

# MHT-CET Physics Sample Paper-18

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 body of mass  $m$  is moving in a circle of radius  $r$  with a constant speed  $v$ . The force on the body is  $mv^2/r$  and is directed towards the center. What is the work done by this force in moving the body over half the circumference?

- (A)  $mv^2/r \cdot \pi r$
- (B) Zero
- (C)  $mv^2/r \cdot 2r$
- (D)  $mg \cdot 2r$

**Q2.** The ratio of the surface tension of a liquid at two different temperatures  $T_1$  and  $T_2$  is 2 : 1. If the critical temperature of the liquid is  $T_c$ , then:

- (A)  $T_1 > T_2$
- (B)  $T_1 < T_2$
- (C)  $T_1 = T_2$
- (D) None of these

**Q3.** In a thermodynamic process, the pressure of a fixed mass of gas is changed in such a manner that the gas releases 20 J of heat and 8 J of work is done on the



gas. If the initial internal energy of the gas was 30 J, the final internal energy will be:

- (A) 18 J
- (B) 2 J
- (C) 42 J
- (D) 58 J

**Q4.** A simple harmonic oscillator has an amplitude  $A$  and time period  $T$ . The time required by it to travel from  $x = A$  to  $x = A/2$  is:

- (A)  $T/6$
- (B)  $T/4$
- (C)  $T/3$
- (D)  $T/12$

**Q5.** The fundamental frequency of a string stretched with a weight of 4 kg is 256 Hz. The weight required to produce its octave is:

- (A) 4 kg
- (B) 8 kg
- (C) 12 kg
- (D) 16 kg

**Q6.** A parallel plate capacitor with air between the plates has a capacitance of 8 pF. What will be the capacitance if the distance between the plates is reduced by half and the space between them is filled with a substance of dielectric constant 6?

- (A) 8 pF
- (B) 48 pF
- (C) 96 pF



(D) 24 pF

**Q7.** If a copper wire is stretched to make it 0.1% longer, the percentage change in its resistance is:

(A) 0.2%

(B) 2%

(C) 0.1%

(D) 0.4%

**Q8.** 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)  $3R$

**Q9.** An inductor of 0.5 H and a resistor of  $100\ \Omega$  are connected in series to an AC source of 240 V, 50 Hz. The phase angle between the voltage and the current is:

(A)  $\tan^{-1}\left(\frac{\pi}{2}\right)$

(B)  $\tan^{-1}(\pi)$

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

(D) 0

**Q10.** The stopping potential for photoelectrons from a metal surface is  $V_1$  when incident light of wavelength  $\lambda$  is used, and  $V_2$  when light of wavelength  $2\lambda$  is used. If  $h, c, e$  are standard constants, the work function of the metal is:

(A)  $e(2V_2 - V_1)$



- (B)  $e(V_1 - 2V_2)$
- (C)  $e(V_1 + V_2)$
- (D)  $e(V_1 - V_2)$

**Q11.** The moment of inertia of a solid sphere of mass  $M$  and radius  $R$  about a tangent to the sphere is:

- (A)  $2/5MR^2$
- (B)  $3/5MR^2$
- (C)  $7/5MR^2$
- (D)  $2/3MR^2$

**Q12.** A car is moving on a circular path of radius 100 m with a speed of 20 m/s. If its speed is increasing at the rate of  $3 \text{ m/s}^2$ , the total acceleration of the car is:

- (A)  $3 \text{ m/s}^2$
- (B)  $4 \text{ m/s}^2$
- (C)  $5 \text{ m/s}^2$
- (D)  $7 \text{ m/s}^2$

**Q13.** The kinetic energy of a molecule of an ideal gas at  $27^\circ\text{C}$  is  $E$ . At  $327^\circ\text{C}$ , the kinetic energy will be:

- (A)  $2E$
- (B)  $\sqrt{2}E$
- (C)  $E/2$
- (D)  $4E$

**Q14.** Two satellites  $A$  and  $B$  go round a planet  $P$  in circular orbits having radii  $4R$  and  $R$  respectively. If the speed of  $A$  is  $3v$ , the speed of  $B$  is:

- (A)  $12v$



- (B)  $6v$
- (C)  $3v/2$
- (D)  $3v/4$

**Q15.** In a pipe open at both ends, the  $n^{\text{th}}$  harmonic frequency is  $f$ . If one end of the pipe is closed, the fundamental frequency will be:

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

**Q16.** The electric potential at any point  $(x, y, z)$  is given by  $V = 4x^2$  Volts. The electric field at the point  $(1, 0, 2)$  m is:

- (A)  $8\hat{i}$  V/m
- (B)  $-8\hat{i}$  V/m
- (C)  $16\hat{i}$  V/m
- (D)  $-16\hat{i}$  V/m

**Q17.** A galvanometer of resistance  $50 \Omega$  gives full-scale deflection for a current of  $0.05$  A. The resistance to be connected in series to convert it into a voltmeter of range  $0$  to  $20$  V is:

- (A)  $350 \Omega$
- (B)  $400 \Omega$
- (C)  $450 \Omega$
- (D)  $500 \Omega$

**Q18.** A ray of light is incident on a glass plate at the polarizing angle  $57.5^\circ$ . The angle between the reflected and refracted rays is:



- (A)  $57.5^\circ$
- (B)  $0^\circ$
- (C)  $90^\circ$
- (D)  $32.5^\circ$

**Q19.** In a p-type semiconductor, the acceptor impurity level lies:

- (A) Just below the conduction band
- (B) Just above the valence band
- (C) In the middle of the forbidden gap
- (D) Inside the conduction band

**Q20.** The energy of an electron in the  $n^{\text{th}}$  orbit of a hydrogen atom is  $E_n = -13.6/n^2$  eV. The energy required to excite the electron from the first orbit to the third orbit is:

- (A) 12.09 eV
- (B) 10.2 eV
- (C) 13.6 eV
- (D) 1.51 eV

**Q21.** A liquid is flowing through a pipe of non-uniform cross-section. If the ratio of the radii of the pipe at two points is 3 : 2, then the ratio of the velocities of flow at these points is:

- (A) 3 : 2
- (B) 2 : 3
- (C) 4 : 9
- (D) 9 : 4

**Q22.** The displacement of a particle in S.H.M. is given by  $x = 10 \sin(2\pi t + \pi/6)$  cm. The maximum velocity of the particle is:



- (A) 20 cm/s
- (B)  $20\pi$  cm/s
- (C)  $10\pi$  cm/s
- (D)  $5\pi$  cm/s

**Q23.** A soap bubble is given a negative charge. Its radius will:

- (A) Increase
- (B) Decrease
- (C) Remain unchanged
- (D) Become zero

**Q24.** The work function of a metal is 2.5 eV. If the radiation of wavelength 4000 Å falls on it, the maximum kinetic energy of the emitted photoelectrons is:

- (A) 0.1 eV
- (B) 0.6 eV
- (C) 1.1 eV
- (D) No emission occurs

**Q25.** The angle of dip at the magnetic equator is:

- (A)  $0^\circ$
- (B)  $45^\circ$
- (C)  $90^\circ$
- (D)  $180^\circ$

**Q26.** A thermodynamic system is taken from state A to B along path ACB and is brought back to A along path BDA. The net work done by the system in the complete cycle is:



- (A) Zero
- (B) Area of the loop ACBDA
- (C) Internal energy change
- (D) Heat absorbed

**Q27.** If the intensity of light is increased in a photoelectric experiment, which of the following increases?

- (A) Stopping potential
- (B) Maximum kinetic energy
- (C) Photocurrent
- (D) Threshold frequency

**Q28.** In a series LCR circuit, the voltage across the inductor, capacitor, and resistor are 70 V, 70 V, and 40 V respectively. The amplitude of the source voltage is:

- (A) 40 V
- (B) 180 V
- (C) 140 V
- (D)  $40\sqrt{2}$  V

**Q29.** A radioactive element has a half-life of 1600 years. The fraction of the sample that will remain undecayed after 6400 years is:

- (A)  $1/4$
- (B)  $1/8$
- (C)  $1/16$
- (D)  $1/32$

**Q30.** The molar specific heat at constant volume of a monatomic gas is:



- (A)  $3/2R$
- (B)  $5/2R$
- (C)  $7/2R$
- (D)  $R$

**Q31.** A wire of length  $L$  and resistance  $R$  is bent into a circle. The resistance between any two points at the ends of a diameter is:

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

**Q32.** The de Broglie wavelength of an alpha particle is  $\lambda$ . What is the de Broglie wavelength of a proton moving with the same velocity?

