Class XI Session 2023-24
Subject - Physics
Sample Question Paper - 1

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. Which pairs do not have equal dimensions? **[1]**

a) Force and impulse
b) Elastic modulus and pressure
c) Energy and torque
d) Angular momentum and Planck's constant

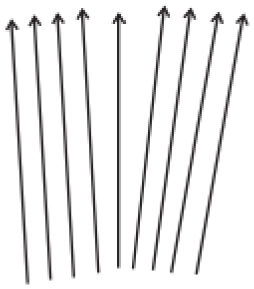
2. The equation of a progressive wave can be given by y = 15 sin$(660\pi t - 0.02\pi x)$ cm. The frequency of the wave is **[1]**

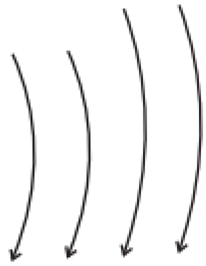
a) 365 Hz
b) 342 Hz
c) 330 Hz
d) 660 Hz

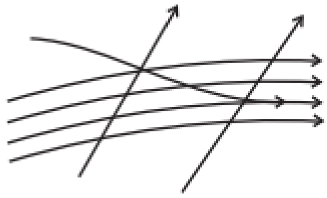
3. The reduced mass of two particles having masses m and 2m is **[1]**

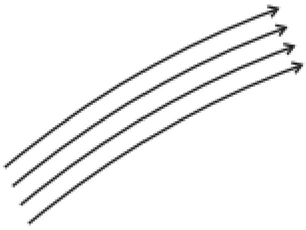
a) 2m
b) 3m
c) $\frac{m}{2}$
d) $\frac{2m}{3}$

4. Which of the following diagrams (Fig.) does not represent a streamline flow? **[1]**

a) 

b) 

c) 

d) 

5. The orbital velocity of a satellite orbiting near the surface of the earth is given by **[1]**

a) v = $\sqrt{gR_e}$, where g = $\frac{GM_e}{R_e^2}$

b) v = $\sqrt{\frac{gh}{R_e}}$ where g = $\frac{GM_e}{R_e^2}$

c) v = $\sqrt{gR_e}$, where g = $\frac{GM_e}{R_e^2}$

d) v = $\sqrt{gh}$ where g = $\frac{GM_e}{R_e^2}$

6. The ratio of the velocity of sound in hydrogen and oxygen at STP is: **[1]**

a) 8 : 1

b) 4 : 1

c) 16 : 1

d) 2 : 1

7. A jet lands on an aircraft carrier at 63 m/s. What is its acceleration in m/s^2 if it stops in 2.0 s? **[1]**

a) -35

b) 34

c) -31.5

d) -33

8. A speeding motorcyclist sees traffic jam ahead of him. He slows down to 36 km/hour. He finds that traffic has eased and a car moving ahead of him at 18 km/hour is honking at a frequency of 1392 Hz. If the speed of sound is 343 m/s, the frequency of the honk as heard by him will be **[1]**

a) 1372 Hz

b) 1412 Hz

c) 1454 Hz

d) 1332 Hz

9. Water rises to a height of 16.3 cm in a capillary of height 18 cm above the water level. If the tube is suddenly cut at a height of 12 cm. **[1]**

a) the height of the water in the capillary will be 10.3 cm

b) water will stay at a height of 12 cm in the capillary tube

c) water will come as a fountain from the capillary tube

d) water will flow down the sides of the capillary tube

10. If the mass of earth is 80 times of that of moon and its diameter is double that of moon and g on earth is 98 m/sec^2, then the value of g on moon is: **[1]**

a) $9.8\ m/s^2$

b) $0.98\ m/s^2$

c) $4.9\ m/s^2$

d) $0.49\ m/s^2$

11. Two wheels having radii in the ratio 1 : 3 are connected by a common belt. If the smaller wheel is accelerated from rest at a rate 1.5 $rads^{-2}$ for 10 s, find the velocity of bigger wheel. **[1]**

a) 15 $rads^{-1}$

b) none of these

c) 45 $rads^{-1}$

d) 5 $rads^{-1}$

12. Temperatures of two stars are in ratio 3 : 2. If wavelength of maximum intensity of first body is 4000 $\overset{o}{A}$, what is corresponding wavelength of second body? **[1]**

a) 2000 $\overset{o}{A}$

b) 8000 $\overset{o}{A}$

c) 6000 $\overset{o}{A}$

d) 9000 $\overset{o}{A}$

13. **Assertion:** Work done by static friction may be positive. **[1]**

Reason: Static friction may acts along the direction of motion of an object.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

14. **Assertion:** It is not possible for a system, unaided by an external agency to transfer heat from a body at lower temperature to another body at a higher temperature. **[1]**

Reason: According to Clausius statement "No process is possible whose sole result is the transfer of heat from a cooled object to a hotter object."

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** The value of acceleration due to gravity does not depend upon the mass of the body. **[1]**

Reason (R): Acceleration due to gravity is a constant quantity.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

16. **Assertion (A):** If $\vec{\mathbf{A}} \times \vec{\mathbf{B}} = \vec{\mathbf{A}} \times \vec{\mathbf{C}}$, then $\vec{\mathbf{C}}$ need not be equal to $\vec{\mathbf{B}}$. **[1]**

Reason (R): The cross product of two vectors depend upon the angle between them.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

17. One end of a long string of linear mass density 8.0×10^{-3} kg m^{-1} is connected to an electrically driven tunning folk of frequency 256 H_Z. The other end passes over a pulley and is tied to a pan containing a mass of 90 kg. The pulley end absorbs all the incoming energy so that reflected waves at this end have negligible amplitude. At t = 0, the left end of the string x = 0 has zero transverse displacement (y = 0) and is mowing along positive y-direction. The amplitude of the wave is 5.0 cm. Write down the transverse displacement y as a function of x and t that describes the Wave on the string. **[2]**

18. Consider a simple pendulum, having a bob attached to a string, that oscillates under the action of the force of gravity. Suppose that the period of oscillation of the simple pendulum depends on its length (l), mass of the bob (m) and acceleration due to gravity (g). Derive the expression for its time period using method of dimensions. **[2]**

19. Let us consider an equation $\frac{1}{2}mv^2 = mgh$ where m is the mass of the body, v its velocity, g is the acceleration due to gravity, and h is the height. Check whether this equation is dimensionally correct. **[2]**

20. A circular racetrack of radius 300 m is banked at an angle of 15°. If the coefficient of friction between the wheels of a race-car and the road is 0.2, what is the **[2]**

a. optimum speed of the racecar to avoid wear and tear on its tyres, and
b. maximum permissible speed to avoid slipping?

