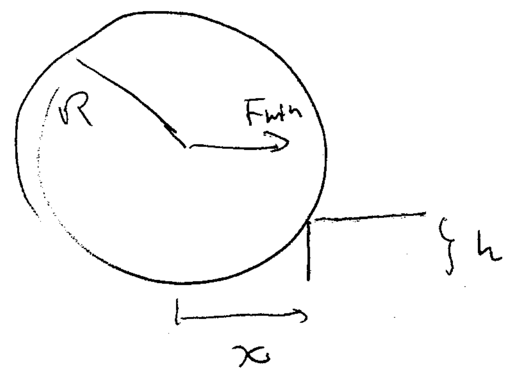
Physics 247 Lecture 38 — Gary Shiu — 12/11/06 (1)

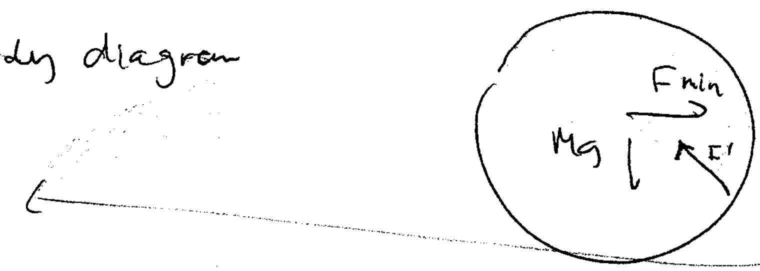
<u>Example</u>: Raising a wheel (Push a cart up the stairs)



What is $\vec{F}_{min}$ necessary to raise the wheel over the step?

$\boxed{F_n = 0}$

Free body diagram



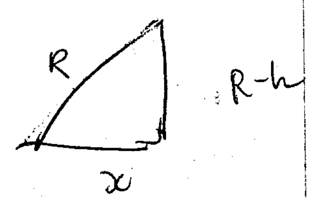
$\vec{F}'$ direction & magnitude unknown

$\Rightarrow$ Chose pt of contact as O

$$F_{min}(R-h) - Mg\,x = 0$$

$$F_{min} = \frac{Mg\,x}{R-h}$$

Express x in terms of h



$$x^2 + (R-h)^2 = R^2$$

$$x = \sqrt{2Rh - h^2} = \sqrt{h(2R-h)}$$

Hence

$$F_{min} = \frac{Mg\sqrt{h(2R-h)}}{R-h}$$

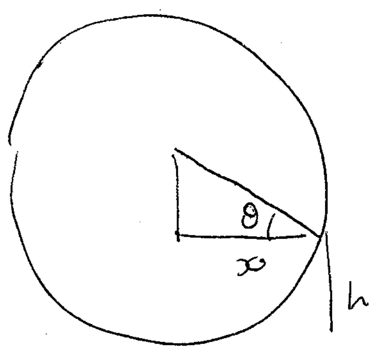
Check
$h \to R$ $F_{min} \to \infty$
$h \to 0$ $F_{min} \to 0$

We have chosen O as pivot point to get rid of $\vec{F}'$ in eqn.

Direction of $\vec{F}'$? Choose O as center of wheel

$\Rightarrow$ $\vec{F}'$ must pt towards the center otherwise there is a torque

Magnitude of $\vec{F}'$? $\sum \vec{F} = 0$



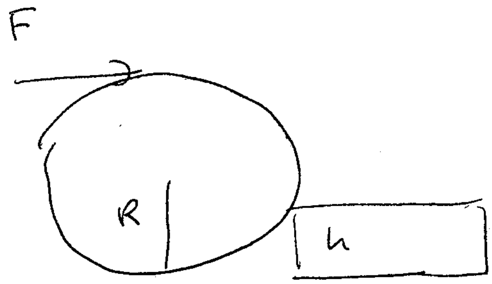
$F' \cos\theta = F_{min}$

$F' \sin\theta = Mg$

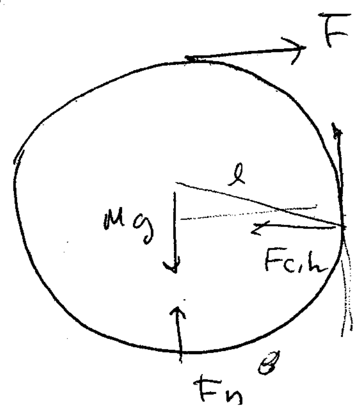
$F' = \sqrt{F_{min}^2 + (Mg)^2}$

#

A slightly different example (Ch 12 # 35)



Free body diagram



Torque about contact pt (Why?).

