OBJECTIVE - I

1. Consider the following two equations :

(A) $\vec{R} = \frac{1}{M} \sum_i m_i \vec{r}_i$ and (B) $\vec{a}_{CM} = \frac{\vec{F}}{M}$.

In a non-inertial frame

(A) both are correct

(B) both are wrong

(C*) A is correct but B is wrong

(D) B is correct but A is wrong

Sol. *C*

In a noninertial frame, positing the particle is not change.

2. Consider the following two statements :

(a) linear momentum of the system remains constant

(b) centre of mass of the system remains at rest.

(A) a implies b and b implies a

(B) a does not imply b and b does not imply a

(C) a implies b but b does not imply a

(D*) b implies a but a does not imply b

Sol. *D*

Centre of mass of the system

$$\vec{R} = \frac{1}{M} \Sigma m_i \vec{r}_i$$

$$\frac{d\vec{R}}{dt} = 0 = \frac{1}{M} S\ m_i \vec{v}_i$$

It means linear momentum of the system remain constant.

3. Consider the following two statements :

(a)Linear momentum of the system of particles is zero

(b) Kinetic energy of a system of particles is zero

(A) a implies b and b implies a

(B) a does not imply b and b does not imply a

(C) a implies b but b does not imply a

(D*) b implies a but a does not imply a

Sol. *D*

Kinetic energy of the system = $1/2\ m_1 v_1^2 + 1/2\ m_2 v_2^2 + \ldots\ldots\ldots\ldots\ldots$

= zero

mean $v_1 = v_2 = v_3 = \ldots\ldots\ldots\ldots\ldots\ldots = 0$

Linear momentum of the system = $m_1 \vec{v}_1 + m_2 \vec{v}_2 + \ldots\ldots\ldots\ldots\ldots\ldots$

In this case $\vec{v}_1 \neq \vec{v}_2 \neq 0$

It is possible that $m_1 \vec{v}_1 = - m_2 \vec{v}_2$ (If two particle system)

4. Consider the following two statements :

(a) the linear momentum of a particle is independent of the frame of reference

(b) the kinetic energy of a particle is independent of the frame of reference

(A) both a and b are true (B) a is true but b is false

(C) a is false but b is true (D*) both a and b are false

Sol. *D*

Linear momentum & kinetic energy of a particle is dependent of the frame of reference. Because velocity is dependent on the frame of reference

Linear momentum = mv

K.E. = 1/2 mv^2

5. All the particles of a body are situated at a distance R from the origin. The distance of the centre of mass of the body from the origin is

(A) = R (B*) £ R (C*) > R (D) ³ R

Sol. *B*

Distance of centre of mass from the origin

$$R' = \frac{1}{M}\,\frac{S}{\ell}\,m_1\vec{r}_1$$

Half particle lies in y-axis

$$Þ \qquad y_{com} = \frac{m_3R\vec{j} + m_4R\vec{j} + \dots\dots\dots\dots}{m_1 + m_2 + m_3 + m_4 + \dots\dots\dots\dots}$$

$$= \frac{R\vec{j}}{2}$$

Coordinate of com is $\left(\frac{R}{2}, \frac{R}{2}\right)$

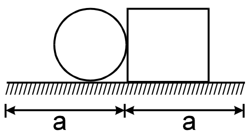
Distance centre mass from the origin = $\frac{R}{\sqrt{2}}$ .... (1)

R' < R

When conclude

Distance of centre of mass from the origin £ R

6. A circular plate of diameter d is kept in contact with a square plate of edge d as shown in figure. The density of the material and the thickness are same everywhere. The centre of mass of the composite system will be



(A) inside the circular plate (B) inside the square plate

(C) at the point of contact (D*) outside the system

Sol. *B*

$m_1 = dp\,(d/2)^2 t$ {t ® thichness}

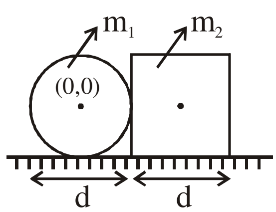
$m_2 = d\,d^2 t$ {mass = desily x volume}

Centre of mass of circular plate at centre. Lett the centre of circular plate is origin.

$$\vec{r}_1 = 0$$

Centre of mass of square plate at centre.

$$\vec{r}_2 = 2d$$



$$R = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2} = \frac{m_1 \times 0 + \delta d^2 t \times 2d}{\delta\pi(d/2)^2 t + \delta d^2 t}$$

$$R = \frac{2d}{\pi/4 + 1} = (1.12)\,d$$

R > d

Centre of mass of the system lies in the square plate.

