Dynamics

UNDERSTANDING THE FORCES THAT CAUSE MOTION

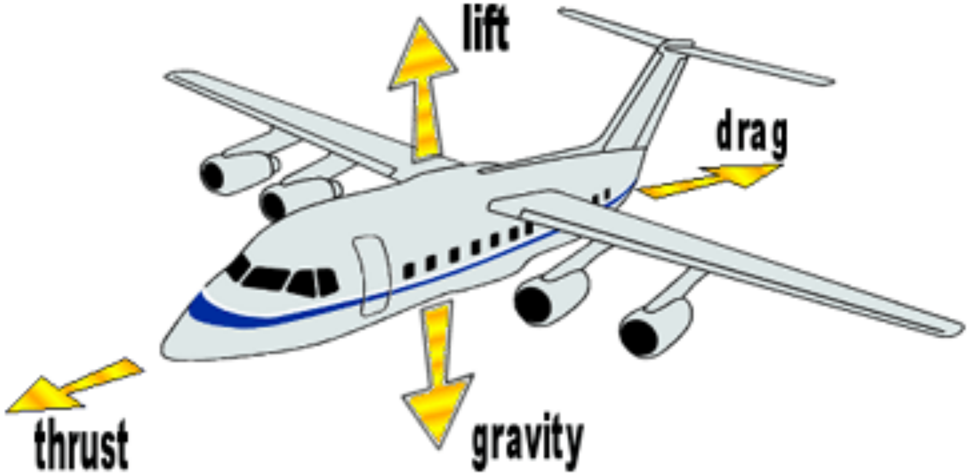
<u>Force</u> is the push or pull on an object

Examples of forces:

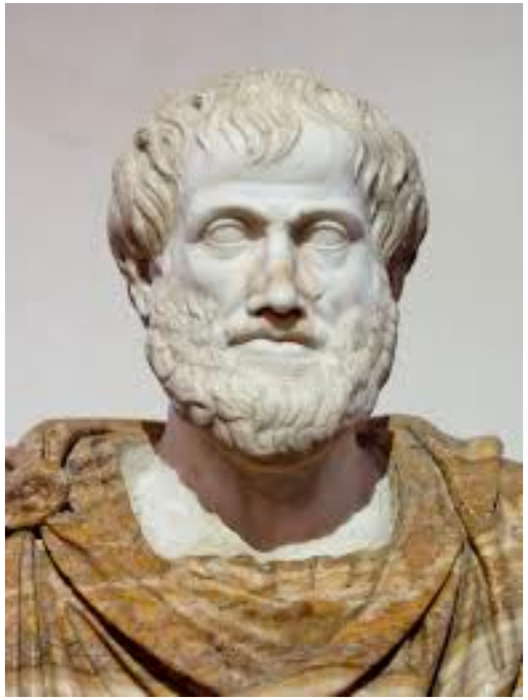
- Lifting your backpack full of books
- Holding a magnet to a fridge
- Gravity
- Friction

Force is a **vector**

Measured in **Newtons (N) = kg m/s^2**

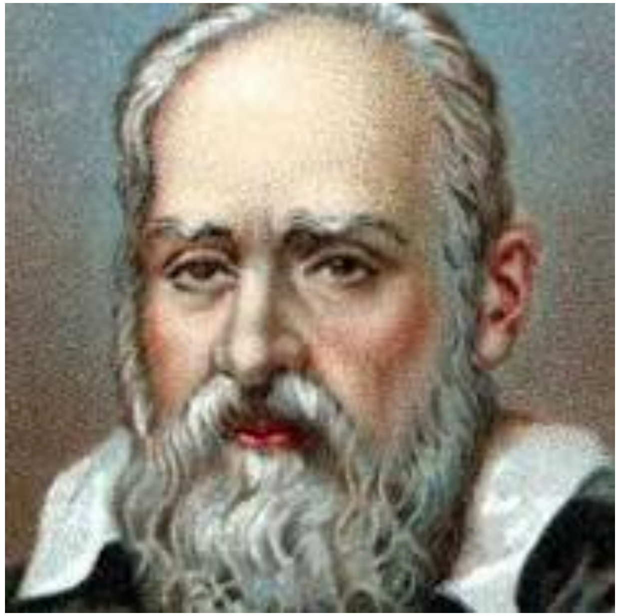


Aristotle believed that for objects to maintain motion, there had to be a constant force acting on them.



