Physics 30

Momentum

POS Checklist:

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

Review of Conservation Laws:

1. Conservation of Mass

- **Formulated by Antoine Lavoisier in the late 16th century.**

- **"The mass of the reactants in a chemical reaction is the same as the mass of the products."**

2. Conservation of Energy

- Formulated by Gottfried Leibniz in the late 16th century.

- "The sum of all energy in an isolated system remains the same".

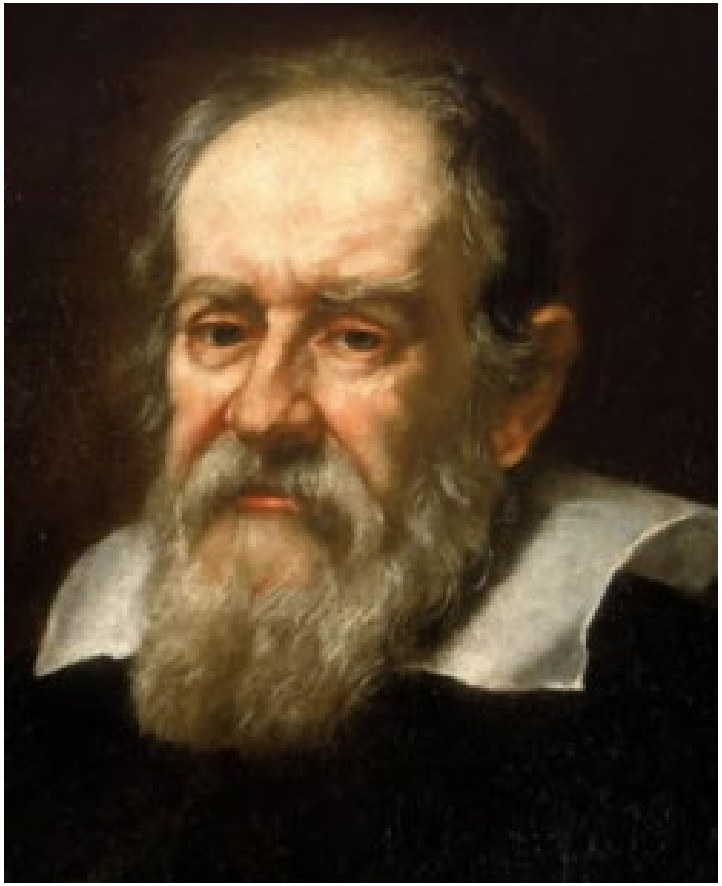
- Energy is never created or lost, just changed in form.

- **Now, mass and energy are not the only things that are conserved…there is yet another quantity!**
- **And it has been known for thousands of years…**

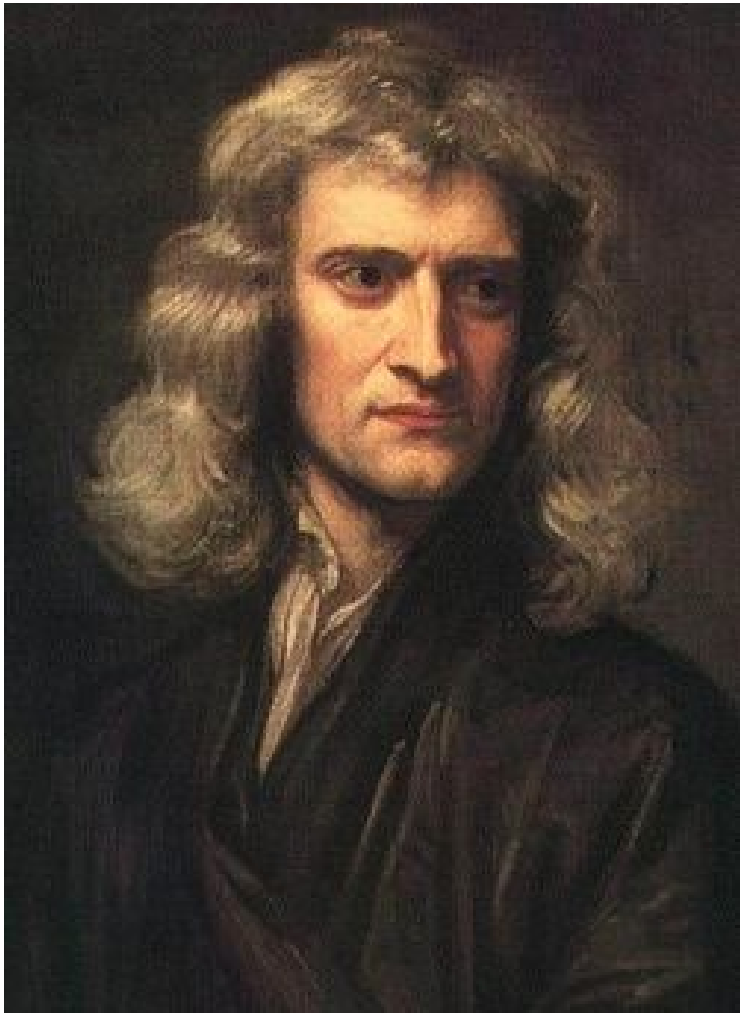
- **1000 AD, Sina describes a quantity called "impetus" which is weight multiplied by speed.**

Abū Alī alusayn ibn Abd Allāh ibn Sīnā

- **Mid 16th century, Galileo calls the quantity "impeto"**



- 18th century, Newton calls the quantity "motus"



Momentum

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

where:

m = mass (kg)

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

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

All objects in motion have momentum.

Momentum is a vector quantity.

Practice Problems (pg 244):

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.

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

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?

Units of momentum:

$$\vec{p} = (kg)(m/s) = \frac{kgm}{s}$$

- Hmm...looks like a Newton (kinda)
- Can you turn a kgm/s into a N?

$$N = \frac{kgm}{s^2}$$

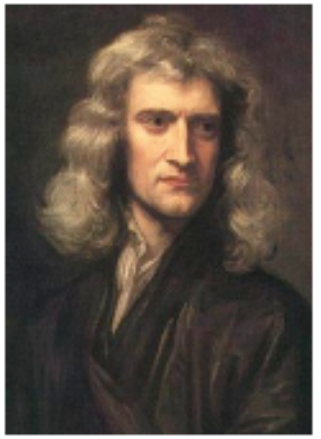
Let's just multiply the top by seconds on both sides...

$$Ns = \frac{kgm\cancel{s}}{\cancel{s^2}}$$

$$Ns = \frac{kgm}{s}$$

Oh, the units of momentum could also be Ns!

Momentum and Newton's Second Law



While he had a funny name for it, Newton had momentum figured out when he penned his famous second law:

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

"a net force causes acceleration"

Let's have a look at that acceleration...

Recall that we can write acceleration as:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

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

$$\vec{F} = \frac{m(\vec{v}_f - \vec{v}_i)}{\Delta t}$$

$$\vec{F} = \frac{m\vec{v}_f - m\vec{v}_i}{\Delta t}$$

$$\vec{F} = \frac{\vec{p}_f - \vec{p}_i}{\Delta t}$$

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

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

Newton's Second Law: Momentum

(where $\vec{F}^{net}$ is constant)

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

Practice Problems (page 247)

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.

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

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

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.

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.