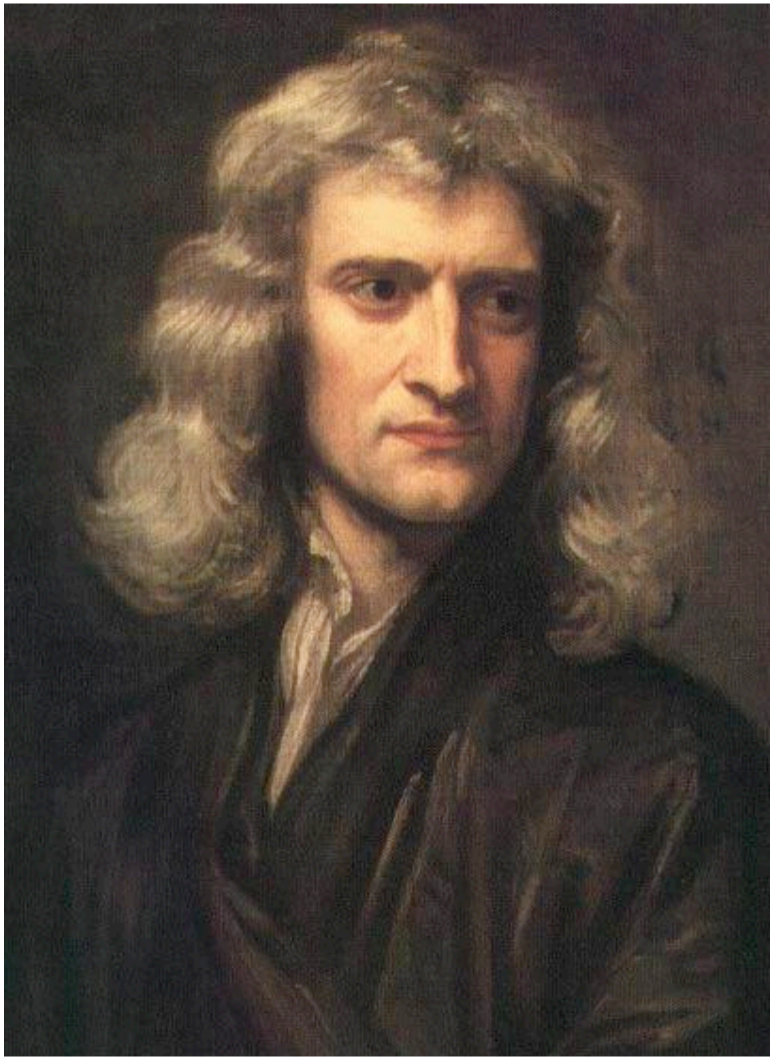
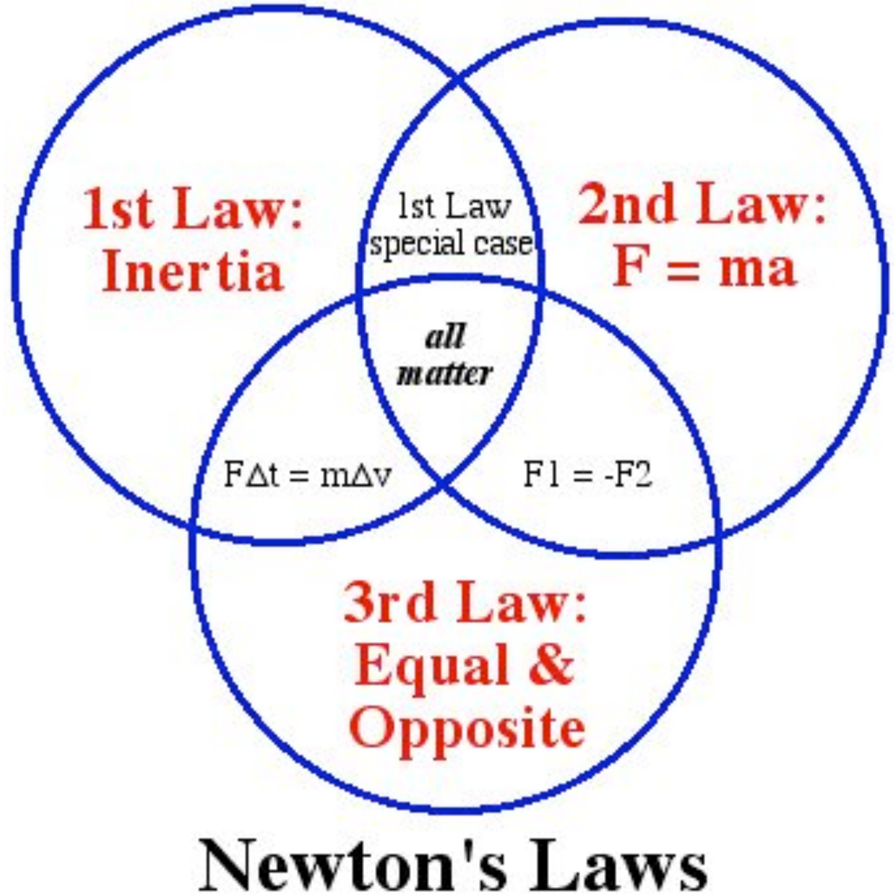
Newton and 3 Laws of Motion - How Rockets Actually Work!





