PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

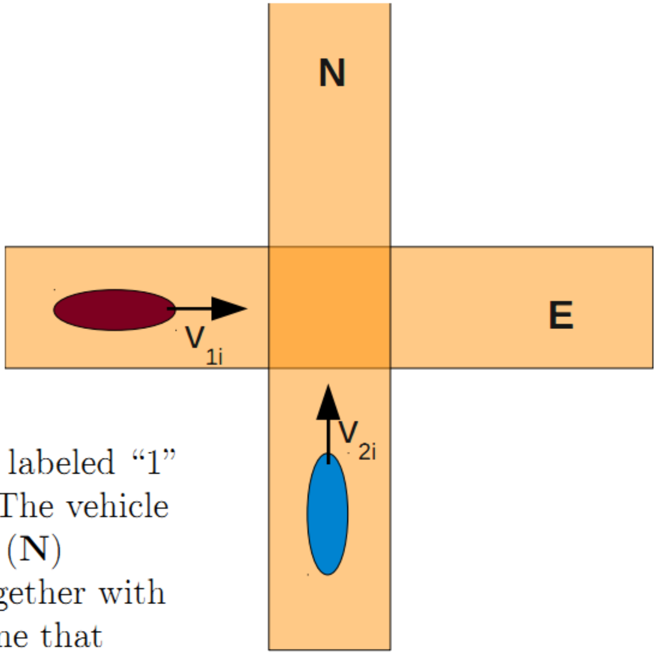
Plan for Lecture 20:

Chapter 12 – Static equilibrium

1. Balancing forces and torques; stability
2. Center of gravity
3. Note: May not have time to cover elastic properties of materials

	10/05/2012	Review	6-9		
	10/08/2012	Exam	6-9		
15	10/10/2012	Rotational motion	10.1-10.5	10.6, 10.13, 10.25	10/12/2012
16	10/12/2012	Torque	10.6-10.9	10.37, 10.55	10/15/2012
17	10/15/2012	Angular momentum	11.1-11.5	11.11, 11.34	10/17/2012
18	10/17/2012	Equilibrium	12.1-12.4	12.11, 12.39	10/22/2012
	10/19/2012	*Fall Break*			
19	10/22/2012	Simple harmonic motion	15.1-15.3		10/24/2012
20	10/24/2012	Resonance	15.4-15.7		10/26/2012
21	10/26/2012	Gravitational force	13.1-13.3		10/29/2012
22	10/29/2012	Kepler's laws and satellite motion	13.4-13.6		10/31/2012
	10/31/2012	Review	10-13,15		
	11/02/2012	Exam	10-13,15		
23	11/05/2012	Fluid mechanics	14.1-14.4		11/07/2012
24	11/07/2012	Fluid mechanics	14.5-14.7		11/09/2012
25	11/09/2012	Temperature	19.1-19.5		11/12/2012
26	11/12/2012	Heat	20.1-20.4		11/14/2012
27	11/14/2012	First law of thermodynamics	20.5-20.7		11/16/2012