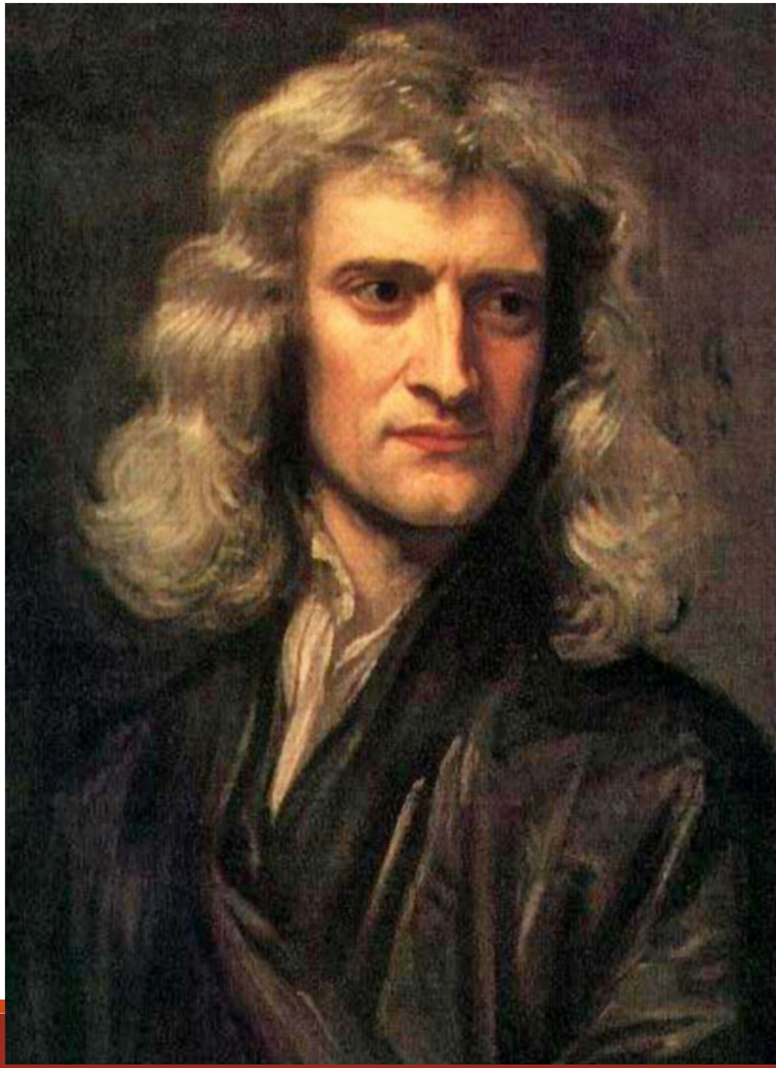
Galileo gave a new view of forces

What forces are acting on a book when you push it across the table at a constant speed?



Isaac Newton got excited about Galileo's conclusions and wrote a book about it

- *Principia* (1687)



What happens when there is net force?

A force on an **object at rest** will cause it to **move**

A force **with** the motion of a moving object will cause it to **speed up**

A force **against** the motion of a moving object will cause it to **slow down**

A force **perpendicular** to an object’s motion will cause it to **change direction**

Therefore…

Better definition of force:

Force is an action capable of causing an object to accelerate

$$\Sigma F = ma$$

Acceleration

A *constant acceleration* means that the object's velocity is changing at a constant rate

-Example: if the acceleration is *along* the direction of motion, the speed *grows* by the same amount in each time interval (e.g., second)

if the speed changes by 1 meter per second each second, the acceleration is (1 meter per second) per second, or 1 m/s^2.

if v = 15 m/s at time t = 0, and a = 1 m/s^2, then, v = 16 m/s at t = 1 sec, v = 17 m/s at t = 2 sec, v = 20 m/s at t = 5 sec, etc.

