \cdot 2\%) = 3\% + 6\% = 9\%$. This total represents the worst-case scenario for the uncertainty in the calculated density based on the precision of the initial measurements.

Final Answer: The maximum error in density is 9%.

Answer: (C)

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Q3.

Solution**Concept:**

Projectile motion involves two independent perpendicular components: a constant horizontal velocity and a vertical motion subject to constant acceleration due to gravity. Maximum height (H) and horizontal range (R) are two critical parameters of a trajectory. Both are functions of the initial velocity and the angle of projection. By taking the ratio of their respective formulas, the velocity term cancels out, leaving the ratio dependent solely on the launch angle.

Solution:

- The formula for the maximum height attained by a projectile is $H = (u^2 \sin^2 \theta)/2g$, where u is the initial velocity, θ is the angle of projection, and g is the acceleration due to gravity.
- The formula for the horizontal range is $R = (u^2 \sin 2\theta)/g$. Using the trigonometric identity $\sin 2\theta = 2 \sin \theta \cos \theta$, the range can be rewritten as $R = (2u^2 \sin \theta \cos \theta)/g$.
- To find the ratio H/R , we divide the two expressions: $(u^2 \sin^2 \theta/2g)/(2u^2 \sin \theta \cos \theta/g)$.
- Simplifying the ratio: The u^2 and g terms cancel out. One $\sin \theta$ term cancels, leaving $(\sin \theta/2)/(2 \cos \theta)$, which simplifies to $(\tan \theta)/4$.
- Given $\theta = 30^\circ$, we know $\tan 30^\circ = 1/\sqrt{3}$. Substituting this into our simplified ratio: $(1/\sqrt{3})/4 = 1/4\sqrt{3}$.

Final Answer: The ratio is $1 : 4\sqrt{3}$.

Answer: (B)

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Q4.

Solution**Concept:**

Kinematics describes the motion of objects using derivatives. Velocity is defined as the first derivative of displacement with respect to time, representing the rate of change of position. Acceleration is the second derivative of displacement (or the first derivative of velocity), representing the rate of change of velocity. To solve this problem, we must find the specific time when the acceleration function equals zero and then evaluate the velocity at that moment.

Solution:

- (a) Given the displacement equation $x = t^3 - 6t^2 + 3t + 4$. To find the velocity v , we differentiate x with respect to time t : $v = dx/dt = 3t^2 - 12t + 3$.
- (b) To find the acceleration a , we differentiate the velocity equation with respect to time t : $a = dv/dt = 6t - 12$.
- (c) The problem specifies the condition where acceleration is zero. Setting $a = 0$: $6t - 12 = 0$, which yields $t = 2$ seconds.
- (d) Now, we substitute this value of time back into the velocity equation to find the instantaneous velocity at $t = 2$: $v = 3(2)^2 - 12(2) + 3$.
- (e) Calculating the result: $v = 3(4) - 24 + 3 = 12 - 24 + 3 = -9$ m/s. The negative sign indicates the direction of motion relative to the chosen coordinate system.

Final Answer: The velocity is -9 m/s.

Answer: (D)

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Q5.

Solution**Concept:**

Friction is a resistive force that opposes the relative motion or the tendency of motion between two surfaces in contact. It is crucial to distinguish between static friction and kinetic friction. Static friction is a self-adjusting force that increases to match the applied force up to a maximum threshold known as limiting friction. Only if the applied force exceeds this limiting value will the object move, at which point kinetic friction takes over.

Solution:

- (a) First, we calculate the normal force N acting on the block. Since it is on a horizontal surface and no other vertical forces are mentioned, $N = mg = 5 \text{ kg} \cdot 10 \text{ m/s}^2 = 50 \text{ N}$ (using $g = 10$ for standard calculation).
- (b) Next, we determine the limiting friction f_{max} , which is the maximum value static friction can attain: $f_{max} = \mu N = 0.6 \cdot 50 \text{ N} = 30 \text{ N}$.
- (c) Now, we compare the applied horizontal force $F = 20 \text{ N}$ with the limiting friction $f_{max} = 30 \text{ N}$.
- (d) Since the applied force (20 N) is less than the limiting friction (30 N), the block will not move. It remains in a state of static equilibrium.
- (e) In this state, the actual frictional force acting on the block is not the limiting value, but rather exactly equal to the applied force to maintain equilibrium. Therefore, the frictional force must be 20 N acting in the opposite direction of the applied force.

Final Answer: The frictional force is 20 N.

Answer: (B)

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Q6.

Solution**Concept:**

Banked curves are an application of circular motion where the road surface is tilted at an angle to help vehicles negotiate turns without relying solely on friction. For a frictionless road, the horizontal component of the normal force provides the necessary centripetal force required to keep the car on its circular path. This specific speed is known as the optimum speed or the rated speed of the banked curve.

Solution:

- When a car moves on a banked road of inclination θ , the forces acting on it are the weight mg acting downwards and the normal force N acting perpendicular to the road surface.
- Resolving the normal force into two components: $N \cos \theta$ balances the weight mg , and $N \sin \theta$ acts towards the center of the circular path to provide the centripetal force mv^2/r .
- Dividing these two equations ($N \sin \theta = mv^2/r$ and $N \cos \theta = mg$) leads to the fundamental relationship for banking: $\tan \theta = v^2/rg$.
- Rearranging this equation to solve for velocity gives $v = \sqrt{rg \tan \theta}$. We now substitute the given values: radius $r = 90$ m, banking angle $\theta = 45^\circ$, and acceleration due to gravity $g \approx 10$ m/s².
- Since $\tan 45^\circ = 1$, the calculation becomes $v = \sqrt{90 \cdot 10 \cdot 1} = \sqrt{900} = 30$ m/s. At this speed, the car does not require any lateral frictional force to stay on the track.

Final Answer: The speed of the car is 30 m/s.

Answer: (B)

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Q7.

Solution**Concept:**

The force constant or spring constant (k) of a spring is an intrinsic property that defines its stiffness. It is inversely proportional to the natural length of the spring. This relationship stems from the fact that for a given material and wire thickness, a longer spring is more easily deformed than a shorter one because the total strain is distributed over a larger number of coils.

Solution:

- (a) The stiffness of a spring is mathematically defined by the relation $k \propto 1/L$, where L is the length of the spring. This implies that the product of the spring constant and the length remains constant ($k \cdot L = \text{constant}$).
- (b) Let the original spring have a length L and a force constant k . When the spring is cut into two equal halves, the length of each new spring segment becomes $L' = L/2$.
- (c) Let k' be the force constant of one of these halves. According to the inverse proportionality rule, we can set up the equation $k \cdot L = k' \cdot L'$.
- (d) Substituting $L' = L/2$ into the equation gives $k \cdot L = k' \cdot (L/2)$. Canceling L from both sides of the equation leads to $k = k'/2$.
- (e) Solving for the new constant, we find $k' = 2k$. This result shows that cutting a spring in half doubles its stiffness. This is a common point of confusion in physics, as many students mistakenly assume the constant remains the same regardless of length.