Comment on exam question #4

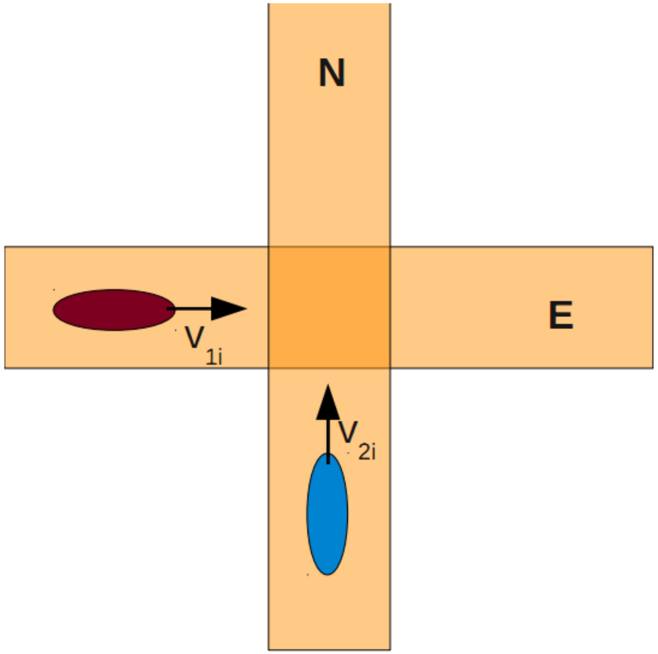


The diagram above shows two vehicles approaching an intersection. The vehicle labeled "1" has mass $m_1 = 1500kg$ and a velocity of $v_{1i} = 20m/s$ in the east (**E**) direction. The vehicle labeled "2" has a mass $m_2 = 2000kg$ and a velocity of $v_{2i} = 20m/s$ in the north (**N**) direction. The two vehicles collide in the middle of the intersection and stick together with the velocity of the combined system of $\mathbf{v_f}$ immediately after the collision. Assume that because of road conditions (small friction due to ice), it is a good approximation to assume that momentum is conserved immediately before and after the collision.

(a) What is the momentum of the two vehicle system before the collision?

(b) What is the momentum of the two vehicle system immediately after the collision?

(c) What is the velocity of the combined system of $\mathbf{v_f}$ (magnitude and direction) immediately after the collision?



Solution:

(a)

$$\mathbf{p}_i = m_1 v_{1i}\hat{\mathbf{E}} + m_2 v_{2i}\hat{\mathbf{N}}.$$

$$\mathbf{p}_i = (1500)(20)kg \cdot m/s\hat{\mathbf{E}} + (2000)(20)kg \cdot m/s\hat{\mathbf{N}} = 30000kg \cdot m/s\hat{\mathbf{E}} + 40000kg \cdot m/s\hat{\mathbf{N}}.$$

(b)

$$\mathbf{p}_i = \mathbf{p}_f.$$

(c)

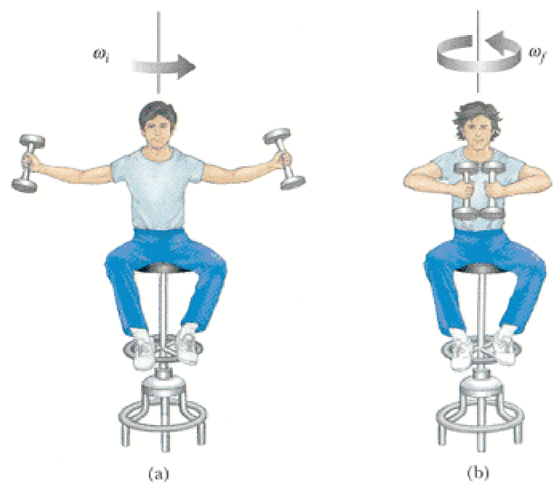
$$\mathbf{v_f} = \frac{\mathbf{p}_f}{m_1 + m_2} = \frac{30000kg \cdot m/s\hat{\mathbf{E}} + 40000kg \cdot m/s\hat{\mathbf{N}}}{3500kg} = 8.5714m/s\hat{\mathbf{E}} + 11.4286m/s\hat{\mathbf{E}}.$$

$$v_f = 14.29m/s; \text{ angle north of east: } \theta = 53.13^o.$$

From Webassign #17 (11.34)

5. –/0.5 points My Notes | SerPSE8 11.P.034.WI.

A student sits on a freely rotating stool holding two dumbbells, each of mass 2.99 kg (see figure below). When his arms are extended horizontally (figure a), the dumbbells are 1.07 m from the axis of rotation and the student rotates with an angular speed of 0.757 rad/s. The moment of inertia of the student plus stool is 2.54 kg · m^2 and is assumed to be constant. The student pulls the dumbbells inward horizontally to a position 0.301 m from the rotation axis (figure b).



(a) Find the new angular speed of the student.

_____ rad/s

(b) Find the kinetic energy of the rotating system before and after he pulls the dumbbells inward.

