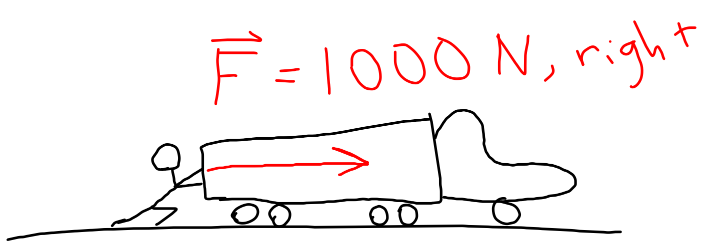
Chapter 4 - Newton's Laws

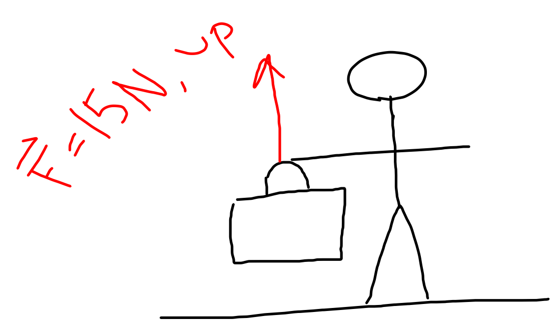
So far we have described how objects move (e.g. position, velocity, time, acceleration). Now we will investigate why objects move.

* ***1st Law***: When observed from an inertial reference frame, objects move with constant velocity (a=0) unless a force acts on the object.

- IRF - a reference frame moving at constant velocity
  - see "Breakthrough Junior challenge" video
- Force - that which causes a change in motion (velocity) of an object.
  - less formally, a push or a pull.
    - ↳ magnitude & direction
      - ↳ vector

ex:

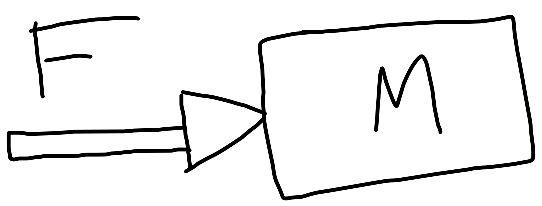


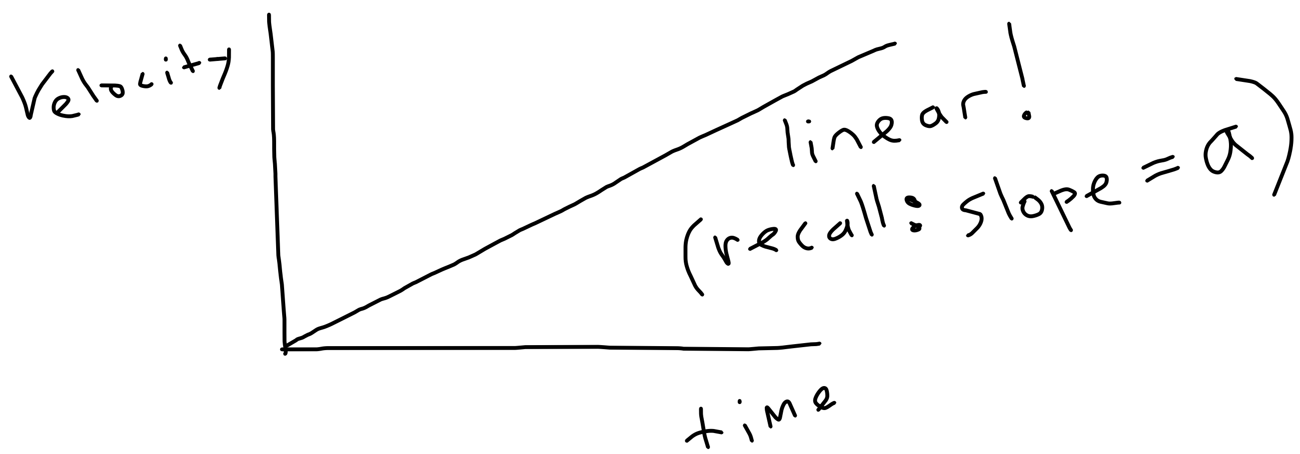


summary: forces (pushes or pulls) are vectors that cause accelerations (by definition).

