Ch4 : Forces + Newton's Laws of Motion

Forces = cause of motion

Dynamics = study of forces that drive/cause motion

Mechanics = Kinematics + Dynamics

- Kinematics → motion
- Dynamics → force/power

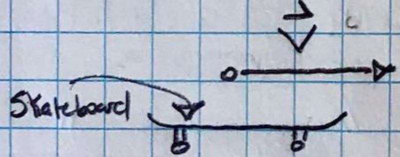
When you **push** your skateboard or **pedal** your bike, your exerting a **Force** that propels you!

Newton's 1st Law:

> An objects velocity is constant (or Conserved) unless acted upon by a **net force.**

your skateboard + bike slow down due to Friction + Drag...

so, to maintain constant velocity... we push or pedal.



$\vec{F}_{drag} + \vec{F}_{push} = 0$ & $\vec{v}$ = constant

Stop pushing... $\frac{\Delta V}{\Delta t} \propto \vec{F}_{drag} < 0$

and you slow down!

Force is a Vector (Magnitude + Direction)

An "agent" applies a force on an "Object".

Some forces require "contact" ⇒ push, pull ...

others ar "long-range" ⇒ gravity, magnetism

↳ No physical Contact

Forces obey vector addition + multiplication rules

↳ the "net Force" on an object determines its motion.

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \ldots$$

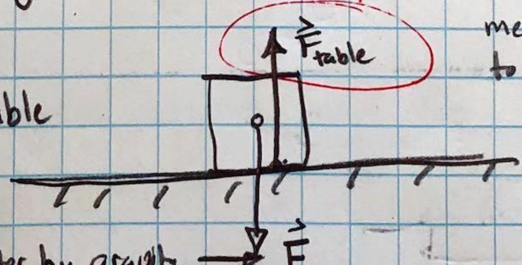
So for skateboard: $\vec{F}_{net} = \vec{F}_{drag} + \vec{F}_{push}$

s.t. if $\vec{V}$ = constant: $F_{net} = 0$ & $\vec{F}_{push} = -\vec{F}_{drag}$

Weight = the force of gravity on an object

→ F_{table} is a Normal Force meaning its perpendicular to the table.

A block siting on the table



is pulled toward earth's center by gravity → $\vec{F}_g$

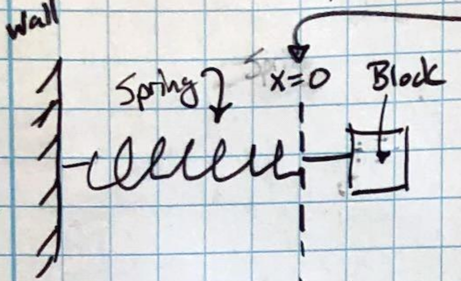
the table supports its weight with an upward forse $\vec{F}_{table} = -\vec{F}_g$

$$F_{net} = \vec{F}_g + \vec{F}_{table} = \vec{F}_g - \vec{F}_g = 0$$

∴ Block doesnt move!

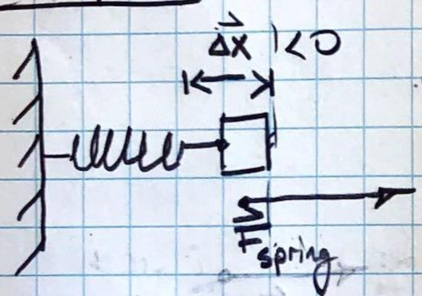
Springs – the Force of a spring depends on the **displacement**

→ Compression / Extension from **equilibrium**



$\Rightarrow F_{net} = 0!$

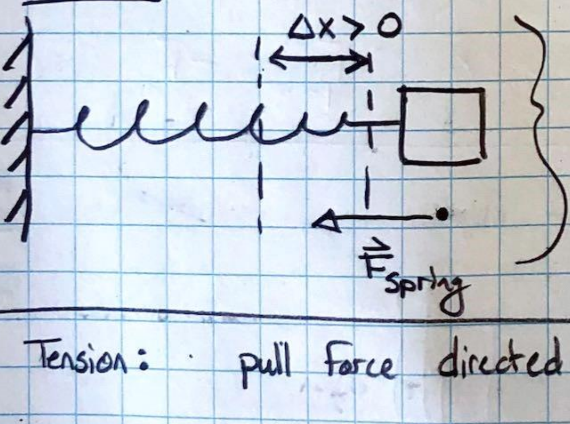
Compressed:



$\Delta x < 0$

$\vec{F}_{spring} > 0$

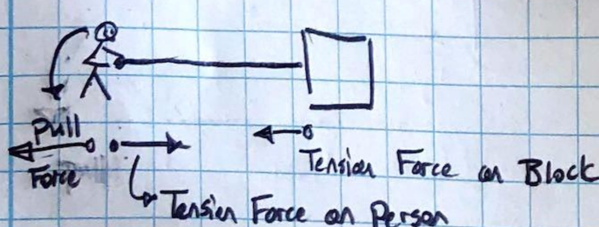
Stretched:

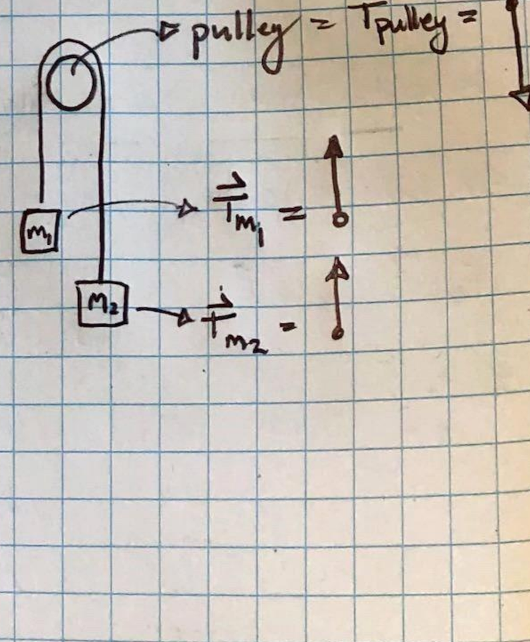


$\Delta x > 0$

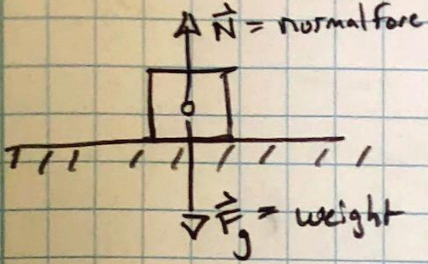
$F_{spring} < 0$

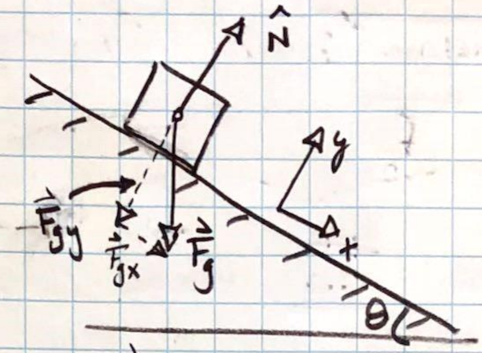
Tension: pull force directed away from object.





Normal Force: Force on object by surface (perpendicular to surface)





Block sliding down ramp...

$\vec{F}_{gy}$ = y-component force of gravity = $\vec{F}_g \cos\theta$

$\vec{N}$ = normal force of ramp (supporting weight of Block) = $-\vec{F}_g \cos\theta$

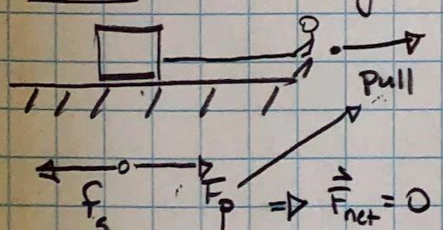
net y-component Force:

$$\vec{F}_{y,net} = \vec{F}_g \cos\theta + \vec{N} = (\vec{F} - \vec{F}) \cos\theta = 0$$

∴ Block stays on ramp!

Friction: due to contact between object + agent

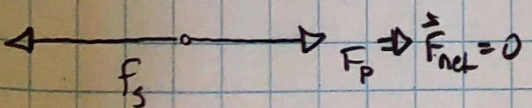
Static Friction: stationary

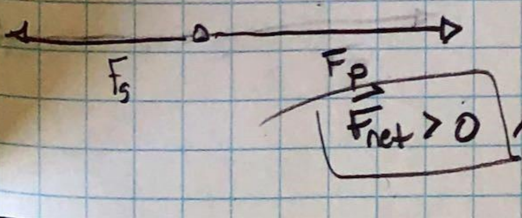


you pull, but object won't budge...

so you pull harder...

but f_s increases, too...