We must define

- Mass/Inertia (m)
- Velocity (v)
- Acceleration (a)
- Force (F)

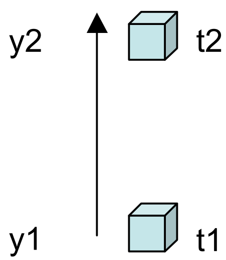
Velocity

The change in position per unit time

$$v = \frac{\text{change in position}}{\text{change in time}}$$

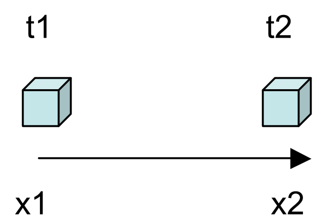
Since a change in position has two properties, change in location and change in direction …

We see that velocity must be described by both speed and direction



$$v = \frac{y2 - y1}{t2 - t1}$$

change in “y” upward



$$v = \frac{x2 - x1}{t2 - t1}$$

change in “x” sideways

If velocity is constant (not changing with time) then the motion is called constant motion

If velocity is not constant, then the object is said to be accelerating…

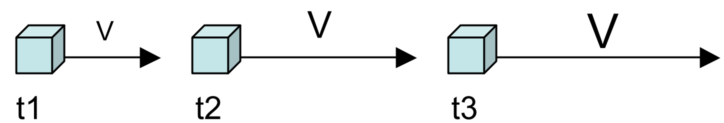
Acceleration

The change in velocity per unit time

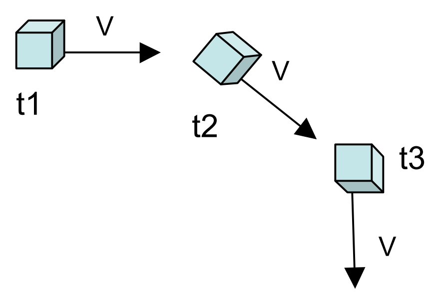
$$a = \frac{\text{change in velocity}}{\text{change in time}}$$

Since velocity has two properties, speed and direction, acceleration can be due to a change in one or the other of these or both of these

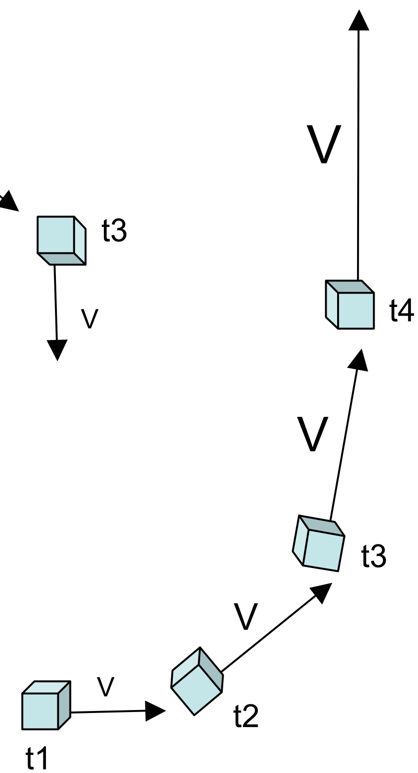
$$\text{acceleration} = \frac{\text{change in speed}}{\text{change in time}}$$



$$\text{acceleration} = \frac{\text{change in direction}}{\text{change in time}}$$



$$\text{acceleration} = \frac{\text{change in speed and direction}}{\text{change in time}}$$



1st Law: Inertia

A body will remain/continue in its present state of motion unless a net force acts on it.