Final Answer: The force constant of each half is $2k$.

Answer: (C)

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Q8.

Solution**Concept:**

The moment of inertia (I) represents the rotational inertia of a body and depends on the distribution of mass relative to the axis of rotation. For a thin wire bent into various shapes, we must first determine the radius of the resulting figure in terms of its original length. Since the semi-circle is a subset of a full ring, its moment of inertia about the central perpendicular axis follows the same form as a ring.

Solution:

- A rod of length L is bent into a semi-circle. The length L corresponds to the circumference of a semi-circle, which is πR . Therefore, the radius of this semi-circle is $R = L/\pi$.
- The moment of inertia of a system of particles about an axis is given by the summation of mr^2 . For a thin semi-circular ring, every element of mass dm is at the same distance R from the center of curvature.
- Integrating over the entire mass M , the moment of inertia about the axis passing through the center and perpendicular to the plane is $I = \int R^2 dm = R^2 \int dm = MR^2$.
- Now, we substitute the expression for R that we derived in step 1: $I = M \cdot (L/\pi)^2$.
- Squaring the terms inside the parentheses results in $I = M \cdot (L^2/\pi^2)$, which simplifies to ML^2/π^2 . It is important to note that the moment of inertia of a semi-circle is the same as that of a full circle of the same mass and radius because the mass distribution relative to the axis is identical.

Final Answer: The moment of inertia is ML^2/π^2 .

Answer: (B)

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Q9.

Solution**Concept:**

The acceleration due to gravity (g) varies with the distance from the center of the Earth. As we move away from the Earth's surface, the gravitational force decreases according to the inverse-square law. For heights that are significant compared to the Earth's radius (R), we must use the general formula rather than the linear approximation often used for small altitudes.

Solution:

- The acceleration due to gravity at a height h above the Earth's surface is given by the formula $g' = g \cdot [R/(R + h)]^2$, where g is the acceleration at the surface ($h = 0$).
- The problem states that at a certain height, the acceleration becomes 1/9th of its surface value. Therefore, we set $g' = g/9$.
- Substituting this value into our formula: $g/9 = g \cdot [R/(R + h)]^2$. We can cancel g from both sides to get $1/9 = [R/(R + h)]^2$.
- To solve for h , we take the square root of both sides: $1/3 = R/(R + h)$. This eliminates the quadratic term and makes the equation linear.
- Cross-multiplying gives $R + h = 3R$. Solving for h by subtracting R from both sides yields $h = 2R$. This indicates that at an altitude equal to twice the radius of the Earth, the gravity is reduced to one-ninth of its surface value.

Final Answer: The height is $2R$.

Answer: (B)

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Q10.

Solution**Concept:**

The deformation of a solid under tension is described by Young's Modulus (Y), which is the ratio of tensile stress to tensile strain. For wires made of the same material, Young's Modulus is a constant. The elongation of a wire depends on the applied force, its length, its cross-sectional area, and the material's elastic properties. This problem requires comparing these variables for two different wires.

Solution:

- (a) The elongation ΔL is given by the formula $\Delta L = (F \cdot L)/(A \cdot Y)$. Since the cross-sectional area of a wire is $\pi D^2/4$, we can rewrite the elongation as $\Delta L \propto L/D^2$ for the same force and material.
- (b) We are given two wires A and B . Let their lengths be L_A, L_B and their diameters be D_A, D_B . The ratios are given as $L_A/L_B = 1/2$ and $D_A/D_B = 2/1$.
- (c) We want to find the ratio of their elongations: $\Delta L_A/\Delta L_B = (L_A/L_B) \cdot (D_B/D_A)^2$.
- (d) Notice that the diameter ratio is inverted in the elongation ratio because area is in the denominator. Substituting the given ratios: $\Delta L_A/\Delta L_B = (1/2) \cdot (1/2)^2$.
- (e) Calculating the final ratio: $1/2 \cdot 1/4 = 1/8$. Thus, the elongation of wire A is one-eighth that of wire B . This happens because although wire A is shorter, it is significantly thicker, making it much harder to stretch.

Final Answer: The ratio of increase in length is 1 : 8.

Answer: (C)

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Q11.

Solution**Concept:**

Surface tension is a property of liquid surfaces that causes them to behave like an elastic membrane. Because of this tension, the surface of a liquid drop tends to contract to the minimum possible area, which is a sphere. This contraction creates an internal pressure that is higher than the external atmospheric pressure. The difference between these two values is known as the excess pressure, and it is inversely proportional to the radius of the drop.

Solution:

- (a) For a liquid drop, there is only one free surface (the outer interface with air). The formula for excess pressure ΔP inside a spherical drop is given by $\Delta P = 2S/R$, where S is the surface tension and R is the radius.
- (b) We are given the radius $R = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}$ and the surface tension of water $S = 70 \times 10^{-3} \text{ N/m}$.
- (c) Substituting these values into the excess pressure formula: $\Delta P = (2 \times 70 \times 10^{-3}) / (1 \times 10^{-3})$.
- (d) The 10^{-3} terms in the numerator and denominator cancel out, simplifying the calculation to 2×70 .
- (e) This results in an excess pressure of 140 N/m^2 . It is important to note that if this were a soap bubble instead of a water drop, the excess pressure would be doubled ($4S/R$) because a bubble has two surfaces: one inner and one outer.

Final Answer: The difference of pressure is 140 N/m^2 .

Answer: (A)

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Q12.

Solution**Concept:**

The Kinetic Theory of Gases provides a microscopic explanation for macroscopic properties like temperature and pressure. According to this theory, the absolute temperature of an ideal gas is a direct measure of the average kinetic energy of its molecules. The root mean square (RMS) speed is the square root of the average of the squares of the speeds of the molecules, and it is a key parameter in describing the motion of gas particles.

Solution:

- (a) The formula for the root mean square speed of gas molecules is $v_{rms} = \sqrt{3RT/M}$, where R is the universal gas constant, T is the absolute temperature in Kelvin, and M is the molar mass.
- (b) From this formula, we can see that for a given gas, v_{rms} is directly proportional to the square root of its absolute temperature ($v_{rms} \propto \sqrt{T}$).
- (c) First, we must convert the given temperatures from Celsius to Kelvin. The initial temperature $T_1 = 27 + 273 = 300$ K. The final temperature $T_2 = 927 + 273 = 1200$ K.
- (d) We can now find the ratio of the speeds: $v_2/v_1 = \sqrt{T_2/T_1} = \sqrt{1200/300}$.
- (e) Simplifying the fraction inside the square root gives $\sqrt{4}$, which equals 2. This means the final RMS speed is twice the initial RMS speed. Increasing the temperature fourfold leads to a doubling of the molecule speed.