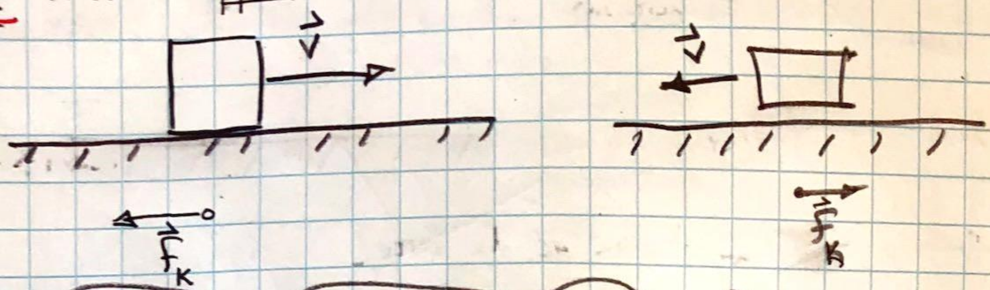




until you reach a critical threshold and object **Moves**

once moving Kinetic Friction kicks in

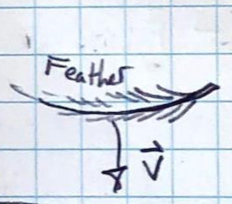
Kinetic friction opposes motion!



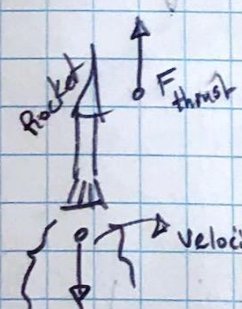
Friction has **no** normal component!!

Drag is due to air flow around a moving object

↳ also opposes motion!



Thrust = Forward force produced by expelling material (mass) backward



Force ⟺ Acceleration

1) An object subject to constant force $\vec{F}$ undergoes constant acceleration $\vec{a}$

☆ in the same direction as the force!

2) If the net force is scaled by a constant (c), i.e. $\vec{F}_2 = c\vec{F}_1$

the acceleration scales by the same amount, $\vec{a}_2 = c\vec{a}_1$

$\therefore \quad \vec{a} \propto \vec{F}_{net}$

3) If the mass of the object is scaled by (c), i.e. $m_2 = c\, m_1$ (mass 2 = c · mass 1)

the acceleration is scaled by $1/c$, $\vec{a}_2 = \vec{a}_1/c$

Corollary:

if $c > 1$, then $a_2 < a_1$, and we say that

mass 2 has larger inertia than mass 1

↳ resistance to Δ in motion

Newton's 2nd Law

$$\vec{F}_{net} = m\vec{a} \qquad (\text{net force} = (\text{mass}) \times (\text{acceleration}))$$

or

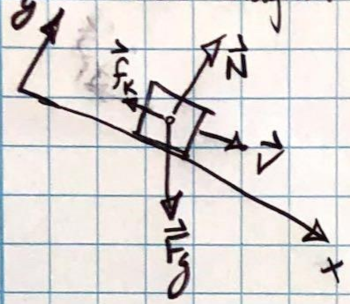
$$\vec{a} = \vec{F}_{net}/m$$

Units: $\vec{a}\left(\frac{m}{s^2}\right) = \frac{\vec{F}_{net}(?)}{m(kg)} \Rightarrow m\vec{a}\left(kg\frac{m}{s^2}\right) = \vec{F}(?)$

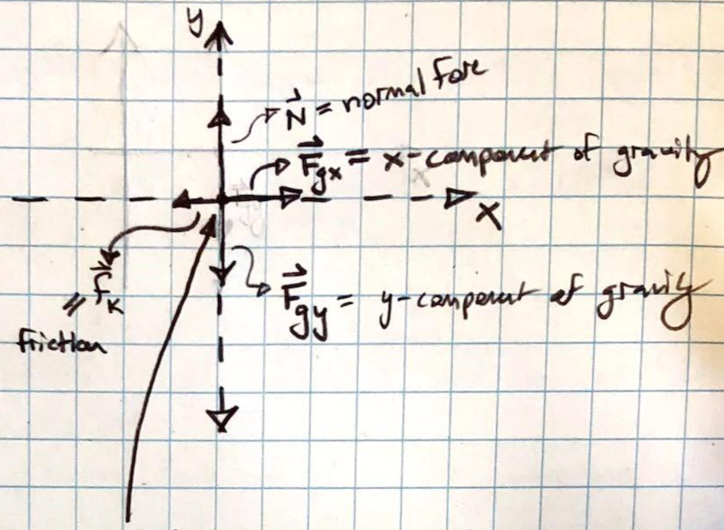
$$\boxed{1\ \text{Newton} = 1\ \frac{kg\,m}{s^2}}$$

$$\frac{35\,m/s}{2\times10^{-6}\,s}$$

Force Diagram



Free body diagram



Free body diagram = particle model showing forces on object.

Newton's 3rd Law: every action (Force) has an equal and opposite reaction (Force)

if you push on a wall with force $\vec{F}_p$,

the wall pushes back with force $\vec{F}_W = -\vec{F}_p$