# Momentum and Impulse

# Let’s start with everyday language

What do you say when a sports team is on a roll?

They may not have the lead but they may have

______________

**MOMENTUM**

A team that has momentum is hard to stop.

# What is Momentum?

An object with a lot of momentum is also hard to stop

Momentum = p = mv

Units: kg·m/s^2

m=mass

v=velocity

Momentum is also a vector (it has direction)

# Let's practice

- A 1200 kg car drives west at 25 m/s for 3 hours. What is the car's momentum?
- Identify the variables:
  - – 1200 kg = mass
  - – 25m/s, west = velocity
  - – 3 hours = time

P = mv = 1200 x 25 = 30000 kg m/s^2, west

# How hard is it to stop a moving object?

To stop an object, we have to apply a force over a period of time.

This is called **Impulse**

Impulse = $F\Delta t$ Units: N·s

F = force (N)

$\Delta t$ = time elapsed (s)

# How hard is it to stop a moving object?

- Using Newton's 2nd Law we get

$$F=ma \ldots F=m \cdot \Delta v / \Delta t$$

$$F\Delta t = m\Delta v$$

$$F \Delta t = \Delta m v$$

Which means

Impulse = change in momentum

Hewitt Drew-it   Momentum

# Why does an egg break or not break?

- An egg dropped on a tile floor breaks, but an egg dropped on a pillow does not. Why?

$$F\Delta t = \Delta mv$$

If $\Delta t$ goes up, what happens to F, the force?

Right! Force goes down. When dropped on a pillow, the egg starts to slow down as soon as it touches it. A pillow increases the time the egg takes to stops.

# Practice Problem

A 57 gram tennis ball falls on a tile floor. The ball changes velocity from -1.2 m/s to +1.2 m/s in 0.02 s. What is the average force on the ball?

Identify the variables:

Mass = 57 g = 0.057 kg

$\Delta$velocity = +1.2 – (-1.2) = 2.4 m/s

Time = 0.02 s

using $F\Delta t = m\Delta v$

$$F \times (0.02\ s) = (0.057\ kg)(2.4\ m/s)$$

$$F = 6.8\ N$$

# Law of Conservation of Momentum

- For a collision occurring between object 1 and object 2 in an isolated system (Closed System).

The total momentum of the two objects before the collision is equal to the total momentum of the two objects after the collision.

That is, the momentum lost by object 1 is equal to the momentum gained by object 2.

$$m_1v_1 + m_2v_2 = m'_1v'_1 + m'_2v'_2$$

- mass and velocity of two objects before a collision equal mass and velocity after a collision

# Law of Conservation of Momentum

- A 35.0 g bullet moving at 475 m/s strikes a 2.5 kg bag of flour sitting on a table. The bullet passes through the bag and exits at 275 m/s. How fast is the bag moving when the bullet exits.

Known

$m_1$ = 35 g$m_1$' =

$v_1$ = 475 m/s$v_1$' =

$m_2$ = 2.5 kg$m_2$' =

$v_2$ = 0 m/s$v_2$' =

$(.035\ kg)\ (475\ m/s) + (2.5\ kg)\ (0) =$

$(.035\ kg)\ (\ 275\ m/s) + (2.5\ kg)\ v$

$16.2\ kg\ m/s\ \ + 0 = 9.625\ kg\ m/s + (2.5)v_f$

$7.02\ \ = (2.5)\ v_f$

$v_f = 2.8\ m/s$

# Car Crash

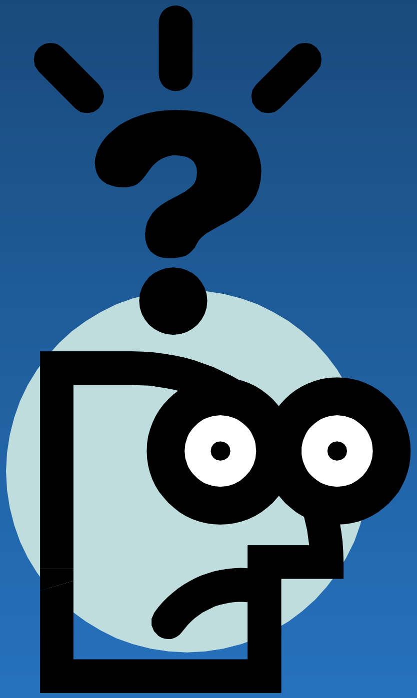
Would you rather be in a head on collision with an identical car, traveling at the same speed as you, or a brick wall?

Assume in both situations you come to a complete stop.

Take a guess

http://techdigestuk.typepad.com/photos/uncategorized/car_crash.JPG

# Car Crash (cont.)



The answer is…

It Does Not Matter!

Look at $F\Delta t = m\Delta v$

In both situations, $\Delta t$, $m$, and $\Delta v$ are the same! The time it takes you to stop depends on your car, m is the mass of your car, and $\Delta v$ depends on how fast you were initially traveling.

Crash force mythbusters

100 mph crash

# What happens when two objects collide and stick together ?

2 freight cars each with a mass of $3.0 \times 10^5$ Collide and stick together. One was initially moving at 2.2 m/s and the other was at rest. What is their final speed?

- Initial momentum ($p_i$) = final momentum($p_f$)

$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

$m_1 v_{1i} + m_2 v_{2i} = 2 m v_f$

cancel out mass…

$v_1 + v_2 = 2v_f$

$v_f = v_1 + v_2 / 2 \quad = \underline{2.2\ m/s + 0.0\ m/s}$

2

$v_f = 1.1 m/s$

Momentum in outer space

Hewitt Drew-it  Conservation of momentum

- Understanding car crashes

space station tour

# Egg Drop connection

- How are you going to use this in your egg drop?

Which of these variables can you control?

$$F\Delta t = m\Delta v$$

Which of them do you want to maximize, which do you want to minimize

(note: we are looking at the force on the egg. Therefore, m represents the egg mass, not the entire mass of the project)