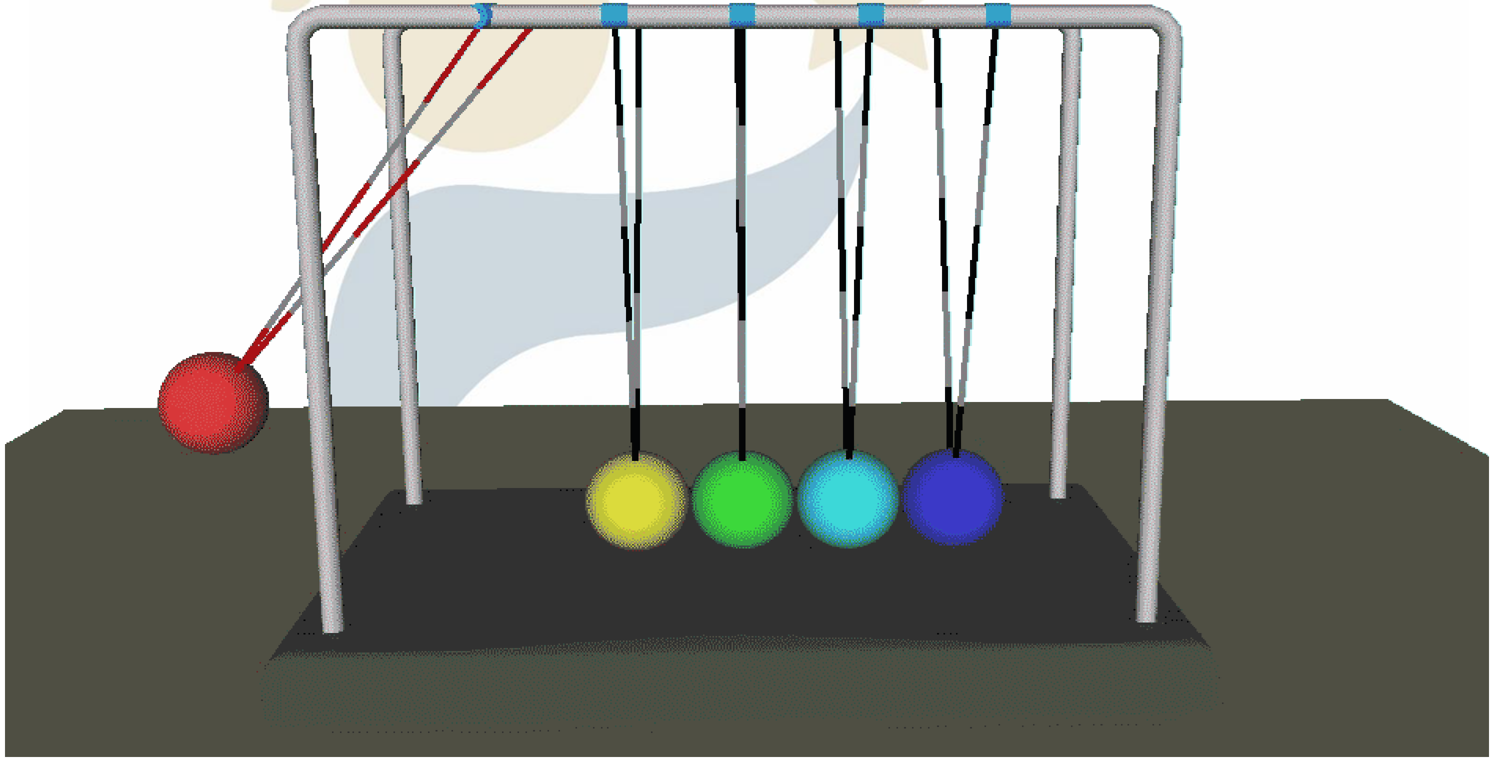
Grade 12 LS – Physics

Chapter 2: Linear Momentum



Prepared and presented by: Mr. Mohamad Seif

OBJECTIVES

1. Identify the types of rectilinear motion
2. Recall position and velocity vector
3. Apply Newton’s 3^{rd} law (Principle of interaction)

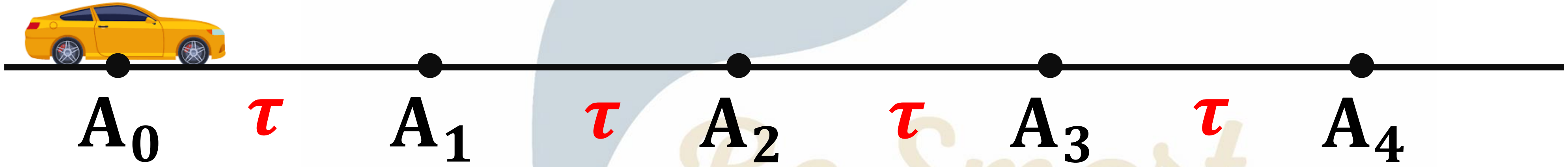
Types of rectilinear motion.

- Rectilinear motion
  - URM
  - UVRM
    - UARM
    - UDRM

Types of rectilinear motion.

Uniform Rectilinear Motion (U.R.M):

A motion is said to be U.R.M if the velocity is constant ($V = cst$), and the acceleration is zero ($a = 0$), during a constant time between two consecutive points (τ)



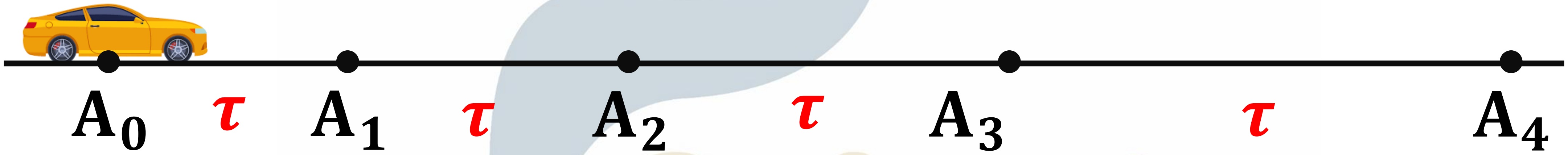
The average velocity between two points (A_0 & A_4) is:

$$V_{av} = V_{0,4} = \frac{\Delta x}{\Delta t} = \frac{A_0A_4}{4\tau}$$

Types of rectilinear motion.

Uniformly Accelerated Rectilinear Motion (U.A.R.M):

A motion is said to be U.A.R.M if the velocity increases with time, and the acceleration is positive & constant ($a > 0$).



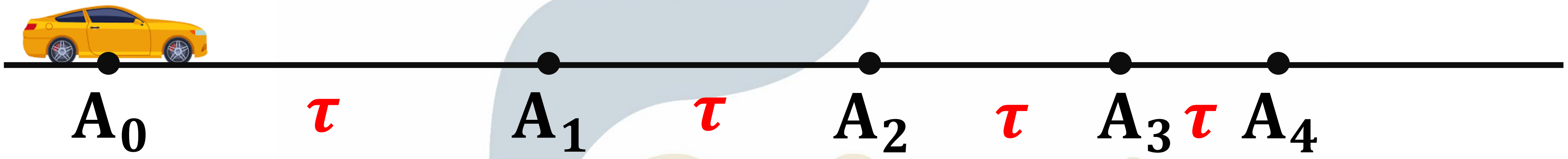
The average velocity between any two points (A_1 & A_4) is:

$$V_{av} = V_{1,4} = \frac{\Delta x}{\Delta t} = \frac{A_1A_4}{3\tau}$$

Types of rectilinear motion.

Uniformly Decelerated Rectilinear Motion (U.D.R.M):

A motion is said to be U.D.R.M if the velocity decreases with time, and the acceleration is negative & constant ($a < 0$).



The average velocity between any two points (A_2 & A_4) is:

$$V_{av} = V_{2,4} = \frac{\Delta x}{\Delta t} = \frac{A_2A_4}{2\tau}$$

Types of rectilinear motion.

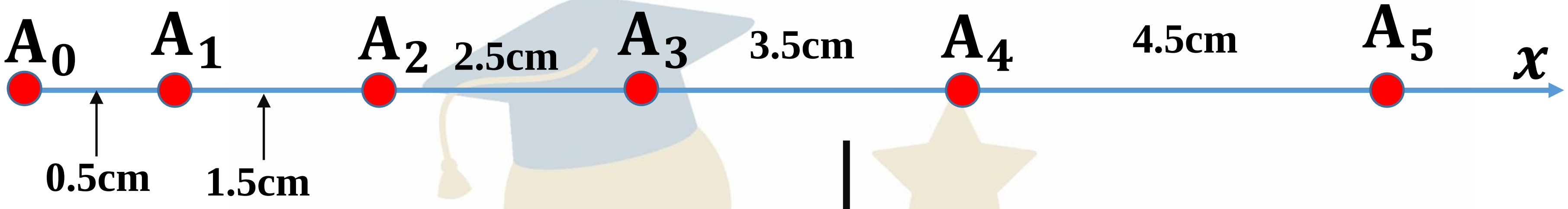
Application 1:

Consider a particle moves a straight line, where A_0, to A_5 are the successive positions of the center of mass at different instants.

Let $\tau = 50\text{ms}$ to be the time interval between any two successive position

Determine the magnitude of the average velocity of the particle between A_1 & A_3 then between A_0 & A_5

Types of rectilinear motion.



$$V_{1,3} = \frac{A_1A_3}{2\tau}$$

$$V_{1,3} = \frac{A_1A_2 + A_2A_3}{t_3 - t_1}$$

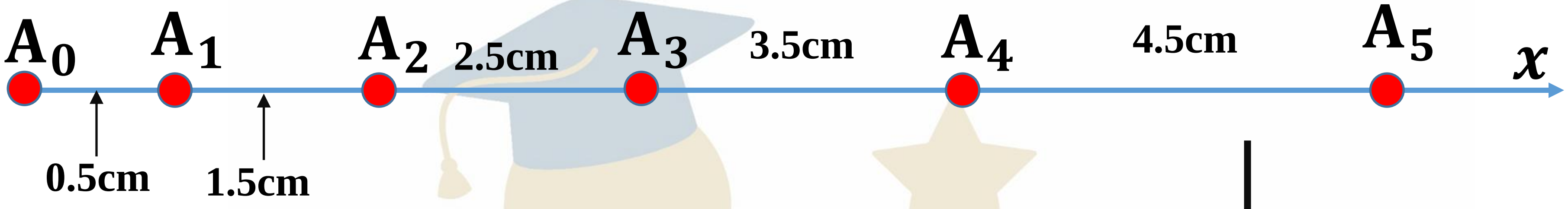
$$V_{1,3} = \frac{A_1A_2 + A_2A_3}{3\tau - \tau}$$

$$V_{1,3} = \frac{(1.5 + 2.5) \times 10^{-2}}{2\tau}$$

$$V_{1,3} = \frac{4 \times 10^{-2}}{2 \times 50 \times 10^{-3}}$$

$$V_{1,3} = 0.4 m/s$$

Types of rectilinear motion.



$$V_{0,5} = \frac{A_0A_5}{t_5 - t_0}$$

$$V_{0,5} = \frac{A_0A_1 + A_1A_2 + A_2A_3 + A_3A_4 + A_4A_5}{5\tau - 0}$$

$$V_{0,5} = \frac{(0.5 + 1.5 + 2.5 + 3.5 + 4.5).10^{-2}}{5\tau}$$

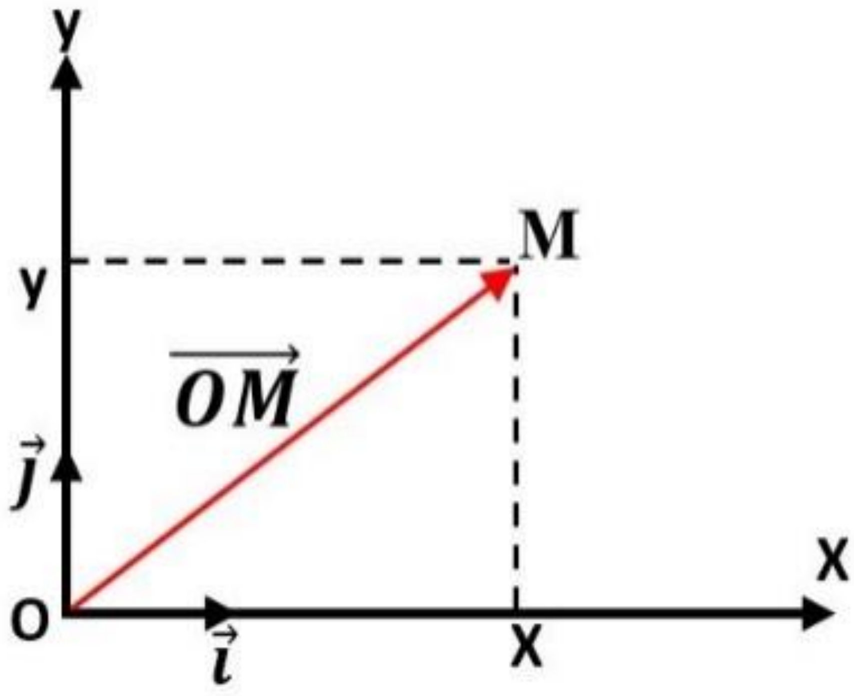
$$V_{0,5} = \frac{12.5 \times 10^{-2}}{5 \times 50 \times 10^{-3}}$$

$$V_{0,5} = 0.5m/s$$

Recall position and velocity vector

Position vector: It is the vector that joins the origin O to the moving particle:

$$\overrightarrow{OM} = \vec{r} = x\vec{i} + y\vec{j}$$



Velocity Vector: The velocity vector is the derivative of the position vector w.r.t time:

$$\vec{V} = (x)'\vec{i} + (y)'\vec{j}$$

Recall position and velocity vector

Application 2:

Given the parametric equations $x = 2t$ and $y = 4t^2$ are the coordinates of point (M) at time t.

