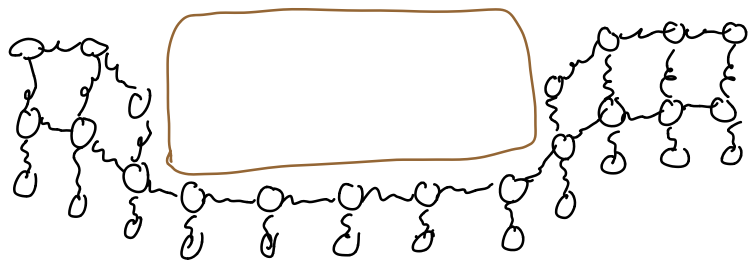
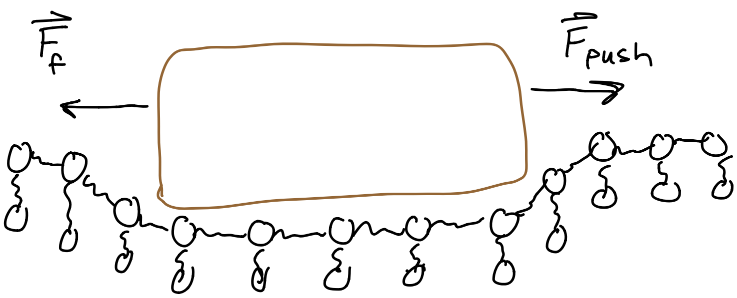
When we last left our table brick



If I push on the brick



If I push the brick, it runs into uncompressed
springs ahead of it

These springs will push back and oppose the force

The magnitude of this force depends on:

- The material of the surface AND the object
    - the object is also just a bunch of springs

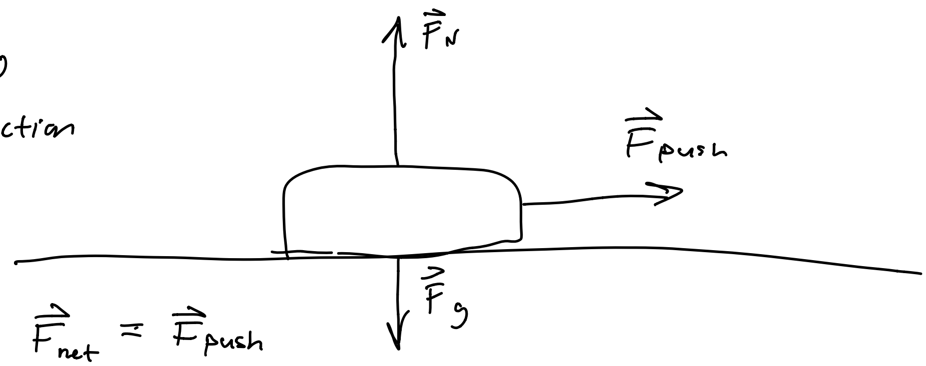
- The force of the object against the surface

