

PART A — PHYSICS

Directions : Questions number 1 – 3 are based on the following paragraph.

An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.

1. The initial shape of the wavefront of the beam is
 - ☒ (1) planar
 - (2) convex
 - (3) concave
 - (4) convex near the axis and concave near the periphery
2. The speed of light in the medium is
 - (1) maximum on the axis of the beam
 - ☒ (2) minimum on the axis of the beam
 - (3) the same everywhere in the beam
 - (4) directly proportional to the intensity I
3. As the beam enters the medium, it will
 - (1) travel as a cylindrical beam
 - ☒ (2) diverge
 - (3) converge
 - (4) diverge near the axis and converge near the periphery

Directions : Questions number 4 – 5 are based on the following paragraph.

A nucleus of mass $M + \Delta m$ is at rest and decays into two daughter nuclei of equal mass $\frac{M}{2}$ each. Speed of light is c .

4. The speed of daughter nuclei is

(1) $c \sqrt{\frac{\Delta m}{M + \Delta m}}$

(2) $c \frac{\Delta m}{M + \Delta m}$

☒ (3) $c \sqrt{\frac{2\Delta m}{M}}$

(4) $c \sqrt{\frac{\Delta m}{M}}$

5. The binding energy per nucleon for the parent nucleus is E_1 and that for the daughter nuclei is E_2 . Then

(1) $E_1 = 2E_2$

(2) $E_2 = 2E_1$

(3) $E_1 > E_2$

☒ (4) $E_2 > E_1$

Directions : Questions number 6–7 contain Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.

6. **Statement-1 :** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{\max} . When the ultraviolet light is replaced by X-rays, both V_0 and K_{\max} increase.

Statement-2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light.

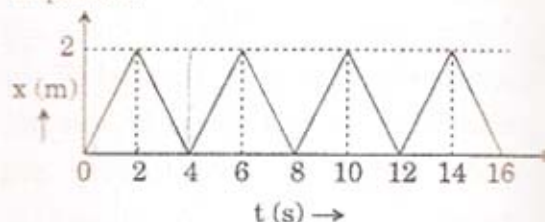
- (1) Statement-1 is true, Statement-2 is false.
 (2) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
 (3) Statement-1 is true, Statement-2 is true; Statement-2 is **not** the correct explanation of Statement-1.
 (4) Statement-1 is false, Statement-2 is true.

7. **Statement-1 :** Two particles moving in the same direction do not lose all their energy in a completely inelastic collision.

Statement-2 : Principle of conservation of momentum holds true for all kinds of collisions.

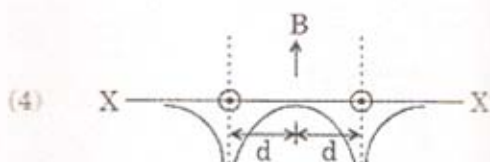
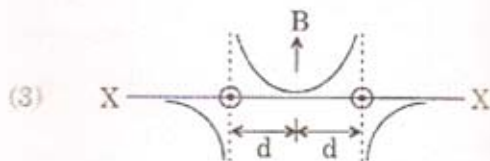
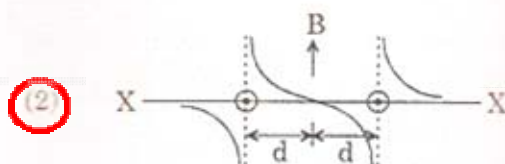
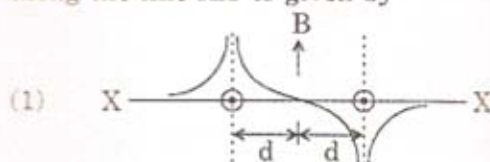
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8. The figure shows the position–time ($x-t$) graph of one-dimensional motion of a body of mass 0.4 kg. The magnitude of each impulse is