1. Find the position vector of (M) at instant t.

$$\overrightarrow{OM} = \vec{r} = x\vec{i} + y\vec{j}$$

$$\overrightarrow{OM} = \vec{r} = 2t\vec{i} + 4t^2\vec{j}$$

2. Find the velocity vector of the point M at instant t

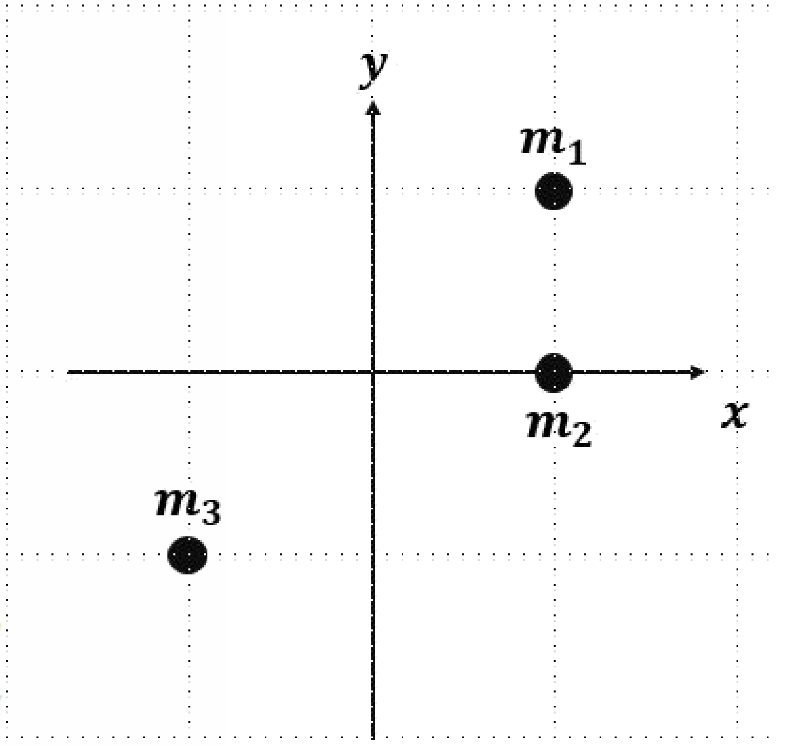
The velocity vector is the derivative of position vector w.r.t time:

$$\vec{V} = 2\vec{i} + 8t\vec{j}$$

Recall position and velocity vector

A system of particles consists three particles:

- Particle (1): of mass m_1 and a position vector $\vec{r}_1$
- Particle (2): of mass m_2 and a position vector $\vec{r}_2$
- Particle (3): of mass m_3 and a position vector $\vec{r}_3$



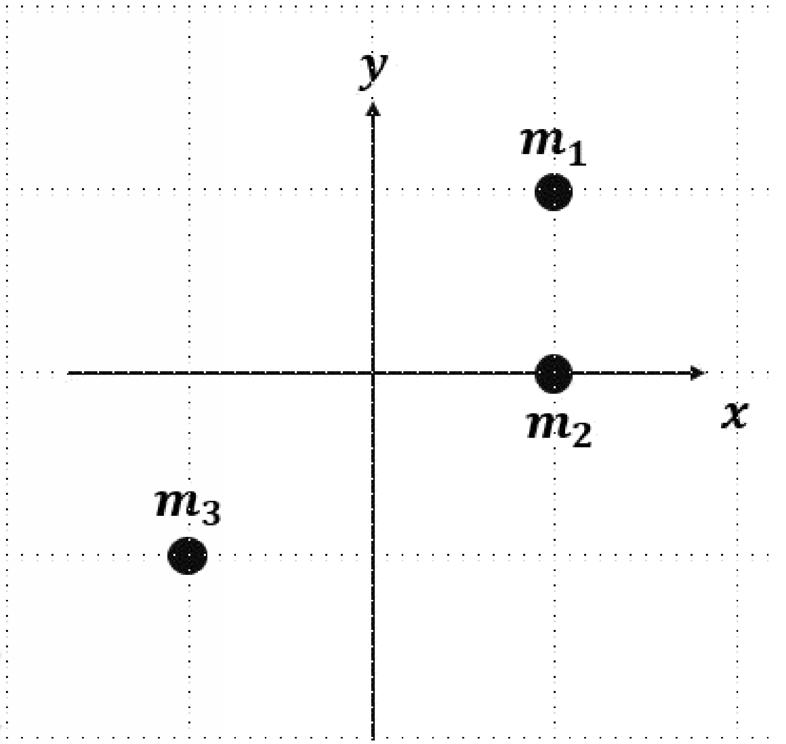
Recall position and velocity vector

The position of the center of mass of the above system is:

$$\vec{r}_G = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots m_N\vec{r}_N}{m_1 + m_2 + \cdots m_N}$$

$$x_G = \frac{m_1 x_1 + m_2 x_2 + \cdots m_N x_N}{m_1 + m_2 + \cdots m_N}$$

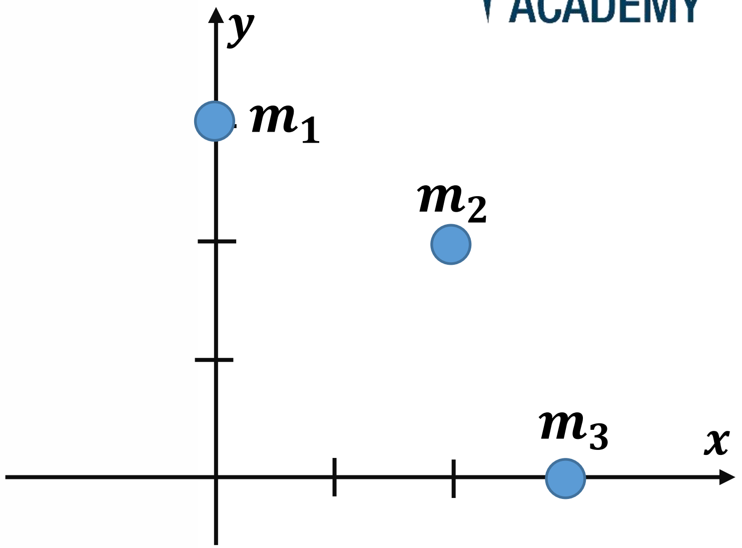
$$y_G = \frac{m_1 y_1 + m_2 y_2 + \cdots m_N y_N}{m_1 + m_2 + \cdots m_N}$$



Recall position and velocity vector

Application 3: A system formed of three particles as shown in the figure. Given $m_1 = 1kg; m_2 = 2kg; m_3 = 3kg$

Find the position vector of the center of mass of the above system.



$$\overrightarrow{OG} = \vec{r}_G = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3}{m_1 + m_2 + m_3}$$

$$\vec{r}_G = \frac{1(3\vec{j}) + 2(2\vec{i} + 2\vec{j}) + 3(3\vec{i})}{(1 + 2 + 3)}$$

$$\vec{r}_G = \frac{3\vec{j} + 4\vec{i} + 4\vec{j} + 9\vec{i}}{6}$$

$$\vec{r}_G = \frac{13\vec{i} + 7\vec{j}}{6}$$

$$\vec{r}_G = 2.16\vec{i} + 1.16\vec{j}$$

Newton's 3rd law (Principle of interaction)

Principle of interaction:

For every action there exists an equal and opposite reaction

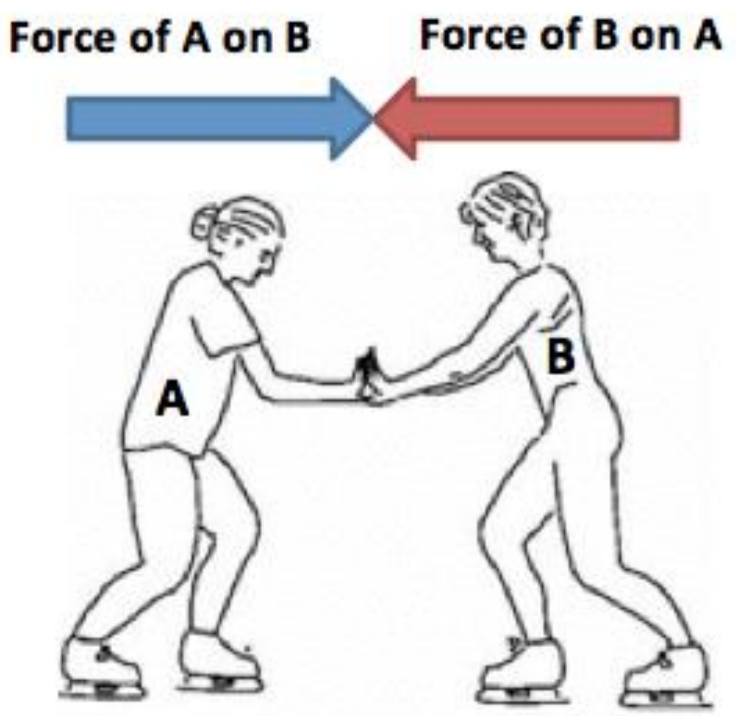
Vector relation

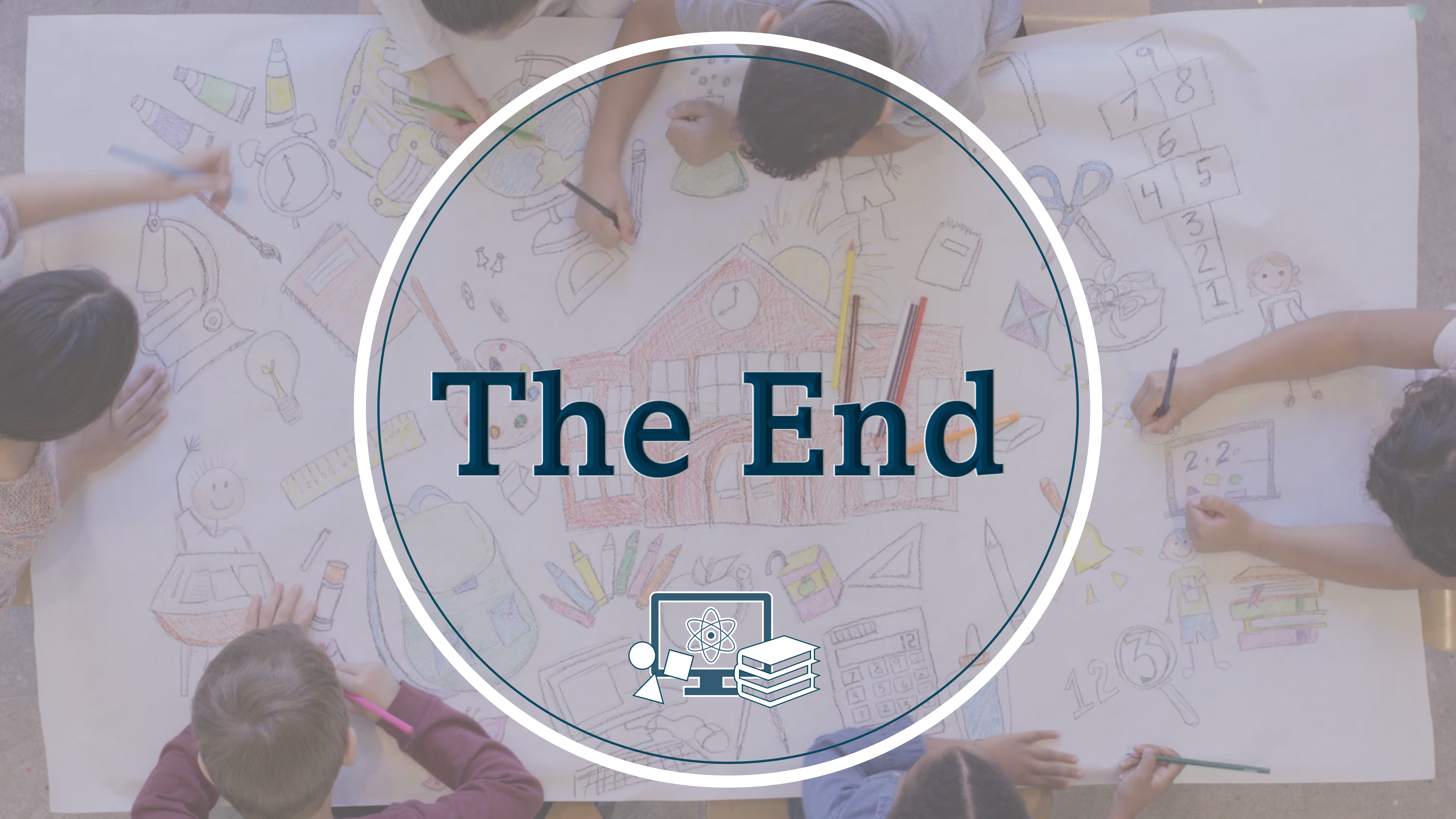
$$\vec{F}_{A/B} + \vec{F}_{B/A} = \vec{0}$$

