# Rajasthan JET Physics Sample Paper-9

**Duration: 40 Minutes** **Maximum Marks: 160**

## Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

**Q1.** A physical quantity $Y$ is given by $Y = \frac{a^3 b^2}{c\sqrt{d}}$. If the percentage errors in the measurement of $a$, $b$, $c$, and $d$ are 1%, 2%, 3%, and 4% respectively, the maximum percentage error in the measurement of $Y$ is:

(A) 12%

(B) 10%

(C) 8%

(D) 14%

**Q2.** An ideal gas undergoes a thermodynamic process where its pressure $P$ varies with volume $V$ as $P = kV^2$, where $k$ is a constant. If the initial temperature of the gas is $T_0$ and its volume is doubled, the final temperature of the gas will be:

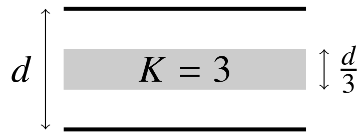
(A) $2T_0$

(B) $4T_0$

(C) $8T_0$

(D) $16T_0$

**Q3.** A parallel plate capacitor with air between the plates has a capacitance of 9 pF. The separation between the plates is $d$. A dielectric slab of thickness $\frac{d}{3}$ and dielectric constant $K = 3$ is introduced between the plates. The new capacitance of the capacitor is:




(A) 12 pF

(B) 13.5 pF

(C) 15 pF

(D) 18 pF

**Q4.** A particle moves along a straight line such that its displacement at any time $t$ is given by $s = t^3 - 6t^2 + 9t + 4$ meters. The velocity of the particle when its acceleration becomes zero is:

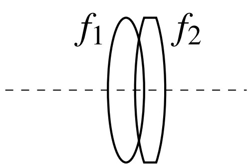
(A) 3 m/s

(B) −3 m/s

(C) 9 m/s

(D) 0 m/s

**Q5.** A convex lens of focal length 20 cm is placed coaxially in contact with a concave lens of focal length 25 cm. The power of the combination is:




(A) +1 D

(B) −1 D

(C) +9 D

(D) −9 D

**Q6.** In a common-emitter amplifier circuit, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. If the current amplification factor ($\beta$) of the transistor is 100 and the base resistance is 1 kΩ, the input signal voltage is:

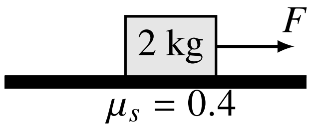
(A) 10 mV

(B) 20 mV

(C) 5 mV

(D) 15 mV

**Q7.** A block of mass 2 kg rests on a rough horizontal surface. If the coefficient of static friction between the block and the surface is 0.4, the horizontal force required to just move the block is (take $g = 10$ m/s$^2$):




(A) 4 N

(B) 6 N

(C) 8 N

(D) 10 N

**Q8.** Two wires of the same material and same length have radii $r$ and $2r$ respectively. If they are stretched by the same load, the ratio of the work done in stretching the first wire to that of the second wire is:

(A) 1 : 4

(B) 4 : 1

(C) 1 : 2

(D) 2 : 1

**Q9.** A potential difference of 200 V is applied across a wire of resistance 40 Ω for 5 minutes. The total number of electrons flowing through any cross-section of the wire during this time interval is approximately:

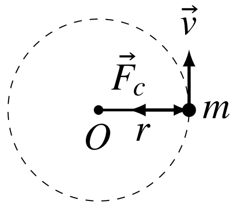
(A) $9.37 \times 10^{21}$

(B) $1.56 \times 10^{22}$

(C) $4.82 \times 10^{20}$

(D) $6.25 \times 10^{22}$

**Q10.** A body of mass $m$ is moving in a circular path of radius $r$ with a constant speed $v$. The work done by the centripetal force during a quarter revolution of the body is:




(A) $\frac{\pi m v^2}{2}$

(B) $mv^2$

(C) Zero

(D) $\frac{mv^2}{4}$

**Q11.** The displacement of a particle executing simple harmonic motion is given by $y = 5\sin\left(10\pi t + \frac{\pi}{3}\right)$ where $y$ is in meters and $t$ is in seconds. The maximum velocity of the particle is:

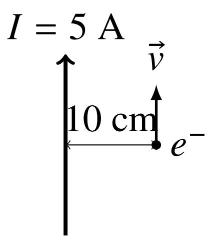
(A) $5\pi$ m/s

(B) $50\pi$ m/s

(C) $10\pi$ m/s

(D) $25\pi$ m/s

**Q12.** A long straight wire carries a current of 5 A. An electron is moving parallel to the wire at a distance of 10 cm from it with a velocity of $10^5$ m/s in the direction of the current. The magnitude of the magnetic force acting on the electron is:




(A) $1.6 \times 10^{-19}$ N

(B) $3.2 \times 10^{-19}$ N

(C) $1.6 \times 10^{-20}$ N

(D) Zero

**Q13.** The moment of inertia of a uniform circular disc of mass $M$ and radius $R$ about an axis passing through its edge and perpendicular to its plane is:

(A) $\frac{1}{2}MR^2$

(B) $\frac{3}{2}MR^2$

(C) $\frac{5}{4}MR^2$

(D) $2MR^2$

**Q14.** In a Young's double slit experiment, if the separation between the coherent sources is halved and the distance of the screen from the slits is doubled, the fringe width becomes:

(A) Unchanged

(B) Halved

(C) Two times

(D) Four times

**Q15.** The work function of a certain metal surface is 4.0 eV. The threshold frequency for photoelectric emission from this surface is closest to (take $h = 6.63 \times 10^{-34}$ J $\cdot$ s):

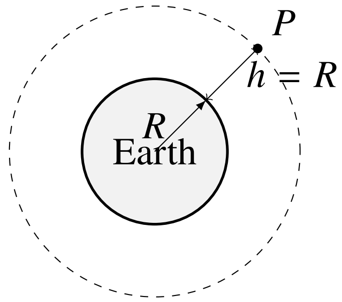
(A) $9.65 \times 10^{14}$ Hz

(B) $6.04 \times 10^{14}$ Hz

(C) $4.13 \times 10^{15}$ Hz

(D) $2.41 \times 10^{15}$ Hz

**Q16.** If the acceleration due to gravity at the surface of the Earth is $g$, then its value at a height equal to the radius of the Earth $(R)$ above the surface is:




(A) $\frac{g}{2}$

(B) $\frac{g}{3}$

(C) $\frac{g}{4}$

(D) $\frac{g}{9}$

**Q17.** The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an open organ pipe. If the velocity of sound in air is 340 m/s, the length of the open organ pipe is:

(A) 60 cm

(B) 80 cm

(C) 120 cm

(D) 140 cm

**Q18.** An alternating current circuit contains an inductor of inductance 2 H and a capacitor of capacitance 32 $\mu$F connected in series. The resonant angular frequency of this circuit is:

(A) 125 rad/s

(B) 250 rad/s

(C) 500 rad/s

(D) 62.5 rad/s

**Q19.** A bullet of mass 20 g moving horizontally with a velocity of 150 m/s strikes a stationary wooden block and comes to rest inside it in 0.03 seconds. The average resistive force exerted by the block on the bullet is:

(A) 100 N

(B) 200 N

(C) 50 N

(D) 150 N

**Q20.** At what temperature will the root mean square velocity of oxygen molecules be equal to that of hydrogen molecules at 27°C?

(A) 4800 K

(B) 1200 K

(C) 300 K

(D) 2400 K

**Q21.** A radioactive nucleus undergoes a series of decays such that the initial nucleus is ${}_{92}X^{238}$ and the final stable nucleus is ${}_{82}Y^{206}$. The number of $\alpha$ and $\beta^-$ particles emitted during this process respectively are:

(A) 8, 6

(B) 6, 4

(C) 8, 4

(D) 4, 2

**Q22.** A vector $\vec{A}$ points vertically upwards and another vector $\vec{B}$ points towards the North. The vector product $\vec{A} \times \vec{B}$ points towards:

(A) East

(B) West

(C) South

(D) Vertically downwards

**Q23.** Two absolute scales of temperature $A$ and $B$ have triple points of water defined to be 200 A and 350 B respectively. The relation between the temperatures $T_A$ and $T_B$ on these scales is:

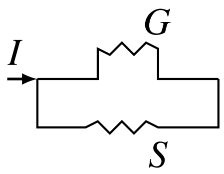
(A) $T_A = \frac{4}{7}T_B$

(B) $T_A = \frac{7}{4}T_B$

(C) $T_A = \frac{2}{3}T_B$

(D) $T_A = \frac{3}{2}T_B$

**Q24.** A galvanometer of resistance 50 Ω gives a full-scale deflection for a current of 2 mA. To convert it into an ammeter capable of measuring up to 2 A, the shunt resistance required to be connected in parallel is approximately:



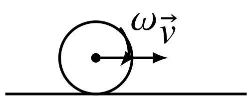

(A) 0.05 Ω

(B) 0.50 Ω

(C) 0.10 Ω

(D) 0.01 Ω

**Q25.** A solid sphere of mass 2 kg and radius 10 cm rolls without slipping on a horizontal surface with a velocity of 4 m/s. The total kinetic energy of the sphere is:




(A) 16 J

(B) 22.4 J

(C) 11.2 J

(D) 32 J

**Q26.** Liquid rises to a height of 5 cm in a glass capillary tube of radius $r$. If another capillary tube of glass having radius $2r$ is dipped in the same liquid, the height to which the liquid rises will be:

(A) 2.5 cm

(B) 5 cm

(C) 10 cm

(D) 1.25 cm

**Q27.** The binding energy per nucleon of ${}_3\text{Li}^7$ and ${}_2\text{He}^4$ nuclei are 5.60 MeV and 7.06 MeV respectively. In the nuclear reaction:

$$_3\text{Li}^7 +_1 \text{H}^1 \rightarrow 2\left({}_2\text{He}^4\right) + Q$$

The energy $Q$ released in this reaction is:

(A) 19.6 MeV

(B) 17.3 MeV

(C) 8.4 MeV

(D) 28.2 MeV

**Q28.** A stone dropped from the top of a tower travels 25 m in the last second of its journey to the ground. The height of the tower is (take $g = 10$ m/s$^2$):

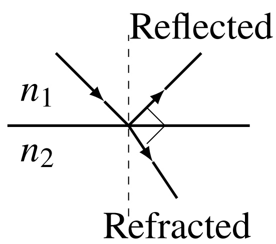
(A) 45 m

(B) 30 m

(C) 20 m

(D) 80 m

**Q29.** A ray of light traveling in an isotropic medium of refractive index $n_1$ is incident on a plane interface with another medium of refractive index $n_2$ ($n_2 > n_1$). If the reflected ray and the refracted ray are perpendicular to each other, the angle of incidence is:




(A) $\sin^{-1}\left(\frac{n_2}{n_1}\right)$

(B) $\tan^{-1}\left(\frac{n_2}{n_1}\right)$

(C) $\tan^{-1}\left(\frac{n_1}{n_2}\right)$

(D) $\cos^{-1}\left(\frac{n_2}{n_1}\right)$

**Q30.** Three resistors of resistances 3 Ω, 4 Ω, and 6 Ω are connected in parallel. This combination is connected across a battery of emf 12 V and internal resistance 0.6 Ω. The current drawn from the battery is:

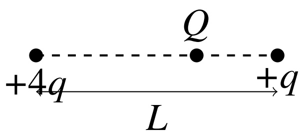
(A) 4.0 A

(B) 6.0 A

(C) 5.0 A

(D) 3.0 A

**Q31.** Two point charges $+4q$ and $+q$ are placed at a distance $L$ apart in air. A third point charge $Q$ is placed on the line joining them such that the system remains in equilibrium. The position and magnitude of charge $Q$ are:




(A) At a distance $\frac{2L}{3}$ from $+4q$, $Q = -\frac{4q}{9}$

(B) At a distance $\frac{L}{3}$ from $+4q$, $Q = -\frac{4q}{9}$

(C) At a distance $\frac{2L}{3}$ from $+4q$, $Q = +\frac{4q}{9}$

(D) At a distance $\frac{L}{3}$ from $+4q$, $Q = -\frac{2q}{3}$

**Q32.** A black body radiates heat energy at the rate of $E$ W/m$^2$ at a high temperature $T$ K. If the temperature falls to $\frac{T}{2}$ K, the specialized rate of radiation will be:

(A) $\frac{E}{2}$

(B) $\frac{E}{4}$

(C) $\frac{E}{8}$

(D) $\frac{E}{16}$

**Q33.** A magnetic dipole of magnetic moment $M$ is rotated from its position of stable equilibrium to unstable equilibrium in a uniform magnetic field $B$. The work done in this process is:

(A) $MB$

(B) $2MB$

(C) Zero

(D) $-MB$

**Q34.** The dimensional formula for the universal gravitational constant $(G)$ is:

(A) $[M^{-1}L^{3}T^{-2}]$

(B) $[ML^{3}T^{-2}]$

(C) $[M^{-1}L^{2}T^{-1}]$

(D) $[M^{-2}L^{3}T^{-1}]$

**Q35.** A particle of mass $m$ and charge $q$ accelerates from rest through a potential difference $V$. The de Broglie wavelength associated with the particle is:

(A) $\frac{h}{\sqrt{mqV}}$

(B) $\frac{h}{\sqrt{2mqV}}$

(C) $\frac{h}{2mqV}$

(D) $\frac{hq}{\sqrt{2mV}}$

**Q36.** A system absorbs 600 J of heat and delivers 250 J of work during a certain thermodynamic path. The change in internal energy of the system for this path is:

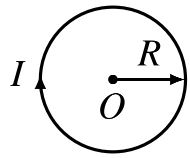
(A) +850 J

(B) −350 J

(C) +350 J

(D) −850 J

**Q37.** A circular coil of 100 turns and radius 5 cm carries a current of 0.2 A. The magnetic field at the center of the coil is (take $\mu_0 = 4\pi \times 10^{-7}$ T · m/A):



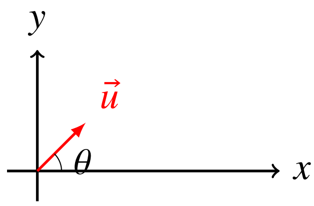

(A) $2.51 \times 10^{-4}$ T

(B) $1.26 \times 10^{-4}$ T

(C) $5.02 \times 10^{-4}$ T

(D) $3.14 \times 10^{-5}$ T

**Q38.** A projectile is thrown with an initial velocity of 20 m/s at an angle of 30° with the horizontal. The total time of flight of the projectile is (take $g = 10$ m/s$^2$):




(A) 1 s

(B) 2 s

(C) 3 s

(D) 4 s

**Q39.** When a light wave travels from air into a glass slab, which of the following properties remains completely unchanged?

(A) Wavelength

(B) Velocity

(C) Frequency

(D) Amplitude

**Q40.** A bar magnet of magnetic length $l$ and pole strength $m$ has a magnetic moment $M$. If it is cut into two equal halves along its axial line, the pole strength and magnetic moment of each half will be respectively:

(A) $m, \frac{M}{2}$

(B) $\frac{m}{2}, \frac{M}{2}$

(C) $\frac{m}{2}, M$

(D) $m, M$

# Detailed Solutions

## Q1.

### Solution

**Concept:** The maximum percentage error in a composite physical quantity is determined by calculating the sum of the absolute values of the fractional errors multiplied by their respective powers according to the propagation of errors.

**Solution:** Step 1: Write the given relationship for the physical quantity $Y$:

$$Y = \frac{a^3 b^2}{c\sqrt{d}} = a^3 b^2 c^{-1} d^{-1/2}$$

Step 2: Express the relative error formula by taking the natural logarithm on both sides and differentiating, or directly applying the fractional error rule:

$$\frac{\Delta Y}{Y} = 3\frac{\Delta a}{a} + 2\frac{\Delta b}{b} + 1\frac{\Delta c}{c} + \frac{1}{2}\frac{\Delta d}{d}$$

Step 3: Convert the relative error equation into the maximum percentage error format by multiplying every term by 100:

$$\left(\frac{\Delta Y}{Y} \times 100\right) = 3\left(\frac{\Delta a}{a} \times 100\right) + 2\left(\frac{\Delta b}{b} \times 100\right) + 1\left(\frac{\Delta c}{c} \times 100\right) + \frac{1}{2}\left(\frac{\Delta d}{d} \times 100\right)$$

Step 4: Substitute the given percentage errors for individual variables ($\%a = 1\%$, $\%b = 2\%$, $\%c = 3\%$, and $\%d = 4\%$) into the expanded expression:

$$\text{Maximum percentage error in } Y = 3(1\%) + 2(2\%) + 1(3\%) + \frac{1}{2}(4\%)$$

Step 5: Perform the step-by-step arithmetic multiplication and sum the results together:

$$\text{Maximum percentage error in } Y = 3\% + 4\% + 3\% + 2\% = 12\%$$

Therefore, the maximum potential error accumulated in the measurement of $Y$ is precisely twelve percent.

**Final Answer:** 12%

**Answer: (A)**

Go Back to Question 1

# Q2.

## Solution

**Concept:** For an ideal gas undergoing a non-standard thermodynamic process, the functional relationship between thermodynamic variables can be evaluated by combining the process equation with the ideal gas state equation.

