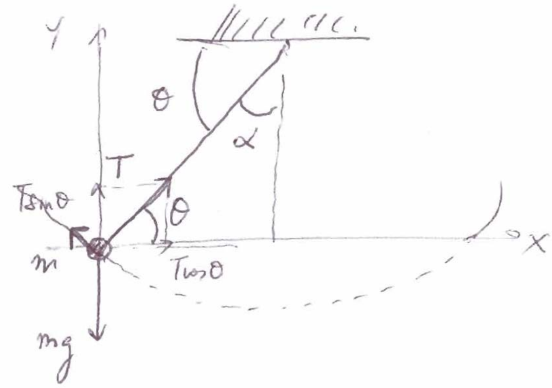
Ch6: Using Newton's Laws

Strategies:

1) Understanding problem, making a sketch
2) Select a convenient coord. system
   ↳ most forces along axis
3) Draw free-body diagram of forces involved for each object.
4) Draw components of forces along coordinate axes as needed
5) Write Newton's Second Law for each object using net forces.
6) Solve equations and obtain numeric solutions with units.

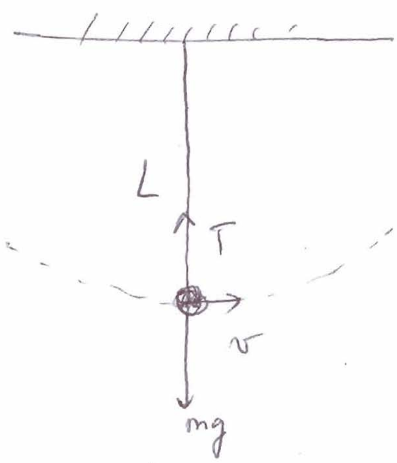
Circular motion and Newton's Law: The pendulum.



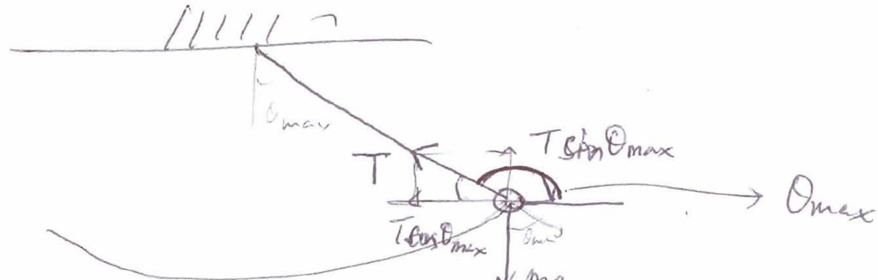
2D

Thread is massless

$$\begin{cases} F_{net_y} = T\sin\theta - mg \\ F_{net_x} = T\cos\theta \end{cases}$$

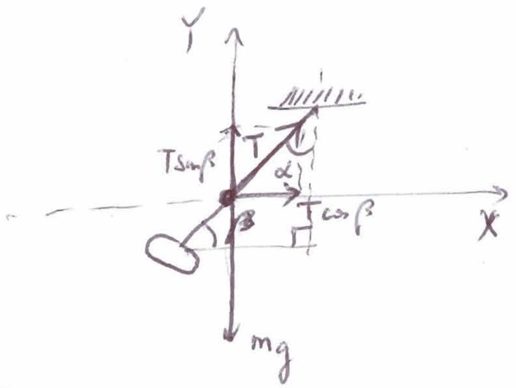


$$F_{net_{radial}} = T - mg = m\frac{v^2}{L}$$



$$\begin{cases} F_{net_y} = T\sin\theta_{max} - mg = 0 \\ F_{net_x} = + T\cos\theta_{max} \end{cases}$$

6.29



$\alpha = 15°$

$v_{train} = 67 \frac{km}{h} = \frac{67}{3.6}$ m/s

$\beta = 180 - \alpha - 90 = 75°$

mg & T are acting on the strap

Newton's 2nd Law
$(\vec{F}_{net} = m\vec{a})$ $\begin{cases} F_{net\,x} = ma_x \\ F_{net\,y} = ma_y \end{cases}$ $\begin{cases} x: \; T\cos\beta = m\frac{v^2}{R} \\ y: \; T\sin\beta - mg = 0 \rightarrow T\sin\beta = mg \end{cases}$

Dividing: $\frac{1}{\tan\beta} = \frac{v^2}{Rg} \rightarrow \boxed{R = \frac{v^2}{g}\tan\beta}$