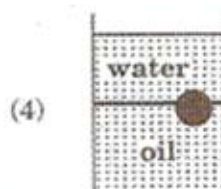
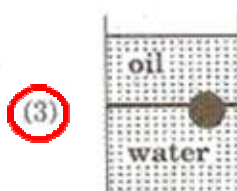
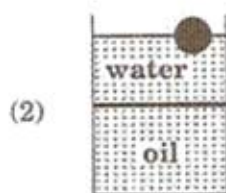
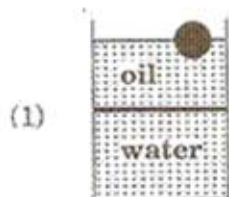


- (1) 0.2 Ns
 (2) 0.4 Ns
 (3) 0.8 Ns
 (4) 1.6 Ns

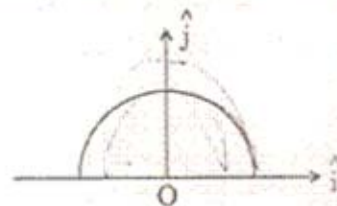
9. Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by



10. A ball is made of a material of density ρ where $\rho_{\text{oil}} < \rho < \rho_{\text{water}}$ with ρ_{oil} and ρ_{water} representing the densities of oil and water, respectively. The oil and water are immiscible. If the above ball is in equilibrium in a mixture of this oil and water, which of the following pictures represents its equilibrium position?



11. A thin semi-circular ring of radius r has a positive charge q distributed uniformly over it. The net field \vec{E} at the centre O is



(1) $\frac{q}{2\pi^2 \epsilon_0 r^2} \hat{j}$

(2) $\frac{q}{4\pi^2 \epsilon_0 r^2} \hat{j}$

(3) $-\frac{q}{4\pi^2 \epsilon_0 r^2} \hat{j}$

(4) $-\frac{q}{2\pi^2 \epsilon_0 r^2} \hat{j}$

12. A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to $32V$, the efficiency of the engine is

(1) 0.25

(2) 0.5

(3) 0.75

(4) 0.99

13. The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1×10^{-3} are

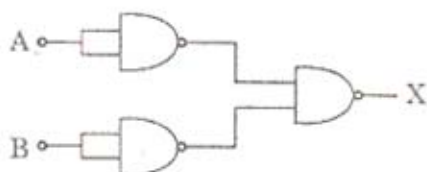
(1) 4, 4, 2

(2) 5, 1, 2

(3) 5, 1, 5

(4) 5, 5, 2

14. The combination of gates shown below yields

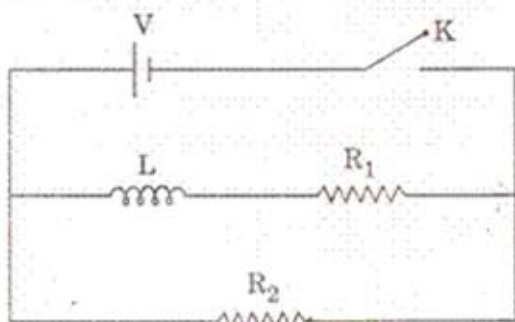


- (1) NAND gate
(2) OR gate
(3) NOT gate
(4) XOR gate
15. If a source of power 4 kW produces 10^{20} photons/second, the radiation belongs to a part of the spectrum called
- (1) γ -rays
(2) X-rays
(3) ultraviolet rays
(4) microwaves
16. A radioactive nucleus (initial mass number A and atomic number Z) emits 3 α -particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be
- (1) $\frac{A-Z-4}{Z-2}$
(2) $\frac{A-Z-8}{Z-4}$
(3) $\frac{A-Z-4}{Z-8}$
(4) $\frac{A-Z-12}{Z-4}$

17. Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0 \left(\frac{5}{4} - \frac{r}{R} \right)$ upto $r = R$, and $\rho(r) = 0$ for $r > R$, where r is the distance from the origin. The electric field at a distance r ($r < R$) from the origin is given by

- (1) $\frac{\rho_0 r}{3\epsilon_0} \left(\frac{5}{4} - \frac{r}{R} \right)$
(2) $\frac{4\pi\rho_0 r}{3\epsilon_0} \left(\frac{5}{3} - \frac{r}{R} \right)$
(3) $\frac{\rho_0 r}{4\epsilon_0} \left(\frac{5}{3} - \frac{r}{R} \right)$
(4) $\frac{4\rho_0 r}{3\epsilon_0} \left(\frac{5}{4} - \frac{r}{R} \right)$
18. In a series LCR circuit $R = 200 \Omega$ and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30° . On taking out the inductor from the circuit the current leads the voltage by 30° . The power dissipated in the LCR circuit is
- (1) 242 W
(2) 305 W
(3) 210 W
(4) Zero W