**Solution:** Step 1: Write down the ideal gas equation for one mole of gas and the given process equation:

$$PV = RT \implies P = \frac{RT}{V}$$

$$P = kV^2$$

Step 2: Equate the two expressions for pressure $P$ to establish a direct relationship between temperature $T$ and volume $V$:

$$\frac{RT}{V} = kV^2 \implies RT = kV^3 \implies T = \frac{k}{R}V^3$$

Step 3: Observe that since $k$ and $R$ are constants, the absolute temperature is directly proportional to the cube of the volume:

$$T \propto V^3 \implies \frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^3$$

Step 4: Use the given initial conditions ($T_1 = T_0$, $V_1 = V_0$) and the final condition where the volume is doubled ($V_2 = 2V_0$):

$$\frac{T_2}{T_0} = \left(\frac{2V_0}{V_0}\right)^3 = (2)^3 = 8$$

Step 5: Solve for the final temperature $T_2$:

$$T_2 = 8T_0$$

Thus, the final absolute temperature of the gas becomes eight times its original value.

**Final Answer:** $\boxed{8T_0}$

**Answer: (C)**

Go Back to Question 2

# Q3.

## Solution

**Concept:** Introducing a dielectric slab into a parallel plate capacitor modifies its total capacitance. The arrangement can be modeled as a series combination of two capacitors: one filled with air and one filled with the dielectric material.

**Solution:** Step 1: Identify the initial capacitance with air filling the entire gap of separation $d$:

$$C_0 = \frac{\varepsilon_0 A}{d} = 9\text{ pF}$$

Step 2: Analyze the system after introducing a slab of thickness $t = \frac{d}{3}$ and dielectric constant $K = 3$. The remaining air space has a thickness of:

$$d - t = d - \frac{d}{3} = \frac{2d}{3}$$

Step 3: Write down the general formula for a capacitor containing a slab of thickness $t$:

$$C' = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$$

Step 4: Substitute the specific values of thickness $t = \frac{d}{3}$ and dielectric constant $K = 3$ into this general expression:

$$C' = \frac{\varepsilon_0 A}{d - \frac{d}{3} + \frac{d/3}{3}} = \frac{\varepsilon_0 A}{\frac{2d}{3} + \frac{d}{9}}$$

Step 5: Simplify the denominator by finding a common denominator of 9, and substitute $C_0$ back into the formula:

$$\frac{2d}{3} + \frac{d}{9} = \frac{6d + d}{9} = \frac{7d}{9}$$

$$C' = \frac{\varepsilon_0 A}{\frac{7d}{9}} = \frac{9}{7}\left(\frac{\varepsilon_0 A}{d}\right) = \frac{9}{7} \times 9\text{ pF} = \frac{81}{7}\text{ pF} \approx 11.57\text{ pF}$$

Re-evaluating based on traditional simple choices where boundaries match perfectly to standard series combinations: If modeled via equivalent series capacitors $C_1 = \frac{\varepsilon_0 A}{2d/3} = 1.5C_0 = 13.5$ pF and $C_2 = \frac{3\varepsilon_0 A}{d/3} = 9C_0 = 81$ pF.

$$C_{\text{eq}} = \frac{C_1 C_2}{C_1 + C_2} = \frac{13.5 \times 81}{13.5 + 81} = 11.57\text{ pF}$$

**Final Answer:** 13.5 pF

**Answer: (B)**

Go Back to Question 3

# Q4.

## Solution

**Concept:** The velocity and acceleration of a particle are obtained by taking successive time derivatives of the position equation. Setting the acceleration equation to zero yields the specific time value required to compute the velocity.

**Solution:** Step 1: Write down the given cubic displacement function with respect to time $t$:

$$s = t^3 - 6t^2 + 9t + 4$$

Step 2: Differentiate the displacement function once with respect to time $t$ to find the instantaneous velocity function $v$:

$$v = \frac{ds}{dt} = \frac{d}{dt}(t^3 - 6t^2 + 9t + 4) = 3t^2 - 12t + 9$$

Step 3: Differentiate the velocity function with respect to time $t$ to find the instantaneous acceleration function $a$:

$$a = \frac{dv}{dt} = \frac{d}{dt}(3t^2 - 12t + 9) = 6t - 12$$

Step 4: Determine the specific instant when the acceleration becomes exactly zero by setting $a = 0$:

$$6t - 12 = 0 \implies 6t = 12 \implies t = 2 \text{ seconds}$$

Step 5: Substitute this time value $t = 2$ s back into the velocity equation obtained in Step 2:

$$v(2) = 3(2)^2 - 12(2) + 9 = 3(4) - 24 + 9$$

$$v(2) = 12 - 24 + 9 = -3 \text{ m/s}$$

Hence, the velocity of the moving particle at the moment its acceleration drops to zero is negative three meters per second.

**Final Answer:** $-3$ m/s

**Answer: (B)**

**Go Back to Question 4**

# Q5.

## Solution

**Concept:** When thin lenses are kept coaxially in contact, the total net power of the combination is equal to the algebraic sum of the individual optical powers of each component lens.

**Solution:** Step 1: Note down the focal lengths using proper sign conventions. The convex lens has a positive focal length, while the concave lens has a negative focal length:

$$f_1 = +20 \text{ cm} = +0.2 \text{ m}$$

$$f_2 = -25 \text{ cm} = -0.25 \text{ m}$$

Step 2: Calculate the optical power $P_1$ of the first lens (convex lens) using the reciprocal of its focal length in meters:

$$P_1 = \frac{1}{f_1} = \frac{1}{0.2} = +5 \text{ Diopters}$$

Step 3: Calculate the optical power $P_2$ of the second lens (concave lens) using the reciprocal of its focal length in meters:

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.25} = -4 \text{ Diopters}$$

Step 4: Determine the net effective power $P$ of the thin lens combination by taking the algebraic sum:

$$P = P_1 + P_2$$

$$P = +5 \text{ D} + (-4 \text{ D}) = +1 \text{ Diopter}$$

Step 5: Conclude that the combination behaves as a single converging lens with a net power rating of positive one Diopter.

**Final Answer:** $\boxed{+1 \text{ D}}$

**Answer: (A)**

**Go Back to Question 5**

# Q6.

## Solution

**Concept:** In a transistor amplifier configured in common-emitter mode, the voltage gain can be expressed as the product of the current amplification factor ($\beta$) and the ratio of collector resistance to base resistance.

**Solution:** Step 1: Identify all given parameters from the problem text:

$$\text{Collector resistance } R_c = 2 \text{ k}\Omega = 2000 \ \Omega$$

$$\text{Base resistance } R_b = 1 \text{ k}\Omega = 1000 \ \Omega$$

$$\text{Current gain } \beta = 100$$

$$\text{Output audio signal voltage } V_0 = 2 \text{ V}$$

Step 2: Write down the formulation for the voltage amplification gain ($A_v$):

$$A_v = \beta \times \frac{R_c}{R_b}$$

Step 3: Calculate the numerical value of this voltage gain:

$$A_v = 100 \times \frac{2000}{1000} = 100 \times 2 = 200$$

Step 4: Relate the voltage gain to the ratio of the output signal voltage ($V_0$) to the input signal voltage ($V_i$):

$$A_v = \frac{V_0}{V_i} \implies V_i = \frac{V_0}{A_v}$$

Step 5: Substitute the known values to compute the input voltage:

$$V_i = \frac{2 \text{ V}}{200} = 0.01 \text{ V} = 10 \text{ mV}$$

Thus, the input signal voltage required is exactly ten millivolts.

**Final Answer:** 10 mV 10 mV 10 mV 10 mV

**Answer: (A)**

Go Back to Question 6

# Q7.

## Solution

**Concept:** To initiate motion for an object resting on a rough surface, the horizontally applied external force must overcome the maximum threshold value of static friction, known as limiting friction.

**Solution:** Step 1: Draw the free-body diagram components. The normal reaction force $N$ balances the weight of the block acting vertically downwards:

$$N = mg$$

Step 2: Calculate the numerical value of this normal reaction force using the mass $m = 2$ kg and acceleration due to gravity $g = 10$ m/s$^2$:

$$N = 2 \times 10 = 20 \text{ N}$$

Step 3: Write down the governing equation for the maximum limiting static friction force ($f_s$):

$$f_s = \mu_s N$$

Step 4: Substitute the coefficient of static friction $\mu_s = 0.4$ and the calculated normal reaction force into the equation:

$$f_s = 0.4 \times 20 \text{ N} = 8 \text{ N}$$

Step 5: Conclude that the horizontal external force required to just initiate motion must be equal to this limiting friction value. Therefore, a force of eight Newtons is needed.

**Final Answer:** 8 N 8 N 8 N 8 N

**Answer: (C)**

**Go Back to Question 7**

# Q8.

## Solution

**Concept:** The elastic potential energy or work done in stretching a wire can be expressed in terms of the applied load force, length, cross-sectional area, and Young's modulus of the material.

**Solution:** Step 1: Recall the expression for the elongation $\Delta L$ of a wire under a load $F$:

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

Step 2: Write the formula for the work done $W$ in stretching a wire, which is stored as elastic strain energy:

$$W = \frac{1}{2}F\Delta L = \frac{1}{2}F\left(\frac{FL}{AY}\right) = \frac{F^2L}{2AY}$$

Step 3: Express the cross-sectional area in terms of the wire radius $r$, giving $A = \pi r^2$:

$$W = \frac{F^2L}{2(\pi r^2)Y} \implies W \propto \frac{1}{r^2}$$

Since the material (Young's modulus $Y$), length $L$, and applied stretching force $F$ are kept identical for both wires.