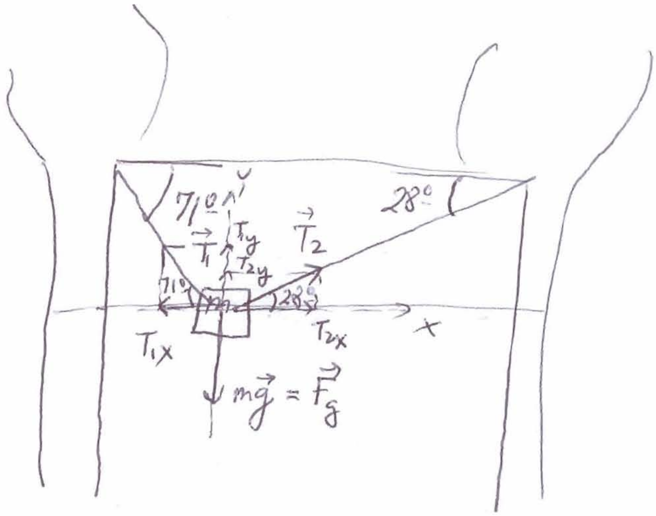
$$R = \frac{\left(\frac{67}{3.6}\right)^2 \tan 75°}{9.81} = 132 \text{ m}$$

(Application of Newton's law to circular motion.)

$A = B$
$C = D$

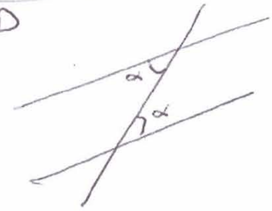
$\frac{A}{C} = \frac{B}{D}$

6.13



T_1 ? T_2 ?

2D



$m = 26\,kg$

$\underbrace{\vec{F}_{net} = 0}_{\text{no acceleration in neither x nor y direction}} \rightarrow \vec{F}_g + \vec{T}_1 + \vec{T}_2 = 0$

(a) $F_{net\,x} = T_{2x} - T_{1x} = T_2 \cos 28 - T_1 \cos 71 = 0$

(b) $F_{net\,y} = T_{1y} + T_{2y} - mg = T_1 \sin 71° + T_2 \sin 28° - mg = 0$

solve for T_1 & T_2

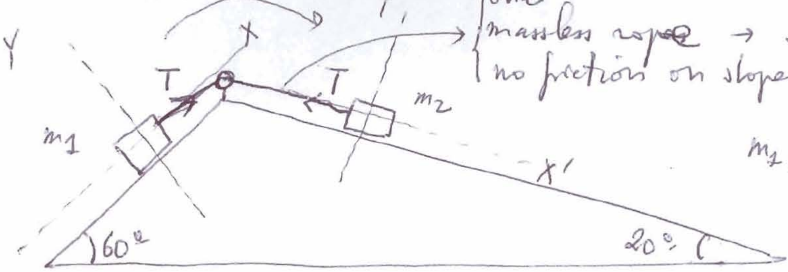
(a) $T_1 = \dfrac{\cos 28}{\cos 71} T_2$

(b) $\cos 28° \tan 71° \, T_2 + T_2 \sin 28° = 26 \times 9.81$

$T_2 = \dfrac{26 \times 9.81}{\cos 28° \tan 71° + \sin 28°} N = 84N$

$\rightarrow T_1 = \dfrac{\cos 28°}{\cos 71°} 84\ N = 228N$

6.17



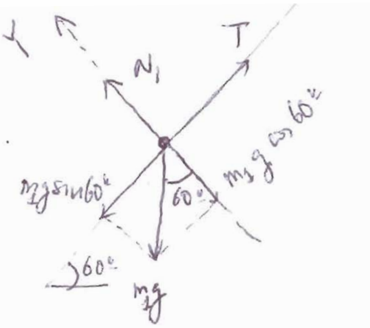
one
massless rope → same tension
no friction on slopes

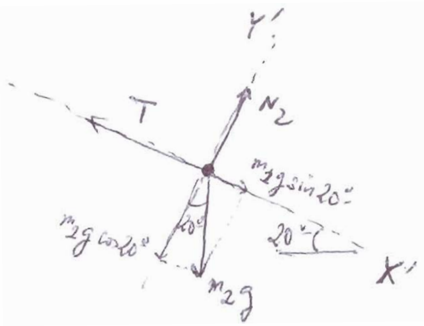
m_1 / m_2 ? such that they stay still

Newton's Law m_1 $\begin{cases} F_{net\,x} = 0 = T - m_1 g \sin 60° & (a) \\ F_{net\,y} = 0 = N_1 - m_1 g \cos 60° & (b) \end{cases}$

