•**11** SSM A 68 kg crate is dragged across a floor by pulling on a rope attached to the crate and inclined 15° above the horizontal. (a) If the coefficient of static friction is 0.50, what minimum force magnitude is required from the rope to start the crate moving? (b) If $\mu_k = 0.35$, what is the magnitude of the initial acceleration of the crate?

•**14** Figure 6-22 shows the cross section of a road cut into the side of a mountain. The solid line AA' represents a weak bedding plane along which sliding is possible. Block B directly above the highway is separated from uphill rock by a large crack (called a *joint*), so that only friction between the block and the bedding plane prevents sliding. The mass of the block is 1.8×10^7 kg, the *dip angle* θ of the bedding plane is 24°, and the coefficient of static friction between block and plane is 0.63. (a) Show that the block will not slide under these circumstances. (b) Next, water seeps into the joint and expands upon freezing, exerting on the block a force $\vec{F}$ parallel to AA'. What minimum value of force magnitude F will trigger a slide down the plane?

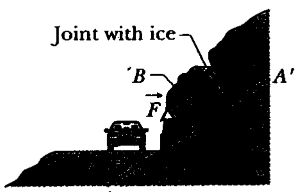


Fig. 6-22 Problem 14.

••**23** When the three blocks in Fig. 6-29 are released from rest, they accelerate with a magnitude of 0.500 m/s². Block 1 has mass M, block 2 has $2M$, and block 3 has $2M$. What is the coefficient of kinetic friction between block 2 and the table?

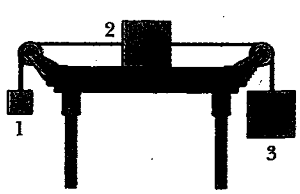


Fig. 6-29 Problem 23.

••**27** Body A in Fig. 6-33 weighs 102 N, and body B weighs 32 N. The coefficients of friction between A and the incline are $\mu_s = 0.56$ and $\mu_k = 0.25$. Angle θ is 40°. Let the positive direction of an x axis be up the incline. In unit-vector notation, what is the acceleration of A if A is initially (a) at rest, (b) moving up the incline, and (c) moving down the incline?

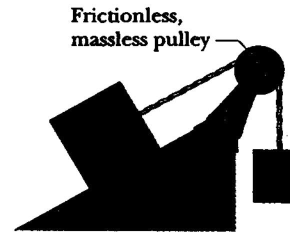


Fig. 6-33 Problems 27 and 28.

••**30** A toy chest and its contents have a combined weight of 180 N. The coefficient of static friction between toy chest and floor is 0.42. The child in Fig. 6-35 attempts to move the chest across the floor by pulling on an attached rope. (a) If θ is 42°, what is the magnitude of the force $\vec{F}$ that the child must exert on the rope to put the chest on the verge of moving? (b) Write an expression for the magnitude F required to put the chest on the verge of moving as a function of the angle θ. Determine (c) the value of θ for which F is a minimum and (d) that minimum magnitude.

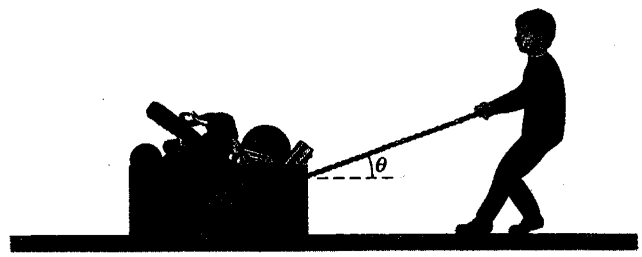


Fig. 6-35 Problem 30.

