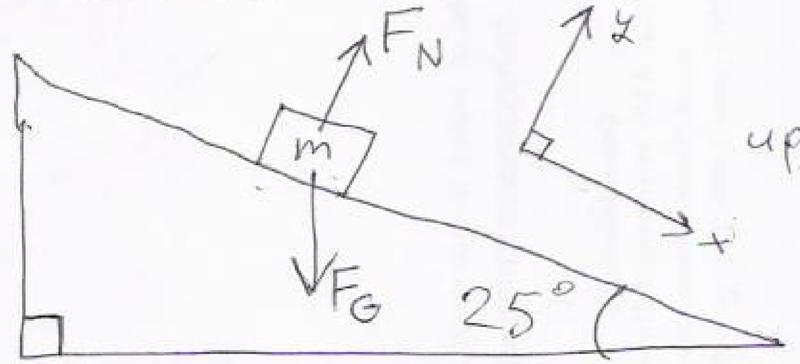
Feb. 7: • More on Ch. 4 (ramps)
• 5.1: Friction

Feb. 9: Problem Solving & Simulations

Feb. 10: Review session (1 hour) 9AM

9AM (10, 13) ~~10AM (2, 4)~~ ~~11AM (5, 4)~~ ~~12PM (11, 4)~~ ~~1PM (0)~~ ~~2PM (3)~~ ~~3PM (4)~~ ~~4PM (0)~~

Feb. 14: Midterm I
(60 exercises due)



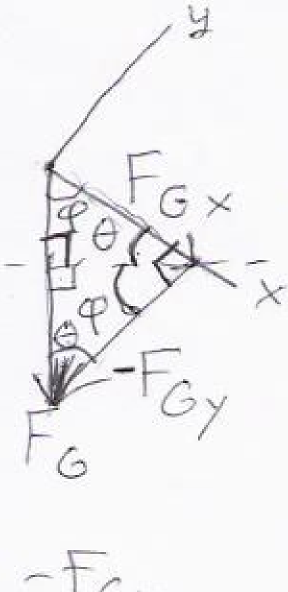
block <u>sliding</u> up/down ramp

What is its acceleration?

$a_y = 0$.

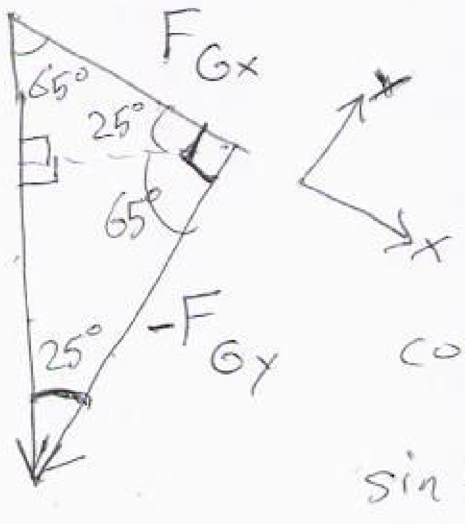
Ignore friction for now

$F_{Nx} = 0 \qquad F_{Ny} = F_N$



$\theta = 25°$
$\varphi = 90° - \theta$
$\varphi = 65°$

$mg = F_G$



$\theta = 25°$

$\cos\theta = \frac{-F_{Gy}}{F_G}$

$\sin\theta = F_{Gx}/F_G$

$F_{Gy} = -F_G \cos\theta \qquad F_{Gx} = F_G \sin\theta$

$F_{Gy} = -mg\cos 25^\circ \qquad F_{Gx} = mg\sin 25^\circ$

$g = 9.80\ m/s^2$

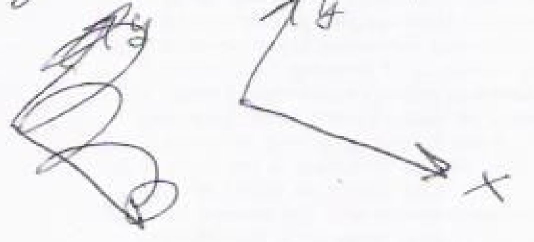
$0 = ma_y = \sum F_y = F_{Ny} + F_{Gy} = F_N - mg\cos 25^\circ$

$F_N = mg\cos 25^\circ$

$ma_x = \sum F_x = F_{Nx} + F_{Gx} = 0 + mg\sin 25^\circ$

$a_x = g\sin 25^\circ = 4.1\ m/s^2$ (constant)

How long does it take for the block to slide $\ell = 1.0\,m$ along the ramp, starting from rest?