Force of sliding friction

$$|\vec{F}_{friction}| \approx \mu_k |\vec{F}_N|$$

- Does not depend on speed
  size
- Only an approximation

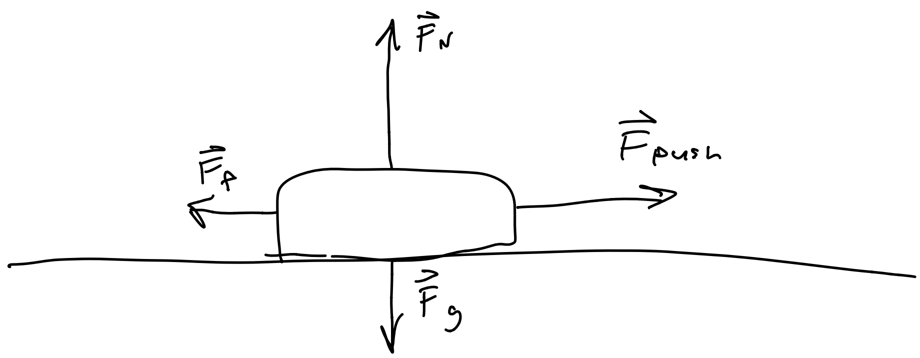
w/o Friction



$$\vec{F}_{net} = \vec{F}_{push}$$

$$\Delta\vec{p} = \vec{F}_{push}\Delta t$$

Block will continually accelerate



$$\vec{F}_{net} = \vec{F}_{push} - \vec{F}_f$$

$\Delta \vec{p} = (\vec{F}_{push} - \vec{F}_f)\Delta t$

$\vec{F}_{push} > \vec{F}_f$: block accelerates

$\vec{F}_{push} = \vec{F}_f$: constant velocity

$\vec{F}_{push} < \vec{F}_f$: block slows down

Eventually, block comes to rest

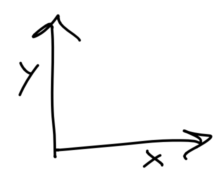
No more friction force now!

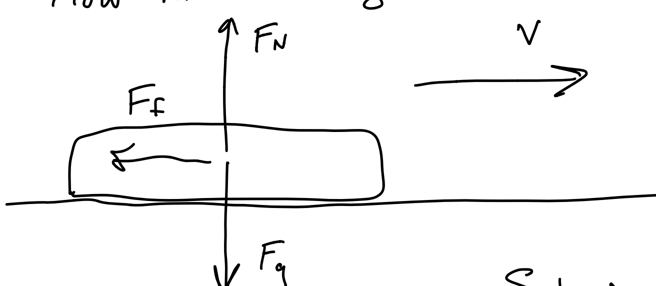
Friction won't spontaneously move the block if it is motionless

Ex: I release this book @ $V_0 = 4$ m/s $(m = 5 \text{ kg})$

$\mu_k = 0.4$

How far will it go?





System: Book

Surr : Earth, table

$\Delta \vec{p} = \vec{F}_{net}\Delta t$

$\Delta p_x = -F_f \Delta t$

Strategy:

Constant force motion

$x(t) = x_i + v_{xi}t + \frac{1}{2}\frac{F_x}{m}t^2$

Find $t = \Delta t$, time to come to a stop, then find $x(\Delta t)$

$F_f = \mu_k F_N$

$F_N = ?$

$\Delta p_y = 0 = F_N - mg$

$$F_N = mg = (5\ kg)(9.8\ m/s^2) = 49.0\ N$$

$F_f = \mu_k F_N = (0.4)(49.0 N) = 19.6\ N$

$\Delta p_x = -F_f \Delta t = -19.6 \Delta t$

$p_{xf} = p_{xi} - 19.6 \Delta t$

$p_{xi} = m v_{xi} = (5\ kg)(4\ m/s) = 20\ kg\,m/s$

$p_{xf} = 20 \frac{kg\,m}{s} - 19.6 N \Delta t$

$0 = 20 - 19.6 \Delta t \ ; \quad \Delta t = 1.02\ s$

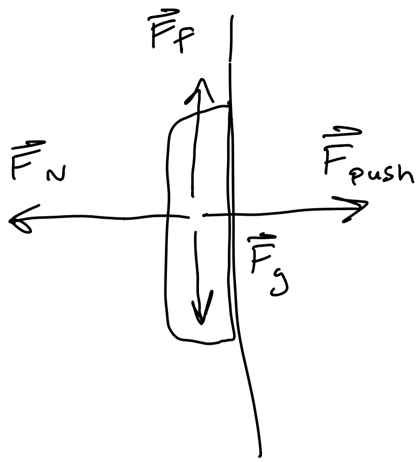
$x(t) = x_i + v_{xi} t + \frac{1}{2} \frac{F_x}{m} t^2 \ , \quad x_i = 0$

