

# MHT-CET Physics Sample Paper-14

Duration: 45 Minutes

Maximum Marks: 50

## Instructions

- This paper contains a total of **50** Multiple Choice Questions.
- Each correct answer carries **+1 marks**.
- No negative marking for incorrect questions.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.
- No marks will be deducted for questions that are left unattempted.

**Q1.** A thin uniform rod of length  $L$  and mass  $M$  is bent at its midpoint to form an angle of  $90^\circ$ . The moment of inertia of this bent rod about an axis passing through the vertex and perpendicular to the plane of the rod is:

- (A)  $\frac{1}{3}ML^2$   
(B)  $\frac{1}{6}ML^2$   
(C)  $\frac{1}{12}ML^2$   
(D)  $\frac{1}{24}ML^2$

**Q2.** A particle executes S.H.M. with an amplitude  $A$ . At what displacement from the mean position is the potential energy equal to three times the kinetic energy?

- (A)  $\frac{A}{2}$   
(B)  $\frac{A}{\sqrt{2}}$   
(C)  $\frac{\sqrt{3}A}{2}$   
(D)  $\frac{2A}{\sqrt{3}}$

**Q3.** Two parallel plate capacitors of capacitances  $C$  and  $2C$  are connected in parallel and charged to a potential difference  $V$ . The battery is then disconnected and the region between the plates of the first capacitor is filled with a dielectric of constant  $K$ . The new potential difference across the combination is:



- (A)  $\frac{3V}{K+2}$
- (B)  $\frac{V}{K+3}$
- (C)  $\frac{3V}{K}$
- (D)  $\frac{2V}{K+2}$

**Q4.** A current of 2 A flows through a network of resistors. One of the resistors is a wire of length  $L$  and resistance  $10\Omega$ . If this wire is stretched to triple its length, the new current in this specific branch, assuming the voltage across it remains constant, will be:

- (A) 0.66 A
- (B) 0.22 A
- (C) 1.2 A
- (D) 0.44 A

**Q5.** A long straight wire carries a current  $I$ . A square loop of side  $a$  is placed in the same plane as the wire at a distance  $a$  from it. The mutual inductance between the wire and the loop is:

- (A)  $\frac{\mu_0 a}{2\pi} \ln 2$
- (B)  $\frac{\mu_0 a}{\pi} \ln 2$
- (C)  $\frac{\mu_0 a}{2\pi}$
- (D)  $\frac{\mu_0 a}{4\pi} \ln 2$

**Q6.** In an AC circuit, the voltage applied is  $V = V_0 \sin(\omega t)$  and the resulting current is  $I = I_0 \sin(\omega t - \pi/2)$ . The power consumption in the circuit is:

- (A)  $V_0 I_0$
- (B)  $\frac{V_0 I_0}{\sqrt{2}}$
- (C) Zero
- (D)  $\frac{V_0 I_0}{2}$



- Q7.** A biconvex lens of focal length  $f$  is cut into two identical plano-convex lenses. The focal length of each new lens is:
- (A)  $f/2$
  - (B)  $f$
  - (C)  $2f$
  - (D)  $4f$
- Q8.** The molar specific heat of an ideal gas at constant pressure is  $C_p = \frac{7}{2}R$ . When 200 J of heat is supplied to the gas at constant pressure, the change in internal energy is:
- (A) 142.8 J
  - (B) 100 J
  - (C) 200 J
  - (D) 57.2 J
- Q9.** The de-Broglie wavelength of an electron accelerated through a potential difference of  $V$  is  $\lambda$ . If the accelerating potential is increased to  $4V$ , the new de-Broglie wavelength will be:
- (A)  $2\lambda$
  - (B)  $4\lambda$
  - (C)  $\lambda/2$
  - (D)  $\lambda/4$
- Q10.** A ball is thrown vertically upwards with a velocity  $u$ . The distance traveled by the ball in the last second of its upward journey is:
- (A)  $gu^2/2$
  - (B)  $g/2$
  - (C)  $u - g/2$



(D)  $g$

**Q11.** A body of mass 5 kg is moving with a momentum of 10 kg m/s. A force of 0.2 N acts on it in the direction of motion for 10 s. The increase in its kinetic energy is:

(A) 4.4 J

(B) 2.2 J

(C) 10 J

(D) 8.8 J

**Q12.** Two satellites  $A$  and  $B$  go round a planet in circular orbits of radii  $R$  and  $4R$  respectively. If the speed of satellite  $A$  is  $3v$ , then the speed of satellite  $B$  is:

(A)  $12v$

(B)  $6v$

(C)  $1.5v$

(D)  $0.75v$

**Q13.** The terminal velocity of a small sphere of radius  $r$  falling through a viscous liquid is  $v$ . What will be the terminal velocity of a sphere of the same material but of radius  $2r$  in the same liquid?

(A)  $v$

(B)  $2v$

(C)  $4v$

(D)  $8v$

**Q14.** In a common base amplifier, the phase difference between the input signal voltage and output voltage is:

(A) 0



- (B)  $\pi/4$
- (C)  $\pi/2$
- (D)  $\pi$

**Q15.** If the error in the measurement of the radius of a sphere is 2%, then the error in the measurement of its volume is:

- (A) 2%
- (B) 4%
- (C) 6%
- (D) 8%

**Q16.** A bar magnet of magnetic moment  $M$  is placed in a uniform magnetic field  $B$  at an angle of  $30^\circ$  to the direction of the field. The torque acting on the magnet is:

- (A)  $MB$
- (B)  $MB/2$
- (C)  $\sqrt{3}MB/2$
- (D)  $2MB$

**Q17.** In a series LCR circuit, the resonant frequency is  $f$ . If the capacitance is made 4 times its initial value, the new resonant frequency will be:

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

**Q18.** A simple microscope consists of a convex lens of focal length 5 cm. If the image is formed at the least distance of distinct vision (25 cm), its magnifying power is:



- (A) 5
- (B) 4
- (C) 6
- (D) 1.2

**Q19.** At what temperature will the rms speed of oxygen molecules be double their rms speed at  $27^{\circ}\text{C}$ ?

- (A)  $54^{\circ}\text{C}$
- (B)  $600^{\circ}\text{C}$
- (C)  $327^{\circ}\text{C}$
- (D)  $927^{\circ}\text{C}$

**Q20.** The ionization energy of a hydrogen atom in its first excited state is:

- (A) 13.6 eV
- (B) 3.4 eV
- (C) 1.51 eV
- (D) 0.85 eV

**Q21.** The angle of minimum deviation for a prism of refractive index  $\sqrt{3}$  is equal to the angle of the prism. The angle of the prism is:

- (A)  $30^{\circ}$
- (B)  $45^{\circ}$
- (C)  $60^{\circ}$
- (D)  $90^{\circ}$

**Q22.** A circular coil of radius  $R$  carries a current  $I$ . The magnetic field at its center is  $B$ . At what distance from the center on the axis of the coil will the magnetic field be  $B/8$ ?



- (A)  $\sqrt{2}R$
- (B)  $\sqrt{3}R$
- (C)  $2R$
- (D)  $3R$

**Q23.** The work function of a metal is 2.5 eV. The maximum wavelength of light that can cause photoelectric emission from this metal is:

- (A) 4960 Å
- (B) 5000 Å
- (C) 4000 Å
- (D) 3100 Å

**Q24.** A car moves at a speed of 36 km/h on a level road. The coefficient of friction between the tires and the road is 0.5. The minimum turning radius of the car is: ( $g = 10 \text{ m/s}^2$ )

- (A) 20 m
- (B) 40 m
- (C) 10 m
- (D) 5 m

**Q25.** Two soap bubbles of radii 3 cm and 4 cm coalesce under isothermal conditions to form a single bubble. The radius of the new bubble is:

- (A) 7 cm
- (B) 5 cm
- (C) 3.5 cm
- (D) 4.5 cm



- Q26.** An engine pumps water through a hose pipe. Water passes through the pipe and leaves it with a velocity of 2 m/s. The mass per unit length of water in the pipe is 100 kg/m. What is the power of the engine?
- (A) 800 W  
(B) 400 W  
(C) 200 W  
(D) 100 W
- Q27.** A radioactive substance has a half-life of 10 days. What fraction of the substance will remain undecayed after 30 days?
- (A)  $1/3$   
(B)  $1/6$   
(C)  $1/8$   
(D)  $1/4$
- Q28.** A capillary tube of radius  $r$  is immersed in water and water rises to a height  $h$ . If the mass of water in the capillary tube is  $m$ , what will be the mass of water that will rise in another capillary tube of radius  $2r$ ?
- (A)  $m$   
(B)  $2m$   
(C)  $4m$   
(D)  $m/2$
- Q29.** The fundamental frequency of a closed organ pipe is 200 Hz. The frequency of the second overtone of this pipe is:
- (A) 400 Hz  
(B) 600 Hz  
(C) 800 Hz



