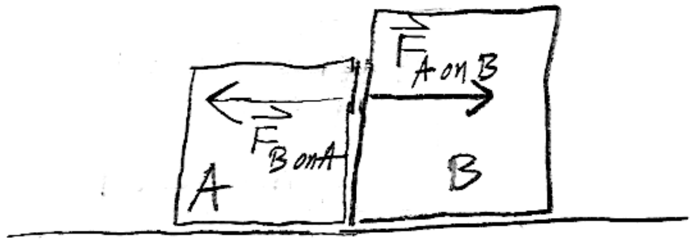
Demo - air track

Newton's Laws:

1. Objects move with constant velocity unless a force acts on them.

2. $\sum \vec{F}_i = m\vec{a}$

3. If body A exerts a force on body B (an "action"), then body B exerts a force on body A (a "reaction"). These two forces have the same magnitude but are opposite in direction. These two forces act on different bodies




$$\vec{F}_{A\,on\,B} = -\vec{F}_{B\,on\,A}$$

units: mass ≠ weight

1. "quantity of matter" $\simeq K\left[\begin{array}{l}\#\text{ neutrons} \\ +\#\text{ protons}\end{array}\right]$ (K: constant) (electrons ≃ negligible)

→ Einstein clarified

2. $\sum \vec{F} = m\vec{a}$

weight : · force due to gravity
· different on different planets for same mass
· far away from large bodies, no weight.

---

· The "standard" kilogram is outside Paris... must compare to that to make other standards.

· time : still 1 second = 9,192,631,770 cycles of Cesium-133 transition.

· length : meter = c · 1 second

$$c = 299792458 \frac{\text{meters}}{\text{second}}.$$

---

Doing Newton's Law Problems...

Directions : ⓪ Look at the big picture.. exploit

① Divide into smaller systems, each ≈ point mass.

③ ~~②~~ Draw a "force diagram" for each mass:

ⓐ Condense body to point or symbol

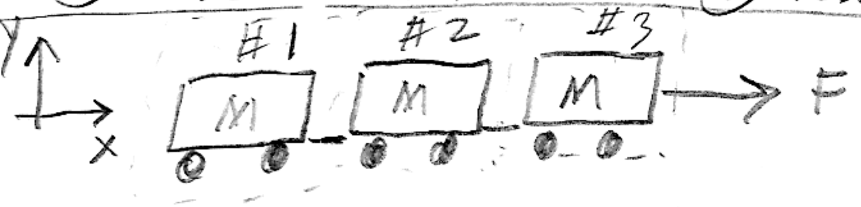
ⓑ Draw a force vector on the mass for each force acting on it

!!! : on body, not by body.

(2) ~~(3)~~ Introduce coordinate system.

(4) When 2 bodies interact, forces between them must be equal and opposite

(5) Use Newton #2, (6) Resolve into components + Go!




no friction. Find forces on each car.

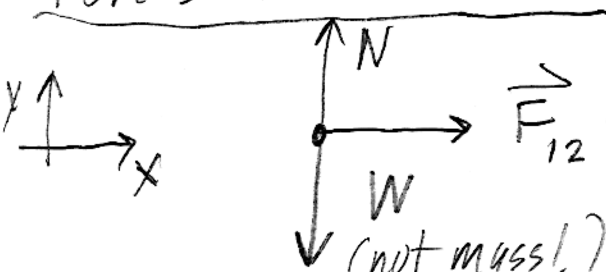
<u>Big Picture</u>: • x-direction

• $3M \cdot a_x = F$

$$a_x = \frac{F}{3M}$$ all do it (constant).

<u>means</u>: $$\frac{d^2x}{dt^2} = \ddot{x} = \frac{F}{3M}$$

<u>Forces on car #1:</u>




<u>on</u> #1 due to #2

but.. $a_y = 0$!

$-W + ? = 0$

↑ y-component of weight

$? = W$ ... "normal force"

no other forces.

x-component $F_{12} = M \cdot a_x = M \cdot \frac{F}{3M} = \frac{F}{3}$ > 0 way now omit y ...

## Forces on car #2


N3: $F_{21} = -F_{12} = -\frac{F}{3}$

why + ? → x-component

$$F_{23} + F_{21} = M \cdot a_x = M \cdot \frac{F}{3M} = \frac{1}{3} F$$

$$F_{23} = \frac{1}{3}F - F_{21} = \frac{1}{3}F - \left(-\frac{F}{3}\right) = \frac{2}{3}F$$