$$\vec{F}_{A/B} = -\vec{F}_{B/A}$$

Magnitude

$$F_{A/B} = F_{B/A}$$

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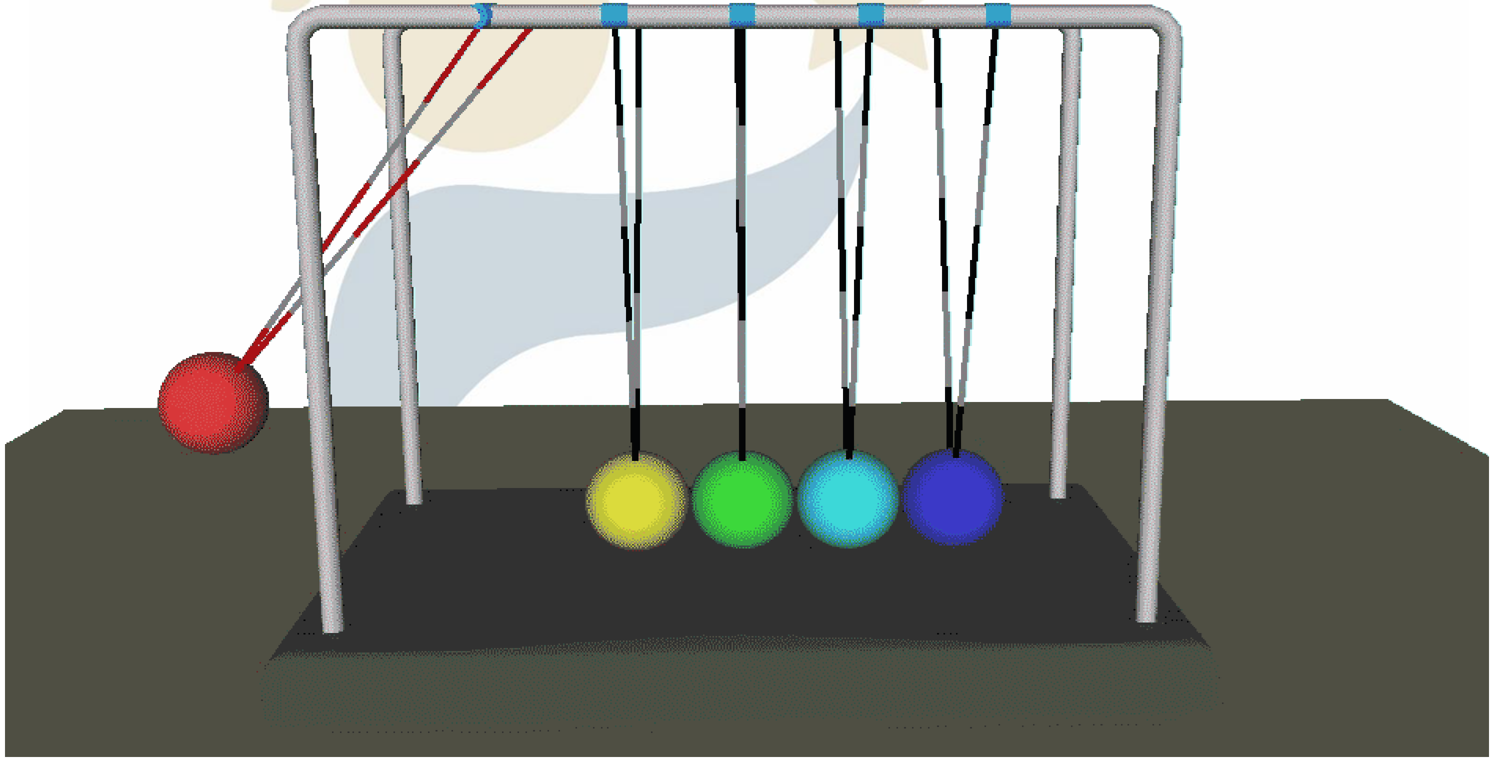
Grade 12 LS – Physics

Chapter 2: Linear Momentum



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OBJECTIVES

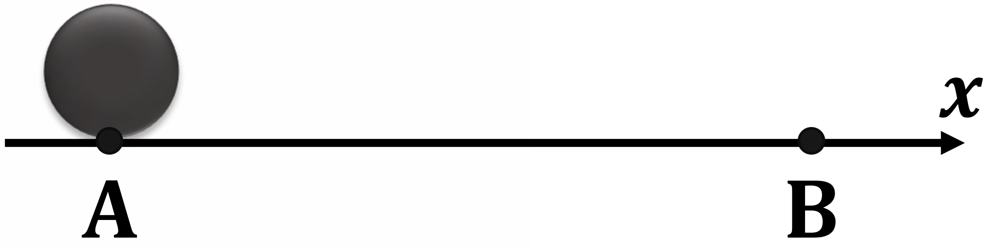
1. Definition of Linear Momentum
2. Linear Momentum of system of particles
3. Linear Momentum of center of mass

Definition of Linear Momentum

Linear momentum is a vector quantity that depends on the motion of an object.

Linear momentum is the product of mass with the velocity vector.

$$\vec{P} = m.\vec{V}$$



- m: mass of the particle, expressed in kg.
- $\vec{V}$: velocity vector of the particle. Its magnitude is the speed, expressed in m/s.
- $\vec{P}$: Linear momentum of the particle. Its magnitude is expressed in kg.m/s.

Definition of Linear Momentum

Application 4:

Consider a ball of mass 250g moving with a velocity of magnitude $V = 3m/s$ as shown in the figure.

Calculate the linear momentum of the ball.

$$\vec{P} = m \times \vec{V} = 0.25 \times (+3\vec{i})$$

$$\vec{P} = 0.75\vec{i}\ (kg.m/s)$$

Definition of Linear Momentum

Application 5:

A ball of mass $m = 250g$ moves with a velocity of magnitude $V = 3m/s$ as shown in the figure.

1. Calculate the linear momentum of the ball.

$$\vec{P} = m \times \vec{V} = 0.25 \times (-3\vec{i}) \qquad \vec{P} = -0.75\vec{i}\ (kg.m/s)$$

2. Draw on the figure the linear momentum vector without scale

The linear momentum is of same direction as the velocity vector.

Linear Momentum of system of particles

Consider a system consists of of particles as shown in the figure.
The linear momentum of the system of particles is the vector sum of all the linear momentum of its particles.

$$\vec{P}_{sys} = \vec{P}_1 + \vec{P}_2 + \vec{P}_3 + \cdots + \vec{P}_n$$

Where:

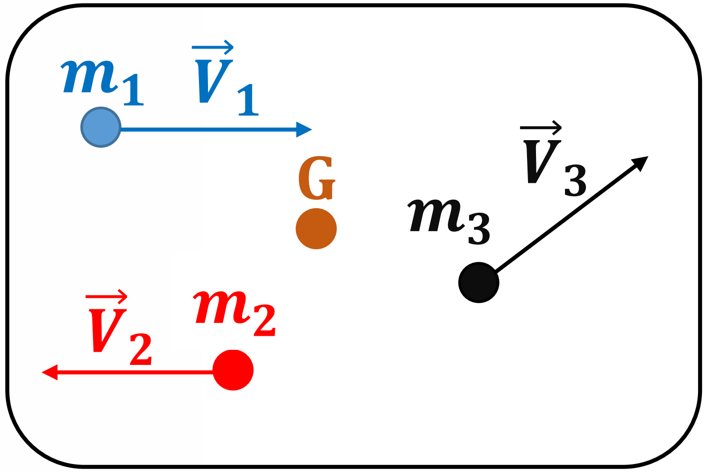
$$\vec{P}_1 = m_1\vec{V}_1$$

$$\vec{P}_2 = m_2\vec{V}_2$$

$$\vec{P}_3 = m_3\vec{V}_3$$

$$\vdots$$

$$\vec{P}_n = m_n\vec{V}_n$$

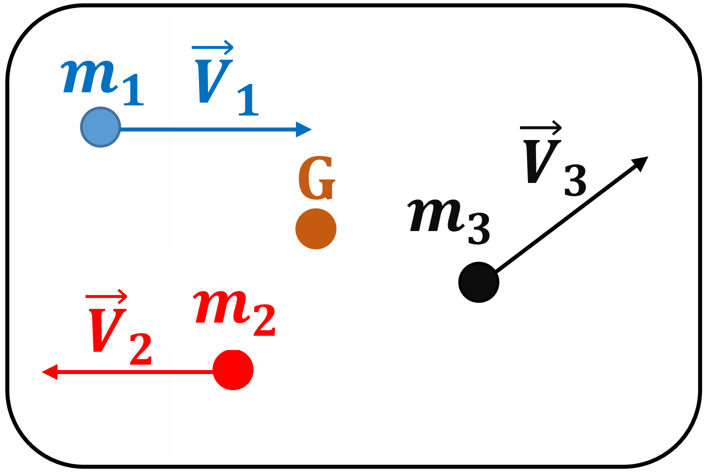


Linear Momentum of center of mass

Consider the system of particles as shown in the figure.

The position vector of the center of mass is:

$$\vec{r}_G = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3}{m_1 + m_2 + m_3}$$



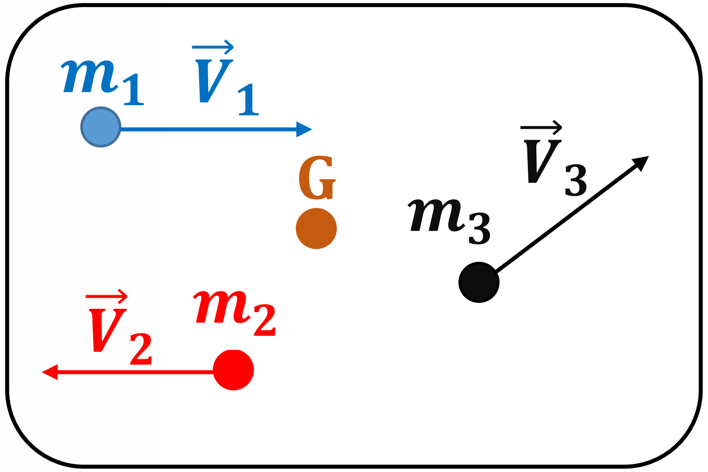
Where: $M = m_1 + m_2 + m_3$

$$M\vec{r}_G = m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3$$

Linear Momentum of center of mass

$$\mathbf{M}\vec{\mathbf{r}}_{\mathbf{G}} = \boldsymbol{m_1}\vec{\boldsymbol{r}}_1 + \boldsymbol{m_2}\vec{\boldsymbol{r}}_2 + \boldsymbol{m_3}\vec{\boldsymbol{r}}_3$$

Differentiate the above equation w.r.t time:



$$\mathbf{M}\vec{\mathbf{V}}_{\mathbf{G}} = \mathbf{m}_1\vec{\mathbf{V}}_1 + \mathbf{m}_1\vec{\mathbf{V}}_2 + \mathbf{m}_3\vec{\mathbf{V}}_3$$

$$\vec{\mathbf{P}}_{\mathbf{G}} = \vec{\mathbf{P}}_1 + \vec{\mathbf{P}}_2 + \vec{\mathbf{P}}_3$$

But $\vec{\mathbf{P}}_{\mathbf{sys}} = \vec{\mathbf{P}}_1 + \vec{\mathbf{P}}_2 + \vec{\mathbf{P}}_3$ ⟹ $\vec{\mathbf{P}}_{\mathbf{G}} = \vec{\mathbf{P}}_{\mathbf{sys}} = \mathbf{M}\vec{\mathbf{V}}_{\mathbf{G}}$

Linear Momentum of center of mass

Application 6:

Consider a system of two balls A of mass $m_1 = 50\text{g}$ and B of mass $m_2 = 75\text{g}$ are moving horizontally in opposite directions as shown in the figure.