-If the acceleration is *against* the direction of motion, the speed *decreases* by the same amount in each time interval.

if v = 15m/s at time 0, and a = 1m/s^2 against the motion, then v = 14 m/s at t = 1s, v = 13 m/s at t = 2 s, etc.

What is the force of gravity (F_G) on a person of mass 60 kg?

$F_G = ma = 60\ kg \times 9.8\ m/s^2 = 588N$

This is their **weight**

The moon's acceleration due to gravity is 1/6 that of Earth's.

- *How much more do you weigh on Earth than you do on the moon?*
- *How much does your mass change?*

$$\Sigma F = ma$$

Newton's 2nd Law

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to an object's mass

$$a = \frac{\Sigma F}{m}$$

This is called **proportional reasoning**

Mass is the measure of how much **matter** is in an object.

- It is measured in kilograms (kg)

Newton's 1st Law = Law of Inertia

Inertia is an object's tendency to resist change

- A measure of an object's "laziness"
- The more mass an object has, the more inertia it has
- What makes the giant boulder following Indiana at 5 m/s have more inertia than a marble rolling on the ground at 5 m/s?

Weight vs. Mass vs. Volume

Not the same!

Mass measures inertia

Weight measures force of gravity (F_G) on that mass

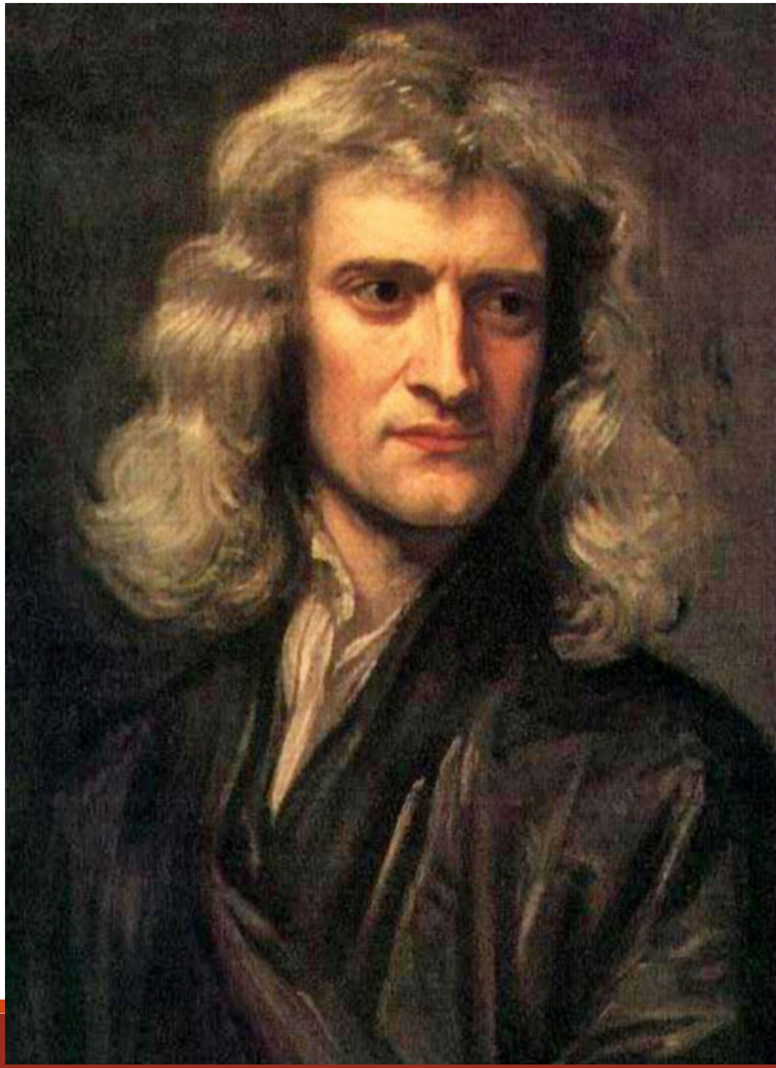
- Your weight on the moon < weight on Earth

Volume measures the amount of space an object occupies

- A 1500 kg junk car is crushed to ½ its original volume. What is its mass?