$\Delta x = \ell$

$\Delta t = ?$

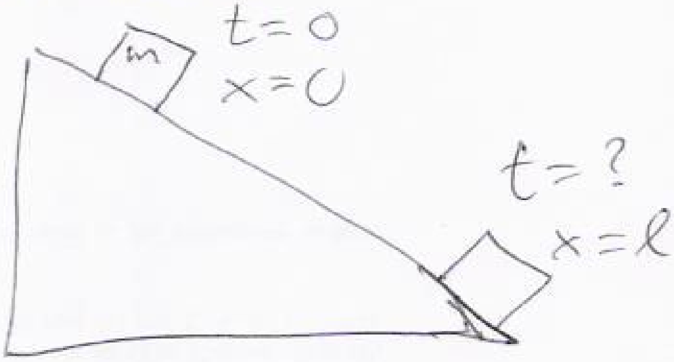
$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$ (p. 62)

choose coordinates so that $x_0 = 0$

$v_{x0} = 0$

assuming a_x constant

$$x = \frac{1}{2} a_x t^2$$ Solve for t when $x = \ell$



$$\ell = \frac{1}{2} a_x t^2$$

$$\sqrt{2\ell / a_x} = t$$

$$\sqrt{\frac{2(1.0\,m)}{4.1\,m/s^2}} = \sqrt{0.49\,s^2} = \boxed{0.70\,s}$$

Let's add Friction.

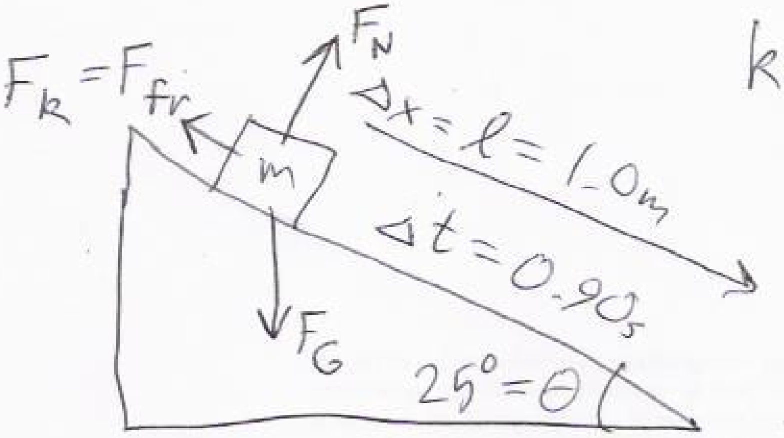
F_k = kinetic friction force (slows down motion)

F_s = static friction force (prevents motion)

There are constant μ_k & μ_s which depend only on the two materials involved, such that

$$F_k = \mu_k F_N \qquad \boxed{F_s \leq \mu_s F_N}$$

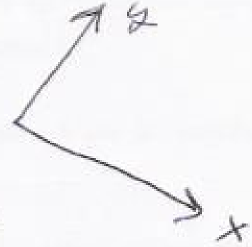
Usually, $1 > \mu_s > \mu_k > 0$.



Kinetic Friction:

Suppose block starts at rest and slides $\ell = 1.0\,m$ in $0.90\,s$

What is μ_k?



$$F_{Nx} = 0 \qquad F_{Ny} = F_N$$

$$F_{kx} = -F_k \qquad F_{ky} = 0$$

$$F_N = mg\cos\theta \qquad F_{Gx} = mg\sin \overbrace{25°}^{\theta}$$

$$F_k = \mu_k F_N = mg\mu_k \cos 25°$$

$a_y = 0$ as before

$$ma_x = \sum F_x = \underbrace{F_{Nx}}_{0} + \underbrace{F_{Gx}}_{mg\sin\theta} + F_{kx}$$

