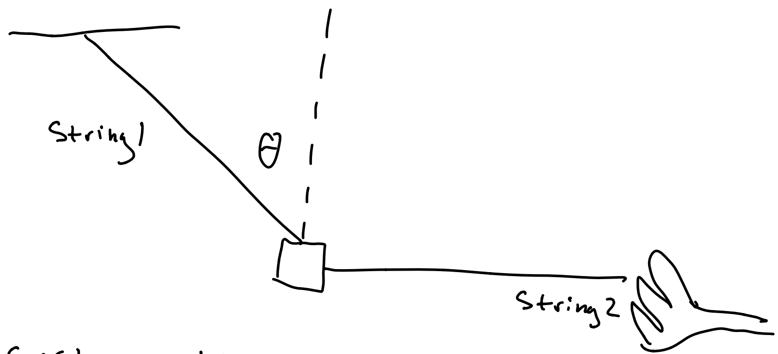
CQ 5.4.a



① System: block

Earth, string 1, string 2

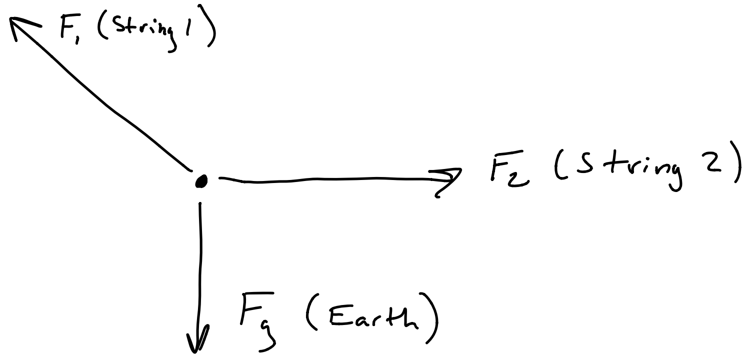
Block is the system

- Ceiling + hand aren't touching block
- Block isn't charged (no F_{elec})
- grav force between block + hand/ceiling is ignorable
- Ceiling + hand can't exert a force on the block

- Ceiling + hand exert force on string 1 + string 2
- String 1 + string 2 exert forces on block

FBD

2



Now we've identified all forces

- Find an expression for $\vec{F}_{net}$
- Find $\frac{d\vec{p}}{dt}$
- Solve

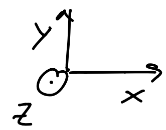
To find $\vec{F}_{net}$, we need x, y, z components of every force

$$\vec{F}_1 = \langle F_{1x}, F_{1y}, F_{1z} \rangle$$

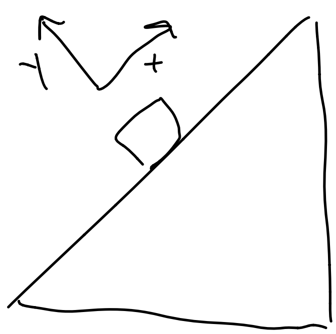
$$\vec{F}_2 = \langle F_{2x}, F_{2y}, F_{2z} \rangle$$

$$\vec{F}_{net} = = \langle F_{1x} + F_{2x}, F_{1y} + F_{2y}, F_{1z} + F_{2z} \rangle$$

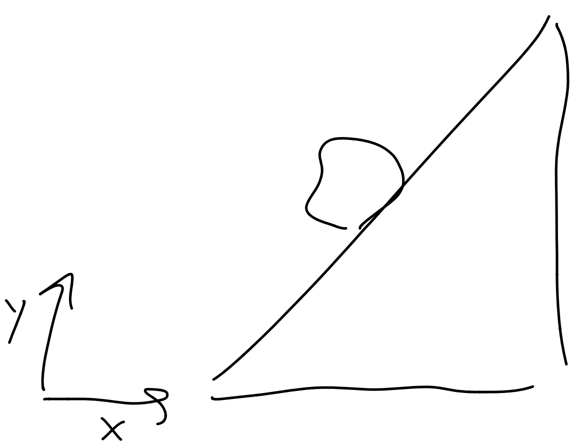
3. Pick a coordinate system
   - can be anything
   - default to