K_{before} = _____ J

K_{after} = _____ J

Conservation of angular momentum:

$$L_i = L_f$$

$$I_i\omega_i = I_f\omega_f$$

$$I_i = I_{Student} + 2md_i^2$$

$$I_f = I_{Student} + 2md_f^2$$

$$\omega_f = \omega_i \frac{I_i}{I_f}$$

Rotational kinetic energy:

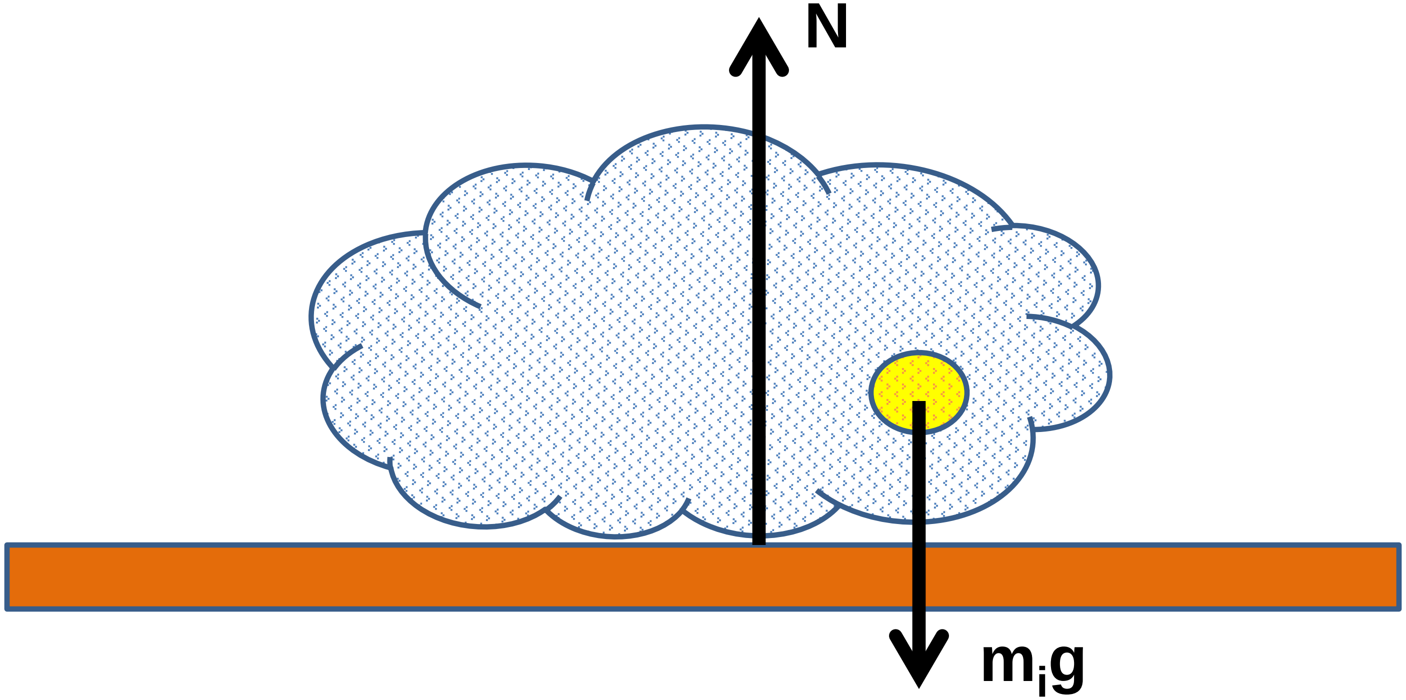
$$K_i = \frac{1}{2}I_i\omega_i^2 \quad K_f = \frac{1}{2}I_f\omega_f^2$$

Conditions for stable equilibrium

$$\text{Balance of force:} \quad \sum_i \mathbf{F}_i = 0$$

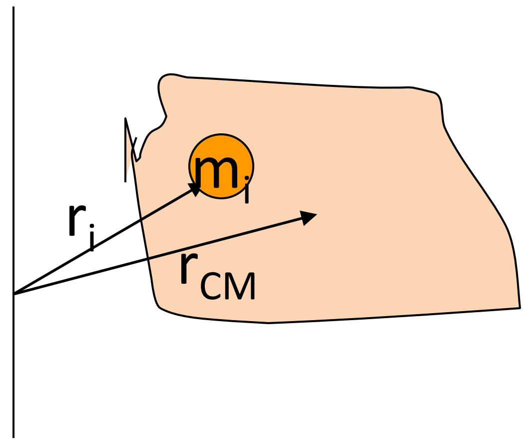
$$\text{Balance of torque:} \quad \sum_i \boldsymbol{\tau}_i = 0$$

Stability of "rigid bodies"