Newton's Law m_2 $\begin{cases} F_{net\,x'} = 0 = m_2 g \sin 20° - T & (c) \\ F_{net\,y'} = 0 = N_2 - m_2 g \cos 20° & (d) \end{cases}$

m_1





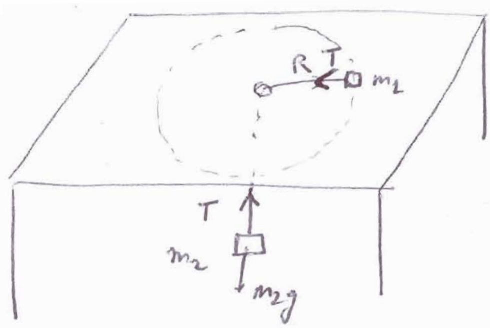
m_2

(a) & (c) :

$$\left.\begin{aligned} T &= m_1 g \sin 60° \\ T &= m_2 g \sin 20° \end{aligned}\right\} \quad 1 = \frac{m_1}{m_2}\,\frac{\sin 60°}{\sin 20°}$$

$$\boxed{\frac{m_2}{m_1} = \frac{\sin 60°}{\sin 20°} \simeq 2.5}$$

6.26



· No friction on table
· Massless string connecting m_1 & m_2
· m_2 stationary ✓

T?, period of circular motion (time for m_1 to complete one turn of $2\pi R$)

UCM: $a = \dfrac{v^2}{R}$

$$t = \frac{2\pi R}{v} = \frac{2\pi R}{\sqrt{aR}} = 2\pi\sqrt{\frac{R}{a}}$$

Newton's law

m_1: $N_1 - m_1 g = 0$; $T = m_1 a$ ← centripetal acc.

m_2: $\boxed{T - m_2 g = 0}$

$$\boxed{a = \frac{m_2}{m_1} g}$$

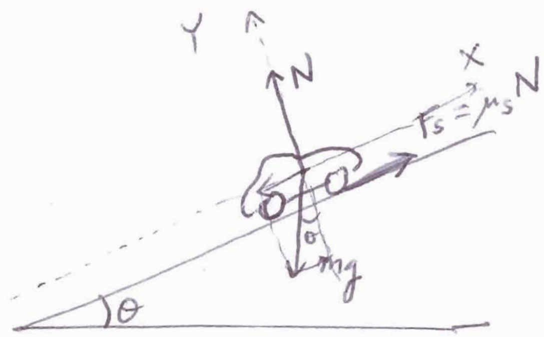
$$t = 2\pi\sqrt{\frac{R}{\frac{m_2}{m_1} g}}$$

$$\boxed{\text{Period} = 2\pi \frac{\sqrt{m_1 R}}{\sqrt{m_2 g}}}$$

(6.46)

ice storm $\begin{cases} \mu_K = 0.088 \\ \mu_S = 0.14 \end{cases}$ a) Max slope a car can be parked without sliding ?

b) a? (slope steeper than max.)



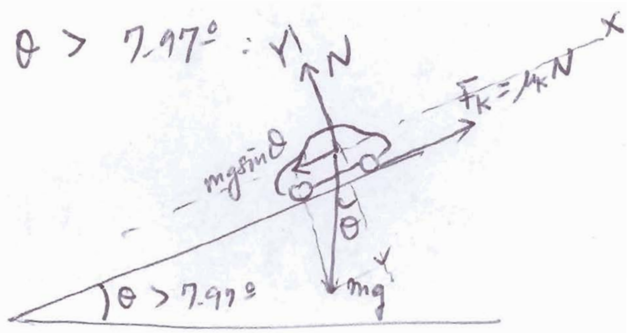
Newton's law $\begin{cases} F_{net_x} = \mu_S N - mg\sin\theta = 0 & \text{(parked car)} \\ F_{net_y} = N - mg\cos\theta = 0 \rightarrow N = mg\cos\theta \end{cases}$

$$\mu_S \cancel{mg}\cos\theta = \cancel{mg}\sin\theta$$

$$\mu_S = \tan\theta \rightarrow \boxed{\theta = \tan^{-1}\mu_S}$$

a) $\theta = 7.97^\circ$

b) $\theta > 7.97^\circ$:



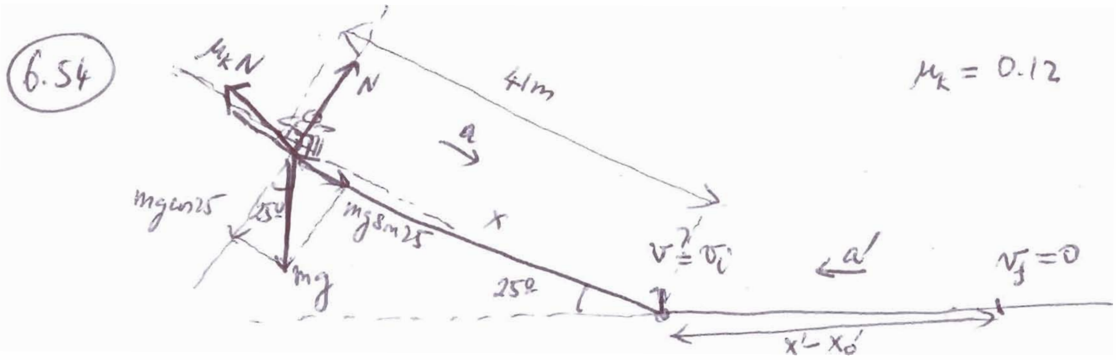
Newton's law $\begin{cases} F_{net_x} = ma = mg\sin\theta - \mu_K N \\ F_{net_y} = N - mg\cos\theta = 0 \rightarrow N = mg\cos\theta \end{cases}$

$$\cancel{m}a = \cancel{m}g\sin\theta - \mu_K \cancel{m}g\cos\theta$$

$$a = g(\sin\theta - \mu_K\cos\theta)$$

$$a = 9.81(\sin 7.97^\circ - 0.088\cos 7.97^\circ) = 0.5053\,m/s$$

(6.54)



Sled will acquire a final vel. at bottom of slope due to gravity minus friction. This vel. will decrease to zero during flat bottom piece of trajectory due to friction (no gravity ~~here~~ along direction of motion here)

Newton's law $\begin{cases} x: & mg\sin25 - \mu_k N = ma \\ y: & N - mg\cos25 = 0 \end{cases}$

$\rightarrow \cancel{m}g\sin25 - \mu_k \cancel{m}g\cos25 = \cancel{m}a$

$a = g(\sin25 - \mu_k \cos25) = 3.08\,m/s^2$

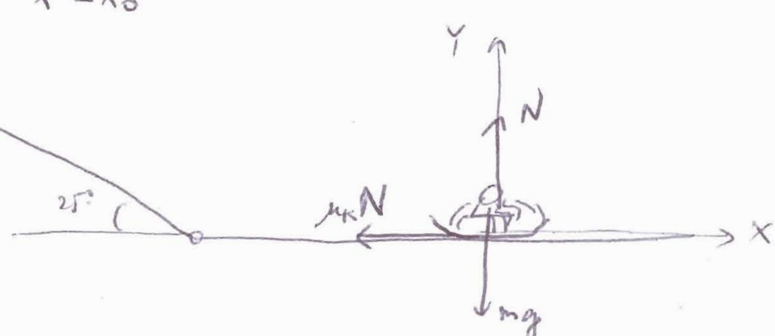
$\rightarrow$ To get v: Kin. eq. III: $\dfrac{v^2 - \cancel{v_0^2}}{x - x_0} = 2a \rightarrow v = \sqrt{2a(x-x_0)}$ ($v_0^2 \rightarrow 0$ (sled starts from rest))

$= \sqrt{2 \times 3.08 \times 41}$ m/s

$= 15.9$ m/s

To get $x' - x_0'$:

$\rightarrow$ Kin. eq III: $\dfrac{v_f^2 - v_i^2}{x' - x_0'} = 2a'$



Newton's law on flat bottom $\begin{cases} x: & -\mu_k N = ma' \\ y: & N - mg = 0 \end{cases}$

$\hookrightarrow -\mu_k \cancel{m}g = \cancel{m}a'$

$\boxed{a' = -\mu_k g}$

$\dfrac{0 - 15.9^2}{x' - x_0'} = -2\mu_k g$

$x' - x_0' = \dfrac{-15.9^2}{-2 \times 0.12 \times 9.81} = 107\,m$