- (A)  $\lambda$
- (B)  $2\lambda$
- (C)  $4\lambda$
- (D)  $\lambda/4$

**Q33.** A thin convex lens of focal length 10 cm is placed in contact with a thin concave lens of focal length 20 cm. The focal length of the combination is:

- (A) 10 cm
- (B)  $-10$  cm
- (C) 20 cm
- (D)  $-20$  cm

**Q34.** The magnifying power of a compound microscope is 30. The magnification produced by the objective is 5. The magnification produced by the eyepiece is:



- (A) 6
- (B) 150
- (C) 25
- (D) 35

**Q35.** The escape velocity from the surface of the moon is less than that from the earth because:

- (A) Moon has no atmosphere
- (B) The radius of the moon is less than that of the earth
- (C) The mass of the moon is less than that of the earth
- (D) Both (B) and (C)

**Q36.** An ideal heat engine exhausts 600 J of heat for every 1000 J of heat absorbed from the source. If the source temperature is 400 K, the sink temperature is:

- (A) 240 K
- (B) 300 K
- (C) 360 K
- (D) 200 K

**Q37.** A particle is executing S.H.M. At the mean position:

- (A) Velocity is minimum, acceleration is maximum
- (B) Velocity is maximum, acceleration is zero
- (C) Velocity is zero, acceleration is maximum
- (D) Both are zero

**Q38.** The energy stored in a capacitor of capacitance  $10\ \mu\text{F}$  charged to 100 V is:

- (A) 0.05 J



- (B) 0.5 J
- (C) 0.1 J
- (D) 1 J

**Q39.** The force of attraction between two parallel current-carrying wires is  $F$ . If the current in both wires is doubled, the force becomes:

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

**Q40.** In a common emitter amplifier, the current gain  $\beta$  is 100. If the base current changes by  $20 \mu\text{A}$ , the collector current will change by:

- (A) 2 mA
- (B)  $200 \mu\text{A}$
- (C) 0.2 mA
- (D) 5 mA

**Q41.** The Young's modulus of a wire depends on:

- (A) Length of the wire
- (B) Diameter of the wire
- (C) Material of the wire
- (D) Load applied

**Q42.** A transformer works on the principle of:

- (A) Self-induction
- (B) Mutual induction



- (C) Eddy currents
- (D) Seebeck effect

**Q43.** The ratio of the speeds of an electron in the first and second orbits of a hydrogen atom is:

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

**Q44.** Which of the following waves cannot travel through vacuum?

- (A) X-rays
- (B) Radio waves
- (C) Sound waves
- (D) Light waves

**Q45.** The power of a lens is  $-2.0$  D. Its focal length is:

- (A) 50 cm
- (B)  $-50$  cm
- (C) 20 cm
- (D)  $-20$  cm

**Q46.** When the temperature of a semiconductor is increased, its resistance:

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



- Q47.** In a series LCR circuit at resonance, the impedance is:
- (A) Maximum
  - (B) Minimum
  - (C) Zero
  - (D) Infinite
- Q48.** The centripetal force required to keep a body in a circular path is provided by:
- (A) Inertia
  - (B) Any real force like friction or tension
  - (C) Centrifugal force
  - (D) Angular momentum
- Q49.** If the Earth stops rotating about its axis, the value of  $g$  at the equator will:
- (A) Increase
  - (B) Decrease
  - (C) Remain same
  - (D) Become zero
- Q50.** The electric flux through a cube of side  $a$  which encloses a charge  $q$  at its center is:
- (A)  $q/\epsilon_0$
  - (B)  $q/6\epsilon_0$
  - (C)  $6qa^2/\epsilon_0$
  - (D) Zero



## Detailed Solutions

Q1.

## Solution

**Concept:**

When a body moves in a horizontal or vertical circle, the work done by the centripetal force is determined by the angle between the force vector and the displacement vector. The centripetal force ( $F_c$ ) always acts towards the center of the circle, while the instantaneous displacement ( $ds$ ) is along the tangent to the circle at any point.

**Solution:**

1. The centripetal force acting on the body of mass  $m$  is:

$$F_c = \frac{mv^2}{r}$$

2. This force is always directed radially inwards towards the center of the circular path. 3. The displacement of the body at any instant is along the tangent to the circular path. 4. Therefore, the angle  $\theta$  between the force vector  $\vec{F}$  and the displacement vector  $d\vec{s}$  is always  $90^\circ$  at every point of the motion. 5. The work done  $W$  is given by the dot product of force and displacement:

$$W = \int \vec{F} \cdot d\vec{s} = \int F ds \cos(\theta)$$

6. Since  $\cos(90^\circ) = 0$ , the work done by the centripetal force is:

$$W = \int F ds(0) = 0$$

7. This remains true regardless of the distance covered (half circumference or full circumference) as long as the speed is constant and the force is purely centripetal.

**Final Answer:** The work done by this force is Zero.

**Answer: (B)**



Q2.

**Solution****Concept:**

Surface tension of a liquid is a temperature-dependent property. As the temperature of a liquid increases, the intermolecular cohesive forces weaken due to the increase in the kinetic energy of the molecules. Consequently, the surface tension decreases with an increase in temperature and becomes zero at the critical temperature ( $T_c$ ).

**Solution:**

1. Let  $S_1$  and  $S_2$  be the surface tensions at temperatures  $T_1$  and  $T_2$  respectively. 2. Given the ratio of surface tensions:

$$\frac{S_1}{S_2} = \frac{2}{1}$$

3. This implies that  $S_1 > S_2$ . 4. According to the property of liquids, surface tension is inversely proportional to temperature (specifically following the relation  $S_T = S_0[1 - \alpha\Delta T]$  or similar empirical formulas). 5. Since  $S_1$  is greater than  $S_2$ , it means the liquid at temperature  $T_1$  has stronger cohesive forces than at  $T_2$ . 6. Therefore, temperature  $T_1$  must be lower than temperature  $T_2$ .

$$T_1 < T_2$$

**Final Answer:** The relationship between the temperatures is  $T_1 < T_2$ .

**Answer: (B)**



Q3.

**Solution****Concept:**

According to the First Law of Thermodynamics, the change in internal energy ( $\Delta U$ ) of a system is equal to the heat added to the system ( $Q$ ) minus the work done by the system ( $W$ ). The mathematical expression is:

$$\Delta U = Q - W$$

Sign conventions are crucial: heat released by the system is negative, and work done on the system is negative.

**Solution:**

1. Identify the given values with proper signs: Heat released,  $Q = -20$  J Work done on the gas,  $W = -8$  J Initial internal energy,  $U_i = 30$  J 2. Calculate the change in internal energy ( $\Delta U$ ):

$$\Delta U = Q - W$$

$$\Delta U = -20 - (-8)$$

$$\Delta U = -20 + 8 = -12 \text{ J}$$

3. The final internal energy  $U_f$  is given by:

$$U_f = U_i + \Delta U$$

4. Substitute the values:

$$U_f = 30 + (-12)$$

$$U_f = 18 \text{ J}$$

**Final Answer:** The final internal energy will be 18 J.

**Answer: (A)**



Q4.

