A train is traveling at 100 km/h.

How large of a force is needed to stop it?

- If the train hits a wall, it stops immediately.
- It can be stopped if the engineer breaks

(Constant negative acceleration)

- The engineer can break and release for a long time to eventually stop it

(complicated F(t))

JRcentral bullet train

Dr Richmond's class note
http://spiff.rit.edu/classes/phys211/workshops/w7c/w7c.html

Variable force

Kinematic assumes
constant Force ~ constant $\vec{a}$

What if $\vec{F}$ is a function of time

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

$$\int_{t_1}^{t_2} \vec{F}\, dt = \int_{t_1}^{t_2} m\vec{a}\, dt$$

$$\int_{t_1}^{t_2} \vec{F}\, dt = m\int_{t_1}^{t_2} \vec{a}\, dt$$

$$\int_{t_1}^{t_2} \vec{F}\, dt = m(\vec{v}_2 - \vec{v}_1)$$

Linear Momentum

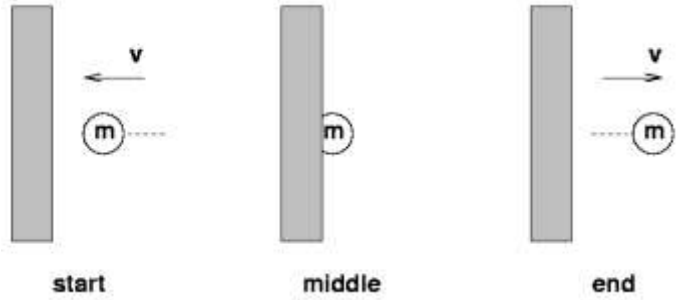
$$\vec{P} = m\vec{v}$$

Impulse on a tennis ball

Tennisracket.me

A tennis ball of mass **m = 0.03 kg** flies towards a wall with velocity **v = 20 m/s west**. It hits the wall, stops momentarily, and then bounces back with the same speed in the opposite direction.

1.What is the ball's initial momentum?
2.What is the ball's final momentum?
3.What is the ball's momentum in the middle frame?
3.What is the **impulse**, defined as the change in momentum



impulse = (final momentum) - (initial momentum)

4.We can simplify things a bit by defining an **average force** over the course of the impact.

If the ball is in contact with the wall for about **Δt = 0.03 s**, then what is the average force on the ball during that time?

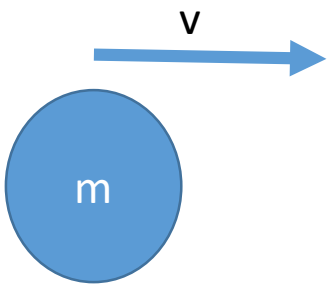
$$\int_{t_1}^{t_2} \vec{F}\, dt \quad = \quad \vec{F}_{\text{avg}} \int_{t_1}^{t_2} dt \quad = \quad \vec{F}_{\text{avg}} \, (t_2 - t_1)$$

Impulse on a baseball

A baseball of mass **m = 0.14 kg** is thrown towards home plate at **100 mph**. The batter whacks it squarely and sends it back towards center field at a speed of **150 mph**.

1. What is the ball's initial momentum?
2. What is the ball's final momentum?
3. What is the **impulse**, defined as the change in momentum
4. If the ball is in contact with the bat for about **t = 0.0007 s**, then what is the average force on the ball during that time?

Conservation of momentum



$\vec{F}$ =0

$\vec{a}$ =0

Velocity is constant

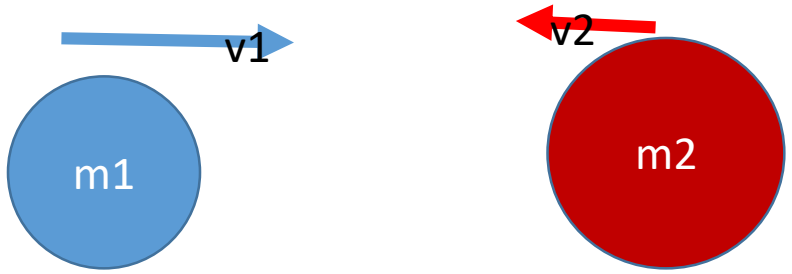
$$\frac{d\vec{v}}{dt} = 0$$

$$\frac{d(m\vec{v})}{dt} = 0$$

Momentum is conserved.

If there are no external forces, momentum is conserved

Collision



Two objects collide, complicated forces between them during collision.
Can we predict what will their velocities be after collision?

$$m_1 \overrightarrow{v_1} \neq m_1 \vec{v}_{1after}$$

But we can put them in 1 system, with no external forces
Total momentum is conserved

Write down the systems total initial momentum.
Define your coordinate system and express P in terms of i,j

Guess what would be the configuration after collision?
What is the system's momentum after collision

Problem to hand in, pistol as an engine

http://spiff.rit.edu/classes/phys211/workshops/w7c/bebop.html

Conservation of momentum for problems with external forces?

In most problems, there are external forces we cannot ignore and momentum is not conserved.

But in many of them we can still use conservation of momentum if we ONLY look at the moment before collision and after collision.

Example
A large truck of mass **M = 10 tons** travelling at 60 mph southwards collides with a minivan of mass **m = 1 ton** going 55 mph northwards. Which way does the mangled wreckage slide afterwards, and how fast does it initially move?

1 ton=907kgr

Collision

Elastic

- Momentum
- Kinetic energy

Two billiard balls of mass **1 kg** each are moving to the right. Initially, the blue ball moves at **5 m/s** and the red ball at **2 m/s**. After they collide, the blue ball moves at **2 m/s.**

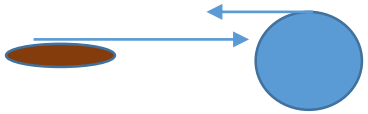
a. Use conservation of momentum to find the final speed of the red ball.

b. What is the initial KE of the system?

c. What is the final KE of the system

Inelastic

- Momentum



JJ throws a baseball (**M = 0.14 kg**) at $\mathbf{v_1}$ **= 45 m/s**. AJ fires a bullet (**m = 0.05 kg**) towards the pitcher's mound at $\mathbf{v_2}$ **= 400 m/s**. The bullet embeds itself into the ball.

a. Use conservation of momentum to find the final speed of the combined object.

b. What is the initial KE of the system?

c. What is the final KE of the system?