21. Show that for a two-particle system $\vec{F}_{12} = \vec{F}_{21}$. **[2]**

OR

Calculate the escape speed of a body from the solar system from the following data:

i. Mass of the sun = 2×10^{30} kg.
ii. Separation of the earth from the sun = 1.5×10^{11} m.

Section C

22. A freshwater reservoir is 10 m deep. A horizontal pipe 2 cm in diameter passes through the reservoir 8.0 m below the water surface. A plug secures the pipe opening. At a certain time the plug is removed. What volume of water flows out of the pipe in 1 h? Assume cross-section area of the reservoir to be too large. **[3]**

23. A certain substance has a mass of 50 g/mole. When 300 J of heat is added to 25g of sample of this material, its temperature rises from 25^{o}C to 45^{o}C. Calculate **[3]**

i. the thermal capacity,
ii. specific heat capacity, and
iii. molar heat capacity of the sample.

24. A three-wheeler starts from rest, accelerates uniformly with 1 ms^{-2} on a straight road for 10 sec, and then moves with uniform velocity. Plot a graph between the distance covered by the vehicle during the nth second (n = 1,2, 3,...) versus n. What do you expect the plot to be during accelerated motion, a straight line or a parabola? **[3]**

25. Explain: **[3]**

i. Why are ball bearings used in machinery?
ii. Why does a horse have to apply more force to start a cart than to keep it moving?
iii. What is the need for banking the tracks?

26. A gas can have any value of specific heat depending upon how heating is carried out. Explain? **[3]**

27. A 100 kg gun fires a ball of 1 kg horizontally from a cliff of height 500 m. It falls on the ground at a distance of 400 m from the bottom of the cliff. Find the recoil velocity of the gun. (acceleration due to gravity = 10 ms^{-2}). **[3]**

28. The manual of a car instructs the owner to inflate the tyres to a pressure of 200 kPa. **[3]**

i. What is the recommended gauge pressure?
ii. What is the recommended absolute pressure?
iii. If after the required inflation of the tyres, the car is driven to a mountain peak where the atmospheric pressure is 10% below that at sea level, what will the tyre gauge read?

OR

Briefly explain Magnus effect.

Section D

29. **Read the text carefully and answer the questions:** **[4]**

Certain collisions are referred to as elastic collisions. Elastic collisions are collisions in which both momentum and kinetic energy are conserved. The total system kinetic energy before the collision equals the total system kinetic energy after the collision. If total kinetic energy is not conserved, then the collision is referred to as an inelastic collision.

The coefficient of restitution, denoted by (e), is the measure of degree elasticity of collision. It is defined as the ratio of the final to inital relative speed between two objects after they collide. It normally ranges from 0 to 1 where 1 would be a perfectly elastic collision. A perfectly inelastic collision has a coefficient of 0. In real life most of the collisions are neither perfectly elastic nor perfectly inealstic and $0 < e < 1$.

(i) The following are the data of a collision between a truck and a car.

Mass of the car = 1000 kg

Mass of the truck = 3000 kg

Mass of the truck Before collision:

Speed of the car = 20 m/s

Momentum of the car = 20000 kg m/s

Speed of the truck = 20 m/s

Momentum of the truck = 60000 kg m/s

After collision:

Speed of the car = 40 m/s in the opposite direction

Momentum of the car = 40000 kg m/s in the opposite direction

Speed of the truck = 0

Momentum of the truck = 0

The collision is

a) Both elastic since kinetic energy and momentum is conserved
b) Elastic since momentum is conserved
c) Inelastic since kinetic energy is conserved
d) Elastic since kinetic energy is conserved

(ii) The coefficient of restitution is the measure of

a) Malleability of a substance
b) Conductivity of a substance
c) degree of elasticity of collision
d) Elasticity of a substance

(iii) Coefficient of restitution is defined as

a) $\frac{\text{Relative velocity before collision}}{\text{Relative velocity after collision}}$
b) Relative velocity after collision $\times$ relative velocity before collision
c) None of these
d) $\frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}}$

OR

In real life most of the collisions are

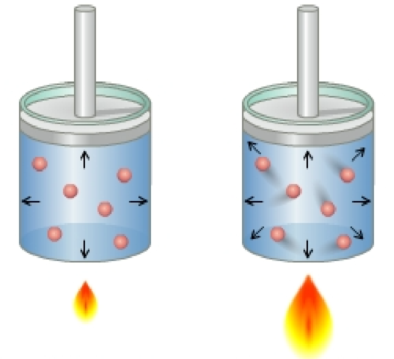
a) Range of coefficient of restitution is $0 < e < 1$
b) both neither perfectly nor perfectly inelastic and range of coefficient of restitution is $0 < e < 1$.
c) neither perfectly elastic nor perfectly inelastic
d) perfectly inelastic

(iv) For perfectly elastic and perfectly inelastic collision, the value of coefficient of restitution are respectively

a) +1, -1
b) 0, 1
c) 0, -1
d) 1, 0

30. **Read the text carefully and answer the questions:** **[4]**

In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



(i) If the temperature of the gas increases from 300 K to 600 K then the average kinetic energy becomes:

a) same
b) becomes double
c) becomes half
d) none of these

(ii) What is the average velocity of the molecules of an ideal gas?

a) Infinite
b) Same
c) None of these
d) Zero

(iii) Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will ________.

a) decrease
b) none of these
c) increase
d) remains same

(iv) Find the ratio of average kinetic energy per molecule of Oxygen and Hydrogen:

a) 1:1
b) 4:1
c) 1:2
d) 1:4

OR

The velocities of the three molecules are 3v, 4v, and 5v. calculate their root mean square velocity?

a) 4.0 v
b) 4.02 v
c) 4.08 v
d) 4.04 v

Section E

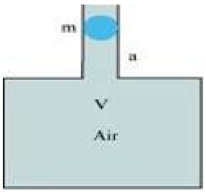
31. A person normally weighing 50 kg stands on a mass less platform which oscillates up and down harmonically at a frequency of 2.0 s^{-1} and an amplitude 5.0 cm. A weighing machine on the platform gives the persons weight against time. **[5]**

i. Will there be any change in weight of the body, during the oscillation? Figure In extensible string.

ii. If answer to part (a) is yes, what will be the maximum and minimum reading in the machine and at which position?