**Solution****Concept:**

The displacement of a particle performing Simple Harmonic Motion (SHM) starting from the positive extreme position is given by:

$$x = A \cos(\omega t)$$

where  $A$  is the amplitude,  $\omega = 2\pi/T$  is the angular frequency, and  $T$  is the time period.

**Solution:**

1. The particle starts at the extreme position  $x = A$  at  $t = 0$ . 2. We need to find the time  $t$  when the displacement reaches  $x = A/2$ . 3. Using the equation:

$$A/2 = A \cos(\omega t)$$

4. Simplify the equation:

$$1/2 = \cos(\omega t)$$

5. We know that  $\cos(60^\circ)$  or  $\cos(\pi/3) = 1/2$ . Therefore:

$$\omega t = \frac{\pi}{3}$$

6. Substitute  $\omega = \frac{2\pi}{T}$ :

$$\left(\frac{2\pi}{T}\right)t = \frac{\pi}{3}$$

7. Solve for  $t$ :

$$t = \frac{\pi}{3} \times \frac{T}{2\pi}$$

$$t = \frac{T}{6}$$

**Final Answer:** The time required is  $T/6$ .

**Answer: (A)**



Q5.

**Solution****Concept:**

The fundamental frequency ( $f$ ) of a stretched string is given by the formula:

$$f = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$

where  $L$  is the length,  $T$  is the tension ( $mg$ ), and  $\mu$  is the linear mass density. For a given string, frequency is directly proportional to the square root of the tension ( $f \propto \sqrt{T}$ ). An "octave" means the frequency is doubled.

**Solution:**

1. Initial frequency  $f_1 = 256$  Hz with mass  $m_1 = 4$  kg. 2. The tension  $T_1 = m_1g$ . 3. We want the new frequency  $f_2$  to be an octave higher, so:

$$f_2 = 2 \times f_1 = 2 \times 256 = 512 \text{ Hz}$$

4. Using the proportionality  $f \propto \sqrt{T}$  or  $f \propto \sqrt{m}$ :

$$\frac{f_2}{f_1} = \sqrt{\frac{m_2}{m_1}}$$

5. Substitute the values:

$$\frac{512}{256} = \sqrt{\frac{m_2}{4}}$$
$$2 = \sqrt{\frac{m_2}{4}}$$

6. Square both sides:

$$4 = \frac{m_2}{4}$$
$$m_2 = 16 \text{ kg}$$

**Final Answer:** The weight required is 16 kg.

**Answer: (D)**



Q6.

**Solution****Concept:**

The capacitance ( $C$ ) of a parallel plate capacitor is given by:

$$C = \frac{K\epsilon_0 A}{d}$$

where  $K$  is the dielectric constant,  $\epsilon_0$  is the permittivity of free space,  $A$  is the area of the plates, and  $d$  is the separation between them. Initially, for air,  $K = 1$ . When the separation is changed and a dielectric is inserted, the capacitance changes accordingly.

**Solution:**

1. Initial capacitance with air ( $K = 1$ ):

$$C_1 = \frac{\epsilon_0 A}{d} = 8 \text{ pF}$$

2. New conditions: Dielectric constant  $K = 6$  New distance  $d' = d/2$  3. New capacitance  $C_2$  is:

$$C_2 = \frac{K\epsilon_0 A}{d'}$$

4. Substitute  $K = 6$  and  $d' = d/2$ :

$$C_2 = \frac{6\epsilon_0 A}{d/2} = 12 \left( \frac{\epsilon_0 A}{d} \right)$$

5. Since  $\frac{\epsilon_0 A}{d} = 8 \text{ pF}$ :

$$C_2 = 12 \times 8 = 96 \text{ pF}$$

**Final Answer:** The new capacitance will be 96 pF.

**Answer: (C)**



Q7.

**Solution****Concept:**

The resistance ( $R$ ) of a wire is given by  $R = \rho \frac{l}{A}$ . When a wire is stretched, its volume ( $V = A \cdot l$ ) remains constant. This means if length  $l$  increases, the area of cross-section  $A$  must decrease proportionally. For small percentage changes, the change in resistance can be approximated using the formula:

$$\frac{\Delta R}{R} = 2 \frac{\Delta l}{l}$$

**Solution:**

1. Resistance  $R$  depends on length  $l$  and area  $A$ . Since volume  $V = Al$  is constant:

$$A = \frac{V}{l}$$

2. Substituting this into the resistance formula:

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

3. Since  $\rho$  and  $V$  are constants for the given wire:

$$R \propto l^2$$

4. For small changes, the fractional change is:

$$\frac{\Delta R}{R} = 2 \frac{\Delta l}{l}$$

5. Given the percentage change in length is 0.1%:

$$\text{Percentage change in } R = 2 \times 0.1\% = 0.2\%$$

**Final Answer:** The percentage change in its resistance is 0.2%.

**Answer: (A)**



Q8.

**Solution****Concept:**

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

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

The magnetic field at the center ( $x = 0$ ) is:

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

**Solution:**

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

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

3. Simplify by canceling common terms ( $\mu_0, I, 2$ ):

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

4. Rearrange the equation:

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

5. Take the cube root of both sides:

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

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

6. Square both sides:

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

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

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

**Answer: (B)**



Q9.

**Solution****Concept:**

In a series LR circuit, the phase angle ( $\phi$ ) between the voltage and the current is determined by the ratio of the inductive reactance ( $X_L$ ) to the resistance ( $R$ ):

$$\tan(\phi) = \frac{X_L}{R}$$

where  $X_L = \omega L = 2\pi fL$ .

**Solution:**

1. Identify the given values:  $L = 0.5 \text{ H}$ ,  $R = 100 \Omega$ ,  $f = 50 \text{ Hz}$ .
2. Calculate the inductive reactance ( $X_L$ ):

$$X_L = 2\pi \times 50 \times 0.5$$

$$X_L = 2\pi \times 25 = 50\pi \Omega$$

3. Use the phase angle formula:

$$\tan(\phi) = \frac{50\pi}{100}$$

4. Simplify the fraction:

$$\tan(\phi) = \frac{\pi}{2}$$

5. Therefore:

$$\phi = \tan^{-1} \left( \frac{\pi}{2} \right)$$

**Final Answer:**  $\phi = \tan^{-1} \left( \frac{\pi}{2} \right)$ .

**Answer:** (A)



Q10.

**Solution****Concept:**

According to Einstein's photoelectric equation, the stopping potential ( $V_s$ ) is related to the wavelength of incident light ( $\lambda$ ) and the work function ( $\Phi$ ) by:

$$eV_s = \frac{hc}{\lambda} - \Phi$$

This can be written as  $\Phi = \frac{hc}{\lambda} - eV_s$ .

**Solution:**

1. For wavelength  $\lambda$  and stopping potential  $V_1$ :

$$\Phi = \frac{hc}{\lambda} - eV_1 \quad \text{--- (Equation 1)}$$

2. For wavelength  $2\lambda$  and stopping potential  $V_2$ :

$$eV_2 = \frac{hc}{2\lambda} - \Phi$$

3. From Equation 1, we find  $\frac{hc}{\lambda} = \Phi + eV_1$ . Substitute this into Equation 2:

$$eV_2 = \frac{1}{2}(\Phi + eV_1) - \Phi$$

4. Multiply the entire equation by 2 to clear the fraction:

$$2eV_2 = \Phi + eV_1 - 2\Phi$$

5. Simplify the right side:

$$2eV_2 = eV_1 - \Phi$$

6. Rearrange to solve for  $\Phi$ :

$$\Phi = eV_1 - 2eV_2$$

$$\Phi = e(V_1 - 2V_2)$$

**Final Answer:** The work function of the metal is  $e(V_1 - 2V_2)$ .

**Answer: (B)**



Q11.