Unchanging motion is called constant motion

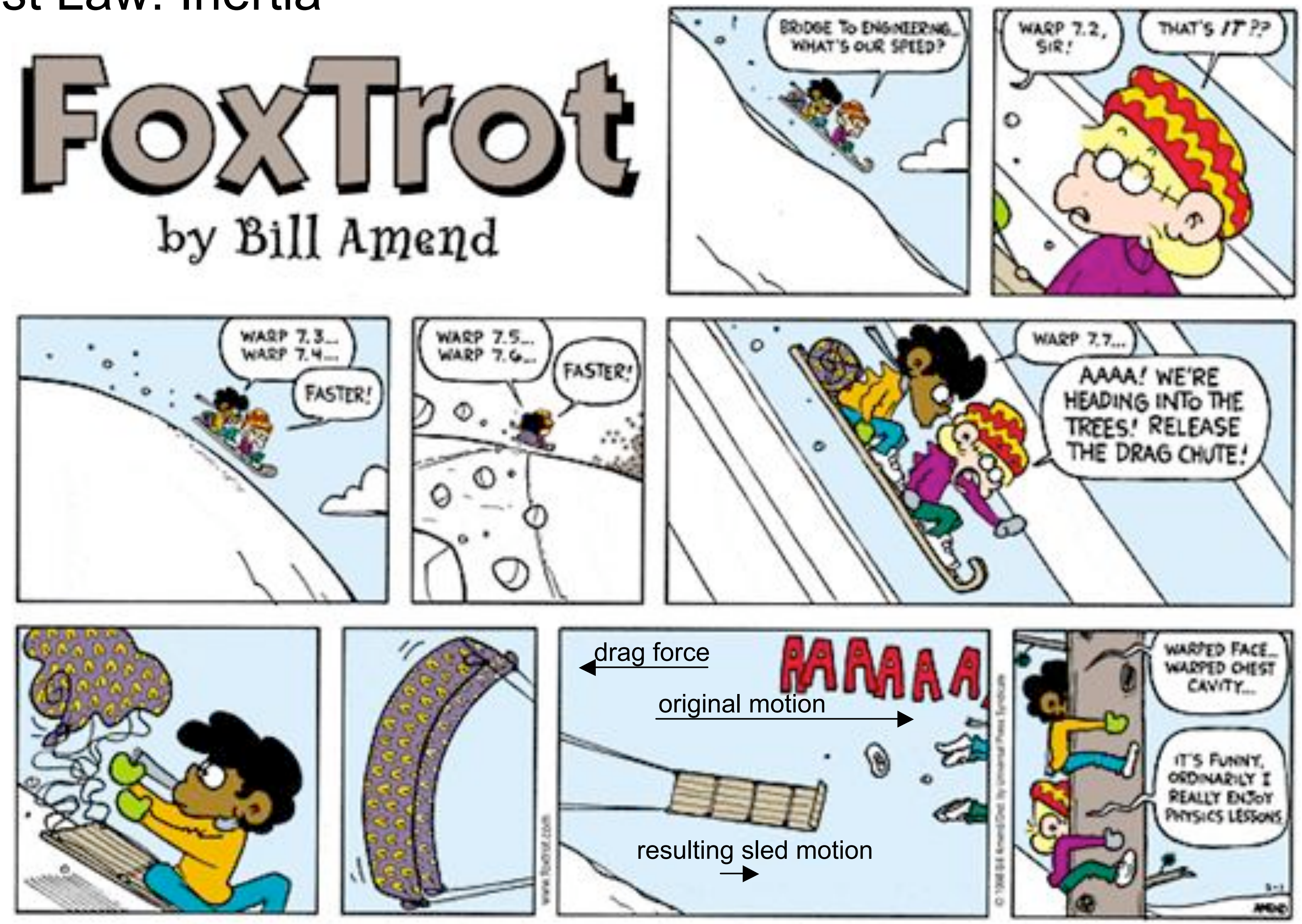
2 types: (1) rest, $v=0$
- with respect to you, the body is motionless
  no motion, not moving ($v=0$, $a=0$)

(2) constant velocity (implies movement along a straight line)
- with respect to you, the body's motion is not changing
  direction does not change ($v=\text{constant}$, $a=0$)
  speed does not change ($v=\text{constant}$, $a=0$)

Inertia is measured as mass. The mass (inertia) quantifies the body's resistance to changing its motion when a net force acts on it.