7. Consider a system of two identical particles. One of the particles is at rest and the other has an acceleration $\vec{a}$. The centre of mass has an acceleration.

(A*) zero 'kwU; (B) $\frac{1}{2}\vec{a}$ (C) $\vec{a}$ (D*) $2\vec{a}$

Sol. *B*

$\underset{\text{rest}}{\overset{m}{\bullet}}$ $\overset{m}{\bullet}\longrightarrow \vec{a}$

Acceleration of centre of mass = $\dfrac{m_1\vec{a}_1 + m_2\vec{a}_2}{m_1 + m_2}$

$$= \frac{m \times 0 + m\vec{a}}{2m} = \frac{\vec{a}}{2}$$

8. Internal forces can change

(A) the linear momentum but not the kinetic energy

(B*) the kinetic energy but not the linear momentum

(C) linear momentum as well as kinetic energy

(D) neither the linear momentum nor the kinetic energy

(**Sol.** *B*

Internal forces can change the kinetic energy but not the linearmomentum.

Because the centre of mass of the system remains at rest.

9. A bullet hits a block kept at rest on a smooth horizontal surface and gets embedded into it. Which of the following does not change ?

(A) linear momentum of the block (B) kinetic energy of the block

(C*) gravitational potential energy of the block (D) temperature of the block

Sol. *C*

Initial position final position

$\underset{m_2}{\bullet}\longrightarrow v$ $\underset{m_1}{\overset{\text{(rest)}}{\bullet}}$ $\boxed{m_1+m_2}\longrightarrow v'$

Linear momentum conservation

$$m_1 \times 0 + m_2 v = (m_1 + m_2)\, v'$$

Þ $$v' = \frac{m_2 v}{m_1 + m_2}$$

Initial linear momentum of the block = $m_1 \times 0 = 0$

Final linear momentum of the block = $m_1 v'$

$$= \left(\frac{m_1 m_2}{m_1 + m_2} v\right)$$

Change in kinetic energy of the block = $K.E_f - K.E_i$

$$= 1/2\, m_1 v'^2 - 0$$

$$= 1/2\, m_1 \left(\frac{m_1 m_2}{m_1 + m_2} v\right)^2$$

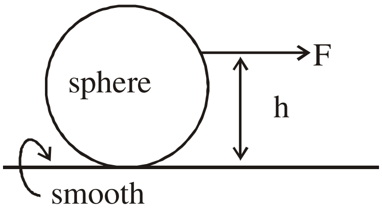
In this process energy temperature of the block increases. But gravitation potential energy of the block is remain same. Because height of the block is not change.

10. A uniform sphere is placed on a smooth horizontal surface and a horizontal force F is applied on it at a distance h above the surface. The acceleration of the centre

(A) is maximum when h = 0 (B) is maximum when h = R

(C) is maximum when h = 2R (D*) is independent of h

Sol. *D*



On smooth surface, sphere is only slip.

Acceleration of centre of sphere is = F/m which is independent of h.

11. A body falling vertically downwards under gravity breaks in two parts of unequal masses. The centre of mass of the two parts taken together shifts horizontally towards

(A) heavier piece

(B) lighter piece

(C*) does not shift horizontally

(D) depends on the vertical velocity at the time of breaking

Sol. *C*

A body falling vertically downwards under gravity breaks in two parts of unequal masses. The centre of mass of the system does not shift horizontally. As external horizontal force is zero.

12. A ball kept in a closed box moves in the box making collisions with the walls. The box is kept on a smooth surface. The velocity of the centre of mass

(A) of the box remains constant

(B*) of the box plus the ball system remains constant

(C) of the ball remains constant

(D) of the ball relative to the box remains constant

Sol. *B*

The velocity of the centre of masss of the system is ramains constant. (assume that collision will taken as perfectly elastic).

13. A body at rest breaks into two pieces of equal masses. The parts will move

(A) in same direction (B) along different lines

(C*) in opposite directions with equal speeds (D) in opposite directions with unequal speeds

Sol. *C*

By linear momentum conservation

$$p_i = p_f$$

$$m \times 0 = \frac{m}{2} v_1 + \frac{m}{2} v_2$$

$$v_1 = -v_2$$

14. A heavy ring of mass m is clamped on the periphery of a light circular disc. A small particle having equal mass is clamped at the centre of the disc. The system is rotated in such a way that the centre moves in a circle of radius r with a uniform speed v. We conclude that an external force

(A) $\frac{mv^2}{r}$ must be acting on the central particle (B) $\frac{2mv^2}{r}$ must be acting on the central particle

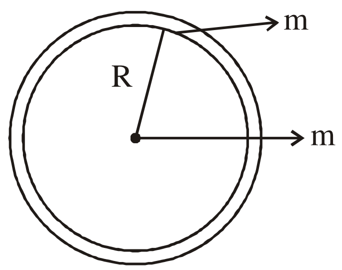
(C*) $\frac{2mv^2}{r}$ must be acting on the system (D) $\frac{2mv^2}{r}$ must be acting on the ring.