OR

An air chamber of volume V has a neck area of cross section a into which a ball of mass m just fits and can move up and down without any friction (Figure). Show that when the ball is pressed down a little and released, it executes SHM. Obtain an expression for the time period of oscillations assuming pressure-volume variations of air to be isothermal.



32. State the parallelogram law of vector addition and find the magnitude and direction of the resultant of two vectors $\vec{P}$ and $\vec{Q}$ inclined at an angle θ with each other. What happens, when θ = 0° and θ = 90°? **[5]**

OR

Establish the following inequalities geometrically or otherwise

i. $|\vec{A}+\vec{B}| \leq |\vec{A}|+|\vec{B}|$
ii. $|\vec{A}+\vec{B}| \geq ||\vec{A}|-|\vec{B}||$
iii. $|\vec{A}-\vec{B}| \leq |\vec{A}|+|\vec{B}|$
iv. $|\vec{A}-\vec{B}| \geq ||\vec{A}|-|\vec{B}||$

When does equality sign above apply?

33. Define centre of mass. Derive an expression for the centre of mass of a two-particle system. Show that the centre of mass of two-particle system of equal masses lies at the centre of the line joining them. **[5]**

OR

Calculate the moment of inertia of uniform circular disc of mass 500 g, radius 10 cm about

i. diameter of the disc
ii. the axis tangent to the disc and parallel to its diameter and
iii. the axis through the centre of the disc and perpendicular to its plane.

Solution

Section A

1. **(a)** Force and impulse

   Explanation: [Force] = [MLT^{-2}], [Impulse] = [MLT^{-1}]

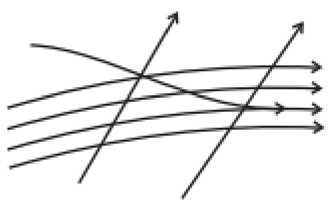
2. **(c)** 330 Hz

   Explanation: 330 Hz

3. **(d)** $\frac{2m}{3}$

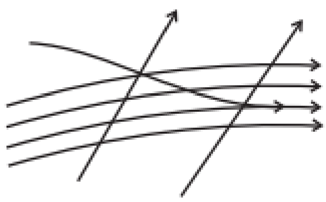
   Explanation: Reduced mass

   $= \frac{m \times 2m}{m+2m} = \frac{2m}{3}$

4. **(c)** 

   Explanation:

   The following diagram does not represent a streamline flow.

   A streamline can be straight or curved and tangent at which gives the direction of the flow.

   As two streamlines cannot cross each other, the given diagram does not represent a streamline.

5. **(a)** v = $\sqrt{gR_e}$, where g = $\frac{GM_e}{R_e^2}$

   Explanation: Orbital velocity of satellite, v = $\sqrt{\frac{GM_e}{(R_e+h)}}$

   If the satellite is close to the surface of the earth, h = 0

   $\Rightarrow$ v = $\sqrt{\frac{GM_e}{R_e}}$ $\Rightarrow$ v = $\sqrt{\left(\frac{GM_e}{R_e^2}\right) R_e}$

   = $\sqrt{gR_e}$ [$\because$ g = $\frac{GM_e}{R_e^2}$]

6. **(b)** 4 : 1

   Explanation: $v = \sqrt{\frac{\gamma RT}{M}}$

   Y is same as both hydrogen and oxygen are diatomic.

   $\therefore v \propto \sqrt{\frac{1}{M}}$

   or $\frac{v_{\mathrm{H}}}{v_{\mathrm{O}}} = \sqrt{\frac{M_{\mathrm{O}}}{M_{\mathrm{H}}}} = \sqrt{\frac{16}{1}} = \frac{4}{1}$

7.

(c) -31.5

Explanation: Initial velocity, u = 63 m/s

As it stops, so final velocity, v = 0 m/s

Time t = 2.0 s

We know that, v - u = at

$|\Rightarrow a=\frac{v-u}{t}$

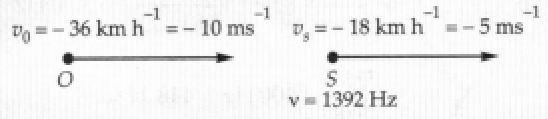
$\Rightarrow a=\frac{0-63}{2}$

$\Rightarrow a=-31.5\ m/s^2$

8.

(b) 1412 Hz

Explanation:



$v'=\frac{v-v_0}{v-v_s}\times v=\frac{343+10}{343+5}\times$ 1392 Hz

= $\frac{353}{348}\times$ 1392 Hz = 1412 Hz

9.

(d) water will flow down the sides of the capillary tube

Explanation: The height of a liquid in a capillary is given by

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

But if the capillary tube is of a length less than h the liquid does not overflow or came out if it is cut suddenly. The angle made by the liquid surface with the tube changes in such a way that force due to the surface of tube on the surface of the liquid $F=2\pi\ rS\ \cos\ \theta$ equals the weight of the liquid raised.

10.

(d) 0.49 m/s^2

Explanation: For earth, g = $\frac{GM}{R^2}$ = 9.8 ms^{-2}

For moon, $g'=\frac{G(\frac{M}{80})}{(\frac{R}{2})^2}=\frac{1}{20}\frac{GM}{R^2}$

= $\frac{1}{20}\times$ = 0.49 m/s^2

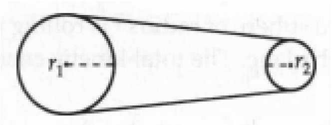
11.