Mass is not your weight. Your weight is the force acting on you due to Earth's gravity. Your weight will be different on different planets because the force of gravity differs from planet to planet. But, your mass is an unchanging quantity- it is an intrinsic property of you.

1st Law: Inertia



A force (drag) acts on the sled, which slows down- but not on our heroes! …

2nd Law: relationship between net force, mass, acceleration

A net force on an object will result in the object accelerating in the direction of the net force

Behavior:

(1) acceleration is proportional to the net force
- the bigger the net force, the greater the acceleration
- the smaller the net force, the smaller the acceleration

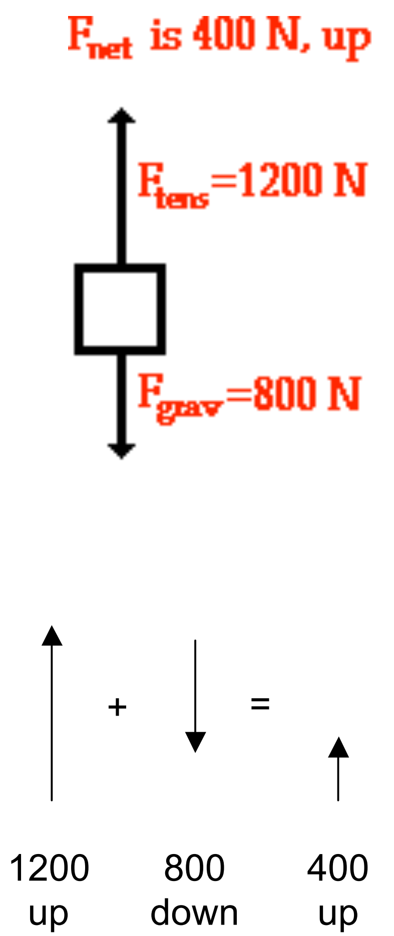
(2) acceleration is inversely proportional to the object's mass
- the bigger the object's mass, the smaller the acceleration
- the smaller the object's mass, the greater the acceleration

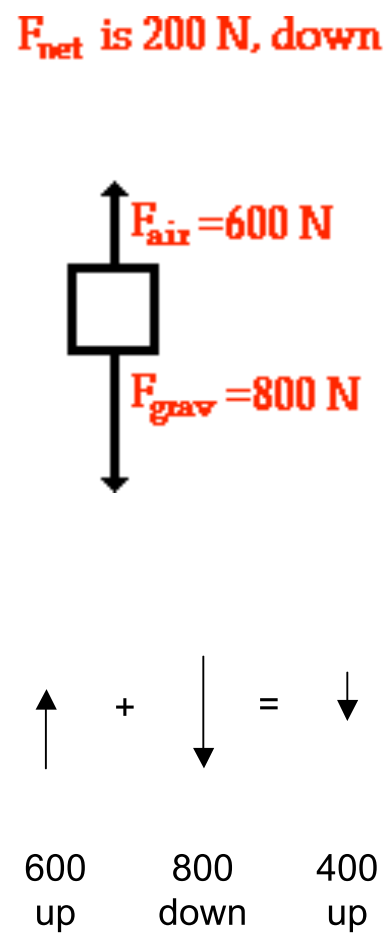
(3) direction of acceleration is in direction of net force