Table 6-1

Some Terminal Speeds in Air

Object	Terminal Speed (m/s)	95% Distance[a] (m)
Shot (from shot put)	145	2500
Sky diver (typical)	60	430
Baseball	42	210
Tennis ball	31	115
Basketball	20	47
Ping-Pong ball	9	10
Raindrop (radius = 1.5 mm)	7	6
Parachutist (typical)	5	3

[a]This is the distance through which the body must fall from rest to reach 95% of its terminal speed.
Source: Adapted from Peter J. Brancazio, *Sport Science*, 1984, Simon & Schuster, New York.

••**38** Assume Eq. 6-14 gives the drag force on a pilot plus ejection seat just after they are ejected from a plane traveling horizontally at 1300 km/h. Assume also that the mass of the seat is equal to the mass of the pilot and that the drag coefficient is that of a sky diver. Making a reasonable guess of the pilot's mass and using the appropriate v_t value from Table 6-1, estimate the magnitudes of (a) the drag force on the *pilot* + *seat* and (b) their horizontal deceleration (in terms of g), both just after ejection. (The result of (a) should indicate an engineering requirement: The seat must include a protective barrier to deflect the initial wind blast away from the pilot's head.)

••57 A puck of mass $m = 1.50$ kg slides in a circle of radius $r = 20.0$ cm on a frictionless table while attached to a hanging cylinder of mass $M = 2.50$ kg by means of a cord that extends through a hole in the table (Fig. 6-43). What speed keeps the cylinder at rest?

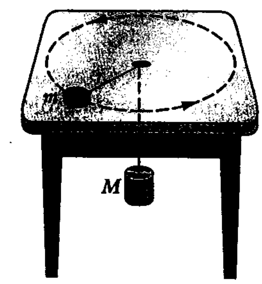


Fig. 6-43 Problem 57.

••39 Calculate the ratio of the drag force on a jet flying at 1000 km/h at an altitude of 10 km to the drag force on a prop-driven transport flying at half that speed and altitude. The density of air is 0.38 kg/m^3 at 10 km and 0.67 kg/m^3 at 5.0 km. Assume that the airplanes have the same effective cross-sectional area and drag coefficient C.

••58 *Brake or turn?* Figure 6-44 depicts an overhead view of a car's path as the car travels toward a wall. Assume that the driver begins to brake the car when the distance to the wall is $d = 107$ m, and take the car's mass as $m = 1400$ kg, its initial speed as $v_0 = 35$ m/s, and the coefficient of static friction as $\mu_s = 0.50$. Assume that the car's weight is distributed evenly on the four wheels, even during braking. (a) What magnitude of static friction is needed (between tires and road) to stop the car just as it reaches the wall? (b) What is the maximum possible static friction $f_{s,\max}$? (c) If the coefficient of kinetic friction between the (sliding) tires and the road is $\mu_k = 0.40$, at what speed will the car hit the wall? To avoid the crash, a driver could elect to turn the car so that it just barely misses the wall, as shown in the figure. (d) What magnitude of frictional force would be required to keep the car in a circular path of radius d and at the given speed v_0, so that the car moves in a quarter circle and then parallel to the wall? (e) Is the required force less than $f_{s,\max}$ so that a circular path is possible?

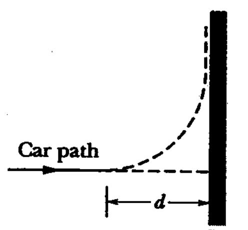


Fig. 6-44 Problem 58.

••51 An airplane is flying in a horizontal circle at a speed of 480 km/h (Fig. 6-41). If its wings are tilted at angle $\theta = 40°$ to the horizontal, what is the radius of the circle in which the plane is flying? Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the wing surface.

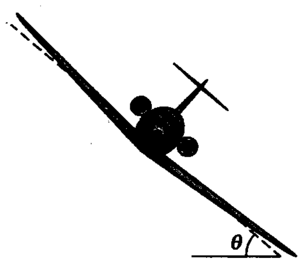


Fig. 6-41 Problem 51.

82 In Fig. 6-57, a stuntman drives a car (without negative lift) over the top of a hill, the cross section of which can be approximated by a circle of radius $R = 250$ m. What is the greatest speed at which he can drive without the car leaving the road at the top of the hill?

