Announcements

1. Second exam scheduled for Oct. 28th -- practice exams now available -- http://www.wfu.edu/~natalie/f03phy113/extrapractice/

2. Today's lecture –

   Review of rotations & angular momentum

   Analyzing mechanical equilibrium and stability

   Elastic response of materials

HW 12 --

A bowler throws a bowling ball of radius $R = 11$ cm along a lane. The ball slides on the lane, with initial speed $v_{com,0} = 8.5$ m/s and initial angular speed $w_0 = 0$. The coefficient of kinetic friction between the ball and the lane is 0.21. The kinetic frictional force $\vec{f}_k$ acting on the ball (Fig. 12-34) causes a linear acceleration of the ball while producing a torque that causes an angular acceleration of the ball. When speed v_{com} has decreased enough and angular speed w has increased enough, the ball stops sliding and then rolls smoothly. (a) What then is v_{com} in terms of w? During the sliding, what are the ball's (b) linear acceleration and (c) angular acceleration? (d) How long does the ball slide? (e) How far does the ball slide? (f) What is the speed of the ball when smooth rolling begins?

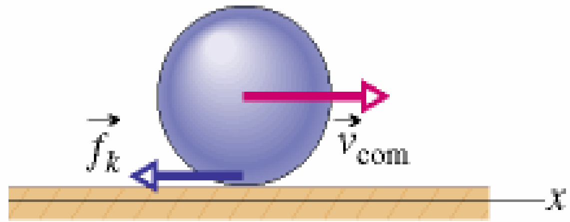
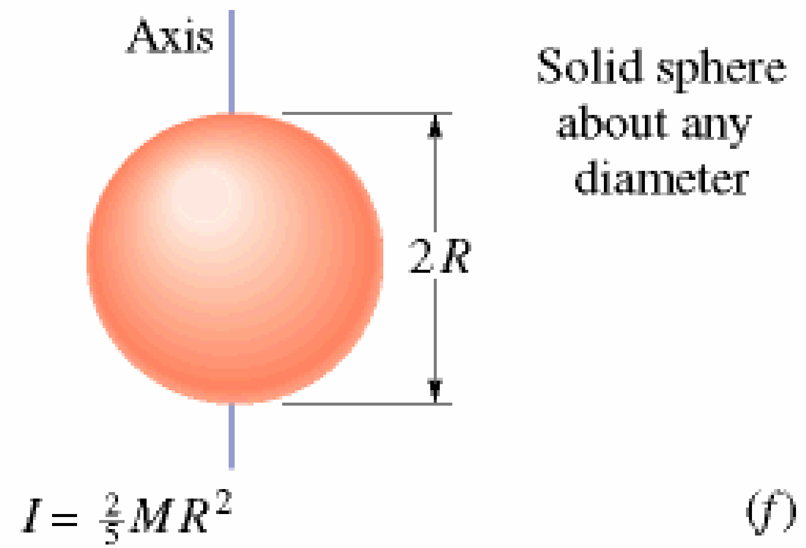
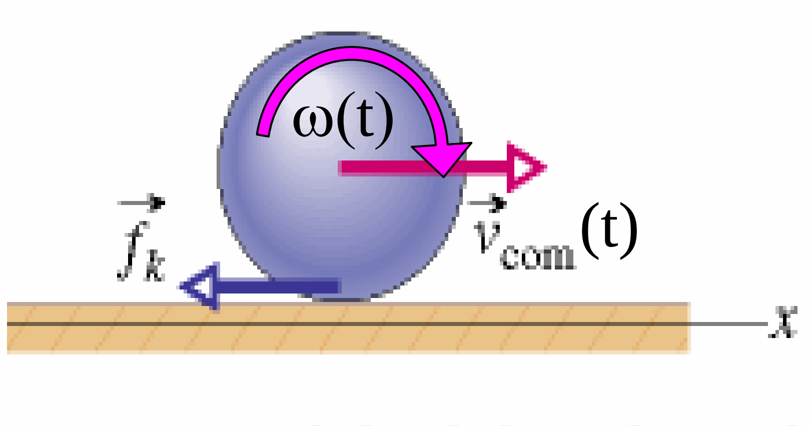


Fig. 12-34 Problem 14.



HW 12 --



First: While sliding due to kinetic friction:

$$\text{Linear motion about com}: \; F = ma_{com} \Rightarrow -f_k = ma_{com}$$

$$\text{Angular motion about com}: \; \tau = I\alpha \Rightarrow Rf_k = I\alpha$$

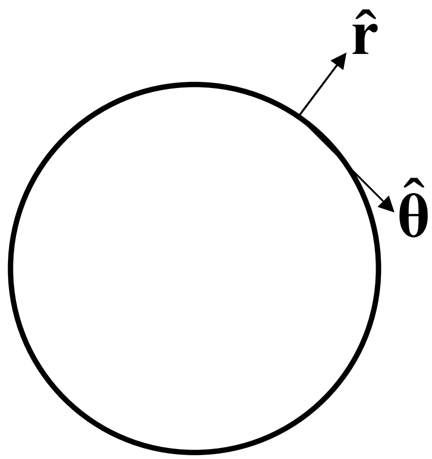
Second: While rolling without sliding:

$$v_{com} = R\omega \qquad \text{In this case -- } \; F_{com} = ma_{com} = 0 \Rightarrow v_{com} = \text{constant}$$