(D) 1000 Hz

**Q30.** If the current in a copper wire is increased by 20%, the percentage increase in the heat produced in the wire, assuming resistance remains constant, is:

(A) 20%

(B) 40%

(C) 44%

(D) 10%

**Q31.** A particle of mass  $m$  is attached to a string and swung in a vertical circle of radius  $r$ . The minimum velocity required at the lowest point to just complete the circle is:

(A)  $\sqrt{gr}$

(B)  $\sqrt{3gr}$

(C)  $\sqrt{5gr}$

(D)  $2\sqrt{gr}$

**Q32.** In a Young's double slit experiment, the distance between the slits is 0.1 mm and the distance to the screen is 1 m. If the wavelength used is 600 nm, the fringe width is:

(A) 6 mm

(B) 0.6 mm

(C) 0.06 mm

(D) 60 mm

**Q33.** The resistance of a conductor is  $10\Omega$  at  $0^\circ\text{C}$  and  $15\Omega$  at  $100^\circ\text{C}$ . The temperature coefficient of resistance is:

(A)  $0.005/^\circ\text{C}$



- (B)  $0.05/^{\circ}\text{C}$
- (C)  $0.5/^{\circ}\text{C}$
- (D)  $0.0005/^{\circ}\text{C}$

**Q34.** A thermodynamic system is taken through a cycle  $ABCD$ . If the work done by the gas is 10 J and 50 J of heat is absorbed, the net change in internal energy for the cycle is:

- (A) 40 J
- (B) 60 J
- (C) Zero
- (D) 10 J

**Q35.** The Boolean expression  $Y = \overline{A \cdot B}$  represents which logic gate?

- (A) AND
- (B) OR
- (C) NAND
- (D) NOR

**Q36.** A body weighs 72 N on the surface of the earth. What is the gravitational force on it at a height equal to half the radius of the earth?

- (A) 32 N
- (B) 30 N
- (C) 24 N
- (D) 48 N

**Q37.** A transformer has an efficiency of 90% and works on 200 V and 3 kW power supply. If the current in the secondary coil is 6 A, the voltage across the secondary is:



- (A) 450 V
- (B) 500 V
- (C) 400 V
- (D) 300 V

**Q38.** The magnetic flux linked with a coil is given by  $\phi = 5t^2 + 3t + 16$ . The induced emf in the coil at  $t = 2$  s is:

- (A) 23 V
- (B) 20 V
- (C) 10 V
- (D) 16 V

**Q39.** Two spheres of radii  $R_1$  and  $R_2$  are charged to the same potential. The ratio of their surface charge densities is:

- (A)  $R_1/R_2$
- (B)  $R_2/R_1$
- (C)  $R_1^2/R_2^2$
- (D) 1 : 1

**Q40.** A simple pendulum has a period  $T$ . If the length of the pendulum is increased by 21%, the percentage increase in the period is:

- (A) 10%
- (B) 11%
- (C) 21%
- (D) 42%

**Q41.** A light of wavelength  $5000 \text{ \AA}$  falls on a plane reflecting surface. What are the wavelength and frequency of reflected light?



- (A)  $5000 \text{ \AA}, 6 \times 10^{14} \text{ Hz}$
- (B)  $2500 \text{ \AA}, 12 \times 10^{14} \text{ Hz}$
- (C)  $5000 \text{ \AA}, 3 \times 10^{14} \text{ Hz}$
- (D)  $10000 \text{ \AA}, 3 \times 10^{14} \text{ Hz}$

**Q42.** The displacement of a particle is given by  $x = 3 \sin(2t + \pi/4)$  m. The maximum velocity of the particle is:

- (A) 3 m/s
- (B) 6 m/s
- (C) 2 m/s
- (D) 1.5 m/s

**Q43.** A wire of resistance  $R$  is divided into  $n$  equal parts. These parts are then connected in parallel. The equivalent resistance of the combination is:

- (A)  $nR$
- (B)  $R/n$
- (C)  $R/n^2$
- (D)  $n^2R$

**Q44.** In a photoelectric experiment, the stopping potential is 3 V for a certain monochromatic light. The maximum kinetic energy of photoelectrons is:

- (A) 3 eV
- (B) 1.5 eV
- (C) 6 eV
- (D)  $4.8 \times 10^{-19} \text{ J}$

**Q45.** A solid sphere and a hollow sphere of the same mass and same outer radius are released from rest from the top of an inclined plane. Which one reaches the bottom first?



- (A) Hollow sphere
- (B) Solid sphere
- (C) Both together
- (D) Depends on the angle of inclination

**Q46.** The half-life of a radioactive element is 1600 years. Its average life is:

- (A) 2309 years
- (B) 1109 years
- (C) 3200 years
- (D) 800 years

**Q47.** The electric field intensity at a point  $P$  due to a point charge  $q$  is  $E$ . If the distance of the point  $P$  from the charge is doubled and the charge is halved, the new electric field intensity will be:

- (A)  $E/2$
- (B)  $E/4$
- (C)  $E/8$
- (D)  $E/16$

**Q48.** An inductor of 5 mH carries a current of 2 A. The energy stored in the magnetic field of the inductor is:

- (A) 10 mJ
- (B) 20 mJ
- (C) 5 mJ
- (D) 1 mJ

**Q49.** The process in which no heat enters or leaves the system is called:



- (A) Isothermal
- (B) Isobaric
- (C) Isochoric
- (D) Adiabatic

**Q50.** The dimension of Planck's constant is same as that of:

- (A) Energy
- (B) Linear momentum
- (C) Angular momentum
- (D) Power



## Detailed Solutions

Q1.

## Solution

**Concept:**

The moment of inertia ( $I$ ) of a uniform rod of mass  $m$  and length  $l$  about an axis passing through one end and perpendicular to its length is given by:

$$I = \frac{1}{3}ml^2$$

For a composite system, the total moment of inertia is the sum of the moments of inertia of its individual parts about the same axis.

**Solution:**

1. The original rod has mass  $M$  and length  $L$ . 2. When bent at the midpoint, it forms two segments, each of mass  $m = M/2$  and length  $l = L/2$ . 3. The axis passes through the vertex (the joint). Both segments are attached at one of their ends to this vertex. 4. The moment of inertia of one segment about the vertex is:

$$I_{segment} = \frac{1}{3} \left( \frac{M}{2} \right) \left( \frac{L}{2} \right)^2$$

5. Calculating this value:

$$I_{segment} = \frac{1}{3} \times \frac{M}{2} \times \frac{L^2}{4} = \frac{ML^2}{24}$$

6. Since there are two such segments, the total moment of inertia  $I_{total}$  is:

$$I_{total} = I_{segment} + I_{segment} = 2 \times \frac{ML^2}{24} = \frac{ML^2}{12}$$

**Final Answer:** The moment of inertia of the bent rod is  $\frac{1}{12}ML^2$ .

**Answer: (C)**



Q2.

**Solution****Concept:**

In Simple Harmonic Motion (S.H.M.), the potential energy ( $U$ ) and kinetic energy ( $K$ ) at a displacement  $x$  from the mean position are given by:

$$U = \frac{1}{2}kx^2$$

$$K = \frac{1}{2}k(A^2 - x^2)$$

where  $k$  is the force constant and  $A$  is the amplitude.

**Solution:**

1. The problem states that the potential energy is three times the kinetic energy:

$$U = 3K$$

2. Substitute the expressions for  $U$  and  $K$ :

$$\frac{1}{2}kx^2 = 3 \left[ \frac{1}{2}k(A^2 - x^2) \right]$$

3. Cancel the common factor  $\frac{1}{2}k$  from both sides:

$$x^2 = 3(A^2 - x^2)$$

4. Expand the bracket and solve for  $x$ :

$$x^2 = 3A^2 - 3x^2$$

$$4x^2 = 3A^2$$

$$x^2 = \frac{3A^2}{4}$$

5. Taking the square root:

$$x = \frac{\sqrt{3}A}{2}$$

**Final Answer:** The displacement is  $\frac{\sqrt{3}A}{2}$ .

**Answer: (C)**



Q3.

**Solution****Concept:**

When capacitors are connected in parallel, the total capacitance is  $C_{total} = C_1 + C_2$ . The charge on the system is  $Q = C_{total}V$ . If the battery is disconnected, the total charge  $Q$  remains conserved even if the dielectric is inserted. The new capacitance of a capacitor with a dielectric constant  $K$  is  $C' = KC$ .

**Solution:**

1. Initial state: Capacitors  $C$  and  $2C$  are in parallel. Total initial capacitance  $C_{initial} = C + 2C = 3C$ . 2. Initial charge stored:  $Q = C_{initial}V = 3CV$ . 3. After disconnecting the battery, a dielectric  $K$  is inserted into the first capacitor ( $C$ ). 4. New capacitance of the first capacitor:  $C'_1 = KC$ . 5. New total capacitance of the parallel combination:

$$C_{final} = C'_1 + C_2 = KC + 2C = (K + 2)C$$

6. Since charge is conserved, the new potential  $V'$  is:

$$V' = \frac{Q}{C_{final}}$$

7. Substitute  $Q = 3CV$  and  $C_{final} = (K + 2)C$ :

$$V' = \frac{3CV}{(K + 2)C} = \frac{3V}{K + 2}$$

**Final Answer:** The new potential difference is  $\frac{3V}{K+2}$ .

**Answer: (A)**



Q4.

