MOMENTUM

MOMENTUM AND IMPULSE

- MOMENTUM IS DEFINED AS THE PRODUCT OF MASS AND VELOCITY.
- MOMENTUM IS A VECTOR.

$$\boxed{\vec{p} = m\vec{v}}$$

$\vec{p}$: MOMENTUM ($kg\frac{m}{s}$)
m : MASS (kg)
$\vec{v}$: VELOCITY ($\frac{m}{s}$)

- IMPULSE IS A FORCE ACTING ON AN OBJECT FOR A TIME INTERVAL, Δt.
- IMPULSE CAUSES A CHANGE IN MOMENTUM.

CONSIDER NEWTON'S SECOND LAW:

$$\vec{F}_{NET} = m\vec{a}$$

$$\vec{F}_{NET} = m\frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{F}_{NET}\Delta t = m\Delta\vec{v} = \Delta\vec{p}$$

$$\boxed{\vec{J} = \vec{F}_{NET}\Delta t = m\Delta\vec{v} = \Delta\vec{p}}$$

$\vec{J}$: IMPULSE (N·s) EQUIVALENT TO $kg\frac{m}{s}$

$\vec{F}_{NET}$: NET FORCE (N)

Δt : TIME INTERVAL (s)

m : MASS (kg)

$\Delta\vec{v}$: CHANGE IN VELOCITY ($\frac{m}{s}$)

$\Delta\vec{p}$: CHANGE IN MOMENTUM ($kg\frac{m}{s}$)

- IMPULSE IS EQUAL TO THE AREA UNDER AN F-t GRAPH.

EXAMPLE

A 50 g BALL STRIKES A WALL AT A SPEED OF $3.0\ \frac{m}{s}$. IT BOUNCES BACK AT A SPEED OF $2.0\ \frac{m}{s}$.

a) WHAT IS THE INITIAL MOMENTUM OF THE BALL?

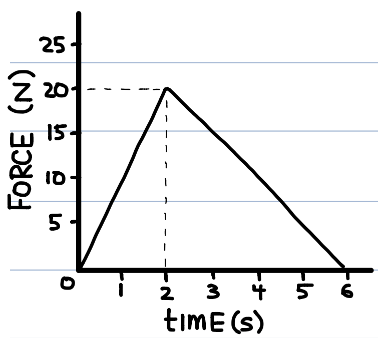
b) WHAT IS THE FINAL MOMENTUM OF THE BALL?

c) WHAT IS THE IMPULSE?

d) IF THE BALL IS IN CONTACT WITH THE WALL FOR 0.10 s, WHAT IS THE AVERAGE FORCE THAT THE WALL EXERTS ON THE BALL?

EXAMPLE

A BOY PUSHES A 20 kg BOX, INITIALLY AT REST, WITH A VARYING FORCE AS SHOWN BELOW. WHAT IS THE SPEED OF THE BOX WHEN THE BOY STOPS PUSHING? ASSUME NO FRICTION.



EXAMPLE

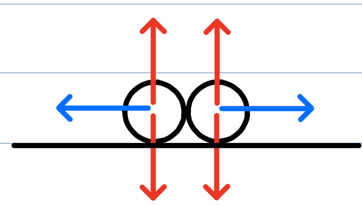
A 10g BALL WITH A SPEED OF $15 \frac{m}{s}$ STRIKES A WALL AT AN ANGLE OF 23° AND THEN REBOUNDS AT THE SAME SPEED AND ANGLE. WHAT IS THE IMPULSE?

CONSERVATION OF MOMENTUM

- A SYSTEM IS A COLLECTION OF TWO OR MORE OBJECTS.
- A CLOSED SYSTEM IS A SYSTEM ON WHICH THE NET EXTERNAL FORCE IS ZERO.

EXAMPLE

A COLLISION BETWEEN TWO BALLS



THE FORCES THE BALLS EXERT ON EACH OTHER ARE INTERNAL.

THE EXTERNAL FORCES BALANCE EACH OTHER OUT.

- THE MOMENTUM OF A CLOSED SYSTEM IS CONSTANT.

$$\boxed{\sum \vec{p}_i = \sum \vec{p}_f}$$

FOR TWO OBJECTS: $\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$

EXAMPLE

A 2.0 kg BALL MOVING TO THE RIGHT AT 4.0 $\frac{m}{s}$ COLLIDES WITH A 4.0 kg BALL MOVING TO THE LEFT AT 3.0 $\frac{m}{s}$. AFTER THE COLLISION, THE 2.0 kg BALL HAS A VELOCITY OF 4.0 $\frac{m}{s}$ TO THE LEFT. DETERMINE THE VELOCITY OF THE 4.0 kg BALL.

1. DRAW TWO DIAGRAMS:
   1) INITIAL
   2) FINAL

   PUT GIVENS ON DIAGRAM.

