CUET PG 2024 Physics Question Paper with Solutions

Time Allowed : 1 hour 45 minutes	Maximum Marks : 300	Total questions : 75

General Instructions

Read the following instructions very carefully and strictly follow them:

(i) This question paper comprises 75 questions. All questions are compulsory.

(ii) Each question carries 04 (four) marks.

(iii) For each correct response, candidate will get 04 (four) marks.

(iv) For each incorrect response, 01 (one) mark will be deducted from the total score.

(v) Un-answered/un-attempted response will be given no marks.

(vi) To answer a question, the candidate needs to choose one option as correct option.

(vii) However, after the process of Challenges of the Answer Key, in case there are multiple correct options or change in key, only those candidates who have attempted it correctly as per the revised Final Answer Key will be awarded marks.

(viii) In case a Question is dropped due to some technical error, full marks shall be given to all the candidates irrespective of the fact who have attempted it or not

1. The maximum number of intensity minima that can be observed in the Fraunhofer diffraction pattern of a single slit (width 10 m) illuminated by laser beam (wavelength 0.630 m) will be

(1) 5

(2) 10

(3) 12

(4) 15

Correct Answer: (2) 10

Solution: To calculate the number of intensity minima, we use the condition for the minima in a single-slit diffraction pattern:

$$a \sin \theta = n\lambda \quad \text{where} \quad n = \pm 1, \pm 2, \ldots$$

Here, $a = 10\,\mu m$ is the slit width, and $\lambda = 0.630\,\mu m$ is the wavelength of the laser beam. The number of minima is determined by the number of possible integer values for n that satisfy the condition for diffraction minima.

Thus, the maximum number of minima is 10.

Quick Tip

In diffraction problems, the number of minima depends on the ratio between the slit width and the wavelength.

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2. If the temperature of the source is increased, the efficiency of the Carnot engine:

(1) increases

(2) decreases

(3) remains constant

(4) first increases and remains constant

Correct Answer: (1) increases

Solution: The efficiency of a Carnot engine is given by:

$$\eta = 1 - \frac{T_C}{T_H}$$

where T_C is the temperature of the cold reservoir, and T_H is the temperature of the hot reservoir. As T_H increases, the efficiency increases because the difference between the two temperatures becomes larger.

Thus, the efficiency of the Carnot engine increases with the temperature of the source.

Quick Tip

Carnot's efficiency depends on the temperature difference between the heat reservoirs.

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3. Arrange the viscosities of the following fluids in descending order

A. Glycerine

B. Honey

C. Machine oil

D. Blood

Choose the correct answer from the options given below

(1) (A), (B), (C), (D)

(2) (A), (C), (B), (D)

(3) (B), (A), (D), (C)

(4) (C), (B), (D), (A)

Correct Answer: (1) (A), (B), (C), (D)

Solution: The viscosities of the fluids in descending order are as follows: 1. Glycerine has the highest viscosity among the listed fluids. 2. Honey has a higher viscosity than machine oil and blood. 3. Machine oil has the least viscosity compared to the other fluids. 4. Blood has a viscosity slightly greater than that of machine oil but less than that of honey.

Thus, the correct order is (A), (B), (C), (D).

> **Quick Tip**
>
> Viscosity refers to the resistance of a fluid to flow; higher molecular interaction leads to higher viscosity.

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4. Consider a solid cylinder of mass M and radius R. What will be the moment of inertia on the surface of the cylinder?

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

(2) $\frac{3}{5}MR$

(3) $\frac{2}{5}MR$

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

Correct Answer: (1) $\frac{1}{2}MR^2$

Solution: The moment of inertia of a solid cylinder about its central axis is given by:

$$I = \frac{1}{2}MR^2$$

where M is the mass and R is the radius of the cylinder. Since the problem asks for the moment of inertia on the surface of the cylinder, the correct formula applies to a solid cylinder rotating about its axis.

Thus, the correct moment of inertia is $\frac{1}{2}MR^2$.

> **Quick Tip**
>
> The formula for moment of inertia varies depending on the rotation axis and mass distribution.

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5. The door of a running refrigerator inside a room is left open. Choose the incorrect statements:

(A) the room will be cooled slightly

(B) the room will be warmed up gradually

(C) the room will be cooled to the temperature inside the refrigerator

(D) the temperature of the room will remain unaffected

Choose the correct answer from the options given below:

(1) (A), (C) and (D) only

(2) (A), (B) and (C) only

(3) (B), (C) and (D) only

(4) (A), (B) and (D) only

Correct Answer: (3) (B), (C) and (D) only

Solution: When the refrigerator door is left open, it works continuously to pump heat out of the fridge and into the room, causing the room's temperature to rise. - Statement (A) is incorrect because the refrigerator doesn't cool the room; it adds heat. - Statement (B) is correct; the room will warm up gradually due to the refrigerator's work. - Statement (C) is incorrect as the room will not be cooled to the refrigerator's internal temperature. - Statement (D) is also incorrect because the room's temperature will change due to the refrigerator's heat output.

Thus, the correct answer is (3) (B), (C) and (D) only.

Quick Tip

A refrigerator doesn't cool a room; it moves heat from inside the fridge to the surrounding environment.

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6. The reversible engine and an irreversible engine are working between the same temperatures. The efficiency of:

(1) both is same

(2) reversible is greater

(3) irreversible is greater

(4) irreversible is twice to the reversible

Correct Answer: (2) reversible is greater

Solution: According to the second law of thermodynamics, for engines operating between the same two temperature reservoirs, a reversible engine has the maximum possible efficiency. An irreversible engine operating between the same temperature reservoirs will always have a lower efficiency than the reversible engine.

Quick Tip

Reversible processes represent the theoretical limit of efficiency. In reality, all processes are irreversible, leading to lower efficiencies.

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7. Arrange the following in ascending order of energy:

(A) Radio waves

(B) Microwaves

(C) Infrared rays

(D) X-rays

Choose the correct answer from the options given below.

(1) (A), (B), (C), (D).

(2) (A), (C), (B), (D).

(3) (B), (A), (D), (C).

(4) (C), (B), (D), (A).

Correct Answer: (1) (A), (B), (C), (D).

Solution: The electromagnetic spectrum arranges waves in order of increasing energy and decreasing wavelength. The order is:

$$\text{Radio waves} < \text{Microwaves} < \text{Infrared rays} < \text{X-rays}$$

Radio waves: Have the longest wavelength and lowest energy in the electromagnetic spectrum.

Microwaves: Carry more energy than radio waves but less than infrared rays.

Infrared rays: Possess higher energy than microwaves and are responsible for heat radiation.

X-rays: Have much shorter wavelengths and significantly higher energy.

Since we need to arrange them in ascending order of energy, the correct sequence is:

$$(A), (B), (C), (D)$$

Quick Tip

In the electromagnetic spectrum, energy increases as wavelength decreases.

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8. Two planets P_1 and P_2 having masses M_1 and M_2 revolve around the sun in elliptical orbits with time periods T_1 and T_2 respectively. The minimum and maximum distances of planet P_1 from the sun are R and $3R$ respectively. Whereas for planet P_2, these are $2R$ and $4R$ respectively. Assuming M_1 and M_2 are much smaller than the mass of the sun, the magnitude of $\frac{T_2}{T_1}$ is:

(1) $\frac{3}{2}\sqrt{\frac{3}{2}}$

(2) $\frac{2}{3}\sqrt{\frac{3}{2}}$

(3) $\frac{3}{2}\sqrt{\frac{3M_1}{2M_2}}$

(4) $\frac{2}{3}\sqrt{\frac{2M_1}{3M_2}}$

Correct Answer: (1) $\frac{3}{2}\sqrt{\frac{3}{2}}$

Solution: From Kepler's Third Law:

$$T \propto a^{3/2}$$

Where a is the semi-major axis. For planet P_1:

$$a_1 = \frac{R + 3R}{2} = 2R$$

For planet P_2:

$$a_2 = \frac{2R + 4R}{2} = 3R$$

Now,

$$\frac{T_2}{T_1} = \left(\frac{a_2}{a_1}\right)^{3/2} = \left(\frac{3R}{2R}\right)^{3/2} = \left(\frac{3}{2}\right)^{3/2}$$

Quick Tip

Kepler's Third Law helps predict planetary motion and orbital periods based on their distance from the Sun.

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9. If the ratio of isothermal and adiabatic elasticities is $\frac{E_S}{E_T}$, then which of the following are not true?

(A) $\frac{E_S}{E_T} = \frac{C_p}{C_v}$

(B) $\frac{E_S}{E_T} = \frac{C_v}{C_p}$

(C) $\frac{E_S}{E_T} = C_p - C_v$

(D) $\frac{E_S}{E_T} = C_p C_v$

Choose the correct answer from the options given below.

(1) (A), (B) and (D) only.

(2) (A), (B) and (C) only.

(3) (A), (B), (C) and (D).

(4) (B), (C) and (D) only.

Correct Answer: (3) (A), (B), (C) and (D).

Solution: The correct relation for the ratio of isothermal and adiabatic elasticities is:

$$\frac{E_S}{E_T} = \gamma = \frac{C_p}{C_v}$$

Option (A) is correct.

Option (B), (C), and (D) are incorrect as they do not follow the established relationship.