**Solution****Concept:**

The moment of inertia ( $I$ ) of a solid sphere about an axis passing through its center of mass is given by:

$$I_{cm} = \frac{2}{5}MR^2$$

To find the moment of inertia about a tangent, we use the Parallel Axis Theorem:

$$I_{parallel} = I_{cm} + Mh^2$$

where  $h$  is the distance between the center of mass axis and the parallel axis.

**Solution:**

1. The distance from the center of the sphere to any tangent on its surface is equal to the radius, so  $h = R$ . 2. Applying the Parallel Axis Theorem:

$$I_{tangent} = I_{cm} + MR^2$$

3. Substitute the value for  $I_{cm}$  of a solid sphere:

$$I_{tangent} = \frac{2}{5}MR^2 + MR^2$$

4. Find a common denominator to add the terms:

$$I_{tangent} = \frac{2}{5}MR^2 + \frac{5}{5}MR^2$$

5. Simplify the expression:

$$I_{tangent} = \frac{7}{5}MR^2$$

**Final Answer:** The moment of inertia about a tangent is  $7/5MR^2$ .

**Answer: (C)**



Q12.

**Solution****Concept:**

When a particle moves in a circle with changing speed, it experiences two types of acceleration: 1. Centripetal (radial) acceleration ( $a_r = v^2/r$ ), which changes the direction of velocity. 2. Tangential acceleration ( $a_t = dv/dt$ ), which changes the magnitude of velocity. The total acceleration ( $a$ ) is the vector sum of these two perpendicular components:

$$a = \sqrt{a_r^2 + a_t^2}$$

**Solution:**

1. Identify the given values:  $v = 20$  m/s,  $r = 100$  m,  $a_t = 3$  m/s<sup>2</sup>. 2. Calculate the radial (centripetal) acceleration:

$$a_r = \frac{v^2}{r} = \frac{20^2}{100} = \frac{400}{100} = 4 \text{ m/s}^2$$

3. The tangential acceleration is given as the rate of increase of speed:

$$a_t = 3 \text{ m/s}^2$$

4. Calculate the total acceleration using the Pythagorean theorem:

$$a = \sqrt{4^2 + 3^2}$$

5. Solve the calculation:

$$a = \sqrt{16 + 9} = \sqrt{25} = 5 \text{ m/s}^2$$

**Final Answer:** The total acceleration of the car is 5 m/s<sup>2</sup>.

**Answer: (C)**



Q13.

**Solution****Concept:**

The average translational kinetic energy ( $K$ ) of a molecule of an ideal gas is directly proportional to its absolute temperature ( $T$ ) in Kelvin. The relation is given by:

$$K = \frac{3}{2}k_B T$$

where  $k_B$  is the Boltzmann constant. Therefore,  $K \propto T$ .

**Solution:**

1. Convert the given temperatures from Celsius to Kelvin ( $T_K = T_C + 273$ ): Initial temperature  $T_1 = 27 + 273 = 300$  K Final temperature  $T_2 = 327 + 273 = 600$  K  
2. Use the proportionality  $K_1/K_2 = T_1/T_2$ :

$$\frac{E}{K_2} = \frac{300}{600}$$

3. Simplify the temperature ratio:

$$\frac{E}{K_2} = \frac{1}{2}$$

4. Solve for the new kinetic energy  $K_2$ :

$$K_2 = 2E$$

5. As the absolute temperature is doubled, the kinetic energy of the molecule is also doubled.

**Final Answer:** The kinetic energy at  $327^\circ\text{C}$  will be  $2E$ .

**Answer: (A)**



Q14.

**Solution****Concept:**

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

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

where  $G$  is the gravitational constant and  $M$  is the mass of the planet. This shows that orbital velocity is inversely proportional to the square root of the orbital radius ( $v \propto 1/\sqrt{r}$ ).

**Solution:**

1. Identify the radii of the two satellites:  $r_A = 4R$   $r_B = R$  2. Set up the ratio for their velocities:

$$\frac{v_B}{v_A} = \sqrt{\frac{r_A}{r_B}}$$

3. Substitute the radii into the expression:

$$\frac{v_B}{v_A} = \sqrt{\frac{4R}{R}} = \sqrt{4} = 2$$

4. We are given the speed of  $A$  as  $v_A = 3v$ . 5. Calculate the speed of  $B$ :

$$v_B = 2 \times v_A = 2 \times 3v = 6v$$

**Final Answer:** The speed of satellite  $B$  is  $6v$ .

**Answer: (B)**



Q15.

**Solution****Concept:**

For an open pipe (open at both ends), the  $n^{\text{th}}$  harmonic frequency is given by:

$$f_{n,open} = n \left( \frac{v}{2L} \right)$$

For a closed pipe (closed at one end), the fundamental frequency is:

$$f_{1,closed} = \frac{v}{4L}$$

where  $v$  is the speed of sound and  $L$  is the length of the pipe.

**Solution:**

1. From the given information for the open pipe:

$$f = n \left( \frac{v}{2L} \right)$$

2. Rearrange this equation to find the term  $(v/L)$ :

$$\frac{v}{L} = \frac{2f}{n}$$

3. The fundamental frequency of the same pipe when one end is closed is:

$$f' = \frac{v}{4L} = \frac{1}{4} \left( \frac{v}{L} \right)$$

4. Substitute the expression for  $(v/L)$  from step 2 into the equation for  $f'$ :

$$f' = \frac{1}{4} \left( \frac{2f}{n} \right)$$

5. Simplify the expression:

$$f' = \frac{2f}{4n} = \frac{f}{2n}$$

**Final Answer:** The fundamental frequency will be  $f/2n$ .

**Answer: (A)**



Q16.

**Solution****Concept:**

The relationship between the electric field  $\vec{E}$  and the electric potential  $V$  is given by the negative gradient of the potential:

$$\vec{E} = -\nabla V = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$$

In this problem, the potential  $V$  depends only on the  $x$ -coordinate, so the electric field will only have an  $x$ -component.

**Solution:**

1. Given the potential function:

$$V = 4x^2$$

2. Calculate the  $x$ -component of the electric field by differentiating with respect to  $x$ :

$$E_x = -\frac{\partial V}{\partial x} = -\frac{d}{dx}(4x^2)$$

$$E_x = -8x$$

3. Since  $V$  does not depend on  $y$  or  $z$ , the other components are zero ( $E_y = 0, E_z = 0$ ). 4. The electric field vector is:

$$\vec{E} = -8x\hat{i}$$

5. Evaluate the electric field at the given point  $(1, 0, 2)$  m. Here,  $x = 1$ :

$$\vec{E} = -8(1)\hat{i} = -8\hat{i} \text{ V/m}$$

**Final Answer:** The electric field at the point is  $-8\hat{i}$  V/m.

**Answer: (B)**



Q17.

**Solution****Concept:**

To convert a galvanometer into a voltmeter, a high resistance  $R_s$  must be connected in series with it. The total resistance of the circuit becomes  $G + R_s$ , where  $G$  is the resistance of the galvanometer. The required series resistance is given by:

$$V = I_g(G + R_s) \implies R_s = \frac{V}{I_g} - G$$

**Solution:**

1. Identify the given parameters:

Galvanometer resistance,  $G = 50 \Omega$

Full scale deflection current,  $I_g = 0.05 \text{ A}$

Desired voltage range,  $V = 20 \text{ V}$

2. Use the conversion formula:

$$R_s = \frac{20}{0.05} - 50$$

3. Simplify the division:

$$R_s = 400 - 50$$

4. Calculate the final value:

$$R_s = 350 \Omega$$

5. This high resistance ensures that most of the voltage drops across the series resistor, protecting the galvanometer.

**Final Answer:**  $R_s = 350 \Omega$ .

**Answer: (A)**



Q18.

