# JEE–MAIN EXAMINATION – JANUARY 2025

**(HELD ON WEDNESDAY 29th JANUARY 2025)** **TIME : 3 : 00 PM TO 6 : 00 PM**

## PHYSICS — TEST PAPER WITH SOLUTION

### SECTION-A

**26.** The difference of temperature in a material can convert heat energy into electrical energy. To harvest the heat energy, the material should have

(1) low thermal conductivity and low electrical conductivity

(2) high thermal conductivity and high electrical conductivity

(3) low thermal conductivity and high electrical conductivity

(4) high thermal conductivity and low electrical conductivity

**Ans. (3)**

**Sol.** See-back effect

Low thermal conductivity

High electrical conductivity

**27.** Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

**Assertion (A) :** With the increase in the pressure of an ideal gas, the volume falls off more rapidly in an isothermal process in comparison to the adiabatic process.

**Reason (R) :** In isothermal process, PV = constant, while in adiabatic process $PV^{\gamma}$ = constant. Here $\gamma$ is the ratio of specific heats, P is the pressure and V is the volume of the ideal gas.

In the light of the above statements, choose the **correct** answer from the options given below :

(1) Both **(A)** and **(R)** are true but **(R)** is **NOT** the correct explanation of **(A)**

(2) **(A)** is true but **(R)** is false

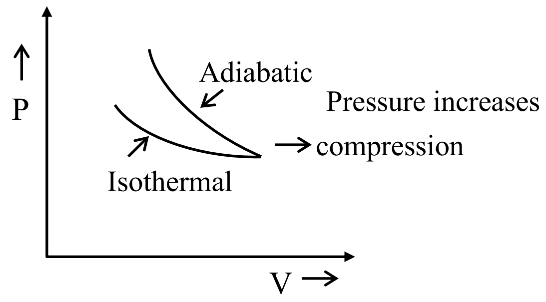
(3) Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**.

(4) **(A)** is false but **(R)** is true

**NTA Ans. (4)**

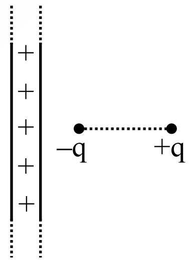
**Allen Ans.(3)**

**Sol.**




$$\left(\frac{dP}{dV}\right)_{Adiabatic} > \left(\frac{dP}{dV}\right)_{Isothermal}$$

**28.** An electric dipole is placed at a distance of 2 cm from an infinite plane sheet having positive charge density $\sigma_0$. Choose the correct option from the following.




(1) Torque on dipole is zero and net force is directed away from the sheet.

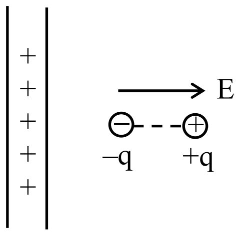
(2) Torque on dipole is zero and net force acts towards the sheet.

(3) Potential energy of dipole is minimum and torque is zero.

(4) Potential energy and torque both are maximum

**Ans. (3)**

**Sol.**




Here $E = \dfrac{\sigma}{2\epsilon_0}, \vec{\tau} = \vec{P} \times \vec{E}$

$\vec{\tau} = 0$

$U = -\vec{P} \cdot \vec{E} \quad U \rightarrow$ minimum

**29.** In an experiment with photoelectric effect, the stopping potential.

(1) increases with increase in the wavelength of the incident light

(2) increases with increase in the intensity of the incident light

(3) is $\left(\frac{1}{e}\right)$ times the maximum kinetic energy of the emitted photoelectrons

(4) decreases with increase in the intensity of the incident light

**Ans. (3)**

**Sol.** $\frac{hC}{\lambda} = W + eV_S$

$\frac{hC}{\lambda} = W + (K_{max})$

$\therefore V_S = \frac{K_{max}}{e}$

Ans. (3)

**30.** A point charge causes an electric flux of $-2 \times 10^4$ $Nm^2C^{-1}$ to pass through a spherical Gaussian surface of 8.0 cm radius, centred on the charge. The value of the point charge is :