$x(1.02 s) = 0 + (4)(1.02) + \frac{1}{2}\left(\frac{-19.6}{5}\right)(1.02)^2$

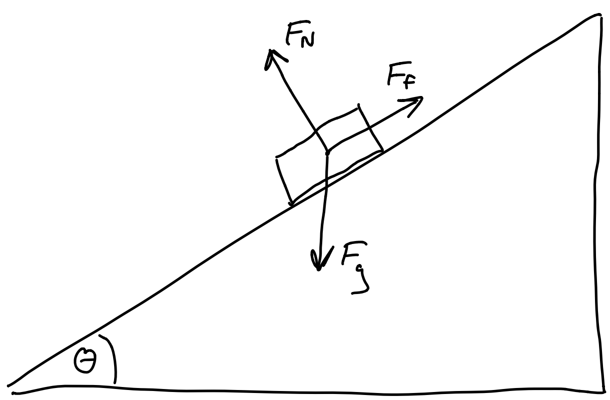
$x = 2.04\ m$

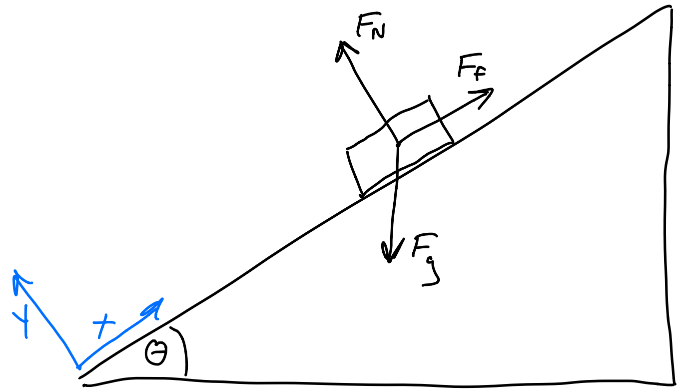
Danger! Normal force is not always the same as gravity