**Solution****Concept:**

When light is incident on a transparent surface at the polarizing angle (also known as Brewster's angle,  $\theta_p$ ), the reflected ray and the refracted ray are perpendicular to each other. This is a fundamental property derived from Brewster's Law.

**Solution:**

1. Brewster's Law states that  $\mu = \tan(\theta_p)$ . 2. At this specific angle of incidence, the vibrations of the reflected ray are restricted to a plane parallel to the surface (completely polarized). 3. Geometric analysis of Snell's law and the definition of Brewster's angle shows that:

$$\theta_p + 90^\circ + r = 180^\circ$$

where  $r$  is the angle of refraction. 4. This simplifies to the fact that the angle between the reflected ray and the refracted ray is exactly  $90^\circ$ . 5. The specific value of the angle given ( $57.5^\circ$ ) is the polarizing angle for glass, but the result ( $90^\circ$ ) holds true for any medium when light is incident at its polarizing angle.

**Final Answer:** The angle between the reflected and refracted rays is  $90^\circ$ .

**Answer: (C)**

Q19.

**Solution****Concept:**

Semiconductors are doped with impurities to change their electrical properties. In a p-type semiconductor, trivalent impurities (acceptors) are added. These impurities create "holes" by accepting electrons from the valence band. This creates a new energy level within the band gap.

**Solution:**

1. In p-type semiconductors, the dopant atoms lack one electron compared to the host semiconductor atoms (like Silicon). 2. Because they "want" to accept an electron, the energy level associated with these impurities is called the acceptor level. 3. For an electron to move from the valence band to this acceptor level, it requires very little energy. 4. Therefore, the acceptor level must be located very close to the top of the valence band. 5. In energy band diagrams, this is represented as the acceptor level lying just above the valence band.

**Final Answer:** The acceptor level lies just above the valence band.

**Answer: (B)**



Q20.

**Solution****Concept:**

The energy of an electron in a hydrogen atom is quantized and depends on the principal quantum number  $n$ . The excitation energy is the difference in energy between the final state ( $n_f$ ) and the initial state ( $n_i$ ):

$$\Delta E = E_{n_f} - E_{n_i} = -13.6 \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \text{ eV}$$

**Solution:**

1. Initial state  $n_i = 1$  (ground state):

$$E_1 = -13.6/1^2 = -13.6 \text{ eV}$$

2. Final state  $n_f = 3$  (second excited state):

$$E_3 = -13.6/3^2 = -13.6/9 \approx -1.51 \text{ eV}$$

3. The energy required for excitation is:

$$\Delta E = E_3 - E_1$$

$$\Delta E = -1.51 - (-13.6)$$

4. Calculate the difference:

$$\Delta E = 13.6 - 1.51 = 12.09 \text{ eV}$$

5. This is the energy that must be absorbed by the electron (usually from a photon) to jump to the higher orbit.

**Final Answer:** The energy required is 12.09 eV.

**Answer: (A)**



Q21.

**Solution****Concept:**

For the flow of an incompressible fluid, the Equation of Continuity states that the volume flow rate remains constant throughout the pipe. Mathematically:

$$A_1 v_1 = A_2 v_2$$

where  $A$  is the area of cross-section and  $v$  is the velocity. For a circular pipe,  $A = \pi r^2$ . This implies that velocity is inversely proportional to the square of the radius ( $v \propto 1/r^2$ ).

**Solution:**

1. Let the radii at two points be  $r_1$  and  $r_2$ . We are given:

$$\frac{r_1}{r_2} = \frac{3}{2}$$

2. According to the equation of continuity:

$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

3. Rearrange the equation to find the ratio of velocities:

$$\frac{v_1}{v_2} = \frac{r_2^2}{r_1^2} = \left(\frac{r_2}{r_1}\right)^2$$

4. Substitute the inverse of the given radius ratio:

$$\frac{v_1}{v_2} = \left(\frac{2}{3}\right)^2$$

5. Calculate the squares:

$$\frac{v_1}{v_2} = \frac{4}{9}$$

**Final Answer:** The ratio of the velocities is 4 : 9.

**Answer: (C)**



Q22.

**Solution****Concept:**

The displacement of a particle in Simple Harmonic Motion (SHM) is given by  $x = A \sin(\omega t + \phi)$ .  
The velocity ( $v$ ) 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 at the mean position and is given by:

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

**Solution:**

1. Identify the given displacement equation:

$$x = 10 \sin(2\pi t + \pi/6)$$

2. Compare this with the standard SHM equation  $x = A \sin(\omega t + \phi)$  to find constants: Amplitude,  $A = 10$  cm Angular frequency,  $\omega = 2\pi$  rad/s 3. Use the formula for maximum velocity:

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

4. Substitute the values:

$$v_{max} = 10 \times 2\pi$$

5. Calculate the final value:

$$v_{max} = 20\pi \text{ cm/s}$$

**Final Answer:** The maximum velocity is  $20\pi$  cm/s.

**Answer: (B)**



Q23.

**Solution****Concept:**

A soap bubble is a thin film of liquid held together by surface tension, which tends to minimize the surface area (contract the bubble). When a charge is given to the bubble (positive or negative), the like charges spread across the outer surface. These charges experience mutual electrostatic repulsion.

**Solution:**

1. Surface tension acts inwards, trying to reduce the radius of the bubble. 2. When a negative charge is applied, the electrons distribute themselves over the surface of the bubble. 3. Due to electrostatic repulsion between these like charges, an outward pressure (electrostatic pressure) is generated. 4. This outward pressure opposes the inward force of surface tension. 5. To reach a new equilibrium, the bubble expands slightly, leading to an increase in its radius. 6. The result is the same whether the charge is positive or negative, as repulsion always acts outwards.

**Final Answer:** Its radius will Increase.

**Answer:** (A)



Q24.

**Solution****Concept:**

Einstein's photoelectric equation relates the maximum kinetic energy ( $K_{max}$ ) of emitted electrons to the energy of incident photons ( $E$ ) and the work function ( $\Phi$ ):

$$K_{max} = E - \Phi = \frac{hc}{\lambda} - \Phi$$

A useful shortcut for energy in eV is  $E(\text{eV}) \approx 12400/\lambda(\text{\AA})$ .

**Solution:**

1. Calculate the energy of the incident photon ( $E$ ):

$$E = \frac{12400}{4000} \text{ eV}$$

$$E = 3.1 \text{ eV}$$

2. Identify the given work function:

$$\Phi = 2.5 \text{ eV}$$

3. Since  $E > \Phi$ , photoemission will occur. 4. Calculate the maximum kinetic energy:

$$K_{max} = E - \Phi$$

$$K_{max} = 3.1 - 2.5$$

5. Calculate the result:

$$K_{max} = 0.6 \text{ eV}$$

**Final Answer:** The maximum kinetic energy is 0.6 eV.

**Answer: (B)**



Q25.

**Solution****Concept:**

The angle of dip (or magnetic inclination) is the angle that the Earth's total magnetic field vector ( $\vec{B}$ ) makes with the horizontal direction at any point on the Earth's surface. It varies from  $0^\circ$  at the magnetic equator to  $90^\circ$  at the magnetic poles.

**Solution:**

1. At the magnetic equator, the magnetic field lines of the Earth are exactly parallel to the surface of the Earth. 2. Therefore, the total magnetic field vector  $\vec{B}$  is purely horizontal. 3. Since the field is horizontal, the vertical component  $B_v$  is zero ( $B_v = B \sin(\theta) = 0$ ). 4. The angle between the horizontal and the magnetic field vector is:

$$\theta = 0^\circ$$

5. In contrast, at the magnetic poles, the field lines are vertical, making the angle of dip  $90^\circ$ .

**Final Answer:** The angle of dip at the magnetic equator is  $0^\circ$ .

**Answer: (A)**

Q26.