Sol. *C*

Centre of mass = $\dfrac{m \times 0 + m \times R}{2m} = \dfrac{R}{2}$

External force acting on the system = $\dfrac{mv^2}{r} = \dfrac{mv^2}{R/2}$

$= \dfrac{2mv^2}{R}$



15. The quantities remaining constant in a collision are

(A) momentum, kinetic energy and temperature

(B) momentum and kinetic energy but not temperature

(C) momentum and temperature but not kinetic energy

(D*) momentum, but neither kinetic energy nor temperature

Sol. *D*

After collision, linear momentun of the system is remain same.

Kinetic energy is not remain same because it depend upon the collision is perfectly elastic or in elastic.

16. A nucleus moving with a velocity $\vec{v}$ emits an a-particle. Let the velocities of the a-particle and the remaining nucleus be $\vec{v}_1$ and $\vec{v}_2$ must be parallel to be m_1 and m_2.

(A) $\vec{v}$, $\vec{v}_1$ and $\vec{v}_2$ must be parallel to each other

(B) None of the two of $\vec{v}$, $\vec{v}_1$ and $\vec{v}_2$ should be parallel to each other

(C) $\vec{v}_1$ and $\vec{v}_2$ must be parallel to $\vec{v}$

(D*) $m_1 \vec{v}_1 + m_2 \vec{v}_2$ must be parallel to $\vec{v}$

Sol. *D*

By linear momentum conservation

pi = pf

$= m_1\vec{v}_1 + m_2\vec{v}_2$

$m_1\vec{v}_1 + m_2\vec{v}_2$ must be parallel to $\vec{v}$.

17. A shell is fired from a canon with a velocity V at an angle q with the horizontal direction. At the highest point in its path, it explodes into two pieces of equal masses. One of the pieces retraces it path to the cannon. The speed of the other piece immediately after the explosion is

(A*) 3V cosq (B) 2V cosq (C) $\dfrac{3}{2}$ V cosq (D) V cosq

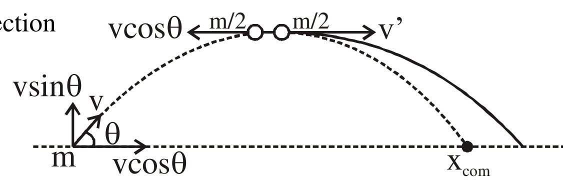
Sol. *A*

Linear momentum is conserved in horizontal direction

$p_i = p_f$

$mv \cos q = -\dfrac{m}{2} v \cos q + \dfrac{m}{2} v'$

$v' = 3 v \cos q$



18. In an elastic collision

(A*) the initial kinetic energy is equal to the final kinetic energy

(B) the final kinetic energy is less than the initial kinetic energy

(C) the kinetic energy remains constant

\+ (D) the kinetic energy first increases then decreases.

Sol. *A*

In an elastic collision, no energy is loss into heat. So the final K.E. is euqal than the initial K.E.

19. In an inelastic collision

(A) the initial kinetic energy is equal to the final kinetic energy

(B*) the final kinetic energy is less than the initial kinetic energy

(C) the kinetic energy remains the constant

(D) the kinetic energy first increases then decreases

Sol. *B*

In an elastic collision, same energy is loss into heat. So the final K.E. is loss than the initial K.E.

OBJECTIVE - II

1. The centre of mass of a system of particles is at the origin. It follows that
(A) the number of particles to the right of the origin is equal to the number of particles to the left
(B) the total mass of the particles to the right of the origin is same as the total mass to the left of the origin
(C) the number of particles on X-axis should be equal to the number of particles on Y-axis.
(D) if there is a particle on the positive X-axis, there must be at least one particle on the negative X-axis.