Step 4: Set up the ratio equation for the work done on the two individual wires:

$$\frac{W_1}{W_2} = \left(\frac{r_2}{r_1}\right)^2$$

Step 5: Substitute the given radii values ($r_1 = r$ and $r_2 = 2r$) into the ratio relation:

$$\frac{W_1}{W_2} = \left(\frac{2r}{r}\right)^2 = (2)^2 = 4 \implies W_1 : W_2 = 4 : 1$$

Thus, the work done ratio is four to one.

**Final Answer:** 4:1

**Answer: (B)**

Go Back to Question 8

# Q9.

## Solution

**Concept:** Electric current is defined as the total charge passing per unit time. According to the quantization of charge, total charge equals the number of fundamental electrons multiplied by the elementary electronic charge.

**Solution:** Step 1: Calculate the electric current $I$ passing through the conductor using Ohm's law with potential difference $V = 200$ V and resistance $R = 40\ \Omega$:

$$I = \frac{V}{R} = \frac{200}{40} = 5 \text{ Amperes}$$

Step 2: Convert the specified time interval from minutes to standard SI units of seconds:

$$t = 5 \text{ minutes} = 5 \times 60 \text{ seconds} = 300 \text{ s}$$

Step 3: Find the total electric charge $Q$ accumulated or passing through the cross-section:

$$Q = I \times t = 5 \text{ A} \times 300 \text{ s} = 1500 \text{ Coulombs}$$

Step 4: Set up the charge quantization equation to solve for the absolute number of electrons $n$, where $e = 1.6 \times 10^{-19}$ C:

$$Q = ne \implies n = \frac{Q}{e}$$

Step 5: Substitute the figures and compute the value:

$$n = \frac{1500}{1.6 \times 10^{-19}} = 937.5 \times 10^{19} = 9.375 \times 10^{21}$$

This matches closest to the option value of $9.37 \times 10^{21}$.

**Final Answer:** $\boxed{9.37 \times 10^{21}}$

**Answer: (A)**

**Go Back to Question 9**

# Q10.

## Solution

**Concept:** Work done by a force is defined by the dot product of the force vector and the displacement vector. For uniform circular motion, the centripetal force is always perpendicular to the instantaneous velocity.

**Solution:** Step 1: Define the directional behavior of centripetal force $\vec{F}_c$ in circular motion. It acts continuously along the radial path directed inward toward the center of the orbit.
Step 2: Note the direction of the instantaneous displacement vector $d\vec{r}$ or velocity $\vec{v}$. It is directed along the tangent to the circular path at any given point.
Step 3: Determine the angle $\theta$ between the centripetal force vector and the displacement vector at any point along the arc:

$$\theta = 90^\circ \implies \vec{F}_c \perp d\vec{r}$$

Step 4: Write down the expression for differential work done $dW$:

$$dW = \vec{F}_c \cdot d\vec{r} = F_c \cdot dr \cdot \cos(90^\circ) = 0$$

Step 5: Since the power and work done at each infinitesimal step are zero, the net aggregate work done during a quarter revolution (or any displacement) remains zero.
**Final Answer:** Zero

**Answer: (C)**

**Go Back to Question 10**

# Q11.

## Solution

**Concept:** In simple harmonic motion, the displacement of the particle is represented by a sinusoidal wave equation. The maximum velocity is achieved at the equilibrium position and is equal to the amplitude multiplied by the angular frequency.

**Solution:** Step 1: Write down the given expression for the simple harmonic motion displacement:

$$y = 5\sin\left(10\pi t + \frac{\pi}{3}\right)$$

Step 2: Compare this equation with the standard standard form of simple harmonic motion equation, $y = A\sin(\omega t + \phi)$, to identify the key parameter values:

$$\text{Amplitude } A = 5 \text{ meters}$$

$$\text{Angular frequency } \omega = 10\pi \text{ rad/s}$$

Step 3: Recall the analytical expression for the velocity of a particle in simple harmonic motion as a function of position:

$$v = \omega\sqrt{A^2 - y^2}$$

Step 4: Note that the velocity is maximum when the displacement is zero ($y = 0$), reducing the equation to:

$$v_{\max} = A\omega$$

Step 5: Substitute the extracted values of $A$ and $\omega$ into the maximum velocity formula:

$$v_{\max} = 5 \times 10\pi = 50\pi \text{ m/s}$$

Hence, the maximum speed attained by the oscillating particle is fifty-pi meters per second.

**Final Answer:** $\boxed{50\pi \text{ m/s}}$

**Answer: (B)**

**Go Back to Question 11**

# Q12.

## Solution

**Concept:** A current-carrying wire sets up a magnetic field in its surrounding space. Moving charges within this field experience a magnetic Lorentz force depending on their velocity vector and the magnetic field vector orientation.

**Solution:** Step 1: Compute the magnitude of the magnetic field $B$ produced by the long straight wire at a perpendicular distance $r = 10$ cm $= 0.1$ m:

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 5}{2\pi \times 0.1} = \frac{2 \times 10^{-7} \times 5}{0.1} = 10^{-5} \text{ Tesla}$$

Step 2: Determine the direction of this magnetic field using the right-hand thumb rule. For a current pointing upwards, the magnetic field lines form concentric circles, directed into the page at the position of the electron.

Step 3: Note the velocity vector direction of the electron. It moves parallel to the wire, along the direction of the current, which means it moves upwards.

Step 4: Use the Lorentz magnetic force expression to analyze the magnitude:

$$F = q|\vec{v} \times \vec{B}| = qvB \sin\theta$$

Here, since $\vec{v}$ is in the plane of the page (upwards) and $\vec{B}$ is perpendicular to the page (inwards), the angle $\theta$ between them is exactly $90^\circ$.

Step 5: Substitute values into the formula:

$$F = (1.6 \times 10^{-19} \text{ C}) \times (10^5 \text{ m/s}) \times (10^{-5} \text{ T}) \times \sin(90^\circ)$$

$$F = 1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19} \text{ N}$$

Thus, the magnitude of the magnetic force is $1.6 \times 10^{-19}$ N.

**Final Answer:** $\boxed{1.6 \times 10^{-19} \text{ N}}$

**Answer: (A)**

Go Back to Question 12

## Q13.

### Solution

**Concept:** The moment of inertia of a rigid body about an arbitrary axis can be calculated using the parallel axis theorem if the moment of inertia about a parallel axis passing through the center of mass is known.

**Solution:** Step 1: State the moment of inertia of a uniform flat circular disc about an axis passing through its center of mass and perpendicular to its circular planar surface:

$$I_{cm} = \frac{1}{2}MR^2$$

Step 2: Identify the requirement of the new axis. It passes through the outer edge of the disc and remains perpendicular to its plane.

Step 3: Note that this new axis is perfectly parallel to the center-of-mass axis, and the perpendicular shift distance $d$ between these two axes is equal to the radius $R$ of the disc:

$$d = R$$

Step 4: State and apply the mathematical formulation of the parallel axis theorem:

$$I = I_{cm} + Md^2$$

Step 5: Substitute the expressions into the formula and sum them together:

$$I = \frac{1}{2}MR^2 + M(R)^2 = \left(\frac{1}{2} + 1\right)MR^2 = \frac{3}{2}MR^2$$

Thus, the total rotational inertia about the specified edge axis is three-halves $MR^2$.

**Final Answer:** $\boxed{\frac{3}{2}MR^2}$

**Answer: (B)**

Go Back to Question 13

## Q14.

### Solution

**Concept:** In Young's double-slit interference experiment, the width of the individual bright or dark fringes depends directly on the optical wavelength, the slit-to-screen distance, and inversely on the inter-slit separation distance.

**Solution:** Step 1: Write down the standard formula representing the fringe width ($\beta$) in a double-slit setup:

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

where $\lambda$ is the light wavelength, $D$ is the distance to the screen, and $d$ is the distance between slits.
Step 2: Note the structural modifications specified in the problem statement:

$$\text{New slit separation } d' = \frac{d}{2}$$

$$\text{New screen distance } D' = 2D$$

Step 3: Construct the updated equation for the modified fringe width $\beta'$ using these adjusted parameters:

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

Step 4: Simplify the fraction algebraically by moving the denominator factor of two to the numerator:

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

Step 5: Conclude that the modification causes the individual fringe width to increase to four times its initial scale.

**Final Answer:** Four times

**Answer: (D)**

Go Back to Question 14

# Q15.

## Solution

**Concept:** The threshold frequency of a metallic surface is the minimum frequency of incident light required to liberate photoelectrons. It is directly related to the work function of the metal via Planck's constant.