**Solution****Concept:**

The work done in a thermodynamic cycle is represented by the area enclosed by the path on a Pressure-Volume ( $P - V$ ) diagram. For a cyclic process, the net change in internal energy ( $\Delta U$ ) is zero because the system returns to its initial state. According to the First Law of Thermodynamics,  $Q_{net} = W_{net}$ .

**Solution:**

1. In a  $P - V$  diagram, the work done during a process is the area under the curve. 2. For a complete cycle  $A \rightarrow C \rightarrow B \rightarrow D \rightarrow A$ , the total work done is the algebraic sum of the work done in each part. 3. Work is positive if the volume increases (expansion) and negative if the volume decreases (compression). 4. The net work done  $W_{net}$  corresponds to the area trapped within the closed loop formed by the paths. 5. If the cycle is clockwise, the net work done by the system is positive; if counter-clockwise, it is negative. 6. Regardless of the sign, the magnitude is always the area of the enclosed loop.

**Final Answer:** The net work done is the Area of the loop ACBDA.

**Answer: (B)**



Q27.

**Solution****Concept:**

In the photoelectric effect, different characteristics of the incident light affect different properties of the emitted electrons: 1. Frequency of light affects the maximum kinetic energy and stopping potential. 2. Intensity of light (number of photons per unit area per unit time) affects the number of photoelectrons emitted per second.

**Solution:**

1. Intensity is defined as the energy incident per unit area per unit time. For a fixed frequency, increasing intensity means more photons are hitting the surface. 2. Since one photon interacts with one electron, more photons result in the emission of more photoelectrons. 3. The rate of flow of charge is defined as electric current. 4. Therefore, an increase in the intensity of incident light leads to a proportional increase in the photoelectric current (photocurrent). 5. Kinetic energy and stopping potential remain unchanged because they depend only on the energy of individual photons ( $hf$ ).

**Final Answer:** The Photocurrent increases.

**Answer: (C)**

Q28.

**Solution****Concept:**

In a series LCR circuit, the voltages across the inductor ( $V_L$ ) and capacitor ( $V_C$ ) are  $180^\circ$  out of phase with each other. The resultant voltage ( $V$ ) is the phasor sum of the individual voltages:

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

Note that for the amplitude of the source, we usually use peak values, but if RMS values are given, the formula remains the same.

**Solution:**

1. Identify the given component voltages:  $V_L = 70 \text{ V}$   $V_C = 70 \text{ V}$   $V_R = 40 \text{ V}$  2. Apply the resultant voltage formula:

$$V = \sqrt{40^2 + (70 - 70)^2}$$

3. Since  $V_L = V_C$ , the circuit is in resonance, and the reactive parts cancel out:

$$V = \sqrt{40^2 + 0^2} = 40 \text{ V}$$

4. This 40 V is the RMS value of the source voltage. The question asks for the amplitude (peak value  $V_0$ ):

$$V_0 = V_{rms} \sqrt{2} = 40\sqrt{2} \text{ V}$$

**Final Answer:** The amplitude of the source voltage is  $40\sqrt{2} \text{ V}$ .

**Answer: (D)**



Q29.

**Solution****Concept:**

The amount of a radioactive substance remaining after a certain time is determined by the number of half-lives that have passed ( $n$ ). The fraction remaining is:

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

where  $n = \text{Total time}/\text{Half-life}$ .

**Solution:**

1. Identify the given values: Half-life ( $T_{1/2}$ ) = 1600 years Total time ( $t$ ) = 6400 years 2. Calculate the number of half-lives ( $n$ ):

$$n = \frac{6400}{1600} = 4$$

3. Calculate the fraction remaining ( $N/N_0$ ):

$$\text{Fraction} = \left(\frac{1}{2}\right)^4$$

4. Evaluate the power:

$$\left(\frac{1}{2}\right)^4 = \frac{1}{2 \times 2 \times 2 \times 2} = \frac{1}{16}$$

5. Thus, 1/16 of the original sample remains undecayed.

**Final Answer:** The fraction of the sample remaining is 1/16.

**Answer: (C)**



Q30.

**Solution****Concept:**

The molar specific heat at constant volume ( $C_v$ ) of a gas is related to its degrees of freedom ( $f$ ) by the formula:

$$C_v = \frac{f}{2}R$$

where  $R$  is the universal gas constant.

**Solution:**

1. A monatomic gas (like Helium or Argon) consists of single atoms. 2. These atoms can move in three independent directions ( $x$ ,  $y$ ,  $z$ ), but they do not rotate or vibrate significantly at standard temperatures. 3. Therefore, a monatomic gas has  $f = 3$  degrees of freedom (all translational). 4. Substitute  $f = 3$  into the molar specific heat formula:

$$C_v = \frac{3}{2}R$$

5. For comparison, a diatomic gas typically has  $f = 5$  ( $C_v = 5/2R$ ) and a polyatomic gas has  $f = 6$  ( $C_v = 3R$ ).

**Final Answer:** The molar specific heat is  $3/2R$ .

**Answer: (A)**



Q31.

**Solution****Concept:**

When a wire is bent into a circle, the two points at the ends of a diameter divide the wire into two equal semicircular sections. Each section acts as an individual resistor, and since they are connected between the same two points, they are in a parallel arrangement.

**Solution:**

1. The total resistance of the wire is  $R$ . 2. When divided into two equal halves (semicircles), the resistance of each half is:

$$R_1 = R_2 = \frac{R}{2}$$

3. These two halves are connected in parallel across the diameter. 4. The equivalent resistance  $R_p$  for a parallel combination is given by:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

5. Substitute the values:

$$\frac{1}{R_p} = \frac{1}{R/2} + \frac{1}{R/2} = \frac{2}{R} + \frac{2}{R} = \frac{4}{R}$$

6. Therefore:

$$R_p = \frac{R}{4}$$

**Final Answer:** The resistance between the ends of a diameter is  $R/4$ .

**Answer: (B)**



Q32.

**Solution****Concept:**

The de Broglie wavelength ( $\lambda$ ) of a particle is inversely proportional to its momentum ( $p = mv$ ). The relationship is:

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

where  $h$  is Planck's constant. If two particles move with the same velocity ( $v$ ), their wavelengths are inversely proportional to their masses.

**Solution:**

1. Let  $\lambda_\alpha$  and  $\lambda_p$  be the wavelengths of the alpha particle and proton respectively. 2. Given  $v_\alpha = v_p$ . 3. The mass of an alpha particle ( $m_\alpha$ ) is approximately 4 times the mass of a proton ( $m_p$ ):

$$m_\alpha = 4m_p$$

4. From the wavelength formula:

$$\lambda_\alpha = \frac{h}{m_\alpha v} \quad \text{and} \quad \lambda_p = \frac{h}{m_p v}$$

5. Taking the ratio:

$$\frac{\lambda_p}{\lambda_\alpha} = \frac{m_\alpha}{m_p} = \frac{4m_p}{m_p} = 4$$

6. Therefore:

$$\lambda_p = 4\lambda_\alpha$$

7. Since  $\lambda_\alpha = \lambda$ , we get  $\lambda_p = 4\lambda$ .

**Final Answer:** The de Broglie wavelength of the proton is  $4\lambda$ .

**Answer: (C)**



Q33.

**Solution****Concept:**

When two thin lenses are placed in contact, the equivalent focal length ( $F$ ) of the combination is given by the reciprocal sum of their individual focal lengths:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Note the sign convention: convex lenses have positive focal lengths, and concave lenses have negative focal lengths.