**Solution****Concept:**

When a wire is stretched, its volume remains constant. If the length  $L$  increases, the cross-sectional area  $A$  decreases. Resistance is given by:

$$R = \rho \frac{L}{A}$$

If length is tripled ( $L' = 3L$ ), the area becomes  $A' = A/3$  to keep volume  $V = LA$  constant. This results in the new resistance  $R' = n^2R$ , where  $n$  is the stretching factor.

**Solution:**

1. The wire is stretched to triple its length, so  $n = 3$ . 2. The new resistance  $R'$  is:

$$R' = n^2R = 3^2 \times 10\Omega = 9 \times 10\Omega = 90\Omega$$

3. The initial current  $I$  was 2 A through a  $10\Omega$  resistance. 4. Using Ohm's Law ( $V = IR$ ), the voltage across the branch is:

$$V = 2 \text{ A} \times 10\Omega = 20 \text{ V}$$

5. The problem states the voltage remains constant. The new current  $I'$  is:

$$I' = \frac{V}{R'}$$

6. Calculation:

$$I' = \frac{20 \text{ V}}{90\Omega} = \frac{2}{9} \text{ A} \approx 0.222 \text{ A}$$

**Final Answer:** The new current is 0.22 A.

**Answer: (B)**



Q5.

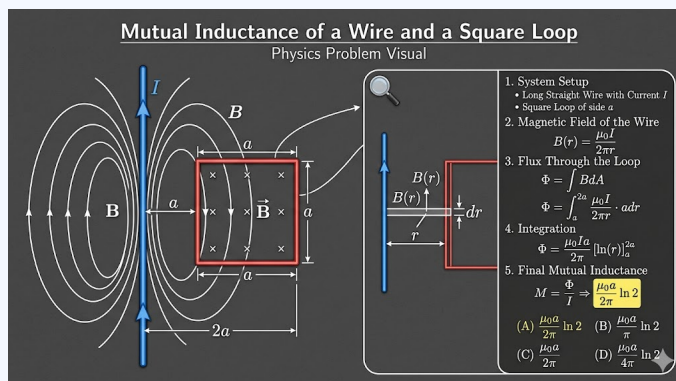
### Solution

#### Concept:

Mutual inductance ( $M$ ) is defined by the flux linkage  $\Phi = MI$ . For a square loop near a long wire, the magnetic field  $B$  produced by the wire is non-uniform and depends on the distance  $r$ :

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

We must integrate to find the total flux through the loop.



#### Solution:

1. Consider a small strip of the loop of width  $dr$  at a distance  $r$  from the wire. 2. The area of this strip is  $dA = a \cdot dr$ . 3. The flux  $d\Phi$  through this strip is:

$$d\Phi = B \cdot dA = \left( \frac{\mu_0 I}{2\pi r} \right) (a \cdot dr)$$

4. To find total flux  $\Phi$ , integrate from  $r = a$  to  $r = 2a$ :

$$\Phi = \int_a^{2a} \frac{\mu_0 I a}{2\pi r} dr = \frac{\mu_0 I a}{2\pi} \int_a^{2a} \frac{1}{r} dr$$

5. Evaluating the integral:

$$\Phi = \frac{\mu_0 I a}{2\pi} [\ln r]_a^{2a} = \frac{\mu_0 I a}{2\pi} (\ln 2a - \ln a) = \frac{\mu_0 I a}{2\pi} \ln 2$$

6. Since  $\Phi = MI$ , the mutual inductance is:

$$M = \frac{\mu_0 a}{2\pi} \ln 2$$

**Final Answer:** The mutual inductance is  $\frac{\mu_0 a}{2\pi} \ln 2$ .

**Answer: (A)**



Q6.

**Solution****Concept:**

In an AC circuit, the average power dissipated is given by:

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

where  $\phi$  is the phase difference between the voltage and the current. The term  $\cos \phi$  is known as the power factor.

**Solution:**

1. The given voltage is  $V = V_0 \sin(\omega t)$ , so its phase is  $\omega t$ . 2. The given current is  $I = I_0 \sin(\omega t - \pi/2)$ , so its phase is  $(\omega t - \pi/2)$ . 3. The phase difference  $\phi$  is the difference between these two phases:

$$\phi = (\omega t) - (\omega t - \pi/2) = \pi/2$$

4. Calculate the power factor:

$$\cos \phi = \cos(\pi/2) = 0$$

5. Substitute the power factor into the average power formula:

$$P_{avg} = V_{rms} I_{rms} \times 0 = 0$$

6. This represents a purely inductive circuit (or a purely capacitive one with a different sign) where the current is "wattless."

**Final Answer:** The power consumption in the circuit is Zero.

**Answer: (C)**



Q7.

**Solution****Concept:**

The focal length of a lens is determined by the Lens Maker's Formula:

$$\frac{1}{f} = (\mu - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

For a symmetric biconvex lens,  $R_1 = R$  and  $R_2 = -R$ . When a lens is cut vertically (along the principal axis), the radius of curvature of one surface becomes infinite (flat).

**Solution:**

1. For the original biconvex lens:

$$\frac{1}{f} = (\mu - 1) \left( \frac{1}{R} - \frac{1}{-R} \right) = (\mu - 1) \frac{2}{R}$$

Thus,  $f = \frac{R}{2(\mu-1)}$ . 2. When cut into two identical plano-convex lenses, for each new lens: The first surface radius  $R_1 = R$  and the second surface is flat  $R_2 = \infty$ . 3. Applying the Lens Maker's Formula for the plano-convex lens ( $f'$ ):

$$\frac{1}{f'} = (\mu - 1) \left( \frac{1}{R} - \frac{1}{\infty} \right) = (\mu - 1) \frac{1}{R}$$

4. Compare  $1/f'$  with  $1/f$ :

$$\frac{1}{f'} = \frac{1}{2} \left( \frac{1}{f} \right)$$

5. Therefore,  $f' = 2f$ .

**Final Answer:** The focal length of each new lens is  $2f$ .

**Answer: (C)**



Q8.

**Solution****Concept:**

For an ideal gas, the heat supplied at constant pressure ( $Q_p$ ), the change in internal energy ( $\Delta U$ ), and the work done ( $W$ ) are related by the first law of thermodynamics:  $Q_p = \Delta U + W$ . Also,  $Q_p = nC_p\Delta T$  and  $\Delta U = nC_v\Delta T$ . The relationship between  $C_p$  and  $C_v$  is  $C_p - C_v = R$ .

**Solution:**

1. Given  $C_p = \frac{7}{2}R$ . 2. Find  $C_v$ :

$$C_v = C_p - R = \frac{7}{2}R - R = \frac{5}{2}R$$

3. The ratio of change in internal energy to heat supplied at constant pressure is:

$$\frac{\Delta U}{Q_p} = \frac{nC_v\Delta T}{nC_p\Delta T} = \frac{C_v}{C_p}$$

4. Substitute the values of  $C_v$  and  $C_p$ :

$$\frac{\Delta U}{Q_p} = \frac{5/2R}{7/2R} = \frac{5}{7}$$

5. Given  $Q_p = 200$  J, solve for  $\Delta U$ :

$$\Delta U = \frac{5}{7} \times 200 = \frac{1000}{7} \approx 142.857 \text{ J}$$

**Final Answer:** The change in internal energy is 142.8 J.

**Answer: (A)**



Q9.

**Solution****Concept:**

The de-Broglie wavelength ( $\lambda$ ) of a particle with mass  $m$  and charge  $q$  accelerated through a potential difference  $V$  is given by:

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

This shows that  $\lambda \propto \frac{1}{\sqrt{V}}$  when mass and charge are constant.

**Solution:**

1. Initially, the wavelength is  $\lambda_1 = \lambda$  for potential  $V_1 = V$ . 2. The new potential is  $V_2 = 4V$ . 3. Using the proportionality:

$$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{V_1}{V_2}}$$

4. Substitute the values:

$$\frac{\lambda_2}{\lambda} = \sqrt{\frac{V}{4V}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

5. Therefore:

$$\lambda_2 = \frac{\lambda}{2}$$

**Final Answer:** The new de-Broglie wavelength will be  $\lambda/2$ .

**Answer: (C)**

Q10.

**Solution****Concept:**

When a ball is thrown upwards, its velocity at the highest point is zero. The "last second of the upward journey" is equivalent to the "first second of the downward journey" because the motion under gravity is symmetric (neglecting air resistance).