↳ How to quantify?

Experiment





m	F	a (observed)
1 kg	1 N	1 m/s^2
2	1	0.5 m/s^2
1	2	2 m/s^2
2	2	1 m/s^2

Pattern:

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

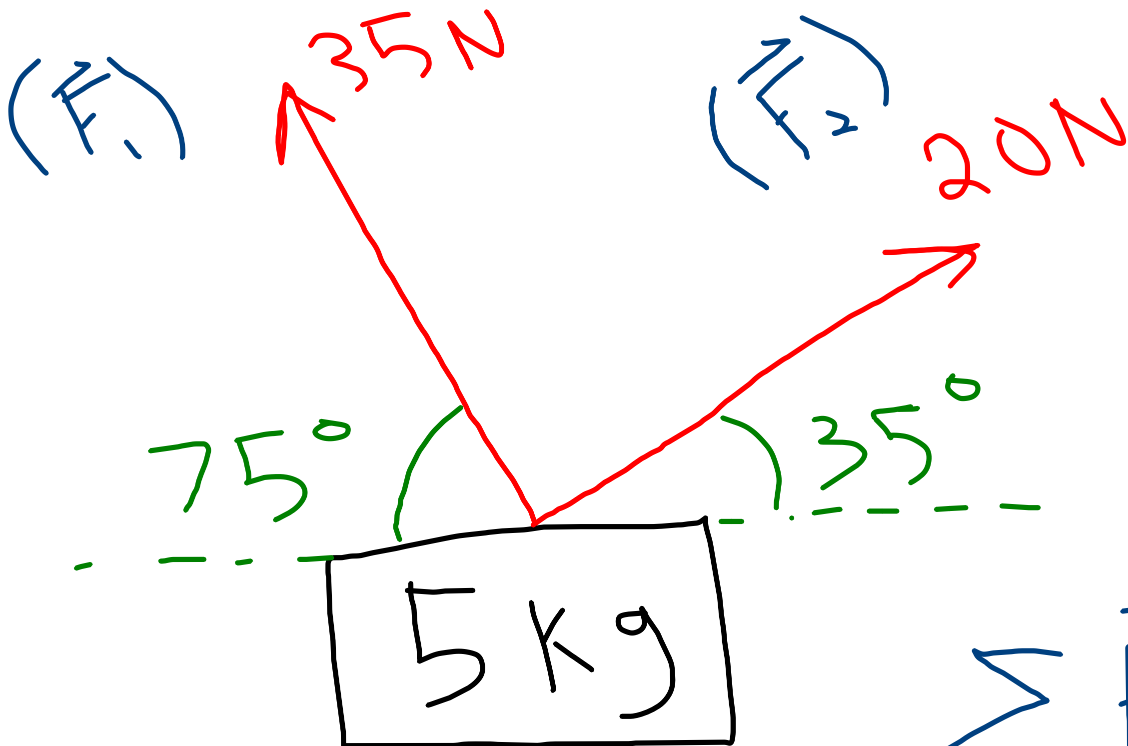
Newton's 2^{nd} Law: $\left(\vec{F} = \frac{d\vec{p}}{dt}\right)$

$$\boxed{\sum \vec{F} = m\vec{a}}$$ *

units: Newtons (N)

$$[N] = \frac{kg \cdot m}{s^2}$$

Ex: find $\vec{a}$.