The two ball (A) and (B) moves with velocities $V_1 = 4m/s$ and $V_2 = 6m/s$ respectively.

1. Determine the linear momentum of the system (A – B).
2. Deduce the velocity of the center of mass of the above system

Linear Momentum of center of mass

(A): $m_1 = 50g; V_1 = 4m/s$; Ball (B) $m_2 = 75g; V_2 = 6m/s$.

1.Determine the linear momentum of the system (A – B).

$$\vec{P}_{sys} = \vec{P}_1 + \vec{P}_2 = m_1\vec{V}_1 + m_2\vec{V}_2$$

$$\vec{P}_{sys} = 0.05 \times (4\vec{i}) + 0.075 \times (-6\vec{i})$$

$$\vec{P}_{sys} = -0.25\vec{i}\ (Kg.m/s)$$

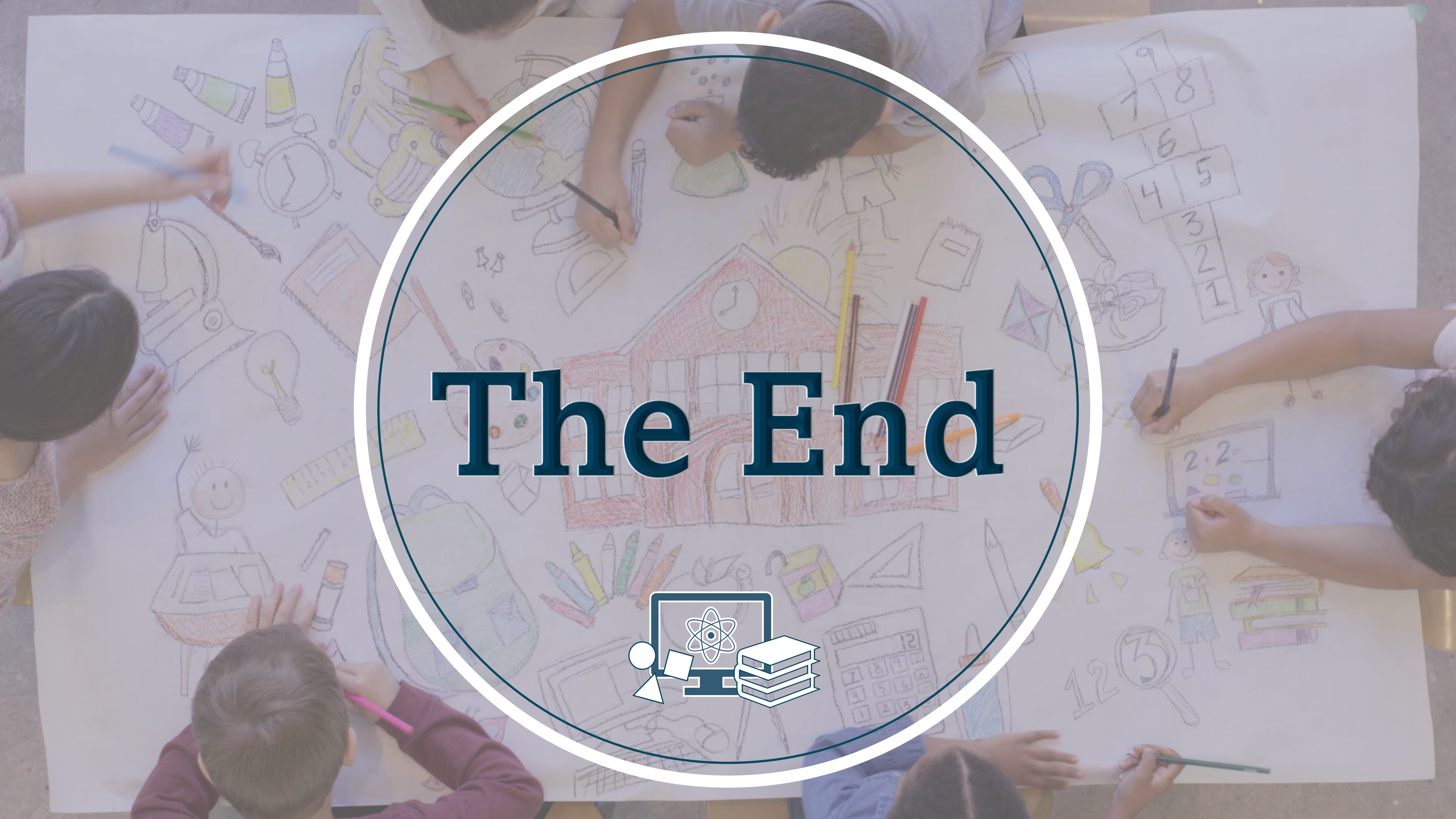
2.Deduce the velocity of the center of mass of the above system

$$\vec{P}_G = \vec{P}_{sys} = M\vec{V}_G$$

$$\vec{V}_G = \frac{\vec{P}_{sys}}{M}$$

$$\vec{V}_G = \frac{-0.25\vec{i}}{(0.05 + 0.075)}$$

$$\vec{V}_G = -2\vec{i}\ (m/s)$$



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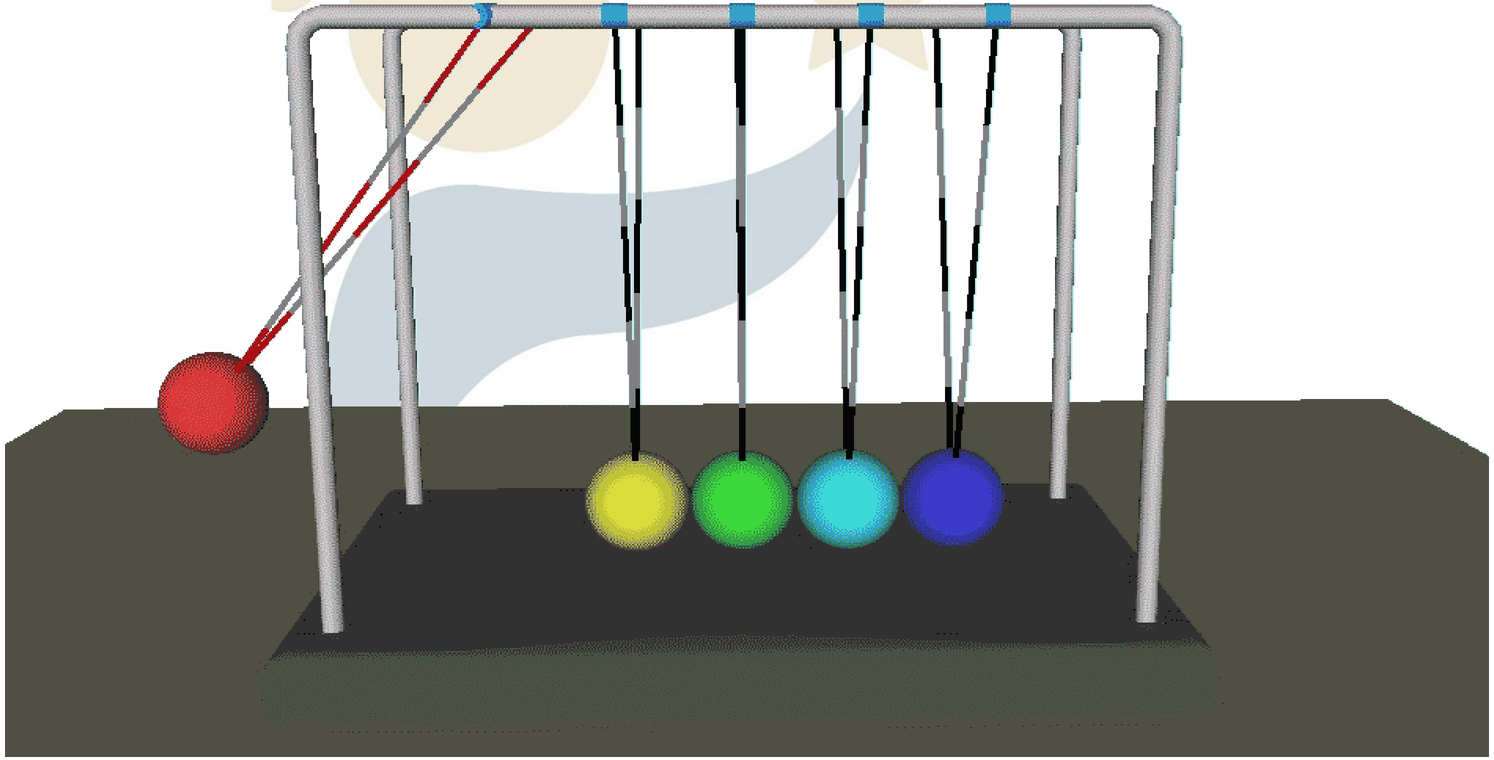
Chapter 2: Linear Momentum



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OBJECTIVES

1. Apply Newton's second law in terms of Linear momentum.
2. Apply the principle of conservation of Linear momentum.

Newton's second law & Linear Momentum

The Linear momentum of a system is given by: $\vec{P} = M\vec{V}_G$

derive w.r.t time: $\frac{d\vec{p}}{dt} = M\vec{V}'$ ⇒ $\frac{d\vec{p}}{dt} = M\vec{a}$

$$\frac{d\vec{P}}{dt} = \sum \vec{F}_{ext}$$

⇒ The sum of all external forces acting on a system of particles is equal to the time derivative of the linear momentum of the system.

Can be applied for system or for particle.

Newton's second law & Linear Momentum

Application 7:

A solid (S) of mass m = 5Kg moves on a horizontal plane. The solid (S) starts its motion from rest at $t_0 = 0$ under the action of friction force of magnitude f.

1. **Name and represent the forces acting on the solid (S).**
2. **Determine using newton's 2nd law, the magnitude of friction, knowing that $\vec{P} = (-2t + 3)\vec{i}$**

Newton's second law & Linear Momentum

m = 5Kg; $g = 10N/kg$.

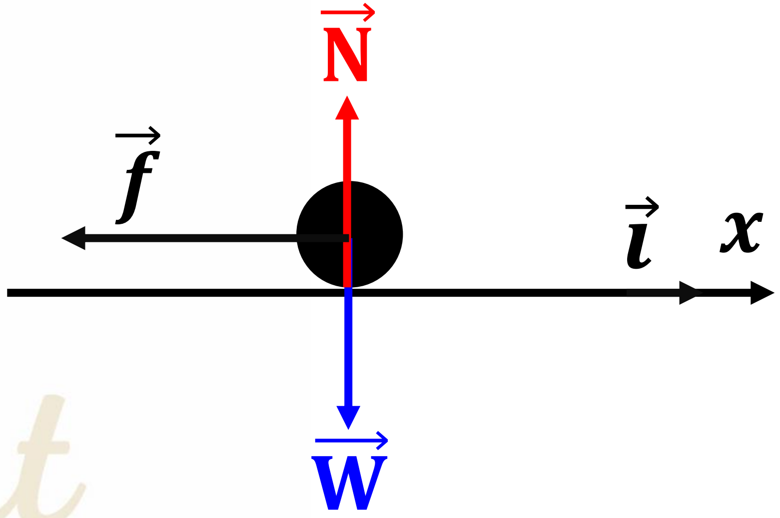
1.Name and represent the forces acting on the solid (S).

The forces are:

Weight ($\overrightarrow{W}$)

Normal ($\overrightarrow{N}$).

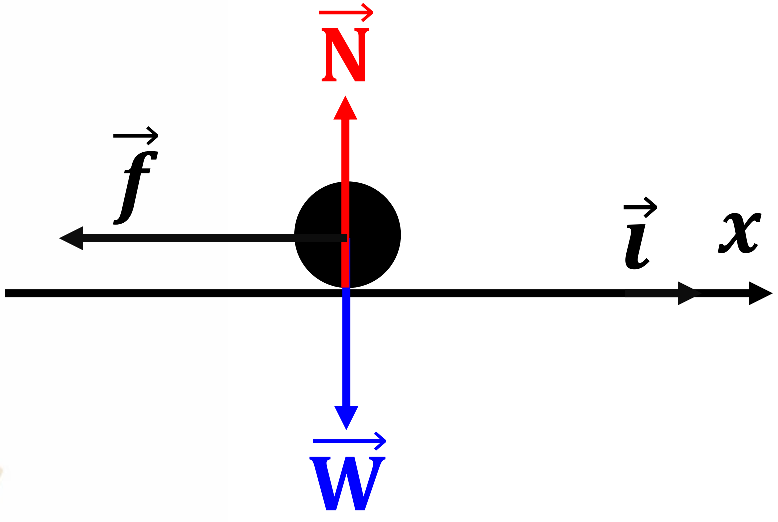
Friction ($\overrightarrow{f}$)



Newton's second law & Linear Momentum

m $= 5$Kg; $g = 10N/kg; \vec{P} = (-2t+3)\vec{\imath}$

2.Determine using newton's 2nd law, the magnitude of friction, knowing that $\vec{P} = 2t + 3$.