**Solution:**

1. In the last second of upward motion, the ball reaches its maximum height where  $v = 0$ . 2. Let's analyze the equivalent downward motion starting from rest ( $u = 0$ ). 3. The distance traveled in time  $t$  starting from rest is  $s = \frac{1}{2}gt^2$ . 4. For the first second ( $t = 1$  s):

$$s = \frac{1}{2} \times g \times (1)^2$$

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

5. By symmetry, the distance covered in the last second of upward motion must be equal to the distance covered in the first second of downward motion.

**Final Answer:** The distance traveled is  $g/2$ .

**Answer: (B)**



Q11.

**Solution****Concept:**

The relationship between force ( $F$ ), time ( $t$ ), and momentum ( $p$ ) is given by the impulse-momentum theorem:

$$\Delta p = F \cdot t$$

The kinetic energy ( $K$ ) can be expressed in terms of momentum ( $p$ ) and mass ( $m$ ) as:

$$K = \frac{p^2}{2m}$$

**Solution:**

1. Initial momentum  $p_1 = 10$  kg m/s and mass  $m = 5$  kg. 2. Initial kinetic energy  $K_1$ :

$$K_1 = \frac{p_1^2}{2m} = \frac{10^2}{2 \times 5} = \frac{100}{10} = 10 \text{ J}$$

3. The change in momentum  $\Delta p$  due to the force is:

$$\Delta p = F \times t = 0.2 \text{ N} \times 10 \text{ s} = 2 \text{ kg m/s}$$

4. Final momentum  $p_2$ :

$$p_2 = p_1 + \Delta p = 10 + 2 = 12 \text{ kg m/s}$$

5. Final kinetic energy  $K_2$ :

$$K_2 = \frac{p_2^2}{2m} = \frac{12^2}{2 \times 5} = \frac{144}{10} = 14.4 \text{ J}$$

6. The increase in kinetic energy  $\Delta K$ :

$$\Delta K = K_2 - K_1 = 14.4 \text{ J} - 10 \text{ J} = 4.4 \text{ J}$$

**Final Answer:** The increase in its kinetic energy is 4.4 J.

**Answer: (A)**



## Q12.

**Solution****Concept:**

The orbital speed ( $v$ ) of a satellite in a circular orbit of radius  $r$  around a planet of mass  $M$  is given by:

$$v = \sqrt{\frac{GM}{r}}$$

This implies that orbital speed is inversely proportional to the square root of the orbital radius:  
 $v \propto \frac{1}{\sqrt{r}}$ .

**Solution:**

1. For satellite  $A$ , the radius is  $R_A = R$  and speed is  $v_A = 3v$ . 2. For satellite  $B$ , the radius is  $R_B = 4R$  and speed is  $v_B$ . 3. Using the proportionality:

$$\frac{v_B}{v_A} = \sqrt{\frac{R_A}{R_B}}$$

4. Substitute the given values:

$$\frac{v_B}{3v} = \sqrt{\frac{R}{4R}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

5. Solve for  $v_B$ :

$$v_B = 3v \times \frac{1}{2} = 1.5v$$

**Final Answer:** The speed of satellite  $B$  is  $1.5v$ .

**Answer: (C)**



Q13.

**Solution****Concept:**

The terminal velocity ( $v$ ) of a sphere falling through a viscous medium is given by Stokes' Law:

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

where  $r$  is the radius,  $\rho$  is the density of the sphere,  $\sigma$  is the density of the liquid, and  $\eta$  is the viscosity. This shows that  $v \propto r^2$  for the same material and liquid.

**Solution:**

1. Initial radius is  $r$  and terminal velocity is  $v$ . 2. New radius is  $r' = 2r$ . 3. Using the proportionality  $v \propto r^2$ :

$$\frac{v'}{v} = \left(\frac{r'}{r}\right)^2$$

4. Substitute  $r' = 2r$ :

$$\frac{v'}{v} = \left(\frac{2r}{r}\right)^2 = 2^2 = 4$$

5. Therefore:

$$v' = 4v$$

**Final Answer:** The new terminal velocity will be  $4v$ .

**Answer: (C)**

Q14.

**Solution****Concept:**

In a transistor amplifier, the phase relationship depends on the configuration. In a Common Emitter (CE) amplifier, there is a phase reversal ( $180^\circ$  or  $\pi$ ). In a Common Base (CB) and Common Collector (CC) amplifier, the input and output signals are in phase.

**Solution:**

1. The question specifies a Common Base (CB) amplifier configuration. 2. In the CB configuration, as the input signal voltage increases, the emitter-base junction becomes more forward-biased, increasing the collector current. 3. This increase in collector current leads to an increase in the voltage drop across the load resistor in a way that the output voltage follows the input signal direction. 4. Therefore, there is no phase shift between the input and output. 5. The phase difference is 0.

**Final Answer:** The phase difference is 0.

**Answer: (A)**



Q15.

**Solution****Concept:**

The volume ( $V$ ) of a sphere is given by the formula  $V = \frac{4}{3}\pi r^3$ . In error analysis, if a quantity  $Z = A^n$ , the relative error in  $Z$  is  $\frac{\Delta Z}{Z} = n \frac{\Delta A}{A}$ .

**Solution:**

1. The relationship for volume is  $V \propto r^3$ . 2. The percentage error in volume is given by:

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

3. Given the percentage error in radius  $\frac{\Delta r}{r} \times 100 = 2\%$ . 4. Substitute the value:

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

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

**Answer: (C)**

Q16.

**Solution****Concept:**

The torque ( $\tau$ ) acting on a magnetic dipole (like a bar magnet or a current loop) placed in a uniform magnetic field ( $B$ ) is given by the vector product:

$$\vec{\tau} = \vec{M} \times \vec{B}$$

The magnitude of the torque is  $\tau = MB \sin \theta$ , where  $M$  is the magnetic dipole moment and  $\theta$  is the angle between  $\vec{M}$  and  $\vec{B}$ .

**Solution:**

1. The magnetic moment of the magnet is  $M$  and the magnetic field strength is  $B$ . 2. The problem specifies that the magnet is placed at an angle of  $30^\circ$  to the direction of the magnetic field ( $\theta = 30^\circ$ ). 3. The torque acting on the magnet is:

$$\tau = MB \sin(30^\circ)$$

4. Since  $\sin(30^\circ) = 1/2$ , the expression becomes:

$$\tau = \frac{MB}{2}$$

5. From this, we can see that the maximum torque ( $\tau_{max}$ ) occurs at  $90^\circ$ , where  $\tau_{max} = MB$ . Thus, the torque at  $30^\circ$  is exactly half of the maximum possible torque for that magnet in that field.

**Final Answer:** The torque is  $MB/2$ .

**Answer: (B)**



Q17.

**Solution****Concept:**

In a series LCR circuit, resonance occurs when the inductive reactance ( $X_L$ ) equals the capacitive reactance ( $X_C$ ). The resonant frequency ( $f_r$ ) is given by:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

At resonance, the impedance of the circuit is minimum and equal to the resistance ( $Z = R$ ), and the current is maximum.

**Solution:**

1. Initially, the resonant frequency is  $f$ . 2. The capacitance is changed from  $C$  to  $4C$  while the inductance  $L$  remains constant. 3. The new resonant frequency  $f'$  is:

$$f' = \frac{1}{2\pi\sqrt{L(4C)}}$$

4. We can take the constant out of the square root:

$$f' = \frac{1}{2\pi\sqrt{4}\sqrt{LC}} = \frac{1}{2} \left( \frac{1}{2\pi\sqrt{LC}} \right)$$

5. Substituting the initial frequency  $f$ :

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

**Final Answer:** The new resonant frequency is  $f/2$ .

**Answer: (A)**



Q18.

**Solution****Concept:**

The magnifying power ( $M$ ) of a simple microscope (a single convex lens) when the image is formed at the least distance of distinct vision ( $D = 25$  cm) is:

$$M = 1 + \frac{D}{f}$$

where  $f$  is the focal length of the lens.

**Solution:**

1. Given the focal length of the convex lens  $f = 5$  cm. 2. The standard value for the least distance of distinct vision is  $D = 25$  cm. 3. Using the formula for magnifying power:

$$M = 1 + \frac{25}{5}$$

4. Calculating the value:

$$M = 1 + 5 = 6$$

5. This means the image appears six times larger than the object when viewed through the lens at this specific distance.

**Final Answer:** The magnifying power is 6.

**Answer: (C)**



Q19.

**Solution****Concept:**

The root mean square (rms) speed of gas molecules is given by the formula:

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

where  $R$  is the gas constant,  $T$  is the absolute temperature (in Kelvin), and  $M$  is the molar mass of the gas. This indicates that  $v_{rms} \propto \sqrt{T}$ .

**Solution:**

1. The initial temperature is  $T_1 = 27^\circ\text{C}$ . Converting to Kelvin:

$$T_1 = 27 + 273 = 300 \text{ K}$$

2. The rms speed needs to be doubled, so  $v_2 = 2v_1$ . 3. From the proportionality  $v \propto \sqrt{T}$ , we have:

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$$

4. Square both sides:

$$\left(\frac{2v_1}{v_1}\right)^2 = \frac{T_2}{300}$$

$$4 = \frac{T_2}{300}$$

5. Solving for  $T_2$ :

$$T_2 = 1200 \text{ K}$$

6. Convert back to Celsius:

$$T_2 = 1200 - 273 = 927^\circ\text{C}$$

**Final Answer:** The temperature must be  $927^\circ\text{C}$ .

**Answer: (D)**



Q20.