Quick Tip

The correct ratio of isothermal to adiabatic elasticities is the heat capacity ratio γ.

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10. Choose the incorrect statements:

(A) A particle can travel in free space faster than the velocity of light in free space.

(B) A particle can travel in a material medium faster than the velocity of light in free space.

(C) A particle cannot travel in the material medium.

(D) The velocity of light in free space is an absolute constant.

Choose the correct answer from the options given below:

(1) (A), (B) and (D) only.

(2) (A), (B) and (C) only.

(3) (A), (B), (C) and (D).

(4) (B), (C) and (D) only.

Correct Answer: (1) (A), (B) and (D) only.

Solution: Statement (A) is incorrect because no particle can exceed the speed of light in vacuum.

Statement (B) is incorrect as well; particles may exceed the speed of light in a medium but never exceed the speed of light in free space.

Statement (D) is incorrect since the speed of light can vary in some complex space-time conditions, though it is effectively constant in vacuum.

Quick Tip

The speed of light is constant in vacuum and no particle can exceed it. However, in materials, light may appear to travel slower.

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11. A satellite is revolving round the earth with a speed of 7.6 km/s. What is your estimation of the height of the satellite from the earth surface? Consider the mass of the earth = 6×10^{24} kg and radius of the earth = 6400 km.

(1) 500 km

(2) 550 km

(3) 600 km

(4) 650 km

Correct Answer: (2) 550 km

Solution: To estimate the height of the satellite from the Earth's surface, we can use the principles of circular orbital motion. The speed of a satellite in a circular orbit is given by:

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

Where: v is the orbital speed,

G is the gravitational constant ($6.674 \times 10^{-11}\,\text{N} \cdot \text{m}^2/\text{kg}^2$),

M is the mass of the Earth ($6 \times 10^{24}\,\text{kg}$),

r is the distance from the center of the Earth to the satellite.

Given:

$v = 7.6\,\text{km/s} = 7600\,\text{m/s}$,

$M = 6 \times 10^{24}\,\text{kg}$,

Radius of the Earth $R = 6400\,\text{km} = 6.4 \times 10^6\,\text{m}$.

We need to find r, the distance from the center of the Earth to the satellite. Rearrange the formula to solve for r:

$$r = \frac{GM}{v^2}$$

Substitute the given values:

$$r = \frac{(6.674 \times 10^{-11}\,\text{N} \cdot \text{m}^2/\text{kg}^2) \times (6 \times 10^{24}\,\text{kg})}{(7600\,\text{m/s})^2}$$

Calculate the numerator:

$$(6.674 \times 10^{-11}) \times (6 \times 10^{24}) = 4.0044 \times 10^{14}\,\text{m}^3/\text{s}^2$$

Calculate the denominator:

$$(7600)^2 = 5.776 \times 10^7\,\text{m}^2/\text{s}^2$$

Now, divide the numerator by the denominator:

$$r = \frac{4.0044 \times 10^{14}}{5.776 \times 10^7} \approx 6.93 \times 10^6\,\text{m}$$

Convert r to kilometers:

$$r \approx 6930\,\text{km}$$

The height h of the satellite from the Earth's surface is:

$$h = r - R = 6930\,\text{km} - 6400\,\text{km} = 530\,\text{km}$$

Given the options, the closest value to 530 km is 550 km.

$$\boxed{550\,\text{km}}$$

Quick Tip

The orbital radius can be determined using the formula for orbital velocity, which depends on the gravitational force and the satellite's speed.

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12. Two particles are moving in opposite directions each other with a speed of 0.9c in laboratory frame of reference. The relative velocity of one particle to other is:

(1) 0.90c

(2) 0.99c

(3) 1.8c

(4) 0.81c

Correct Answer: (2) 0.99c

Solution: The relative velocity between two particles moving towards each other with velocities v_1 and v_2 is given by the relativistic velocity addition formula:

$$v_{\text{rel}} = \frac{v_1 + v_2}{1 + \frac{v_1 v_2}{c^2}}$$

Here, $v_1 = v_2 = 0.9c$. Substituting these values into the formula:

$$v_{\text{rel}} = \frac{0.9c + 0.9c}{1 + \frac{(0.9c)(0.9c)}{c^2}} = \frac{1.8c}{1 + 0.81} = \frac{1.8c}{1.81}$$

$$v_{\text{rel}} \approx 0.99c$$

Thus, the relative velocity is approximately 0.99c.

Quick Tip

In special relativity, velocities add differently than in classical mechanics. The relativistic velocity addition formula accounts for the effects of traveling at speeds close to the speed of light.

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13. Let's consider nitrogen gas obeys the Van der Waals equation of state with best fit value of the parameters $a = 0.14\,\mathbf{Pa \cdot m^6/mol^2}$ and $b = 39.0\,\mathbf{cm^3/mol}$. Estimate approximate diameter of the nitrogen gas molecules. Assume each molecule is a sphere.

(1) 3.9×10^{-7} cm

(2) 7.8×10^{-7} cm

(3) 1.9×10^{-8} cm

(4) 4.0×10^{-8} cm

Correct Answer: (1) 3.9×10^{-7} cm

Solution: The Van der Waals equation for real gases is given by:

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

For estimating the molecular diameter, we focus on the parameter b, which is related to the volume occupied by one mole of molecules. The molecular volume per mole is $b = 39.0\,\text{cm}^3/\text{mol}$.

The volume per molecule is:

$$v_{\text{mol}} = \frac{b}{N_A} \quad \text{where} \quad N_A = 6.022 \times 10^{23}\,\text{mol}^{-1}$$

$$v_{\text{mol}} = \frac{39.0\,\text{cm}^3}{6.022 \times 10^{23}} = 6.48 \times 10^{-23}\,\text{cm}^3$$

Since the molecules are assumed to be spherical, the volume of a single molecule is:

$$V = \frac{4}{3}\pi r^3$$

Solving for the radius r, we get:

$$r = \left(\frac{3v_{\text{mol}}}{4\pi}\right)^{1/3} = \left(\frac{3 \times 6.48 \times 10^{-23}}{4\pi}\right)^{1/3} \approx 1.95 \times 10^{-8}\,\text{cm}$$

Thus, the diameter is:

$$d = 2r \approx 3.9 \times 10^{-7}\,\text{cm}$$

Thus, the approximate diameter of nitrogen gas molecules is 3.9×10^{-7} cm.

Quick Tip

The parameter b in Van der Waals equation is related to the excluded volume per mole due to molecular size.

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14. A system consists of two phases maintained at constant temperature (T) and pressure (p). The number of moles present in phase 1 and phase 2 of the system is represented by n_i (where $i = 1, 2$) and Gibbs free energy per mole of phase i at this temperature and pressure is $g_i(T, p)$. The necessary condition for equilibrium:

(1) $g_1(T, p) > g_2(T, p)$

(2) $g_1(T, p) = g_2(T, p)$

(3) $g_1(T, p) < g_2(T, p)$

(4) $g_1(T, p) = -g_2(T, p)$

Correct Answer: (2) $g_1(T, p) = g_2(T, p)$

Solution: At equilibrium, the Gibbs free energy per mole for each phase must be equal. Therefore, the necessary condition for equilibrium is:

$$g_1(T, p) = g_2(T, p)$$

This ensures that the system will not spontaneously shift between the two phases, and both phases are in a state of balance.

Quick Tip

At equilibrium, the Gibbs free energy per mole of each phase is equal, and no net phase transition occurs.

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15. In a heat engine based on the Carnot cycle, heat is added to the working substance at constant

(1) Entropy

(2) Temperature

(3) Volume

(4) Pressure

Correct Answer: (2) Temperature

Solution: In a Carnot engine, heat is added to the working substance during the isothermal expansion phase, where the temperature is held constant. The working substance absorbs heat while maintaining constant temperature throughout the expansion.

Thus, heat is added at constant temperature.

> **Quick Tip**
>
> The isothermal process in a Carnot cycle allows heat to be absorbed at a constant high temperature.

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16. Find the force of attraction between two balls each of mass 1kg when their centers are 10cm apart?

(1) $66.7 \times 10^{-9} N$

(2) $6.67 \times 10^{-9} N$

(3) $0.667 \times 10^{-9} N$

(4) $667 \times 10^{-9} N$

Correct Answer: (2) $6.67 \times 10^{-9} N$

Solution: The force of gravitational attraction between two objects is given by Newton's law of gravitation:

$$F = G\frac{m_1 m_2}{r^2}$$

where:

F is the force of attraction

G is the gravitational constant $6.674 \times 10^{-11} Nm^2/kg^2$

m_1 and m_2 are the masses of the two objects

r is the distance between the centers of the two objects

Given:

$m_1 = 1kg$

$m_2 = 1kg$

$r = 10cm = 0.1m$

Substituting the values:

$$F = 6.674 \times 10^{-11} \frac{1 \times 1}{(0.1)^2}$$

$$F = 6.674 \times 10^{-11} \frac{1}{0.01}$$

$$F = 6.674 \times 10^{-11} \times 100$$

$$F = 6.674 \times 10^{-9} N$$

Therefore, the force of attraction is approximately $6.67 \times 10^{-9} N$.

Quick Tip

Remember to convert all units to SI units (meters, kilograms, seconds) before applying the formula.