Summary of equations for rotational motion:

$$\omega(t) = \frac{d\theta(t)}{dt} \Rightarrow v_{\text{tangential}}(t) = R\omega(t)$$

$$\alpha(t) = \frac{d\omega(t)}{dt} \Rightarrow a_{\text{tangential}}(t) = R\alpha(t)$$



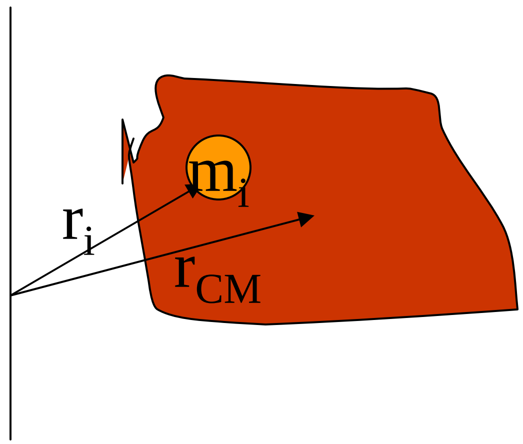
What happened to centripetal acceleration ???

(a) Previous chapter – no longer relevant

(b) It is there, but not important

Center-of-mass $$\mathbf{r}_{CM} \equiv \frac{\sum_i m_i \mathbf{r}_i}{\sum_i m_i}$$

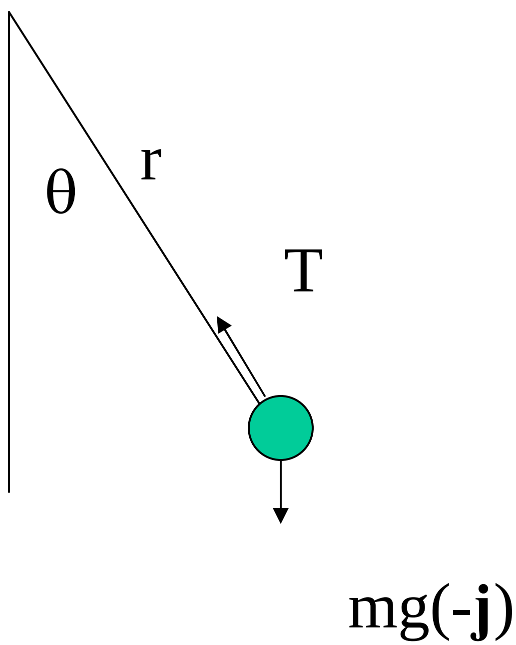
Torque on an extended object due to gravity (near surface of the earth) is the same as the torque on a point mass M located at the center of mass.



$$\boldsymbol{\tau} = \sum_i \mathbf{r}_i \times \{m_i g(-\mathbf{j})\} = \mathbf{r}_{CM} \times \{Mg(-\mathbf{j})\}$$

Notion of equilibrium: $\sum_i \mathbf{F}_i = 0$ $\sum_i \boldsymbol{\tau}_i = 0$

Notion of stability:



$\mathbf{F}=m\mathbf{a}$ ➔ $T - mg\cos\theta = 0$

$-mg\sin\theta = -ma_\theta$

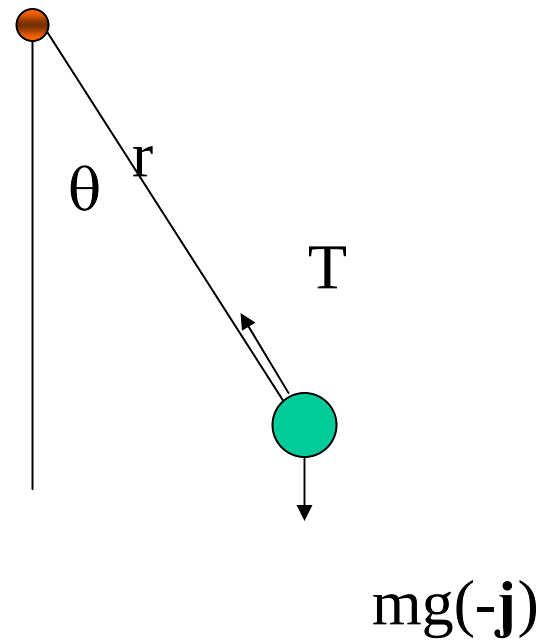
$\tau = I\alpha$ ➔ $r\,mg\sin\theta = mr^2\alpha = mra_\theta$

Example of stable equilibrium.