**Solution:**

1. Identify the focal lengths: Convex lens:  $f_1 = +10$  cm Concave lens:  $f_2 = -20$  cm 2. Use the combination formula:

$$\frac{1}{F} = \frac{1}{10} + \frac{1}{-20}$$

3. Find a common denominator:

$$\frac{1}{F} = \frac{2}{20} - \frac{1}{20} = \frac{1}{20}$$

4. Therefore:

$$F = 20 \text{ cm}$$

5. The positive sign indicates that the combination behaves like a convex lens.

**Final Answer:** The focal length of the combination is 20 cm.

**Answer: (C)**

Q34.

**Solution****Concept:**

In a compound microscope, the total magnifying power ( $M$ ) is the product of the magnification produced by the objective lens ( $m_o$ ) and the magnification produced by the eyepiece ( $m_e$ ):

$$M = m_o \times m_e$$

**Solution:**

1. Identify the given values: Total magnification,  $M = 30$  Objective magnification,  $m_o = 5$  2. Use the total magnification formula:

$$30 = 5 \times m_e$$

3. Solve for  $m_e$ :

$$m_e = \frac{30}{5} = 6$$

4. The eyepiece acts like a simple magnifier, providing an additional magnification of 6.

**Final Answer:** The magnification produced by the eyepiece is 6.

**Answer: (A)**



Q35.

**Solution****Concept:**

The escape velocity ( $v_e$ ) from the surface of a celestial body is the minimum velocity required to break free from its gravitational pull. It is given by:

$$v_e = \sqrt{\frac{2GM}{R}}$$

where  $M$  is the mass and  $R$  is the radius of the body.

**Solution:**

1. From the formula, escape velocity depends on both the mass ( $M$ ) and the radius ( $R$ ) of the body.
2. The mass of the moon is significantly smaller than the mass of the earth ( $M_{moon} \approx M_{earth}/81$ ).
3. The radius of the moon is also smaller than the radius of the earth ( $R_{moon} \approx R_{earth}/3.7$ ).
4. Although a smaller radius tends to increase escape velocity, the drastic reduction in mass dominates the equation, leading to a much lower  $v_e$  for the moon.
5. Lack of atmosphere is a *consequence* of low escape velocity, not the cause of it.

**Final Answer:** It is because both (B) and (C) are true.

**Answer: (D)**



Q36.

**Solution****Concept:**

The efficiency ( $\eta$ ) of an ideal heat engine (Carnot engine) is defined as the ratio of work done to the heat absorbed from the source. It can be expressed in terms of heat ( $Q$ ) or absolute temperature ( $T$ ):

$$\eta = 1 - \frac{Q_{sink}}{Q_{source}} = 1 - \frac{T_{sink}}{T_{source}}$$

**Solution:**

1. Identify the given values: Heat absorbed ( $Q_{source}$ ) = 1000 J Heat exhausted ( $Q_{sink}$ ) = 600 J  
Source temperature ( $T_{source}$ ) = 400 K 2. First, calculate the efficiency using heat:

$$\eta = 1 - \frac{600}{1000} = 1 - 0.6 = 0.4$$

3. Now, equate this to the temperature-based efficiency formula:

$$0.4 = 1 - \frac{T_{sink}}{400}$$

4. Rearrange the equation to solve for  $T_{sink}$ :

$$\frac{T_{sink}}{400} = 1 - 0.4 = 0.6$$

5. Calculate the final temperature:

$$T_{sink} = 0.6 \times 400 = 240 \text{ K}$$

**Final Answer:** The sink temperature is 240 K.

**Answer: (A)**



Q37.

**Solution****Concept:**

In Simple Harmonic Motion (SHM), the displacement is  $x = A \sin(\omega t)$ . The velocity is  $v = \omega \sqrt{A^2 - x^2}$  and the acceleration is  $a = -\omega^2 x$ . The mean position is defined as  $x = 0$ .

**Solution:**

1. At the mean position ( $x = 0$ ): 2. Velocity:

$$v = \omega \sqrt{A^2 - 0^2} = A\omega$$

This is the maximum possible value for velocity during the oscillation. 3. Acceleration:

$$a = -\omega^2(0) = 0$$

Since there is no displacement from the equilibrium point, the restoring force and acceleration are zero. 4. Conversely, at the extreme positions ( $x = A$ ), velocity is zero and acceleration is maximum.

**Final Answer:** At the mean position, Velocity is maximum and acceleration is zero.

**Answer: (B)**



Q38.

**Solution****Concept:**

The electrostatic potential energy ( $U$ ) stored in a capacitor can be calculated using the capacitance ( $C$ ) and the potential difference ( $V$ ) applied across it:

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

**Solution:**

1. Identify the given values and convert them to SI units:

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

Potential difference,  $V = 100 \text{V}$

2. Substitute the values into the energy formula:

$$U = \frac{1}{2} \times 10^{-5} \times (100)^2$$

3. Square the voltage:

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

4. Simplify the powers of 10:

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

5. Final calculation:

$$U = 0.05 \text{J}$$

**Final Answer:**  $U = 0.05 \text{J}$ .

**Answer:** (A)



Q39.

**Solution****Concept:**

The magnetic force per unit length ( $f$ ) between two long, straight, parallel wires carrying currents  $I_1$  and  $I_2$  separated by a distance  $r$  is given by:

$$f = \frac{\mu_0 I_1 I_2}{2\pi r}$$

This shows that the force is directly proportional to the product of the two currents ( $f \propto I_1 I_2$ ).

**Solution:**

1. Initial force  $F_1 = k(I_1 \cdot I_2)$ . 2. According to the problem, the current in both wires is doubled: New current  $I'_1 = 2I_1$  New current  $I'_2 = 2I_2$  3. The new force  $F_2$  is:

$$F_2 = k(2I_1 \cdot 2I_2) = 4 \cdot k(I_1 I_2)$$

4. Therefore:

$$F_2 = 4F_1$$

5. The force becomes four times its original value.

**Final Answer:** The force becomes 4F.

**Answer: (B)**



Q40.

**Solution****Concept:**

In a transistor amplifier configuration, the current gain in common emitter mode ( $\beta$  or  $h_{fe}$ ) is defined as:

$$\beta = \frac{\Delta I_c}{\Delta I_b}$$

**Solution:**

1. Identify the given parameters:

Current gain,  $\beta = 100$

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

2. Use the formula to find the change in collector current:

$$\Delta I_c = \beta \times \Delta I_b$$

3. Substitute the values:

$$\Delta I_c = 100 \times 20 \mu\text{A} = 2000 \mu\text{A}$$

4. Convert the result into milliamperes:

$$2000 \mu\text{A} = 2 \text{ mA}$$

5. This indicates a significant amplification of the input current signal.

**Final Answer:**  $\Delta I_c = 2 \text{ mA}$ .

**Answer: (A)**



Q41.

**Solution****Concept:**

Young's modulus ( $Y$ ) is a fundamental property of a material that measures its stiffness or resistance to elastic deformation under tension or compression. It is defined as the ratio of longitudinal stress to longitudinal strain:

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

As an intensive property, it depends only on the nature of the material and the temperature.

**Solution:**

1. Young's modulus is a characteristic constant for a particular substance (e.g., steel, copper, rubber). 2. While the force required to stretch a wire depends on its length and area, the ratio defined as  $Y$  remains constant for that material. 3. If you double the length or the diameter of the wire, the Young's modulus of the material itself does not change. 4. It does not depend on the load applied, as long as the deformation is within the elastic limit. 5. Therefore, it is solely a property of the material of the wire.

**Final Answer:** Young's modulus depends on the Material of the wire.

**Answer: (C)**

Q42.

**Solution****Concept:**

A transformer is a static device used to increase or decrease the voltage of an alternating current (AC) without changing its frequency. It consists of two coils, primary and secondary, wound on a common iron core.