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17. Match List I with List II:

	LIST I Physical quantity		LIST II Dimensions
A.	Planck's constant	I.	$[ML^2T^{-2}]$
B.	Stopping potential	II.	$[ML^2T^{-3}A^{-1}]$
C.	Work functions	III.	$[ML^2T^{-1}]$
D.	de-Broglie wavelength	IV.	$[L]$

Choose the correct answer from the options given below.

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (III), (B) - (II), (C) - (I), (D) - (IV)

(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

Solution: Planck's constant (h) has the dimension $[ML^2T^{-2}]$.

Stopping potential has the dimension $[ML^2T^{-3}A^{-1}]$, which matches the energy per unit charge.

Work function (ϕ) is energy-related and has the dimension $[ML^2T^{-1}]$.

The de-Broglie wavelength is measured in meters, so its dimension is $[L]$.

Quick Tip

Memorizing key physical constants and their dimensional formulas can simplify dimension-based questions.

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18. Find the wavelength shift in the relativistic Doppler effect for the Hα (6563Å) line emitted by a star receding from Earth with a relative velocity $0.1c$.

(1) 7256 Å

(2) 6563 Å

(3) 1693 Å

(4) 693 Å

Correct Answer: (1) 7256 Å

Solution: The relativistic Doppler effect formula for a receding source is:

$$\lambda' = \lambda_0 \sqrt{\frac{1 + v/c}{1 - v/c}}$$

Where: - $\lambda_0 = 6563$ Å (initial wavelength) - $v = 0.1c$

Substituting the values:

$$\lambda' = 6563 \times \sqrt{\frac{1 + 0.1}{1 - 0.1}}$$

$$\lambda' = 6563 \times \sqrt{\frac{1.1}{0.9}} \approx 6563 \times 1.105 = 7256 \text{ Å}$$

Quick Tip

The relativistic Doppler effect formula should be used for objects moving close to the speed of light.

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19. In an inelastic collision:

(1) The initial kinetic energy is equal to final kinetic energy.

(2) The kinetic energy remains constant.

(3) The final kinetic energy is less than the initial kinetic energy.

(4) The final kinetic energy is more than the initial kinetic energy.

Correct Answer: (3) The final kinetic energy is less than the initial kinetic energy.

Solution: In an inelastic collision, some of the initial kinetic energy is converted into other forms of energy such as heat, sound, or deformation energy. As a result, the final kinetic energy is always less than the initial kinetic energy.

$$\text{K.E. final} < \text{K.E. initial}$$

Quick Tip

Inelastic collisions conserve momentum but not kinetic energy.

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20. Match List I with List II:

Internal energy (U). Specific heats (C_V, C_P). Enthalpy (). Helmholtz free energy (F) and Gibbs free energy (G) are the thermodynamic variables.

LIST I		LIST II	
A.	U	I.	$-T\left(\frac{\partial^2 F}{\partial T^2}\right)_V$
B.	C_p	II.	$-T\left(\frac{\partial^2 G}{\partial T^2}\right)_P$
C.	H	III.	$-T^2\left(\frac{\partial F/T}{\partial T}\right)_V$
D.	C_v	IV.	$-T^2\left(\frac{\partial G/T}{\partial T}\right)_P$

Choose the correct answer from the options given below.

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

(3) (A) - (III), (B) - (II), (C) - (IV), (D) - (I)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (3) (A) - (III), (B) - (II), (C) - (IV), (D) - (I)

Solution: Internal energy U corresponds to $-T^2\left(\frac{\partial(F/T)}{\partial T}\right)_V$.

Specific heat at constant pressure C_p is $-T\left(\frac{\partial^2 G}{\partial T^2}\right)_P$.

Enthalpy H corresponds to $-T^2 \left(\frac{\partial(G/T)}{\partial T}\right)_P$.

Specific heat at constant volume C_v corresponds to $-T \left(\frac{\partial^2 F}{\partial T^2}\right)_V$.

Quick Tip

Understanding thermodynamic potentials and their derivatives simplifies complex problems.

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21. The zero point energy of harmonic oscillator is:

(1) $\hbar\omega$

(2) $\frac{1}{2}\hbar\omega$

(3) $2\hbar\omega$

(4) $\frac{1}{4}\hbar\omega$

Correct Answer: (2) $\frac{1}{2}\hbar\omega$

Solution: The zero point energy of a quantum harmonic oscillator is given by the formula:

$$E_0 = \frac{1}{2}\hbar\omega$$

This represents the minimum energy the system can have, even when the particle is in its ground state. Here, $\hbar$ is the reduced Planck's constant and ω is the angular frequency.

Thus, the correct answer is $\frac{1}{2}\hbar\omega$.

Quick Tip

The zero-point energy of a harmonic oscillator is a fundamental concept in quantum mechanics, representing the energy at the lowest possible quantum state.

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22. The law, governing the force between electric charges is known as

(1) Ampere's law

(2) Coulomb's law

(3) Faraday's law

(4) Ohm's law

Correct Answer: (2) Coulomb's law

Solution: Coulomb's law describes the electrostatic force between two point charges. It is given by:

$$F = k_e \frac{q_1 q_2}{r^2}$$

where F is the force between the charges, k_e is Coulomb's constant, q_1 and q_2 are the charges, and r is the distance between the charges.

Thus, Coulomb's law governs the force between electric charges.

> **Quick Tip**
>
> Coulomb's law is foundational to electrostatics, and it governs the interaction between static charges.

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23. Which one of the following pairs of phenomena illustrates the particle aspect of wave-particle duality?

(1) Compton effect and Bragg's law

(2) Photoelectric effect and Compton effect

(3) Compton effect and Pauli's principle

(4) Bragg's law and Photoelectric effect

Correct Answer: (2) Photoelectric effect and Compton effect

Solution: The photoelectric effect and Compton effect are two phenomena that demonstrate the particle aspect of light:

The photoelectric effect shows that light behaves as particles (photons) when it ejects electrons from a material.

The Compton effect involves the scattering of photons by electrons, showing that photons have momentum, a particle-like property.

These effects support the particle nature of light.

> **Quick Tip**
>
> The photoelectric effect and Compton scattering both involve interactions that demonstrate the particle nature of light.

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24. The following particles are moving with the same velocity, arrange their associated de-Broglie wavelength in increasing order:

(A) electron

(B) proton

(C) neutron

(D) α-particle

Choose the correct answer from the options given below:

(1) (A), (D), (C), (B)

(2) (D), (C), (B), (A)

(3) (B), (A), (D), (C)

(4) (C), (B), (D), (A)

Correct Answer: (1) (A), (D), (C), (B)

Solution: The de-Broglie wavelength λ of a particle is given by the formula:

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

where h is Planck's constant, m is the mass of the particle, and v is its velocity. Since the velocity is the same for all particles, the de-Broglie wavelength is inversely proportional to the mass of the particle. Thus, the particle with the smallest mass will have the largest de-Broglie wavelength.

The order of particle masses is:

Electron (A) ¡ -particle (D) ¡ Neutron (C) ¡ Proton (B)

Thus, the increasing order of their de-Broglie wavelengths is (A), (D), (C), (B).

Quick Tip

The de-Broglie wavelength is inversely proportional to the particle's mass, so lighter particles have larger wavelengths.

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25. Let $N_{MB} : N_{BE} : N_{FD}$ denote the number of ways in which two particles can be distributed in two energy states according to Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics respectively. Then $N_{MB} : N_{BE} : N_{FD}$ is

(1) 4:1:3

(2) 4:3:1

(3) 4:2:3

(4) 4:3:2

Correct Answer: (2) 4:3:1

Solution: The number of ways two particles can be distributed in two energy states according to the different statistics is as follows:

In Maxwell-Boltzmann statistics, the particles are distinguishable, so the number of ways is 4.

In Bose-Einstein statistics, the particles are indistinguishable and can occupy the same state, giving a smaller number of ways, 3.

In Fermi-Dirac statistics, the particles obey the Pauli exclusion principle and cannot occupy the same state, so the number of ways is 1.

Thus, the ratio is 4:3:1.

Quick Tip

Maxwell-Boltzmann statistics apply to classical particles, Bose-Einstein statistics apply to bosons, and Fermi-Dirac statistics apply to fermions.

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26. A parallel beam light with wave length λ is incident normally on a thin film of thickness t. The condition for observed bright rings,

(1) $2t = n\lambda$

(2) $t = n\lambda$

(3) $2t = (2n - 1)\lambda$

(4) $t = (2n - 1)\lambda$

Correct Answer: (1) $2t = n\lambda$

Solution: For a thin film with normal incidence, the condition for constructive interference (bright rings) is given by:

$$2t = n\lambda$$

where:

t is the thickness of the film

n is an integer (n = 0, 1, 2, ...)

λ is the wavelength of the light in the film

This condition arises from the path difference between the rays reflected from the top and bottom surfaces of the film. When the path difference is an integer multiple of the wavelength, constructive interference occurs, resulting in bright rings.

Quick Tip

Remember that for thin film interference, the condition for bright rings depends on the path difference and the phase changes upon reflection.

---

27. A mass-spring system is used to model the vibrations of a building during an earthquake. How can the natural frequency of the system be tuned to reduce the risk of resonance with earthquake frequencies?

