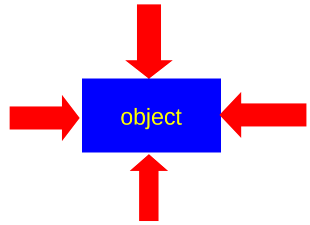
L-6 – Newton's Second Law

- 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

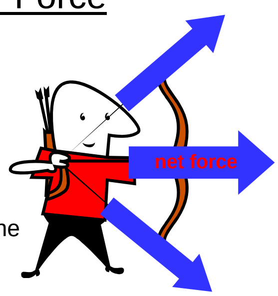
Force is a *vector* quantity

The effect of a force depends on both its *magnitude* (strength), and its *direction*.

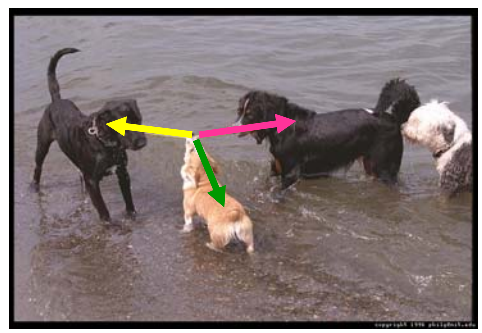


The NET Force

- 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

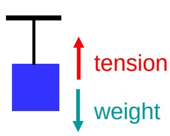


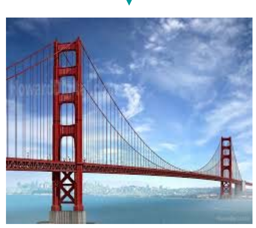
Example: Net force = 0



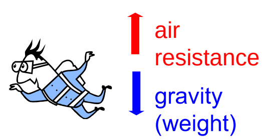
Net force = 0

- An object may 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.*
- If the net force is zero and the object is at rest, this is called *static equilibrium.*





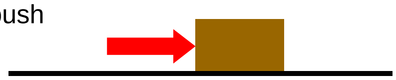
Skydiving: motion with constant velocity



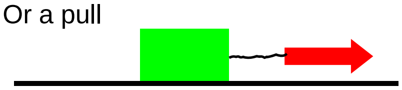
- Two forces act on a sky-diver:
  - gravity (weight) and
  - air resistance (drag)
- The force of air resistance *increases* with velocity
- When the air resistance equals the weight, the forces cancel, and the skydiver then falls with constant velocity called the *"terminal velocity."*
- Without a parachute, a skydiver's terminal speed would be greater than about 100 mph (not good for landing!)
- The parachute increases the air resistance and reduces the terminal speed to about 10 mph (landing is more pleasant!)
- ***Zero net force means zero acceleration, not zero velocity***

Newton's 2nd Law

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



- Or a pull



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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

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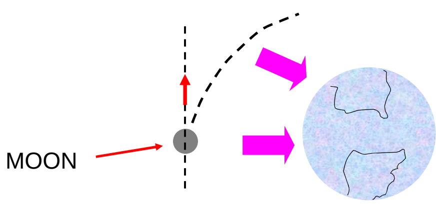
The moon is always falling

The force of gravity acting on the moon pulls it away from the straight line path it would follow if the Earth was not pulling on it.



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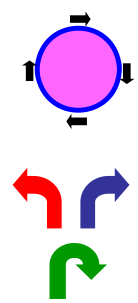
Acceleration

- *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



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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)

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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)

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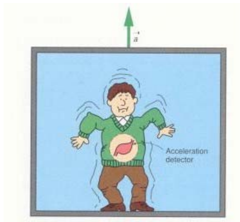
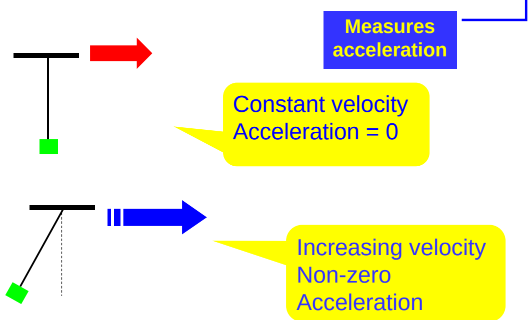
Your stomach is an acceleration detector!

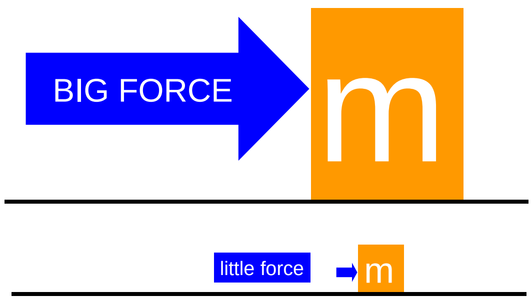


- The funny feeling you have when the elevator starts to go up (or down) is your stomach's inertia resisting motion.
- Your body starts going up but your stomach lags behind a bit, before it catches up!

Hanging mass accelerometer



What does it take to get it going?



Newton's 2nd Law

Force = mass *times* acceleration

$$F = m \times a \quad \text{or,} \quad a = \frac{F}{m}$$

NET Force in Newtons (N)

Mass in Kilograms (kg)

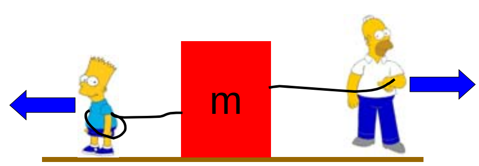
Acceleration in m/s^2

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.

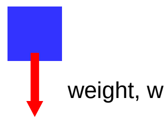
The "F" in F = m a

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



Acceleration due to gravity

- $w = m \times g$



- Combine with Newton's 2nd Law:
  $F = \cancel{m} \times g = \cancel{m} \times a$

➔ $a = g$ for all masses (Galileo)

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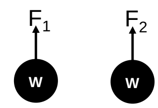
Breaking the string

- F_1 is applied gently to lift the weight ($F_1 \approx W$, so $a \approx 0$), the string does not break
- A much larger F_2 is applied and the string breaks
  $F_2 - W = ma$, so
  $F_2 = ma + W >> F_1$
- If the string is not strong enough to provide the tension, it breaks



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Example Problem -1

- 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 right at $3\ m / s^2$, in the direction of the NET force

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Example Problem 2

A 2 kg box initially at rest, is pushed by a 10 N force while a 2 N friction force acts on the box.
a) What is the acceleration of the box?
b) What is its velocity 3 s after it begins to accelerate?

Solution:
(a) Net force = 10 N – 2 N = 8 N to the right
a = F/m = 8N / 2 kg = 4 m/s^2 to the right, in the direction of the NET Force
(b) v = at = 4 m/s^2 x 3 s = 12 m/s.

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