(d) 5 rads^{-1}

Explanation:

For smaller wheel,

$\omega_1=\omega_0+\alpha t=0+1.5\times$ 10 = 15 rads^{-1}



As both the wheels are connected by a belt, they have common linear velocity,

$v_1 = v_2$

$r_1\omega_1=r_2\omega_2$

$\omega_2=\frac{r_1}{r_2}\cdot\omega_1=\frac{1}{3}\times 15$

= 5 rad s^{-1}

12.

(c) 6000 $\overset{o}{A}$

Explanation: $\frac{\lambda'_m}{\lambda_m}=\frac{T}{T'}=\frac{3}{2}$

$\lambda'_m = \frac{3}{2}\lambda_m = \frac{3}{2} \times 4000$

$= 6000\ \overset{o}{A}$.

13. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

14. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation: Second law of thermodynamics can be explained with the help of example of refrigerator, as we know that refrigerator, the working substance extracts heat from colder body and rejects a large amount of heat to a hotter body with the help of an external agency, i. e, the electric supply of the refrigerator. No refrigerator can ever work without external supply of electric energy to it.

15.

(c) A is true but R is false.

Explanation: Acceleration due to gravity is given by g = $\frac{GM}{R^2}$

Thus it does not depend on the mass of the body on which it is acting. Also, it is not a constant quantity change with a change in the value of both M and R (distance between two bodies). Even for the earth, it is a constant only near the earth's surface.

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

Explanation: Both A and R are true and R is the correct explanation of A.

Section B

17. The wave is travelling along x-axis and its equation is given by

$y = a\sin\frac{2\pi}{\lambda}(vt - x) = a\sin\left(\frac{2\pi}{\lambda}vt - \frac{2\pi}{\lambda}x\right)$

$y = a\sin(2\pi ut - kx) = a\sin(\omega t - kx)$

To determine a, ω and k:

a = 5.0 cm = 0.05m, υ = 256 Hz

w = 2πv = $2\pi \times 256 = 1.61 \times 10^3\ s^{-1}$

m = $8.0 \times 10^{-3}\ kg\ m^{-1}$, T = 90×9.8N

$v = \sqrt{\frac{T}{m}} = \sqrt{\frac{90\times 9.8}{8.0\times 10^{-3}}} = 332ms^{-1}$

$\therefore \quad \lambda = \frac{v}{\upsilon} = \frac{332}{256} = 1.297\text{m}$

and $k = \frac{2\pi}{\lambda} = \frac{2\pi}{1.297} = 4.84\text{m}^{-1}$

substituting for a, ω and k in e.q. (i) we have

y = 0.05 sin (1.61×10^3 t - 4.84x)

Here, x, y are in metre and t is in second.

18. Let us assume that T $\propto m^a l^b g^c$

or, T = $km^al^bg^c$ ...(i)

where, k is a dimensionless constant.

The dimensions of various quantities are

[T] = T, [m] = M,

[l] = L, and [g] = LT^{-2}

Substitute these values in Eq.(i), we obtain

T = $[M]^a[L]^b[LT^{-2}]^c$

or, $M^0L^0T^1 = M^aL^{b+c}T^{-2c}$

Now equate the powers of M, L and T on both sides, we obtain

a = 0, b + c = 0, -2c = 1

On solving, a = 0, $b = \frac{1}{2}, \quad c = -\frac{1}{2}$

$\therefore T = km^0 l^{1/2} \text{g}^{-1/2} = k\sqrt{\frac{l}{g}}$

From experiments, k = 2π

Therefore, T = $2\pi\sqrt{\frac{l}{g}}$, which is the required expression.

19. The dimensions of LHS are

$[M]\ [L\ T^{-1}]^2 = [M]\ [L^2\ T^{-2}]$

$= [M\ L^2\ T^{-2}]$

The dimensions of RHS are [M][L T^{-2}] [L] = [M][L^2 T^{-2}]

= [M L^2 T^{-2}]

The dimensions of LHS and RHS are the same and hence the equation is dimensionally correct.

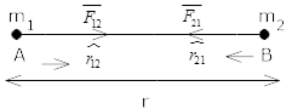
20. On a banked road, the horizontal component and the frictional force contribute to providing centripetal force to keep the car moving on a circular turn without slipping. At the optimum speed, the normal reaction's component is enough to provide the needed centripetal force, and the frictional force is not needed. The optimum speed v_o is given by Eq. $v_o = (Rg\tan\theta)^{1/2}$

Here R = 300m, $\theta = 15^\circ$, g = 9.8 ms^{-2}; We have $v_o = 28.1 \text{ms}^{-1}$

The maximum permissible speed $v_{\max}$ is given by eq. $v_{\max} = \left(Rg\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}\right)^{1/2}$ =38.1 ms^{-1}

.....

21. $\overrightarrow{F_{12}} = \frac{Gm_1m_2}{r^2}\widehat{r_{21}}$ ......(1)



$\overrightarrow{F_{21}} = \frac{Gm_1m_2}{r^2}\widehat{r_{12}}$ ....(2)

& (1) and (2) cam be written as $\left(\hat{a} = \frac{\hat{a}}{1a1}\right)$

$\overrightarrow{F_{12}} = \frac{Gm_1m_2}{r^3}\overrightarrow{r_{21}}$

$\overrightarrow{F_{21}} = \frac{Gm_1m_2}{r^3}\overrightarrow{r_{12}}$

Since $\overrightarrow{r_{12}} = \overrightarrow{r_{21}}$

$\rightarrow \overrightarrow{F_{21}} = \frac{-Gm_1m_2}{r^3}\overrightarrow{r_{21}}$

$\rightarrow \overrightarrow{F_{21}} = -\overrightarrow{F_{12}}$

Hence proved.