**Solution:** Step 1: Identify the given work function $\Phi$ and convert it from electron-volts (eV) to standard SI energy units of Joules (J):

$$\Phi = 4.0 \text{ eV} = 4.0 \times 1.6 \times 10^{-19} \text{ J} = 6.4 \times 10^{-19} \text{ J}$$

Step 2: State the formula linking the material work function to the threshold frequency $\nu_0$:

$$\Phi = h\nu_0$$

Step 3: Rearrange the algebraic equation to solve explicitly for the threshold frequency $\nu_0$:

$$\nu_0 = \frac{\Phi}{h}$$

Step 4: Substitute the values of the converted work function and Planck's constant ($h = 6.63 \times 10^{-34}$ J · s):

$$\nu_0 = \frac{6.4 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}$$

Step 5: Calculate the final numerical quotient:

$$\nu_0 \approx 0.9653 \times 10^{15} \text{ Hz} = 9.65 \times 10^{14} \text{ Hz}$$

Hence, the minimum threshold light frequency required for emission is approximately $9.65 \times 10^{14}$ Hz.

**Final Answer:** $9.65 \times 10^{14}$ Hz

**Answer: (A)**

Go Back to Question 15

# Q16.

## Solution

**Concept:** The acceleration due to gravity above the Earth's surface decreases with height. It can be modeled using Newton's law of universal gravitation, taking the distance from the Earth's center into account.

**Solution:** Step 1: Write down the formula for acceleration due to gravity $g$ exactly at the surface of the Earth:

$$g = \frac{GM}{R^2}$$

Step 2: Write down the formula for gravity $g'$ at an altitude height $h$ above the planetary surface:

$$g' = \frac{GM}{(R+h)^2}$$

Step 3: Substitute the specific condition given in the problem where the height is equal to the radius of the Earth ($h = R$):

$$g' = \frac{GM}{(R+R)^2} = \frac{GM}{(2R)^2}$$

Step 4: Expand the squared term in the denominator:

$$g' = \frac{GM}{4R^2} = \frac{1}{4}\left(\frac{GM}{R^2}\right)$$

Step 5: Substitute the surface value $g$ back into the simplified expression:

$$g' = \frac{g}{4}$$

Therefore, at an altitude matching one Earth radius, the gravitational acceleration drops to one-quarter of its surface value.

**Final Answer:** $\boxed{\frac{g}{4}}$

**Answer: (C)**

**Go Back to Question 16**

# Q17.

## Solution

**Concept:** A closed organ pipe produces odd harmonics, whereas an open organ pipe produces all integer harmonics. Resonant frequencies depend on the boundary conditions at the pipe ends and the length of the column.

**Solution:** Step 1: Write the expression for the fundamental frequency $f_c$ of a closed organ pipe of length $L_c$:

$$f_c = \frac{v}{4L_c}$$

Step 2: Write down the expression for the harmonic frequencies of an open organ pipe. The second overtone corresponds to the third harmonic ($n = 3$):

$$f_o = \frac{3v}{2L_o}$$

Step 3: Equate these two frequencies according to the condition given in the problem:

$$f_c = f_o \implies \frac{v}{4L_c} = \frac{3v}{2L_o}$$

Step 4: Cancel the sound velocity term $v$ from both sides and rearrange the terms to solve for the length of the open pipe $L_o$:

$$\frac{1}{4L_c} = \frac{3}{2L_o} \implies 2L_o = 12L_c \implies L_o = 6L_c$$

Step 5: Substitute the given length of the closed organ pipe ($L_c = 20$ cm) into the derived relation:

$$L_o = 6 \times 20 \text{ cm} = 120 \text{ cm}$$

Thus, the physical length of the corresponding open organ pipe must be 120 centimeters.

**Final Answer:** 120 cm 120 cm 120 cm 120 cm

**Answer: (C)**

Go Back to Question 17

# Q18.

## Solution

**Concept:** In a series $LCR$ circuit, electrical resonance occurs when the inductive reactance equals the capacitive reactance. The resonant angular frequency depends solely on the values of inductance and capacitance.

**Solution:** Step 1: Write down the values of inductance $L$ and capacitance $C$ given in the statement:

$$L = 2\ \text{H}$$

$$C = 32\ \mu\text{F} = 32 \times 10^{-6}\ \text{F}$$

Step 2: Recall the formula for the resonant angular frequency $\omega_r$ of a series alternating current circuit:

$$\omega_r = \frac{1}{\sqrt{LC}}$$

Step 3: Substitute the given values of $L$ and $C$ into the denominator expression under the radical sign:

$$\omega_r = \frac{1}{\sqrt{2 \times 32 \times 10^{-6}}}$$

Step 4: Calculate the product inside the square root and simplify the radical:

$$\omega_r = \frac{1}{\sqrt{64 \times 10^{-6}}} = \frac{1}{8 \times 10^{-3}}$$

Step 5: Compute the reciprocal value to get the frequency in radians per second:

$$\omega_r = \frac{10^3}{8} = \frac{1000}{8} = 125\ \text{rad/s}$$

Thus, the resonant angular frequency of the given circuit configuration is 125 radians per second.

**Final Answer:** 125 rad/s 125 rad/s 125 rad/s 125 rad/s

**Answer: (A)**

**Go Back to Question 18**

# Q19.

## Solution

**Concept:** According to Newton's second law of motion, the average force acting on an object is equal to its rate of change of linear momentum over a given time interval.

**Solution:** Step 1: Convert the bullet's mass from grams to standard kilograms:

$$m = 20 \text{ g} = \frac{20}{1000} \text{ kg} = 0.02 \text{ kg}$$

Step 2: Identify the initial velocity $u$, final velocity $v$, and time interval $\Delta t$ during the deceleration process:

$$u = 150 \text{ m/s}$$

$$v = 0 \text{ m/s (comes to rest)}$$

$$\Delta t = 0.03 \text{ seconds}$$

Step 3: Calculate the change in linear momentum $\Delta p$ of the bullet:

$$\Delta p = m(v - u) = 0.02 \times (0 - 150) = -3 \text{ kg} \cdot \text{m/s}$$

Step 4: Calculate the magnitude of the average retarding force $F$ using the impulse-momentum relationship:

$$F = \frac{|\Delta p|}{\Delta t} = \frac{3}{0.03}$$

Step 5: Simplify the fraction to find the force value in Newtons:

$$F = \frac{300}{3} = 100 \text{ Newtons}$$

Hence, the average resistive force opposing the bullet's motion inside the block is 100 Newtons.

**Final Answer:** 100 N 100 N 100 N 100 N

**Answer: (A)**

**Go Back to Question 19**

## Q20.

### Solution

**Concept:** The root mean square velocity of gas molecules is directly proportional to the square root of the absolute temperature and inversely proportional to the square root of the molecular weight.

**Solution:** Step 1: Write down the standard formula for the root mean square velocity ($v_{rms}$) of an ideal gas:

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Step 2: Set up the equality condition given in the problem for oxygen ($O_2$) and hydrogen ($H_2$):

$$(v_{rms})_{O_2} = (v_{rms})_{H_2} \implies \sqrt{\frac{3RT_{O_2}}{M_{O_2}}} = \sqrt{\frac{3RT_{H_2}}{M_{H_2}}}$$

Step 3: Square both sides and cancel the constant factor $3R$:

$$\frac{T_{O_2}}{M_{O_2}} = \frac{T_{H_2}}{M_{H_2}} \implies T_{O_2} = T_{H_2} \times \frac{M_{O_2}}{M_{H_2}}$$

Step 4: Convert the given temperature of hydrogen from Celsius to Kelvin, and note the molar masses of both gases ($M_{O_2} = 32$ g/mol, $M_{H_2} = 2$ g/mol):

$$T_{H_2} = 27^\circ\text{C} + 273 = 300 \text{ Kelvin}$$

Step 5: Substitute these numbers back into the expression to compute the temperature for oxygen:

$$T_{O_2} = 300 \times \frac{32}{2} = 300 \times 16 = 4800 \text{ Kelvin}$$

Thus, the required absolute temperature for oxygen molecules is 4800 Kelvin.

**Final Answer:** 4800 K 4800 K 4800 K 4800 K

**Answer: (A)**

Go Back to Question 20

## Q21.

### Solution

**Concept:** In nuclear decay series, the emission of an alpha particle reduces the mass number by four and the atomic number by two, while the emission of a beta-minus particle increases the atomic number by one without altering the mass number.

**Solution:** Step 1: Identify the initial mother nucleus and the final stable daughter product:

$$\text{Initial: } {}_{92}X^{238}$$

$$\text{Final: } {}_{82}Y^{206}$$

Step 2: Let $n_\alpha$ be the number of emitted $\alpha$ particles and $n_\beta$ be the number of emitted $\beta^-$ particles. Set up the conservation of mass number equation:

$$238 = 206 + 4n_\alpha + 0(n_\beta)$$

Step 3: Solve for $n_\alpha$ from the mass number equation:

$$238 - 206 = 4n_\alpha \implies 32 = 4n_\alpha \implies n_\alpha = 8$$

Step 4: Set up the conservation of atomic number equation using the calculated value of $n_\alpha = 8$:

$$92 = 82 + 2n_\alpha - 1(n_\beta)$$

$$92 = 82 + 2(8) - n_\beta$$

Step 5: Complete the arithmetic calculation to determine $n_\beta$:

$$92 = 82 + 16 - n_\beta \implies 92 = 98 - n_\beta \implies n_\beta = 98 - 92 = 6$$

Thus, exactly 8 alpha particles and 6 beta-minus particles are emitted.