$F_{1x} = -35\cos(75)$, $F_{1y} = 35\sin(75)$

$F_{2x} = 20\cos(35)$, $F_{2y} = 20\sin(35)$

$$\frac{\sum \vec{F}}{m} = \frac{(7.32,\ 45.28)\ \text{N}}{m} = a$$

$[a] = \left[\frac{F}{M}\right]$, $[N] = \frac{kg\cdot m}{s^2}$

$$\frac{m}{s^2} = \frac{N}{kg} = \frac{\frac{\cancel{kg}\cdot m}{s^2}}{\cancel{kg}} = \frac{m}{s^2}$$

$$\vec{a} = (1.46, 9.06)\ \frac{m}{s^2}$$

The gravitational Force (aka weight)

m

$\downarrow a = 9.8 \frac{m}{s^2}$

Apply Newton's 2^{nd} Law:

$$F_{gravity} = m\left(9.8 \frac{m}{s^2}\right)$$

* on planet earth.

$$\boxed{\vec{F}_g = mg, \text{ down}} \; *$$

where $g = +9.8 \frac{m}{s^2}$

Ex: Weight = 900 N on earth

If $a_g^J = 25.9 \frac{m}{s^2}$

what is your weight on Jupiter?

step 1: find mass - $F = ma$

$900 = m(9.8)$

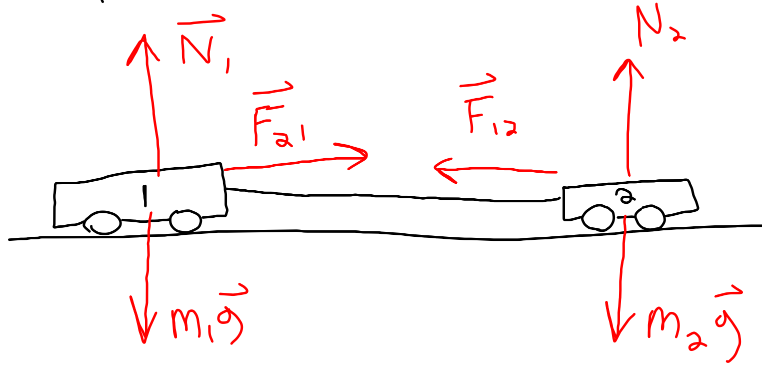
$m = 91.84 \text{ kg}$

step 2 - $F_g^J = m\, a_g^J = (91.84)(25.9)$

$= \boxed{2377.6 \text{ N}}$

Newton's 3rd Law -

For every force, there is another equal and opposite force.



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

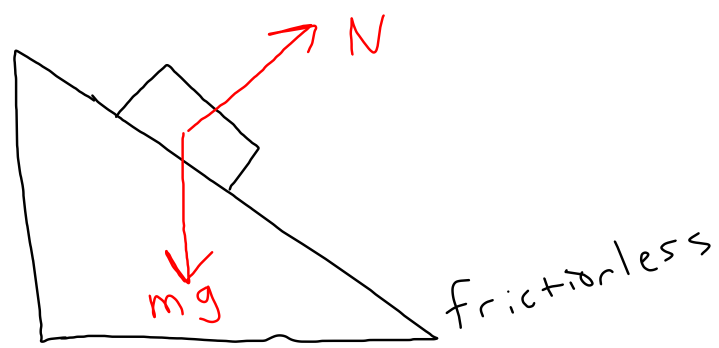
$\vec{N}_1 = -m_1\vec{g}$

$\vec{N}_2 = -m_2\vec{g}$

The Ns are normal forces and occur when surfaces push back on objects. They are always perpendicular to the surface.

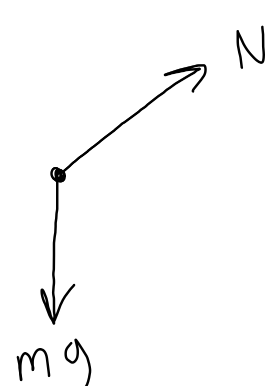
Common forces and applications of Newton's Laws