Tip: choose a system where $\frac{d\vec{p}}{dt}$ is zero in at least one direction

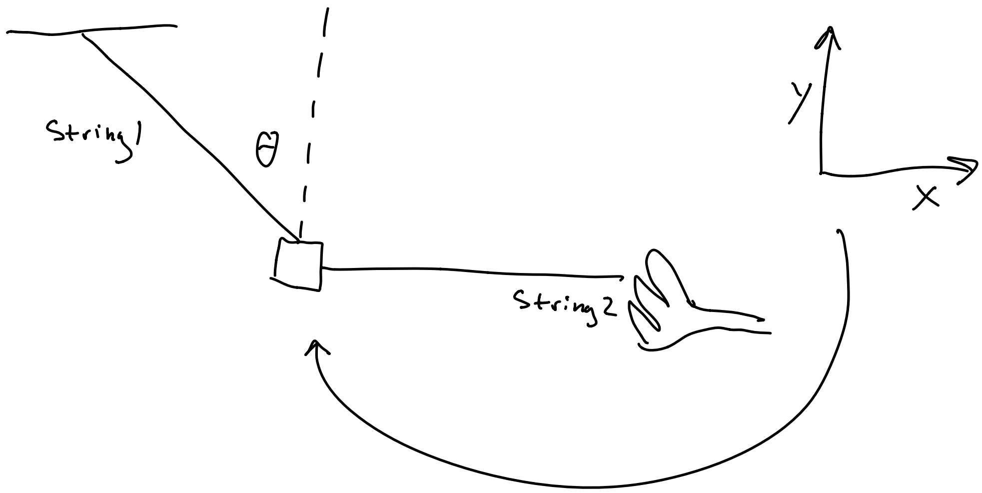


$$\frac{dp_y}{dt} = 0$$



$$\frac{dp_y}{dt} \neq 0$$

$$\frac{dp_x}{dt} \neq 0$$

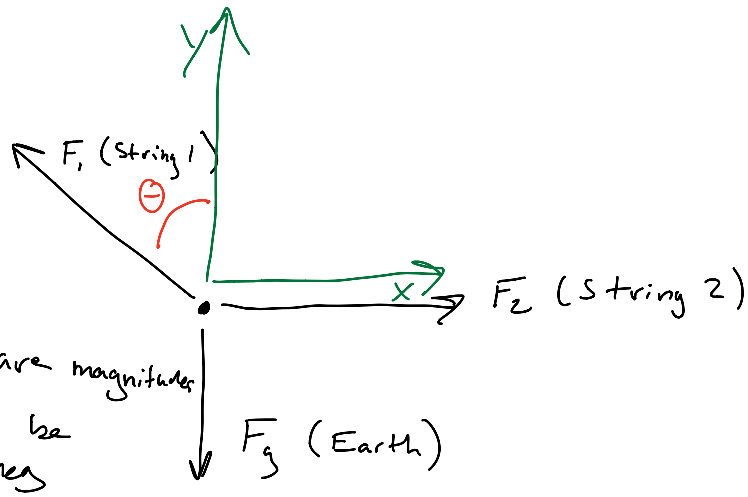


④ Split forces into $\langle x, y, z \rangle$ components to get 2 (or 3) equations