Unstable equilibrium:

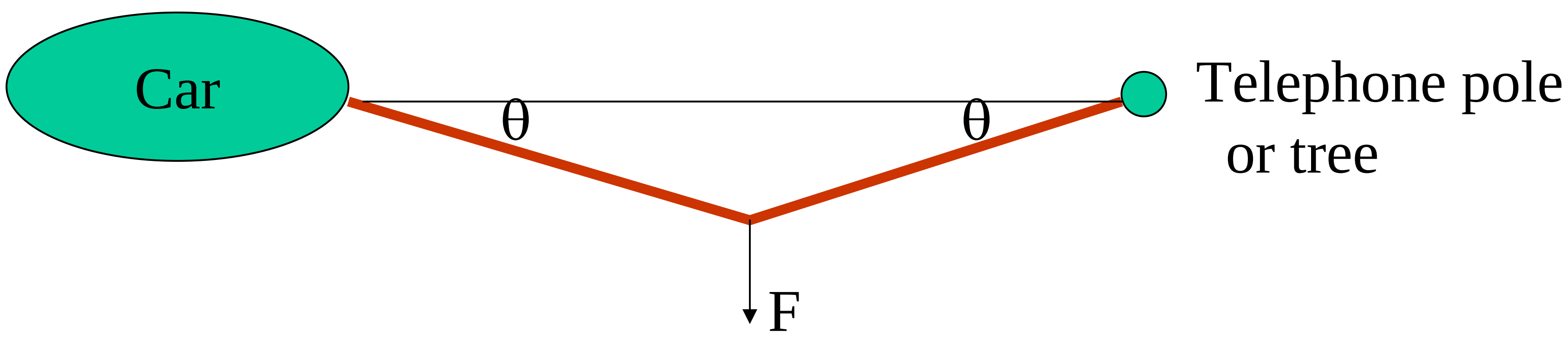
Support
below com:

Support ***above*** com:

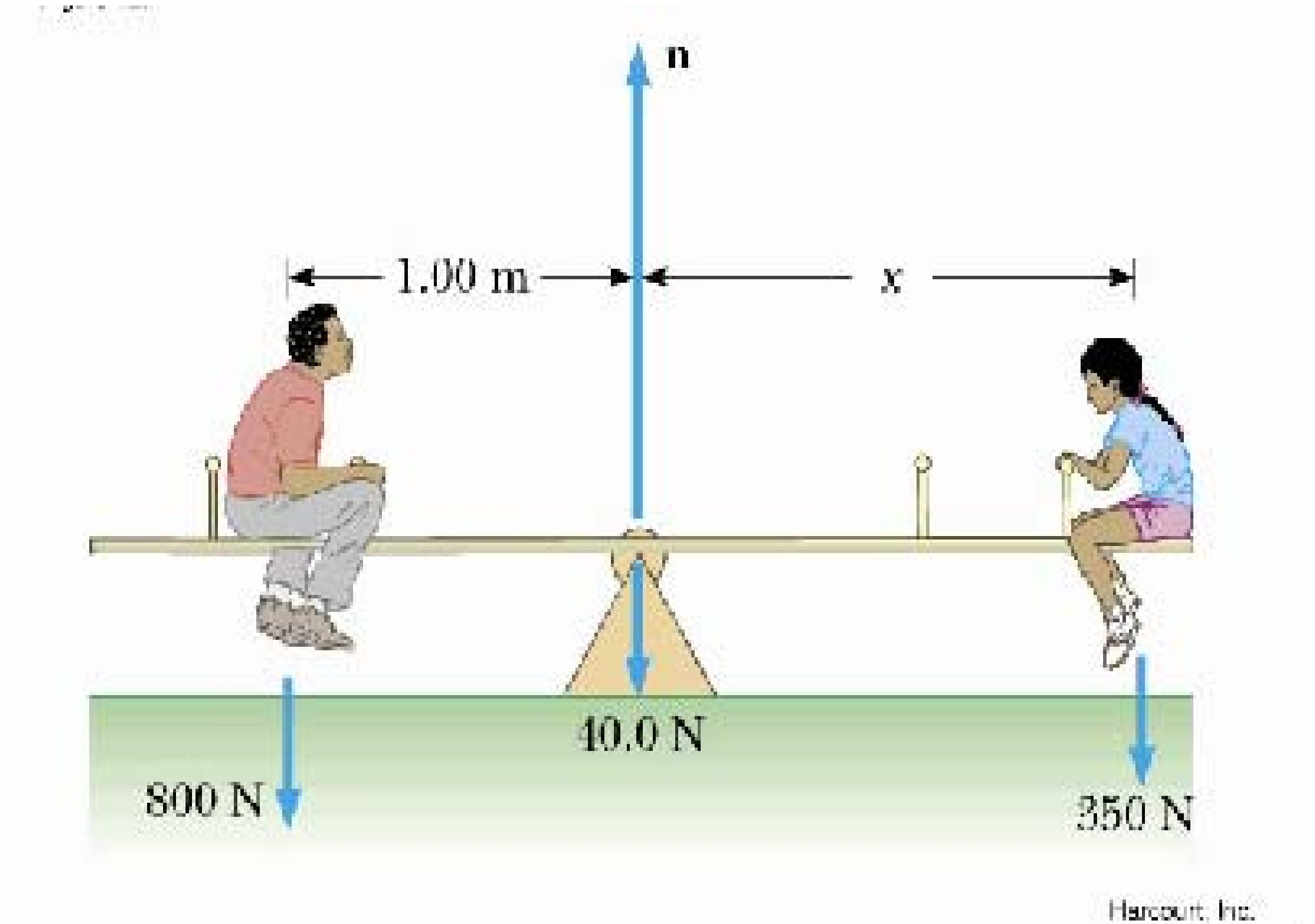


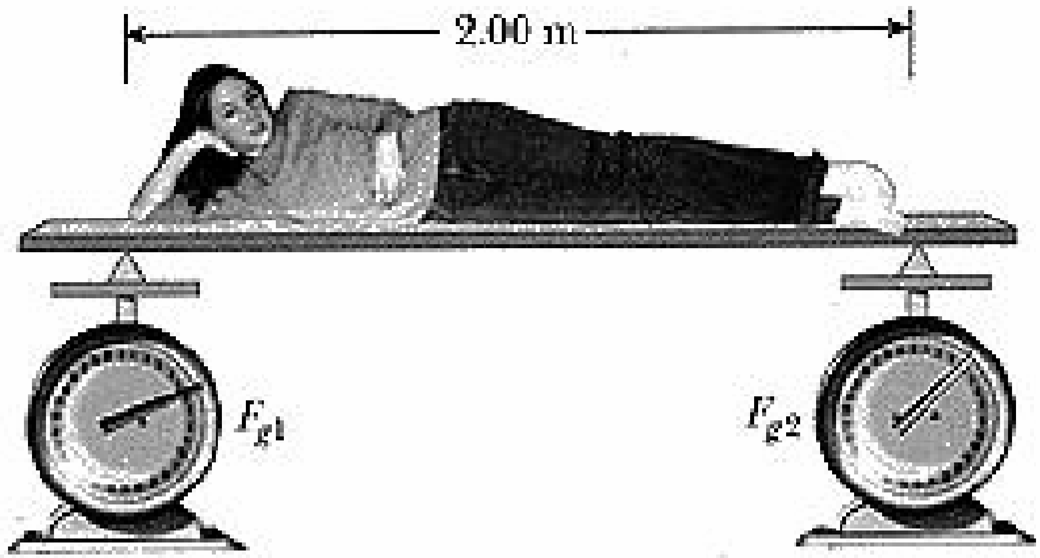
Example of equilibrium analysis:

Pulling car out of the mud. Bird's eye view:



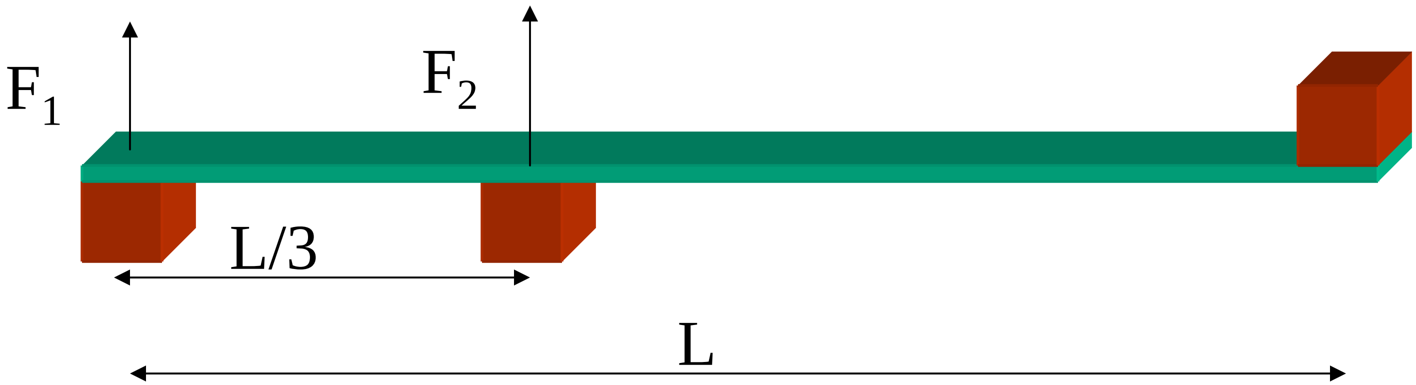
Analysis of stability: $$\sum_i \mathbf{F}_i = 0 \quad \sum_i \boldsymbol{\tau}_i = 0$$





A student takes a nap on a massless plank which is supported by two scales as shown. If the left and right scale readings are $F_{g1} = 350$ N and $F_{g2} = 300$ N, respectively, what is her total weight and where is her center of mass located? (Please indicate whether you are measuring her center of mass from her feet or head.)