(Given $\in_0 = 8.85 \times 10^{-12} C^2N^{-1}m^{-2}$)

(1) $-17.7 \times 10^{-8}$C (2) $-15.7 \times 10^{-8}$C

(3) $17.7 \times 10^{-8}$C (4) $15.7 \times 10^{-8}$C

**Ans. (1)**

**Sol.** $\phi = -2 \times 10^4 \frac{Nm^2}{C}$

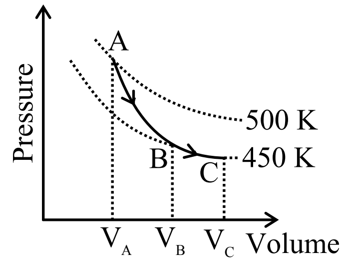
r = 8.0 cm

$\phi = \frac{q}{\in_0} \Rightarrow q = \in_0 \phi$

$= (8.85 \times 10^{-12}) \times (-2 \times 10^4)$

$q = -17.7 \times 10^{-8}$ C

**31.**




A poly-atomic molecule ($C_V = 3R$, $C_P = 4R$, where R is gas constant) goes from phase space point A($P_A = 10^5$ Pa, $V_A = 4 \times 10^{-6}m^3$) to point B ($P_B = 5 \times 10^4$ Pa, $V_B = 6 \times 10^{-6}m^3$) to point C ($P_C = 10^4$ Pa, $V_C = 8 \times 10^{-6}m^3$). A to B is an adiabatic path and B to C is an isothermal path.

The net heat absorbed per unit mole by the system is :

(1) 500R(ln3 + ln4) (2) 450R(ln4 – ln3)

(3) 500R ln2 (4) 400R ln4

**Ans. (2)**

**Sol.** $\Delta Q_{AB} = 0$ adiabatic

$\Delta Q_{BC} = \Delta W_{BC}$

$= nRT\ell n\left(\frac{V_C}{V_B}\right) = 450R\ell n\left(\frac{8 \times 10^{-6}}{6 \times 10^{-6}}\right)$

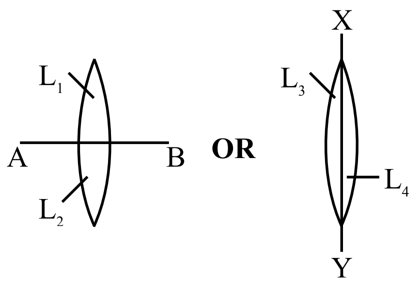
$= 450R\ell n\left(\frac{4}{3}\right) = 450R\ (\ell n4 - \ell n3)$

$\therefore \Delta Q = \Delta Q_{AB} + \Delta Q_{BC}$

$\Delta Q = 450\ R\ (\ell n4 - \ell n3)$

**Note : Solution is based on direct data. B and C are not satisfying the condition of isothermal process.**

**32.** Two identical symmetric double convex lenses of focal length *f* are cut into two equal parts $L_1$, $L_2$ by AB plane and $L_3$, $L_4$ by XY plane as shown in figure respectively. The ratio of focal lengths of lenses $L_1$ and $L_3$ is




(1) 1 : 4 (2) 1 : 1

(3) 2 : 1 (4) 1 : 2

**Ans. (4)**

**Sol.** $f_{L_1} = f_{L_2} = f$

$f_{L_3} = f_{L_4} = 2f$

$\therefore f_{L_1} : f_{L_3} = 1:2$

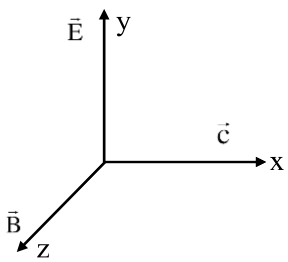
**33.** A plane electromagnetic wave propagates along the + x direction in free space. The components of the electric field, $\vec{E}$ and magnetic field, $\vec{B}$ vectors associated with the wave in Cartesian frame are :

