Momentum and Impulse

When you think of momentum you think of... something going fast, that 's hard to stop.

For once, the meaning in physics is the same! Momentum refers to the quantity of motion that an object has. It depends on the mass and velocity of an object:

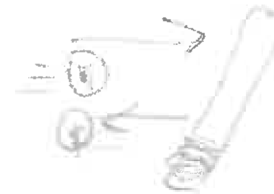
$$\boxed{\vec{p} = m\vec{v}}$$

Momentum, ρ, is measured in kg·m/s or N·s. It is a vector quantity where:

up and right are +ve
down and left are −ve

* draw a picture *

Example: A pitcher hurls a 0.10 kg baseball at 32 m/s.



a. What is the initial momentum of the baseball?

$$\vec{p} = m\vec{v}$$
$$= 0.10\,kg \cdot 32\,m/s = 3.2\,kg\frac{m}{s}$$

b. A batter crushes the ball and the ball leaves the bat at 48 m/s. What was the ball's change in momentum? change in = $v_f - v_i$ so

$$\Delta\vec{p} = m\Delta\vec{v} = m(\vec{v}_f - \vec{v}_i)$$
$$= 0.1\,kg\left(-48\frac{m}{s} - 32\frac{m}{s}\right)$$

−ve indicates opp direction ⟶ $\boxed{= -8\,kg\frac{m}{s}}$

What we see here it that when an unbalanced force acts upon an object for a given amount of time, the object's velocity is changed; and hence, the object's momentum is changed.

The product of that average force and the time it is exerted is called the impulse of force.

$$\text{Impulse } \Delta\vec{p} = \vec{F}_{net} \cdot \Delta t$$

comes from: $F_{net} = ma$ and $a = \frac{\Delta v}{\Delta t}$ so $\vec{F}_{net} = m\frac{\Delta v}{\Delta t}$

$$\boxed{\vec{F}_{net}\Delta t = m\Delta\vec{v}} \text{ or } \vec{F} \cdot \Delta t = \Delta\vec{p}$$

The equation really says that the impulse is equal to... change in momentum

Everyday Examples:

a. Coaches for many sports such as baseball, tennis and golf can often be heard telling their athletes to "follow through" with their swing. How does this help a weaker player hit a ball farther than a stronger player?

$F_{net} \cdot \Delta t = m \Delta V$

constant ↑ constant ↑

contact time increased velocity

b. Using the principle of impulse, explain why an airbag can help people sustain less damage during a collision.

$F_{net} \cdot \Delta t = m \Delta V$

↓ ↑ constant

reduced impact extended time of collision

c. Conventional wisdom suggest that cars should be made tough and rigid to prevent injury during a collision, however newer vehicles are all built with large crumple zones. Why?

$F_{net} \cdot \Delta t = m \Delta V$

↓ ↑ constant

decreased force increased time

Example: A soccer player kicks a 0.450 kg ball at 25.0 m/s east. If the goalie stops the ball by exert 215 N of force, how long does it take the ball to stop?

$F_{net} \cdot \Delta t = m \Delta V$

$\Delta t = \frac{m \Delta V}{F_{net}} = \frac{0.450 \text{ kg} \cdot 25 \text{ m/s [E]}}{215 \text{ N}} = \boxed{0.0523 \text{ s}}$

Example: A 115 kg fullback running at 4.0 m/s East is stopped in 0.75 s by a head-on tackle. Calculate:

a. the impulse felt by the fullback.

$\vec{\Delta p} = m \vec{\Delta V}$ $v_f - v_i$

$= 115 \text{ kg} \cdot (0 - 4 \text{ m/s})$

$= -460 \text{ kg} \cdot \text{m/s}$ or $-460 \text{ N} \cdot \text{s}$

b. the impulse felt by the tackler.

equal in magnitude but opposite in direction (3rd law)

c. the average net force exerted on the tackler.

$F_{net} \cdot \Delta t = m \cdot \Delta V$

$F_{net} = \frac{m \cdot \Delta V}{\Delta t} = \frac{460}{0.75 \text{ s}} = 613 = \boxed{610 \text{ N}}$