Apply newton's 2^{nd} law: $\sum \vec{F}_{ex} = \frac{d\vec{P}}{dt}$.

$$\vec{W} + \vec{N} + \vec{f} = \frac{d\vec{P}}{dt} \Rightarrow m\vec{g} + \vec{N} + \vec{f} = \frac{d\vec{P}}{dt}$$

Project along x-axis: $-f = -2 \Rightarrow f = 2N$

Conservation of Linear Momentum

A system is called mechanically isolated, if the sum of external forces applied on the system is zero ($\sum \vec{F}_{ext} = 0$); then

$$\frac{d\vec{P}}{dt} = \sum \vec{F}_{ext}$$

$$\frac{d\vec{P}}{dt} = 0 \qquad \sum \vec{F}_{ext} = 0$$

$$\vec{P}_i = \vec{P}_f$$

Linear momentum is conserved

Conservation of Linear Momentum

Application 8:

Consider two pucks (A) and (B) of respective masses $m_A = 200\text{g}$ and $m_B = 300\text{g}$.

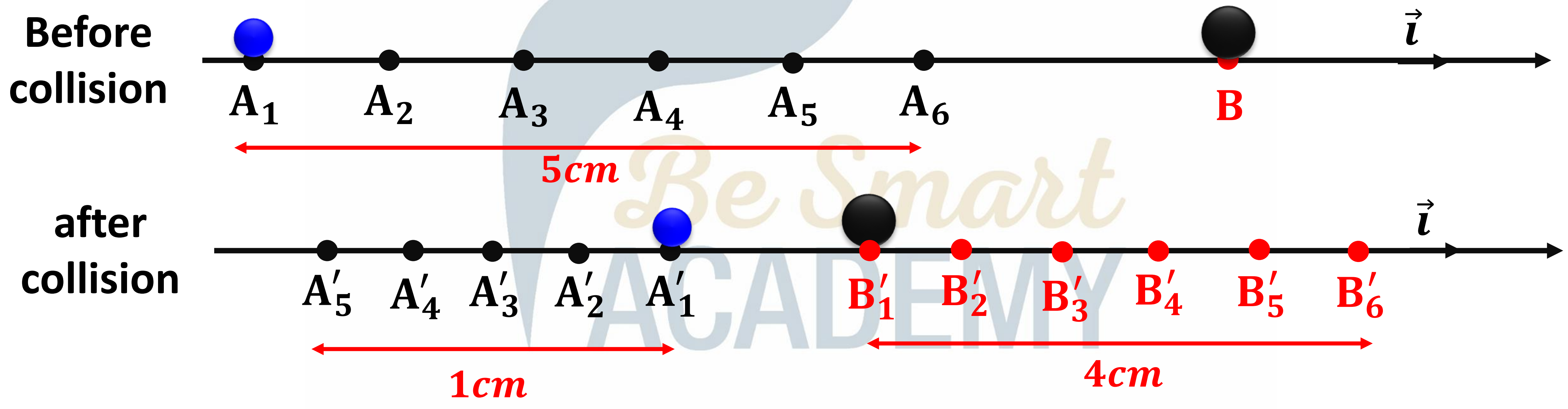
(A), moves with the velocity $\vec{V}_A = V_A\vec{i}$, enters in a head-on collision with (B), initially at rest.

After collision, (A) rebounds with the velocity $\vec{V}'_A = V'_A\vec{i}$ and (B) is moves with the velocity $\vec{V}'_B = V'_B\vec{i}$.

Conservation of Linear Momentum

The figure below shows the positions of the centers of masses of (A) and (B) obtained.

The time interval separating two successive dots is $\tau = 20ms$.



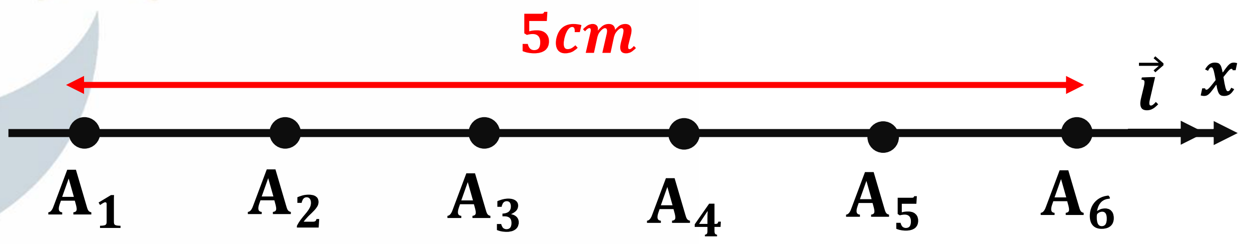
Conservation of Linear Momentum

1. Calculate the algebraic values V_A, V'_A and V'_B.
2. Determine the linear momentums $\overrightarrow{P}_A$ and $\overrightarrow{P}'_A$ of the puck (A) before and after collision respectively and $\overrightarrow{P}'_B$ of the puck (B) after collision.
3. Deduce the linear momentums $\overrightarrow{P}$ and $\overrightarrow{P}'$ of the center of mass of the system [(A) and (B)] before and after collision, respectively.
4. Compare $\overrightarrow{P}$ and $\overrightarrow{P}'$ then conclude.

Conservation of Linear Momentum

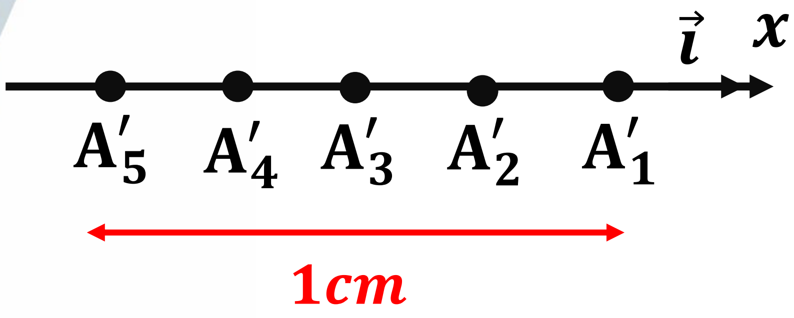
$m_A = 0.2Kg; V_A; \& V'_A; m_B = 0.3\,Kg\,; V_B = 0; \& V'_B; \tau = 20ms$

1) Calculate the algebraic values V_A, V'_A and V'_B



$$V_A = \frac{A_1A_6}{5\tau} = \frac{5 \times 10^{-2}}{5 \times (20 \times 10^{-3})}$$

$$V_A = 0.5m/s$$



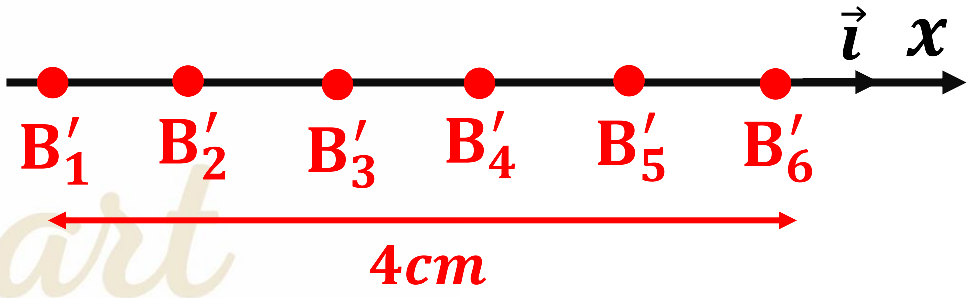
$$V'_A = \frac{A'_1A'_6}{5\tau} = \frac{1 \times 10^{-2}}{5 \times (20 \times 10^{-3})}$$

$$V'_A = 0.1m/s$$

Conservation of Linear Momentum

$m_A = 0.2Kg; V_A = ?; \& V'_A = ?; m_B = 0.3\ Kg; V_B = 0; \& V'_B = ?$

$$V'_B = \frac{B'_1 B'_6}{5\tau}$$



$$V'_B = \frac{4 \times 10^{-2}}{5 \times (20 \times 10^{-3})}$$

$$V'_B = 0.4 m/s$$

Conservation of Linear Momentum

$m_A = 0.2Kg;\ V_A = 0.5m/s;\ \&\ V'_A = 0.1m/s;\ m_B = 0.3Kg;$
$V_B = 0;\ \&\ V'_B = 0.4m/s$

2.Determine the linear momentums $\vec{P}_A$ and $\vec{P}'_A$ of the puck (A) before and after collision respectively and $\vec{P}'_B$ of the puck (B) after collision.

$\vec{P}_A = m_A.\vec{V}_A = 0.2 \times (0.5\vec{i})$ ➡ $\vec{P}_A = 0.1\vec{i}\ (Kg.m/s)$

$\vec{P}'_A = m_A.\vec{V}'_A = 0.2 \times (-0.1\vec{i})$ ➡ $\vec{P}'_A = -0.02\vec{i}\ (Kg.m/s)$

$\vec{P}'_B = m_B.\vec{V}'_B = 0.3 \times (0.4\vec{i})$ ➡ $\vec{P}'_B = 0.12\vec{i}\ (Kg.m/s)$

Conservation of Linear Momentum

$\vec{P}_A = 0.1\vec{i}$ (kgm/s); $\vec{P}'_A = -0.02\vec{i}$ (kgm/s); $\vec{P}'_B = 0.12\vec{i}$ (kgm/s)

3. Deduce the linear momentums $\vec{\mathrm{P}}$ and $\vec{\mathrm{P}}'$ of the center of mass of the system [(A) and (B)] before and after collision, respectively.

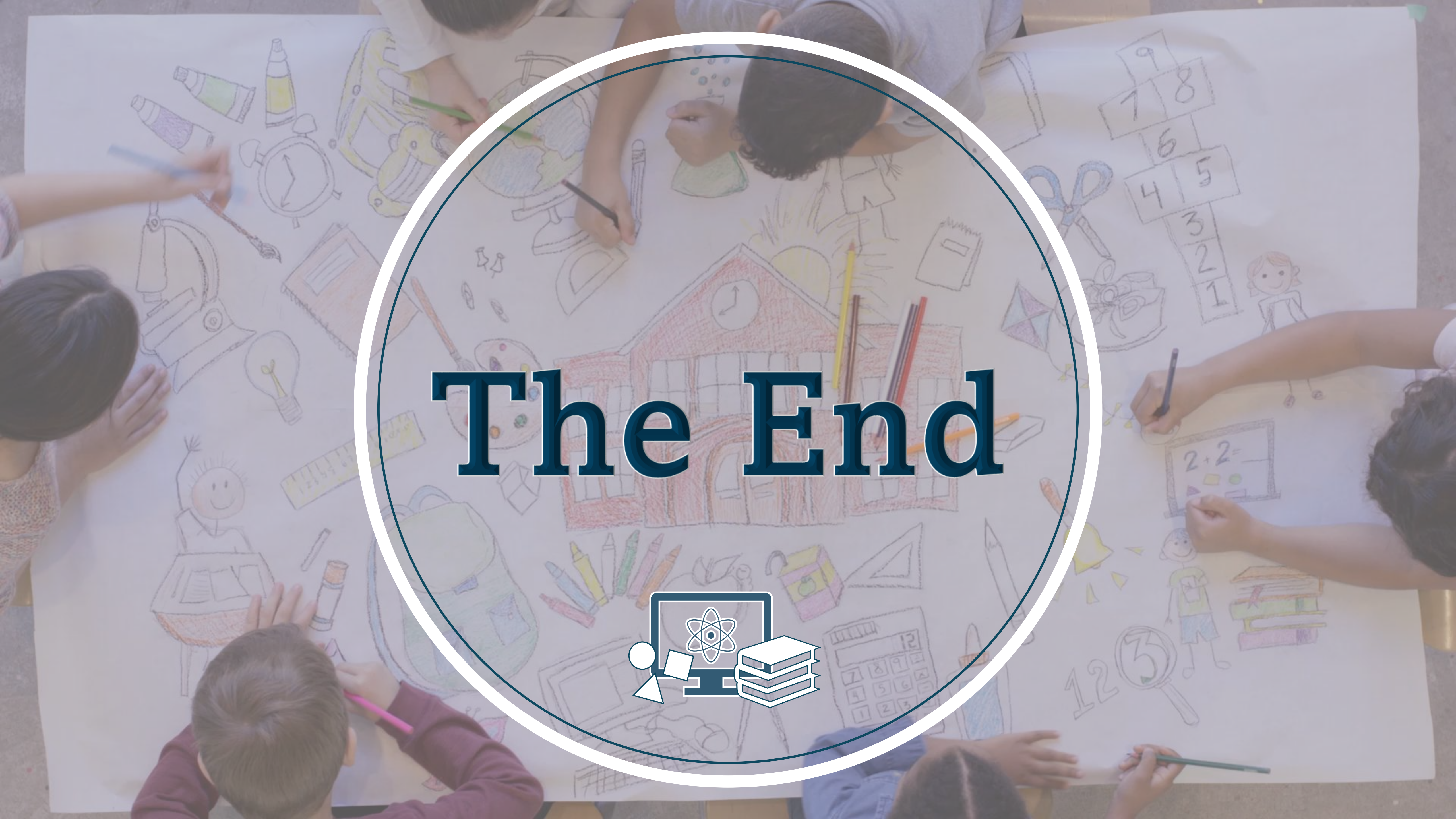
$\vec{P} = \vec{P}_A + \vec{P}_B = 0.1\vec{i} + 0$ → $\vec{P} = 0.1\vec{i}\,(Kg.m/s)$