(1) $E_y, B_x$ (2) $E_y, B_z$

(3) $E_x, B_y$ (4) $E_z, B_y$

**Ans.** **(2)**

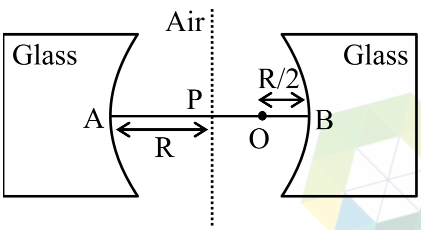
**Sol.**




Direction of propogation

$= \vec{E} \times \vec{B}$

**34.**




Two concave refracting surfaces of equal radii of curvature and refractive index 1.5 face each other in air as shown in figure. A point object O is placed midway, between P and B. The separation between the images of O, formed by each refracting surface is :

(1) 0.214R

(2) 0.114R

(3) 0.411R

(4) 0.124R

**Ans.** **(2)**

**Sol.** For B

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1.5}{V} + \frac{1}{\frac{R}{2}} = \frac{0.5}{-R}$$

$$\frac{1.5}{V} = -\frac{1}{2R} - \frac{2}{R}$$

$$\frac{1.5}{V} = \frac{-5}{2R} \Rightarrow V_B = -0.6R$$

For A

$$\frac{1.5}{V} + \frac{2}{3R} = \frac{0.5}{-R}$$

$$\frac{1.5}{V} = -\frac{1}{2R} - \frac{2}{3R}$$

$$\frac{1.5}{V} = -\frac{7}{6R}$$

$$V_A = -\frac{9}{7}R$$

Distance between images

$$= 2R - \left(0.6R + \frac{9}{7}R\right) = 0.114\ R$$

option (2)

**35.** Two bodies A and B of equal mass are suspended from two massless springs of spring constant $k_1$ and $k_2$, respectively. If the bodies oscillate vertically such that their amplitudes are equal, the ratio of the maximum velocity of A to the maximum velocity of B is

(1) $\sqrt{\frac{k_1}{k_2}}$ (2) $\frac{k_1}{k_2}$

(3) $\frac{k_2}{k_1}$ (4) $\sqrt{\frac{k_2}{k_1}}$

**Ans.** **(1)**

**Sol.** $V_1 = A_1\omega_1$

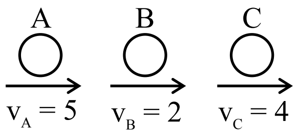
$V_2 = A_2\omega_2$

$A_1 = A_2$

$$\frac{V_1}{V_2} = \frac{\omega_1}{\omega_2} = \frac{\sqrt{\frac{K_1}{m}}}{\sqrt{\frac{K_2}{m}}}$$

$$\frac{V_1}{V_2} = \sqrt{\frac{K_1}{K_2}}$$

**36.** Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

**Assertion (A) :** 


Three identical spheres of same mass undergo one dimensional motion as shown in figure with initial velocities $v_A = 5$ m/s, $v_B = 2$ m/s, $v_C = 4$ m/s If we wait sufficiently long for elastic collision to happen, then $v_A = 4$ m/s, $v_B = 2$ m/s, $v_C = 5$ m/s will be the final velocities.

**Reason (R) :** In an elastic collision between identical masses, two objects exchange their velocities.

In the light of the above statements, choose the **correct** answer from the options given below :

(1) Both **(A)** and **(R)** are true but **(R)** is **NOT** the correct explanation of **(A)**

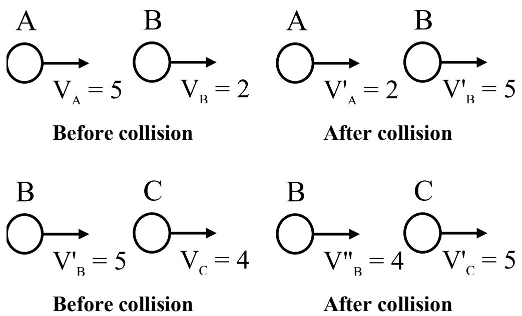
(2) **(A)** is true but **(R)** is false

(3) Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**.