OR

Suppose M be the mass of the sun and R be the distance of the earth from the sun, then escape velocity,

$v_e = \sqrt{\frac{2GM}{R}}$ = $\sqrt{\frac{2\times6.67\times10^{-11}\times2\times10^{30}}{1.5\times10^{11}}}$ ms^{-1}

= $\sqrt{\frac{4\times6.67}{1.5}}$ $\times$ $10^4 ms^{-1} = 4.217 \times 10^4 ms^{-1}$

$v_e = 42.17\ kms^{-1}$

$\therefore$ The escape speed for the solar system is $42.17\ kms^{-1}$

Section C

22. When the plug is removed

velocity of efflux v $= \sqrt{2gh}$

Here, $h = 8.0m$, $\therefore v = \sqrt{2\times9.8\times8} = 12.52 \text{ms}^{-1}$

$\therefore$ Rate of volume flow of water = $Av = \frac{\pi d^2}{4}v$

The rate of flow of water may be taken as to be uniform throughout as cross-section area of reservoir is too large,

$\therefore$ amount of water flown in time t $= 1h = 3600s$

$V = Avt = \frac{\pi d^2}{4}vt = \frac{3.140\times(0.02)^2\times12.52\times3600}{4}$

$= 14.2m^3$

23. i. Total heat supplied to sample ΔQ = 300 J and rise in temperature ΔT = T_2 - T_1 = 45 - 25 = 20°C

$\therefore$ Thermal capacity of substance is given as = $\frac{\Delta Q}{\Delta T} = \frac{300}{20}$ = 15 J^oC^{-1}

ii. mass, m = 25 g = 0.025 kg

$\therefore$ Specific heat capacity, c = $\frac{1}{m}\cdot\frac{\Delta Q}{\Delta T}$ = $\frac{1}{0.025}$ $\times$ 15 = 600 Jkg^{-1} $^oC^{-1}$

iii. Number of moles in 25 g sample of 50 g/mol is

$\mu = \frac{25}{50} = 0.5$ moles

$\therefore$ Molar heat capacity C = $\frac{1}{\mu}\frac{\Delta Q}{\Delta T}$ = $\frac{1}{0.5}$ $\times$ 15 = 30 $Jmol^{-1}$ $^0C^{-1}$.

24. Given that, u = 0, a = 1 ms^{-2}

The distance covered in nth second is,

$D_n = u + \frac{a}{2}(2n - 1)$

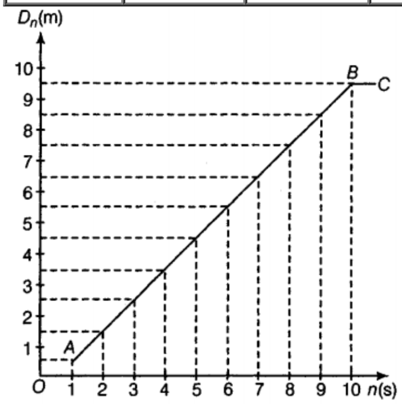
$D_n = 0 + \frac{1}{2}(2n - 1)$

$= 0.5(2n - 1)$

Putting n = 1, 2, 3......., we can find the value of D_n.

The various values of n and corresponding values of D_n are shown below.

n	1	2	3	4	5	6	7	8	9	10
D_n	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5



On plotting a graph between D_n and n, we get a straight line AB as shown in the figure. Upto 10 sec, during accelerated uniform motion, the graph remains straight line inclined with some angle w.r.t. time axis.

After 10 sec, the automobile moves with uniform velocity, hence the graph becomes a straight line BC parallel to the time axis.

25. i. By using ball bearings between the moving parts of a machinery, the sliding friction gets converted into rolling friction. The rolling friction is much smaller than sliding friction. This reduces power dissipation.

ii. When the horse cart is stationary, the muscular force provided by the horse is used to overcome the static friction as well as to provide acceleration to the cart.

As the cart begins to move, the friction becomes lesser since it is rolling friction and the muscular force of the horse is utilised to only overcome this friction.

Hence, initially to set the cart in motion, the horse needs to do more work than, when the cart is in motion.

iii. When the circular track is banked, the horizontal component of the normal reaction of the road provides the necessary centripetal force for the vehicle to move it along the curved path. This reduces wear and tear of the tyres.

26. Yes, specific heat of gas depends on thermodynamic processes as given below,

If m = Mass of gas

Q = heat supplied

ΔT = Change in temperature

f = Degree of freedom

1) For the Isobaric process (ΔP = 0)

$C_p = (\frac{f}{2} + 1)R$

2) For isochoric process (ΔV = 0)

$C_v = \frac{fR}{2}$

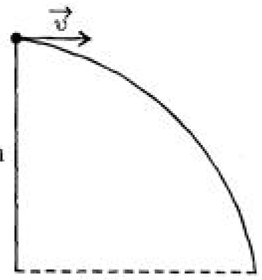
3) For Isothermal process ($\Delta T = 0$)

$C = \frac{Q}{m\Delta T} = \frac{Q}{m \times 0} = infinite$

4) For Adiabatic process ($\Delta Q = 0$)

$C = \frac{\Delta Q}{m\Delta T} = 0$

Hence, depending upon conditions of heating. The value of C will be different.

27. 

Let the horizontal speed of the ball is ums^{-1} its vertical component will be zero.
Consider the motion off ball vertically downward
Here, mass of ball, m_b=1kg, Mass of gun, M_G = 100 kg

u_b = initial velocity of ball,

v_b = final velocity of ball,

v_g = final velocity of gun

u = 0, s = h = 500 m, g = 10 s m^{-2}
$s = ut + \frac{1}{2}at^2$
$500 = a \times t + \frac{1}{2} \times 10t^2 \Rightarrow t^2 = \frac{500}{5} = 100$
$t = \sqrt{100} = 10$ sec
Horizontal distance covered by the ball is $x = u \times 10$
$400 = v \times 10 \Rightarrow v = 40m/\text{sec}$
By the law of conservation of momentum
$m_b u_j + M_G u_g = m_b v_b + M_G v_G$
$\Rightarrow m_b \times 0 + M_G \times 0 = 1 \times 40 + 100 v_G$
100 v_G = - 40

Recoil velocity of Gun= $\frac{-40}{100} ms^{-1} = \frac{-2}{5} ms^{-1}$ = - 0.4 ms^{-1} i.e opposite to the speed of ball.

28. i. Recommended gauge pressure = Pressure recommended in the manual P_g = 200kPa.

ii. Recommended absolute pressure P = P_a + P_g = 101 kPa + 200 kPa = 301 kPa.