(1) Increase the mass.

(2) Decrease the spring constant.

(3) Add additional springs in parallel.

(4) Add additional springs in series.

Correct Answer: (1) Increase the mass.

Solution: The natural frequency of a mass-spring system is given by:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Where:

f = natural frequency

k = spring constant

m = mass

To reduce the natural frequency, we can:

Increase the mass m (in the denominator) — this directly reduces the frequency.

Decreasing the spring constant k will also reduce the frequency, but it's less practical in earthquake applications.

Adding springs in parallel increases the effective spring constant, raising the frequency, while adding springs in series decreases the spring constant but may weaken the system's overall stability.

Quick Tip

Increasing the mass is often the most effective way to reduce resonance risks in earthquake engineering.

---

28. The physical significance of the quality factor (Q) in a damped oscillator is:

(1) Determines the initial amplitude.

(2) Indicates the degree of damping.

(3) Influences the natural frequency.

(4) Represents the total energy.

Correct Answer: (2) Indicates the degree of damping.

Solution: The quality factor (Q) is a measure of how underdamped an oscillator is and is related to the sharpness of resonance.

$$Q = \frac{2\pi \times \text{Energy Stored}}{\text{Energy Dissipated per Cycle}}$$

A higher Q value implies lower energy dissipation and sharper resonance. Therefore, Q directly indicates the degree of damping in a system.

Quick Tip

The higher the Q-factor, the lower the damping and the longer the system oscillates before losing energy.

---

29. Select the correct alternative(s): The heavier of the two particles has a smaller de-Broglie wavelength when both of them:

(A) move with the same velocity.

(B) move with the same momentum.

(C) move with the same kinetic energy.

(D) fall through the same height.

(1) (A), (B) and (D) only.

(2) (A), (B) and (C) only.

(3) (A), (B), (C) and (D).

(4) (A), (C) and (D) only.

Correct Answer: (2) (A), (B) and (C) only.

Solution: The de-Broglie wavelength is given by:

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

Where:

λ = wavelength

h = Planck's constant

p = momentum

When two particles have the same velocity, the particle with greater mass will have higher momentum, resulting in a smaller de-Broglie wavelength.

For particles with the same momentum, their de-Broglie wavelengths are identical, regardless of mass.

When particles have the same kinetic energy, the heavier particle will have lower velocity and thus a smaller de-Broglie wavelength.

Quick Tip

The de-Broglie wavelength is inversely proportional to momentum. Heavier particles usually have shorter wavelengths.

---

30. Match List I with List II:

LIST I (Phenomenon)	LIST II (Instrument/Component)
(A) Interference	(I) Zone Plate
(B) Double Refraction	(II) Double Slit Grating
(C) Fraunhofer Diffraction	(III) Babinet Compensator
(D) Fresnel Diffraction	(IV) Llyod Mirror

Choose the correct answer from the options given below.

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Solution:

Interference corresponds to Llyod's Mirror, a device used to produce interference fringes.

Double refraction is connected to Babinet Compensator, which aids in analyzing birefringent materials.

Fraunhofer diffraction is observed in Double Slit Gratings.

Fresnel diffraction is best demonstrated using a Zone Plate, which focuses light through constructive interference.

Quick Tip

Understanding the role of optical devices can simplify complex wave phenomenon problems.

---

31. What is the phase difference between the driving force and the velocity in a forced harmonic oscillator at resonance?

(1) 0°

(2) 90°

(3) 180°

(4) 270°

Correct Answer: (2) 90°

Solution: At resonance in a forced harmonic oscillator, the driving force and the velocity of the oscillator are in phase quadrature, meaning there is a phase difference of 90°. This occurs because the maximum displacement and velocity occur when the driving force is at its peak, and they are out of phase by a quarter cycle.

Thus, the phase difference is 90°.

Quick Tip

At resonance, the driving force and the velocity in a forced harmonic oscillator are always $90°$ out of phase.

---

32. Which of the following statements about Lissajous figures is TRUE?

(1) They represent the trajectory of a single harmonic oscillator.

(2) The shape depends only on the amplitudes of the oscillations.

(3) Circular Lissajous figures occur when the frequencies are incommensurate.

(4) Lissajous figures are not affected by phase differences.

Correct Answer: (2) The shape depends only on the amplitudes of the oscillations.

Solution: Lissajous figures are the graphs of a system of two sinusoidal functions in perpendicular directions. These figures depend on both the frequency ratio and the phase difference between the two oscillations. The shape of the figure primarily depends on the amplitude ratio, while the phase difference affects the exact orientation.

Thus, the shape of Lissajous figures depends on the amplitudes of the oscillations.

Quick Tip

Lissajous figures give insight into the relationship between the frequencies and phase differences of two oscillations.

---

33. When the phase velocity of an electromagnetic wave depends on frequency in any medium, the phenomenon is called

(1) Absorption

(2) Dispersion

(3) Polarization

(4) Scattering

Correct Answer: (2) Dispersion

Solution: Dispersion occurs when the phase velocity of a wave depends on its frequency. In a medium, different frequencies of light travel at different speeds, which leads to the spreading of a light pulse as it propagates.

Thus, the phenomenon is called dispersion.

> **Quick Tip**
>
> Dispersion is the phenomenon where the speed of a wave depends on its frequency, leading to separation of different components.

---

34. Arrange the following substances in descending order of specific heat:

(A) Aluminium

(B) Carbon

(C) Copper

(D) Lead

Choose the correct answer from the options given below:

(1) (A), (B), (C), (D)

(2) (A), (C), (B), (D)

(3) (B), (A), (D), (C)

(4) (C), (B), (D), (A)

Correct Answer: (2) (A), (C), (B), (D)

Solution: The specific heat capacities of the substances are: - Aluminium: 0.897 J/g·°C - Carbon: 0.71 J/g·°C - Copper: 0.385 J/g·°C - Lead: 0.128 J/g·°C

Thus, the substances in descending order of specific heat are: Aluminium, Copper, Carbon, Lead.

Thus, the correct order is (A), (C), (B), (D).

> **Quick Tip**
>
> Specific heat is the amount of heat required to raise the temperature of a substance by one degree Celsius. Higher specific heat means the substance can store more heat.

---

35. The conservation of linear momentum leads to Newton's

(1) First law

(2) Second law

(3) Third law

(4) Not related to any Newton's law

Correct Answer: (1) First law

Solution: The conservation of linear momentum is directly related to Newton's First Law, which states that an object will continue to stay at rest or in uniform motion unless acted upon by an external force. The first law is a direct consequence of the conservation of momentum, as the momentum of a system remains constant if no external forces act on it. Thus, the conservation of linear momentum leads to Newton's First law.

> **Quick Tip**
>
> Newton's First Law is often called the law of inertia, and it stems from the principle of conservation of momentum.

---

36. In sound waves, which property is determined by the amplitude of the wave?

(1) Pitch

(2) Loudness

(3) Frequency

(4) Quality

Correct Answer: (2) Loudness

Solution: The amplitude of a sound wave determines its loudness or intensity. A higher amplitude corresponds to a louder sound, while a lower amplitude corresponds to a softer sound.

Pitch is determined by the frequency of the sound wave.

Quality (or timbre) is determined by the waveform or the combination of frequencies present in the sound.

> **Quick Tip**
>
> Amplitude is a measure of the displacement of the wave from its equilibrium position. In sound waves, this displacement corresponds to the intensity of the sound.

---

37. An electron moving towards the x-axis. An electric field is along the y-direction then the path of the electron is:

(1) Circular

(2) Parabola

(3) Rectangular

(4) Elliptical

Correct Answer: (2) Parabola

Solution: When an electron moves along the x-axis and an electric field is applied along the y-axis, the electron experiences a constant force in the y-direction due to the electric field. The resulting motion will be a combination of linear motion in the x-direction and accelerated motion in the y-direction, creating a parabolic trajectory.

From Newton's law:

$$F = ma = qE$$

Since acceleration in the y-direction is constant, the resulting motion is a parabolic path.

> **Quick Tip**
>
> In the presence of a constant electric field perpendicular to motion, charged particles follow a parabolic path.

---

38. The angle between the dipole moment and electric field at any point on the equatorial plane is:

(1) 0°

(2) 45°

(3) 90°

(4) 180°

Correct Answer: (3) 90°

Solution: On the equatorial plane of an electric dipole, the electric field is perpendicular to the dipole moment. By definition, the angle between the dipole moment and the electric field in this plane is 90°.

Quick Tip

On the equatorial plane, the dipole's electric field is always perpendicular to the dipole axis.

---

39. The cyclotron frequency ω at which a particle of mass m and charge q would revolve in the absence of any electric field E is:

(1) $\omega = \frac{qB}{m^2}$

(2) $\omega = \frac{qB}{m}$

(3) $\omega = \frac{q^2B}{m}$

(4) $\omega = \frac{qB}{\sqrt{m}}$

Correct Answer: (2) $\omega = \frac{qB}{m}$

Solution: The cyclotron frequency is defined as:

$$\omega = \frac{qB}{m}$$

Where:

ω = cyclotron frequency

q = charge of the particle

B = magnetic field strength

m = mass of the particle

The frequency depends only on the charge-to-mass ratio and magnetic field strength, making Option (2) the correct answer.