(4) **(A)** is false but **(R)** is true

**Ans. (4)**

**Sol.** In elastic collision for same mass, velocities interchange




$V'_A = 2m/s \quad V''_B = 4m/s \quad V'_C = 5m/s$

**37.** A sand dropper drops sand of mass m(t) on a conveyer belt at a rate proportional to the square root of speed (v) of the belt, i.e. $\frac{dm}{dt} \propto \sqrt{v}$. If P is the power delivered to run the belt at constant speed then which of the following relationship is true ?

(1) $P^2 \propto v^3$ (2) $P \propto \sqrt{v}$

(3) $P \propto v$ (4) $P^2 \propto v^5$

**Ans. (4)**

**Sol.** Power = $\vec{F} \cdot \vec{V}$

$$F = \frac{dp}{dt}[p = mv]$$

$$F = \left(\frac{dm}{dt}\right)v = C\left(\sqrt{v}\right)v$$

$$F = Cv^{\frac{3}{2}}$$

$$\text{Power} = C(v^{3/2})v = Cv^{5/2}$$

$$p^2 \propto v^5$$

**38.** A convex lens mode of glass (refractive index = 1.5) has focal length 24 cm in air. When it is totally immersed in water (refractive index = 1.33), its focal length changes to

(1) 72 cm (2) 96 cm

(3) 24 cm (4) 48 cm

**Ans. (2)**

**Sol.** $$\frac{1}{8} = \left(\frac{\mu_\ell}{\mu_S} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{24} = (1.5 - 1)\left[\frac{2}{R}\right] \quad \dots (i)$$

$$\frac{1}{f'} = \left(\frac{1.5}{1.33} - 1\right)\left(\frac{2}{R}\right)$$

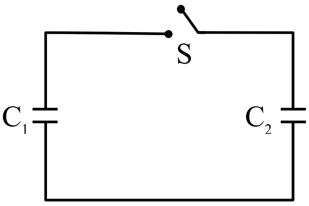
$$\frac{1}{f'} = \left(\frac{1.5 \times 3}{4} - 1\right)\frac{2}{R} \quad \dots (ii)$$

(i) divided by (ii)

$$\frac{f'}{24} = 4$$

f' = 96 cm

**39.** A capacitor, $C_1 = 6\mu F$ is charged to a potential difference of $V_0 = 5V$ using a 5V battery. The battery is removed and another capacitor, $C_2 = 12\ \mu F$ is inserted in place of the battery. When the switch 'S' is closed, the charge flows between the capacitors for some time until equilibrium condition is reached. What are the charges ($q_1$ and $q_2$) on the capacitors $C_1$ and $C_2$ when equilibrium condition is reached.




(1) $q_1 = 15\ \mu C$, $q_2 = 30\ \mu C$

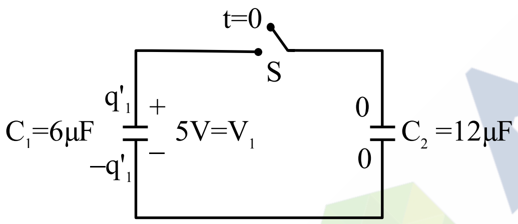
(2) $q_1 = 30\ \mu C$, $q_2 = 15\ \mu C$