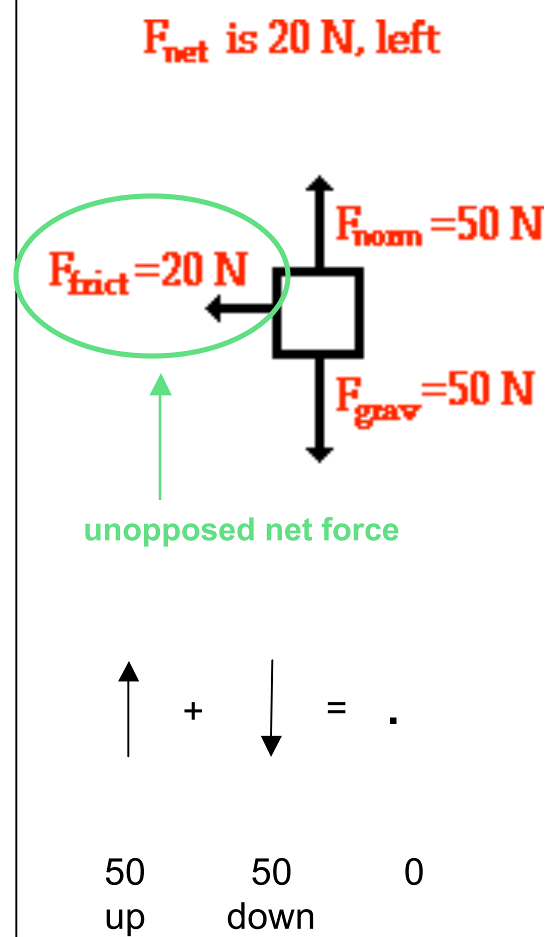
$$a = \frac{\text{net force}}{\text{object's mass}}$$

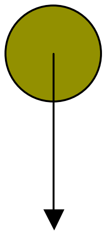
Net Force…

Must account for direction and magnitude (strength)





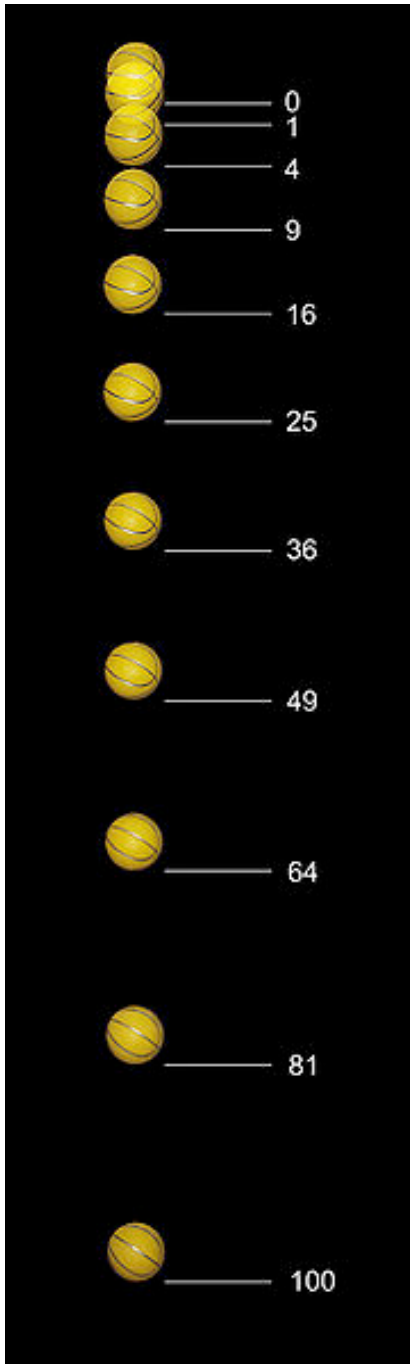




gravity
force
(down)

Each second the velocity of the ball increases due to a constant acceleration

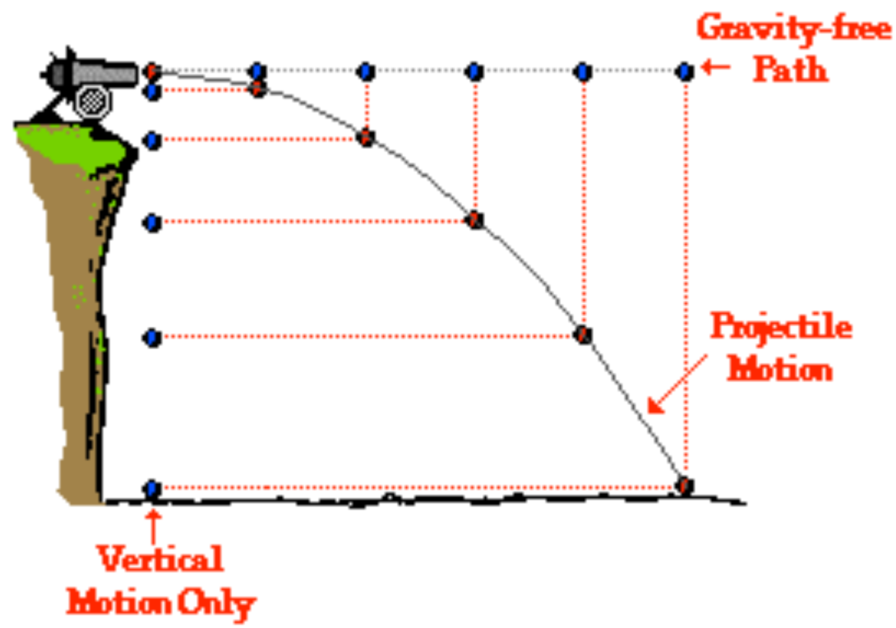
The acceleration is constant because the net force is a constant force.