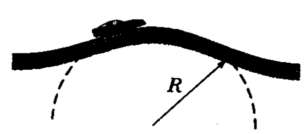
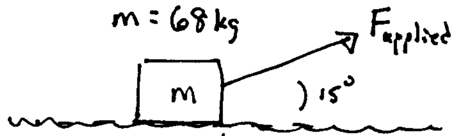


Fig. 6-57 Problem 82.

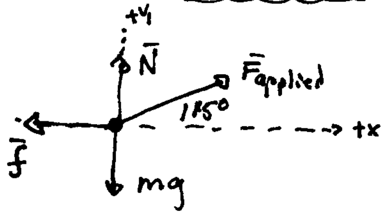
6.11

$m = 68\,kg$



$\mu_{static} = 0.5$

$\mu_{kinetic} = 0.35$



$ma_x = \sum F_x$ $\qquad ma_y = \sum F_y$

$\cancel{\approx F_{applied} - f}$

$ma_x = F_{app}\cos\theta - f$ $\qquad \cancel{ma_y}^{\,0} = N + F_{app}\sin\theta - mg$

a) Asks about the maximum static friction case

$m\cancel{a_x}^{\,0} = F_{app}\cos\theta - \mu_s N$ $\qquad \cancel{ma_y}^{\,0} = N + F_{app}\sin\theta - mg$

$N = mg - F_{app}\sin\theta$

$0 = F_{app}\cos\theta - \mu\left[mg - F_{app}\sin\theta\right]$

$0 = F_{app}\cos\theta + \mu F_{app}\sin\theta - \mu mg$

$0 = F_{app}\left[\cos\theta + \mu_s\sin\theta\right] - \mu mg$

$$F_{app} = \frac{\mu mg}{\cos\theta + \mu_s\sin\theta} = \frac{0.5\,(68)\,9.8}{\cos 15^\circ + 0.5\sin 15^\circ}$$

$= 304$ Newtons

b) ~~If~~ $F_{app} = 304$ Newtons, and now breaks loose + slides, what is the acceleration?

Start with

$ma_x = F_{app}\cos\theta - f$ $\qquad \cancel{ma_y}^{\,0} = N + F_{app}\sin\theta - mg$

$N = mg - F_{app}\sin\theta$

$\therefore F_{app}\cos\theta - \mu_k N$

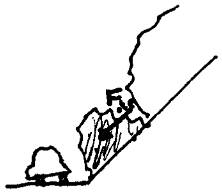
$ma_x = F_{app}\cos\theta - \mu_k\left[mg - F_{app}\sin\theta\right]$

$= F_{app}\left[\cos\theta + \mu_k\sin\theta\right] - \mu_k mg$

$68\,a_x = 304\left[\cos 15^\circ + 0.35\sin 15^\circ\right] - 0.35(68)9.8$

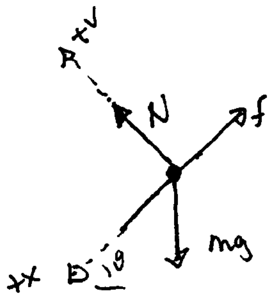
$a_x = 1.29\ m/s$

6.14



$m = 1.8 \times 10^7$ kg
$\theta = 24°$
$\mu_s = 0.63$

NO ICE



$ma_x = \Sigma F_x$

$ma_x = mg\sin\theta - f$

$ma_y = \Sigma F_y$

$m\cancel{a_y} = N - mg\cos\theta$ ($a_y = 0$)

