Impulse - Momentum-Elastic Collisions

Momentum $= mv$ $\quad Kg\,ms^{-1}$

Impulse $= Ft = mV - mv =$ change in momentum

$Kg\,ms^{-1}$ or Ns

Principle of Conservation of Linear Momentum PCLM

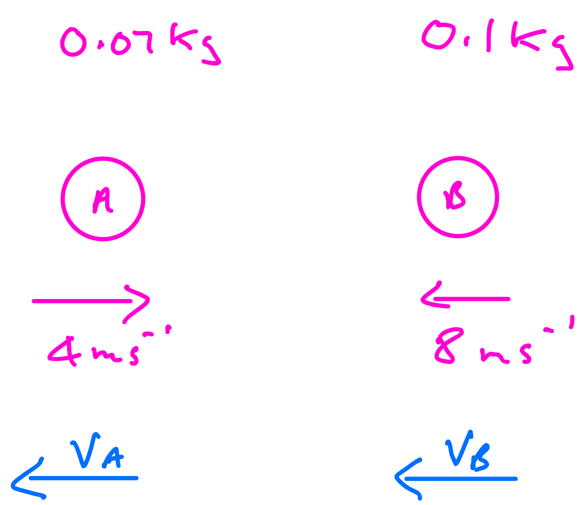
Momentum before impact = Momentum after impact

Newtons law of restitution

$$\frac{\text{speed of separation}}{\text{speed of approach}} = e \qquad 0 \le e \le 1$$

Kinetic Energy $= \frac{1}{2}mv^2$ $\quad$ Joules

Example



← +ve direction.

PCLM $\quad m_A u_A + m_B u_B = m_A v_A + m_B v_B$

$$-0.07\times 4 + 0.1\times 8 = 0.07V_A + 0.1V_B$$

$$0.52 = 0.07V_A + 0.1V_B$$

$$52 = 7V_A + 10V_B \quad (1)$$

Law of Restitution

$$e = \frac{5}{12} = \frac{\text{speed of separation}}{\text{speed of approach}}$$

$$\frac{5}{12} = \frac{V_A - V_B}{4+8}$$

$$\frac{5}{12} = \frac{V_A - V_B}{12}$$

$$5 = V_A - V_B \quad (2)$$

From (2) $\quad V_A = 5 + V_B$

Sub in (1)

$$52 = 7(5+V_B) + 10V_B$$

$$52 = 35 + 7V_B + 10V_B$$

$$17 = 17V_B$$

$$V_B = 1 \text{ ms}^{-1}$$

from (2) $\quad V_B = 5 - V_A$

$$V_B = 5 - 1$$

$$V_B = 4 \ ms^{-1}$$

Initial KE $= \frac{1}{2} m_A v_A^2 + \frac{1}{2} m_B u_B^2$

$= \frac{1}{2} \times 0.07 \times 4^2 + \frac{1}{2} \times 0.1 \times 8^2$

$= 3.76 \ J$

Final KE

$= \frac{1}{2} \times 0.07 \times 4^2 + \frac{1}{2} \times 0.1 \times 1^2$

$= 0.61 \ J$

Loss in KE $= 3.76 - 0.61$

$= 3.15 \ J$

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1 A sledge and a child sitting on it have a combined mass of 29.5 kg. The sledge slides on horizontal ice with negligible resistance to its movement.

(i) While at rest, the sledge is hit directly from behind by a ball of mass 0.5 kg travelling horizontally at $10\,\text{m s}^{-1}$. The coefficient of restitution in the collision is 0.8. After the impact the speeds of the sledge and the ball are $V_1\,\text{m s}^{-1}$ and $V_2\,\text{m s}^{-1}$ respectively.

Calculate V_1 and V_2 and state the direction in which the ball is travelling after the impact. [7]

(ii) While at rest, the sledge is hit directly from behind by a snowball of mass 0.5 kg travelling horizontally at $10\,\text{m s}^{-1}$. The snowball sticks to the sledge.

(*A*) Calculate the velocity with which the combined sledge and snowball start to move. [3]

(*B*) The child scoops up the 0.5 kg of snow and drops it over the back of the sledge. What happens to the velocity of the sledge? Give a reason for your answer. [2]

(iii) In another situation, the sledge is travelling over the ice at $2\,\text{m s}^{-1}$ with 10.5 kg of snow on it (giving a total mass of 40 kg). The child throws a snowball of mass 0.5 kg from the sledge, parallel to the ground and in the positive direction of the motion of the sledge. Immediately after the snowball is thrown, the sledge has a speed of $V\,\text{m s}^{-1}$ and the snowball and sledge are separating at a speed of $10\,\text{m s}^{-1}$.

Draw a diagram showing the velocities of the sledge and snowball before and after the snowball is thrown.

Calculate V. [5]

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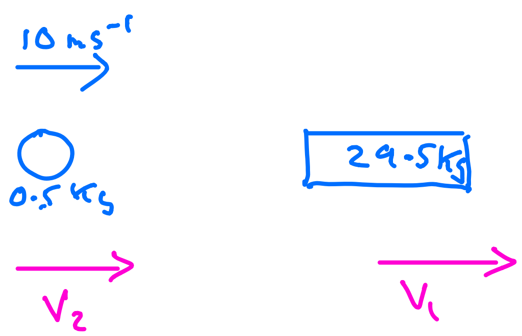

$e = 0.8$

PCLM $10 \times 0.5 = 0.5V_2 + 29.5V_1$

$5 = 0.5V_2 + 29.5V_1$ ①

Restitution Law

$$\frac{\text{speed of sep}}{\text{Speed of approach}} = 0.8$$

$$\frac{V_1 - V_2}{10}$$

$$V_1 - V_2 = 8 \quad (2)$$

$$V_1 = 8 + V_2$$

Sub in (1)

$$5 = 0.5V_2 + 29.5(8 + V_2)$$

$$5 = 0.5V_2 + 236 + 29.5V_2$$

$$-231 = 30V_2$$

$$V_2 = -\frac{231}{30} = -7.7 \text{ ms}^{-1}$$

$$V_1 = 8 - 7.7 \text{ ms}^{-1} = 0.3 \text{ ms}^{-1}$$

Ball has reversed direction of travel and has velocity -7.7 ms^{-1}

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ii) PCLM $= 10 \times 0.5 = 30V$

$$5 = 30V$$

$$V = \frac{1}{6}\ ms^{-1}$$

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iii) sledge continues at same velocity initially since snowball has momentum $0.5 \times \frac{1}{6}$
sledge has momentum $29.5 \times \frac{1}{6}$

No external force on sledge