**Solution:**

1. When an alternating current flows through the primary coil, it creates a varying magnetic flux in the core. 2. This varying magnetic flux passes through the secondary coil. 3. According to Faraday's Law, this changing flux induces an Electromotive Force (EMF) in the secondary coil. 4. The phenomenon where a change of current in one coil induces an EMF in a nearby coil is called mutual induction. 5. Self-induction occurs within a single coil, while eddy currents are circulating currents induced in the core material itself (which transformers try to minimize).

**Final Answer:** A transformer works on the principle of Mutual induction.

**Answer: (B)**



Q43.

**Solution****Concept:**

According to Bohr's model of the hydrogen atom, the velocity ( $v$ ) of an electron in the  $n^{\text{th}}$  permitted orbit is given by:

$$v = \frac{1}{n} \left( \frac{e^2}{2\epsilon_0 h} \right)$$

This indicates that the velocity of the electron is inversely proportional to the principal quantum number ( $v \propto 1/n$ ).

**Solution:**

1. Let  $v_1$  be the velocity in the first orbit ( $n = 1$ ). 2. Let  $v_2$  be the velocity in the second orbit ( $n = 2$ ). 3. Using the proportionality:

$$\frac{v_1}{v_2} = \frac{n_2}{n_1}$$

4. Substitute the values  $n_1 = 1$  and  $n_2 = 2$ :

$$\frac{v_1}{v_2} = \frac{2}{1}$$

5. Thus, the electron moves twice as fast in the first orbit compared to the second orbit.

**Final Answer:** The ratio of the speeds is 2 : 1.

**Answer: (B)**

Q44.

**Solution****Concept:**

Waves are generally classified into two types based on their requirement for a medium: 1. Electromagnetic waves: These consist of oscillating electric and magnetic fields and can travel through a vacuum. 2. Mechanical waves: These require a physical medium (solid, liquid, or gas) to propagate.

**Solution:**

1. X-rays, Radio waves, and Light waves are all forms of electromagnetic radiation. They do not require a medium and can travel through the vacuum of space. 2. Sound waves are mechanical longitudinal waves. They propagate through the compression and rarefaction of molecules in a medium. 3. In a vacuum, there are no molecules to transmit these vibrations. 4. Therefore, sound cannot travel through a vacuum.

**Final Answer:** Sound waves cannot travel through vacuum.

**Answer: (C)**



Q45.

**Solution****Concept:**

The power ( $P$ ) of a lens is defined as the reciprocal of its focal length ( $f$ ) measured in meters. The unit of power is the Dioptre (D). The formula is:

$$P = \frac{1}{f(\text{in meters})}$$

A negative power indicates a diverging (concave) lens.

**Solution:**

1. Identify the given power:  $P = -2.0$  D. 2. Use the power formula to find the focal length in meters:

$$f = \frac{1}{P} = \frac{1}{-2.0} = -0.5 \text{ m}$$

3. Convert the focal length from meters to centimeters:

$$f = -0.5 \times 100 \text{ cm}$$

$$f = -50 \text{ cm}$$

4. The negative sign confirms the lens is concave.

**Final Answer:** Its focal length is  $-50$  cm.

**Answer: (B)**

Q46.

**Solution****Concept:**

The electrical conductivity of a substance depends on the availability of charge carriers. In semiconductors, the charge carriers are electrons in the conduction band and holes in the valence band. Unlike metals, semiconductors have a negative temperature coefficient of resistance.

**Solution:**

1. In a semiconductor, there is a small energy gap (band gap) between the valence band and the conduction band. 2. At low temperatures, few electrons have enough thermal energy to cross this gap, resulting in high resistance. 3. As the temperature increases, more thermal energy is provided to the valence electrons. 4. This causes more covalent bonds to break, promoting more electrons to the conduction band and creating more holes in the valence band. 5. Since the concentration of charge carriers increases exponentially with temperature, the conductivity increases. 6. Therefore, the resistance of the semiconductor decreases as temperature rises.

**Final Answer:** Its resistance decreases with the increase in temperature.

**Answer: (B)**



Q47.

**Solution****Concept:**

In a series LCR circuit, the impedance ( $Z$ ) is the total opposition to the flow of alternating current. It is given by:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Resonance is a specific state where the inductive reactance ( $X_L$ ) and capacitive reactance ( $X_C$ ) are equal.

**Solution:**

1. At resonance, the condition is  $X_L = X_C$ . 2. Substitute this condition into the impedance formula:

$$Z = \sqrt{R^2 + (X_L - X_L)^2}$$

$$Z = \sqrt{R^2 + 0} = R$$

3. At this point, the impedance is purely resistive. 4. Since the reactive components cancel each other out, the value of  $Z$  is at its minimum possible value. 5. Because impedance is minimum, the current in the circuit ( $I = V/Z$ ) reaches its maximum value at resonance.

**Final Answer:** In a series LCR circuit at resonance, the impedance is Minimum.

**Answer: (B)**

Q48.

**Solution****Concept:**

Centripetal force is not a "new" or separate kind of force; rather, it is a requirement for circular motion. Any body moving in a circle must experience a net force directed toward the center of the circle to change its direction continuously.

**Solution:**

1. According to Newton's First Law, a body will move in a straight line unless acted upon by an external force. 2. To keep a body in a circular path, a center-seeking (centripetal) force is necessary. 3. This force is always provided by some "real" force existing in the physical situation. 4. Examples: - For a planet orbiting a star, gravity provides the centripetal force. - For a car turning on a road, friction provides the centripetal force. - For a stone whirled on a string, tension provides the centripetal force. 5. Inertia is a property that resists change, and centrifugal force is a pseudo-force observed only in a non-inertial frame.

**Final Answer:** It is provided by any real force like friction or tension.

**Answer: (B)**



Q49.

**Solution****Concept:**

The effective acceleration due to gravity ( $g'$ ) at a latitude  $\phi$  on the Earth's surface is affected by the Earth's rotation. The formula is:

$$g' = g - R\omega^2 \cos^2 \phi$$

where  $g$  is the acceleration due to gravity if the Earth were stationary,  $R$  is the radius of the Earth, and  $\omega$  is the angular velocity of rotation.

**Solution:**

1. At the equator, the latitude is  $\phi = 0^\circ$ . 2. Substitute  $\cos(0^\circ) = 1$  into the formula:

$$g'_{equator} = g - R\omega^2$$

3. This shows that the current value of gravity at the equator is less than  $g$  due to the outward "centrifugal effect" caused by rotation. 4. If the Earth stops rotating, the angular velocity  $\omega$  becomes 0. 5. The formula then becomes:

$$g'_{new} = g - R(0)^2 = g$$

6. Since  $g > (g - R\omega^2)$ , the value of  $g$  at the equator will increase to its maximum potential value.

**Final Answer:** The value of  $g$  at the equator will increase.

**Answer: (A)**

Q50.

**Solution****Concept:**

Gauss's Law states that the total electric flux ( $\Phi$ ) through any closed surface is equal to the net charge ( $q_{enclosed}$ ) inside the surface divided by the permittivity of free space ( $\epsilon_0$ ):

$$\Phi = \frac{q_{enclosed}}{\epsilon_0}$$

**Solution:**

1. The cube is a closed Gaussian surface. 2. The problem states that a charge  $+q$  is placed at the center of the cube. 3. According to Gauss's Law, the total flux leaving the entire cube depends only on the charge enclosed, not on the shape or size of the container. 4. Total Flux  $\Phi_{total} = q/\epsilon_0$ . 5. If the question asked for the flux through a *single face* of the cube, it would be  $q/6\epsilon_0$  (due to symmetry), but for the whole cube, it is the total enclosed charge divided by  $\epsilon_0$ . 6. Therefore, the flux is independent of the side length  $a$ .

**Final Answer:** The electric flux is  $q/\epsilon_0$ .

**Answer: (A)**



## Answer Key

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