**Solution****Concept:**

According to Bohr's model of the hydrogen atom, the energy of an electron in the  $n$ -th orbit is given by:

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

The ionization energy is the energy required to remove the electron from its current state to infinity ( $n = \infty$ ), which is numerically equal to the positive value of the energy of that state.

**Solution:**

1. The electron is in the first excited state. For the ground state  $n = 1$ , and for the first excited state,  $n = 2$ . 2. Calculate the energy in the  $n = 2$  state:

$$E_2 = -\frac{13.6}{2^2} = -\frac{13.6}{4} = -3.4 \text{ eV}$$

3. The ionization energy ( $E_{ion}$ ) is:

$$E_{ion} = E_{\infty} - E_2 = 0 - (-3.4 \text{ eV}) = 3.4 \text{ eV}$$

4. Therefore, 3.4 eV of work must be done to ionize the hydrogen atom from its first excited state.

**Final Answer:** The ionization energy is 3.4 eV.

**Answer: (B)**



Q21.

**Solution****Concept:**

The refractive index ( $\mu$ ) of a prism is related to the angle of the prism ( $A$ ) and the angle of minimum deviation ( $\delta_m$ ) by the formula:

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

This formula is derived from Snell's law applied at the condition of minimum deviation where the ray passes symmetrically through the prism.

**Solution:**

1. Given that the angle of minimum deviation is equal to the angle of the prism:

$$\delta_m = A$$

2. Substitute  $\delta_m = A$  into the prism formula:

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

3. Use the trigonometric identity  $\sin(A) = 2 \sin(A/2) \cos(A/2)$ :

$$\mu = \frac{2 \sin(A/2) \cos(A/2)}{\sin(A/2)} = 2 \cos(A/2)$$

4. Given the refractive index  $\mu = \sqrt{3}$ :

$$\sqrt{3} = 2 \cos(A/2)$$

$$\cos(A/2) = \frac{\sqrt{3}}{2}$$

5. Find the angle:

$$\frac{A}{2} = 30^\circ \implies A = 60^\circ$$

**Final Answer:** The angle of the prism is  $60^\circ$ .

**Answer: (C)**



Q22.

### Solution

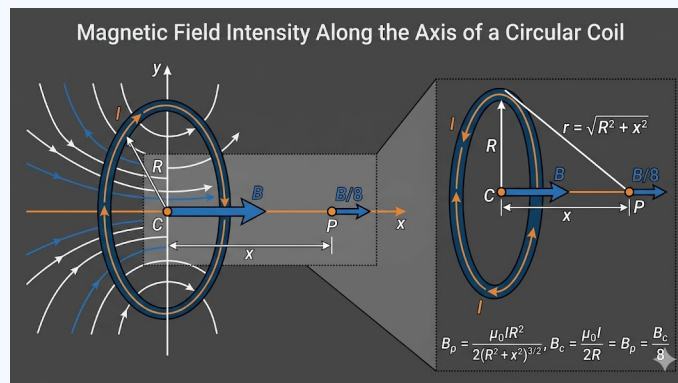
#### Concept:

The magnetic field ( $B_{axis}$ ) at a distance  $x$  from the center of a circular coil of radius  $R$  carrying current  $I$  is:

$$B_{axis} = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$$

The magnetic field at the center ( $B_{center}$ ) is found by setting  $x = 0$ :

$$B_{center} = \frac{\mu_0 I}{2R}$$



#### Solution:

1. We are given  $B_{axis} = \frac{B_{center}}{8}$ . 2. Substitute the expressions:

$$\frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}} = \frac{1}{8} \left( \frac{\mu_0 I}{2R} \right)$$

3. Simplify the equation by canceling  $\mu_0$ ,  $I$ , and 2:

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

4. Rearrange the terms:

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

5. Take the cube root of both sides (since  $8R^3 = (2R)^3$ ):

$$(2R)^2 = R^2 + x^2$$

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

6. Solve for  $x$ :

$$x^2 = 3R^2 \implies x = \sqrt{3}R$$

**Final Answer:** The distance from the center is  $\sqrt{3}R$ .

**Answer: (B)**



Q23.

**Solution****Concept:**

The maximum wavelength ( $\lambda_0$ ), also known as the threshold wavelength, is the longest wavelength of light that can eject electrons from a metal surface. It is related to the work function ( $\phi$ ) by:

$$\phi = \frac{hc}{\lambda_0}$$

A useful shortcut is  $\lambda_0(\text{in } \text{\AA}) = \frac{12400}{\phi(\text{in eV})}$ .

**Solution:**

1. Given the work function  $\phi = 2.5 \text{ eV}$ . 2. Use the shortcut formula to find  $\lambda_0$ :

$$\lambda_0 = \frac{12400}{2.5} \text{ \AA}$$

3. Perform the calculation:

$$\lambda_0 = \frac{12400 \times 2}{5} = \frac{24800}{5} = 4960 \text{ \AA}$$

4. Any wavelength longer than  $4960 \text{ \AA}$  will have energy lower than the work function and will not cause photoelectric emission.

**Final Answer:** The maximum wavelength is  $4960 \text{ \AA}$ .

**Answer: (A)**



Q24.

**Solution****Concept:**

For a car to take a turn on a level (unbanked) road without skidding, the necessary centripetal force is provided by the static friction between the tires and the road. The condition is:

$$\frac{mv^2}{r} \leq \mu mg \implies r \geq \frac{v^2}{\mu g}$$

The minimum radius is thus  $r_{min} = \frac{v^2}{\mu g}$ .

**Solution:**

1. Convert the speed from km/h to m/s:

$$v = 36 \text{ km/h} = 36 \times \frac{5}{18} \text{ m/s} = 10 \text{ m/s}$$

2. Given the coefficient of friction  $\mu = 0.5$  and  $g = 10 \text{ m/s}^2$ . 3. Substitute the values into the formula for  $r_{min}$ :

$$r_{min} = \frac{10^2}{0.5 \times 10}$$

4. Calculate the result:

$$r_{min} = \frac{100}{5} = 20 \text{ m}$$

**Final Answer:** The minimum turning radius is 20 m.

**Answer: (A)**



Q25.

**Solution****Concept:**

Under isothermal conditions, the surface energy is conserved if no work is done on the system. However, for bubbles coalescing in a vacuum/isothermal environment, the total surface area changes. The key relation for two soap bubbles of radii  $r_1$  and  $r_2$  forming a bubble of radius  $R$  (isothermally and in a vacuum) is:

$$R^2 = r_1^2 + r_2^2$$

This comes from the fact that the total pressure and volume energy balance out such that  $P_1V_1 + P_2V_2 = P_RV_R$ .

**Solution:**

1. Given radii  $r_1 = 3$  cm and  $r_2 = 4$  cm. 2. Apply the relation for the new radius  $R$ :

$$R^2 = 3^2 + 4^2$$

3. Calculate the values:

$$R^2 = 9 + 16 = 25$$

4. Find  $R$ :

$$R = \sqrt{25} = 5 \text{ cm}$$

**Final Answer:** The radius of the new bubble is 5 cm.

**Answer: (B)**



Q26.

**Solution****Concept:**

When a fluid (like water) is ejected from a pipe, the force ( $F$ ) exerted by the fluid is equal to the rate of change of momentum. For a fluid with mass per unit length  $\mu$  and velocity  $v$ , the mass flow rate is  $dm/dt = \mu v$ . The power ( $P$ ) required to move the fluid is the rate of doing work, given by  $P = Fv$  or  $P = \frac{1}{2}(dm/dt)v^2$ .

**Solution:**

1. Given mass per unit length  $\mu = 100 \text{ kg/m}$  and velocity  $v = 2 \text{ m/s}$ . 2. The mass of water leaving the pipe per second (mass flow rate) is:

$$\frac{dm}{dt} = \mu \times v = 100 \text{ kg/m} \times 2 \text{ m/s} = 200 \text{ kg/s}$$

3. The force required to eject this water is:

$$F = \frac{dp}{dt} = v \frac{dm}{dt} = 2 \text{ m/s} \times 200 \text{ kg/s} = 400 \text{ N}$$

4. The power of the engine is:

$$P = F \times v = 400 \text{ N} \times 2 \text{ m/s} = 800 \text{ W}$$

5. Alternatively, using  $P = \mu v^3$ , we get  $100 \times 2^3 = 800 \text{ W}$ . Note: If the question asks for the kinetic energy imparted per second, it would be  $\frac{1}{2}\mu v^3 = 400 \text{ W}$ . However, for a pump maintaining a steady flow against its own momentum, the power consumed is  $Fv = \mu v^3$ .