Ramps

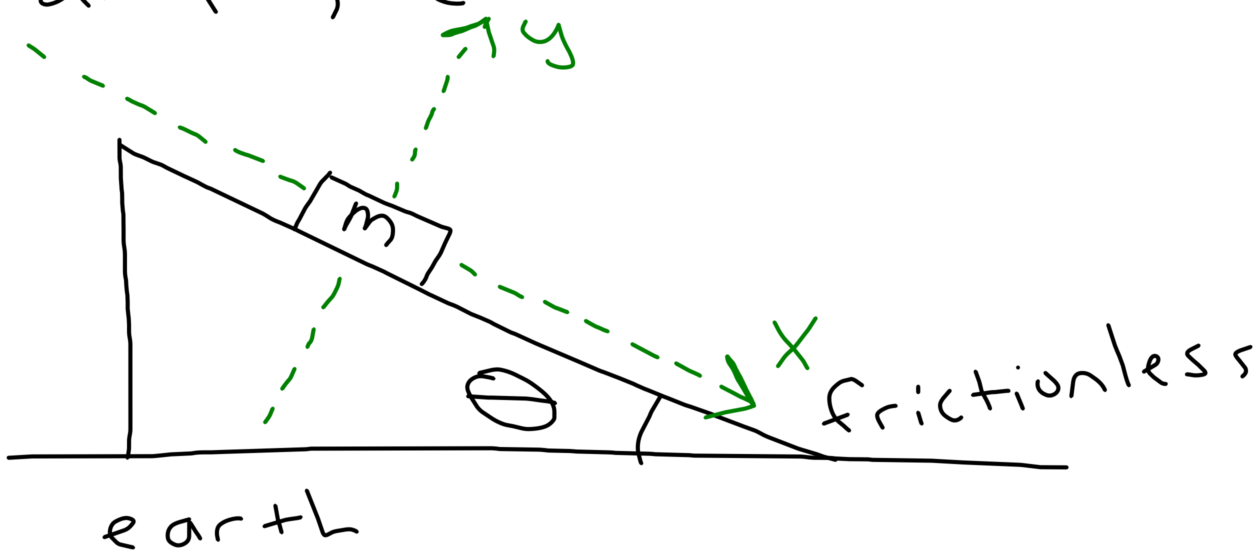


Representing an object by a point and drawing all the force is called a free-body diagram. *

above example:



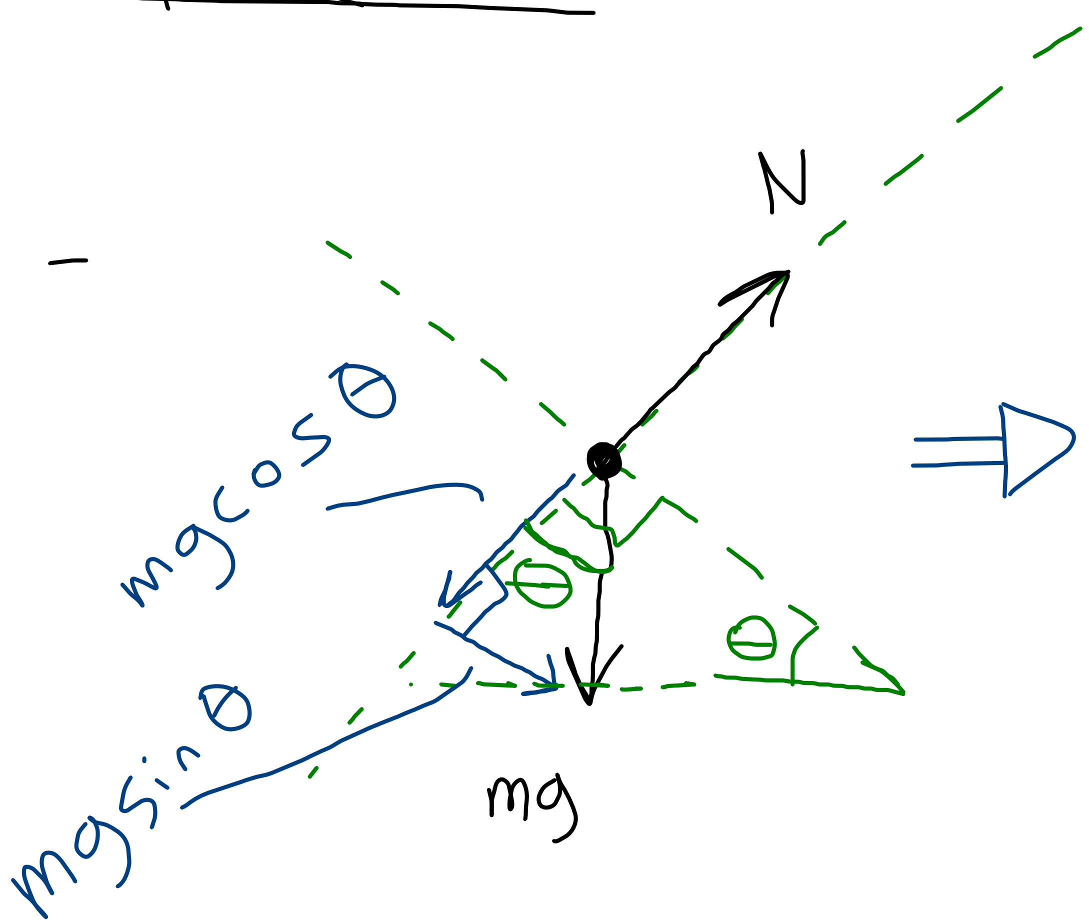
ramps, cont...