Newton's 1st Law:

I. An object continues in its state of rest or uniform speed in a straight line unless acted on by an external, unbalanced force



Balanced Force

Equal forces in opposite directions produce no motion

Equilibrium

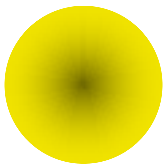
When there is a balanced force:

- This object is in **mechanical equilibrium**
- $\Sigma F = 0$
- Acceleration = 0
  - If the velocity = 0, it is in **static equilibrium**
  - If the velocity = constant, it is in **dynamic equilibrium**

Constant Velocity Motion – No NET Forces

- If no external forces are acting, velocity is constant
- Position changes at a steady (constant) rate

t=0 sec	1 sec	2 sec	3 sec	4 sec	5 sec	6 sec
*	*	*	*	*	*	*
x =1 m	2 m	3 m	4 m	5 m	6 m	7 m
v= 1 m/s	1 m/s	1 m/s	1 m/s	1 m/s	1 m/s *to right*	



If objects in motion tend to stay in motion, why don't moving objects keep moving forever?

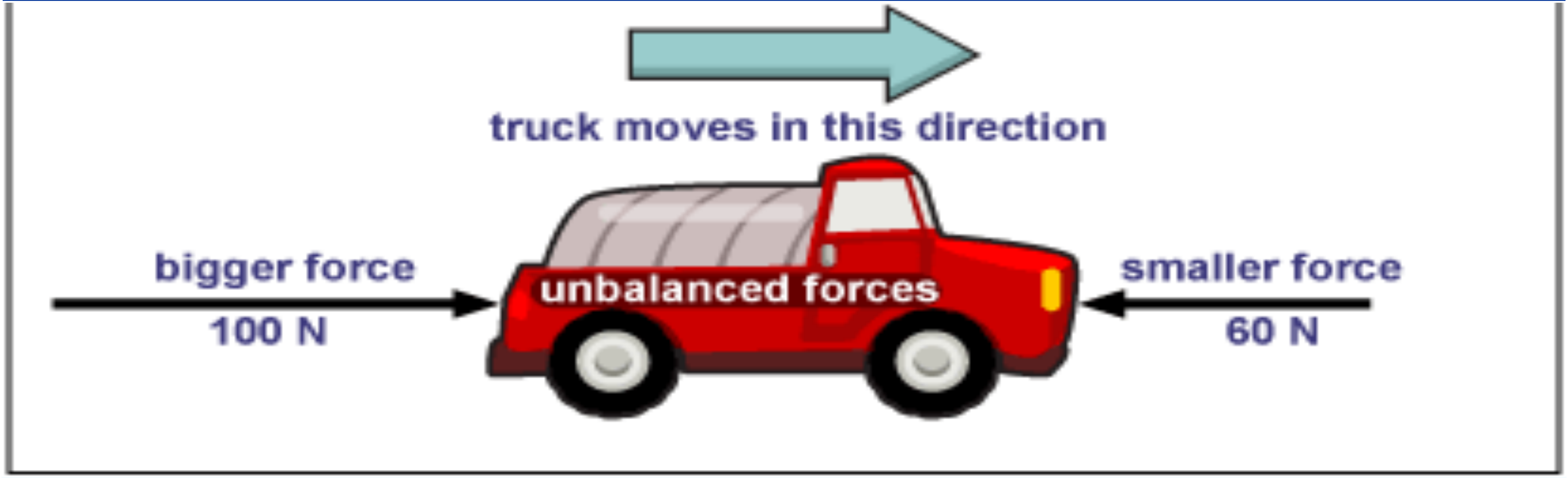
Things don't keep moving forever because there's almost always an unbalanced force acting upon them.

A book sliding across a table slows down and stops because of the force of *friction*.

If you throw a ball upwards it will eventually slow down and fall because of the force of *gravity*.