$N = mg\cos\theta$

Part a) asks us to demonstrate that the rocks don't slide.
This occurs if

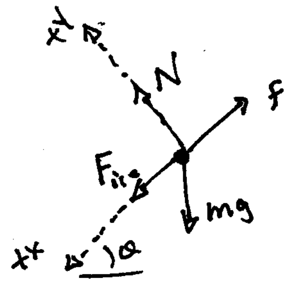
mg sinθ is less than max static f

$mg\sin 24°$
$mg(0.41)$

$\mu_s N$
$\mu_s mg$
$(0.63)\, mg$

which turns out to be true

WITH ICE



$ma_x = \Sigma F_x$

$ma_x = F_{ice} + mg\sin\theta - f$

$m\cancel{a_x} = F_{ice} + mg\sin\theta - \mu_s N$ (0 static)

$ma_y = \Sigma F_y$

$m\cancel{a_y} = N - mg\cos\theta$ (0)

$N = mg\cos\theta$

$0 = F_{ice} + mg\sin\theta - \mu_s mg\cos\theta$

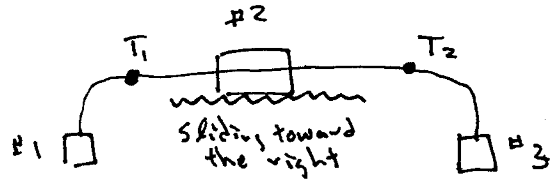
$0 = F_{ice} + mg[\sin\theta - \mu_s\cos\theta]$

$$F_{ice} = \frac{mg}{\mu_s\cos\theta - \sin\theta}$$

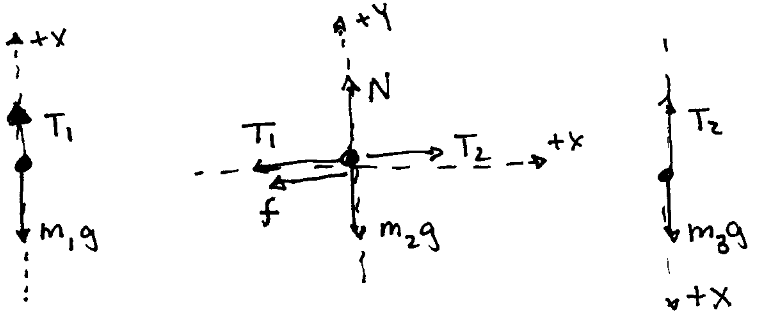
$$= \frac{(1.8\times10^7)(9.8)}{0.63\cos 24° - \sin 24°}$$

$= 1.05\times10^9$ Newtons

6.23



$m_1 = M$
$m_2 = 2M$
$m_3 = 2M$
$a_x = 0.5$



Pick a consistent coordinate system.

$m_1 a_x = T_1 - m_1 g$ $\qquad$ $m_2 a_x = T_2 - T_1 - f$ $\qquad$ $m_3 a_x = m_3 g - T_2$

$$= T_2 - T_1 - \mu N$$

for this situation

$$m_2 a_x = T_2 - T_1 - \mu m_2 g$$

Add ALL 3-equations

$$(m_1 + m_2 + m_3) a_x = -m_1 g - \mu m_2 g + m_3 g$$

$$(M + 2M + 2M) a_x = -Mg - \mu 2Mg + 2Mg$$

$$5 a_x = -g - \mu 2g + 2g$$

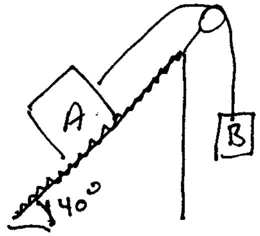
$$= g - \mu 2g$$

$$5 a_x = g(1 - 2\mu)$$

$$5(0.5) = 9.8(1 - 2\mu)$$

$$(1 - 2\mu) = 0.255 \longrightarrow \mu = 0.372$$

6.27



~~m_A~~

$m_A g = 102$ Newtons $\quad m_A = 10.41$ kg

$m_B g = 32 \quad m_B = 3.27$ kg

$\mu_s = 0.56$

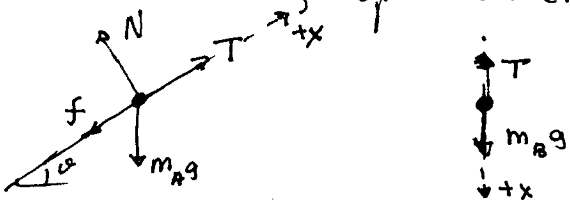
$\mu_k = 0.25$

Told to choose +x up incline

a) What is acceleration vector if block A is at ~~rest~~ rest?