Final Answer: The RMS speed becomes twice.

Answer: (A)

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Q13.

Solution**Concept:**

Internal energy is a state function that, for an ideal gas, depends solely on its absolute temperature. This relationship is a consequence of the fact that ideal gas molecules are assumed to have no intermolecular forces of attraction, meaning there is no potential energy contribution to the internal energy. Therefore, the internal energy is entirely composed of the total kinetic energy of the molecules.

Solution:

- (a) According to Joule's Law for ideal gases, the internal energy U is a function of temperature T only ($U = f(T)$). For n moles of an ideal gas, the change in internal energy is given by $dU = nC_v dT$.
- (b) An isothermal process is defined as a thermodynamic process in which the temperature of the system remains constant throughout ($dT = 0$).
- (c) Since the temperature does not change during an isothermal process, the average kinetic energy of the molecules remains unchanged.
- (d) Substituting $dT = 0$ into the internal energy equation gives $dU = 0$. This implies that the change in internal energy is zero, meaning the internal energy remains constant.
- (e) In such a process, any heat added to the system is entirely converted into work done by the gas, as per the First Law of Thermodynamics ($Q = W + \Delta U$), since ΔU is zero. This principle is fundamental to understanding the behavior of heat engines and refrigerators.

Final Answer: The internal energy remains constant.

Answer: (C)

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Q14.

Solution**Concept:**

In wave mechanics, it is essential to distinguish between the wave velocity and the particle velocity. Wave velocity is the speed at which the disturbance or energy propagates through the medium. Particle velocity is the speed at which the individual molecules of the medium oscillate about their mean positions. While wave velocity is constant for a given medium and frequency, particle velocity varies sinusoidally with time and position.

Solution:

- (a) The given wave equation is $y = 3 \sin\left[\frac{\pi}{2}(50t - x)\right]$. This can be rewritten in the standard form $y = A \sin(\omega t - kx)$, where A is the amplitude, ω is the angular frequency, and k is the wave number.
- (b) By comparison, $A = 3$, $\omega = 50\pi/2 = 25\pi$, and $k = \pi/2$.
- (c) The wave velocity v is given by $v = \omega/k$. Substituting our values: $v = (25\pi)/(\pi/2) = 50$ m/s.
- (d) The particle velocity is the derivative of displacement with respect to time: $v_p = dy/dt = 3 \cdot \omega \cos(\omega t - kx)$. The maximum particle velocity is $v_{p(max)} = A\omega = 3 \cdot 25\pi = 75\pi$.
- (e) The ratio of maximum particle velocity to wave velocity is $v_{p(max)}/v = 75\pi/50$. Simplifying this fraction by dividing both terms by 25 gives $3\pi/2$. This ratio characterizes the steepness and energy density of the wave.

Final Answer: The ratio is $3\pi/2$.

Answer: (B)

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Q15.

Solution**Concept:**

The Doppler Effect describes the change in frequency or wavelength of a wave in relation to an observer who is moving relative to the wave source. When an observer moves toward a stationary source, they encounter wave fronts more frequently than if they were stationary. This results in an increase in the perceived frequency. The magnitude of this shift depends on the relative speed of the observer and the speed of sound in the medium.

Solution:

- (a) The apparent frequency f' heard by an observer moving with velocity v_o toward a stationary source is given by $f' = f \cdot [(v + v_o)/v]$, where f is the actual frequency and v is the speed of sound.
- (b) The problem states that the observer's speed is 1/5th of the speed of sound, so $v_o = v/5$.
- (c) Substituting this into the Doppler formula: $f' = f \cdot [(v + v/5)/v] = f \cdot [(6v/5)/v] = f \cdot (6/5)$.
- (d) To find the percentage increase, we first find the change in frequency: $\Delta f = f' - f = 6f/5 - f = f/5$.
- (e) The percentage increase is calculated as $(\Delta f/f) \times 100\% = (1/5) \times 100\% = 20\%$. This significant increase in pitch is a hallmark of relative approach between an observer and a source in acoustics.

Final Answer: The percentage increase is 20%.

Answer: (B)

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Q16.

Solution**Concept:**

Electrostatic equilibrium occurs when the net force on a charge is zero. For a system of two like charges, a third charge must be placed between them to experience opposing forces that cancel out. The position of this equilibrium point depends only on the magnitudes of the two fixed charges and the distance between them. This point is often called the neutral point, where the electric field intensity of the two charges is equal and opposite.

Solution:

- (a) Let the two charges be $Q_1 = +9e$ and $Q_2 = +e$, separated by a distance $r = 16$ cm. Let a third charge q be placed at a distance x from the $+9e$ charge.
- (b) The force exerted by Q_1 on q is $F_1 = kQ_1q/x^2$, and the force exerted by Q_2 on q is $F_2 = kQ_2q/(r-x)^2$.
- (c) For equilibrium, $F_1 = F_2$. This implies $(k \cdot 9e \cdot q)/x^2 = (k \cdot e \cdot q)/(16-x)^2$.
- (d) Canceling k , e , and q from both sides, we get $9/x^2 = 1/(16-x)^2$. To simplify, we take the square root of both sides: $3/x = 1/(16-x)$.
- (e) Cross-multiplying gives $3(16-x) = x$, which expands to $48 - 3x = x$. Solving for x , we find $4x = 48$, resulting in $x = 12$ cm. Thus, the charge should be placed 12 cm from the $+9e$ charge.

Final Answer: The distance is 12 cm.

Answer: (A)

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Q17.

Solution**Concept:**

Capacitance is the ability of a component to store electrical charge. Inserting a dielectric material between the plates of a capacitor increases its capacitance because the dielectric polarizes, creating an internal electric field that opposes the applied field, thereby reducing the net voltage. When a slab only partially fills the gap, the system behaves like two capacitors in series: one with air and one with the dielectric.

Solution:

- (a) The initial capacitance is $C_0 = \epsilon_0 A/d$. When a slab of thickness t and dielectric constant K is inserted, the new capacitance C is given by $C = \epsilon_0 A/[d - t + (t/K)]$.
- (b) According to the problem, $C = (4/3)C_0$ and $t = d/2$. Substituting these into the equation: $(4/3)(\epsilon_0 A/d) = \epsilon_0 A/[d - d/2 + (d/2K)]$.
- (c) Canceling $\epsilon_0 A$ and d from both sides: $4/(3d) = 1/[d/2 + d/2K]$. This simplifies to $4/3 = 1/[1/2 + 1/2K]$.
- (d) Inverting both sides: $3/4 = 1/2 + 1/2K$. Subtracting $1/2$ from $3/4$ gives $1/4 = 1/2K$.
- (e) Cross-multiplying results in $2K = 4$, which gives $K = 2$. Therefore, a material with a dielectric constant of 2 must be used to achieve the specified increase in capacitance.