$$\frac{dp_x}{dt} = F_{net,x}$$

$$\frac{dp_y}{dt} = F_{net,y}$$

$$\frac{dp_z}{dt} = F_{net,z}$$



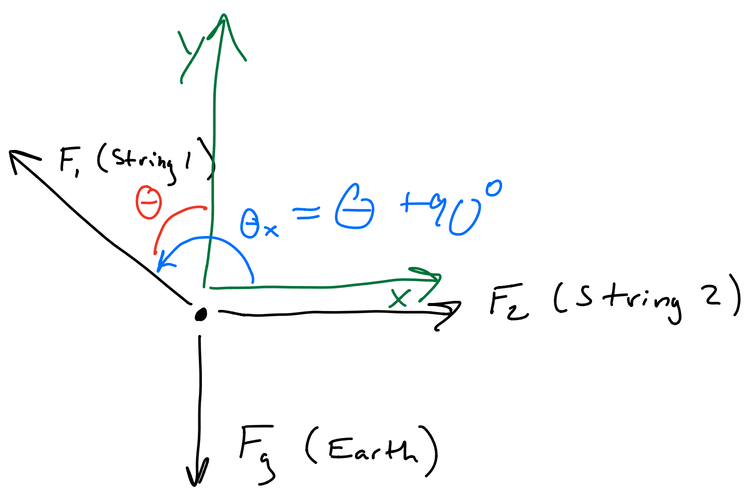
These are magnitudes can't be neg

$\vec{F}_2 = \langle F_2, 0, 0 \rangle$

$\vec{F}_g = \langle 0, -F_g, 0 \rangle$

I'm including the minus sign so $F_g = +mg$

$\vec{F}_1 = F_1 \langle \cos\theta_x, \cos\theta_y, \cos\theta_z \rangle$



$\theta_x = \theta + 90°$

$\theta_y = \theta$

$\vec{F}_1 = F_1 \langle \cos(\theta + \frac{\pi}{2}), \cos\theta, 0 \rangle$

$$\vec{F}_1 = F_1 \langle -\sin\theta, \cos\theta, 0 \rangle$$

$$F_{net,x} = F_2 - F_1 \sin\theta$$

$$F_{net,y} = F_1 \cos\theta - F_g$$