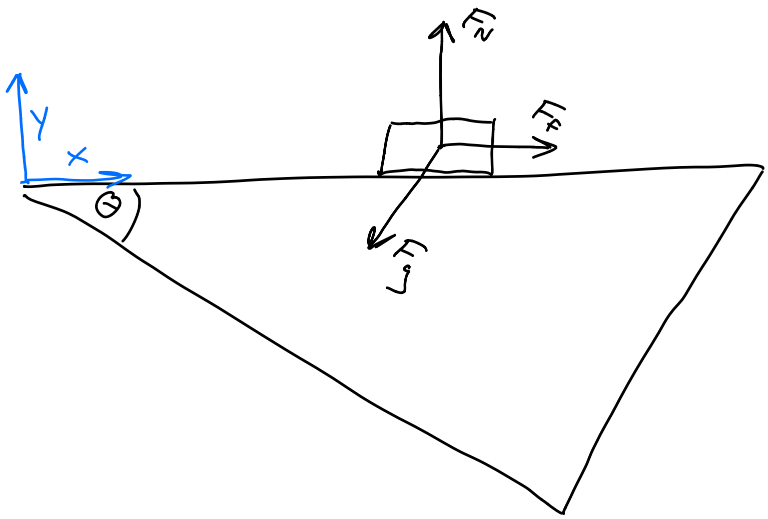
Ex: Pressing the book against the wall



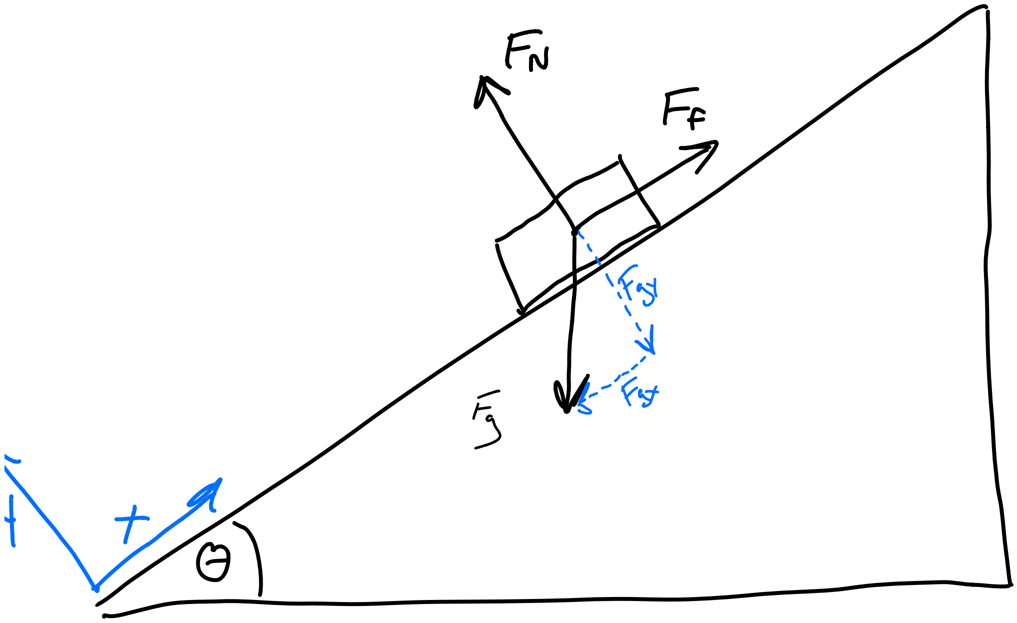
Ex: Block sliding down a ramp



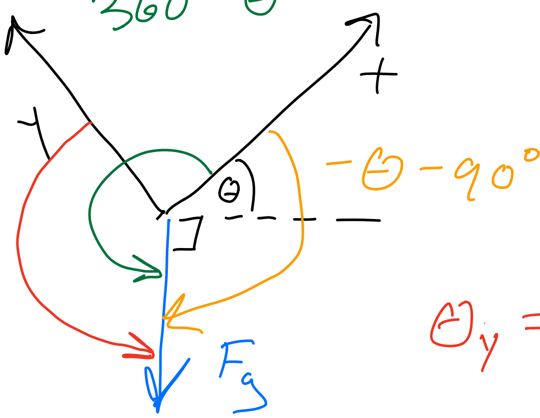




$\vec{F_g}$ pushes against the surface + also pulls the block down the slope



$360° - \theta - 90° = 270° - \theta = \theta_x$



$\theta_y = \theta_x - 90° = 180° - \theta$

$\hat{F_g} = \langle \cos\theta_x, \cos\theta_y \rangle$

$$\hat{F_g} = \langle \cos(270^\circ - \theta), \cos(180^\circ - \theta) \rangle$$

$$\vec{F_g} = mg \langle \cos(270^\circ - \theta), \cos(180^\circ - \theta) \rangle$$

$$\vec{F_g} = mg \langle -\sin\theta, -\cos\theta \rangle$$

$$F_{net,x} = F_{gx} + F_f$$

$$F_{net,x} = -mg\sin\theta + \mu_k F_N$$

$$F_{net,y} = 0 = F_{gy} + F_N$$

$$= -mg\cos\theta + F_N$$

$$F_N = mg\cos\theta$$

$$F_{net,x} = \mu_k F_N - mg\sin\theta$$

$$F_{net,x} = \mu_k mg\cos\theta - mg\sin\theta$$

$$F_{net,x} = mg(\mu_k \cos\theta - \sin\theta)$$

What if the book is initially at rest?

We can exert a force without causing the book to move.

I exert force on book, book compresses springs, springs push back on book, $F_{net} = 0$, book doesn't move.

As I increase the force, the springs compress more, until eventually the book breaks loose & begins to move. The force required to start moving:

$$F_F = \mu_s F_N$$; μ_s is coeff of static friction

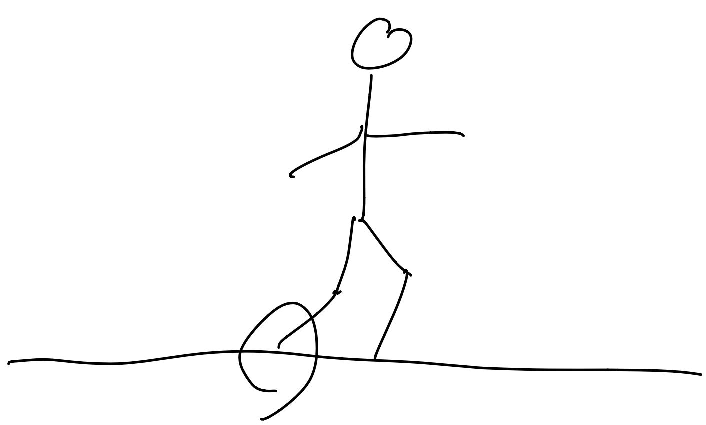
$F_{static} = \mu_s F_N$ ← Force needed to <u>start</u> moving

