Center of Mass and Collision

Question1

During an elastic collision between two bodies, which of the following statements are correct?

I. The initial kinetic energy is equal to the final kinetic energy of the system.

II. The linear momentum is conserved.

III. The kinetic energy during Δt (the collision time) is not conserved.

KCET 2025

Options:

A. II and III only

B. I and III only

C. I, II and III

D. I and II only

Answer: C

Solution:

I. Final total kinetic energy equals initial

II. Linear momentum is always conserved

III. During collision kinetic energy gets parthy converted to potential energy

$\therefore$ All statements are correct

Question2

Three particles of mass $1\ \mathrm{kg}$, $2\ \mathrm{kg}$ and 3 kg are placed at the vertices A, B and C respectively of an equilateral triangle ABC of side 1 m . The centre of mass of the system from vertex A (located at origin) is

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Options:

A. $\left(\frac{7}{12}, \frac{3\sqrt{3}}{12}\right)$

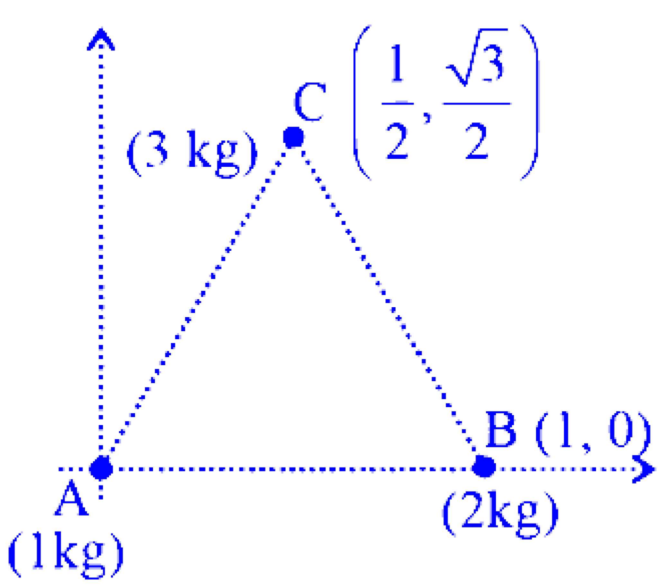
B. $\left(\frac{9}{12}, \frac{3\sqrt{3}}{12}\right)$

C. $\left(\frac{7}{12}, \frac{6+3\sqrt{3}}{12}\right)$

D. $(0, 0)$

Answer: A

Solution:



$$x_{cm} = \frac{\sum mixi}{\sum mi}$$

$$= \frac{1 \times 0 + 2 \times 1 + 3 \times \frac{1}{2}}{6} = \frac{7}{12}$$

$$y_{cm} = \frac{\sum miyi}{\sum mi} = \frac{1 \times 0 + 2 \times 0 + 3 \times \frac{\sqrt{3}}{2}}{6} = \frac{3\sqrt{3}}{12}$$

Question3

The centre of mass of an extended body on the surface of the earth and its centre of gravity

KCET 2022

Options:

A. are always at the same point only for spherical bodies.

B. can never be at the same point.

C. centre of mass coincides with the centre of gravity of a body if the size of the body is negligible as compared to the size (or radius) of the earth.

D. are always at the same point for any size of the body.

Answer: C

Solution:

The correct option is C: Centre of mass coincides with the centre of gravity of a body if the size of the body is negligible as compared to the size (or radius) of the earth.

The center of mass of an object is the point where the distribution of mass is balanced in all directions, and it is calculated using the positions and masses of the object's components. The center of mass is purely a function of the distribution of mass within the object and does not depend on external gravitational fields.

The center of gravity, on the other hand, is the point within an object from which the force of gravity appears to act. When the gravitational field is uniform, as it is often approximated to be close to the Earth's surface, the center of gravity falls directly on the center of mass.

For very large bodies or for those where the gravitational field is not uniform across the object, such as a large mountain near the Earth's pole, the center of gravity and center of mass may not coincide. This is because the center of gravity is influenced by the distribution of mass and the gradient of the gravitational field it is in.

Options A and D are incorrect because they make general assertions that do not take into account the uniformity of the gravitational field or the relative size of the body to the Earth.

Option B is also incorrect because the center of mass and center of gravity do coincide in common situations where bodies are small compared to the size of the Earth or when the gravitational field can be considered uniform. Although there may be specific cases where they do not coincide, this option states they "can never be at the same point" which is false as in many practical situations they are at the same point.

In summary, if the body is small relative to the Earth and the gravitational field can be approximated as uniform, the center of mass and center of gravity are effectively in the same location, which is the essence of option C.

Question4

A 1 kg ball moving at 12 ms^{-1} collides with a 2 kg ball moving in opposite direction at 24 ms^{-1}. If the coefficient of restitution is $2/3$, then their velocities after the collision are

KCET 2021

Options:

A. $-4 \text{ ms}^{-1}, -28 \text{ ms}^{-1}$

B. $-28 \text{ ms}^{-1}, -4 \text{ ms}^{-1}$

C. $4 \text{ ms}^{-1}, 28 \text{ ms}^{-1}$

D. $28 \text{ ms}^{-1}, 4 \text{ ms}^{-1}$

Answer: B

Solution:

Given the problem parameters:

Mass of the first ball, $m_1 = 1 \text{ kg}$

Initial velocity of the first ball, $u_1 = 12 \text{ m/s}$

Mass of the second ball, $m_2 = 2 \text{ kg}$

Initial velocity of the second ball, $u_2 = -24 \text{ m/s}$ (the negative sign indicates movement in the opposite direction)