$$\frac{dp_x}{dt} = 0 = F_{net\,x} = F_2 - F_1 \sin\theta$$

$$\frac{dp_y}{dt} = 0 = F_1 \cos\theta - F_g$$

$$F_g = mg$$

2 EQN

$$0 = F_2 - F_1 \sin\theta$$

$$0 = F_1 \cos\theta - mg$$

If we knew θ, could solve for F_1 & F_2

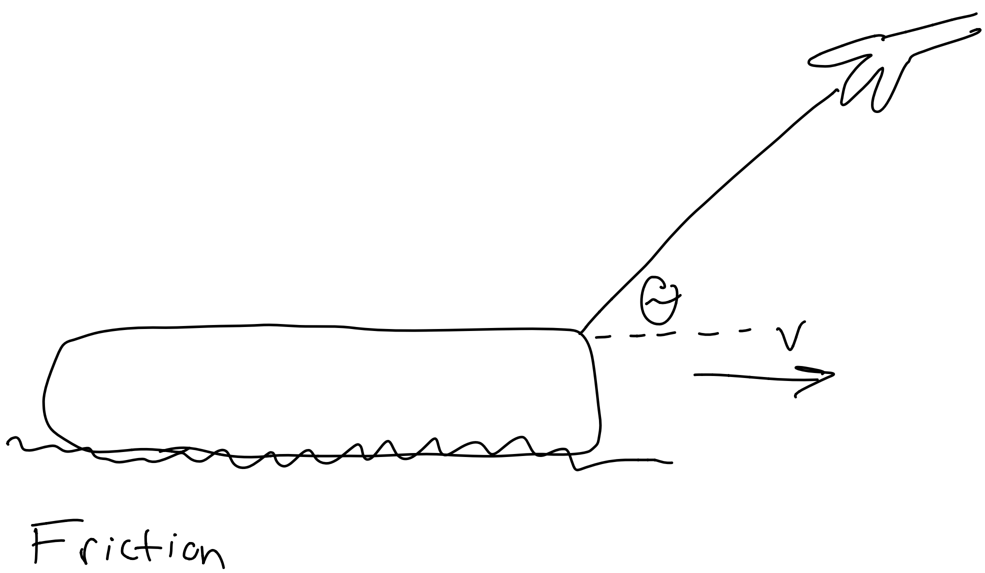
$$F_1 = \frac{mg}{\cos\theta}$$

$$0 = F_2 - mg\frac{\sin\theta}{\cos\theta}$$

$$F_2 = mg\tan\theta$$

$$F_1 = mg\sec\theta$$

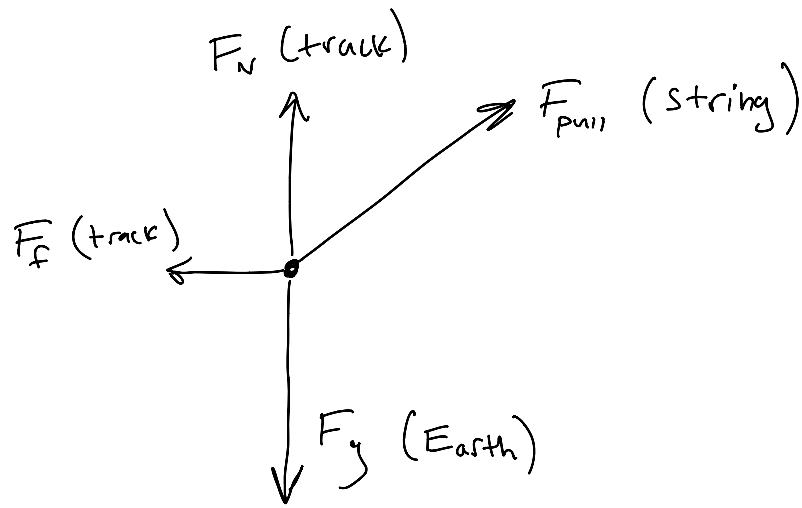
Ex:



$\theta = 25°$, $|\vec{F}_{pull}| = 0.4\ N$ $m = 130g$

$v = 2\ m/s$, what is μ_k?

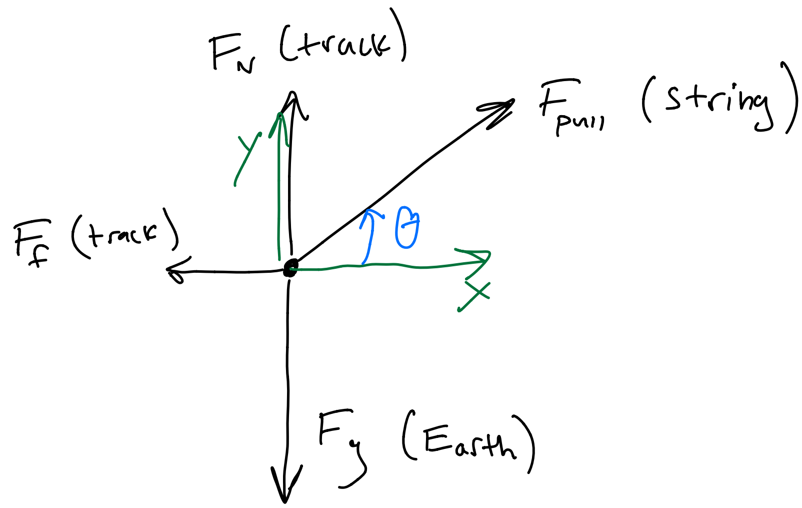
1. System: Block
   Surroundings: Track, earth, string

2. 

3. 