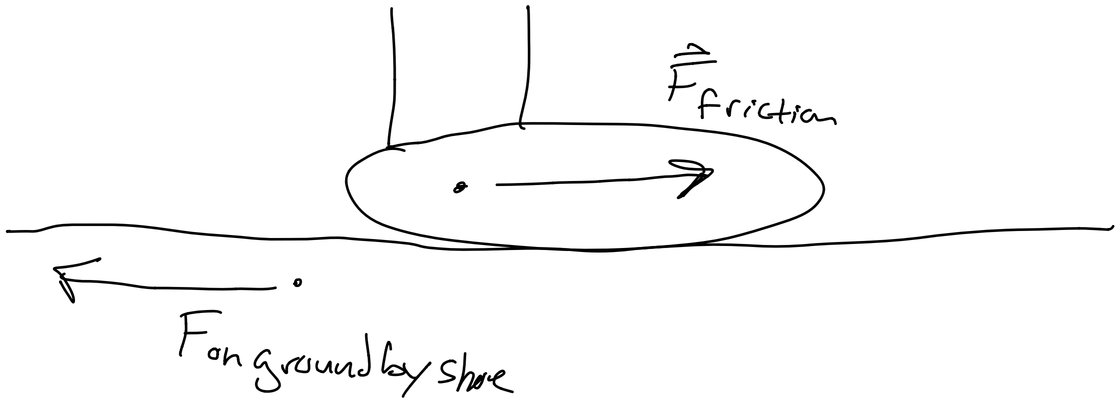
$F_{kinetic} = \mu_K F_N$ ← Force needed to <u>keep</u> moving

In general, $\mu_s \gtrsim \mu_K$

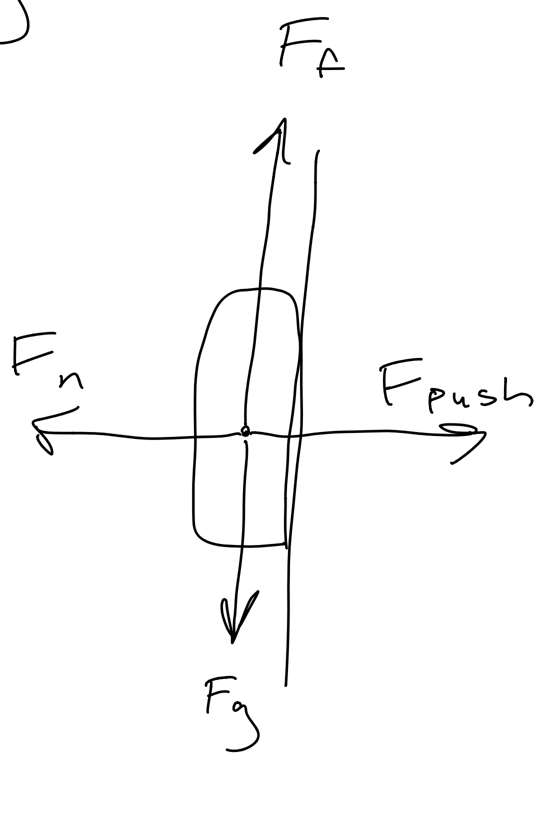
Pull really hard to get an object to start moving; once it starts you don't need to pull as hard

Static Friction is how we walk!





It's also how I can hold this book against the wall w/o it slipping



In order to keep it here,
I need $F_{net,y} = 0$

$$F_f + F_g = 0$$

$$\mu_s F_N - mg = 0$$

$$F_{net\,x} = 0$$

$$F_N = F_{push}$$

$$\mu_s F_{push} - mg = 0$$

$$F_{push} = \frac{mg}{\mu_s}$$

$m = 5\ kg$
$g = 9.8\ m/s^2$ $\mu_s = 0.5$

$F_{push} = 98\ N$
(22 lbs)