Final Answer: The dielectric constant is 2.

Answer: (A)

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Q18.

Solution**Concept:**

The resistance of a conductor depends on its resistivity, length, and cross-sectional area. When a wire is stretched, its length increases while its cross-sectional area decreases simultaneously to maintain a constant volume. Since resistance is directly proportional to length and inversely proportional to area, both changes contribute to an increase in total resistance. This relationship is quadratic with respect to the stretching factor.

Solution:

- (a) The resistance is $R = \rho L/A$. Since the volume $V = AL$ is constant during stretching, we can express area as $A = V/L$. Substituting this into the resistance formula gives $R = \rho L^2/V$.
- (b) From this, we see that for a given wire, $R \propto L^2$.
- (c) Let the initial length be L_1 and the final length be $L_2 = 2L_1$. Let the initial resistance be R and the final resistance be R' .
- (d) Using the proportionality: $R'/R = (L_2/L_1)^2 = (2L_1/L_1)^2 = 2^2 = 4$.
- (e) Therefore, $R' = 4R$. The resistance increases by a factor of four because the length is doubled and the cross-sectional area is halved. This principle is vital in designing strain gauges and understanding the mechanical limits of electrical components.

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

Answer: (B)

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Q19.

Solution**Concept:**

A magnetic needle behaves like a magnetic dipole. In a magnetic field, it tends to align itself with the field lines. A torque is produced whenever the dipole is at an angle to the field, as the two poles experience forces in opposite directions. However, the net translational force depends on whether the field is uniform or non-uniform. In a uniform field, the forces on both poles are equal and opposite, resulting in zero net force.

Solution:

- (a) A magnetic needle consists of a north pole and a south pole of equal strength m . In a magnetic field B , the force on a pole is $F = mB$.
- (b) If the magnetic field is non-uniform, the magnetic field strength B_n at the north pole is different from the magnetic field strength B_s at the south pole ($B_n \neq B_s$).
- (c) Consequently, the forces $F_n = mB_n$ and $F_s = mB_s$ are unequal in magnitude. Since they are unequal and act in different directions, they cannot cancel each other out, resulting in a non-zero net translational force.
- (d) Additionally, because these forces act along different lines of action and are not aligned with the dipole axis, they create a net torque $\tau = \vec{M} \times \vec{B}$.
- (e) Thus, in a non-uniform magnetic field, the needle experiences both a force that pulls it toward regions of stronger field and a torque that rotates it. This is in contrast to a uniform field, where only torque is present.

Final Answer: It experiences both a force and a torque.

Answer: (C)

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Q20.

Solution**Concept:**

The Earth's magnetic field at any point can be resolved into two perpendicular components: the horizontal component (B_h) and the vertical component (B_v). The total magnetic field intensity (B) is the vector sum of these components. The angle that the total magnetic field makes with the horizontal is called the angle of dip (δ). By applying basic trigonometry to the vector triangle formed by these components, we can determine the total field strength.

Solution:

- The relationship between the horizontal component B_h , the total field B , and the angle of dip δ is given by the trigonometric function $B_h = B \cos \delta$.
- We are given that the horizontal component is B_0 and the angle of dip is 45° .
- Substituting these values into the formula: $B_0 = B \cos 45^\circ$.
- We know from trigonometry that $\cos 45^\circ = 1/\sqrt{2}$. Therefore, the equation becomes $B_0 = B \cdot (1/\sqrt{2})$.
- To find the total intensity B , we rearrange the equation: $B = B_0\sqrt{2}$. This shows that the total magnetic field is greater than the horizontal component by a factor of the square root of two when the dip is at a 45° angle. At the magnetic poles, where the dip is 90° , the horizontal component would be zero.

Final Answer: The total intensity is $\sqrt{2}B_0$.

Answer: (B)

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Q21.

Solution**Concept:**

Alternating current (AC) varies sinusoidally with time, meaning its value is constantly changing. To compare the heating effect of AC with that of direct current (DC), we use the Root Mean Square (RMS) value. The RMS value, also known as the virtual or effective value, represents the DC equivalent that would produce the same amount of heat in a given resistor over the same time period. For a pure sine wave, the RMS value is mathematically related to the peak value by a constant factor derived from integration over a full cycle.

Solution:

- The relationship between the peak value of current (I_0) and the RMS value (I_{rms}) for a sinusoidal alternating current is given by the formula $I_{rms} = I_0/\sqrt{2}$.
- In the given problem, the peak value of the alternating current is stated as $I_0 = 5\sqrt{2}$ A.
- Substituting this peak value into the RMS formula: $I_{rms} = (5\sqrt{2})/\sqrt{2}$.
- The $\sqrt{2}$ term in the numerator and the denominator cancel each other out perfectly.
- This leaves us with $I_{rms} = 5$ A. This means that an alternating current with a peak of approximately 7.07 A performs the same electrical work as a steady 5 A direct current. This distinction is critical in power engineering, as most AC ammeters and voltmeters are calibrated to display RMS values rather than peak values.

Final Answer: The RMS value is 5 A.

Answer: (A)

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Q22.

Solution**Concept:**

The electromagnetic spectrum encompasses all types of electromagnetic radiation, arranged according to frequency or wavelength. All electromagnetic waves travel at the speed of light in a vacuum, but they differ significantly in their energy levels. According to the Planck-Einstein relation, energy is directly proportional to frequency and inversely proportional to wavelength. Consequently, radiation with the highest energy and frequency will possess the shortest wavelength.

Solution:

- (a) The order of the electromagnetic spectrum from longest wavelength to shortest wavelength is: Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-rays, and Gamma rays.
- (b) Gamma rays are produced by nuclear transitions and subatomic particle interactions. They possess extremely high frequencies and, therefore, very short wavelengths, typically less than 10^{-11} metres.
- (c) While Cosmic rays (mentioned in option D) consist of high-energy particles like protons, when considering the electromagnetic wave categories provided in standard physics curricula, Gamma rays represent the high-energy extreme of the spectrum.
- (d) Comparing the options: X-rays have longer wavelengths than Gamma rays. Ultraviolet rays have longer wavelengths than X-rays.
- (e) Therefore, among the standard electromagnetic wave categories listed, Gamma rays have the highest frequency and the minimum wavelength. This extreme energy allows them to penetrate most materials, which is why they require heavy lead shielding for containment.

