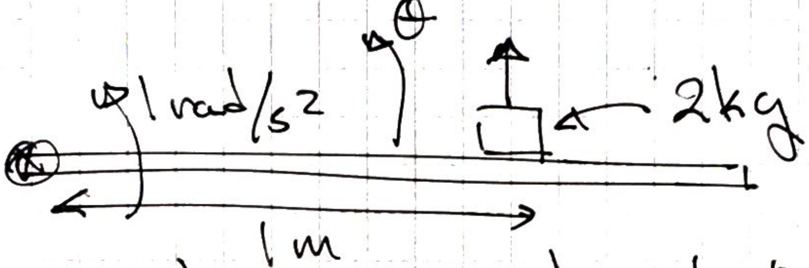
**Given:**

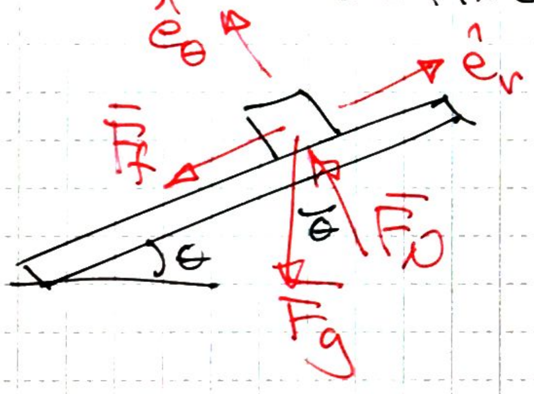


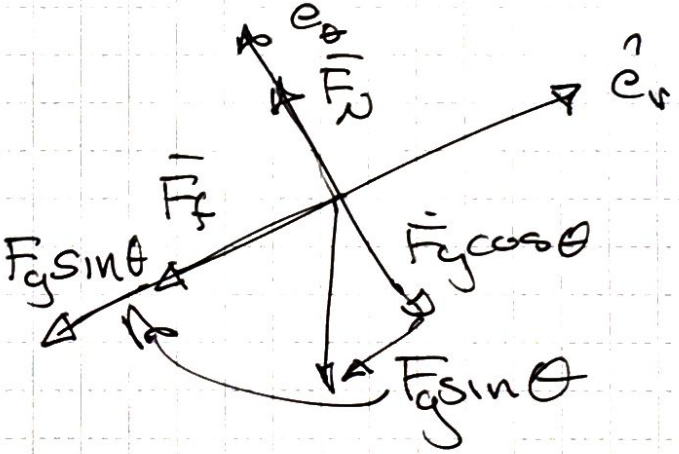

starts slipping @ $\theta = 30° = \pi/6$
what is $\mu_s$?

**Req'd** $\mu_s$ & which way does it slip?

**Assump** vertical plane, planar motion,

**Strategy** FBD (polar) = m(a-polar) take it 1 term @ a time.




**Estimate** $r\alpha = a_{tan} \cong 1\ m/s^2$ @ $30° \Rightarrow \frac{1}{6}\cdot\pi r \cong .5\,m$

for an acceleration of $1\ m/s^2 \Rightarrow v\big|_{t=1s} = 1\ m/s \Rightarrow v_{ave}\big|_{\text{first } 1s} \cong .5\ m/s$

$\Rightarrow$ box travels to $30°$ in $\approx 1s$ : going $1\ m/s \Rightarrow \frac{v^2}{r} = 1\ m/s^2 = a_r$

<u>Estimate:</u> cont. $a_{radial} \approx 1\ m/s^2 \Rightarrow F_{rad} \cong 2N$ $F_g = 20N$

$F_g \sin 30° \cong 10N \Rightarrow F_f$ must be other way $\cong 8N$

$8N \cong \mu F_g \cos\theta = \mu(15N) \Rightarrow \underline{\mu \approx .5}$

<u>Soln:</u> (I'm going to leave $F_f \swarrow$ to see what happens)

$F_r = -(F_f + mg\sin\theta) = -(\mu F_N + mg\sin\theta)$

$a_r = -\left(\frac{\mu F_N}{m} + g\sin\theta\right)$

$F_\theta = (F_N - mg\cos\theta) \Rightarrow a_\theta = \frac{F_N}{m} - g\cos\theta$

$$a_{polar} = \left[\underbrace{\frac{d^2r}{dt^2}}_{\to 0} - r\omega^2\right]\hat{e}_r + \left[r\alpha + \cancel{2\underbrace{\frac{dr}{dt}}_{\to 0}\omega}\right]\hat{e}_\theta \qquad \frac{dr}{dt} = 0!!$$

$$\Rightarrow +r\omega^2 = +\left(\frac{\mu F_N}{m} + g\sin\theta\right) \qquad r\alpha = \frac{F_N}{m} - g\cos\theta$$

$$\frac{F_N}{m} = r\alpha + g\cos\theta = 1m\left(1\frac{rad}{s^2}\right) + \underbrace{9.8\frac{m}{s^2}\cos(30°)}_{8.49} = \underline{9.49\ m/s^2}$$

now I need $\omega$ to solve eqn from $a_r$! $\alpha$ = const makes it straight forward.

Soln: cont

$$\alpha = \frac{d\omega}{dt} \Rightarrow \int d\omega = \alpha\int dt \Rightarrow \omega - \underbrace{\cancel{\omega_0}}_{\to 0} = \alpha(t - \underbrace{\cancel{t_0}}_{\to 0})$$

$$\omega = \alpha t = \frac{d\theta}{dt} \Rightarrow \int_0^t \alpha t\,dt = \int_0^\theta d\theta \Rightarrow \frac{\alpha t^2}{2} = \theta \Rightarrow$$

$$t = \sqrt{\frac{2\theta}{\alpha}} = \sqrt{\frac{2(\pi/6)\text{rad}}{1\ \text{rad/s}^2}} = \underline{1.02\,s} \Rightarrow \omega = 1\ \text{rad/s}^2\,(1.02\,s) = \underline{1.02\ \text{rad/s}}$$

now, back to eqn $r\omega^2 - g\sin\theta = \mu\frac{F_N}{m}$

$$1m\left(1.02\,\frac{rad}{s}\right)^2 - 9.8\sin 30^\circ = -\mu\,(9.49\ m/s^2)$$

$+3.86 = +\mu(9.49)$ ⟸ implies $F_f$ is other way due to (−) sign. Change sign

$$\mu = \frac{3.86\ m/s^2}{9.49\ m/s^2} = \boxed{.406 = \mu_s}$$

track sign change → (−)

sliding "down" toward origin!

Discussion: #'s are all close to estimate AND the math told me I had put $F_f$ in wrong direction. I really like it when it works that way