---Duh, it's zero $\quad a_x = 0 \quad a_y = 0$

b) Block A moving up incline.



$m_A a_x = T - m_A g \sin\theta - f \qquad m_A \overset{0}{a_y} = N - m_A g \cos\theta \qquad m_B a_x = m_B g - T$

$N = m_A g \cos\theta$

$m_A a_x = T - m_A g \sin\theta - \mu_k N$

$m_A a_x = T - m_A g \sin\theta - \mu_k m_A g \cos\theta$

ADD EQUATIONS

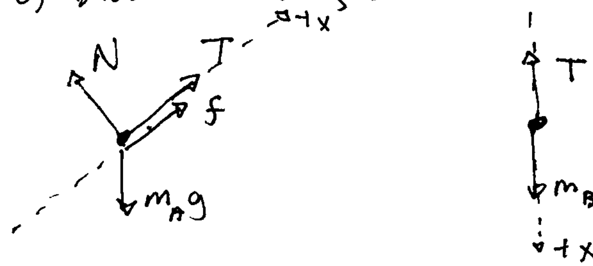
$(m_A + m_B)\, a_x = m_B g - m_A g \sin\theta - \mu_k m_A g \cos\theta$

$(10.41 + 3.27)\, a_x = 32 - 102 \sin 40° - 0.25(102)\cos 40°$

$13.68\, a_x = -53.10$

$a_x = -3.88$ m/s²

c) Block A moving down incline



$m_A a_x = T + f - m_A g \sin\theta \qquad m_A \overset{0}{a_y} = N - m_A g \cos\theta \qquad m_B a_x = m_B g - T$

$N = m_A g \cos\theta$

$m_A a_x = T + \mu_k N - m_A g \sin\theta$

$m_A a_x = T + \mu_k m_A g \cos\theta - m_A g \sin\theta$

ADD EQUATIONS

$(m_A + m_B)\, a_x = m_B g + \mu_k m_A g \cos\theta - m_A g \sin\theta$

$(10.41 + 3.27)\, a_x = 32 + 0.25(102)\cos 40° - 102 \sin 40°$

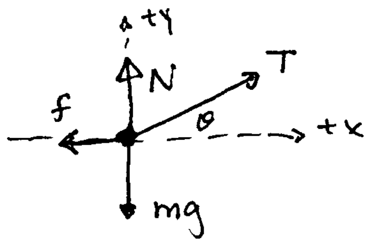
$13.68\, a_x = -14.03$

$a_x = -1.03$ m/s²

6.30

$mg = 180$ Newtons

$\mu_s = 0.42$



$ma_x = T\cos\theta - f$

$m\cancel{a_y}^{0} = T\sin\theta + N - mg$

maximum static

$N = mg - T\sin\theta$

$m\cancel{a_x}^{0} = T\cos\theta - \mu N$

$0 = T\cos\theta - \mu\left[mg - T\sin\theta\right]$

$0 = T\cos\theta + \mu T\sin\theta - \mu mg$

$0 = T\left[\cos\theta + \mu\sin\theta\right] - \mu mg$

$$T = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$

a) If $\theta = 42°$

$$T = \frac{\mu mg}{\cos\theta + \mu\sin\theta} = \frac{0.42\,[180]}{\cos 42° + 0.42\sin 42°}$$

$= 73.8$ Newtons

b) What is the best angle to pull?

$$T = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$

The best angle occurs when the denominator is maximum $\therefore$ smallest T.