Final Answer: Gamma rays have the minimum wavelength.

Answer: (C)

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Q23.

Solution**Concept:**

The power of a lens (P) is a measure of its ability to converge or diverge light and is defined as the reciprocal of its focal length in metres. When two or more thin lenses are placed in contact, the total power of the combination is simply the algebraic sum of the individual powers of each lens. This principle allows opticians to combine different lenses to achieve a specific corrective effect. It is essential to use the correct sign convention: positive for converging (convex) lenses and negative for diverging (concave) lenses.

Solution:

- (a) First, we identify the focal lengths with their appropriate signs. The convex lens has $f_1 = +20 \text{ cm} = +0.2 \text{ m}$. The concave lens has $f_2 = -40 \text{ cm} = -0.4 \text{ m}$.
- (b) The power of the first lens is $P_1 = 1/f_1 = 1/0.2 = +5.0 \text{ D}$ (Dioptres).
- (c) The power of the second lens is $P_2 = 1/f_2 = 1/(-0.4) = -2.5 \text{ D}$.
- (d) The total power P of the combination is $P = P_1 + P_2$.
- (e) Substituting the values: $P = +5.0 + (-2.5) = +2.5 \text{ D}$. Since the result is positive, the combination behaves like a converging lens with a net focal length of 40 cm. This calculation is fundamental in the design of compound optical instruments like telescopes and camera lenses.

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

Answer: (A)

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Q24.

Solution**Concept:**

In Young's Double Slit Experiment, the interference pattern consists of bright and dark fringes. The intensity of light at any point on the screen depends on the amplitudes of the waves arriving from the two slits. The intensity of light passing through a slit is directly proportional to the width of that slit. When the waves interfere constructively, the amplitudes add up, leading to maximum intensity. When they interfere destructively, the amplitudes subtract, leading to minimum intensity.

Solution:

- (a) Let the widths of the two slits be w_1 and w_2 . The intensity of light from each slit is $I \propto w$. Therefore, $I_1/I_2 = w_1/w_2 = 4/9$.
- (b) Since intensity is proportional to the square of the amplitude ($I \propto a^2$), the ratio of the amplitudes is $a_1/a_2 = \sqrt{I_1/I_2} = \sqrt{4/9} = 2/3$.
- (c) The maximum intensity I_{max} occurs during constructive interference and is proportional to $(a_1 + a_2)^2$. The minimum intensity I_{min} occurs during destructive interference and is proportional to $(a_1 - a_2)^2$.
- (d) The ratio is $I_{max}/I_{min} = [(a_1 + a_2)/(a_1 - a_2)]^2$. Substituting $a_1 = 2$ and $a_2 = 3$ (or using their ratio): $[(2 + 3)/(3 - 2)]^2 = (5/1)^2 = 25/1$.
- (e) Thus, the ratio of maximum to minimum intensity is 25 : 1. A higher ratio indicates a pattern with better contrast or "visibility" of the fringes.

Final Answer: The ratio is 25 : 1.

Answer: (A)

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Q25.

Solution**Concept:**

Quantum mechanics postulates that every moving particle has an associated wave, a concept known as wave-particle duality. The wavelength of this matter wave is called the de-Broglie wavelength. For charged particles like electrons, this wavelength can be controlled by accelerating them through an electric potential. As the kinetic energy of the electron increases, its momentum increases, and its de-Broglie wavelength decreases.

Solution:

- (a) The de-Broglie wavelength λ is given by $\lambda = h/p$, where h is Planck's constant and p is momentum. For an electron of mass m and charge e accelerated through a potential V , the kinetic energy is $eV = p^2/2m$.
- (b) This gives the momentum $p = \sqrt{2meV}$. Substituting this into the wavelength formula: $\lambda = h/\sqrt{2meV}$.
- (c) By substituting the standard values for h , m , and e , we get a simplified practical formula for electrons: $\lambda = \sqrt{150/V}$ Å or $\lambda \approx 12.27/\sqrt{V}$ Å.
- (d) Given the potential difference $V = 100$ V.
- (e) Substituting V into the simplified formula: $\lambda = 12.27/\sqrt{100} = 12.27/10 = 1.227$ Å. This wavelength is in the same order of magnitude as the spacing between atoms in a crystal, which is why electron diffraction can be used to study crystal structures.

Final Answer: The wavelength is approximately 1.227 Å.

Answer: (B)

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Here are the detailed solutions for the next batch of five questions (Q26–Q30), formatted precisely according to your LaTeX template.



Q26.

Solution**Concept:**

When a hydrogen atom transitions from a higher energy state to a lower one, it emits a photon to conserve energy. Due to the principle of conservation of linear momentum, the atom must recoil in the opposite direction of the emitted photon. Since the atom was initially at rest, the magnitude of the momentum of the recoiling atom must be equal to the momentum of the emitted photon. This recoil speed, while very small compared to the speed of light, is a fundamental result of quantum mechanical conservation laws.

Solution:

- (a) First, we calculate the energy of the emitted photon (E) using the Bohr model formula: $E = 13.6(1/n_1^2 - 1/n_2^2)$ eV. For a transition from $n = 5$ to $n = 1$, $E = 13.6(1/1^2 - 1/5^2) = 13.6(1 - 1/25) = 13.6(24/25) \approx 13.056$ eV.
- (b) Convert this energy into Joules: $E \approx 13.056 \times 1.6 \times 10^{-19}$ J $\approx 2.09 \times 10^{-18}$ J.
- (c) The momentum of the photon (p_p) is given by $p_p = E/c$, where c is the speed of light (3×10^8 m/s). Thus, $p_p \approx (2.09 \times 10^{-18}) / (3 \times 10^8) \approx 6.96 \times 10^{-27}$ kg · m/s.
- (d) According to momentum conservation, the recoil momentum of the atom (p_a) equals the photon momentum ($p_a = mv$). The mass of a hydrogen atom (m) is approximately 1.67×10^{-27} kg.
- (e) Solving for recoil speed v : $v = p_p/m = (6.96 \times 10^{-27}) / (1.67 \times 10^{-27}) \approx 4.17$ m/s. Among the given options, 4 m/s is the closest approximation.

Final Answer: The recoil speed is nearly 4 m/s.

Answer: (C)

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Q27.

Solution**Concept:**

A common emitter (CE) amplifier uses a transistor to increase the amplitude of an input signal. The performance of the amplifier is characterized by various gains, including voltage gain (A_v) and current gain (β). Voltage gain is the ratio of the output signal voltage (across the collector resistor) to the input signal voltage (across the base-emitter junction). It can also be expressed as the product of the current gain and the resistance gain (the ratio of output resistance to input resistance).