**Final Answer:** The power of the engine is 800 W.

**Answer:** (A)



Q27.

**Solution****Concept:**

The amount of a radioactive substance remaining undecayed after  $n$  half-lives is given by the formula:

$$N = N_0 \left(\frac{1}{2}\right)^n$$

where  $N_0$  is the initial amount and  $n = \frac{\text{Total time}}{\text{Half-life}}$ .

**Solution:**

1. Given half-life  $T_{1/2} = 10$  days and total time  $t = 30$  days. 2. Calculate the number of half-lives ( $n$ ):

$$n = \frac{30}{10} = 3$$

3. The fraction of the substance remaining undecayed is:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^3$$

4. Calculating the power:

$$\frac{N}{N_0} = \frac{1}{2 \times 2 \times 2} = \frac{1}{8}$$

**Final Answer:** The fraction remaining undecayed is  $1/8$ .

**Answer: (C)**



Q28.

**Solution****Concept:**

When a liquid rises in a capillary tube, the height  $h$  is given by Jurin's Law:

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

This implies  $h \propto 1/r$ . The mass of the liquid column is  $m = \rho V = \rho(\pi r^2 h)$ .

**Solution:**

1. Since  $h \propto 1/r$ , we can write  $h = k/r$  for some constant  $k$ . 2. The mass  $m$  is proportional to  $r^2 \times h$ . 3. Substitute  $h$  in terms of  $r$ :

$$m \propto r^2 \times \left(\frac{1}{r}\right) \implies m \propto r$$

4. If the radius is doubled ( $r' = 2r$ ), the new mass  $m'$  will be:

$$m' \propto 2r$$

5. Therefore,  $m' = 2m$ .

**Final Answer:** The mass of water in the second tube will be  $2m$ .

**Answer: (B)**

Q29.

**Solution****Concept:**

For an organ pipe closed at one end, only odd harmonics are present. The frequencies are given by:

$$f_n = (2n - 1)f_1$$

where  $f_1$  is the fundamental frequency ( $n = 1$ ),  $f_3$  is the first overtone ( $n = 2$ ), and  $f_5$  is the second overtone ( $n = 3$ ).

**Solution:**

1. Given fundamental frequency  $f_1 = 200$  Hz. 2. The harmonics in a closed pipe are  $f_1, 3f_1, 5f_1, \dots$  3. The first overtone is the 3rd harmonic ( $3f_1$ ). 4. The second overtone is the 5th harmonic ( $5f_1$ ). 5. Calculate the frequency of the second overtone:

$$f_{2nd\_overtone} = 5 \times 200 \text{ Hz} = 1000 \text{ Hz}$$

**Final Answer:** The frequency of the second overtone is 1000 Hz.

**Answer: (D)**



Q30.

**Solution****Concept:**

The heat produced ( $H$ ) in a resistor is given by Joule's Law of Heating:

$$H = I^2 R t$$

If the resistance ( $R$ ) and time ( $t$ ) are constant, the heat produced is proportional to the square of the current:  $H \propto I^2$ .

**Solution:**

1. Let the initial current be  $I_1$  and initial heat be  $H_1 = kI_1^2$ . 2. The current is increased by 20%, so the new current  $I_2$  is:

$$I_2 = I_1 + 0.20I_1 = 1.2I_1$$

3. The new heat produced  $H_2$  is:

$$H_2 = k(1.2I_1)^2 = 1.44kI_1^2 = 1.44H_1$$

4. The increase in heat is  $H_2 - H_1 = 0.44H_1$ . 5. Convert the increase to a percentage:

$$\text{Percentage increase} = 0.44 \times 100\% = 44\%$$

**Final Answer:** The percentage increase in heat produced is 44%.

**Answer: (C)**

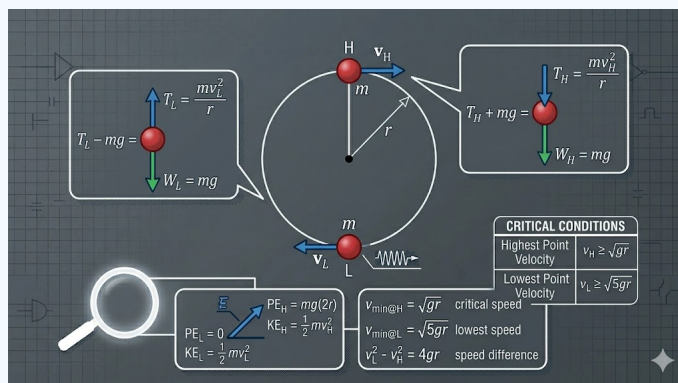


Q31.

### Solution

#### Concept:

For a particle to just complete a vertical circle, the tension in the string at the highest point must be greater than or equal to zero. The critical condition occurs when the tension at the top is exactly zero. Applying the conservation of mechanical energy between the lowest point (L) and the highest point (H) allows us to find the required minimum velocity.



#### Solution:

1. Let  $v_L$  be the velocity at the lowest point and  $v_H$  be the velocity at the highest point. 2. At the highest point, for the minimum velocity condition:

$$\frac{mv_H^2}{r} = mg \implies v_H = \sqrt{gr}$$

3. Using the Law of Conservation of Energy between the lowest and highest points:

$$(K.E. + P.E.)_L = (K.E. + P.E.)_H$$

4. Taking the lowest point as the reference for potential energy ( $h = 0$ ):

$$\frac{1}{2}mv_L^2 + 0 = \frac{1}{2}mv_H^2 + mg(2r)$$

5. Substitute  $v_H^2 = gr$ :

$$\frac{1}{2}mv_L^2 = \frac{1}{2}m(gr) + 2mgr$$

6. Multiply the entire equation by  $2/m$ :

$$v_L^2 = gr + 4gr = 5gr$$

7. Therefore,  $v_L = \sqrt{5gr}$ .

**Final Answer:** The minimum velocity required is  $\sqrt{5gr}$ .

**Answer: (C)**



Q32.

**Solution****Concept:**

In Young's Double Slit Experiment (YDSE), the fringe width ( $\beta$ ) is defined as the distance between two consecutive bright or dark fringes on the screen. It is given by the formula:

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

where  $\lambda$  is the wavelength of light,  $D$  is the distance from the slits to the screen, and  $d$  is the distance between the two slits.

**Solution:**

1. Given values: - Wavelength  $\lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}$  - Distance to screen  $D = 1 \text{ m}$  - Slit separation  $d = 0.1 \text{ mm} = 0.1 \times 10^{-3} \text{ m} = 10^{-4} \text{ m}$  2. Substitute these values into the fringe width formula:

$$\beta = \frac{(600 \times 10^{-9}) \times 1}{10^{-4}}$$

3. Simplify the powers of ten:

$$\beta = 600 \times 10^{-9} \times 10^4 = 600 \times 10^{-5} \text{ m}$$

4. Convert the result to millimeters:

$$\beta = 6 \times 10^{-3} \text{ m} = 6 \text{ mm}$$

**Final Answer:** The fringe width is 6 mm.

**Answer: (A)**



Q33.

**Solution****Concept:**

The resistance of a conductor varies with temperature according to the linear relation:

$$R_t = R_0(1 + \alpha\Delta t)$$

where  $R_t$  is the resistance at temperature  $t$ ,  $R_0$  is the resistance at  $0^\circ\text{C}$ ,  $\alpha$  is the temperature coefficient of resistance, and  $\Delta t$  is the change in temperature.

**Solution:**

1. Given  $R_0 = 10\Omega$  at  $t_1 = 0^\circ\text{C}$ . 2. Given  $R_{100} = 15\Omega$  at  $t_2 = 100^\circ\text{C}$ . 3. The change in temperature  $\Delta t = 100 - 0 = 100^\circ\text{C}$ . 4. Rearrange the formula to solve for  $\alpha$ :

$$\alpha = \frac{R_t - R_0}{R_0\Delta t}$$

5. Substitute the known values:

$$\alpha = \frac{15 - 10}{10 \times 100} = \frac{5}{1000}$$

6. Calculate the decimal value:

$$\alpha = 0.005/^\circ\text{C}$$

**Final Answer:** The temperature coefficient of resistance is  $0.005/^\circ\text{C}$ .

**Answer: (A)**



Q34.

**Solution****Concept:**

According to the First Law of Thermodynamics, for any process, the change in internal energy ( $\Delta U$ ) is given by:

$$\Delta U = Q - W$$

where  $Q$  is the heat absorbed by the system and  $W$  is the work done by the system. For a cyclic process, the system returns to its initial state.

**Solution:**

1. Internal energy ( $U$ ) is a state function. This means its value depends only on the current state of the system (pressure, volume, temperature), not on the path taken to get there. 2. In a thermodynamic cycle (like  $ABCD A$ ), the final state is identical to the initial state. 3. Therefore, the change in any state function over a complete cycle must be zero. 4. Mathematically:

$$\Delta U_{cycle} = U_{final} - U_{initial} = 0$$

5. While the net heat absorbed (50 J) and net work done (10 J) are used to calculate the area of the cycle, they do not result in a net change in internal energy once the cycle is closed.