(3) $q_1 = 10\ \mu C$, $q_2 = 20\ \mu C$

(4) $q_1 = 20\ \mu C$, $q_2 = 10\ \mu C$

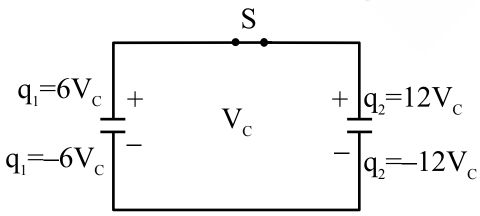
**Ans. (3)**

**Sol.**




$q'_1 = 6 \times 5 = 30\mu C$

Finally




$6V_C + 12V_C = 30 + 0$

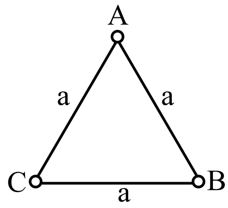
$18V_C = 30$

$$V_C = \frac{30}{18} = \frac{5}{3}\text{Volt}$$

$$\Rightarrow q_1 = \frac{6 \times 5}{3} = 10\mu C$$

$$\Rightarrow q_2 = \frac{12 \times 5}{3} = 20\mu C$$

**40.**




Three equal masses m are kept at vertices (A, B, C) of an equilateral triangle of side a in free space. At t = 0, they are given an initial velocity $\vec{V}_A = V_0\overrightarrow{AC}$, $\vec{V}_B = V_0\overrightarrow{BA}$ and $\vec{V}_C = V_0\overrightarrow{CB}$. Here, $\overrightarrow{AC}, \overrightarrow{CB}$ and $\overrightarrow{BA}$ are unit vectors along the edges of the triangle. If the three masses interact gravitationally, then the magnitude of the net angular momentum of the system at the point of collision is :

(1) $\frac{1}{2}a\,m\,V_0$

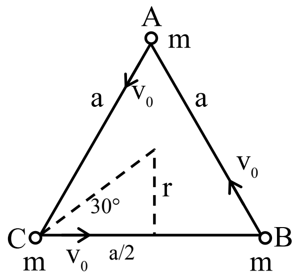
(2) $3\ a\ m\ V_0$

(3) $\frac{\sqrt{3}}{2}a\,m\,V_0$

(4) $\frac{3}{2}a\,m\,V_0$

**Ans. (3)**

**Sol.**




$$\tan 30° = \frac{2r}{a} = \frac{1}{\sqrt{3}}$$

$$r = \frac{a}{2\sqrt{3}}$$

$$L = (mvr_\perp) \times 3$$

$$= mv_0\frac{a}{2\sqrt{3}} \times 3$$

$$= \frac{\sqrt{3}}{2}mv_0a$$

**41.** Match **List-I** with **List-II**.

| | List-I | | List-II |
|---|---|---|---|
| (A) | Young's Modulus | (I) | $ML^{-1}T^{-1}$ |
| (B) | Torque | (II) | $ML^{-1}T^{-2}$ |
| (C) | Coefficient of Viscosity | (III) | $M^{-1}L^{3}T^{-2}$ |
| (D) | Gravitational Constant | (IV) | $ML^{2}T^{-2}$ |

Choose the **correct** answer from the options given below :

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

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

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

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

**Ans.** **(4)**

**Sol.** (A) $[Y] = \frac{F}{A\left(\frac{\Delta\ell}{\ell}\right)} \Rightarrow \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$ (II)

(B) Torque $(\vec{\tau}) = \vec{r} \times \vec{F}$

$(\vec{\tau}) = L \times MLT^{-2} = ML^2T^{-2}$ (IV)

(C) Coefficient of viscosity $\Rightarrow F = \eta A \frac{dV}{dt}$

$\eta \to$ Pa·sec

$[\eta] = \frac{MLT^{-2}}{L^2} \times T = ML^{-1}T^{-1}$ (I)

(D) Gravitational constant (G)

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

$[G] = \frac{F \cdot r^2}{m_1 m_2} = \frac{MLT^{-2} \times L^2}{M^2} = M^{-1}L^3T^{-2}$ (III)

**42.** Match **List-I** with **List-II**.

| | List-I | | List-II |
|---|---|---|---|
| (A) | Magnetic induction | (I) | Ampere meter$^2$ |
| (B) | Magnetic intensity | (II) | Weber |
| (C) | Magnetic flux | (III) | Gauss |
| (D) | Magnetic moment | (IV) | Ampere meter |

