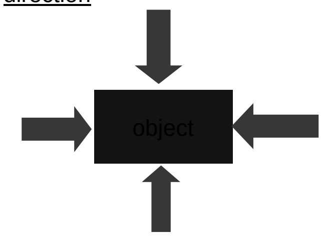
L-6 – Newton's Second Law

- Objects have a property called inertia which causes them to resist changes in their motion (Newton's1st Law or Galileo's law of inertia)
  - → *if it is at rest, it stays at rest*
  - → *if it is moving, it keeps moving with constant velocity*
- forces can overcome inertia to produce acceleration (2nd Law)

Change in velocity

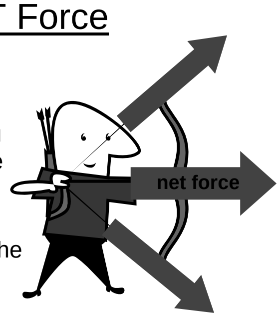
Force is a vector quantity

- It matters not only how hard you push, but also in what direction

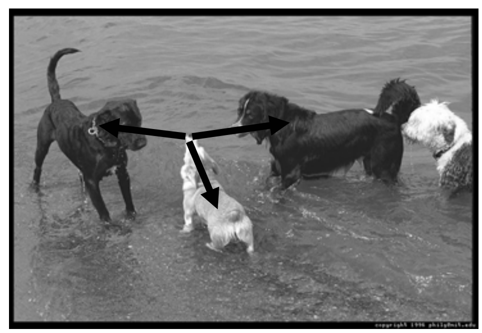


The NET Force

- What really matters is the Net Force
- The Net Force is what you get when all the forces are properly combined
- The Net Force takes into account both how strong the forces are and in what direction they act
- The Net Force determines the acceleration of the object



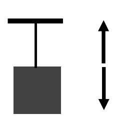
Example: Net force = 0



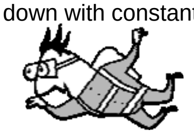
Net force = 0

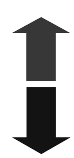
- An object can have many forces acting on it at the same time.
- If all the forces oppose each other exactly then the net force = 0 and the object will *either be at rest or move with constant velocity.*

Example: a block hanging by a string from a ceiling



A skydiver has two forces - gravity (his weight) and air resistance. When they balance, he coasts down with constant speed.

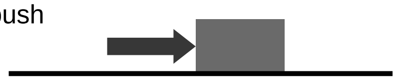




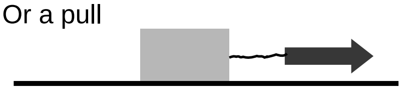
- *Zero net force does not necessarily imply zero velocity* (a skydiver's terminal speed will be greater than 100 mph)
- Zero force → constant velocity, v = 0 is a special case of constant velocity. A parachutes reduce the terminal speed to about 10 mph.

Newton's 2nd Law

- To change the velocity of an object a net force must be applied to it.
- A push



- Or a pull

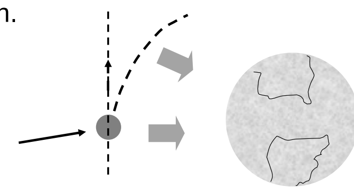


Contact and non-contact forces

- Pushes, pulls, friction, and tension are <u>contact forces-</u> whatever exerts the force actually touches the object
- <u>Non-contact forces</u>: → Forces that act without contact between objects
  - a) electric forces
  - b) magnetic forces
  - c) gravity

The moon is falling away from its straight line path

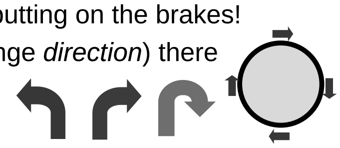
- The force of gravity acting on the moon pulls it away from its otherwise straight line path.



• the moon is constantly *falling* toward the earth in the sense that it falls away from the straight line it would follow if the earth were not there

Acceleration

- *Any* change in velocity is acceleration
- If you speed up (velocity *increases)*, there is acceleration
- If you slow down (velocity *decreases)* there is acceleration – we call this <u>deceleration</u> – putting on the brakes!
- If you turn (change *direction*) there is acceleration



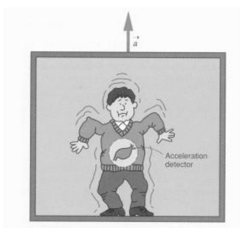
You are NOT accelerating if

- You are riding your bike up a hill at *constant speed* (v = a constant)
- You are in a *parked* car (v = 0)
- You are in an elevator that is going up with *constant speed*. (v = a constant)
- You are in an elevator that is going down with *constant speed*. (v = a constant)