$$Mg\,x - F_n x - F\,(2R-h) = 0$$

$$F_n = Mg - \frac{F(2R-h)}{x}$$

Express x in terms of R & h

$$x = \sqrt{h(2R-h)}$$

$$F_n = Mg - \frac{F(2R-h)}{\sqrt{h(2R-h)}}$$

In partlaller $F_n = 0$ wheel off the ground

when $F_{min} = \frac{Mg\sqrt{h(2R-h)}}{2R-h}$

↑ only difference

Check $F_{min} = \begin{cases} 0 & \text{as } h \to 0 \\ \infty & \text{as } h = 2R \end{cases}$

- $\vec{F}_c$ at contact pt is no longer pointing towards the center of wheel. Why? (ext $\vec{F}$ provides a torque)

- Newton's laws

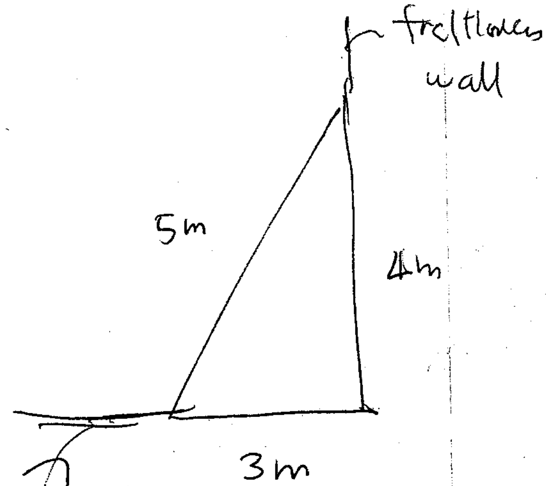
$$F_{c,h} = F$$

$$F_{c,v} = Mg - F_n$$

$$= \frac{F(2R-h)}{\sqrt{h(2R-h)}}$$

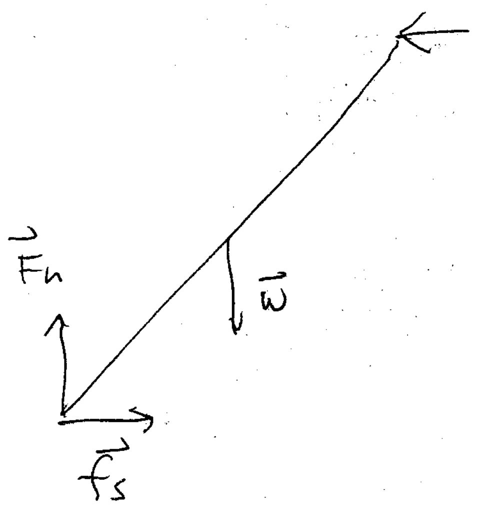
↳ can find the angle of $\vec{F}_c$

<u>Example</u> Leaning Ladder



What is min μ_s ~~for~~ ladder not to slip?

<u>Free body diagram</u>



Newton's law: $f_s = F_1$

$F_n = w$

To find μ: Need to find f_s in terms of F_n.

First find F_1 in terms of w.

Choose O to be foot of ladder

$\sum \vec{\tau} = 0 \Rightarrow F_1(4m) - w(1.5m) = 0$

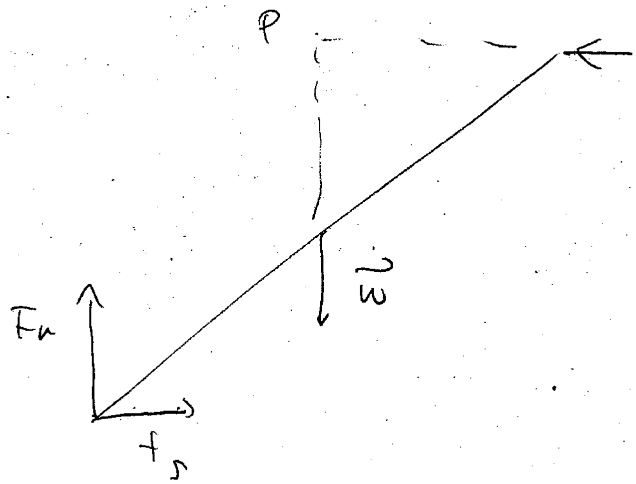
$F_1 = \frac{3}{8} w$

Since $f_s \leq \mu_s F_n$ no slipp

$$\mu_{s,min} = \frac{f_s}{F_n}$$

$$\Rightarrow \boxed{\mu_{s\,min} = \frac{F_1}{W} = \frac{3}{8}}$$

Alternatively, choose another pt P as pivot pt



No torque due to $\vec{F_1}$ & $\vec{w}$ at P

$$\Rightarrow F_n\,(1.5\,m) = f_s\,(4m)$$

$$\Rightarrow \mu_{s,min} = \frac{f_s}{F_n} = \frac{3}{8}$$ ✓