Peer instruction question

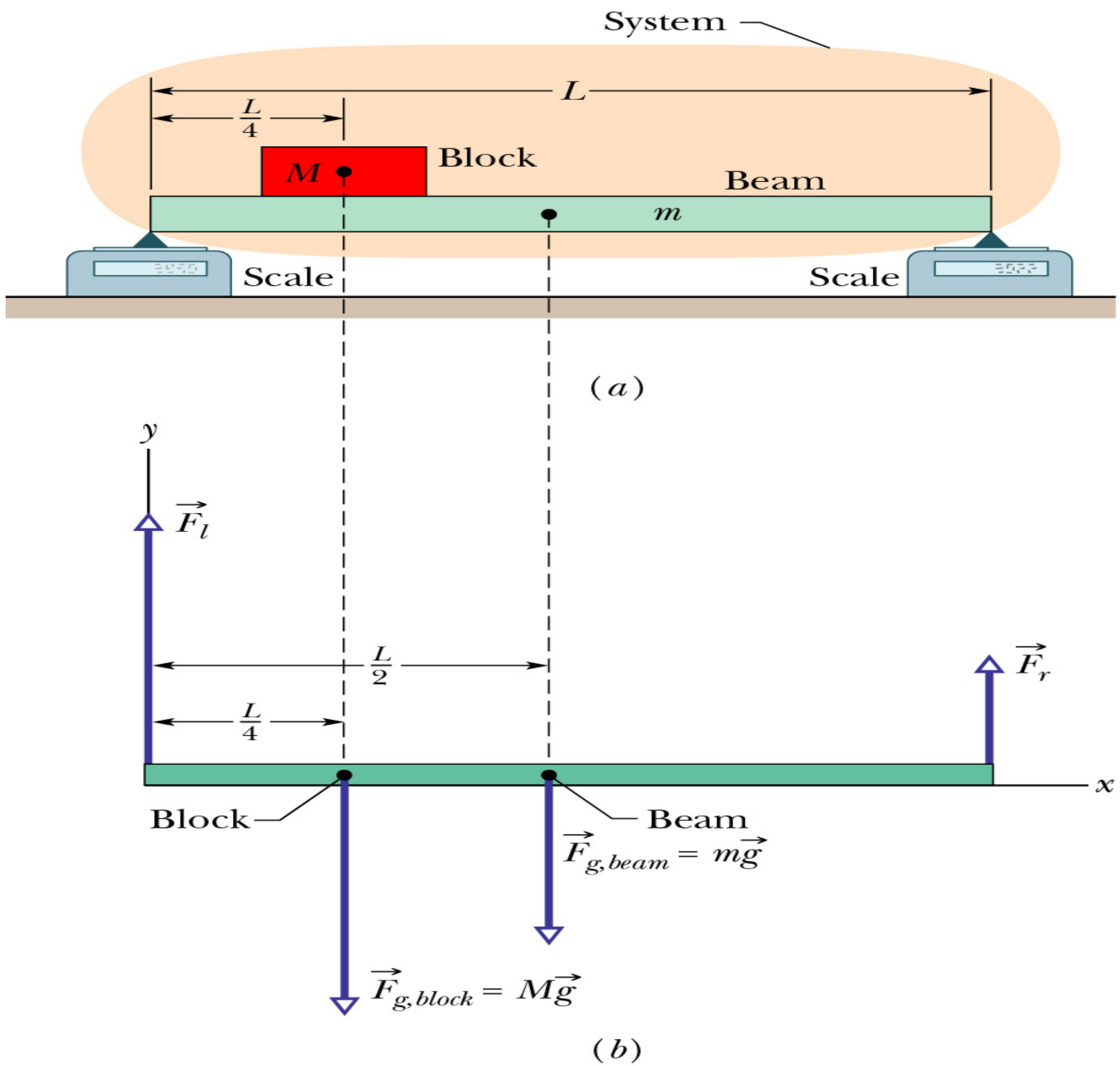


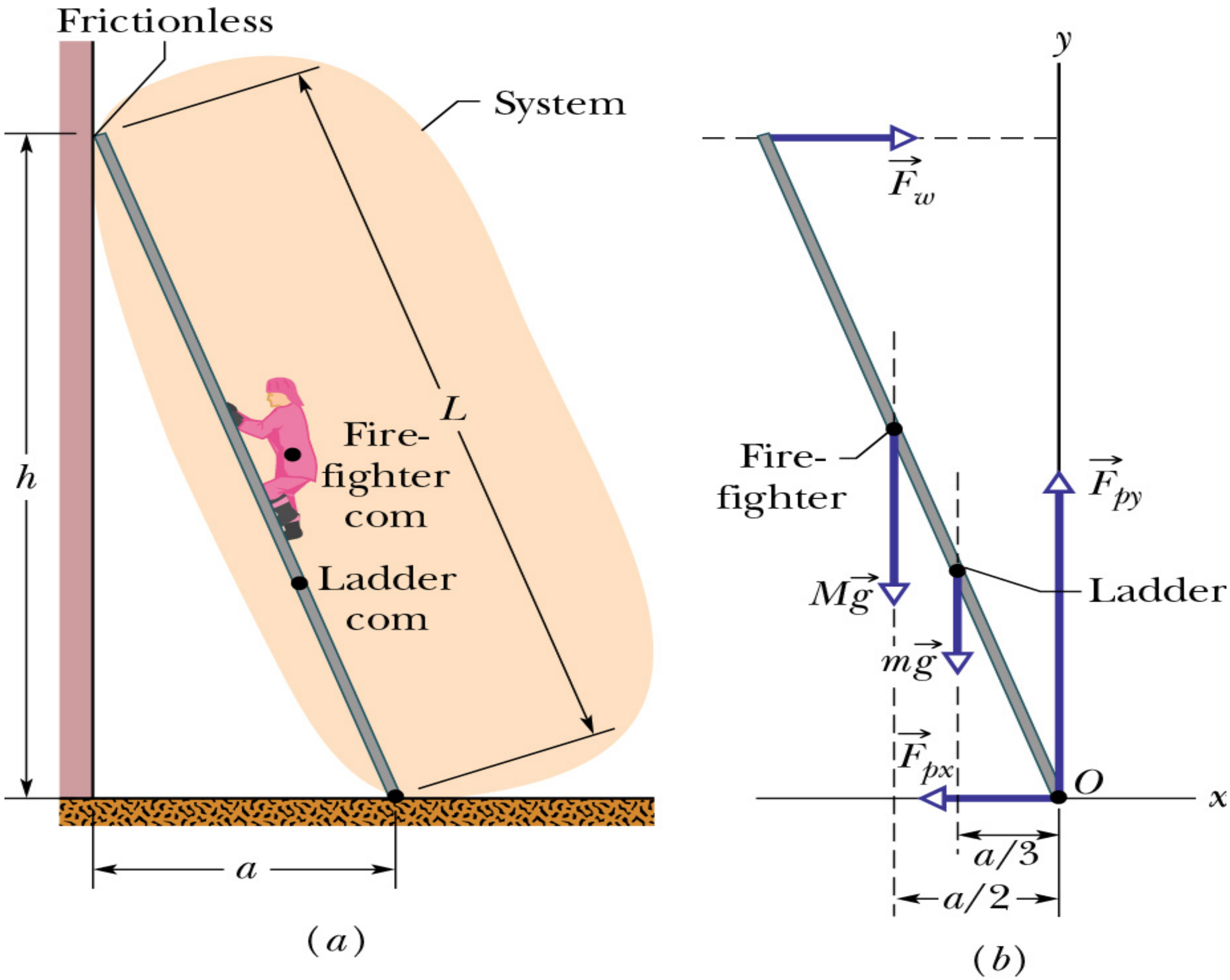
Consider the above drawing of the two supports for a uniform plank which has a total weight Mg and has a weight mg at its end. What can you say about F_1 and F_2?

(a) F_1 and F_2 are both up as shown.

(b) F_1 is up but F_2 is down.

(c) F_1 is down but F_2 is up.


System
L
$\frac{L}{4}$
M
Block
Beam
m
Scale
Scale
(a)
y
$\vec{F}_l$
$\frac{L}{2}$
$\frac{L}{4}$
$\vec{F}_r$
x
Block
Beam
$\vec{F}_{g,beam} = m\vec{g}$
$\vec{F}_{g,block} = M\vec{g}$
(b)