2. APPLY THE CONSERVATION OF MOMENTUM.

EXAMPLE

A 2500 kg CAR TRAVELLING AT 10 $\frac{m}{s}$ COLLIDES WITH A STATIONARY 12000 kg TRUCK. IF THEY STICK TOGETHER AFTER THE COLLISION, WHAT IS THE VELOCITY OF THEIR COMBINED MASS?

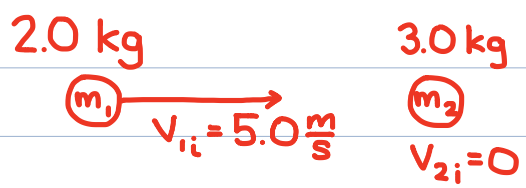
EXAMPLE

A 58.5 g TENNIS BALL IS LOADED INTO A 1.27 kg CANNON AT REST. IMMEDIATELY AFTER THE BALL IS FIRED, THE CANNON RECOILS BACKWARDS A DISTANCE OF 6.0 cm IN 0.020 s. DETERMINE THE SPEED AT WHICH THE BALL IS FIRED.

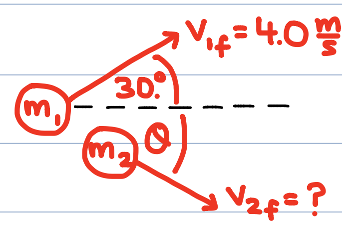
EXAMPLE

A 2.0 kg BALL IS MOVING AT A VELOCITY OF 5.0 $\frac{m}{s}$ TO THE EAST. IT COLLIDES WITH A STATIONARY 3.0 kg BALL. AFTER THE COLLISION, THE 2.0 kg BALL MOVES AT A VELOCITY OF 4.0 $\frac{m}{s}$ 30° NORTH OF EAST. WHAT IS THE VELOCITY OF THE 3.0 kg BALL?

INITIAL



FINAL



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

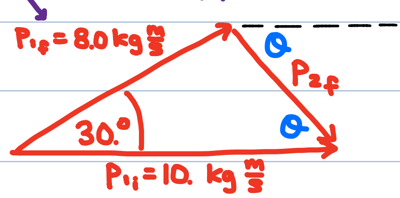
$$\vec{p}_{1i} + \cancel{\vec{p}_{2i}}^{\,0} = \vec{p}_{1f} + \vec{p}_{2f}$$

$$\vec{p}_{1i} = \vec{p}_{1f} + \vec{p}_{2f}$$

$$p_{1i} = m_1 v_{1i} = (2.0)(5.0) = 10.\ kg\frac{m}{s}$$

$$p_{1f} = m_1 v_{1f} = (2.0)(4.0) = 8.0\ kg\frac{m}{s}$$

VECTOR DIAGRAM MUST SHOW MOMENTUM (NOT VELOCITY)



$$p_{2f}^2 = p_{1i}^2 + p_{1f}^2 - 2p_{1i}p_{1f}\cos 30.°$$

$$= 10.^2 + 8.0^2 - 2(10.)(8.0)\cos 30.°$$

$$= 25.4359$$

$$p_{2f} = 5.0434\ kg\frac{m}{s}$$

$$p_{2f} = m_2 v_{2f}$$

$$v_{2f} = \frac{p_{2f}}{m_2}$$

$$= \frac{5.0434}{3.0}$$

$$= 1.6811 \ \frac{m}{s}$$

$$\frac{p_{1f}}{\sin\theta} = \frac{p_{2f}}{\sin 30.^\circ}$$

$$\sin\theta = \frac{p_{1f}}{p_{2f}} \sin 30.^\circ$$

$$\theta = \sin^{-1}\left(\frac{p_{1f}}{p_{2f}} \sin 30.^\circ\right)$$

$$= \sin^{-1}\left(\frac{8.0}{5.0434} \sin 30.^\circ\right)$$

$$= 52^\circ$$

1.7 $\frac{m}{s}$ 52° SOUTH OF EAST

ELASTIC AND INELASTIC COLLISIONS

- **ELASTIC COLLISIONS** ARE THOSE IN WHICH KINETIC ENERGY IS CONSERVED.
- **INELASTIC COLLISIONS** ARE THOSE IN WHICH KINETIC ENERGY IS NOT CONSERVED.
- **TOTALLY INELASTIC COLLISIONS** ARE THOSE IN WHICH THE COLLIDING OBJECTS STICK TOGETHER RESULTING IN THE GREATEST LOSS IN KINETIC ENERGY.

EXAMPLE

A 2.0 kg BALL MOVING TO THE RIGHT AT 4.0 $\frac{m}{s}$ COLLIDES WITH A 4.0 kg BALL MOVING TO THE LEFT AT 3.0 $\frac{m}{s}$. AFTER THE COLLISION, THE 2.0 kg BALL HAS A VELOCITY OF 4.0 $\frac{m}{s}$ TO THE LEFT.

a) DETERMINE THE VELOCITY OF THE 4.0 kg BALL.

b) IS THE COLLISION ELASTIC OR INELASTIC? IF INELASTIC, HOW MUCH KINETIC ENERGY IS LOST?