$$\boxed{F_{23} = \frac{2}{3}F}$$ > 0 why

## Forces on car #3

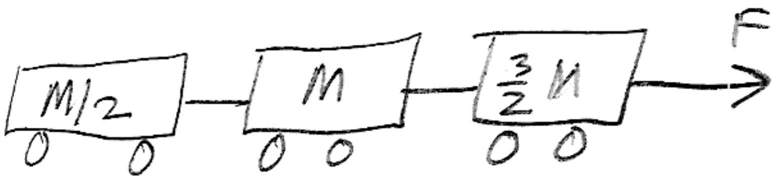

$$F + F_{32} = M \cdot a_x = M \cdot \frac{F}{3M} = \frac{1}{3}F$$

$$F_{32} = -F_{23} = -\frac{2}{3}F$$

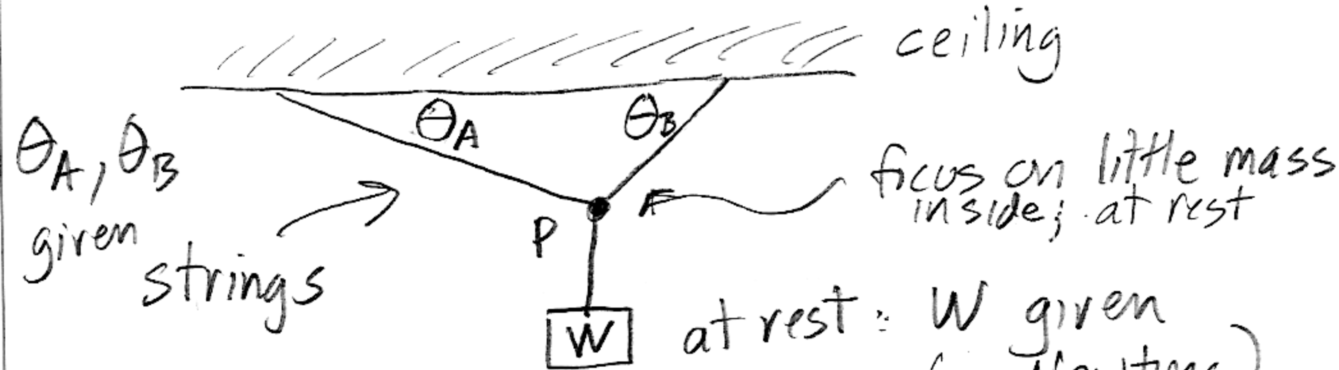
$$F = \frac{1}{3}F - F_{32} = \frac{1}{3}F + \frac{2}{3}F$$

$F = F$ good!

## Problem:

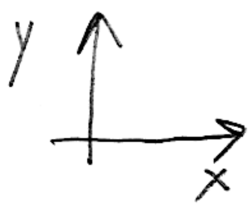


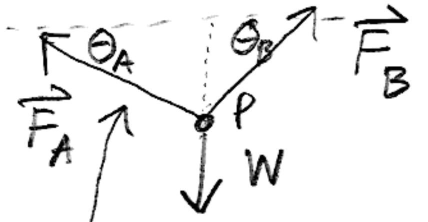
# Into the second dimension




W at rest: W given (in Newtons).

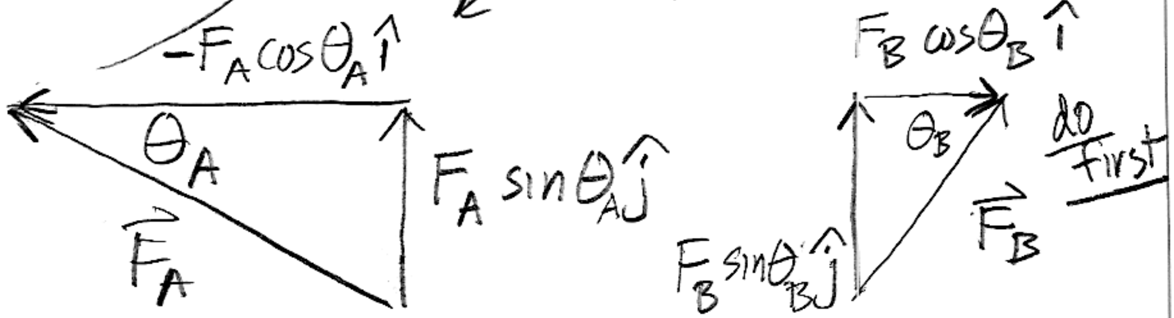
Find forces on point P




$F_A, F_B$ unknown

note, $F_A$ will be > 0




x: $-F_A \cos\theta_A + F_B \cos\theta_B = 0$

y: $F_A \sin\theta_A + F_B \sin\theta_B - W = 0$

↑ why − ?

$$-F_A + F_B \frac{\cos\theta_B}{\cos\theta_A} = 0$$

$$F_A + F_B \frac{\sin\theta_B}{\sin\theta_A} - \frac{W}{\sin\theta_A} = 0$$

---

$$F_B \left( \frac{\cos\theta_B}{\cos\theta_A} + \frac{\sin\theta_B}{\sin\theta_A} \right) - \frac{W}{\sin\theta_A} = 0$$

$$F_B = \frac{\dfrac{W}{\sin\theta_A}}{\dfrac{\cos\theta_B}{\cos\theta_A} + \dfrac{\sin\theta_B}{\sin\theta_A}} = \frac{W}{\sin\theta_A\left(\dfrac{\cos\theta_B}{\cos\theta_A}\right) + \sin\theta_B}$$

$$\boxed{F_B = \frac{W}{\sin\theta_A\left(\dfrac{\cos\theta_B}{\cos\theta_A}\right) + \sin\theta_B}}$$

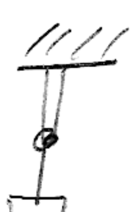
$$F_A = -\left(-F_B \cdot \frac{\cos\theta_B}{\cos\theta_A}\right)$$

$$= \frac{W \cdot \dfrac{\cos\theta_B}{\cos\theta_A}}{\sin\theta_A\left(\dfrac{\cos\theta_B}{\cos\theta_A}\right) \cdot \sin\theta_B}$$

$$\boxed{F_A = \frac{W}{\sin\theta_A + \dfrac{\cos\theta_A}{\cos\theta_B} \cdot \sin\theta_B}}$$

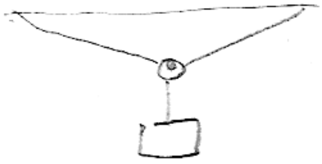
## Limiting Cases:

(1) $\theta_A = \theta_B = 90^\circ$



$$F_A = \frac{W}{1 + 1 \cdot 1} = \frac{W}{2} = F_B$$

(2)



$\theta_A \to 0$,

$\theta_A = \theta_B \equiv \theta$

$$F_A = \frac{W}{2\sin\theta} \to \infty = F_B$$