[∴ Atmospheric pressure $P_a = 1.01 \times 10^5$ Pa = 101 kPa]

iii. At the mountain peak the atmospheric pressure is 10% below that at sea level, hence new atmospheric pressure

$P'_a = \frac{90}{100} \times 101$ kPa = 91 kPa.

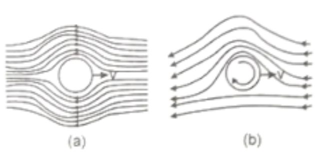
Presuming that the absolute pressure in the tyre has not changed during the drive, the new gauge pressure

$P'_g = P - P'_a$ = 301 kPa - 91 kPa = 210 kPa.

OR

Magnus effect, generation of a sidewise force on a spinning cylindrical or spherical solid immersed in a fluid (liquid or gas) when there is relative motion between the spinning body and the fluid. It is responsible for the “curve” of a served tennis ball or a driven golf ball and affects the trajectory of a spinning artillery shell.

A spinning object moving through a fluid departs from its straight path because of pressure differences that develop in the fluid as a result of velocity changes induced by the spinning body. The Magnus effect is a particular manifestation of Bernoulli's theroem, fluid pressure decreases at points where the speed of the fluid increases. In the case of a ball spinning through the air, the turning ball drags some of the air around with it. Viewed from the position of the ball, the air is rushing by on all sides. The drag of the side of the ball turning into the air (into the direction the ball is traveling) retards the airflow, whereas on the other side the drag speeds up the airflow. Greater pressure on the side where the airflow is slowed down forces the ball in the direction of the low-pressure region on the opposite side, where a relative increase in airflow occurs.



Section D

29. **Read the text carefully and answer the questions:**

Certain collisions are referred to as elastic collisions. Elastic collisions are collisions in which both momentum and kinetic energy are conserved. The total system kinetic energy before the collision equals the total system kinetic energy after the collision. If total kinetic energy is not conserved, then the collision is referred to as an inelastic collision.

The coefficient of restitution, denoted by (e), is the measure of degree elasticity of collision. It is defined as the ratio of the final to inital relative speed between two objects after they collide. It normally ranges from 0 to 1 where 1 would be a perfectly elastic collision. A perfectly inelastic collision has a coefficient of 0. In real life most of the collisions are neither perfectly elastic nor perfectly inealstic and 0 < e < 1.

(i) **(b)** Elastic since momentum is conserved

Explanation: From the given data kinetic energy is 800000 Joules, before and after collision and momentum is 40000 kg m/s before and after the collision. So the collision is elastic.

(ii) **(c)** degree of elasticity of collision

Explanation: degree of elasticity of collision

(iii) **(d)** $\frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}}$

Explanation: $\frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}}$

OR

(b) both neither perfectly nor perfectly inelastic and range of coefficient of restitution is 0 < e < 1.

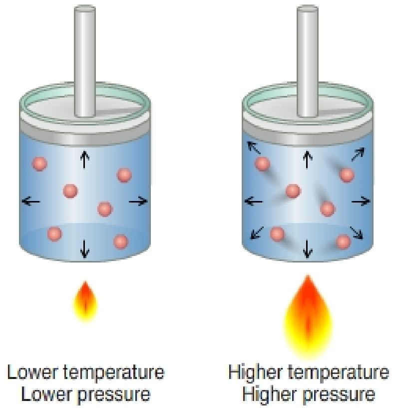
Explanation: both neither perfectly nor perfectly inelastic and range of coefficient of restitution is 0 < e < 1.

(iv) **(d)** 1, 0

Explanation: 1, 0

30. **Read the text carefully and answer the questions:**

In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



(i) **(b)** becomes double

Explanation: becomes double

(ii) **(d)** Zero

Explanation: Zero

(iii) **(d)** remains same

Explanation: remains same

(iv) **(a)** 1:1

Explanation: 1:1

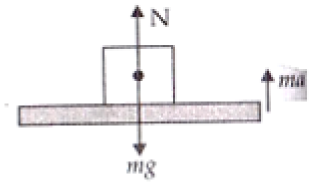
OR

(c) 4.08 v

Explanation: 4.08 v

Section E

31. a. Weight in weight machine will be due to the normal reaction (N) by platform. Consider the top position of platform, two forces acting on it are due to weight of person and oscillator. They both act downward.



(mg = weight of the person with the oscillator is acting downwards, ma = force due to oscillation is acting upwards, N = normal reaction force acting upwards)

Now for the downward motion of the system with an acceleration a,

ma = mg - N .....(i)

When platform lifts form its lowest position to upward

ma = N - mg ......(ii)

$a = \omega^2 A$ is value of acceleration of oscillator

$\therefore$ From equation (i) we get,

$N = mg - m\omega^2 A$

Where A is amplitude, ω angular frequency and m mass of oscillator.

$\omega = 2\pi\nu$

$\therefore \omega = 2\pi \times 2 = 4\pi\ rad/$sec

Again using $A = 5\ cm = 5 \times 10^{-2} m$ we get

$N = 50 \times 9.8 - 50 \times 4\pi \times 4\pi \times 5 \times 10^{-2}$

$= 50\left[9.8 - 16\pi^2 \times 5 \times 10^{-2}\right]$ N

$= 50\left[9.8 - 80 \times 3.14 \times 3.14 \times 10^{-2}\right]$ N

$\Rightarrow N = 50[9.8 - 7.89] = 50 \times 1.91 = 95.50$N

So minimum weight is 95.50 N(for downward motion of the platform)

From equation (ii), N – mg = ma

For upward motion from the lowest to the highest point of oscillator,

$N = mg + ma$

$= m\left[9.81 + \omega^2 A\right] \quad \because a = \omega^2 A$

$= 50\left[9.81 + 16\pi^2 \times 5 \times 10^{-2}\right]$

$= 50[9.81 + 7.89] = 50 \times 17.70$ N = 885 N

Hence, there is a change in weight of the body during oscillation.

b. The maximum weight is 885 N, when platform moves from lowest to upward direction.

And the minimum weight is 95.5 N, when platform moves from the highest point to downward direction.

OR

Given

$\Rightarrow$ Volume of the air chamber = V

$\Rightarrow$ Area of cross-section of the neck = a

$\Rightarrow$ Mass of the ball = m

The pressure inside the chamber is equal to the atmospheric pressure.

