



# Momentum

## POS Checklist:

define momentum as a vector quantity equal to the product of the mass and velocity of an object ( $p = mv$ ).

### what does it mean to be conserved?

defn: Things that are conserved cannot be created or destroyed.

things that are conserved:

- Energy
- matter
- momentum!

### what do you know about momentum?



## Momentum

"Is the product of mass and velocity."

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

where:

All objects in motion have momentum.

$m$  = mass (kg)

$\vec{v}$  = velocity (m/s)

$\vec{p}$  = momentum (kgm/s)

Momentum is a vector quantity.

### Practice Problems (From Handout):

1. While stepping off a skateboard, the rider propels the skateboard with a velocity of 2.50 m/s [N]. If the mass of the skateboard is 2.2 kg, calculate the momentum of the skateboard.

$$\vec{p} = m\vec{v} \quad \vec{p} = (2.2 \text{ kg})(2.5 \frac{\text{m}}{\text{s}}) = \underline{\underline{5.5 \text{ kgm/s}}}$$

2. A 900 kg car has a momentum of  $1.35 \times 10^4$  kgm/s [E]. Calculate the velocity of the vehicle.

$$\vec{p} = m\vec{v} \quad 1.35 \times 10^4 \text{ kgm/s} = (900 \text{ kg})\vec{v} \quad \vec{v} = \underline{\underline{15 \text{ m/s}}}$$

3. A ball thrown with a velocity of 32.0 m/s [W] has a momentum of 4.5 kgm/s [W]. What is the mass of the ball?

$$\vec{p} = m\vec{v} \quad -4.5 \frac{\text{kgm}}{\text{s}} = m(-32 \text{ m/s}) \quad m = \underline{\underline{0.14 \text{ kg}}}$$

West = negative!

# Momentum and Newton's Second Law



Our old friend Newton had momentum in mind when he penned his famous second law:

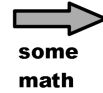
$$\vec{F} = m\vec{a}$$

"a net force causes acceleration"

Newton found a way to connect forces to momentum.

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

"a net force causes acceleration"



$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$$

This means that any change in momentum causes a change in force, or vice-versa.

We now have two equations to calculate momentum:

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

or

$$\vec{p} = \vec{F}\Delta t$$

4. A water balloon with a mass of 4.00 kg is dropped from a window. The balloon reaches a velocity of 31.3 m/s just before striking the ground.

a) Determine the momentum of the balloon just before it strikes the ground.

$$\vec{p} = m\vec{v} \quad \vec{p} = (4 \text{ kg})(31.3 \text{ m/s}) = \underline{\underline{-125 \text{ kgm/s}}}$$

b) If the velocity of the balloon is 0 upon striking the ground, determine the change in momentum of the balloon.

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i = -125 \text{ kgm/s} - 0 \text{ kgm/s} = -125 \text{ kgm/s}$$

c) If the impact with the ground took 0.011 s, calculate the force exerted by the ground on the balloon.

$$\Delta\vec{p} = \vec{F}\Delta t \quad -125 \text{ kgm/s} = \vec{F}(0.011 \text{ s})$$

$$\vec{F} = \frac{-125 \text{ kgm/s}}{0.011 \text{ s}} = \underline{\underline{1.14 \times 10^4 \text{ N}}}$$

5. A 2000 kg car traveling 25 m/s strikes a tree and comes to rest. If the impact took 0.23 s, determine the force exerted on the car.

Step 1:

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

$$\vec{p} = (2000 \text{ kg})(25 \text{ m/s}) = 50000 \text{ kgm/s}$$

Step 2:

$$\Delta\vec{p} = \vec{F}\Delta t$$

$$50000 \text{ kgm/s} = \vec{F}(0.23 \text{ s})$$

$$\vec{F} = \underline{\underline{2.2 \times 10^5 \text{ N}}}$$

6. A 500 g rubber ball is thrown at a velocity of 5.00 m/s and strikes a wall. After only 0.25 s, the ball rebounds straight back with a velocity of -4.50 m/s. Calculate the force exerted on the ball.

omit during covid-19!

## Next: Impulse