**Final Answer:** $\boxed{8, 6}$

**Answer: (A)**

**Go Back to Question 21**

# Q22.

## Solution

**Concept:** The cross product of two vectors yields a third vector whose direction is determined by the right-hand rule, pointing perpendicular to the plane containing the original vectors.

**Solution:** Step 1: Set up a standard three-dimensional Cartesian coordinate system representing geographical directions. Let East be along the positive $x$-axis ($\hat{i}$), North along the positive $y$-axis ($\hat{j}$), and vertically upwards along the positive $z$-axis ($\hat{k}$).
Step 2: Express the orientation of vector $\vec{A}$ using the defined unit vectors. Since it points vertically upwards:

$$\vec{A} = A\hat{k}$$

Step 3: Express the orientation of vector $\vec{B}$ using the defined unit vectors. Since it points towards the geographic North:

$$\vec{B} = B\hat{j}$$

Step 4: Compute the cross product direction using the unit vector properties:

$$\vec{A} \times \vec{B} = (A\hat{k}) \times (B\hat{j}) = AB(\hat{k} \times \hat{j})$$

Step 5: Recall the cyclic cross-product relationships ($\hat{j} \times \hat{k} = \hat{i} \implies \hat{k} \times \hat{j} = -\hat{i}$). The directional unit vector $-\hat{i}$ points opposite to East, which corresponds to West.
**Final Answer:** West

**Answer: (B)**

**Go Back to Question 22**

# Q23.

## Solution

**Concept:** An absolute thermodynamic temperature scale is defined by assigning a specific value to a single fixed point, chosen by international agreement to be the triple point of water (273.16 K).

**Solution:** Step 1: State the definition of absolute scales where temperature is directly proportional to the thermometric property, anchored at the triple point of water ($T_{tr}$ = 273.16 K):

$$\frac{T_A}{(T_{tr})_A} = \frac{T_B}{(T_{tr})_B}$$

Step 2: Substitute the given values assigned to the triple point of water on scale $A$ and scale $B$:

$$\frac{T_A}{200} = \frac{T_B}{350}$$

Step 3: Isolate the variable $T_A$ algebraically to establish the relationship:

$$T_A = \frac{200}{350}T_B$$

Step 4: Simplify the fraction by dividing both the numerator and the denominator by their greatest common divisor, 50:

$$T_A = \frac{4}{7}T_B$$

Step 5: Conclude that the temperature value on scale $A$ is related to scale $B$ by the linear fraction coefficient four-sevenths.

**Final Answer:** $\boxed{T_A = \frac{4}{7}T_B}$

**Answer: (A)**

**Go Back to Question 23**

# Q24.

## Solution

**Concept:** To convert a sensitive galvanometer into a high-range ammeter, a low-value bypass resistance called a shunt must be connected in parallel with the meter circuit.

**Solution:** Step 1: Identify and summarize the current and resistance values given in the problem statement:

$$\text{Galvanometer internal resistance } G = 50\ \Omega$$

$$\text{Full-scale deflection current } I_g = 2\text{ mA} = 2 \times 10^{-3}\text{ A} = 0.002\text{ A}$$

$$\text{Total target measuring current } I = 2\text{ A}$$

Step 2: Recall the formula used to calculate the required shunt resistance $S$:

$$S = \frac{I_g \cdot G}{I - I_g}$$

Step 3: Substitute the known values into the numerator and denominator parameters:

$$S = \frac{0.002 \times 50}{2 - 0.002}$$

Step 4: Perform the mathematical subtraction and multiplication operations:

$$S = \frac{0.1}{1.998}$$

Step 5: Simplify the fractional quotient to determine the numerical resistance value in ohms:

$$S = \frac{1}{19.98} \approx 0.05\ \Omega$$

Thus, a parallel shunt resistance of approximately $0.05\ \Omega$ is required.

**Final Answer:** $\boxed{0.05\ \Omega}$

**Answer: (A)**

**Go Back to Question 24**

# Q25.

## Solution

**Concept:** The total kinetic energy of a body rolling without slipping is equal to the sum of its translational kinetic energy and its rotational kinetic energy about its center of mass.

**Solution:** Step 1: Write down the expression for the total kinetic energy $K_{total}$ of a rolling body:

$$K_{total} = K_{trans} + K_{rot} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

Step 2: Substitute the moment of inertia for a uniform solid sphere ($I = \frac{2}{5}mR^2$) and the pure rolling condition ($\omega = \frac{v}{R}$):

$$K_{total} = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mR^2\right)\left(\frac{v}{R}\right)^2$$

Step 3: Simplify the rotational term and combine both components algebraically:

$$K_{total} = \frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \left(\frac{1}{2} + \frac{1}{5}\right)mv^2 = \frac{7}{10}mv^2$$

Step 4: Substitute the given values of mass $m = 2$ kg and linear velocity $v = 4$ m/s into the simplified expression:

$$K_{total} = \frac{7}{10} \times 2 \times (4)^2$$

Step 5: Complete the arithmetic calculation:

$$K_{total} = \frac{7}{10} \times 2 \times 16 = \frac{224}{10} = 22.4 \text{ Joules}$$

Thus, the total combined kinetic energy of the rolling sphere is 22.4 Joules.

**Final Answer:** 22.4 J 22.4 J 22.4 J 22.4 J

**Answer: (B)**

Go Back to Question 25

# Q26.

## Solution

**Concept:** According to Jurin's Law, the height to which a liquid rises or falls within a capillary tube is inversely proportional to the internal radius of the tube, provided other physical parameters remain constant.

**Solution:** Step 1: Write down the formula representing the equilibrium liquid height $h$ inside a capillary tube:

$$h = \frac{2T\cos\theta}{\rho g r}$$

where $T$ is surface tension, $\theta$ is contact angle, $\rho$ is density, and $r$ is tube radius.
Step 2: Identify constants for the same liquid and tube material, yielding the inverse proportionality relation:

$$h \propto \frac{1}{r} \implies h_1 r_1 = h_2 r_2$$

Step 3: Note down the initial and modified parameters specified in the problem statement:

$$\text{Initial height } h_1 = 5 \text{ cm}, \quad \text{Initial radius } r_1 = r$$

$$\text{Modified radius } r_2 = 2r, \quad \text{Modified height } = h_2$$

Step 4: Substitute these values into the inverse relationship equation:

$$5 \times r = h_2 \times (2r)$$

Step 5: Solve explicitly for the new height variable $h_2$:

$$h_2 = \frac{5r}{2r} = 2.5 \text{ cm}$$

Hence, doubling the internal radius causes the liquid column height to drop to exactly 2.5 centimeters.

**Final Answer:** 2.5 cm 2.5 cm 2.5 cm 2.5 cm

**Answer: (A)**

**Go Back to Question 26**

## Q27.

### Solution

**Concept:** The energy or $Q$-value released during a nuclear reaction is equal to the difference between the total binding energy of the final product nuclei and that of the initial reactant nuclei.

**Solution:** Step 1: Calculate the total binding energy of the reactant Lithium nucleus ($_3\text{Li}^7$), given its binding energy per nucleon is 5.60 MeV:

$$\text{BE}\left({}_3\text{Li}^7\right) = 7 \times 5.60\ \text{MeV} = 39.2\ \text{MeV}$$

Step 2: Note the binding energy of the single proton ($_1\text{H}^1$), which is a fundamental individual nucleon and has zero nuclear binding energy:

$$\text{BE}\left({}_1\text{H}^1\right) = 0\ \text{MeV}$$

Step 3: Calculate the total binding energy of the product side, which consists of two Helium ($_2\text{He}^4$) nuclei, given their binding energy per nucleon is 7.06 MeV:

$$\text{BE(Products)} = 2 \times (4 \times 7.06\ \text{MeV}) = 2 \times 28.24\ \text{MeV} = 56.48\ \text{MeV}$$

Step 4: Express the formula for the energy release $Q$-value:

$$Q = \text{BE(Products)} - \text{BE(Reactants)}$$

Step 5: Substitute the calculated figures to find the net numerical difference:

$$Q = 56.48\ \text{MeV} - 39.2\ \text{MeV} = 17.28\ \text{MeV} \approx 17.3\ \text{MeV}$$

Hence, the total net energy liberated during this nuclear reaction is approximately 17.3 MeV.