$\Rightarrow$ 1-D motion

what is $\vec{a}$ for the block?

F.B.D. -



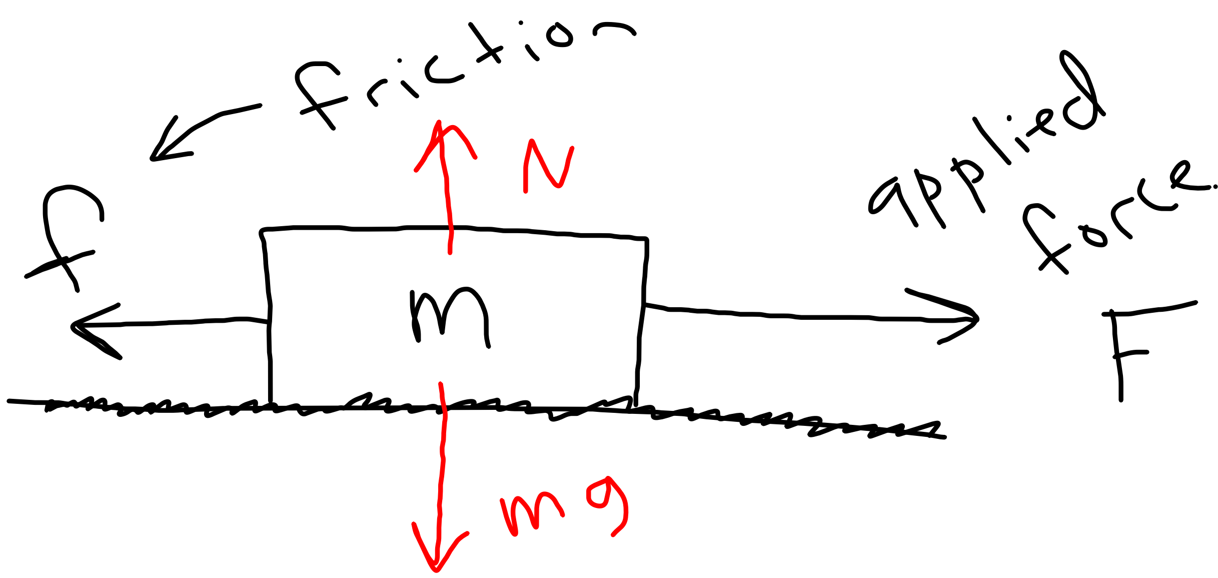
$\Rightarrow$ • N and mgcosθ are equal and opposite - cancel out

• Net force of mgsinθ points down the ramp.

$$\Rightarrow a = \frac{\cancel{m} g \sin\theta}{\cancel{m}}$$

$\vec{a} = g\sin\theta$ down the ramp

friction



parallel to the surface, resists motion

$$f_{s,max} = \mu_s N$$

N = normal force

μ_s = coefficient of (static) friction

$$f_k = \mu_k N$$

kinetic friction

$\mu_{s,k}$ are unit-less