$\vec{\mathrm{P}}' = \vec{P}'_A + \vec{P}'_B = -0.02\vec{i} + 0.12\vec{i}$ → $\vec{\mathrm{P}}' = 0.1\vec{i}\,(Kg.m/s)$

4. Compare $\vec{P}$ and $\vec{P}'$ then conclude.

$$\vec{\mathrm{P}} = \vec{\mathrm{P}}' = 0.1\vec{i}\,(Kg.m/s)$$

Then the linear momentum of the system is conserved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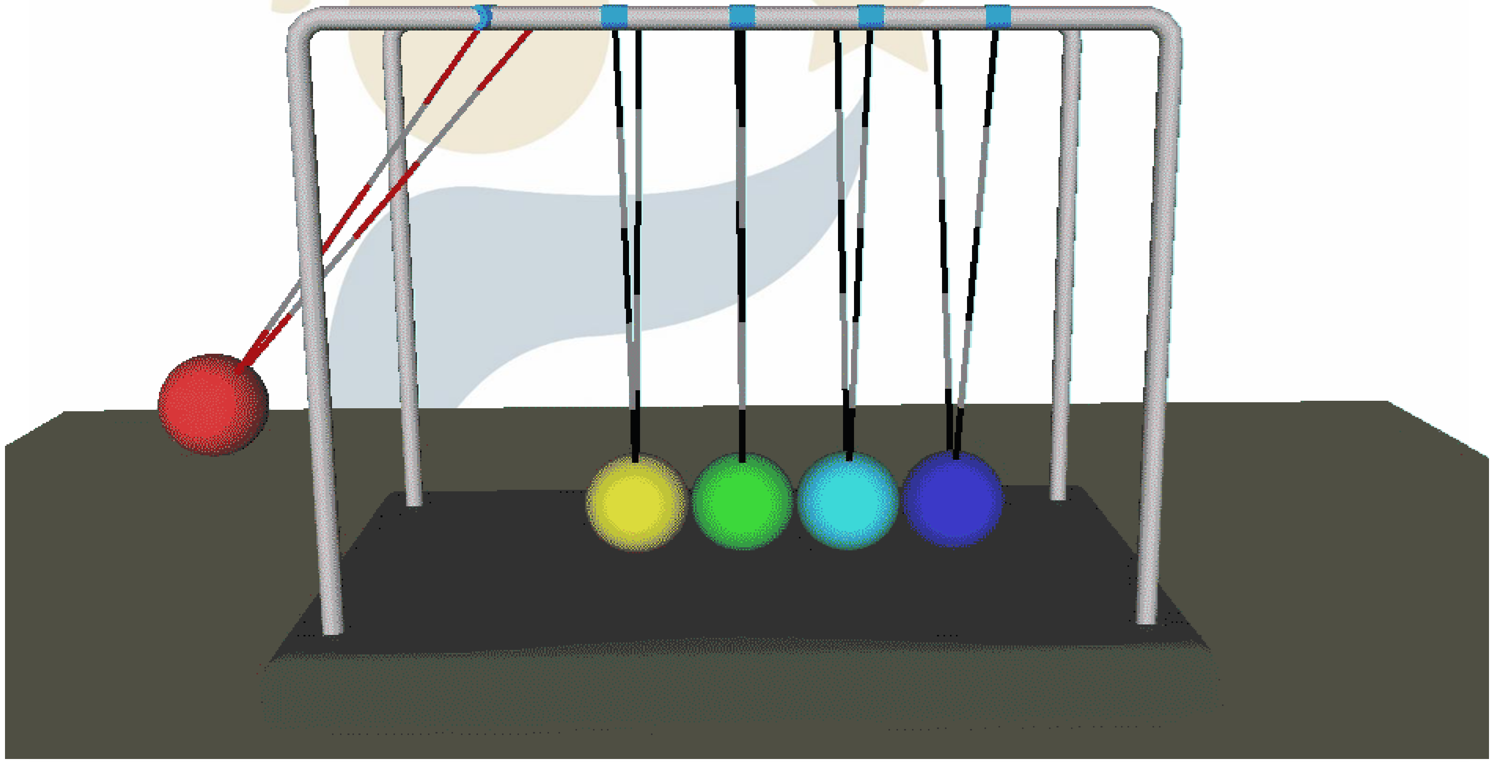

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OBJECTIVES

1. **Identify the types of Collision between two particles**
2. **To study the Elastic Collision of two particles**

Types of Collision between two particles

Collision: are observed between billiards balls or between two cars…

Usually, collision last for a very short time, so external forces are neglected with respect to internal forces.

Collision

Perfectly Elastic Collision

Collision between billiards balls (No change in the shapes of the bodies)

Linear momentum is conserved:

$$\vec{P}_{sys(bef)} = \vec{P}_{sys(aft)}$$

Kinetic energy is conserved:

$$KE_{sys(bef)} = KE_{sys(aft)}$$

Non -elastic Collision

In-elastic Collision

Collision between to cars. <u>Deformation of the shapes of the bodies.</u>

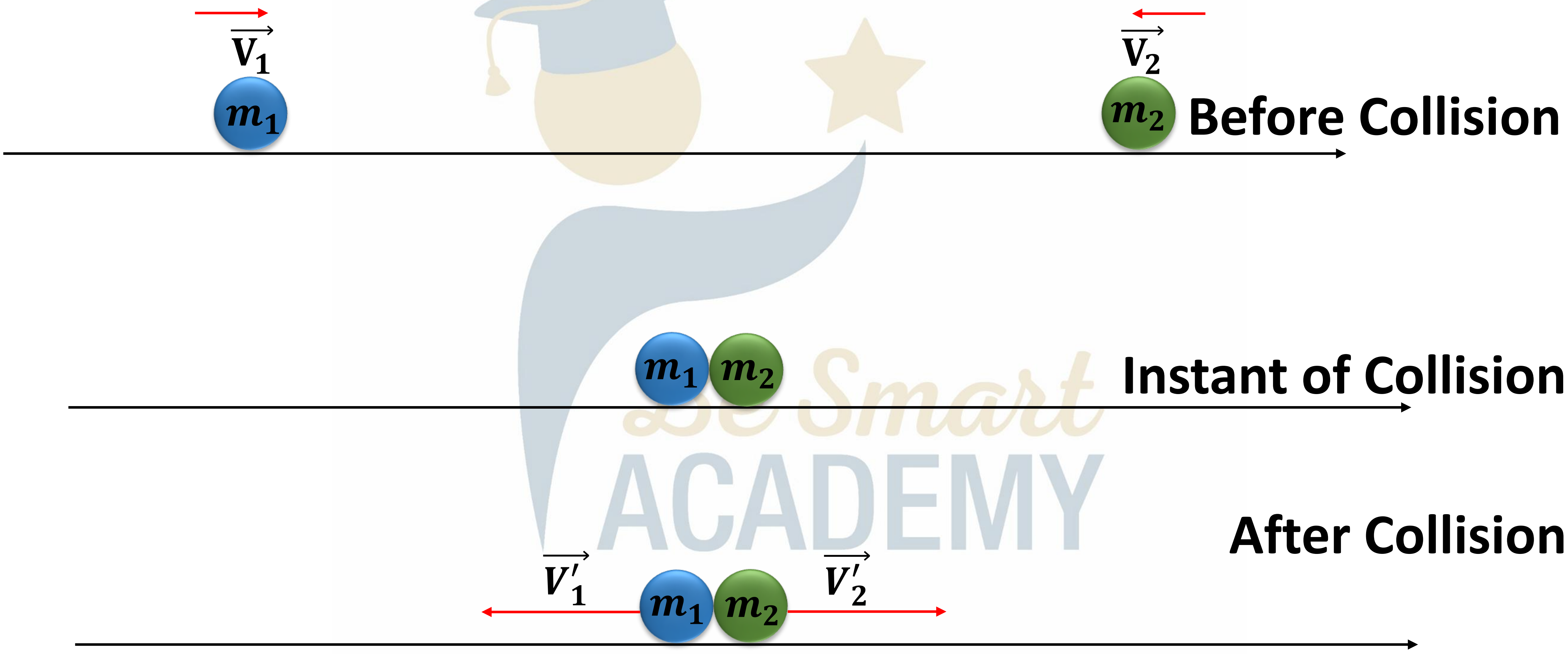
Perfectly In-elastic Collision

Collision between Bullet & wood box. <u>The two bodes stick together and form a new system</u>

Linear momentum is conserved $\vec{P}_{sys(bef)} = \vec{P}_{sys(aft)}$

Kinetic energy is not conserved: $KE_{sys(bef)} \neq KE_{sys(aft)}$

Types of Collision/ Elastic collision



Types of Collision/ Elastic collision

A. Elastic Collision of two particles

The linear momentum of the system is conserved:

$$\vec{P}_{before} = \vec{P}_{after}$$

$$m_1\overrightarrow{V_1} + m_2\overrightarrow{V_2} = m_1\overrightarrow{V_1'} + m_2\overrightarrow{V_2'}$$

The velocities are collinear (head-on collision), then:

$$m_1V_1 + m_2V_2 = m_1V_1' + m_2V_2'$$

$$m_1V_1 - m_1V_1' = m_2V_2' - m_2V_2 \ldots (1)$$

$$m_1(V_1 - V_1') = m_2(V_2' - V_2) \ldots\ldots\ldots (2)$$

Types of Collision/ Elastic collision

The total kinetic energy of the system of the is conserved:

$$\mathbf{K.E_{before} = K.E_{after}}$$

$$\frac{1}{2}m_1V_1^2 + \frac{1}{2}m_2V_2^2 = \frac{1}{2}m_1{V_1'}^2 + \frac{1}{2}m_2{V_2'}^2$$

$$m_1\left(V_1^2 - {V_1'}^2\right) = m_2\left({V_2'}^2 - V_2^2\right)$$

$$m_1(V_1 - V_1')(V_1 + V_1') = m_2(V_2' - V_2)(V_2' + V_2) \dots\dots\dots\dots..(3)$$

Types of Collision/ Elastic collision

$$\mathbf{m_1(V_1 - V_1') = m_2(V_2' - V_2) \ldots\ldots\ldots..(2)}$$

$$\boxed{\mathbf{m_1(V_1 - V_1')(V_1 + V_1') = m_2(V_2' - V_2)(V_2' + V_2) \ldots\ldots\ldots\ldots..(3)}}$$

Divide equation (3) by equation (2):

$$\frac{m_1(V_1 - V_1')(V_1 + V_1')}{m_1(V_1 - V_1')} = \frac{m_2(V_2' - V_2)(V_2' + V_2)}{m_2(V_2' - V_2)}$$

$$\boxed{\mathbf{(V_1 + V_1') = (V_2' + V_2) \ldots\ldots\ldots(4)}}$$

Types of Collision/ Elastic collision

Solve the system of equation (1) and (4):

$$\begin{cases} m_1V_1 - m_1V_1' = m_2V_2' - m_2V_2 \dots\dots\dots (1) \\ (V_1+V_1') = (V_2' + V_2) \dots \times (m_1) \dots\dots (4) \end{cases}$$

$$\begin{cases} m_1V_1 - m_1V_1' = m_2V_2' - m_2V_2 \dots (1) \\ m_1V_1 + m_1V_1' = m_1V_2' + m_1V_2 \dots (4) \end{cases}$$

Add the two equations:

$$2m_1V_1 = m_2V_2' + m_1V_2' - m_2V_2 + +m_1V_2$$

$$2m_1V_1 = V_2'(m_1 + m_2) + V_2(m_1 - m_2)$$

$$2m_1V_1 - V_2(m_1 - m_2) = V_2'(m_1 + m_2)$$

Types of Collision/ Elastic collision

$$V_2' = \frac{2m_1V_1 - V_2(m_1 - m_2)}{(m_1 + m_2)}$$

$$V_2' = \left[\frac{2m_1}{(m_1 + m_2)}\right].V_1 + \left[\frac{m_2 - m_1}{m_1 + m_2}\right].V_2$$