Solution:

- (a) The voltage gain A_v is defined as V_{out}/V_{in} . From transistor theory, we also know $A_v = \beta \times (R_C/R_B)$, where β is the current amplification factor, R_C is the collector resistance, and R_B is the base (input) resistance.
- (b) We are given the following values: output voltage $V_{out} = 2 \text{ V}$, collector resistance $R_C = 2 \text{ k}\Omega = 2000\Omega$, base resistance $R_B = 1 \text{ k}\Omega = 1000\Omega$, and $\beta = 100$.
- (c) First, let us calculate the voltage gain: $A_v = 100 \times (2000/1000) = 100 \times 2 = 200$.
- (d) Now, we use the primary definition of voltage gain to find the input voltage: $A_v = V_{out}/V_{in} \implies 200 = 2/V_{in}$.
- (e) Solving for V_{in} : $V_{in} = 2/200 = 1/100 = 0.01 \text{ V}$. To convert this to millivolts, we multiply by 1000, giving 10 mV. This means a small change of 10 mV at the base results in a significantly larger 2 V change at the collector.

Final Answer: The input signal voltage is 10 mV.

Answer: (A)

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Q28.

Solution**Concept:**

Circular motion involves two types of acceleration: centripetal acceleration, which changes the direction of velocity, and tangential acceleration, which changes the magnitude of velocity. Centripetal acceleration (a_c) is always directed toward the center and is given by v^2/r . Tangential acceleration (a_t) is the rate of change of speed (dv/dt). The total force acting on the particle is the vector sum of the centripetal and tangential forces. Power is the rate at which work is done, typically calculated as the dot product of force and velocity.

Solution:

- (a) We are given $a_c = k^2 r t^2$. Since $a_c = v^2/r$, we can write $v^2/r = k^2 r t^2 \implies v^2 = k^2 r^2 t^2$. Taking the square root, the velocity is $v = k r t$. Thus, option (A) is correct.
- (b) Tangential acceleration a_t is dv/dt . Differentiating $v = k r t$ with respect to t , we get $a_t = k r$. Thus, option (D) is correct.
- (c) The tangential force F_t is $m a_t = m(k r) = m k r$. Option (B) is $m k^2 r^2 t$, which is incorrect as it describes something else.
- (d) Power P delivered is the work done by the tangential force (centripetal force does no work as it is perpendicular to motion). $P = F_t \cdot v = (m k r) \cdot (k r t) = m k^2 r^2 t$. Thus, option (C) is correct.

Final Answer: Correct options are A.

Answer: (C)

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Q29.

Solution**Concept:**

When a rotating solid body undergoes thermal expansion, its mass remains constant, but its physical dimensions increase. This change in geometry alters the distribution of mass relative to the axis of rotation, thereby affecting the moment of inertia (I). In the absence of external torques, the angular momentum (L) of the system must be conserved. This conservation law dictates that if the moment of inertia increases, the angular velocity must decrease proportionally to keep the product constant.

Solution:

- (a) Thermal expansion increases the radius R of the sphere. The moment of inertia for a solid sphere is $I = (2/5)MR^2$. As R increases, I increases significantly. Thus, option (C) is correct.
- (b) Since no external torque acts on the sphere, the angular momentum $L = I\omega$ remains constant. Thus, option (A) is correct.
- (c) Because $L = I\omega$ is constant and I increases, the angular velocity ω must decrease ($\omega \propto 1/I$). Thus, option (B) is correct.
- (d) Rotational kinetic energy is given by $K = L^2/2I$. Since L is constant and I increases, the value of the fraction decreases. Therefore, the rotational kinetic energy decreases. Option (D) is incorrect.
- (e) This problem illustrates the trade-off between rotational speed and mass distribution, similar to an ice skater pulling their arms in to spin faster, but in reverse.

Final Answer: Correct options are A, B, and C.

Answer: (C)

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Q30.

Solution**Concept:**

Capillary action is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity. The height of rise is determined by the balance between the upward force of surface tension and the downward weight of the liquid column. Jurin's Law states that the height of the liquid column is inversely proportional to the radius of the tube. However, the total mass of the liquid depends on both the height and the cross-sectional area.

Solution:

- (a) According to Jurin's Law, $h = (2S \cos \theta)/(r\rho g)$. This means $h \propto 1/r$. If the radius r is doubled ($2r$), the height h becomes $h/2$. Thus, option (A) is correct.
- (b) The mass of the liquid column is $M = \text{volume} \times \text{density} = (\pi r^2 h) \cdot \rho$. Substituting the relationship $h \propto 1/r$, we get $M \propto r^2 \cdot (1/r) \implies M \propto r$.
- (c) If the radius is doubled, the mass M becomes $2M$. Thus, option (B) is correct and option (D) is incorrect.
- (d) The potential energy U of the water column is Mgh_{cm} , where h_{cm} is the height of the center of mass ($h/2$). So, $U = M \cdot g \cdot (h/2)$. For the new tube, $M_{new} = 2M$ and $h_{new} = h/2$.
- (e) Calculating new energy: $U_{new} = (2M) \cdot g \cdot (h/4) = 1/2Mgh = U_{old}$. Wait, the potential energy remains the same because the mass doubles while the center of mass height halves. Thus, option (C) is incorrect.

Final Answer: Correct options are A.

Answer: (A)

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Here are the detailed solutions for the next batch of five questions (Q31–Q35), formatted precisely according to your LaTeX template.



Q31.

Solution**Concept:**

An adiabatic process is a thermodynamic change in which no heat enters or leaves the system ($dQ = 0$). For an ideal gas undergoing such a process, the variables of state are related by Poisson's equations. While the most common form is $PV^\gamma = \text{constant}$, the relationship between pressure (P) and absolute temperature (T) is equally vital for analysis. By comparing a given proportionality to the standard adiabatic power law, we can identify the specific heat ratio, γ , which characterizes the molecular structure of the gas.

Solution:

- (a) The standard adiabatic relation between pressure and temperature is given by $P^{1-\gamma}T^\gamma = \text{constant}$, which can be rearranged as $P \propto T^{\frac{\gamma}{\gamma-1}}$.
- (b) The problem states that pressure is proportional to the cube of the absolute temperature, represented as $P \propto T^3$.
- (c) By equating the exponents of T from the two expressions, we get: $\frac{\gamma}{\gamma-1} = 3$.
- (d) We solve this algebraic equation for γ : $\gamma = 3(\gamma - 1) \implies \gamma = 3\gamma - 3$. Rearranging the terms leads to $3 = 2\gamma$, which gives $\gamma = 3/2$ or 1.5.
- (e) The ratio $\gamma = C_p/C_v$ is a dimensionless constant. A value of 1.5 is between the values for a monatomic gas (1.67) and a diatomic gas (1.4), often associated with specific polyatomic configurations or theoretical models in thermodynamics.