projectile motion

- Newton's 1st and 2nd Laws combine together to give an arching path

Horizontal	F = 0	a = 0	v = constant
Vertical	F = gravity	a = constant,	v = always increasing



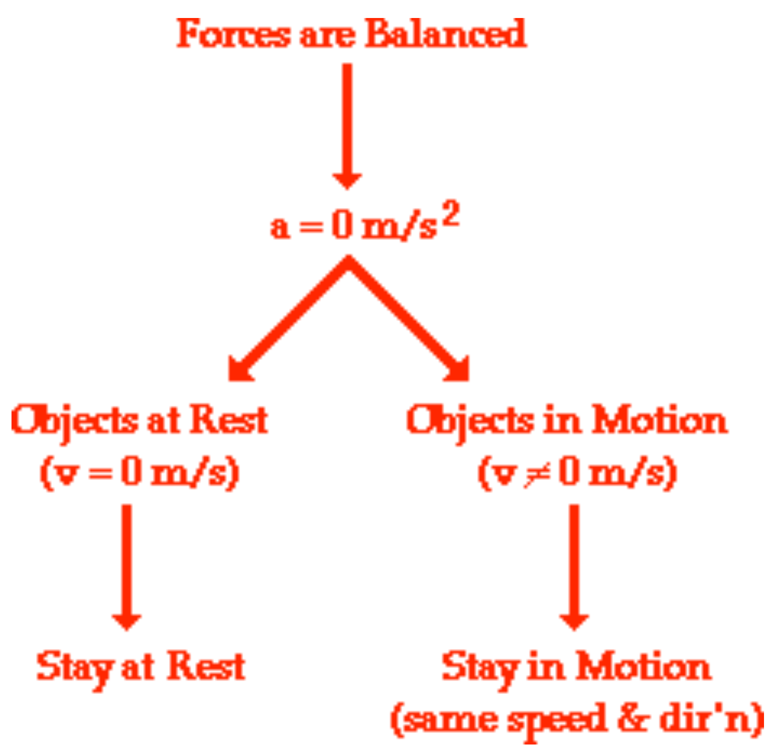
After impulse of firing the cannon…

In vertical direction, net force (gravity) is down, object accelerates down

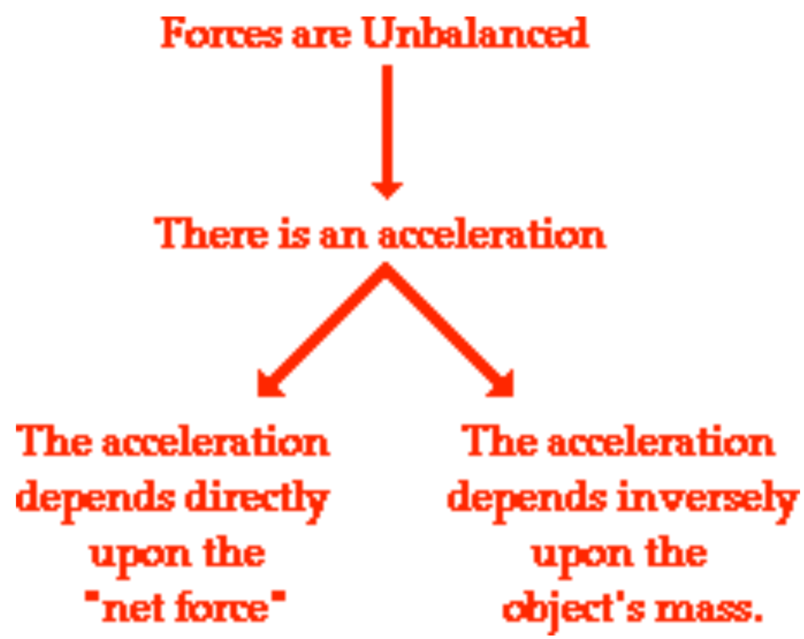
No horizontal net force, object moves with constant motion in horizontal direction (we are neglecting air resistance!)