Substitute V_2' in equation (4):

$$V_1' = \left[\frac{2m_2}{(m_1 + m_2)}\right].V_2 + \left[\frac{m_1 - m_2}{m_1 + m_2}\right].V_1$$

Types of Collision/ Elastic collision

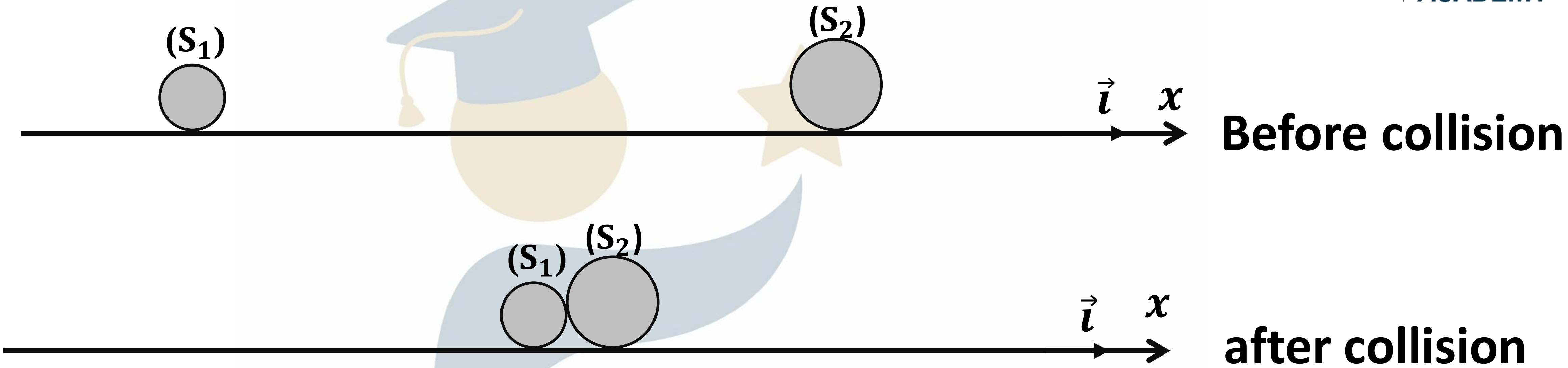
Application 9:

Consider a body (S_1), of mass $m_1 = 400\,g$, moves on a horizontal plane with a speed $V_1 = 3.464 m/s$ enters in a head-on perfectly elastic collision with a body (S_2) of mass $m_2 = 800g$ initially at rest.

After collision (S_1) rebounds with a speed V'_1 and (S_2) moves forward with moves with a speed V'_2 as shown in the figure.

Before collision

Types of Collision/ Elastic collision



Calculate the speeds V_1' of (S_1) and V_2' of (S_2) after collision

Types of Collision/ Elastic collision

$m_1 = 0.4kg; V_1 = 3.464 m/s; m_2 = 0.8kg; V_2 = 0$

Conservation of linear momentum of the system [(A), (B)]:

$$\vec{P}_{before} = \vec{P}'_{after}$$

$$m_1\vec{V}_1 + m_2\vec{V}_2 = m_1\vec{V}'_1 + m_2\vec{V}'_2$$

The velocities are collinear then:

$$m_1V_1 = m_1V'_1 + m_2V'_2$$

$$m_1V_1 - m_1V'_1 = m_2V'_2 \ldots (1)$$

$$m_1(V_1 - V'_1) = m_2V'_2 \quad \ldots\ldots (2)$$

Types of Collision/ Elastic collision

Conservation of kinetic energy of the system [(A), (B)]:

$$KE_{before} = KE_{after}$$

$$\frac{1}{2}m_1V_1^2 + \frac{1}{2}m_2V_2^2 = \frac{1}{2}m_1{V'_1}^2 + \frac{1}{2}m_2{V'_2}^2$$

$$m_1V_1^2 = m_1{V'_1}^2 + m_2{V'_2}^2$$

$$m_1V_1^2 - m_1{V'_1}^2 = m_2{V'_2}^2$$

$$m_1(V_1^2 - {V'_1}^2) = m_2{V'_2}^2$$

$$m_1(V_1 - V'_1)(V_1 + V'_1) = m_2{V'_2}^2 \ldots (3)$$

Types of Collision/ Elastic collision

$$m_1(V_1 - V_1') = m_2 V_2' \quad \ldots\ldots\ldots (2)$$

$$m_1(V_1 - V_1')(V_1 + V_1') = m_2 {V_2'}^2 \quad \ldots\ldots\ldots (3)$$

Divide equation (3) by equation (2):

$$\frac{m_1(V_1 - V_1')(V_1 + V_1')}{m_1(V_1 - V_1')} = \frac{m_2 {V_2'}^2}{m_2 V_2'}$$

$$V_1 + V_1' = V_2' \quad \ldots\ldots\ldots (4)$$

Types of Collision between two particles

Solve the system of equation (1) and (4):

$$\begin{cases} \mathbf{m_1 V_1 - m_1 V_1' = m_2 V_2' \dots \dots (1)} \\ (V_1 + V_1') = (V_2') \dots \times (m_1) \dots \dots (4) \end{cases}$$

$$\begin{cases} m_1 V_1 - m_1 V_1' = m_2 V_2' \dots (1) \\ m_1 V_1 + m_1 V_1' = m_1 V_2' \dots (4) \end{cases}$$

Add the two equations:

$$m_1 V_1 + m_1 V_1 = m_2 V_2' + m_1 V_2'$$

$$2 m_1 V_1 = V_2' (m_1 + m_2)$$

$$V_2' = \frac{2 m_1 V_1}{(m_1 + m_2)}$$

Types of Collision/ Elastic collision

$$V'_2 = \frac{2m_1V_1}{(m_1 + m_2)}$$

$$V'_2 = \frac{2 \times 0.4 \times 3.464}{(0.4 + 0.8)}$$

$$V'_2 = 2.31m/s$$

Substitute in equation (4):

$$\mathbf{V_1 + V'_1 = V'_2}$$

$$\mathbf{3.464 + V'_1 = 2.31}$$

$$\mathbf{V'_1 = -1.15m/s}$$

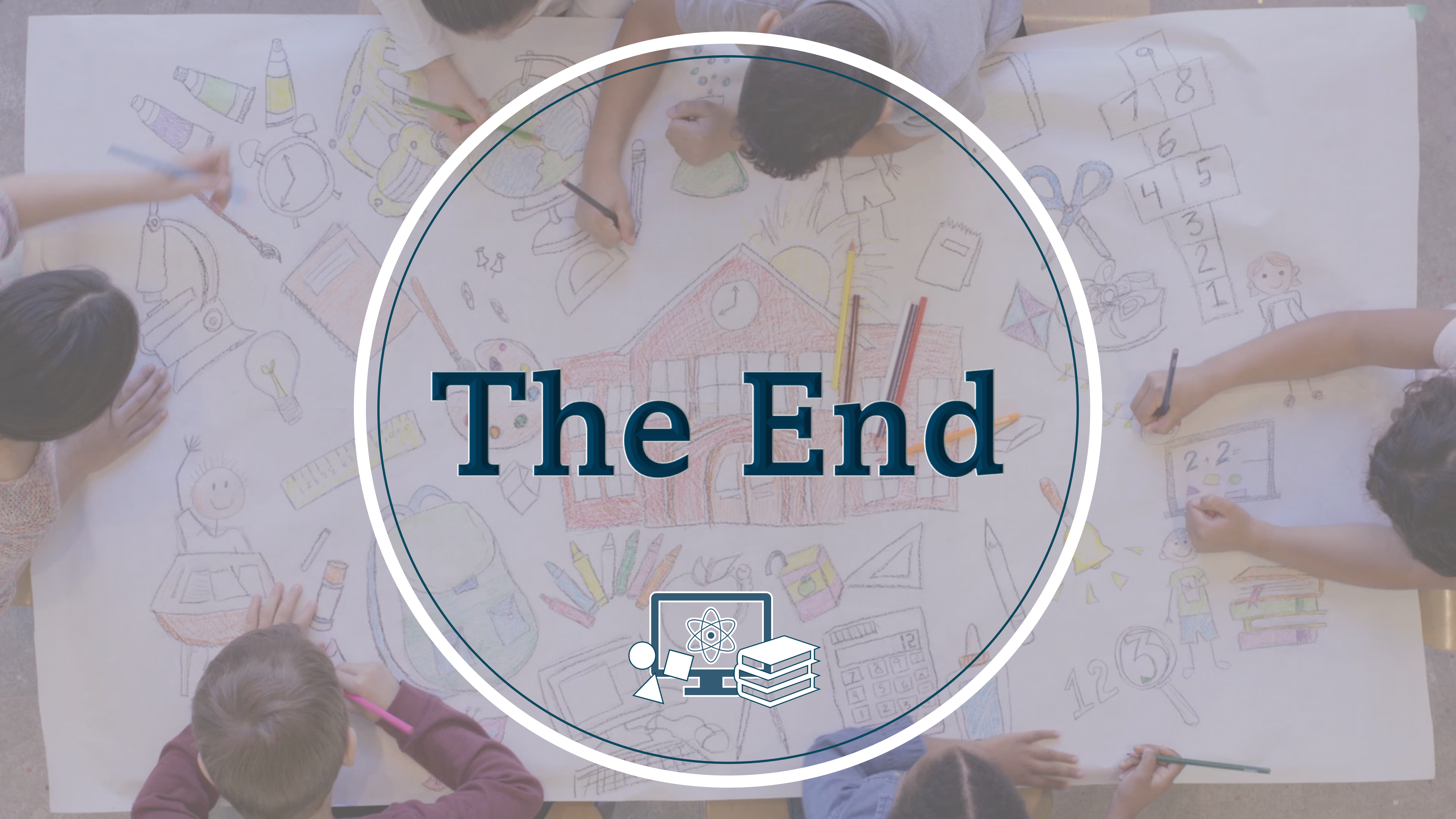
Application 10:

Consider a particle (A), of mass m_1, moves on a horizontal plane with a speed $V_1 = 1.5m/s$ enters in a head-on perfectly elastic collision with a particle (B) of mass $m_2 = 2m_1$ initially at rest.

After collision (A) the speed of (A) is V'_1 and that of (B) is V'_2 as shown in the figure.

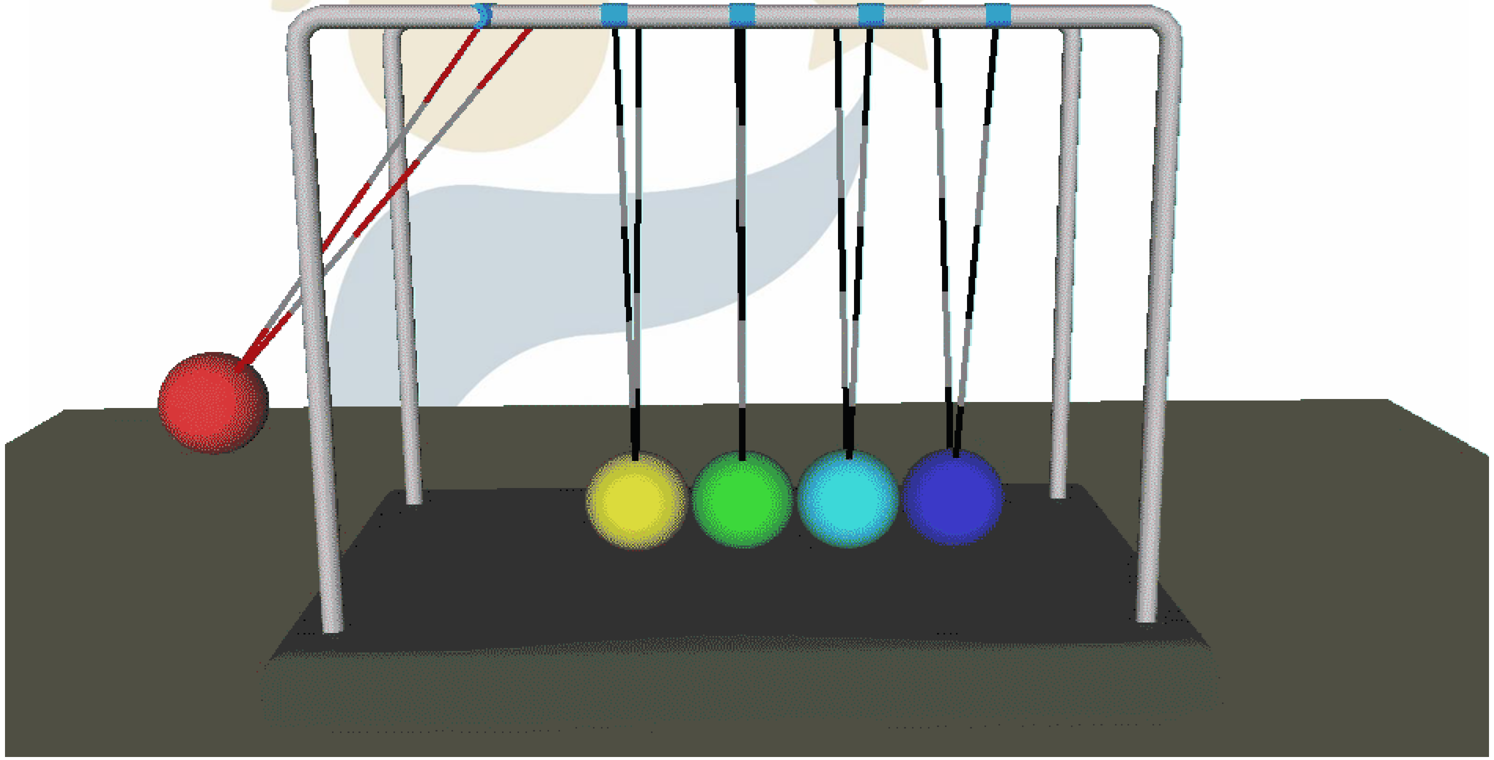
Calculate the speeds V'_1 of (A) and V'_2 of (B) after collision