Coefficient of restitution, $e = \frac{2}{3}$

The coefficient of restitution is defined as:

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

Plugging in the values:

$$\frac{2}{3} = \frac{v_2 - v_1}{12 + 24}$$

$$\frac{2}{3} = \frac{v_2 - v_1}{36}$$

Solving the above equation:

$$v_2 - v_1 = 24 \quad .... \text{(i)}$$

Next, we apply the law of conservation of momentum, which states that the initial momentum equals the final momentum:

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Substitute the known values:

$$1 \times 12 + 2 \times (-24) = 1 \times v_1 + 2 \times v_2$$

$$12 - 48 = v_1 + 2v_2$$

$$v_1 + 2v_2 = -36 \quad .... \text{(ii)}$$

Now, solving equations (i) and (ii) together:

From equation (i):

$$v_2 - v_1 = 24$$

$$v_2 = v_1 + 24$$

Substitute $v_2 = v_1 + 24$ into equation (ii):

$$v_1 + 2(v_1 + 24) = -36$$

$$v_1 + 2v_1 + 48 = -36$$

$$3v_1 + 48 = -36$$

$$3v_1 = -36 - 48$$

$$3v_1 = -84$$

$$v_1 = -28 \, \text{m/s}$$

Using $v_1 = -28 \, \text{m/s}$ in equation (i):

$$v_2 - (-28) = 24$$

$$v_2 + 28 = 24$$

$$v_2 = 24 - 28$$

$$v_2 = -4 \, \text{m/s}$$

Therefore, the velocities after the collision are:

Velocity of the first ball, $v_1 = -28\,\text{m/s}$

Velocity of the second ball, $v_2 = -4\,\text{m/s}$

Question5

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

KCET 2021

Options:

A. the momentum of the ball is conserved

B. the mechanical energy of the ball is conserved

C. the total momentum of the ball and the earth is conserved

D. the total mechanical energy of the ball and the earth is conserved

Answer: C

Solution:

When the net external force on the system is zero, the total momentum of the system is conserved.

In the given case, when a ball hits the floor and rebounds, no external force is acting on them. Thus, the total momentum of the system is conserved.

However, it is an elastic collision.

So, some energy will be lost in the form of heat, etc.

Hence, the total mechanical energy of the system will not conserved.

Question6

During inelastic collision between two objects, which of the following quantity always remains conserved?

KCET 2019

Options:

A. Total kinetic energy

B. Total mechanical energy

C. Total linear momentum

D. Speed of each body

Answer: C

Solution:

Total linear momentum is always conserved in all type of collision.

$\therefore$ During inelastic collision, total linear momentum is conserved but total kinetic energy and total mechanical energy is not conserved.

Question7

Two particles which are initially at rest move towards each other under the action of their mutual attraction. If their speeds are v and $2v$ at any instant, then the speed of centre of mass of the system is

KCET 2019

Options:

A. $2v$

B. zero

C. $1.5v$

D. v

Answer: B

Solution:

To find the speed of the center of mass of the system, we'll use the concept of the center of mass velocity in a two-particle system. Let's consider two particles with masses m_1 and m_2, and their respective velocities being v_1 and v_2.

The velocity of the center of mass V_{cm} is given by:

$$V_{\text{cm}} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

In the given scenario, let's assume the particles have masses m_1 and m_2. The velocities of the particles are v and $2v$ respectively. Since the particles are initially at rest and move due to mutual attraction, by the conservation of momentum, the initial momentum is zero. Therefore, the momentum at any time should also be zero.

Thus, we have:

$$m_1 v + m_2(-2v) = 0$$

This simplifies to:

$$m_1 v - 2m_2 v = 0$$

From here, we find that:

$$m_1 = 2m_2$$

Now, substituting back into the equation for V_{cm} :

$$V_{\text{cm}} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = \frac{m_1 v + m_2(-2v)}{m_1 + m_2} = \frac{m_1 v - 2m_2 v}{m_1 + m_2}$$

Replacing $m_1 = 2m_2$, the equation becomes:

$$V_{\text{cm}} = \frac{2m_2 \cdot v - 2m_2 \cdot v}{2m_2 + m_2} = \frac{0}{3m_2} = 0$$

Therefore, the speed of the center of mass of the system is **zero**.

The correct option is **Option B: zero**.

Question8

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

KCET 2017

Options:

A. is equal to g (acceleration due to gravity)

B. depends on the speeds of the two balls

C. depends on the masses of the two balls

D. depends on the direction of motion of the two balls.

Answer: A

Solution:

To find the acceleration of the center of mass of two balls thrown simultaneously in the air, we can use the formula for the acceleration of the center of mass:

$\mathbf{a}_{\text{cm}} = \frac{m_1\mathbf{a}_1 + m_2\mathbf{a}_2}{m_1 + m_2}$

Here, both balls are subject to the same downward gravitational acceleration, so $a_1 = a_2 = g$, where g is the acceleration due to gravity.

Substituting these values into the formula, we get:

$$\mathbf{a}_{\text{cm}} = \frac{m_1 g + m_2 g}{m_1 + m_2}$$
$$\mathbf{a}_{\text{cm}} = \frac{g(m_1 + m_2)}{m_1 + m_2}$$
$$\mathbf{a}_{\text{cm}} = g$$

Thus, the acceleration of the center of mass of the two balls is equal to g.