Final Answer: The ratio C_p/C_v is 3/2.

Answer: (A)

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Q32.

Solution**Concept:**

A heat engine is a device that operates in a cycle, extracting heat from a high-temperature source to perform mechanical work and rejecting the remaining energy to a low-temperature sink. The performance is governed by the First Law of Thermodynamics (energy conservation) and the Second Law (efficiency limits). The Kelvin-Planck statement implies that no engine can be 100% efficient, and the maximum possible efficiency is defined by the Carnot cycle, which depends solely on the absolute temperatures of the reservoirs.

Solution:

- (a) First, we determine the work done (W) in one cycle using the conservation of energy: $W = Q_1 - Q_2$. Given $Q_1 = 200$ J and $Q_2 = 120$ J, the work done is $200 - 120 = 80$ J. This confirms option (C).
- (b) Next, we calculate the thermal efficiency (η): $\eta = W/Q_1 = 80/200 = 0.4$. Expressed as a percentage, this is 40%. This confirms option (A).
- (c) To find the temperature of the hot reservoir T_1 , we use the efficiency relation for a reversible cycle: $\eta = 1 - (T_2/T_1)$. Substituting our values: $0.4 = 1 - (300/T_1)$.
- (d) Solving for T_1 : $300/T_1 = 0.6 \implies T_1 = 300/0.6 = 500$ K. This confirms option (B).
- (e) For option (D), if an engine is already operating at the Carnot limit (as shown by the heat-temperature ratios matching), it is a Carnot engine. A Carnot engine is the theoretical upper bound; no engine can have a higher efficiency than a Carnot engine for the same T_1 and T_2 . Therefore, (D) is incorrect in saying it would be higher; it would be equal.

Final Answer: Correct options are A, B.

Answer: (A, B)

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Q33.

Solution**Concept:**

Simple Harmonic Motion (SHM) is characterized by a restoring force proportional to displacement. During oscillation, there is a continuous transformation between kinetic energy (K) and potential energy (U). The total energy remains constant. Velocity is a function of position, reaching its maximum at the mean position and vanishing at the extremes. Conversely, acceleration is maximum at the extremes and zero at the mean position. Understanding these spatial relationships is key to solving SHM problems.

Solution:

- (a) For $K = U$: $1/2k(A^2 - x^2) = 1/2kx^2 \implies A^2 = 2x^2 \implies x = A/\sqrt{2}$. Thus, statement (A) is correct.
- (b) Velocity $v = \omega\sqrt{A^2 - x^2}$ and $v_{max} = \omega A$. If $v = v_{max}/2$, then $\omega\sqrt{A^2 - x^2} = \omega A/2$. Squaring both sides: $A^2 - x^2 = A^2/4 \implies x^2 = 3A^2/4 \implies x = \sqrt{3}A/2$. Thus, statement (B) is correct.
- (c) Acceleration $a = -\omega^2 x$. The magnitude is maximum when x is maximum ($x = A$). Thus, statement (C) is correct.
- (d) Potential energy $U = 1/2kx^2$ is maximum at the extreme positions ($x = A$) and minimum at the mean position ($x = 0$). Thus, statement (D) is incorrect.
- (e) This question tests the fundamental position-dependent equations of SHM. In a multi-correct format, one must verify each condition against the standard kinematic and energetic equations.

Final Answer: Correct options are B, and C.

Answer: (B, C)

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Q34.

Solution**Concept:**

When a parallel plate capacitor is charged and then disconnected, it becomes an isolated system. This means the charge Q trapped on the plates remains constant because it has no path to discharge. Any physical change to the capacitor, such as altering the plate separation (d), will affect the capacitance (C), which then dictates changes in potential difference (V), stored energy (U), and the internal electric field (E).

Solution:

- (a) Capacitance $C = \epsilon_0 A/d$. Increasing d increases the denominator, which causes the capacitance to decrease ($C \propto 1/d$). Option (A) is correct.
- (b) The potential difference is $V = Q/C$. Since Q is constant and C has decreased, the value of V must increase. Option (B) is correct.
- (c) Stored energy can be expressed as $U = Q^2/2C$. With Q constant and C decreasing, the energy U increases ($U \propto 1/C$). This increase in energy is equal to the mechanical work done by an external agent to pull the plates apart against their mutual electrostatic attraction. Option (C) is correct.
- (d) The electric field E between the plates is given by $E = V/d$. Substituting $V = Q/C$ and $C = \epsilon_0 A/d$, we find $E = (Qd/\epsilon_0 A)/d = Q/\epsilon_0 A$. Since Q , ϵ_0 , and A are all unchanged, the electric field remains constant. Option (D) is correct.

Final Answer: Correct options are A, B, C, and D.

Answer: (A, B, C, D)

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Q35.

Solution**Concept:**

A potentiometer works on the principle that the potential drop across a segment of a uniform wire is directly proportional to its length, provided a constant current flows through it. The potential gradient (k) is the potential drop per unit length of the wire ($k = V/L$). The balancing length l for a given secondary cell of EMF E is found when $E = k \cdot l$. To increase l , one must either increase the secondary EMF or decrease the potential gradient k .

Solution:

- (a) The potential gradient k is given by $k = (I \cdot R_w)/L$, where I is the primary current and R_w is the wire resistance. $I = E_p/(R_w + R_h + r)$, where R_h is the resistance in the primary circuit.
- (b) If R_h (resistance in the primary) is increased, the primary current I decreases, which in turn decreases the potential gradient k . Since $l = E/k$, a smaller k results in a larger balancing length l . Option (A) is correct.
- (c) Decreasing the primary resistance increases k , thus decreasing l . Option (B) is incorrect.
- (d) If a cell of higher EMF is used in the secondary circuit, a longer length of wire is needed to produce a matching potential drop ($l = E/k$). Option (C) is correct.
- (e) Increasing the total length of the potentiometer wire (L) decreases the potential gradient k (assuming the primary EMF is constant). A lower k means a higher l is required to balance the same secondary EMF. Option (D) is correct.

Final Answer: Correct options are A, C, and D.

Answer: (A, C, D)

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Q36.

Solution**Concept:**

The Maximum Power Transfer Theorem states that to obtain maximum external power from a source with a finite internal resistance, the resistance of the load must equal the resistance of the source as viewed from its output terminals. For a DC circuit consisting of a cell with EMF E and internal resistance r , this occurs when the external resistance R is exactly equal to r . At this condition, the circuit efficiency and terminal voltage reach specific characteristic values.