Let the ball be depressed by x units. As a result of this depression, there would be a decrease in the volume and an increase in the pressure inside the chamber.

Decrease in the volume of the air chamber, ΔV = ax

$\Rightarrow$ Volumetric strain $= \frac{\text{Change in volume}}{\text{Original valume}}$

$\Rightarrow \frac{\Delta V}{V} = \frac{ax}{V}$

$\Rightarrow$ Bulk Modulus of air, $B = \frac{\text{Stress}}{\text{Strain}} = \frac{-p}{\frac{ax}{V}}$

In this case, stress is the increase in pressure. The negative sign indicates that pressure increases with a decrease in volume.

$\Rightarrow p = \frac{-Bax}{V}$

$\Rightarrow$ The restoring force acting on the ball, F = p $\times$ a

$= \frac{-Ba^2x}{V}$

In simple harmonic motion, the equation for restoring force is:

$\Rightarrow$ F = -kx … (ii)

Where k is the spring constant

Comparing equations (i) and (ii), we get:

$= \frac{Ba^2}{V}$

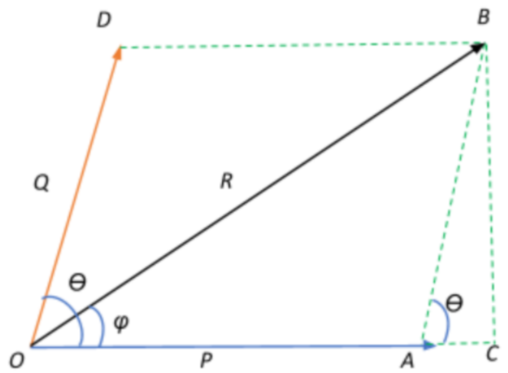
$\Rightarrow$ Time period, $T = 2\pi\sqrt{\frac{m}{k}}$

$= 2\pi\sqrt{\frac{Vm}{Ba^2}}$

32. Let us begin with the parallelogram law of vector addition.

The law states that if two vector quantities are represented by two adjacent sides of a parallelogram then the resultant of these two vectors will be the diagonal of the parallelogram.

Let us try and understand how this works:



Let the two vectors $\vec{P}$ and $\vec{Q}$ acting from the same point O be represented both in magnitude and direction as two adjacent sides OA and OD of a parallelogram OABD.

Let the angle between the two vectors be θ.

According to our definition of the parallelogram law of vector addition, the diagonal of the parallelogram OB represents the resultant of $\vec{P}$ and $\vec{Q}$. Thus, let the resultant of the two vectors be represented by $\vec{R}$ that is at an angle ϕ with $\vec{P}$.

$\vec{R} = \vec{P} + \vec{Q}$

The sides AB = OD = $|Q|$ and OA = BD = $|P|$ and diagonal OB = $|R|$

Consider the right angle triangle OBC. From the Pythagorean theorem.

$OB^2 = OC^2 + BC^2 = (OA + AC)^2 + BC^2$

Consider the triangle ABC:

$\cos\theta = \frac{AC}{AB}$ $\Rightarrow$ AC = AB cos θ = OD cos θ $\Rightarrow$ AC = $|Q|\cos\theta$

Also $\sin\theta = \frac{BC}{AB}$ $\Rightarrow$ BC = AB sin θ = OD sin θ $\Rightarrow$ BC = $|Q|\sin\theta$

Substituting the AC and BC expressions in the OB^2 Pythagorean theorem, we get:

$|R|^2 = (|P| + |Q|\cos\theta)^2 + (|Q|\sin\theta)^2 = |P|^2 + 2|P||Q|\cos\theta + |Q|^2\left(\cos^2\theta + \sin^2\theta\right) = |P|^2 + 2|P||Q|\cos\theta + |Q|^2$

Therefore, the magnitude of the resultant

$|R| = \sqrt{|P|^2 + 2|P||Q|\cos\theta + |Q|^2}$

Now let us find the direction of the resultant:

From triangle ABC $\tan\phi = \frac{BC}{OC} = \frac{BC}{OA+AC} = \frac{|Q|\sin\theta}{|P|+|Q|\cos\theta}$

Therefore, the direction of the resultant with respect to $\vec{P}$ is given by

$\phi = \tan^{-1}\left(\frac{|Q|\sin\theta}{|P|+|Q|\cos\theta}\right)$

We have thus obtained the magnitude and direction of the resultant $\vec{R}$

Now, when $\theta = 0°$:

$|R| = \sqrt{|P|^2 + 2|P||Q|\cos 0 + |Q|^2} = \sqrt{|P|^2 + 2|P||Q| + |Q|^2} = \sqrt{(|P| + |Q|)^2} \Rightarrow |R| = |P| + |Q|$

$\phi = \tan^{-1}\left(\frac{|Q|\sin 0}{|P|+|Q|\cos 0}\right) = \tan^{-1}(0) = 0$

Thus, in this case, the magnitude of the resultant vector will be the sum of the magnitudes of the adjacent vectors and the resultant lies in the direction of $\vec{P}$

And finally, when $\theta = 90^o$:

$|R| = \sqrt{|P|^2 + 2|P||Q|\cos 90 + |Q|^2} = \sqrt{|P|^2 + |Q|^2} = \sqrt{\left(|P|^2 + |Q|^2\right)}$

$\phi = \tan^{-1}\left(\frac{|Q|\sin 90}{|P|+|Q|\cos 90}\right) = \tan^{-1}\left(\frac{Q}{P}\right)$

(since $\sin 0^o = 0$, $\cos 0^o = 1$, $\sin 90^o = 1$, $\cos 90^o = 0$, $\tan 0^o = 0$)

OR

Consider two vectors $\vec{A}$ and $\vec{B}$ be represented by the sides $\overrightarrow{OP}$ and $\overrightarrow{OQ}$ of a parallelogram OPSQ. According to parallelogram law of vector addition, $(\vec{A}+\vec{B})$ will be represented by $\overrightarrow{OS}$ as shown in figure.