4. Force components

$$\vec{F}_N = \langle 0, F_N, 0 \rangle$$
$$\vec{F}_g = \langle 0, -F_g, 0 \rangle$$
$$\vec{F}_f = \langle -F_f, 0, 0 \rangle$$
$$\vec{F}_{pull} = F_{pull} \langle \cos\theta_x, \cos\theta_y, \cos\theta_z \rangle$$



$$\theta_x = \theta$$

$$\theta_y = \theta_x - 90^\circ = \theta - 90^\circ$$

$$\vec{F}_{pull} = F_{pull} \langle \cos\theta, \cos(\theta - 90^\circ), 0 \rangle$$

$$\vec{F}_{pull} = F_{pull} \langle \cos\theta, \sin\theta, 0 \rangle$$

$$F_{net,x} = F_{pull} \cos\theta - F_f$$

$$F_{net,y} = F_{pull} \sin\theta + F_N - F_g$$

$$\frac{dp_x}{dt} = 0 = F_{pull} \cos\theta - F_f$$

$$\frac{dp_y}{dt} = 0 = F_{pull} \sin\theta + F_N - F_g$$

$$F_N = F_g - F_{pull}\sin\theta$$

$$F_f = F_{pull}\cos\theta$$

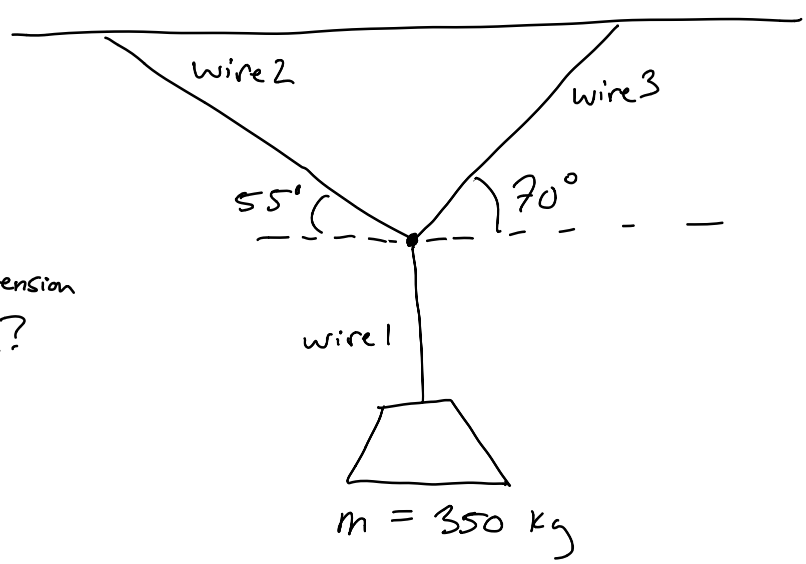
$$F_f = \mu_k F_N, \quad \mu_k = \frac{F_f}{F_N} = \frac{F_{pull}\cos\theta}{F_g - F_{pull}\sin\theta}$$

only get $\mu_k = \dfrac{F_{pull}}{F_g}$ if $\theta = 0°$

$$\mu_k = \frac{(0.4\,N)\cos(25°)}{(0.13\,kg)(9.8\,\frac{N}{kg}) - (0.4\,N)\sin(25°)}$$

$$\boxed{\mu_k = 0.33}$$

Ex:



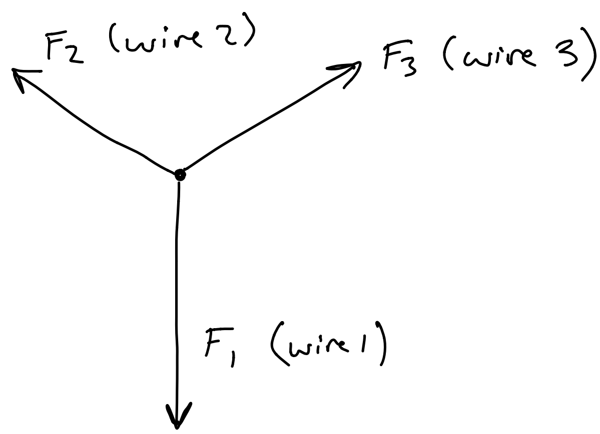
What is the tension in each wire?