Choose the **correct** answer from the options given below :

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

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

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

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

**Ans.** **(2)**

**Sol.** (A) Magnetic induction $\to$ Gauss (III)

(B) Magnetic intensity

$\left(H = \frac{B}{\mu}\right) \to$ Ampere / meter (IV)

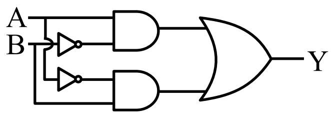
(C) Magnetic flux $\to$ Weber (Wb) (II)

(D) Magnetic moment $\to$ Ampere-meter$^2$

$(\vec{M} = i\vec{A})$

**Note : None of the option(s) are correct but if we need to choose most appropriate option then the answer is (2)**

**43.** The truth table for the circuit given below is :




(1)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

(2)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |
| 0 | 1 | 1 |

(3)

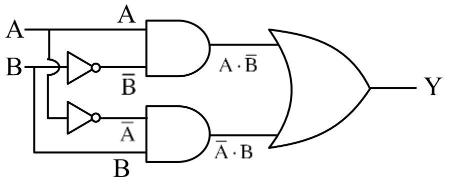
| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 1 | 0 |

(4)

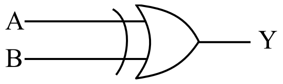
| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 1 | 1 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |

**Ans.** **(1)**

**Sol.**




$Y = A\cdot\overline{B} + \overline{A}\cdot B$




XOR (Exclusive OR)

**44.** A cup of coffee cools from 90°C to 80°C in t minutes when the room temperature is 20°C. The time taken by the similar cup of coffee to cool from 80°C to 60°C at the same room temperature is :

(1) $\frac{13}{5}t$ (2) $\frac{10}{13}t$

(3) $\frac{13}{10}t$ (4) $\frac{5}{13}t$

**Ans.** **(1)**

**Sol.** By using average form of Newton's law of cooling

$$\frac{90-80}{t} = k\left(\frac{90+80}{2} - 20\right) \quad \text{... (i)}$$

$$\frac{80-60}{t'} = k\left(\frac{80+60}{2} - 20\right) \quad \text{... (ii)}$$

(i)/(ii)

$$\frac{10\times t'}{t\times 20} = \frac{65}{50}$$

$$t' = \frac{65}{50}\times 2t = \frac{65}{25}t = \frac{13}{5}t$$

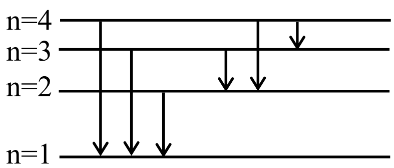
**45.** The number of spectral lines emitted by atomic hydrogen that is in the $4^{th}$ energy level, is

(1) 6 (2) 0

(3) 3 (4) 1

**Ans.** **(1)**

**Sol.**




Total possible transition = 6

**SECTION-B**

**46.** The magnetic field inside a 200 turns solenoid of radius 10 cm is $2.9 \times 10^{-4}$ Tesla. If the solenoid carries a current of 0.29 A, then the length of the solenoid is ________ π cm.

**Ans.** **(8)**

**Sol.** Assuming long solenoid

$$B = \mu_0\left(\frac{N}{\ell}\right)i$$

$$\ell = \frac{\mu_0 N i}{B} = \frac{(4\pi\times10^{-7})(200)(0.29)}{2.9\times10^{-4}}\,m$$

$= 8\pi$ cm

**47.** A parallel plate capacitor consisting of two circular plates of radius 10 cm is being charged by a constant current of 0.15 A. If the rate of change of potential difference between the plates is $7 \times 10^8$ V/s then the integer value of the distance between the parallel plates is –

$\left(\text{Take}, \epsilon_0 = 9\times10^{-12}\frac{F}{m}, \pi = \frac{22}{7}\right)$ ________ μm.