19. In the circuit shown below, the key K is closed at $t = 0$. The current through the battery is



- (1) $\frac{V(R_1 + R_2)}{R_1 R_2}$ at $t = 0$ and $\frac{V}{R_2}$ at $t = \infty$
- (2) $\frac{VR_1 R_2}{\sqrt{R_1^2 + R_2^2}}$ at $t = 0$ and $\frac{V}{R_2}$ at $t = \infty$
- (3) $\frac{V}{R_2}$ at $t = 0$ and $\frac{V(R_1 + R_2)}{R_1 R_2}$ at $t = \infty$
- (4) $\frac{V}{R_2}$ at $t = 0$ and $\frac{VR_1 R_2}{\sqrt{R_1^2 + R_2^2}}$ at $t = \infty$

20. A particle is moving with velocity $\vec{v} = K(y\hat{i} + x\hat{j})$, where K is a constant. The general equation for its path is

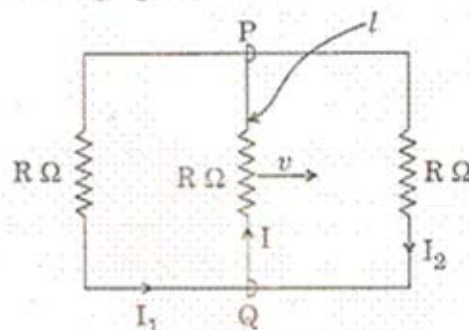
- (1) $y^2 = x^2 + \text{constant}$
- (2) $y = x^2 + \text{constant}$
- (3) $y^2 = x + \text{constant}$
- (4) $xy = \text{constant}$

21. Let C be the capacitance of a capacitor discharging through a resistor R. Suppose t_1 is the time taken for the energy stored in the capacitor to reduce to half its initial value and t_2 is the time taken for the charge to reduce to one-fourth its initial value.

Then the ratio t_1/t_2 will be

- (1) 2
- (2) 1
- (3) $\frac{1}{2}$
- (4) $\frac{1}{4}$

22. A rectangular loop has a sliding connector PQ of length l and resistance $R \Omega$ and it is moving with a speed v as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents I_1 , I_2 and I are



- (1) $I_1 = I_2 = \frac{Blv}{6R}$, $I = \frac{Blv}{3R}$
- (2) $I_1 = -I_2 = \frac{Blv}{R}$, $I = \frac{2Blv}{R}$
- (3) $I_1 = I_2 = \frac{Blv}{3R}$, $I = \frac{2Blv}{3R}$
- (4) $I_1 = I_2 = I = \frac{Blv}{R}$

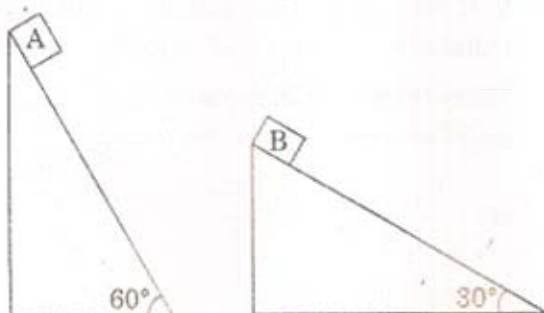
23. The equation of a wave on a string of linear mass density 0.04 kg m^{-1} is given by

$$y = 0.02(\text{m}) \sin \left[2\pi \left(\frac{t}{0.04(\text{s})} - \frac{x}{0.50(\text{m})} \right) \right]$$

The tension in the string is

- (1) 6.25 N
- (2) 4.0 N
- (3) 12.5 N
- (4) 0.5 N

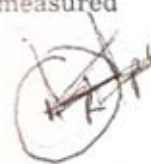
24. Two fixed frictionless inclined planes making an angle 30° and 60° with the vertical are shown in the figure. Two blocks A and B are placed on the two planes. What is the relative vertical acceleration of A with respect to B?