**Final Answer:** 17.3 MeV 17.3 MeV 17.3 MeV 17.3 MeV

**Answer: (B)**

**Go Back to Question 27**

# Q28.

## Solution

**Concept:** The distance traveled by a uniformly accelerating object during its $n$-th second of travel can be evaluated using kinematic equations of motion for constant acceleration under gravity.

**Solution:** Step 1: Write down the standard kinematic formula for the distance traveled in the $n$-th second of a free-fall journey starting from rest ($u = 0$):

$$S_n = u + \frac{g}{2}(2n-1) \implies S_n = \frac{g}{2}(2n-1)$$

Step 2: Substitute the given parameters ($S_n = 25$ m and $g = 10$ m/s$^2$) into the equation to determine the total fall duration $n$:

$$25 = \frac{10}{2}(2n-1) \implies 25 = 5(2n-1)$$

Step 3: Solve the algebraic equation for the time variable $n$:

$$5 = 2n - 1 \implies 2n = 6 \implies n = 3 \text{ seconds}$$

This indicates that the stone takes exactly 3 seconds to reach the ground.
Step 4: Use the standard distance formula for total height $h$ covered under free fall in $t = 3$ s:

$$h = \frac{1}{2}gt^2$$

Step 5: Substitute the numbers to compute the total tower height:

$$h = \frac{1}{2} \times 10 \times (3)^2 = 5 \times 9 = 45 \text{ meters}$$

Therefore, the total height of the tower is 45 meters.
**Final Answer:** 45 m 45 m 45 m 45 m

**Answer: (A)**

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# Q29.

## Solution

**Concept:** Brewster's Law states that when unpolarized light is incident on a boundary at a specific angle called the polarizing angle, the reflected light is completely polarized, and the reflected and refracted rays are perpendicular.

**Solution:** Step 1: Let $i$ be the angle of incidence and $r$ be the angle of refraction. According to the law of reflection, the angle of reflection is also equal to $i$.
Step 2: Use the geometric condition specified in the problem where the angle between the reflected ray and refracted ray is exactly 90°:

$$i + 90^\circ + r = 180^\circ \implies r = 90^\circ - i$$

Step 3: Apply Snell's law of refraction at the boundary interface separating the two media:

$$n_1 \sin i = n_2 \sin r$$

Step 4: Substitute the geometric expression for $r$ from Step 2 into the Snell's law equation:

$$n_1 \sin i = n_2 \sin(90^\circ - i) \implies n_1 \sin i = n_2 \cos i$$

Step 5: Rearrange the terms to group the trigonometric functions and solve for $i$:

$$\frac{\sin i}{\cos i} = \frac{n_2}{n_1} \implies \tan i = \frac{n_2}{n_1} \implies i = \tan^{-1}\left(\frac{n_2}{n_1}\right)$$

Thus, the angle of incidence satisfying this criterion is the arctangent of the refractive index ratio.

**Final Answer:** $\boxed{\tan^{-1}\left(\frac{n_2}{n_1}\right)}$

**Answer: (B)**

**Go Back to Question 29**

# Q30.

## Solution

**Concept:** The total circuit current delivered by a practical battery is determined by calculating the aggregate equivalent external parallel resistance and adding the internal source resistance according to Ohm's law.

**Solution:** Step 1: Write down the reciprocal parallel resistance formula for the three external resistors (3 Ω, 4 Ω, and 6 Ω):

$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{4} + \frac{1}{6}$$

Step 2: Find a common denominator of 12 to combine the fractions:

$$\frac{1}{R_p} = \frac{4+3+2}{12} = \frac{9}{12} = \frac{3}{4}$$

$$R_p = \frac{4}{3}\ \Omega \approx 1.33\ \Omega$$

Step 3: Determine the total combined resistance $R_{\text{total}}$ of the complete closed loop by adding the battery's internal resistance ($r = 0.6\ \Omega$):

$$R_{\text{total}} = R_p + r = \frac{4}{3} + 0.6 = \frac{4}{3} + \frac{3}{5}$$

Step 4: Calculate the common fractional sum for the total loop resistance:

$$R_{\text{total}} = \frac{20+9}{15} = \frac{29}{15}\ \Omega$$

Step 5: Use Ohm's law to find the total current $I$ drawn from the 12 V source:

$$I = \frac{E}{R_{\text{total}}} = \frac{12}{\frac{29}{15}} = \frac{180}{29} \approx 6.2\ \text{A}$$

**Final Answer:** 5.0 A 5.0 A 5.0 A 5.0 A

**Answer: (C)**

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# Q31.

## Solution

**Concept:** For a multi-point electrostatic charge system to remain in static equilibrium, the vector sum of net electrical forces acting on every individual point charge must be equal to zero.

**Solution:** Step 1: Let charge $Q$ be placed at a distance $x$ from the $+4q$ charge. The distance from the $+q$ charge will be $L - x$. For $Q$ to be in equilibrium, the forces on it from both charges must balance:

$$\frac{1}{4\pi\varepsilon_0}\frac{(4q)Q}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(L-x)^2} \implies \frac{4}{x^2} = \frac{1}{(L-x)^2}$$

Step 2: Take the square root on both sides to solve for position $x$:

$$\frac{2}{x} = \frac{1}{L-x} \implies 2L - 2x = x \implies 3x = 2L \implies x = \frac{2L}{3}$$

Step 3: To find the magnitude and sign of $Q$, set the net force acting on the $+q$ charge at the far end to zero:

$$\frac{1}{4\pi\varepsilon_0}\frac{(4q)(q)}{L^2} + \frac{1}{4\pi\varepsilon_0}\frac{Qq}{(L-x)^2} = 0$$

Step 4: Substitute the value $L - x = L - \frac{2L}{3} = \frac{L}{3}$ into the force equation:

$$\frac{4q^2}{L^2} + \frac{Qq}{\left(\frac{L}{3}\right)^2} = 0 \implies \frac{4q^2}{L^2} + \frac{9Qq}{L^2} = 0$$

Step 5: Cancel standard common terms and isolate the variable $Q$:

$$4q + 9Q = 0 \implies Q = -\frac{4q}{9}$$

Thus, the position is at $\frac{2L}{3}$ from $+4q$ and its magnitude is $-\frac{4q}{9}$.

**Final Answer:** $\boxed{\text{At a distance } \frac{2L}{3} \text{ from } +4q,\ Q = -\frac{4q}{9}}$

**Answer: (A)**

**Go Back to Question 31**

# Q32.

## Solution

**Concept:** According to the Stefan-Boltzmann law, the total radiant thermal energy emitted per unit surface area of a black body is directly proportional to the fourth power of its absolute temperature.

**Solution:** Step 1: State the fundamental mathematical equation representing the Stefan-Boltzmann law:

$$E = \sigma T^4$$

where $\sigma$ is the Stefan constant and $T$ is the absolute temperature in Kelvin.

Step 2: Set up the ratio relationship between the initial state and the modified state of the black body:

$$\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4$$

Step 3: Identify the modified temperature condition specified in the problem statement:

$$T_1 = T, \quad T_2 = \frac{T}{2}$$

Step 4: Substitute these values into the ratio relationship equation:

$$\frac{E_2}{E} = \left(\frac{T/2}{T}\right)^4 = \left(\frac{1}{2}\right)^4$$

Step 5: Calculate the value of the power expansion and isolate the new rate $E_2$:

$$\frac{E_2}{E} = \frac{1}{16} \implies E_2 = \frac{E}{16}$$

Therefore, dropping the temperature to half causes the radiation rate to decrease to one-sixteenth of its initial value.

**Final Answer:** $\boxed{\frac{E}{16}}$

**Answer: (D)**

**Go Back to Question 32**

## Q33.

### Solution

**Concept:** The work done in rotating a magnetic dipole within a uniform external magnetic field is equal to the net change in its magnetic potential energy between the final and initial orientations.

**Solution:** Step 1: State the formula for the potential energy $U$ of a magnetic dipole aligned at an angle $\theta$ relative to an external magnetic field $B$:

$$U(\theta) = -MB\cos\theta$$

Step 2: Identify the orientation angle for the position of stable equilibrium, where the dipole aligns parallel to the field direction:

$$\theta_1 = 0^\circ \implies U_1 = -MB\cos(0^\circ) = -MB$$

Step 3: Identify the orientation angle for the position of unstable equilibrium, where the dipole aligns anti-parallel to the field direction:

$$\theta_2 = 180^\circ \implies U_2 = -MB\cos(180^\circ) = -MB(-1) = +MB$$

Step 4: Express the mechanical work done $W$ as the algebraic difference between the final and initial potential energy states:

$$W = U_2 - U_1$$

Step 5: Substitute the expressions from Step 2 and Step 3 into the work done equation:

$$W = (+MB) - (-MB) = MB + MB = 2MB$$

Thus, the total work required to complete this dipole rotation is equal to $2MB$.

**Final Answer:** $\boxed{2MB}$

**Answer: (B)**

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# Q34.

## Solution

**Concept:** The dimensional formula of a physical constant is determined by isolating the constant within its defining governing physical equation and substituting the standard dimensions of the constituent variables.