1. Choose a system

- We might want to pick the hanging weight
- Wire 1 & Wire 2 don't exert forces on the weight, so we couldn't solve for them

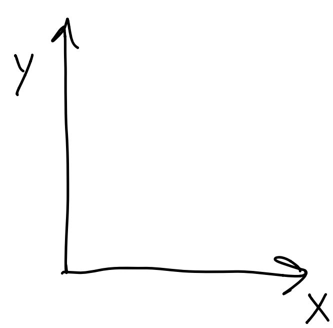
- Choose the knot to be the system

2.

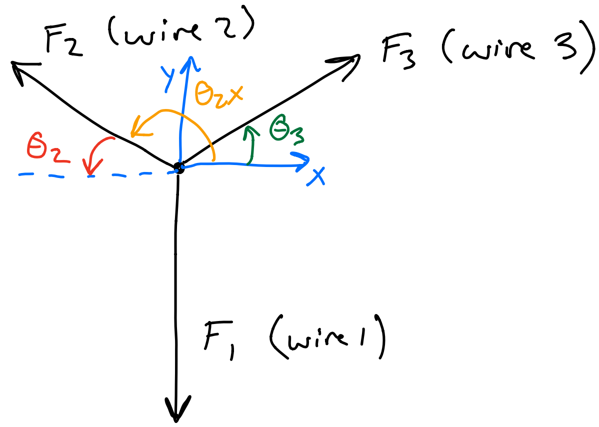


Neglect the mass of the knot so gravity is unimportant

3.



(4)



$$\vec{F}_1 = \langle 0, -F_1, 0 \rangle$$

$$\vec{F}_2 = F_2 \langle \cos\theta_{2x}, \cos\theta_{2y}, 0 \rangle$$

$$\vec{F}_3 = F_3 \langle \cos\theta_{3x}, \cos\theta_{3y}, 0 \rangle$$

$$\theta_{3x} = \theta_3$$

$$\theta_{3y} = \theta_3 - 90^\circ = \theta_3 - \frac{\pi}{2}$$

$$\theta_{2x} + \theta_2 = 180^\circ$$

$$\theta_{2x} = \pi - \theta_2$$

$$\theta_{2y} = \theta_{2x} - 90^\circ = \pi - \theta_2 - \frac{\pi}{2} = \frac{\pi}{2} - \theta_2$$

$$\vec{F}_2 = F_2 \langle \cos(\pi - \theta_2), \cos(\tfrac{\pi}{2} - \theta_2), 0 \rangle$$

$$\vec{F}_2 = F_2 \langle -\cos\theta_2, \sin\theta_2, 0 \rangle$$

$$\vec{F}_3 = F_3 \langle \cos\theta_3, \sin\theta_3, 0 \rangle$$

$$\frac{dp_x}{dt} = 0 = F_3\cos\theta_3 - F_2\cos\theta_2$$

$$\frac{dp_y}{dt} = 0 = F_2\sin\theta_2 + F_3\sin\theta_3 - F_1$$

2 EQN, 3 unknowns

But we know F_1, it's just the weight of the mass

$$F_1 = mg$$

$$0 = F_3\cos\theta_3 - F_2\cos\theta_2 \qquad (1)$$

$$0 = F_2\sin\theta_2 + F_3\sin\theta_3 - mg \qquad (2)$$

(1) $$F_2 = \frac{\cos\theta_3}{\cos\theta_2} F_3$$

(2) $$0 = \frac{\cos\theta_3}{\cos\theta_2} \sin\theta_2 F_3 + F_3 \sin\theta_3 - mg$$

$$F_3 \left(\tan\theta_2 \cos\theta_3 + \sin\theta_3 \right) = mg$$

$$F_3 = \frac{mg}{\tan\theta_2 \cos\theta_3 + \sin\theta_3}$$

$m = 350$ kg , $\theta_2 = 55°$, $\theta_3 = 70°$

$F_3 = 2402$ N

$F_2 = 1432$ N

$F_1 = 3430$ N