Sol. D (none)

Product of the $m_i r_i$ of left side particle equal to the product of the of the $m_j r_j$ of right side particle.

$$R = \frac{1}{M} \; m_k r_k$$

$$O = \frac{1}{M} \; m_k r_k = \frac{1}{M} \left(\quad miri + \quad mjrj \right)$$

Þ $\quad m_i r_i = m_j r_j$

2. A body has its centre of mass at the origin. The x-coordinates of the particles
(A) may be all positive
(B) may be all negative
(C*) may be all non-negative
(D*) may be positive for some cases and negative in other cases

Sol. *CD*

$r_{COM}\,(0, 0)$ (Given)

$$X_{COM} = 0 = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3 ....}{m_1 + m_2 + m_3 + ...}$$

$m_1 x_1 + m_2 x_2 + m_3 x_3 + ... = 0$

May be all mom-negative mean its cansider –ve and zero. All –ve is not possible but all position is zero is posible.

3. In which of the following cases the centre of mass of a rod is certainly not at its centre ?
(A*) the density continuously increases from left to right
(B*) the density continuously decreases from left to right
(C) the density decreases from left to right upto the centre and then increases
(D) the density increases from left to right upto the centre and then decreases

Sol. *AB*

Centre of mass of a rod is not at its centre means mass of the rod varies according to length. Or we can say that density is continuously change according to length from left to right or right to left.

4. If the external forces acting on a system have zero resultant, the centre of mass
(A) must not move
(B*) must not accelerate
(C*) may move
(D) may accelerate

Sol. *BC*

Centre of mass of acceleration is zero. But it may be more uniformaly with costant velocity.

$$\text{Acceleration of centre of mass} = \frac{\vec{F}_{net}}{M} = 0$$

5. A nonzero external force acts on a system of particles. The velocity and the acceleration of the centre of mass are found to be v_0 and a_0 at an instant t. It is possible that

(A) $v_0 = 0$, $a_0 = 0$ (B*) $v_0 = 0$, a_0 ¹ 0 (C) v_0 ¹ 0, $a_0 = 0$ (D*) v_0 ¹ 0, a_0 ¹ 0

Sol. *BD*

A non zero external force acts on a system, that causes acceleration of centre of mass at an instant 't' is 'a_0' But velocity of centre of mass is v_0 or zero.

6. Two balls are thrown simultaneously in air. The acceleration of the centre of mass of the two balls while in air

(A) depends on the direction of the motion of the balls

(B) depends on the masses of the two balls

(C) depends on the speeds of the two balls

(D*) is equal to g

Sol. *D*

Acceleration of centre of mass $= \dfrac{m_1\vec{a}_1 + m_2\vec{a}_2}{m_1 + m_2}$

$$= \frac{m_1 g + m_2 g}{m_1 + m_2}$$

$$= g$$

7. A block moving in air breaks in two parts and the parts separate

(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 change

Sol. *AD*

A block moving in air & breaks in two parts then the total momentum must be conserved. But the total kinetic energy must change.

8. In an elastic collision

(A) the kinetic energy remains constant

(B*) the linear momentum remains constant

(C*) the final kinetic energy is equal to the initial kinetic energy

(D*) the final linear momentum is equal to the initial linear momentum

Sol. *BCD*

In a elastic collision

Þ The linear momentum remain constant

Þ The final linear momentum is equal to the initial linear momentum

Þ The final kinetic energy is equal to the initial kinetic energy.

9. A ball hits a floor and rebounds after an inelastic collision. In this case

(A) the momentum of the ball just after the collision is same as that just before the collision

(B) the mechanical energy of the ball remains the same during the collision

(C*) the total momentum of the ball and the earth is conserved

(D*) the total energy of the ball and the earth remains the same

Sol. *CD*

The total momentum of the system (earth + ball) is conserved.

The total energy of the ball is change but the total energy of the ball and the earth remains the same.

10. A body moving towards a finite body at rest collides with it. It is possible that

(A) both the bodies come to rest

(B*) both the bodies move after collision

(C*) the moving body comes to rest and the stationary body starts moving

(D) the stationary body remains stationary, the moving body changes its velocity.

Sol. *BC*

Before collision after collision

By linear momentum conservation $\Rightarrow$

$$p_i = p_f$$

$$m_1u = m_1v_1 + m_2v_2$$

$\Rightarrow$ $v_1 = v_2 \neq 0$

$\Rightarrow$ may be posible $v_1 = 0$ & $v_2 = \dfrac{m_1u}{m_2}$

11. In head on elastic collision of two bodies of equal masses

(A*) the velocities are interchanged

(B*) the speeds are interchanged

(C*) the momenta are interchanged

(D*) the faster body slows down and the slower body speeds up.

Sol. *ABCD*

Before collision

{Let $u_1 > u_2$}

After elastic collision

(By linear momentum conservation)

$\Rightarrow$ velocities are inter changed

$\Rightarrow$ speeds are inter changed

$\Rightarrow$ momenta are inter changed

$\Rightarrow$ faster body slows down and the slower body speed up.