Frictionless
System
h
L
Fire-
fighter
com
Ladder
com
a
(a)
y
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Fire-
fighter
$M\vec{g}$
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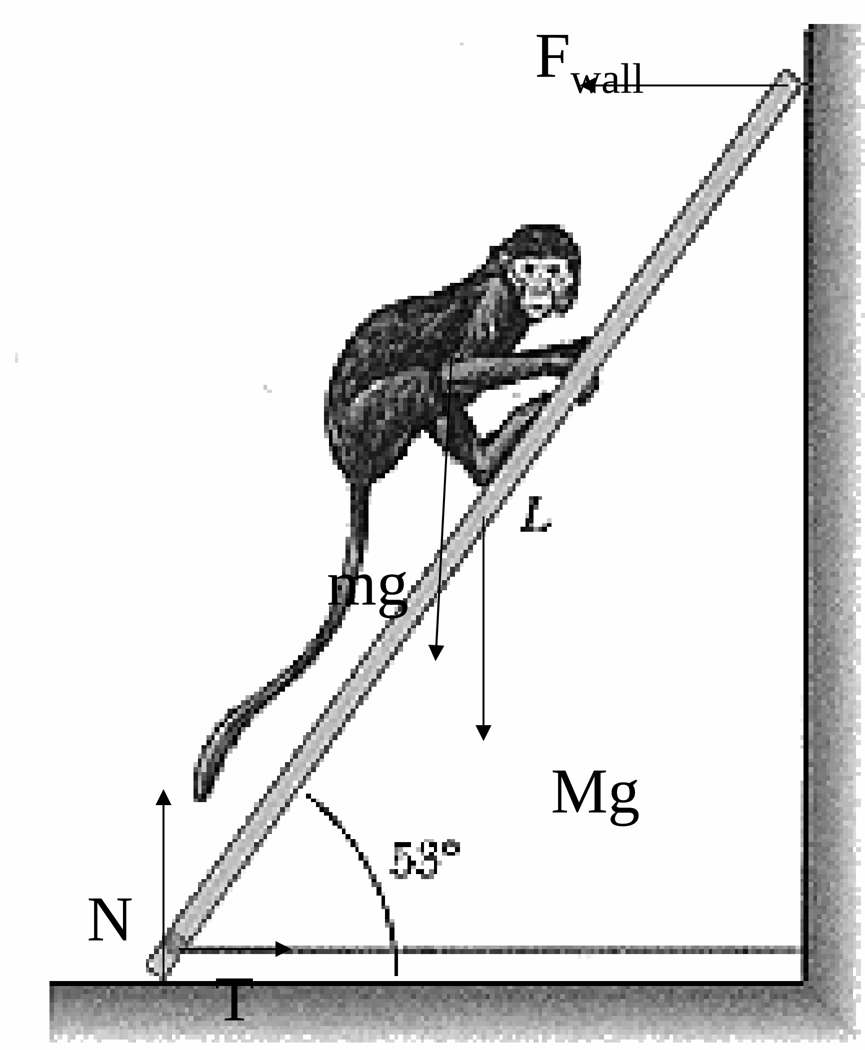
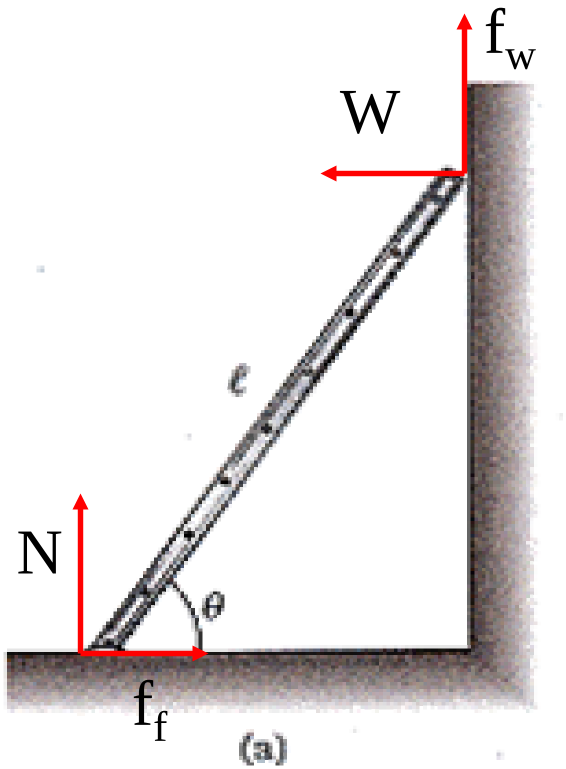
Ladder
$\vec{F}_{px}$
O
x
$a/3$
$a/2$
(b)



Mg = 120 N

mg = 98 N

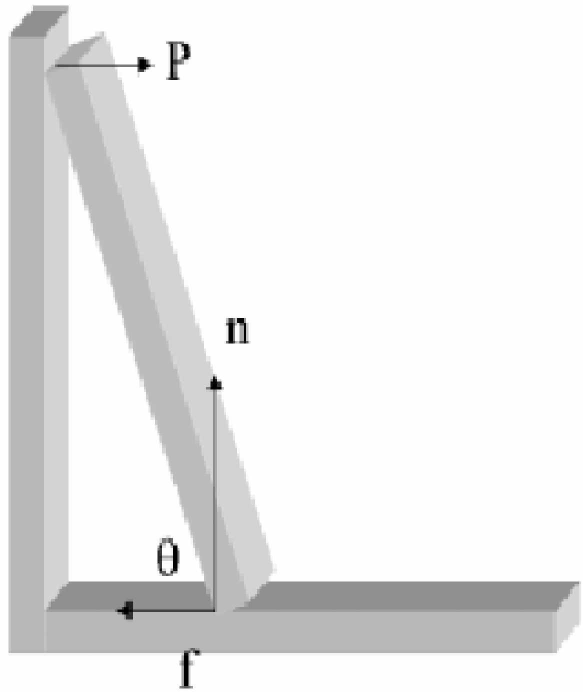
T < 110 N



12-48. A uniform ladder weighing 200 N is leaning against a wall. The ladder slips when θ= 60.0°. Assuming that the coefficients of static friction at the wall and the ground are the same, obtain a value for μ_s.