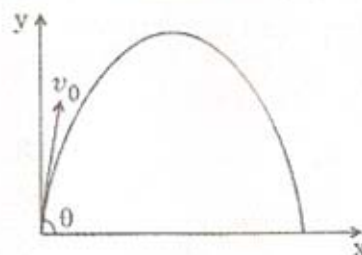
- (1) 4.9 ms^{-2} in vertical direction
- (2) 4.9 ms^{-2} in horizontal direction
- (3) 9.8 ms^{-2} in vertical direction
- (4) Zero

25. For a particle in uniform circular motion, the acceleration \vec{a} at a point P (R, θ) on the circle of radius R is (Here θ is measured from the x-axis)

- (1) $\frac{v^2}{R} \hat{i} + \frac{v^2}{R} \hat{j}$
- (2) $-\frac{v^2}{R} \cos \theta \hat{i} + \frac{v^2}{R} \sin \theta \hat{j}$
- (3) $-\frac{v^2}{R} \sin \theta \hat{i} + \frac{v^2}{R} \cos \theta \hat{j}$
- (4) $-\frac{v^2}{R} \cos \theta \hat{i} - \frac{v^2}{R} \sin \theta \hat{j}$



26. A small particle of mass m is projected at an angle θ with the x-axis with an initial velocity v_0 in the x-y plane as shown in the figure. At a time $t < \frac{v_0 \sin \theta}{g}$, the angular momentum of the particle is



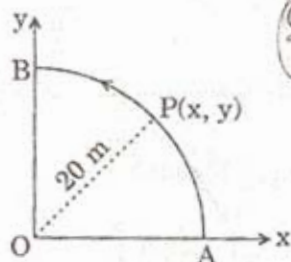
- (1) $\frac{1}{2} mg v_0 t^2 \cos \theta \hat{i}$
- (2) $-mg v_0 t^2 \cos \theta \hat{j}$
- (3) $mg v_0 t \cos \theta \hat{k}$
- (4) $-\frac{1}{2} mg v_0 t^2 \cos \theta \hat{k}$

where \hat{i} , \hat{j} and \hat{k} are unit vectors along x, y and z-axis respectively.

27. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30° with each other. When suspended in a liquid of density 0.8 g cm^{-3} , the angle remains the same. If density of the material of the sphere is 1.6 g cm^{-3} , the dielectric constant of the liquid is

- (1) 1
- (2) 4
- (3) 3
- (4) 2

28. A point P moves in counter-clockwise direction on a circular path as shown in the figure. The movement of 'P' is such that it sweeps out a length $s = t^3 + 5$, where s is in metres and t is in seconds. The radius of the path is 20 m. The acceleration of 'P' when $t = 2 \text{ s}$ is nearly



- (1) 14 m/s^2
- (2) 13 m/s^2
- (3) 12 m/s^2
- (4) 7.2 m/s^2

29. The potential energy function for the force between two atoms in a diatomic molecule is approximately given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$, where a and b are constants and x is the distance between the atoms. If the dissociation energy of the molecule is $D = [U(x = \infty) - U_{\text{at equilibrium}}]$, D is

- (1) $\frac{b^2}{6a}$
- (2) $\frac{b^2}{2a}$
- (3) $\frac{b^2}{12a}$
- (4) $\frac{b^2}{4a}$

30. Two conductors have the same resistance at 0°C but their temperature coefficients of resistance are α_1 and α_2 . The respective temperature coefficients of their series and parallel combinations are nearly

- (1) $\frac{\alpha_1 + \alpha_2}{2}, \frac{\alpha_1 + \alpha_2}{2}$
- (2) $\frac{\alpha_1 + \alpha_2}{2}, \alpha_1 + \alpha_2$
- (3) $\alpha_1 + \alpha_2, \frac{\alpha_1 + \alpha_2}{2}$
- (4) $\alpha_1 + \alpha_2, \frac{\alpha_1 \alpha_2}{\alpha_1 + \alpha_2}$