Let $z = \cos\theta + \mu\sin\theta$

then $\frac{dz}{d\theta} = 0 = -\sin\theta + \mu\cos\theta$

$\sin\theta = \mu\cos\theta$

$\tan\theta = \mu$

$\tan\theta = 0.42$

$\theta = 22.8°$

At this angle

$$T = \frac{0.42\,[180]}{\cos 22.8° + 0.42\sin 22.8°} = 69.7 \text{ Newtons}$$

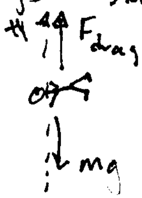
6.38

This problem tells us to calculate

$$\frac{1}{2} C \rho A v^2$$

But first we have to use Table 1 to get information about the values for C, ρ, and A.

Table 1 says skydiver terminal speed is 60 m/s



$$m \cancel{a_y} = F_{drag} - mg$$

0 at terminal speed

$$0 = F_{drag} - mg$$

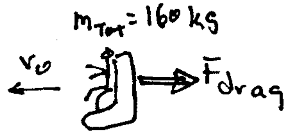
$$0 = \frac{1}{2} C \rho A v^2 - mg$$

I choose to use $m = 80\,kg$

$$0 = \frac{1}{2} C \rho A\, 60^2 - 80(9.8)$$

the product $C\rho A = 0.436$

Then



$$v_0 = 1300 \frac{km}{h} = 1300 \frac{1000\,m}{3600\,s} = 361\ m/s$$

$$m_{Tot} a_x = F_{drag} = \frac{1}{2} C\rho A\, v^2$$

$$160\ a_x = \frac{1}{2}[0.436](361)^2$$

$$160\ a_x = 2.84 \times 10^4 \text{ Newtons}$$

$$a_x = 177.7\ m/s^2 = 18.1 \text{ "g's"}$$

6.39

G550 $\rho = 0.38\ kg/m^3$

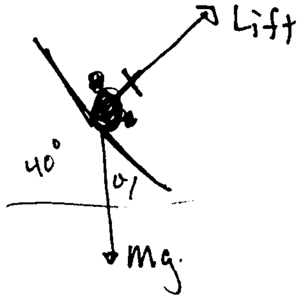
$$1000 \frac{km}{hr} = 1000 \frac{1000\,m}{3600\,s} = 277.8\ m/s$$

KC135 $\rho = 0.67\ kg/m^3$

$$500 \frac{km}{h} = 500 \frac{1000\,m}{3600\,s} = 138.9\ m/s$$

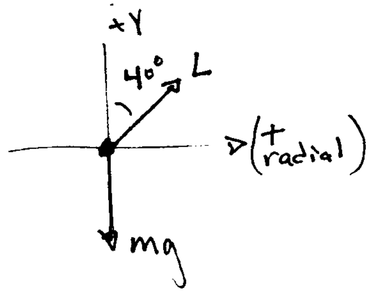
$$\text{Ratio} = \frac{\frac{1}{2} C \rho A v^2}{\frac{1}{2} C \rho A v^2} = \frac{\frac{1}{2} C\ 0.38\ A\ (277.8)^2}{\frac{1}{2} C\ 0.67\ A\ (138.9)^2} = 2.27$$

6.51



$V = 480 \frac{km}{h} = 480 \frac{10^3 m}{3600 s}$

$= 133.3 \; m/s$



$ma_{rad} = \Sigma F_{radial}$

$ma_{rad} = L \sin 40°$

$m \frac{v^2}{R} = L \sin 40°$

$ma_y = \Sigma F_y$

$m \cancel{a_y}^{0} = L \cos 40° - mg$

$L = \frac{mg}{\cos 40°}$

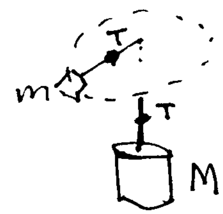
$m \frac{v^2}{R} = \frac{mg}{\cos 40°} \sin 40°$