Thus, OP = $|\vec{A}|$, OQ = PS = $|\vec{B}|$

and OS = $|\vec{A}+\vec{B}|$

i. To prove $|\vec{A}+\vec{B}| \leq |\vec{A}|+|\vec{B}|$

We know that the length of one side of a triangle is always less than the sum of the lengths of the other two sides. Hence from $\triangle$QPS, we have

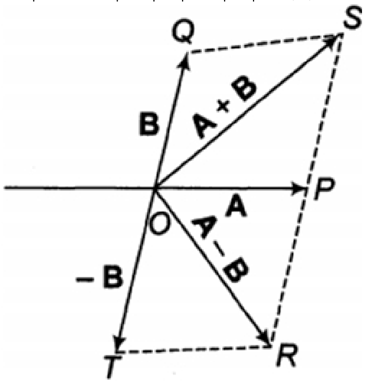
OS < OP + PS

$\Rightarrow$ OS < OP + OQ

or $|\vec{A}+\vec{B}| < |\vec{A}|+|\vec{B}|$ ...(i)

If the two vectors $\vec{A}$ and $\vec{B}$ are acting along the same straight line and in the same direction.

or $|\vec{A}+\vec{B}| = |\vec{A}|+|\vec{B}|$ ...(ii)



Combining the conditions mentioned in Eqs. (i) and (ii), we have $|\vec{A}+\vec{B}| \leq |\vec{A}|+|\vec{B}|$

ii. To prove $|\vec{A}+\vec{B}| \geq ||\vec{A}|+|\vec{B}||$

From $\triangle$OPS, we have

OS + PS > OP or OS > |OP - PS|

or OS > |OP - OQ| ...(iii) [$\because$ PS = OQ]

The modulus of (OP - PS) has been taken because the LHS is always positive but the RHS may be negative if OP < PS. Thus, from Eq. (iii) we have

$|\vec{A}+\vec{B}| > ||\vec{A}|-|\vec{B}||$ ...(iv)

If the two vectors **A** and **B** are acting along a straight line in opposite directions, then

$|\vec{A}+\vec{B}| = ||\vec{A}|-|\vec{B}||$ ...(v)

Combining the conditions mentioned in Eqs. (iv) and (v) we get $|\vec{A}+\vec{B}| \geq ||\vec{A}|-|\vec{B}||$

iii. To prove $|\vec{A}-\vec{B}| \leq |\vec{A}|+|\vec{B}|$

In figure, $\vec{A}$ = $(\overrightarrow{OP})$, $-\vec{B}$ = $\overrightarrow{OT}$ = $\overrightarrow{PR}$

and **(A - B)** = **OR**

From ΔORP, we note that OR < OP + PR.

or $|\vec{A}-\vec{B}| < |\vec{A}|+|\overrightarrow{-B}|$

or $|\vec{A}-\vec{B}| < |\vec{A}|+|\vec{B}|$ ...(vi)

If the two vectors are acting along a straight line. But in the opposite direction, then

$|\vec{A}-\vec{B}| = |\vec{A}|+|\vec{B}|$ ...(vii)

Combined the conditions mentioned in Eqs. (vi) and (vii), we get

$|\vec{A}-\vec{B}| \leq |\vec{A}|+|\vec{B}|$

iv. To prove $|\vec{A}-\vec{B}| \geq |\vec{A}|+|\vec{B}|$

In figure from ΔOPR, we note that [$\because$OT = PR]

OR + PR > OP or OR > |OP - PR|

or OR > |OP - OT| ...(viii)

The modulus of (OP - OT) has been taken because LHS is positive and RHS may be negative if OP < OT. From Eq. (viii), we have

$|\vec{A}-\vec{B}| > |\vec{A}|-|\vec{B}|$ ...(ix)

If the two vectors $\vec{A}$ and $\vec{B}$ are acting along the same straight line in the same direction, then

$|\vec{A}-\vec{B}| = |\vec{A}|-|\vec{B}|$ ...(x)

Combining the conditions mentioned in Eqs. (ix) and (x), we get $|\vec{A}-\vec{B}| \geq |\vec{A}|-|\vec{B}|$

33. Centre of mass of a two particle-system: Consider a system of two particles P_1 and P_2 of masses m_1 and m_2 Let $\vec{r}_1$ and $\overrightarrow{r_2}$ be their position vectors with respect to the origin O, as shown in Fig.

The position vector $\vec{R}_{CM}$ of the centre of mass C of the two-particle system is given by

$\vec{R}_{CM}=\frac{m_1\overrightarrow{r_1}+m_2\overrightarrow{r_2}}{m_1+m_2}$

i. The above equation shows that the position vector of the centre of mass a system of particles is the weighted average of the position vectors of the particles making the system, each particle making a contribution proportional to its mass.

ii. We can write the above equation as $(m_1+m_2)\vec{R}_{CM}=m_1\vec{r}_1+m_2\vec{r}_2$

Thus the product of the total mass of the system and the sum of the position vector of its centre of mass is equal to the products of individual masses and their respective vectors.

iii. If $m_1 = m_2 = m$ (say), then

$\vec{R}_{CM}=\frac{\overrightarrow{r_1}+\overrightarrow{r_2}}{2}$

Thus the centre of mass of two equal masses lies exactly at the centre of the line joining the two masses.

iv. If (x_1, y_1) and (x_2, y_2) are the coordinates of the locations of the two particles, the coordinates of their centre of mass are given by $x_{CM}=\frac{m_1x_1+m_2x_2}{m_1+m_2}$ and $y_{CM}=\frac{m_1y_1+m_2y_2}{m_1+m_2}$

OR

i. M.I. of the disc about any diameter,

$I_d=\frac{1}{4}MR^2=\frac{1}{4}\times 500\times(10)^2$ = 12500 g cm^2

ii. By theorem of parallel axes, M.I. of the disc about a tangent parallel to the diameter of the disc,

$I = I_d + MR^2$ = $I=I_d+MR^2=\frac{5}{4}MR^2=\frac{5}{4}\times 500\times(10)^2$

= 62500 g cm^2

iii. M.I. of the disc about an axis through its centre and perpendicular to its plane,

$I=\frac{1}{2}MR^2=\frac{1}{2}\times 500\times(10)^2$

= 25000 g cm^2