Newton (1642-1727)

First Law: (Law of Inertia)

"A body remains at rest or in uniform motion unless acted upon by a <u>net</u> force."

i.e. If no <u>net</u> force (or <u>total</u> force) acts on a body, the body's velocity cannot change.

- **Inertia** – The tendency of a body to maintain its state of rest or constant velocity.
- **Equilibrium** - A condition during which the velocity of an object is constant, or the object is at rest. The net force acting on the object is zero.
- **Inertial Reference Frame**
  - A reference frame where the First Law is valid
  - Any reference frame moving with constant velocity w.r.t. an inertial frame is also an inertial frame
  - Non-inertial reference frames are accelerating w.r.t. inertial frames

Mass and Weight

- **Mass** - A term used to quantify/measure inertia.
  - a measure of inertia, or resistance to motion
  - has SI units of kilogram (kg)
  - the amount of a substance, or the quantity of matter
  - a scalar
- **Weight** – The **force** exerted on an object while it is under the influence of a gravitational field.
  - a vector of magnitude $W = mg$
  - has SI units of Newtons (N)
  - must be measured in an inertial frame

Second Law:

- The acceleration of an object <u>in an inertial frame</u> is
  - directly proportional to the <u>net</u> force acting on it
  - inversely proportional to its mass
- The direction of the acceleration is in the direction of the net force acting on the object.

$$\vec{a} \propto \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{\text{net}}}{m} \Rightarrow \vec{F}_{\text{net}} = m\vec{a}$$

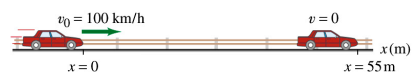
Net force is the vector sum of all forces acting **on** an object.

Definition: The force on a 1 kg object causing a measured acceleration of 1 m/s^2 is defined to be 1 Newton (1 N)

1 N = (1 kg)(1 m/s^2) = 1 kg•m/s^2

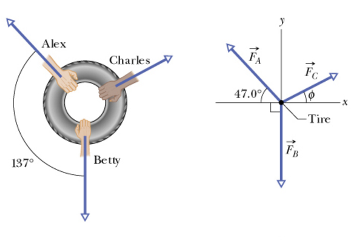
Example

What constant net force must be used to bring a 1500 kg car to rest from a speed of 100 km/hr within a distance of 55 m?



Problem 5.6

A tire is at rest. Given F_C = 170 N and F_A = 220 N, find F_B and φ.



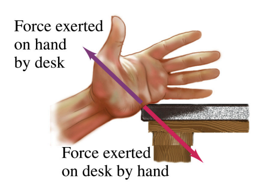
A **free-body diagram** shows all the forces acting **on** an object.

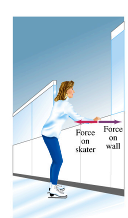
Third Law:

If two objects interact (contact or at a distance), the force exerted on body 1 by body 2 is equal and opposite the force exerted on body 2 by body 1.

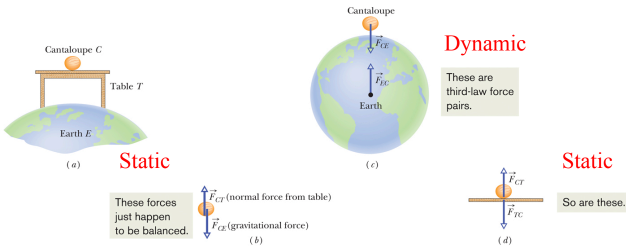
$$\vec{F}_{12} = -\vec{F}_{21}$$

on by

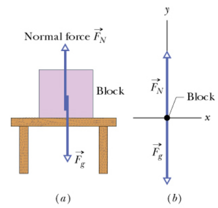




Cautions on the Third Law



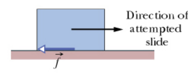
The forces of an action-reaction pair always act on <u>different</u> bodies. They do not combine to give a net force, and cannot cancel each other. The Third Law is valid whether there is motion or not (dynamic or static).



Normal Force: When a body presses against a surface, the surface deforms and pushes on the body with a normal force **perpendicular** to the contact surface.

$$F_{net,y} = ma_y = F_N - mg = 0 \rightarrow F_N = mg$$

Note: In this case $F_N = mg$ is the weight. This is not always the case.



Friction: If we slide or attempt to slide an object over a surface, the motion is resisted by a bonding between the object and the surface. This force is known as "friction". It is in a direction **opposing** motion.

Tension: This is the force exerted by a string or a cable attached to an object. A string is said to be "under tension".

Tension has the following characteristics:

1. It is always directed along the string.
2. It is always pulling the object (no pushing).
3. It is uniform along the string.

We assume the string is massless and does not stretch. If a pulley is used we assume that the pulley is massless and frictionless. The pulley simply redirects the tension (force) in the string.