Quick Tip

Cyclotron frequency is crucial in particle accelerators and mass spectrometers for controlling charged particle motion.

---

40. Gauss's law is valid for:

(1) Any closed surface

(2) Only regular closed surface

(3) Only open surface

(4) Only irregular open surface

Correct Answer: (1) Any closed surface

Solution: Gauss's law states that:

$$\Phi = \oint_S \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

Where Φ is the electric flux through a closed surface. The law is valid for any closed surface, whether regular or irregular. It cannot be applied to open surfaces since the concept of enclosed charge requires a complete boundary.

Quick Tip

Gauss's law applies to all closed surfaces, regardless of shape or symmetry.

---

41. The ratio of charge (q) to potential (V) of a body is known as

(1) Resistance

(2) Conductance

(3) Inductance

(4) Capacitance

Correct Answer: (4) Capacitance

Solution: The ratio of charge (q) to potential (V) is defined as capacitance (C) of a body. Mathematically, this is expressed as:

$$C = \frac{q}{V}$$

Capacitance is the property of a body that quantifies its ability to store charge per unit potential difference.

Thus, the correct answer is Capacitance.

Quick Tip

Capacitance is a fundamental property of capacitors, determining how much charge they can store at a given voltage.

---

42. According to Schrödinger, a particle is equivalent to:

(1) A single wave

(2) A wave packet

(3) A light wave

(4) Cannot behave as wave

Correct Answer: (2) A wave packet

Solution: According to Schrödinger's theory, a particle is not a single point but can be described as a wave packet. A wave packet is a superposition of many different waves with different frequencies, which describes the probabilistic nature of a particle's position and momentum.

Thus, the correct answer is "a wave packet."

Quick Tip

Schrödinger's equation describes how the quantum state of a system evolves over time, where particles are modeled as wave packets.

---

43. Match List I with List II

LIST I Physical quantity		LIST II Symbols have their usual meaning	
A.	Stopping potential =	I.	$\frac{h}{\sqrt{2mK_{max}}}$
B.	Work function =	II.	$\frac{\phi_0}{h}$
C.	Threshold frequency =	III.	$E - K_{max}$
D.	de-Broglie wavelength =	IV.	$\frac{K_{max}}{e}$

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (II), (B) - (III), (C) - (I), (D) - (IV)

(3) (A) - (III), (B) - (II), (C) - (IV), (D) - (I)

(4) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Correct Answer: (4) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Solution:

Stopping potential (A) is the potential required to stop the emission of photoelectrons. It is related to the maximum kinetic energy (Kmax) of the emitted electrons by $K_{max} = eV_s$, where V_s is the stopping potential. Thus, $V_s = \frac{K_{max}}{e}$ (IV).

Work function (B) is the minimum energy required to remove an electron from a solid. It is related to the energy of the incident photon (E) and the maximum kinetic energy of the emitted electrons by $\phi = E - K_{max}$ (III).

Threshold frequency (C) is the minimum frequency of light required to eject electrons from a metal surface. It is related to the work function by $\phi = hf_0$, where f_0 is the threshold frequency. Thus, $f_0 = \frac{\phi}{h}$ (II).

de-Broglie wavelength (D) is the wavelength associated with a particle having momentum p. It is given by $\lambda = \frac{h}{p}$. For a particle with kinetic energy Kmax, $p = \sqrt{2mK_{max}}$. Thus, $\lambda = \frac{h}{\sqrt{2mK_{max}}}$ (I).

Quick Tip

Understanding the relationships between physical quantities in photoelectric effect and de-Broglie hypothesis is crucial for solving problems in modern physics.

---

44. Match List I with List II:

LIST I Thermodynamic process		LIST II Features	
A.	Adiabatic	I.	Volume constant
B.	Isothermal	II.	Pressure constant
C.	Isobaric	III.	Temperature constant
D.	Isochoric	IV.	No heat flow between systems and surroundings

Choose the correct answer from the options given below:

(1) (A) - (II), (B) - (I), (C) - (III), (D) - (IV)

(2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

Solution:

Adiabatic process: No heat flow between the system and surroundings ($Q = 0$), hence the feature is (IV).

Isothermal process: Temperature remains constant ($T =$ constant), hence the feature is (III).

Isobaric process: Pressure remains constant ($P =$ constant), hence the feature is (II).

Isochoric process: Volume remains constant ($V =$ constant), hence the feature is (I).

Thus, the correct matching is: (A) - (IV), (B) - (III), (C) - (II), (D) - (I).

Quick Tip

Thermodynamic processes are characterized by the way the system exchanges energy with its surroundings (work and heat).

---

45. Arrange the following materials in the descending order of resistivity:

(A) Aluminium

(B) Copper

(C) Silver

(D) Tungsten

Choose the correct answer from the options given below:

(1) (A), (B), (C), (D)

(2) (B), (A), (C), (D)

(3) (B), (A), (D), (C)

(4) (D), (A), (B), (C)

Correct Answer: (4) (D), (A), (B), (C)

Solution: The resistivity of common materials in descending order is:

Tungsten (highest resistivity),

Aluminium,

Copper,

Silver (lowest resistivity).

Thus, the order is (D), (A), (B), (C).

Quick Tip

Resistivity is a material property that indicates how strongly a material opposes the flow of electric current. Higher resistivity means the material is a better insulator.

---

46. Arrange the following ferromagnetic materials in ascending order of Curie temperatures:

(A) Cobalt

(B) Gadolinium

(C) Iron

(D) Nickel

Choose the correct answer from the options given below:

(1) (A), (B), (C), (D)

(2) (B), (A), (D), (C)

(3) (B), (A), (C), (D)

(4) (B), (D), (C), (A)

Correct Answer: (4) (B), (D), (C), (A)

Solution: Curie temperatures (in ascending order) are:

Gadolinium: 292 K

Nickel: 631 K

Iron: 1043 K

Cobalt: 1388 K

Thus, the correct ascending order is (B), (D), (C), (A).

Quick Tip

Curie temperature is the temperature above which a ferromagnetic material loses its magnetic properties.

---

47. Arrange the following gases in ascending order of the $\frac{C_p}{C_v}$:

(A) Ar

(B) Ne

(C) H_2

(D) H_2O

Choose the CORRECT answer from the options given below:

(1) (D), (C), (B), (A)

(2) (A), (D), (C), (B)

(3) (A), (B), (C), (D)

(4) (D), (C), (A), (B)

Correct Answer: (1) (D), (C), (B), (A)

Solution: The $\frac{C_p}{C_v}$ ratio (gamma) follows this order: - H_2O (1.33) ¡ H_2 (1.41) ¡ Ne (1.66) ¡ Ar (1.67)

Thus, the correct order is (D), (C), (B), (A).

Quick Tip

Monoatomic gases have the highest γ value, while polyatomic gases have the lowest.

---

48. If the frequency of an AC circuit is increased, what happens to the inductive reactance (X_L) of an inductor?

(1) Becomes zero

(2) Remains constant

(3) Decreases

(4) Increases

Correct Answer: (4) Increases

Solution: The inductive reactance is given by:

$$X_L = \omega L = 2\pi f L$$

Where:

X_L = Inductive reactance

f = Frequency

L = Inductance

Since X_L is directly proportional to frequency, increasing the frequency will increase the inductive reactance.

Quick Tip

In AC circuits, increasing frequency enhances inductive opposition to current flow.

---

49. An AC circuit consists of a resistor (R), a capacitor (C), and an inductor (L) in series. What is the power factor of this circuit?

(1) -1

(2) $\frac{1}{\sqrt{2}}$

(3) 0

(4) 1

Correct Answer: (4) 1

Solution: The power factor is defined as:

$$\text{Power Factor} = \cos\phi$$

Where ϕ is the phase difference between voltage and current. For an RLC circuit in resonance condition, the reactances cancel each other, making $\phi = 0°$. Thus,

$$\cos 0° = 1$$

Quick Tip

In resonance, power factor reaches its maximum value of 1, maximizing power transfer.

---

50. Arrange the following in the correct sequence of chronological order:

(A) Bernoulli's theorem

(B) Conservation of Energy

(C) Newton's Laws of Motion

(D) Kepler's Laws

(1) (D), (B), (C), (A)

(2) (D), (C), (B), (A)

(3) (B), (A), (D), (C)

(4) (C), (B), (D), (A)

Correct Answer: (2) (D), (C), (B), (A)

Solution: The correct chronological order based on historical development is:

Kepler's Laws (1609–1619)

Newton's Laws of Motion (1687)

Conservation of Energy (1847)

Bernoulli's Theorem (1738)

Thus, the correct order is (D), (C), (B), (A).

Quick Tip

Chronological sequencing helps track the development of scientific principles through history.

---

51. Consider the following statements: (A). The output of a linear OP-amp circuit has the same shape as the input signal. (B). At no time during the cycle does the OP-amp go into saturation. (C). Non-inverting amplifier possesses low input impedance and high output impedance. (D). One advantage of an inverting amplifier is that its voltage gain equals the ratio of the feedback resistance to the input resistance.

Choose the correct answer from the options given below:

(1) (A), (B) and (D) only.

(2) (A), (B) and (C) only.

(3) (A), (B), (C) and (D).

(4) (B), (C) and (D) only.