Unbalanced Forces

Unequal opposing forces produce an unbalanced force causing motion



Unbalanced forces

- While the object experiences a constant net force, it will have a constant acceleration ($F=ma$)
- What happens to the object once the force is released? (assuming no other forces act on it)
  - Moves at a constant speed

Real-life examples of Newton's 1st Law

Coins on elbow – Objects at rest stay at rest

Fixing a hammer – Objects in motion stay in motion

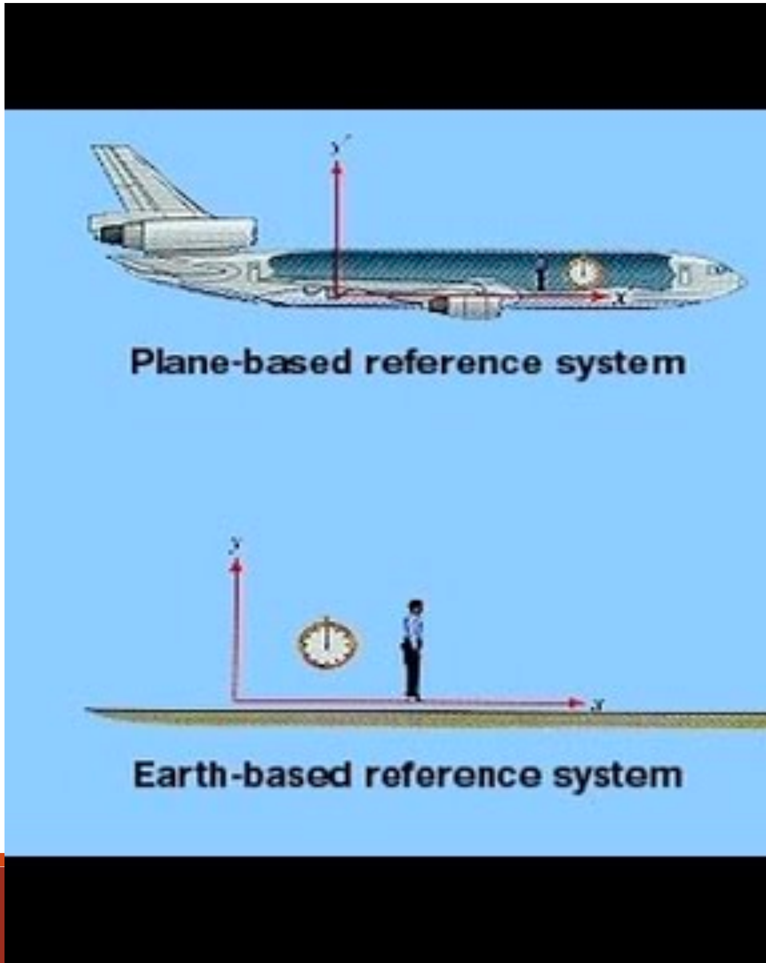
Tablecloth and Dishware - Objects at rest stay at rest

Coins in a cup - Objects at rest stay at rest

Reference Frames

Newton's Laws are true only for **inertial reference frames**

If the frame of reference is accelerating, it is a **non-inertial reference frame** and Newton's Laws no longer apply



If you observe a falling object has an acceleration less than g…

- This object isn't in free fall
- There is a force other than gravity
- The force of air resistance (drag force: F_D) depends on an object's size and speed

Terminal Velocity Revisited

- Reached when $F_{drag} = F_G = \mathrm{mg}$
- For a 75 kg person with a surface area of 0.5 m^2, v_{term} = 50 m/s or about 110 mph
- It takes this person about 5 seconds, 125 m of fall
  - (Actually takes slightly longer because **acceleration is reduced from 9.81 m/s^2 during the fall** as you begin to encounter drag)

Summary

Mass is a property of objects, producing a reluctance to accelerate, called *inertia*

Velocity refers to both speed *and* direction

Acceleration means a change in velocity (either magnitude, *or* direction *or both*)

If an object is accelerating, it is being acted upon by a net force, and $\boldsymbol{F} = m\boldsymbol{a}$. No exceptions.