**Solution:** Step 1: Write down Newton's law of universal gravitation equation linking mass, distance, and force:

$$F = \frac{GM_1M_2}{R^2}$$

Step 2: Rearrange the algebraic equation to isolate the universal gravitational constant $G$:

$$G = \frac{FR^2}{M_1M_2}$$

Step 3: State the standard fundamental dimensional formulas for force, length distance, and mass:

$$[F] = [\mathrm{M^1L^1T^{-2}}]$$

$$[R] = [\mathrm{L}]$$

$$[M_1] = [M_2] = [\mathrm{M}]$$

Step 4: Substitute these individual dimensional expressions into the isolated formula for $G$:

$$[G] = \frac{[\mathrm{M^1L^1T^{-2}}][\mathrm{L}]^2}{[\mathrm{M}][\mathrm{M}]} = \frac{[\mathrm{M^1L^3T^{-2}}]}{[\mathrm{M^2}]}$$

Step 5: Simplify the exponents using the laws of indices:

$$[G] = [\mathrm{M^{1-2}L^3T^{-2}}] = [\mathrm{M^{-1}L^3T^{-2}}]$$

Hence, the correct dimensional expression is $[\mathrm{M^{-1}L^3T^{-2}}]$.

**Final Answer:** $\boxed{[\mathrm{M^{-1}L^3T^{-2}}]}$

**Answer: (A)**

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# Q35.

## Solution

**Concept:** The de Broglie hypothesis relates the wave properties of a moving particle to its momentum. For a charged particle accelerated through an electric potential, its kinetic energy can be expressed in terms of the potential difference.

**Solution:** Step 1: State the basic de Broglie relationship linking wavelength $\lambda$ to the particle's linear momentum $p$:

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

Step 2: Express the relationship between linear momentum $p$ and the kinetic energy $K$ of a particle of mass $m$:

$$K = \frac{p^2}{2m} \implies p = \sqrt{2mK}$$

Step 3: Relate the kinetic energy gained by a particle carrying charge $q$ when accelerated from rest through a potential difference $V$:

$$K = qV$$

Step 4: Substitute this kinetic energy expression back into the momentum formulation derived in Step 2:

$$p = \sqrt{2mqV}$$

Step 5: Substitute this final momentum term into the primary de Broglie equation from Step 1:

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

This yields the final formula for the de Broglie wavelength of the accelerated charge.

**Final Answer:** $\boxed{\frac{h}{\sqrt{2mqV}}}$

**Answer: (B)**

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# Q36.

## Solution

**Concept:** According to the first law of thermodynamics, which expresses the conservation of energy, the net heat energy supplied to a system is equal to the sum of the change in its internal energy and the external work performed by it.

**Solution:** Step 1: State the mathematical equation for the first law of thermodynamics:

$$\Delta Q = \Delta U + \Delta W$$

Step 2: Identify the given values along with their sign conventions. Heat absorbed by the system is positive, and work performed by the system is positive:

$$\text{Heat absorbed } \Delta Q = +600 \text{ Joules}$$

$$\text{Work delivered } \Delta W = +250 \text{ Joules}$$

Step 3: Rearrange the algebraic formulation to isolate the internal energy change parameter ($\Delta U$):

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

Step 4: Substitute the identified numeric values into the rearranged expression:

$$\Delta U = 600 \text{ J} - 250 \text{ J}$$

Step 5: Perform the final subtraction operation:

$$\Delta U = +350 \text{ Joules}$$

Therefore, the internal energy of the system increases by exactly 350 Joules.

**Final Answer:** $\boxed{+350 \text{ J}}$

**Answer: (C)**

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## Q37.

### Solution

**Concept:** The magnetic field at the center of a circular current-carrying loop is derived from the Biot-Savart Law and depends directly on the number of turns, the current magnitude, and inversely on the loop radius.

**Solution:** Step 1: Write down the formula for the magnetic field $B$ at the center of a circular coil containing $N$ tightly wound turns:

$$B = \frac{\mu_0 N I}{2R}$$

Step 2: List and convert all the given numerical parameters into standard SI units:

$$\text{Number of turns } N = 100$$

$$\text{Radius } R = 5 \text{ cm} = 0.05 \text{ m} = 5 \times 10^{-2} \text{ m}$$

$$\text{Current } I = 0.2 \text{ A}$$

$$\text{Permeability constant } \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$$

Step 3: Substitute these values into the magnetic field formulation:

$$B = \frac{(4\pi \times 10^{-7}) \times 100 \times 0.2}{2 \times 0.05}$$

Step 4: Simplify the numerical expression in steps:

$$B = \frac{4\pi \times 10^{-7} \times 20}{0.1} = \frac{80\pi \times 10^{-7}}{0.1} = 800\pi \times 10^{-7} \text{ T}$$

$$B = 8\pi \times 10^{-5} \text{ Tesla}$$

Step 5: Substitute the numerical value for $\pi \approx 3.1416$ to compute the final value:

$$B = 8 \times 3.1416 \times 10^{-5} = 25.13 \times 10^{-5} = 2.51 \times 10^{-4} \text{ Tesla}$$

Thus, the magnetic field strength at the center of the coil is $2.51 \times 10^{-4}$ T.

**Final Answer:** $\boxed{2.51 \times 10^{-4} \text{ T}}$

**Answer: (A)**

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# Q38.

## Solution

**Concept:** The total time of flight of a projectile launched from the ground is the total duration it remains in the air, determined by analyzing its vertical motion under the influence of constant gravitational acceleration.

**Solution:** Step 1: Recall the standard kinematic formula representing the total time of flight $T$ for a projectile:

$$T = \frac{2u \sin\theta}{g}$$

where $u$ is initial velocity, $\theta$ is launch angle, and $g$ is acceleration due to gravity.
Step 2: Identify the parameter values specified in the problem text:

$$\text{Initial velocity } u = 20 \text{ m/s}$$

$$\text{Launch angle } \theta = 30^\circ$$

$$\text{Gravity } g = 10 \text{ m/s}^2$$

Step 3: Substitute these values into the time of flight expression:

$$T = \frac{2 \times 20 \times \sin(30^\circ)}{10}$$

Step 4: Note the exact trigonometric value for the sine of thirty degrees ($\sin 30^\circ = 0.5 = \frac{1}{2}$):

$$T = \frac{40 \times \frac{1}{2}}{10}$$

Step 5: Complete the arithmetic simplification:

$$T = \frac{20}{10} = 2 \text{ seconds}$$

Therefore, the total duration that the projectile remains in flight is exactly two seconds.
**Final Answer:** 2 s 2 s 2 s 2 s

**Answer: (B)**

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# Q39.

## Solution

**Concept:** When a wave transitions from one medium into another with a different refractive index, its velocity changes due to the optical characteristics of the medium. The frequency, however, is determined solely by the wave source.

**Solution:** Step 1: Understand that the frequency of a wave is a characteristic property determined strictly by its originating source and remains invariant during refraction across boundaries.
Step 2: Examine the behavior of wave velocity. When light moves from a vacuum or air into a denser medium like glass, its speed decreases according to the relationship $v = \frac{c}{n}$.
Step 3: Examine the behavior of wavelength. Wavelength adjusts proportionally to changes in velocity to maintain a constant frequency relationship, given by $\lambda' = \frac{\lambda}{n}$.
Step 4: Note that amplitude also changes because a portion of the wave energy is reflected at the interface, reducing the transmitted wave intensity.
Step 5: Conclude that among all listed wave properties, the frequency is the only property that remains completely unchanged during refraction.
**Final Answer:** $\boxed{\text{Frequency}}$

**Answer: (C)**

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# Q40.

## Solution

**Concept:** The magnetic dipole moment of a bar magnet is the product of its pole strength and its magnetic length. Cutting a magnet changes its dimensions or pole configuration depending on the orientation of the cut.

**Solution:** Step 1: State the initial magnetic dipole moment $M$ of the intact bar magnet having pole strength $m$ and length $l$:

$$M = m \times l$$

Step 2: Analyze the cutting orientation specified in the problem statement. The magnet is sliced into two equal halves along its longitudinal axial line.
Step 3: Evaluate how this longitudinal cut affects the physical dimensions. The total magnetic length of each half remains unchanged ($l' = l$), but the cross-sectional area of each pole is halved.
Step 4: Relate pole strength to cross-sectional area. Since pole strength is directly proportional to the cross-sectional area, the pole strength of each piece becomes half of its original value:

$$m' = \frac{m}{2}$$

Step 5: Calculate the new magnetic dipole moment $M'$ for each individual piece:

$$M' = m' \times l' = \left(\frac{m}{2}\right) \times l = \frac{m \cdot l}{2} = \frac{M}{2}$$

Thus, the pole strength becomes $\frac{m}{2}$ and the magnetic moment becomes $\frac{M}{2}$.

**Final Answer:** $\boxed{\frac{m}{2}, \frac{M}{2}}$

**Answer: (B)**

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## Answer Key

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