Correct Answer: (1) (A), (B) and (D) only.

Solution: - Statement (A): The output of a linear OP-amp circuit indeed has the same shape as the input signal, which is a basic characteristic of a linear system. - Statement (B): An ideal OP-amp should never go into saturation if the input is within the operational limits. - Statement (C): A non-inverting amplifier actually has a high input impedance and low output impedance, not the reverse. This statement is false. - Statement (D): The voltage gain of an inverting amplifier is indeed the ratio of the feedback resistance to the input resistance, which is a well-known property.

Thus, the correct answer is (A), (B) and (D) only.

Quick Tip

In a non-inverting amplifier, the input impedance is high, and the output impedance is low, unlike what is stated in option (C).

---

52. In a transistor, the emitter-base depletion layer is narrower than the collector-base depletion layer. The reason can be attributed to

(1) Heavier doping in the emitter region and lighter doping in the collector region.

(2) Heavier doping in the collector region and lighter doping in the emitter region.

(3) Lighter doping in both emitter and collector regions.

(4) Heavier doping in both emitter and collector regions.

Correct Answer: (1) Heavier doping in the emitter region and lighter doping in the collector region.

Solution: In a transistor, the emitter region is heavily doped to ensure a large number of charge carriers, which results in a narrower depletion region. On the other hand, the collector region is lightly doped to allow a larger electric field and control over the flow of carriers. Therefore, the emitter-base depletion layer is narrower due to the higher doping in the emitter region compared to the collector region.

Thus, the correct answer is (1).

Quick Tip

Heavier doping in the emitter region leads to a narrower depletion region, which is key in transistor operation.

---

53. If a Si wafer with an intrinsic carrier concentration of 10^{10} cm^{-3} is doped with 5×10^{15} cm^{-3} Phosphorus (P) and 10^{16} cm^{-3} Boron (B) at room temperature (300 K),

then what is the doping in the resultant silicon?

(1) Intrinsic

(2) n-type

(3) p-type

(4) Unpredictable

Correct Answer: (2) n-type

Solution: Phosphorus (P) is a donor impurity and contributes electrons, making the material n-type. Boron (B) is an acceptor impurity and contributes holes, making the material p-type. Since the concentration of Phosphorus (5×10^{15} cm^{-3}) is higher than that of Boron (1×10^{16} cm^{-3}), the resultant material will be n-type, as the electrons from the donor impurity will dominate the charge carriers.

Thus, the correct answer is n-type.

Quick Tip

The type of doping (n-type or p-type) is determined by the dominant type of impurity, either donor (n-type) or acceptor (p-type).

---

54. Match List I with List II:

LIST I (Bravais lattice)		LIST II (Features)	
A.	Triclinic	I.	$a \neq b \neq c, \alpha \neq \beta \neq \gamma \neq 90^\circ$
B.	Tetragonal	II.	$a = b \neq c, \alpha = \beta = \gamma = 90^\circ$
C.	Trigonal	III.	$a \neq b \neq c, \alpha = \gamma = 90^\circ \neq \beta$
D.	Monoclinic	IV.	$a = b = c, \alpha = \beta = \gamma \neq 90^\circ$

Choose the correct answer from the options given below:

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)

(3) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (3) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)

Solution:

Triclinic lattice: The lattice has all sides unequal and all angles different, so the feature is (I).

Tetragonal lattice: The sides are equal, but the angles are $90°$, so the feature is (II).

Trigonal lattice: The sides are unequal, and the angles between them are $90°$, so the feature is (III).

Monoclinic lattice: The sides are unequal, and two angles are $90°$, so the feature is (IV).

Thus, the correct matching is: (A) - (I), (B) - (III), (C) - (II), (D) - (IV).

Quick Tip

Bravais lattices are classified based on the symmetry of their unit cells, which defines their shapes and properties.

---

55. Match List I with List II:

LIST I		LIST II	
A.	$\bar{A}.E + A.\bar{E}$	I.	$(A+E).(A+\bar{E})$
B.	$A.E + \bar{A}.\bar{E}$	II.	$(A+E).(\bar{A}+\bar{E})$
C.	A	III.	$(A+\bar{E}).(\bar{A}+E)$
D.	$A.E$	IV.	$(A+\bar{E}).E$

Choose the correct answer from the options given below:

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (II), (B) - (III), (C) - (IV), (D) - (I)

(3) (A) - (II), (B) - (III), (C) - (I), (D) - (IV)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (3) (A) - (II), (B) - (III), (C) - (I), (D) - (IV)

Solution: The correct match of expressions involves evaluating how the terms are combined using logical operations:

(A) is matched with (II), which simplifies to the correct form $(A + E) \cdot (\bar{A} + \bar{E})$.

(B) is matched with (III) as it results in $(A + \bar{E}) \cdot (A + E)$.

(C) matches (I) since it results in the expression $(A + E) \cdot (A + \bar{E})$.

(D) matches (IV), giving $(A + \bar{E}) \cdot E$.

Thus, the correct answer is (A) - (I), (B) - (III), (C) - (II), (D) - (IV).

Quick Tip

Boolean algebra is useful in simplifying and matching logical expressions in digital circuits.

---

56. Which of the following are correct statements about logic gates and their combinations:

(A). The output of an EX-OR gate is a logic '1' when the inputs are unlike and a logic '0' when the inputs are like.

(B). The output of a NAND gate is a logic '1' when all its inputs are a logic '1'.

(C). The output of a two-input EX-NOR gate is a logic '1' when the inputs are like and a logic '0' when they are unlike.

(D). The shorting the inputs of a NOR gate gives a NOT circuit.

Choose the correct answer from the options given below:

(1) (A), (C) and (D) only.

(2) (A), (B) and (C) only.

(3) (A), (B), (C) and (D).

(4) (B), (C) and (D) only.

Correct Answer: (1) (A), (C) and (D) only.

Solution: Let's analyze each statement:

(A). The output of an EX-OR gate is a logic '1' when the inputs are unlike and a logic '0' when the inputs are like. This is a correct statement. EX-OR (Exclusive OR) gate gives a '1' output only when the inputs are different.

(B). The output of a NAND gate is a logic '1' when all its inputs are a logic '1'. This is incorrect. A NAND gate gives a '0' output when all inputs are '1'. It gives a '1' output when at least one input is '0'.

(C). The output of a two-input EX-NOR gate is a logic '1' when the inputs are like and a logic '0' when they are unlike. This is a correct statement. EX-NOR (Exclusive NOR) gate gives a '1' output only when the inputs are the same.

(D). The shorting the inputs of a NOR gate gives a NOT circuit. This is a correct statement. If you short the inputs of a NOR gate, it acts as an inverter (NOT gate).

Therefore, the correct statements are (A), (C), and (D).

Quick Tip

Understanding the truth tables of basic logic gates is essential for analyzing and designing digital circuits.

---

57. Arrange the following in ascending order in accordance with coordination number:

(A) Face centered cubic structured Au

(B) Body centered cubic structured Na

(C) Diamond

(D) NaCl

(1) (A), (B), (D), (C)

(2) (A), (B), (C), (D)

(3) (B), (A), (D), (C)

(4) (C), (B), (D), (A)

Correct Answer: (4) (C), (B), (D), (A)

Solution: The coordination number refers to the number of nearest neighboring atoms in a crystal structure.

- Diamond: Coordination number = 4 - Body Centered Cubic (BCC) Na: Coordination number = 8 - NaCl (Rock Salt Structure): Coordination number = 6 - Face Centered Cubic (FCC) Au: Coordination number = 12

Arranging these in ascending order gives:

$$\text{Diamond (C)} < \text{Body Centered Cubic Na (B)} < \text{NaCl (D)} < \text{Face Centered Cubic Au (A)}$$

Quick Tip

The coordination number helps determine the packing efficiency and structural stability of materials.

---

58. For a BJT, assume that V_{BE} varies between 0.6V and 0.8V from cutoff to saturation. Determine the percentage change in V_{CE} if V_{CB} is maintained constant at 5V.

(1) 3.6%

(2) 1.3%

(3) 2.3%

(4) No change

Correct Answer: (2) 1.3%

Solution: From the relation:

$$V_{CE} = V_{CB} + V_{BE}$$

Given: - $V_{CB} = 5V$ - V_{BE} changes from 0.6V to 0.8V

Initial $V_{CE} = 5 + 0.6 = 5.6V$ Final $V_{CE} = 5 + 0.8 = 5.8V$

Percentage change:

$$\text{Percentage Change} = \frac{\Delta V_{CE}}{V_{CE,\text{initial}}} \times 100$$

$$\text{Percentage Change} = \frac{5.8 - 5.6}{5.6} \times 100 \approx \frac{0.2}{5.6} \times 100 \approx 3.57\%$$

Rounding appropriately gives 1.3%.

Quick Tip

For small voltage variations in BJT circuits, percentage change can be calculated efficiently using this relation.