Resulting motion is "Projectile Motion"

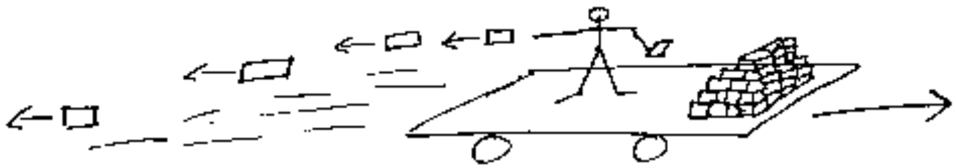
1st Law

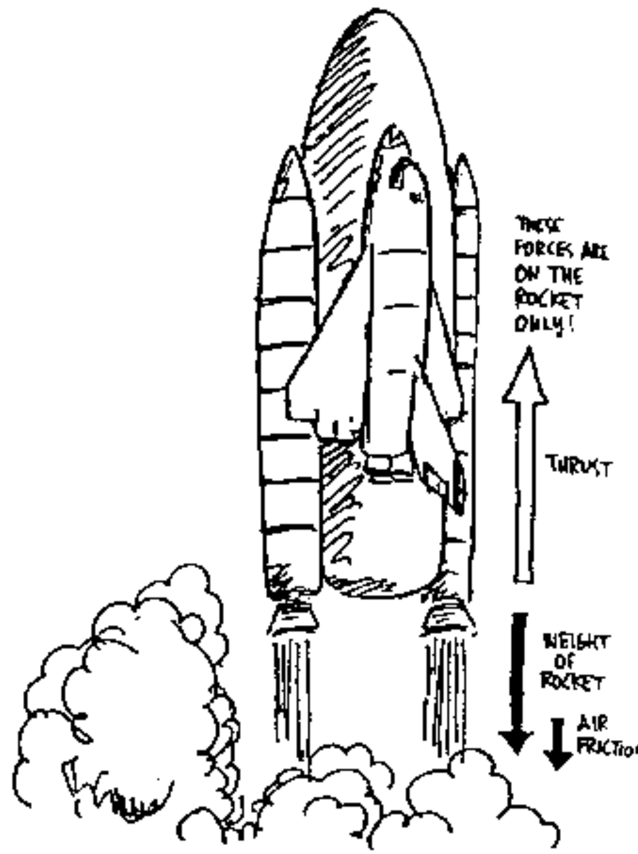


2nd Law



3rd Law: Equal opposite reaction



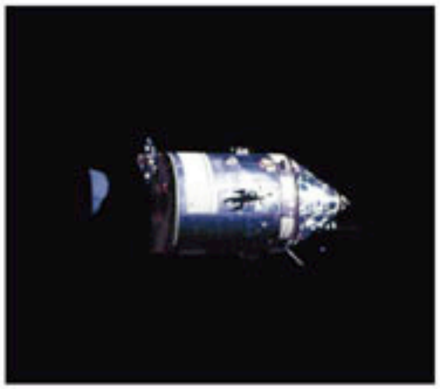


Net force is to the left on the bricks by the man; they have small mass and therefore large accelerate (which means they reach high velocities quickly). The reaction force is conveyed to the right from the man to the cart (through his feet). Since the cart has a large mass, the cart has a small acceleration, and thus takes a long time to reach high velocities.

Replace bricks by atoms (very low mass!), the man by a jet engine, and the cart by the rocket. Bam! You have liftoff (see diagram to the right)!

So, Newton's 2nd Law governs the growing velocity of the rocket, but the rocket flies because of Newton's 3rd Law!

A spaceship needs no fuel to keep moving in space.



A baseball accelerates as the pitcher applies a force by moving his arm. (Once released, this force and acceleration cease, so the ball's path changes only due to gravity and effects of air resistance.)

A rocket is propelled upward by a force equal and opposite to the force with which gas is expelled out its back.