Solution:

- (a) Power delivered to the external resistance R is given by $P = I^2 R = [E/(R + r)]^2 R$. To find the maximum power, we differentiate P with respect to R and set it to zero, which yields the condition $R = r$. Thus, option (A) is correct.
- (b) Substituting $R = r$ into the power formula: $P_{max} = [E/(r + r)]^2 r = (E^2/4r^2) \cdot r = E^2/4r$. Thus, option (B) is correct.
- (c) Terminal voltage V is given by $V = E - Ir$. When $R = r$, the current $I = E/2r$. Therefore, $V = E - (E/2r)r = E - E/2 = E/2$. Thus, option (D) is correct.
- (d) Efficiency η is the ratio of power delivered to the load to total power supplied: $\eta = [I^2 R]/[I^2(R + r)] = R/(R + r)$. When $R = r$, $\eta = r/2r = 0.5$ or 50%. Thus, option (C) is correct.
- (e) All four statements represent the fundamental properties of a circuit operating under maximum power transfer conditions.

Final Answer: Correct options are A, B, C, and D.

Answer: (A, B, C, D)

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Q37.

Solution**Concept:**

A current-carrying wire generates a magnetic field in its vicinity, as described by Ampere's Circuital Law. When a moving charged particle enters this magnetic field, it experiences a magnetic force known as the Lorentz force. The magnitude of this force depends on the charge, velocity, and magnetic field strength, while its direction is determined by the Right-Hand Rule (or Fleming's Left-Hand Rule). The interaction between the particle's velocity vector and the magnetic field vector dictates the trajectory of the particle.

Solution:

- (a) The magnetic field B produced by a long straight wire at a distance d is $B = \mu_0 I / 2\pi d$. The direction of the field, according to the right-hand thumb rule, is perpendicular to the plane containing the wire and the distance d .
- (b) The magnetic force on a charge q moving with velocity v is $\vec{F} = q(\vec{v} \times \vec{B})$. If the particle moves parallel to the wire, v is perpendicular to B . The magnitude is $F = qvB \sin 90^\circ = qv(\mu_0 I / 2\pi d)$. This confirms option (C).
- (c) Using the cross product $\vec{v} \times \vec{B}$, if q is positive and v is in the direction of I , the force vector points toward the wire. This confirms option (A).
- (d) If v is perpendicular to the wire (moving toward or away from it), the velocity and magnetic field lines are still perpendicular, so the force is not zero. Thus, option (B) is incorrect.
- (e) The force depends on q , v , I , and d , but does not depend on the mass m of the particle, although mass affects the resulting acceleration. This confirms option (D).

Final Answer: Correct options are A, C, and D.

Answer: (A, C, D)

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Q38.

Solution**Concept:**

Resonance in a series LCR circuit occurs when the inductive reactance ($X_L = \omega L$) and capacitive reactance ($X_C = 1/\omega C$) become equal in magnitude. At this specific frequency, the two reactances cancel each other out because they are 180° out of phase. This leads to unique electrical conditions where the circuit behaves as a purely resistive circuit, maximizing the current flow for a given source voltage.

Solution:

- (a) The impedance Z of a series LCR circuit is $Z = \sqrt{R^2 + (X_L - X_C)^2}$. At resonance, $X_L = X_C$, so $Z = R$. This is the minimum possible value for impedance. Option (A) is correct.
- (b) Since the circuit is purely resistive at resonance, the phase angle $\phi = \tan^{-1}[(X_L - X_C)/R]$ becomes zero. This means the current and voltage are in phase. Option (B) is correct.
- (c) The voltages across the inductor ($V_L = IX_L$) and capacitor ($V_C = IX_C$) are equal in magnitude. Since one leads the current by 90° and the other lags by 90° , they are opposite in phase and cancel each other. Option (C) is correct.
- (d) The power factor is defined as $\cos \phi$. Since $\phi = 0$ at resonance, $\cos 0 = 1$. This is referred to as a unity power factor. Option (D) is correct.
- (e) Resonance is utilized in tuning circuits, such as those in radios and televisions, to select specific frequencies.

Final Answer: Correct options are A, B, C, and D.

Answer: (A, B, C, D)

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Q39.

Solution**Concept:**

The characteristics of an interference pattern in Young's Double Slit Experiment (YDSE) are determined by the wavelength of the light used and the geometry of the setup. When the apparatus is immersed in a medium other than vacuum or air, the speed of light changes, which directly affects the wavelength. Since the fringe width and angular separation are dependent on the wavelength, the entire interference pattern undergoes a scaling effect.

Solution:

- (a) When light of wavelength λ enters a liquid of refractive index μ , its new wavelength becomes $\lambda' = \lambda/\mu$. Since $\mu > 1$, the wavelength decreases. Option (D) is correct.
- (b) Fringe width is given by $\beta = D\lambda/d$. Since λ decreases to λ/μ , the fringe width β also decreases by the same factor. Option (A) is correct.
- (c) Angular fringe width is given by $\theta = \lambda/d$. As λ decreases, the angular width θ also decreases. Option (B) is correct.
- (d) The position of the central fringe is determined by the path difference $\Delta x = 0$. Since the path difference at the center remains zero regardless of the medium's refractive index, the central fringe does not shift its position. Option (C) is correct.
- (e) Immersing the YDSE setup in water or oil is a common method to increase the resolution of the interference pattern by "compressing" the fringes.

Final Answer: Correct options are A, B, C.

Answer: (A, B, C)

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Q40.

Solution**Concept:**

The photoelectric effect demonstrates the particle nature of light. According to Einstein's photoelectric equation, the energy of an incident photon is used to overcome the work function of the metal and provide kinetic energy to the ejected electron. A critical distinction must be made between the intensity of light (number of photons per unit area per unit time) and the frequency of light (energy of individual photons). Changes in intensity affect the quantity of electrons, while changes in frequency affect their energy.

Solution:

- (a) Intensity is proportional to the number of photons. Doubling the intensity doubles the number of photons striking the surface per second. Consequently, the number of photoelectrons emitted per second (photoelectric current) also doubles. Option (A) is correct.
- (b) The maximum kinetic energy ($K_{max} = h\nu - \phi$) depends only on the frequency ν of the incident light and the nature of the metal (work function ϕ). Changing the intensity does not change the energy of individual photons. Option (B) is correct.
- (c) Stopping potential V_s is related to K_{max} by $eV_s = K_{max}$. Since K_{max} remains the same when intensity is changed, the stopping potential also remains unchanged. Option (C) is correct.
- (d) The threshold frequency is a property of the material itself and is independent of the incident light's intensity. Option (D) is correct.
- (e) This experiment provided pivotal evidence for the quantization of light, as classical wave theory incorrectly predicted that kinetic energy should increase with intensity.

Final Answer: Correct options are A, B, C, and D.

Answer: (A, B, C, D)

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Answer Key

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