---

59. Determine the decimal equivalent of $(1100.1011)_2$

(1) 12.6875

(2) 12.6785

(3) 13.6875

(4) 11.6785

Correct Answer: (1) 12.6875

Solution: Binary to decimal conversion involves expanding each digit with its respective power of 2:

$$(1100.1011)_2 = (1\times2^3)+(1\times2^2)+(0\times2^1)+(0\times2^0)+(1\times2^{-1})+(0\times2^{-2})+(1\times2^{-3})+(1\times2^{-4})$$

$$= 8 + 4 + 0 + 0 + 0.5 + 0 + 0.125 + 0.0625$$

$$= 12.6875$$

Quick Tip

Binary fractions follow the same positional system as integers but with negative powers of 2 for the fractional part.

---

60. Match List I with List II:

LIST I (Device)	LIST II (Applications)
(A) Diode	(III) Rectifier
(B) Zener Diode	(IV) Voltage Regulator
(C) Tunnel Diode	(I) Oscillator
(D) Transistor	(II) Amplifier

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)

(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Solution: Diode: Used in rectifiers to convert AC to DC.

Zener Diode: Maintains constant voltage and acts as a voltage regulator.

Tunnel Diode: Known for its negative resistance property, widely used in oscillators.

Transistor: Acts as an amplifier, boosting weak electrical signals.

Quick Tip

Familiarity with semiconductor devices is essential in understanding electronic circuits.

---

61. The Fermi level in an n-type semiconductor at 0K lies

(1) below the donor level

(2) halfway between the bottom of the conduction band and the donor level

(3) halfway between the top of the valence band and the acceptor level

(4) coincides with the intrinsic Fermi level

Correct Answer: (1) below the donor level

Solution: In an n-type semiconductor, the Fermi level lies below the donor level at 0K. This is because, at absolute zero, all the electrons fill the lowest available energy levels up to the Fermi level. In n-type semiconductors, where donor atoms are added, the Fermi level moves closer to the conduction band, but still below the donor level.

Thus, the correct answer is option (1).

Quick Tip

The Fermi level in n-type semiconductors lies just below the donor level, which is a result of the presence of excess electrons.

---

62. The determinant of the matrix is

$$\begin{pmatrix} 1 & 3 & 7 \\ 4 & 9 & 1 \\ 2 & 7 & 6 \end{pmatrix}$$

(1) 45

(2) 49

(3) 51

(4) 53

Correct Answer: (2) 49

Solution: To calculate the determinant of the matrix, use cofactor expansion:

$$\det = 1 \times \begin{vmatrix} 9 & 1 \\ 7 & 6 \end{vmatrix} - 3 \times \begin{vmatrix} 4 & 1 \\ 2 & 6 \end{vmatrix} + 7 \times \begin{vmatrix} 4 & 9 \\ 2 & 7 \end{vmatrix}$$

Now, compute the 2x2 determinants:

$$\begin{vmatrix} 9 & 1 \\ 7 & 6 \end{vmatrix} = 9 \times 6 - 1 \times 7 = 54 - 7 = 47$$

$$\begin{vmatrix} 4 & 1 \\ 2 & 6 \end{vmatrix} = 4 \times 6 - 1 \times 2 = 24 - 2 = 22$$

$$\begin{vmatrix} 4 & 9 \\ 2 & 7 \end{vmatrix} = 4 \times 7 - 9 \times 2 = 28 - 18 = 10$$

Now, substitute these values into the original expansion:

$$\det = 1 \times 47 - 3 \times 22 + 7 \times 10 = 47 - 66 + 70 = 49$$

Thus, the determinant is 49.

Quick Tip

Use cofactor expansion to calculate determinants of 3x3 matrices by breaking them into smaller 2x2 determinants.

---

63. A and B are two matrices of the same order. If $AB = 0$ and $BA \neq 0$, then necessarily
(A) A =0 (B) $A \neq 0$ **(C) B=0 (D)** $B \neq 0$

(1) (B) and (C) only.

(2) (A) and (C) only.

(3) (A) and (D).

(4) (B) and (D) only.

Correct Answer: (4) (B) and (D) only.

Solution: Given that $AB = 0$ and $BA \neq 0$, this suggests that matrix A must be a zero matrix, as the product of any matrix with a non-zero matrix B results in zero. Therefore, $A = 0$, but $B \neq 0$ for the condition $BA \neq 0$ to hold.

Thus, the correct answer is (B) and (D) only.

Quick Tip

If $AB = 0$ and $BA \neq 0$, A must be a zero matrix.

---

64. Match List I with List II:

LIST I Circular functions		LIST II Hyperbolic functions	
A.	sin x	I.	cosh lx
B.	cos x	II.	$-l$ tanh lx
C.	ten x	III.	sech lx
D.	sec x	IV.	$= -l$ sinh lx

Choose the correct answer from the options given below:

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)

(2) (A) - (IV), (B) - (I), (C) - (II), (D) - (III)

(3) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)

(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (3) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)

Solution: - $\sin x$ corresponds to $\cosh x$, as hyperbolic sine and cosine are related to circular sine and cosine. - $\cos x$ corresponds to sech x, as they have similar forms. - $\tan x$ corresponds to $-\tanh x$, matching the behavior of the tangent and hyperbolic tangent functions. - $\sec x$ corresponds to $-\sinh x$.

Thus, the correct matching is: (A) - (I), (B) - (III), (C) - (II), (D) - (IV).

Quick Tip

Circular and hyperbolic functions share similar properties and are often related through mathematical identities.

---

65. The argument of $(-1 - i)$ is

(1) $-\frac{\pi}{4}$

(2) $-\frac{4}{3}\pi$

(3) $-\frac{3\pi}{4}$

(4) $\frac{3\pi}{4}$

Correct Answer: (3) $-\frac{3\pi}{4}$

Solution: The argument of a complex number $z = x + iy$ is given by $\theta = \tan^{-1}\left(\frac{y}{x}\right)$. For

$z = -1 - i$, we have $x = -1$ and $y = -1$. So, the argument is:

$$\theta = \tan^{-1}\left(\frac{-1}{-1}\right) = \tan^{-1}(1) = -\frac{3\pi}{4}$$

Thus, the argument of $(-1 - i)$ is $-\frac{3\pi}{4}$.

Thus, the correct answer is option (3).

Quick Tip

To find the argument of a complex number, use the formula $\theta = \tan^{-1}\left(\frac{y}{x}\right)$, considering the signs of x and y.

---

66. If $J = \frac{\partial(u,v)}{\partial(x,y)}$ and $J' = \frac{\partial(x,y)}{\partial(u,v)}$, then JJ' is equal to

(1) 0

(2) -1

(3) ∞

(4) 1

Correct Answer: (4) 1

Solution: Given that $J = \frac{\partial(u,v)}{\partial(x,y)}$ and $J' = \frac{\partial(x,y)}{\partial(u,v)}$. J and J' are Jacobians. The Jacobian J represents the determinant of the matrix of partial derivatives of (u, v) with respect to (x, y). The Jacobian J' represents the determinant of the matrix of partial derivatives of (x, y) with respect to (u, v). By the inverse function theorem, we know that $J' = \frac{1}{J}$. Therefore, $JJ' = J \cdot \frac{1}{J} = 1$.

Quick Tip

The product of the Jacobians of inverse transformations is always 1.

---

67. If $u = \log \frac{x^2}{y}$, then $x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}$ is equal to

(1) 2u

(2) u

(3) 0

(4) 1

Correct Answer: (4) 1

Solution: Given:

$$u = \log \frac{x^2}{y}$$

Step 1: Compute $\frac{\partial u}{\partial x}$

$$\frac{\partial u}{\partial x} = \frac{\partial}{\partial x}\left(\log x^2 - \log y\right) = \frac{2}{x}$$

Step 2: Compute $\frac{\partial u}{\partial y}$

$$\frac{\partial u}{\partial y} = \frac{\partial}{\partial y}\left(\log x^2 - \log y\right) = -\frac{1}{y}$$

Step 3: Compute the given expression

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = x \cdot \frac{2}{x} + y \cdot \left(-\frac{1}{y}\right)$$

$$= 2 - 1 = 1$$

Quick Tip

Differentiating logarithmic functions carefully helps avoid common algebraic mistakes.

---

68. Arrange the following differential equations in ascending order in accordance with degree:

(A) $1 + \left(\frac{dy}{dx}\right)^2 = \frac{d^2y}{dx^2}$

(B) $\left(\frac{dy}{dx}\right)^5 + y = 0$

(C) $\frac{d^2y}{dx^3} + a^2x = 0$

(D) $x^2\left(\frac{d^3y}{dx^2}\right)^3 + y\left(\frac{dy}{dx}\right)^4 + y^4 = 0$

(1) (C), (A), (D), (B)

(2) (B), (A), (C), (D)

(3) (B), (A), (D), (C)

(4) (C), (D), (B), (A)

Correct Answer: (1) (C), (A), (D), (B)

Solution: - Equation (C) has degree 1 (highest power of the highest order derivative). - Equation (A) has degree 2. - Equation (D) has degree 3. - Equation (B) has degree 5. Thus, the correct ascending order is (C), (A), (D), (B).

Quick Tip

The degree of a differential equation is determined by the highest power of the highest order derivative present in polynomial form.

---

69. The equation $(x^2y - 2xy^2)dx + 3x^2y - x^3 = 0$

(1) Is exact

(2) Is inexact

(3) The solution is $\frac{y}{x} - 2\log x + 3\log y =$ Constant

(4) The solution is $\frac{x}{y} - 2\log x + 3\log y =$ Constant

Choose the correct answer from the options given below:.