**Ans.** **(1320)**

**Sol.** $V = \frac{Q}{C} = \frac{it}{\left(\frac{\epsilon_0 A}{d}\right)} = \frac{itd}{\epsilon_0(\pi r^2)}$

$$\Rightarrow d = \frac{\epsilon_0(\pi r^2)}{i}\left(\frac{v}{t}\right)$$

$$= \frac{(9\times10^{-12})\left(\frac{22}{7}\right)(0.1)^2}{0.15}(7\times10^8)\,m$$

d = 1320 μm

**48.** A physical quantity Q is related to four observables a, b, c, d as follows : $Q = \frac{ab^4}{cd}$

where, a = (60 ± 3)Pa; b = (20 ± 0.1)m; c = (40 ± 0.2) $Nsm^{-2}$ and d = (50 ± 0.1)m, then the percentage error in Q is $\frac{x}{1000}$, where x = ______.

**NTA Ans. (77)**

**Allen Ans.(7700)**

**Sol.** $Q = \frac{ab^4}{cd}$

$$\Rightarrow \frac{\Delta Q}{Q}\times100 = \left[\frac{\Delta a}{a} + 4\frac{\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}\right]\times100$$

$$\Rightarrow \frac{x}{1000} = \left[\frac{3}{60} + 4\left(\frac{0.1}{20}\right) + \left(\frac{0.2}{40}\right) + \frac{0.1}{50}\right]\times100$$

$\Rightarrow x = 7700$

**49.** Two planets, A and B are orbiting a common star in circular orbits of radii $R_A$ and $R_B$, respectively, with $R_B = 2R_A$. The planet B is $4\sqrt{2}$ times more massive than planet A. The ratio $\left(\frac{L_B}{L_A}\right)$ of angular momentum ($L_B$) of planet B to that of planet A($L_A$) is closest to integer __________.

**Ans.** **(8)**

**Sol.** $L = mv_0R = m\sqrt{\frac{GM}{R}}R = m\sqrt{GMR}$

here M is mass of star

$$\frac{L_B}{L_A} = \frac{m_B}{m_A}\sqrt{\frac{R_B}{R_A}}$$

$$= 4\sqrt{2}\sqrt{\frac{2}{1}}$$

$$\frac{L_B}{L_A} = 8$$

**50.** Two cars P and Q are moving on a road in the same direction. Acceleration of car P increases linearly with time whereas car Q moves with a constant acceleration. Both cars cross each other at time t = 0, for the first time. The maximum possible number of crossing(s) (including the crossing at t = 0) is ________ .

**Ans.** **(3)**

**Sol.** $a_P = kt$, k is constant

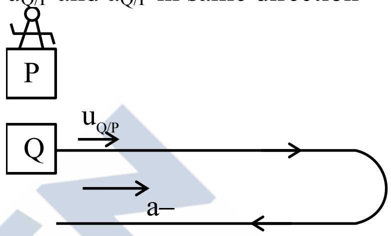
$a_Q = a$, a is constant

$a_{Q/P} = a_Q - a_P = a - kt$

as initial velocities are not mentioned in question, so will have to assume two cases.

Case-I

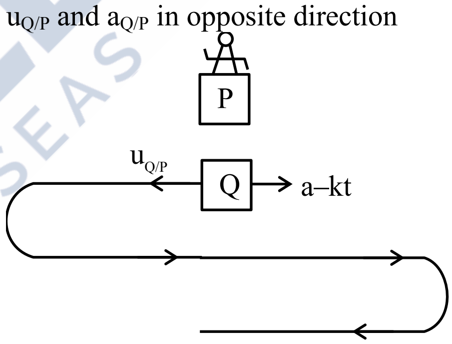
$u_{Q/P}$ and $a_{Q/P}$ in same direction




Total number of crossing = 2

Case-II

$u_{Q/P}$ and $a_{Q/P}$ in opposite direction




Total number of crossing = 3