The End



Grade 12 LS – Physics

Chapter 2: Linear Momentum



Prepared and presented by: Mr. Mohamad Seif

OBJECTIVES

1. To study Inelastic collision between two particles

Types of Collision/ Inelastic Collision

B. Inelastic Collision of two particles

Inelastic Collision

- **Normal Inelastic collision**
- **Completely inelastic collision: objects stick together afterwards**

For both In-Elastic collision

$$\vec{P}_{sys\,(before)} = \vec{P}_{sys\,(after)}$$

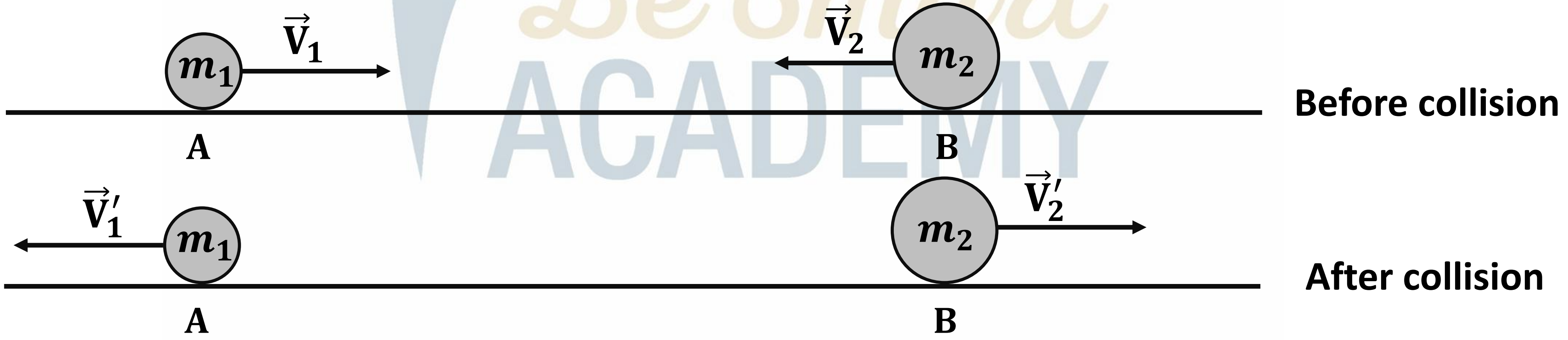
$$KE_{sys\,(before)} \neq KE_{sys\,(after)}$$

Types of Collision/ Inelastic Collision

Application 10:

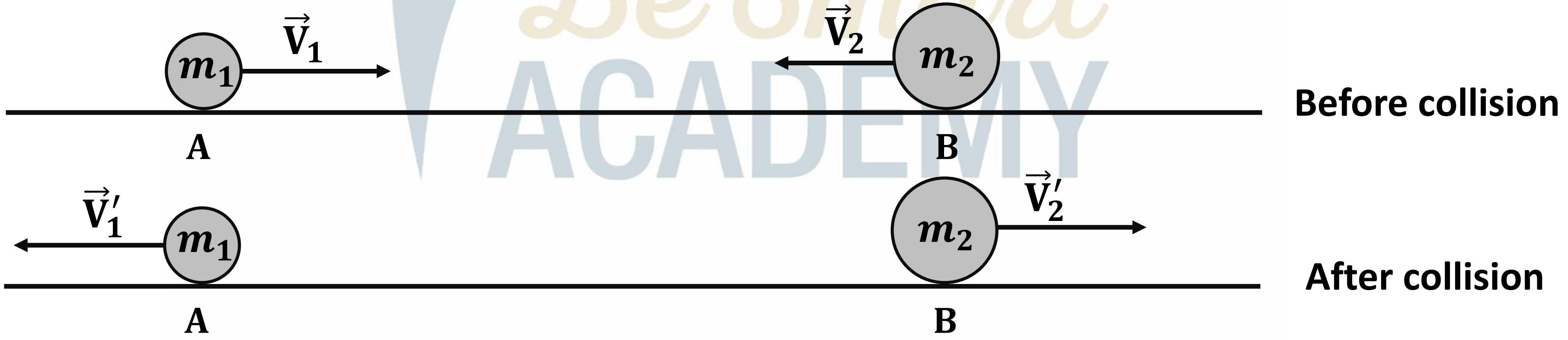
Consider a solid (A), of mass $m_1 = 0.5$kg, moves with a speed $V_1 = 1.5 m/s$enters in a head on collision with a solid (B) of mass $m_2 = 1$kg moves with a speed $V_2 = 0.9 m/s$.

After collision (A) moves back with a speed $V_1' = 3 m/s$ and (B) Moves with a speed V_2'.



Types of Collision/ Inelastic Collision

1. Which variable is conserved during collision.
2. Determine the speed V_2' of body (B) after collision.
3. Calculate the kinetic energy of the system [(A), (B)] before and after collision. Deduce the nature of collision.



Types of Collision/ Inelastic Collision

$m_1 = 0.5kg; V_1 = 1.5m/s; m_2 = 1kg; V_2 = 0.9m/s; V'_1 = 3m/s$

1.Which variable is conserved during collision.

During collision linear momentum is conserved.

2.Determine the magnitude of the speed V'_2 of body (B) after collision.

Apply conservation of linear momentum of the system:

$$\vec{P}_{sys\,(before)} = \vec{P}_{sys\,(after)}$$

$$\vec{P}_1 + \vec{P}_2 = \vec{P}'_1 + \vec{P}'_2$$

$$m_1\vec{V}_1 + m_2\vec{V}_2 = m_1\vec{V}'_1 + m_2\vec{V}'_2$$

$$0.5\times(1.5\vec{i}) + 1\times(-0.9\vec{i}) = 0.5\times(-3\vec{i}) + 1\times\vec{V}'_2$$

$$\vec{V}'_2 = 1.35\vec{i}\ \text{(m/s)}$$

Types of Collision/ Inelastic Collision

$m_1 = 0.5kg; V_1 = 1.5m/s; m_2 = 1kg; V_2 = 0.9m/s; V_1' = 3m/s$

3.Calculate the kinetic energy of the system [(A), (B)] before and after collision.

$$\mathrm{KE(sys)_{bef}} = \mathrm{KE_A} + \mathrm{KE_B}$$

$$\mathrm{KE(sys)_{bef}} = \frac{1}{2}\mathrm{m_1 V_1^2} + \frac{1}{2}\mathrm{m_2 V_2^2}$$

$$\mathrm{KE(sys)}_{bef} = 0.5 \times 0.5 \times (1.5)^2 + 0.5 \times 1 \times (0.9)^2$$

$$\mathrm{KE(sys)}_{before} = 0.56 + 0.405$$

$$KE(sys)_{before} = 0.965\mathrm{J}$$

Types of Collision/ Inelastic Collision

$m_1 = 0.5kg; V_1 = 1.5m/s; m_2 = 1kg; V_2 = 0.9m/s; V_1' = 3m/s$

3.Calculate the kinetic energy of the system [(A), (B)] before and after collision.

$$\mathrm{KE(sys)_{after}} = \mathrm{KE_A} + \mathrm{KE_B}$$

$$\mathrm{KE(sys)_{after}} = \frac{1}{2}\mathrm{m_1}{V_1'}^2 + \frac{1}{2}\mathrm{m_2}{V_2'}^2$$

$$\mathrm{KE(sys)_{after}} = 0.5 \times 0.5 \times (3)^2 + 0.5 \times 1 \times (1.35)^2$$

$$\mathrm{KE(sys)_{after}} = 2.25 + 0.911$$

$$KE(sys)_{after} = 3.16\mathrm{J}$$

Types of Collision/ Inelastic Collision

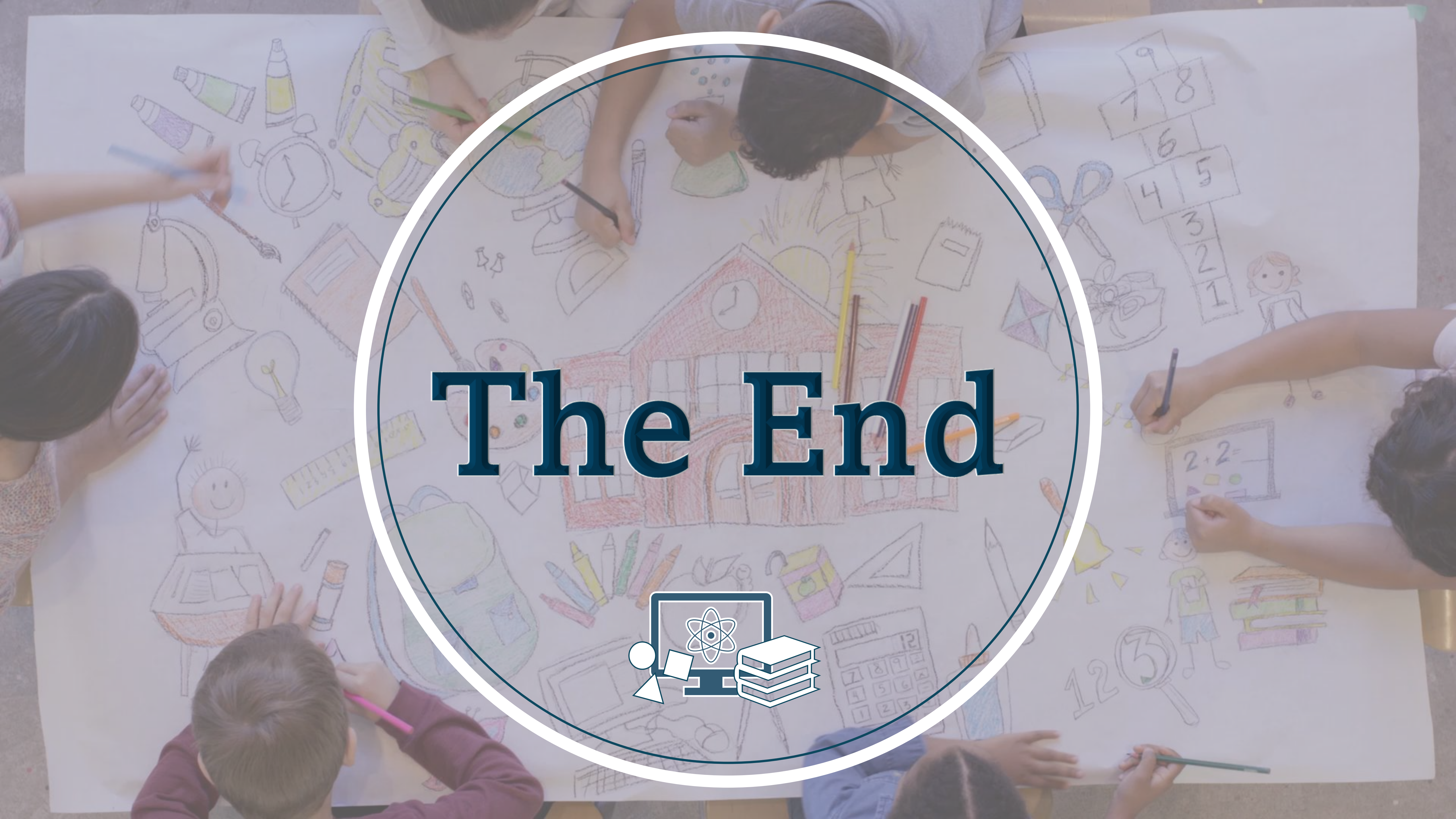
$m_1 = 0.5kg; V_1 = 1.5m/s; m_2 = 1kg; V_2 = 0.9m/s; V_1' = 3m/s$

4. What is the nature of the collision.

$KE(sys)_{after} = 0.965J$ And $KE(sys)_{after} = 3.16J$

$$KE(sys)_{before} \neq KE(sys)_{after}$$

Then the collision is not Elastic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