$\cancel{m} \frac{v^2}{R} = \cancel{m} g \tan 40°$

$\frac{(133.3)^2}{R} = 9.8 \tan 40°$

$R = 2161 \; m$

6.57

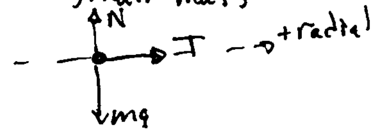


$m = 1.50 \; kg$

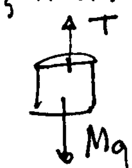
$r = 0.20 \; m$

$M = 2.5 \; kg$

small mass



big mass



$ma_{radial} = \Sigma F_{radial}$

$m \frac{v^2}{R} = T$

if no ~~vertical~~ movement

then

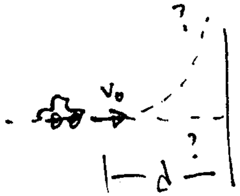
$T = Mg$

$m \frac{v^2}{R} = Mg$

$1.5 \frac{v^2}{0.20} = 2.5 (9.8)$

$V = 1.81 \; m/s$

6.58



$d = 107\ m$

$m = 1400\ kg$

$v_0 = 35\ m/s \sim 79\ mph$

$\mu_s = 0.5$

a) what acceleration + breaking force needed not to hit wall?

Use the "short cut" equation to get acceleration

$$v_f^2 - v_i^2 = 2a\ \Delta x$$

$$0^2 - 35^2 = 2a\ (107.)$$

$$a = -5.72\ m/s$$

The only horizontal force on the car is from friction

$$ma_x = -F_{frict}$$

$$1400(-5.72) = -F_{frict}$$

$$F_{frict} = 8.014 \times 10^3 \text{ Newtons}$$

b) Can the frictional force actually be this large?

$$F_{\substack{static\\max}} = \mu_s N = \mu_s mg = 0.5\,(1400)\,9.8$$

$$= 6.86 \times 10^3 \text{ Newtons}$$

ANSWER: NO, the car will not be able to stop

c) Suppose we lock the breaks up so that we slide into the wall from $d = 107m$?

$$ma_x = -F_{friction}$$

$$= -\mu_k N$$

$$ma_x = -\mu_k mg$$

$$a_x = -\mu_k g = -0.40\,(9.8) = -3.92$$

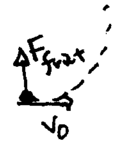
What speed ~~do~~ we hit? Again use shortcut eqn.

$$v_f^2 - v_i^2 = 2a\ \Delta x$$

$$v_f^2 - (35)^2 = 2(-3.98)\,107$$

$$v_f = 19.6\ m/s \sim 44\ mph$$

d) Suppose we try turning to miss the wall (w/o sliding). What is required frictional force?



$$m\,a_{rad} = \sum F_{rad}$$

$$m\frac{v^2}{R} = F_{\substack{frict\\reqd}}$$

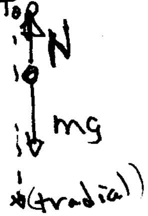
$$1400\,\frac{35^2}{107} = F_{\substack{frict\\reqd}}$$

$$1.60 \times 10^4 \text{ Newtons} = F_{\substack{frict\\reqd}}$$

e) The maximum static frictional force can ~~not~~ accomidate this requirement either

6.82 Speed Bump

right at the top



$R = 250\,m$

$$m a_{rad} = \sum F_{rad}$$

$$m \frac{v^2}{R} = mg - N$$

when $N \to 0$, we no longer have a circular motion problem ----

$$m \frac{v^2}{R} = mg - 0^+$$

$$m \frac{v^2}{R} = mg$$

$$\frac{v^2}{R} = g$$

$$\frac{v^2}{250} = 9.8$$

$$v = 49.5\ m/s$$