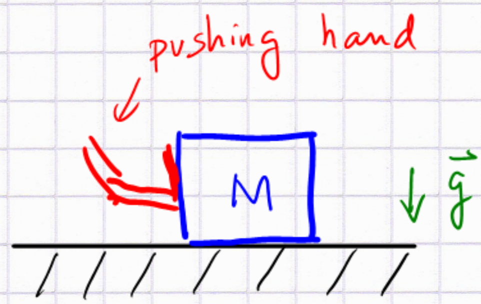
Static Friction

The equation $F_s \leq \mu_s N$ requires explanation.

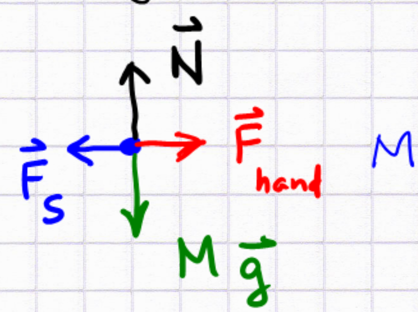
When we push against an object that is in contact with a surface we can analyze the situation as follows:

Suppose $a = 0$, the object is not accelerating

and $v = 0$, the object is not moving



free-body diagram:



The four vectors add up to zero! $M\vec{a} = \vec{F}_{net}$

Vertical "motion" $a_y = 0 \therefore F_{net,y} = 0$

$\therefore N = Mg$ [magnitudes!]

Horizontal "motion" $a_x = 0 \therefore F_{net,x} = 0$

$\therefore F_{hand} = F_S$ [magnitudes!]

This picture is valid as long as

$$F_{hand} \leq \mu_s N = \underbrace{\mu_s M g}$$ [from $a_y = 0$]

If our hand pushes harder, we may overcome the limit set by the inequality.

At the point $F_{hand} = \mu_s N$ the static model breaks down → the object starts moving and the static friction model is replaced by the kinetic friction model.

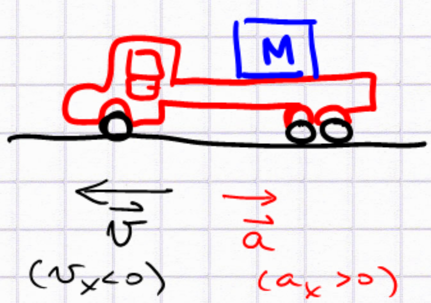
Note: $\mu_k < \mu_s$ (practically always)

and $|\vec{F}_k| = \mu_k |\vec{N}|$ ← a known amount (equal sign, not $\leq$)

Now consider a mass M sitting on the back of a truck moving with $v_x < 0$ and braking ($a_x > 0$)

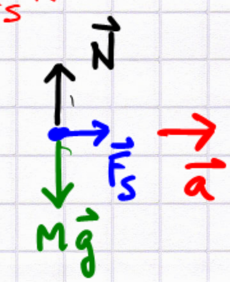
The mass is not moving on the flatbed.

What is $\vec{F}_s$ acting on M?



Solution: M is not moving, i.e., $|F_s| < \mu_s N$

M is accelerating to the right:



$\vec{F}_{net} = \vec{F}_s \quad \therefore \quad M\vec{a} = \vec{F}_{net} = \vec{F}_s$

$\therefore \quad F_s = M|a_x|$

Comment about forces:

1) fundamental forces

A) Gravity (fall term)

B) Electromagnetic (winter term)

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C) strong nuclear — binds protons + neutrons

D) weak nuclear — neutron (beta) decay

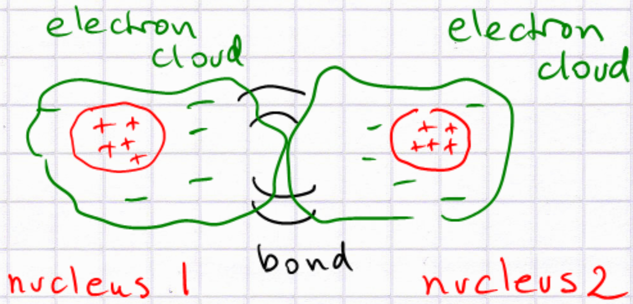
$n \rightarrow p + e^- + \bar{\nu}_e$ $\tau_{1/2} = 11\,\text{min}$

So, what are these "other" forces

- static / kinetic friction
- drag
- spring force → Hooke's law (also: rubber band, elastic)
- normal force

These forces are mostly "effective" forces which allow us to understand macroscopic phenomena

Their origin is mostly electrostatic: atoms in contact → molecular binding



← equal and opposite charge to nucleus

combo of attraction + repulsion can lead to bonding