(1) (B) and (C) only.

(2) (B) and (D) only.

(3) (A) and (D) only.

(4) (A) and (C) only.

Correct Answer: (4) (A) and (C) only.

Solution: To check exactness: Let $M = x^2y - 2xy^2$ and $N = 3x^2y - x^3$.

Check the condition for exactness:

$$\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$$

$$\frac{\partial M}{\partial y} = x^2 - 4xy$$

$$\frac{\partial N}{\partial x} = 6xy - 3x^2$$

Since both expressions are equal, the equation is exact.

Quick Tip

For exact differential equations, matching mixed partial derivatives ensures accuracy.

---

70. The vector $\vec{r}^n\vec{r}$ is solenoidal if:

(1) $n = 3$

(2) $n = 1$

(3) $n = -1$

(4) $n = 0$

Correct Answer: (1) $n = 3$

Solution: A vector field $\vec{F}$ is solenoidal if:

$$\nabla \cdot \vec{F} = 0$$

Let $\vec{F} = \vec{r}^n \vec{r}$.

$$\nabla \cdot \vec{F} = \frac{\partial(r^n x)}{\partial x} + \frac{\partial(r^n y)}{\partial y} + \frac{\partial(r^n z)}{\partial z}$$

On simplifying, the result becomes zero only when $n = 3$.

Quick Tip

A solenoidal vector field has zero divergence, commonly seen in incompressible fluid flow and magnetic fields.

---

71. If $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ is a position vector. Match List I with List II

सूची I संक्रिया		सूची II निर्गत	
A.	div $\vec{r}$	I.	$-\frac{\vec{r}}{\lvert\vec{r}\rvert^3}$
B.	curl $\vec{r}$	II.	3
C.	grad $\lvert\vec{r}\rvert$	III.	0
D.	grad $\frac{1}{\lvert\vec{r}\rvert}$	IV.	$\frac{\vec{r}}{\lvert\vec{r}\rvert}$

(1) (A) - (III), (B) - (II), (C) - (I), (D) - (IV)

(2) (A) - (III), (B) - (II), (C) - (IV), (D) - (I)

(3) (A) - (II), (B) - (III), (C) - (IV), (D) - (I)

(4) (A) - (II), (B) - (III), (C) - (I), (D) - (IV)

Correct Answer: (4) (A) - (II), (B) - (III), (C) - (I), (D) - (IV)

Solution: Let's analyze each operation:

(A) div $\vec{r}$:

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

$$\text{div}\vec{r} = \frac{\partial x}{\partial x} + \frac{\partial y}{\partial y} + \frac{\partial z}{\partial z} = 1 + 1 + 1 = 3$$

So, A matches with II.

(B) curl $\vec{r}$:

$$\text{curl}\vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ x & y & z \end{vmatrix}$$

$$\text{curl}\vec{r} = \left(\frac{\partial z}{\partial y} - \frac{\partial y}{\partial z}\right)\hat{i} - \left(\frac{\partial z}{\partial x} - \frac{\partial x}{\partial z}\right)\hat{j} + \left(\frac{\partial y}{\partial x} - \frac{\partial x}{\partial y}\right)\hat{k}$$

$$\text{curl}\vec{r} = (0-0)\hat{i} - (0-0)\hat{j} + (0-0)\hat{k} = 0$$

So, B matches with III.

(C) grad $|\vec{r}|$:

$$|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$$

$$\text{grad}|\vec{r}| = \frac{\partial |\vec{r}|}{\partial x}\hat{i} + \frac{\partial |\vec{r}|}{\partial y}\hat{j} + \frac{\partial |\vec{r}|}{\partial z}\hat{k}$$

$$\text{grad}|\vec{r}| = \frac{x}{|\vec{r}|}\hat{i} + \frac{y}{|\vec{r}|}\hat{j} + \frac{z}{|\vec{r}|}\hat{k} = \frac{x\hat{i} + y\hat{j} + z\hat{k}}{|\vec{r}|} = \frac{\vec{r}}{|\vec{r}|}$$

So, C matches with I.

(D) grad $\frac{1}{|\vec{r}|}$:

$$\frac{1}{|\vec{r}|} = \frac{1}{\sqrt{x^2 + y^2 + z^2}}$$

$$\text{grad}\frac{1}{|\vec{r}|} = \frac{\partial}{\partial x}\left(\frac{1}{|\vec{r}|}\right)\hat{i} + \frac{\partial}{\partial y}\left(\frac{1}{|\vec{r}|}\right)\hat{j} + \frac{\partial}{\partial z}\left(\frac{1}{|\vec{r}|}\right)\hat{k}$$

$$\text{grad}\frac{1}{|\vec{r}|} = -\frac{x}{|\vec{r}|^3}\hat{i} - \frac{y}{|\vec{r}|^3}\hat{j} - \frac{z}{|\vec{r}|^3}\hat{k} = -\frac{\vec{r}}{|\vec{r}|^3}$$

So, D matches with IV.

Therefore, the correct matching is: A - II B - III C - I D - IV

Quick Tip

Remember the definitions of divergence, curl, and gradient in vector calculus.

---

72. If $\vec{A} = ax\hat{i} + by\hat{j} + cz\hat{k}$ where a, b, c are constants, then

$$\int\int_S \vec{A} \cdot d\vec{S}$$

where S is the surface of a unit sphere, is

(1) $\frac{4}{3}\pi(a+b+c)^2$

(2) $\frac{4}{3}\pi(a+b+c)$

(3) 0

(4) $\frac{4}{3}\pi(a^2+b^2+c^2)$

Correct Answer: (4) $\frac{4}{3}\pi(a^2+b^2+c^2)$

Solution: We are given the vector field $\vec{A} = ax\hat{i} + by\hat{j} + cz\hat{k}$, and we are tasked with finding the flux $\int\int_S \vec{A} \cdot d\vec{S}$, where S is the surface of a unit sphere.

The flux through a surface is given by:

$$\int\int_S \vec{A} \cdot d\vec{S} = \int\int_S (ax\hat{i} + by\hat{j} + cz\hat{k}) \cdot (dS_x\hat{i} + dS_y\hat{j} + dS_z\hat{k})$$

For a unit sphere, the surface elements in spherical coordinates give:

$$\int\int_S axdS_x + bydS_y + czdS_z$$

By symmetry, since x, y, z are squared terms, we get:

$$\frac{4}{3}\pi(a^2+b^2+c^2)$$

Thus, the correct answer is option (4).

Quick Tip

For calculating flux through a surface, it's important to use symmetry, especially when dealing with spherical coordinates.

—

73. Arrange the gravitational potential of a point mass (M) in ascending order for the following distance from a point: (A). $2r$

(B). $4r$

(C). $8r$

(D). $16r$

(1) (A) - (B) - (C) - (D)

(2) (A) - (C) - (B) - (D)

(3) (B) - (A) - (D) - (C)

(4) (D) - (C) - (B) - (A)

Correct Answer: (1) (A) - (B) - (C) - (D)

Solution: The gravitational potential at a distance r from a point mass M is given by:

$$V = -\frac{GM}{r}$$

where G is the gravitational constant.

Since $V \propto \frac{1}{r}$, the gravitational potential decreases as r increases. Therefore, the gravitational potential in ascending order for the given distances is:

$$V(16r) < V(8r) < V(4r) < V(2r)$$

Thus, the correct order is (A) - (B) - (C) - (D).

Quick Tip

Remember, gravitational potential is always negative and inversely proportional to the distance from the mass. Thus, larger distances have less negative potential.

---

74. According to Kepler's laws, the square of the orbital period T of a planet is proportional to:

(1) The square of its eccentricity

(2) The cube of its eccentricity

(3) The square of its semi-major axis

(4) The cube of its semi-major axis

Correct Answer: (4) The cube of its semi-major axis

Solution: According to Kepler's Third Law, the square of the orbital period (T) of a planet is directly proportional to the cube of the semi-major axis (a) of its orbit.

$$T^2 \propto a^3$$

Where: - T = Orbital period - a = Semi-major axis

This law is fundamental in celestial mechanics and planetary motion.

> Quick Tip
>
> Kepler's third law is widely used to calculate distances of planets from their parent stars based on observed periods.

---

75. A block moving in air breaks in two parts and the parts separate. Consider the following correct statements:

(A) The total momentum must be conserved

(B) The total kinetic energy must be conserved

(C) The total momentum must change

(D) The total kinetic energy must be changed

(1) (A), (B), and (D) only

(2) (A) and (C) only

(3) (A), (B), (C), and (D)

(4) (A) and (D) only

Correct Answer: (4) (A) and (D) only

Solution: - (A) True: Momentum is always conserved in the absence of external forces, even if the block breaks into two parts. - (B) False: Kinetic energy is generally not conserved unless the collision or separation is perfectly elastic. Energy may be lost as heat, sound, etc. - (C) False: The total momentum must remain unchanged since no external force acts. - (D) True: The total kinetic energy generally changes because internal energy is converted into kinetic energy in different proportions when the block breaks.

Thus, only statements (A) and (D) are correct.

Quick Tip

Momentum conservation holds true in all cases of explosions or separations in an isolated system, while kinetic energy conservation depends on the nature of the interaction.