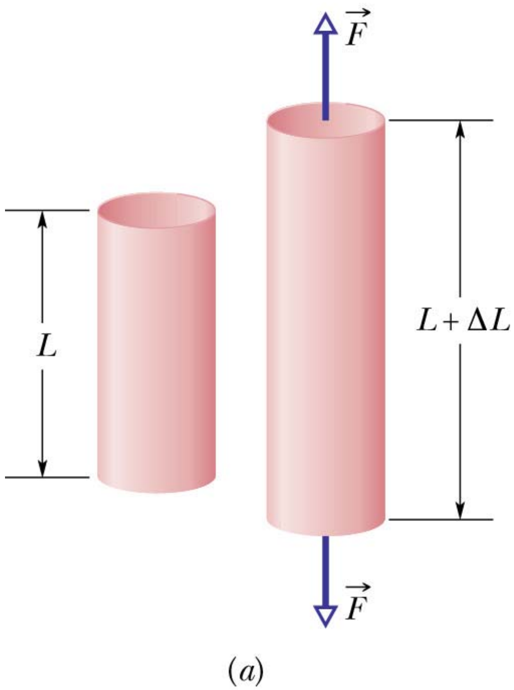
5 unknowns: W, N, f_f, f_w, μ_s

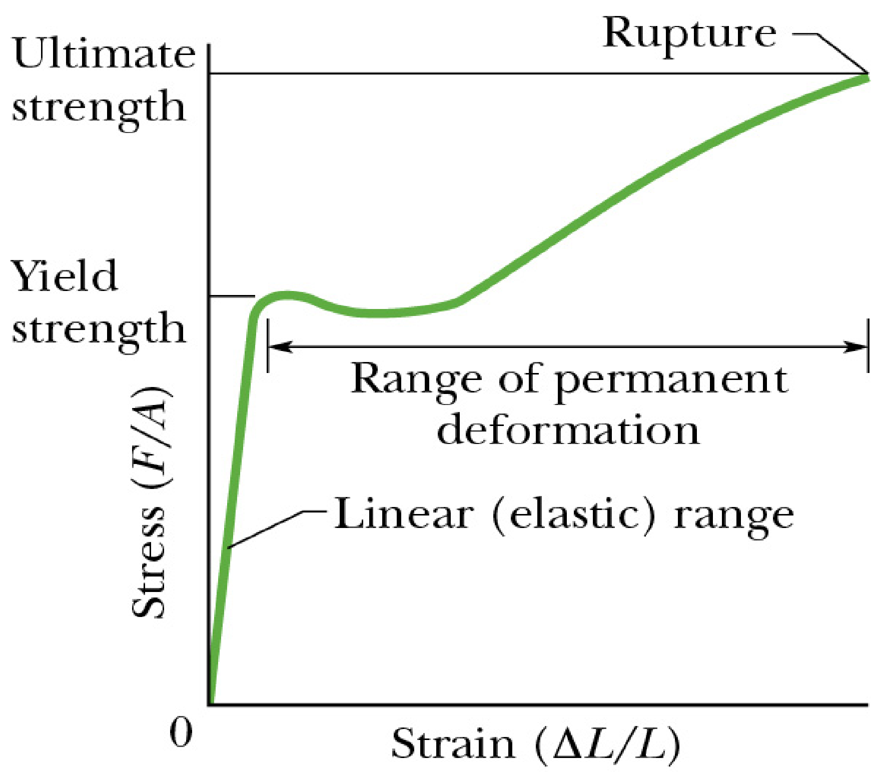
Answer: $\mu_s^2 + 2\tan\theta\,\mu_s - 1 = 0$



7. The figure above shows a plank made of uniform material with a total weight of 500 N and length $\ell = 6m$, supported by the floor and leaning against the wall with an angle $\theta = 50^o$. Assuming that the system is in stable equilibrium, determine the normal force **n**, static friction force **f** provided by the floor, and the wall normal force **P.** (Neglect any possible friction force provided by wall.)

Elasticity of materials:





$$\text{Measure of elasticity: Young's modulus}$$

$$E \equiv \frac{F / A}{\Delta L / L}$$

"stress" (F / A)

"strain" ($\Delta L / L$)

$$\text{Hooke's law: } F = -kx$$

$$k \Leftrightarrow E \frac{A}{L}$$

TABLE 13-1 Some Elastic Properties of Selected Materials of Engineering Interest

Material	Density r (kg/m^3)	Young's Modulus E (10^9 N/m^2)	Ultimate Strength S_u (10^6 N/m^2)	Yield Strength S_y (10^6 N/m^2)
Steel[a]	7860	200	400	250
Aluminum	2710	70	110	95
Glass	2190	65	50[b]	—
Concrete[c]	2320	30	40[b]	—
Wood[d]	525	13	50[b]	—
Bone	1900	9[b]	170[b]	—
Polystyrene	1050	3	48	—

[a]Structural steel (ASTM-A36).
[b]In compression.
[c]High strength.
[d]Douglas fir.

6. HRW6 13.P.029. [71746] A uniform plank, with length L = 6.10 m and weight W = 455 N, rests on the ground and against a frictionless roller at the top of a wall of height h = 3.05 m (see Fig. 13-50). The plank remains in equilibrium for any value of $\theta \geq 70°$ but slips if $\theta < 70°$. Find the coefficient of static friction between the plank and the ground.

[.1176471]

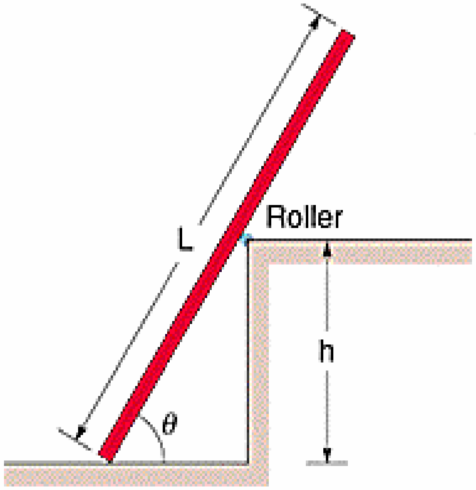


Figure 13-50