Forces: why things move

force: a push or pull

$\vec{F}$: direction and magnitude

Units: 1 Newton

$1\,N = 1\,kg\,\frac{m}{s^2}$

(weight of a small apple)

net force on an object: vector sum of all forces on it

Newton's 1st Law: if net force on an object is zero,
(Law of Inertia) its velocity $\vec{v}$ remains constant.

"Objects at rest tend to stay at rest, ← OK
Objects in motion tend to stay in motion, ← weird, Doesn't everything stop unless you push it?
unless acted on by an outside force."

On Earth, forces abound.
which tend to stop things. (e.g. friction, air resistance)

Newton's 2nd Law: The acceleration of an object is caused by a net force on it.

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

m: mass of object

(or $\vec{F} = m\vec{a}$)

Types of forces

- contact: Object has to be touching to exert the force
  or noncontact forces: touching isn't required (gravity)
- adjustable vs fixed (constant)
  - adjustable - will increase or decrease to balance other forces
  - fixed - have a set value
- breakable forces have a maximum value

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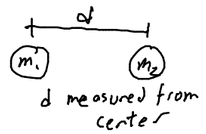
1) Gravity: non-contact, fixed, nonbreakable

All objects with mass pull on each other

$$|\vec{F}| = G\frac{m_1 m_2}{d^2}$$



d measured from center

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

(tiny value, so gravity is a tiny force)

on Earth, $|\vec{F}| = G\frac{M_e m}{R_e^2}$ M_e: mass of earth, R_e: radius of earth

$= \left(G\frac{M_e}{R_e^2}\right)m$ 

$g\ m$

$g = (6.67\times10^{-11})\frac{(5.97\times10^{24})}{(6.37\times10^{6})^2} \approx 9.8\ m/s^2$

on Earth $F = mg$ "weight" $\vec{W}$

weight = force of gravity on you

mass = amount of stuff, measure of inertia

mass is same everywhere, weight changes on other planets, e.g.

units of mass: kg e.g. 108 kg

weight: N is 1058 N on Earth

on moon, $g = 1.6\ m/s^2$

so $W = (108kg)(1.6\ m/s^2) = 172N$

in American system

pounds are unit of weight, not mass

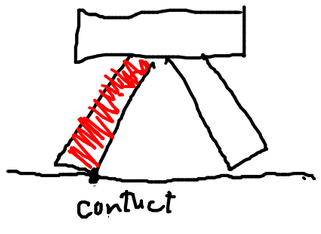
unit of mass is slug (1 slug = 32 lbs on Earth)

2) Normal Force ($\vec{N}$)

"normal" means "perpendicular"

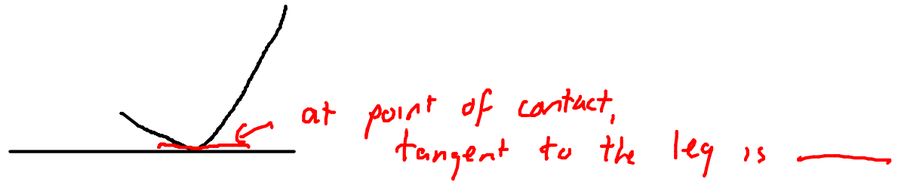
a push $\perp$ to surface of contact

contact, adjustable, breakable



What is the direction of $\vec{N}$ on the left leg?

A) ↖ (B) ↑ C) ↗



at point of contact, tangent to the leg is horizontal

$\vec{N}$ adjusts to cancel out other forces

- must be a push, not a pull
- must be $\perp$ to surface
- has a maximum value (but we'll ignore that in this class)

How can a table push things?

- block on table makes the table bend a little bit
- table "wants" to go back to being flat

restoring force