**Final Answer:** The net change in internal energy is Zero.

**Answer:** (C)

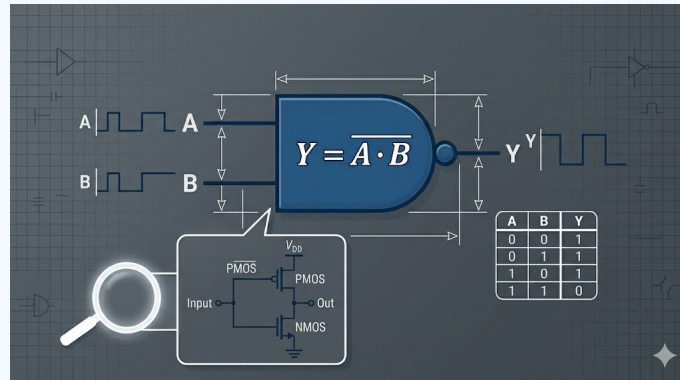


Q35.

### Solution

#### Concept:

Logic gates are the basic building blocks of digital circuits. The standard operations are: - AND:  $Y = A \cdot B$  - OR:  $Y = A + B$  - NOT:  $Y = \overline{A}$  - NAND:  $Y = \overline{A \cdot B}$  (NOT AND) - NOR:  $Y = \overline{A + B}$  (NOT OR)



#### Solution:

1. The expression provided is  $Y = \overline{A \cdot B}$ . 2. This expression indicates that the input signals  $A$  and  $B$  are first multiplied (AND operation) and the result is then inverted (NOT operation). 3. By definition, a NOT-AND operation is called a NAND gate. 4. The truth table for this expression would show an output of 0 only when both  $A$  and  $B$  are 1, and an output of 1 for all other combinations.

**Final Answer:** The Boolean expression represents a NAND gate.

**Answer: (C)**



Q36.

**Solution****Concept:**

The weight of a body is the gravitational force acting on it, given by  $F = \frac{GMm}{r^2}$ . On the surface of the Earth,  $r = R$  and  $W = mg = \frac{GMm}{R^2}$ . At a height  $h$  above the surface, the distance from the center becomes  $r = R + h$ .

**Solution:**

1. Given the weight on the surface  $W_{surface} = 72 \text{ N}$ . 2. The height is given as half the radius of the Earth, so  $h = R/2$ . 3. The distance from the center of the Earth is:

$$r = R + h = R + \frac{R}{2} = \frac{3R}{2}$$

4. The gravitational force (weight) at height  $h$  is:

$$W_h = \frac{GMm}{r^2} = \frac{GMm}{(3R/2)^2} = \frac{GMm}{9R^2/4}$$

5. Rearranging the expression:

$$W_h = \frac{4}{9} \left( \frac{GMm}{R^2} \right) = \frac{4}{9} W_{surface}$$

6. Substitute the given value:

$$W_h = \frac{4}{9} \times 72 \text{ N} = 4 \times 8 \text{ N} = 32 \text{ N}$$

**Final Answer:** The gravitational force at that height is 32 N.

**Answer: (A)**



Q37.

**Solution****Concept:**

For an ideal transformer, the efficiency  $\eta$  is the ratio of output power ( $P_s$ ) to input power ( $P_p$ ):

$$\eta = \frac{P_s}{P_p} = \frac{V_s I_s}{V_p I_p}$$

Output power is also related to secondary voltage and current as  $P_s = V_s I_s$ .

**Solution:**

1. Given: Efficiency  $\eta = 90\% = 0.9$ , Input Power  $P_p = 3 \text{ kW} = 3000 \text{ W}$ , and Secondary Current  $I_s = 6 \text{ A}$ . 2. First, find the output (secondary) power:

$$P_s = \eta \times P_p = 0.9 \times 3000 \text{ W} = 2700 \text{ W}$$

3. The output power is the product of secondary voltage and secondary current:

$$P_s = V_s \times I_s$$

4. Substitute the known values to find  $V_s$ :

$$2700 \text{ W} = V_s \times 6 \text{ A}$$

5. Calculate  $V_s$ :

$$V_s = \frac{2700}{6} = 450 \text{ V}$$

**Final Answer:** The voltage across the secondary is 450 V.

**Answer: (A)**



Q38.

**Solution****Concept:**

According to Faraday's Law of Electromagnetic Induction, the magnitude of the induced electromotive force (emf) in a coil is equal to the rate of change of magnetic flux linked with it:

$$|e| = \frac{d\phi}{dt}$$

**Solution:**

1. The expression for magnetic flux is  $\phi = 5t^2 + 3t + 16$ . 2. To find the induced emf, differentiate the flux with respect to time  $t$ :

$$e = \frac{d}{dt}(5t^2 + 3t + 16)$$

3. Apply the rules of differentiation:

$$e = 10t + 3$$

4. The question asks for the induced emf at  $t = 2$  s. Substitute  $t = 2$  into the expression:

$$e = 10(2) + 3 = 20 + 3 = 23 \text{ V}$$

**Final Answer:** The induced emf at  $t = 2$  s is 23 V.

**Answer: (A)**

Q39.

**Solution****Concept:**

The electric potential ( $V$ ) on the surface of a charged sphere of radius  $R$  is  $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R}$ . The surface charge density ( $\sigma$ ) is the charge per unit area:  $\sigma = \frac{Q}{4\pi R^2}$ .

**Solution:**

1. From the potential formula, we can express charge  $Q$  as  $Q = 4\pi\epsilon_0 RV$ . 2. Substitute this  $Q$  into the formula for surface charge density:

$$\sigma = \frac{4\pi\epsilon_0 RV}{4\pi R^2} = \frac{\epsilon_0 V}{R}$$

3. The problem states that both spheres are charged to the same potential  $V$ . Therefore,  $\sigma \propto 1/R$ .

4. The ratio of their surface charge densities is:

$$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

**Final Answer:** The ratio of their surface charge densities is  $R_2/R_1$ .

**Answer: (B)**



Q40.

**Solution****Concept:**

The time period ( $T$ ) of a simple pendulum is given by:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

This indicates that  $T$  is proportional to the square root of the length  $l$  ( $T \propto \sqrt{l}$ ).

**Solution:**

1. Initially, let the length be  $l_1$  and period be  $T_1 = k\sqrt{l_1}$ . 2. The length is increased by 21%, so the new length  $l_2$  is:

$$l_2 = l_1 + 0.21l_1 = 1.21l_1$$

3. The new period  $T_2$  is:

$$T_2 = k\sqrt{1.21l_1} = 1.1k\sqrt{l_1} = 1.1T_1$$

4. The increase in the period is  $T_2 - T_1 = 0.1T_1$ . 5. Convert this increase to a percentage:

$$\text{Percentage increase} = 0.1 \times 100\% = 10\%$$

**Final Answer:** The percentage increase in the period is 10%.

**Answer: (A)**

Q41.

**Solution****Concept:**

When light is reflected from a plane surface, it undergoes a change in direction, but its fundamental properties such as frequency, wavelength, and speed remain unchanged, provided the medium does not change. Frequency is a property of the source, and since  $v = f\lambda$ , if the medium and frequency are the same, the wavelength remains the same.

**Solution:**

1. Given the wavelength of incident light  $\lambda = 5000 \text{ \AA} = 5000 \times 10^{-10} \text{ m}$ . 2. The frequency ( $f$ ) of light is given by  $f = \frac{c}{\lambda}$ , where  $c = 3 \times 10^8 \text{ m/s}$  is the speed of light. 3. Calculating the frequency:

$$f = \frac{3 \times 10^8}{5000 \times 10^{-10}} = \frac{3 \times 10^8}{5 \times 10^{-7}}$$

$$f = 0.6 \times 10^{15} = 6 \times 10^{14} \text{ Hz}$$

4. Since reflection does not change the frequency or the wavelength of the light: - Reflected wavelength =  $5000 \text{ \AA}$  - Reflected frequency =  $6 \times 10^{14} \text{ Hz}$

**Final Answer:** The wavelength and frequency are  $5000 \text{ \AA}$  and  $6 \times 10^{14} \text{ Hz}$ .

**Answer: (A)**



Q42.

**Solution****Concept:**

The displacement of a particle in S.H.M. is given by  $x = A \sin(\omega t + \phi)$ . The velocity of the particle is the derivative of displacement with respect to time:  $v = \frac{dx}{dt} = A\omega \cos(\omega t + \phi)$ . The maximum velocity ( $v_{max}$ ) occurs when the cosine term is  $\pm 1$ , giving  $v_{max} = A\omega$ .