$$ma_x = mg\sin\theta - mg\mu_k\cos\theta$$

$$a_x = g(\sin\theta - \mu_k\cos\theta)$$

$l = \frac{1}{2} a_x t^2$ $\qquad t = 0.90\,s$

$\qquad\qquad\qquad\quad l = 1.0\,m$

$\Downarrow$

$a_x = \frac{2l}{t^2} = 2.5\,m/s^2$

$g(\sin\theta - \mu_k \cos\theta) = 2.5\,m/s^2$

$\sin 25° - \mu_k \cos 25° = 0.255$

-0.23 ~~[illegible]~~ $\qquad | \; -0.255$

$+\mu_k \cos 25° \qquad | \; +\mu_k \cos 25°$

$\sin 25° - 0.255 = \mu_k \cos 25°$

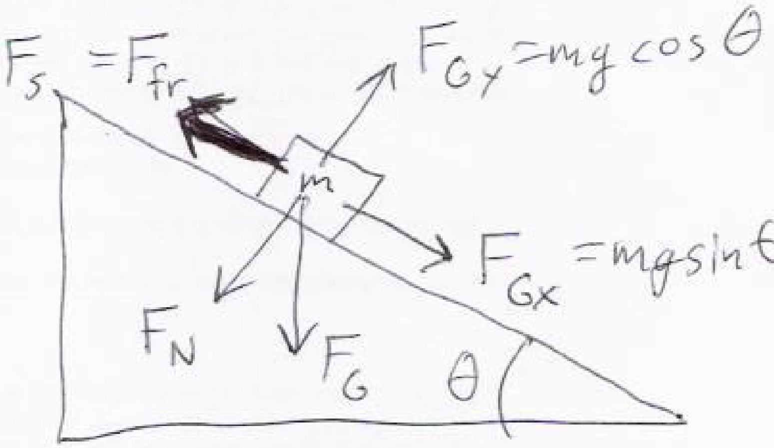
$\frac{\sin 25° - 0.255}{\cos 25°} = \mu_k$

~~$0.22 = \mu_k$~~

$0.19 = \mu_k$

Suppose a block at rest will start sliding down a ramp if the angle of elevation θ is at least $34°$, but not if less than $34°$. What is μ_s?

$$F_s \leq \mu_s F_N$$



If $F_{Gx} \leq \mu_s F_N$, then $F_s = F_{Gx}$, causing $\sum F_x = 0$.

If $F_{Gx} > \mu_s F_N$, then we're in the kinetic friction model:

$$\sum F_x = \quad mg\sin\theta \pm \mu_k mg\cos\theta$$

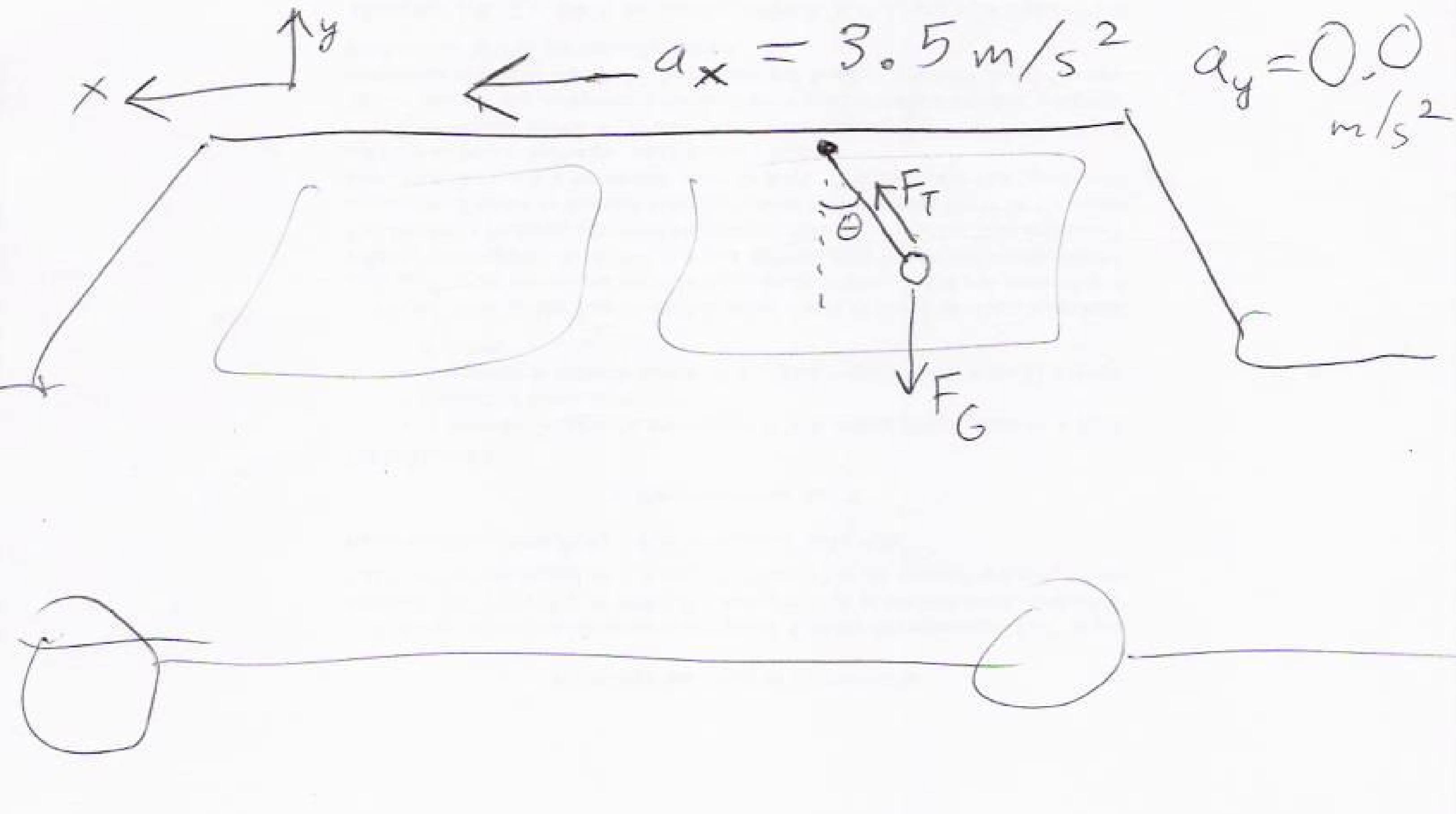
The threshold angle $\theta = 34°$ is where $F_{Gx} = \mu_s F_N$:

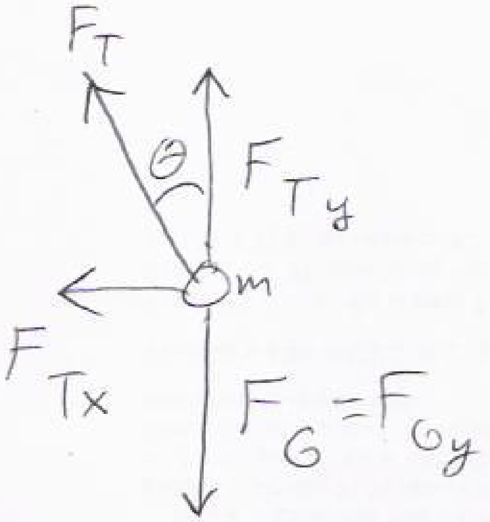
$$mg \sin\theta = \mu_s \, mg \cos\theta$$

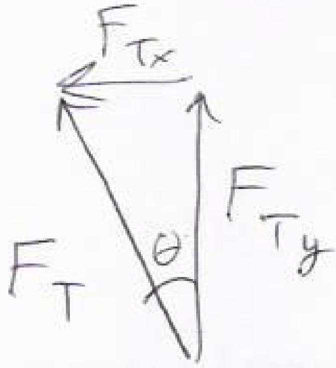
$$\tan\theta = \mu_s$$

$$\mu_s = \tan 34° = 0.67$$

Accelerometer







$$a_y = 0 \Rightarrow 0 = ma_y$$
$$0 = \Sigma F_y$$
$$0 = F_{T_y} - F_G$$
$$mg = F_G = F_{T_y}$$

$$\left.\begin{aligned} ma_x &= F_{T_x} = F_T \sin\theta \\ mg &= F_{T_y} = F_T \cos\theta \end{aligned}\right\} \quad \frac{a_x}{g} = \frac{\sin\theta}{\cos\theta}$$

$$3.5\,m/s^2 = a_x = g \tan\theta$$

$$\theta = \arctan\left(\frac{3.5}{9.80}\right) = 0.34$$
$$= 2.0 \times 10^1 \text{ degrees}$$