You are accelerating if

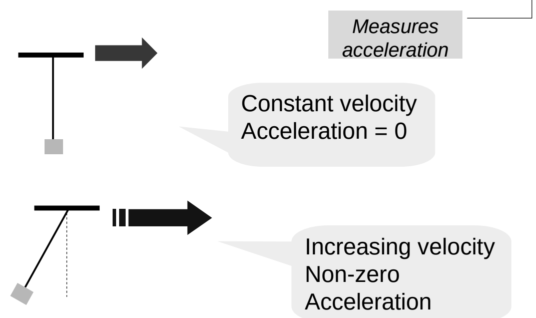
- You are going down a steep hill on rollerblades (*your velocity increases*)
- In an elevator when it starts to go up (*you are at rest then start moving)*
- In a car going around a curve at constant speed (*the direction of your velocity changes)*
- You are on a bus that is slowing down (*your velocity decreases*)
- you are in an elevator and the cable breaks (you will accelerate downward (good luck)

How can you tell if you are accelerating – your stomach knows!

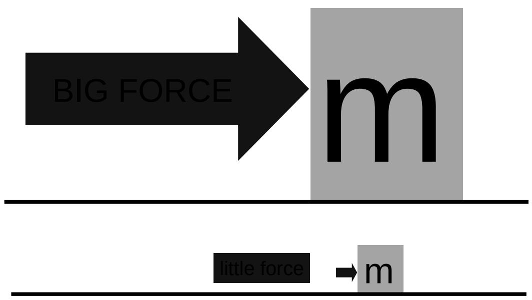


- That funny feeling you have when the elevator starts to go up (or down) is your stomach's inertia resisting motion.
- Your body starts going up but your belly lags behind a bit. It does catch up!

Hanging mass accelerometer



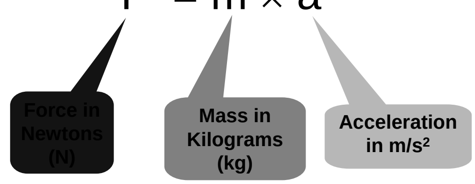
What does it take to get it going?



Newton's 2nd Law

Force = mass *times* acceleration

$$F = m \times a$$



other forms of Newton's 2nd Law

- If a force F is applied to an object of mass M then the acceleration is

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

- If a force F acts on an object and the acceleration is a, then the mass must be

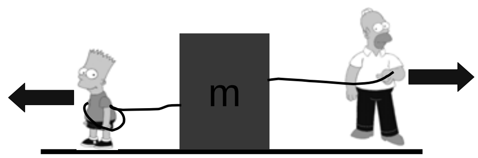
$$m = \frac{F}{a}$$

Newton's 2nd Law: F = m a

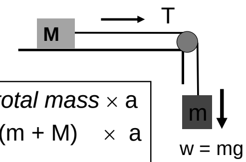
- It is the law which explains how things move - *dynamics*
- If a net force is applied to an object it will accelerate – change its velocity
- It includes the law of inertia → if there is no force, F = 0, then the acceleration = 0
  → the velocity doesn't change
  → no force is needed to keep an object moving with constant velocity.

The “F” in F = m a

- If there is more than one force acting on an object, then F is the <u>net force.</u>
- If two people pull on an object with equal forces in opposite directions, then the net force is zero and the acceleration is zero.



<u>Constant acceleration on the air track</u>

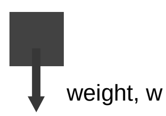


Net Force on *system* = *total mass* × a
➔ mg = (m + M) × a
➔ a = mg / (m+M)

M (kg)	M (kg)	a = mg/(m+M) (m/s^2)
0.02	0.3	0.61
0.02	0.6	0.32
0.04	0.3	1.15
0.04	0.6	0.85

<u>Acceleration due to gravity</u>

- w = m × g

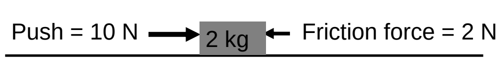


- F = m × g = m × a → a = g for any m

<u>Example Problem -1</u>

- Two forces act on a 4 kg object. A 14 N force acts to the right and a 2 N force acts to the left. What is the acceleration of the object?
- Net force = 14 N – 2 N = 12 N (to the right)
- F = m a → 12 N = 4 kg x a
- → a = 3 m/s^2 ➔ the object accelerates to the <u>right</u> at 3 m / s^2, in the direction of the NET force

<u>Example Problem 2</u>



- A 2 kg box is pushed by a 10 N force while a 2 N friction force acts on the box. What is the acceleration of the box?
- Net force = 10 N – 2 N = 8 N to the right
- acceleration = Force / mass = 8N / 2 kg = 4 m/s^2 to the right.

➔ acceleration is in the direction of the NET Force