Lecture 5:
Newton's Laws

<u>1st Law:</u> Every body continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.

Law of inertia

2nd Law: **The change of *momentum** of an object is proportional to the force impressed; and is made in the direction of the straight line in which the force is impressed.**

*** *momentum* = mass times velocity (vector):** $m\mathbf{v}$

$$\mathbf{F} = d(m\mathbf{v})/dt$$

or, if mass is constant:

$$\mathbf{F} = m\, d\mathbf{v}/dt$$
$$\mathbf{F} = m\mathbf{a}$$

$$\boxed{\mathbf{F} = m\mathbf{a}}$$

3rd Law: **To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.**

$$\boxed{\mathbf{F}_{12} = -\mathbf{F}_{21}}$$

Physics 1a Lecture 5   10/12/11

- Newton's Laws
- Statics
- Torque
- Torque Applications

Newton's Laws

PDF slides

→ 3rd law demo: Force probes on cars

what are these forces?

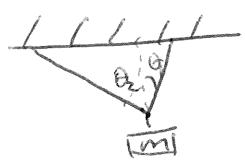
EM, grav, weak, strong → fundamental

$\underbrace{\text{ropes, chains, direct contact, rods,}}_{\text{EM in nature}}$ gravity → this class (macroscopic, empirical)

Statics

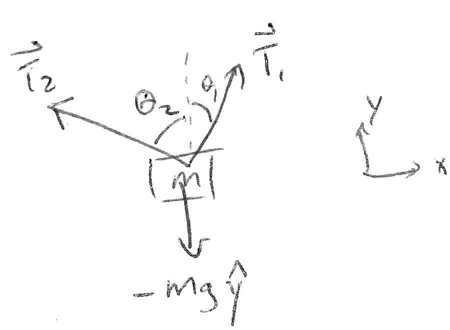
$\vec{F} = m\vec{a}$

$\vec{a} = 0 \Leftrightarrow \vec{F} = 0$



tension?
→ each bit of rope pulling on the next to transmit a force

Aside:
really: $\sum_i \vec{F}_i$



So:

$$\sum \vec{F} = \hat{x}(T_1 \sin\theta_1 - T_2 \sin\theta_2) + \hat{y}(T_1 \cos\theta_1 + T_2 \cos\theta_2 - mg) = 0$$

→ (vector expression) = 0
each component must be 0 ⟹ $\sum F = 0 \iff \begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \\ \sum F_z = 0 \end{cases}$

$$\begin{cases} T_1 \cos\theta_1 + T_2 \cos\theta_2 - mg = 0 \\ T_1 \sin\theta_1 - T_2 \sin\theta_2 = 0 \end{cases}$$

usually just start here

what's T_2 given θ_1, θ_2, m, g?

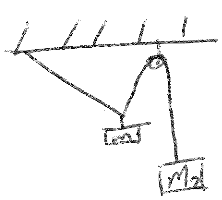
Solve:

$$T_1 = T_2 \frac{\sin\theta_2}{\sin\theta_1}$$

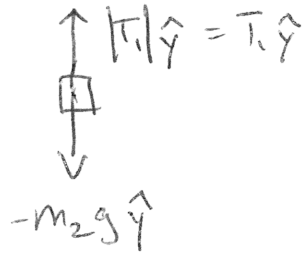
$$\Rightarrow \quad mg = T_2 \frac{\cos\theta_1}{\sin\theta_1} \sin\theta_2 + T_2 \cos\theta_2$$

$$\Rightarrow \quad T_2 = mg \frac{\sin\theta_1}{\sin(\theta_1 + \theta_2)}$$

Could have done:



new diagram!



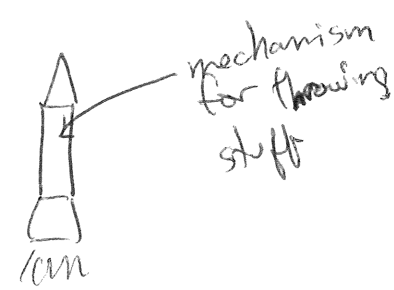
$$\Rightarrow \quad T_1 - m_2 g = 0$$

new equation to work with

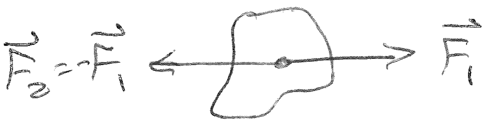
3rd law demo: rockets

(1) bowling ball + skate board

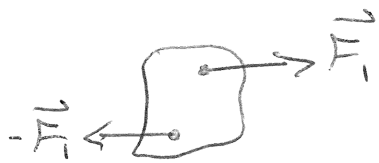
(2) actual rocket!



Torque



$\vec{a} = 0$



$\vec{a} = 0$

but rotates!

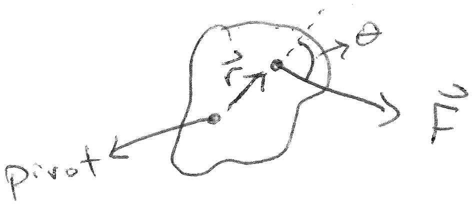
Need both

$$\sum \vec{F} = 0$$

and

$$\sum \vec{\tau} = 0$$

for statics.



$\vec{\tau} = \vec{r} \times \vec{F}$ → vector gives axis of rotation

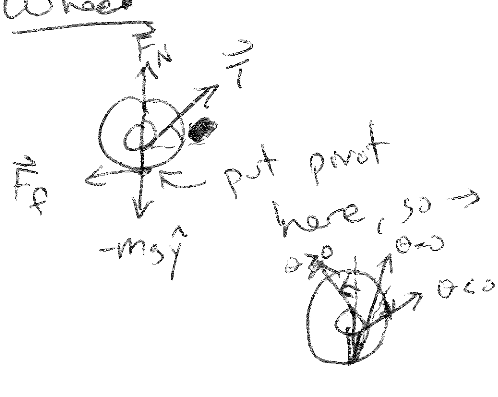
$\tau = rF\sin\theta$ → scalar expression is sufficient if $\vec{r}, \vec{F}$ all in a plane (all give same axis)

$\theta = 0 \Rightarrow$ no rotation

Pivot point choice

If $\sum \vec{F} = 0$, doesn't matter where you put the pivot in your analysis.

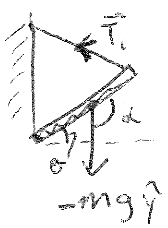
Wheel



no torque from $\vec{F}_f, \vec{F}_N, \vec{F}_{grav}$

torque from $\vec{T}$ can be either direction, or zero.

Drawbridge example



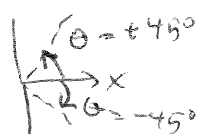
Ran out of time & did not work through it; some tricks & tips noted in class:

(1) put pivot where its most helpful

(2) $\tau = r \underbrace{F \sin\theta}$

really just $|\vec{F}_\perp|$

So use any angles that work eg. $\cos\theta$ might be easier to get than $\sin\alpha$, where α is related to θ.

(3) 

- "$\sin\theta$" refers to the signed angle, possibly $> 90°$.

- Can choose to only use positive angles from 0° to 90° if you handle the signs manually. Just take care of the direction of rotation that ~~the~~ each torque would induce.