**Solution:**

1. The given displacement equation is  $x = 3 \sin(2t + \pi/4)$ . 2. Comparing this with the standard equation  $x = A \sin(\omega t + \phi)$ : - Amplitude  $A = 3$  m - Angular frequency  $\omega = 2$  rad/s 3. The formula for maximum velocity is:

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

4. Substitute the values:

$$v_{max} = 3 \text{ m} \times 2 \text{ rad/s} = 6 \text{ m/s}$$

**Final Answer:** The maximum velocity is 6 m/s.

**Answer: (B)**

Q43.

**Solution****Concept:**

When a wire of resistance  $R$  is cut into  $n$  equal parts, the resistance of each individual part becomes  $r = R/n$ . When these  $n$  identical resistors are connected in parallel, the equivalent resistance ( $R_{eq}$ ) is given by  $R_{eq} = r/n$ .

**Solution:**

1. Initial resistance of the wire =  $R$ . 2. The wire is divided into  $n$  parts, so the resistance of each part is:

$$r = \frac{R}{n}$$

3. These  $n$  parts are connected in parallel. The equivalent resistance  $R_{eq}$  for parallel connection of identical resistors is:

$$R_{eq} = \frac{r}{n}$$

4. Substitute the value of  $r$  from step 2:

$$R_{eq} = \frac{R/n}{n} = \frac{R}{n^2}$$

**Final Answer:** The equivalent resistance is  $R/n^2$ .

**Answer: (C)**



Q44.

**Solution****Concept:**

The stopping potential ( $V_0$ ) in a photoelectric experiment is the negative potential applied to the anode to just stop the most energetic photoelectrons from reaching it. The maximum kinetic energy ( $K_{max}$ ) is related to the stopping potential by the equation:

$$K_{max} = eV_0$$

where  $e$  is the charge of an electron.

**Solution:**

1. Given the stopping potential  $V_0 = 3$  V. 2. The maximum kinetic energy in electron-volts (eV) is numerically equal to the stopping potential in Volts. 3. Therefore:

$$K_{max} = 3 \text{ eV}$$

4. If required in Joules, it would be  $3 \times 1.6 \times 10^{-19} \text{ J} = 4.8 \times 10^{-19} \text{ J}$ . However, the options provided in such tests usually favor the eV unit for simplicity.

**Final Answer:** The maximum kinetic energy is 3 eV.

**Answer: (A)**

Q45.

**Solution****Concept:**

When objects roll down an inclined plane without slipping, their acceleration ( $a$ ) is given by:

$$a = \frac{g \sin \theta}{1 + \frac{I}{mR^2}}$$

where  $I$  is the moment of inertia about the center of mass. The object with the smallest value of  $\frac{I}{mR^2}$  (the distribution of mass closer to the axis) will have the highest acceleration and will reach the bottom first.

**Solution:**

1. For a solid sphere:  $I = \frac{2}{5}mR^2$ . Thus,  $\frac{I}{mR^2} = 0.4$ . 2. For a hollow sphere:  $I = \frac{2}{3}mR^2$ . Thus,  $\frac{I}{mR^2} = 0.66$ . 3. Comparing the ratios:  $0.4 < 0.66$ . 4. The solid sphere has a smaller ratio, meaning it has a higher acceleration down the slope. 5. Higher acceleration results in reaching the bottom in less time.

**Final Answer:** The solid sphere reaches the bottom first.

**Answer: (B)**



Q46.

**Solution****Concept:**

The half-life ( $T_{1/2}$ ) and average life ( $\tau$ ) of a radioactive element are related by the decay constant ( $\lambda$ ). The relations are:

$$T_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$$
$$\tau = \frac{1}{\lambda}$$

By combining these, we find that the average life is greater than the half-life:  $\tau = \frac{T_{1/2}}{0.693} \approx 1.44 \times T_{1/2}$ .

**Solution:**

1. Given the half-life  $T_{1/2} = 1600$  years. 2. Use the relationship between average life and half-life:

$$\tau = 1.44 \times T_{1/2}$$

3. Substitute the given value:

$$\tau = 1.44 \times 1600$$

4. Perform the calculation:

$$\tau = 2304 \text{ years}$$

5. Comparing this to the given options, 2309 years is the most accurate value based on the more precise multiplier ( $1/\ln 2 \approx 1.44269$ ).

$$\tau = 1.44269 \times 1600 \approx 2308.3 \text{ years}$$

**Final Answer:** The average life is 2309 years.

**Answer: (A)**



Q47.

**Solution****Concept:**

The electric field intensity ( $E$ ) at a distance  $r$  from a point charge  $q$  is given by Coulomb's Law:

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

This shows that  $E$  is directly proportional to the charge  $q$  and inversely proportional to the square of the distance  $r$  ( $E \propto q/r^2$ ).

**Solution:**

1. Initial electric field:  $E_1 = E$  with charge  $q_1 = q$  and distance  $r_1 = r$ . 2. New conditions: Charge  $q_2 = q/2$  and distance  $r_2 = 2r$ . 3. The new electric field  $E_2$  is:

$$E_2 \propto \frac{q_2}{r_2^2}$$

4. Substitute the new values in terms of the old ones:

$$E_2 = \frac{1}{4\pi\epsilon_0} \frac{(q/2)}{(2r)^2}$$

5. Simplify the expression:

$$E_2 = \frac{1}{4\pi\epsilon_0} \frac{q/2}{4r^2} = \frac{1}{4\pi\epsilon_0} \frac{q}{8r^2}$$

6. Comparing  $E_2$  to the original  $E$ :

$$E_2 = \frac{1}{8} \left( \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \right) = \frac{E}{8}$$

**Final Answer:** The new electric field intensity will be  $E/8$ .

**Answer: (C)**



Q48.

**Solution****Concept:**

When an electric current flows through an inductor, energy is stored in its magnetic field. The energy ( $U$ ) stored in an inductor of inductance  $L$  carrying a current  $I$  is given by the formula:

$$U = \frac{1}{2}LI^2$$

**Solution:**

1. Given values: - Inductance  $L = 5 \text{ mH} = 5 \times 10^{-3} \text{ H}$  - Current  $I = 2 \text{ A}$  2. Substitute the values into the energy formula:

$$U = \frac{1}{2} \times (5 \times 10^{-3}) \times (2)^2$$

3. Calculate the square of the current:

$$U = \frac{1}{2} \times 5 \times 10^{-3} \times 4$$

4. Simplify:

$$U = 10 \times 10^{-3} \text{ J}$$

5. Convert to millijoules (mJ):

$$U = 10 \text{ mJ}$$

**Final Answer:** The energy stored is 10 mJ.

**Answer: (A)**

Q49.

**Solution****Concept:**

Thermodynamic processes are classified based on which state variable remains constant or how the system interacts with its surroundings: - Isothermal: Temperature ( $T$ ) remains constant. - Isobaric: Pressure ( $P$ ) remains constant. - Isochoric: Volume ( $V$ ) remains constant. - Adiabatic: No heat exchange ( $Q = 0$ ) occurs between the system and surroundings.

**Solution:**

1. The question defines a process where "no heat enters or leaves the system." 2. In thermodynamics, the term "adiabatic" refers to a boundary or process that is impermeable to heat. 3. According to the First Law of Thermodynamics ( $\Delta U = Q - W$ ), for an adiabatic process,  $\Delta U = -W$ . 4. This means that all the work done by or on the system results in a change in its internal energy without any heat contribution.

**Final Answer:** The process is called Adiabatic.

**Answer: (D)**



Q50.

**Solution****Concept:**

Dimensions are the powers to which the fundamental units are raised to represent a physical quantity. - Planck's constant ( $h$ ) is found in  $E = hf$ , so  $[h] = [E]/[f] = [ML^2T^{-2}]/[T^{-1}] = [ML^2T^{-1}]$ . - Angular momentum ( $L$ ) is given by  $L = mvr$ , so  $[L] = [M][LT^{-1}][L] = [ML^2T^{-1}]$ .

**Solution:**

1. Let's determine the dimensions of the given options: - Energy:  $[ML^2T^{-2}]$  - Linear Momentum ( $p = mv$ ):  $[MLT^{-1}]$  - Angular Momentum ( $L = r \times p$ ):  $[ML^2T^{-1}]$  - Power ( $P = W/t$ ):  $[ML^2T^{-3}]$  2. From Bohr's quantization rule, angular momentum is an integral multiple of  $h/2\pi$ . This implies that angular momentum and Planck's constant must have the same units and dimensions. 3. Comparing the dimension of  $h$  calculated in the concept section ( $ML^2T^{-1}$ ) with the options, it matches exactly with Angular Momentum.

**Final Answer:** The dimension of Planck's constant is same as that of Angular momentum.

**Answer:** (C)



## Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	C	3	A	4	B	5	A
6	C	7	C	8	A	9	C	10	B
11	A	12	C	13	C	14	A	15	C
16	B	17	A	18	C	19	D	20	B
21	C	22	B	23	A	24	A	25	B
26	A	27	C	28	B	29	D	30	C
31	C	32	A	33	A	34	C	35	C
36	A	37	A	38	A	39	B	40	A
41	A	42	B	43	C	44	A	45	B
46	A	47	C	48	A	49	D	50	C