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

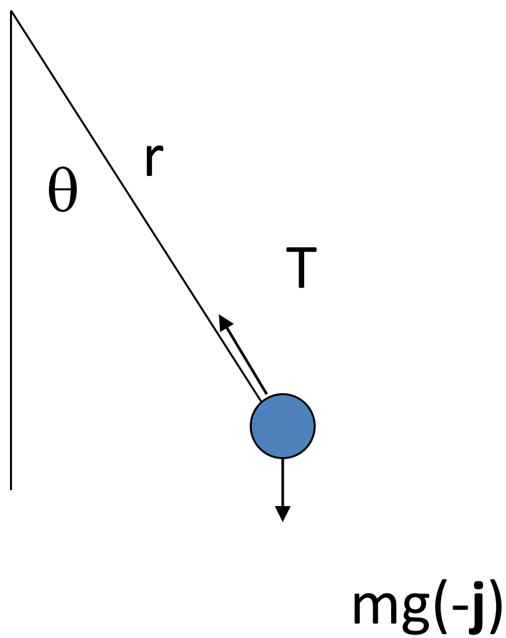
Torque on an extended object due to gravity (near surface of the earth) is the same as the torque on a point mass M located at the center of mass.



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

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

Notion of stability:



F=m**a** ➔ $T - mg\cos\theta = 0$

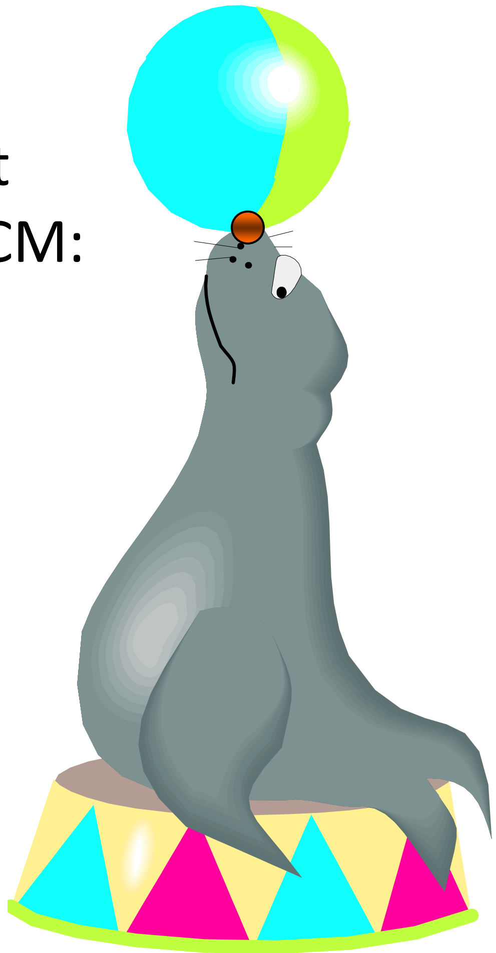
$-mg\sin\theta = -ma_\theta$

τ=I **α** ➔ $r\, mg\sin\theta = mr^2\alpha = mra_\theta$

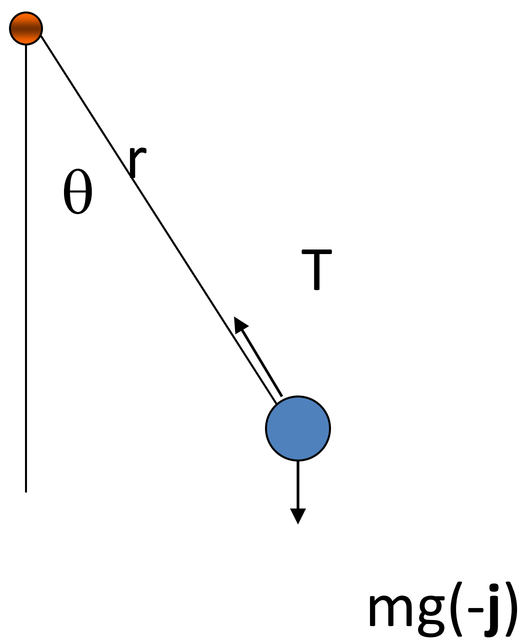
Example of stable equilibrium.

Unstable equilibrium:

Support *below* CM:

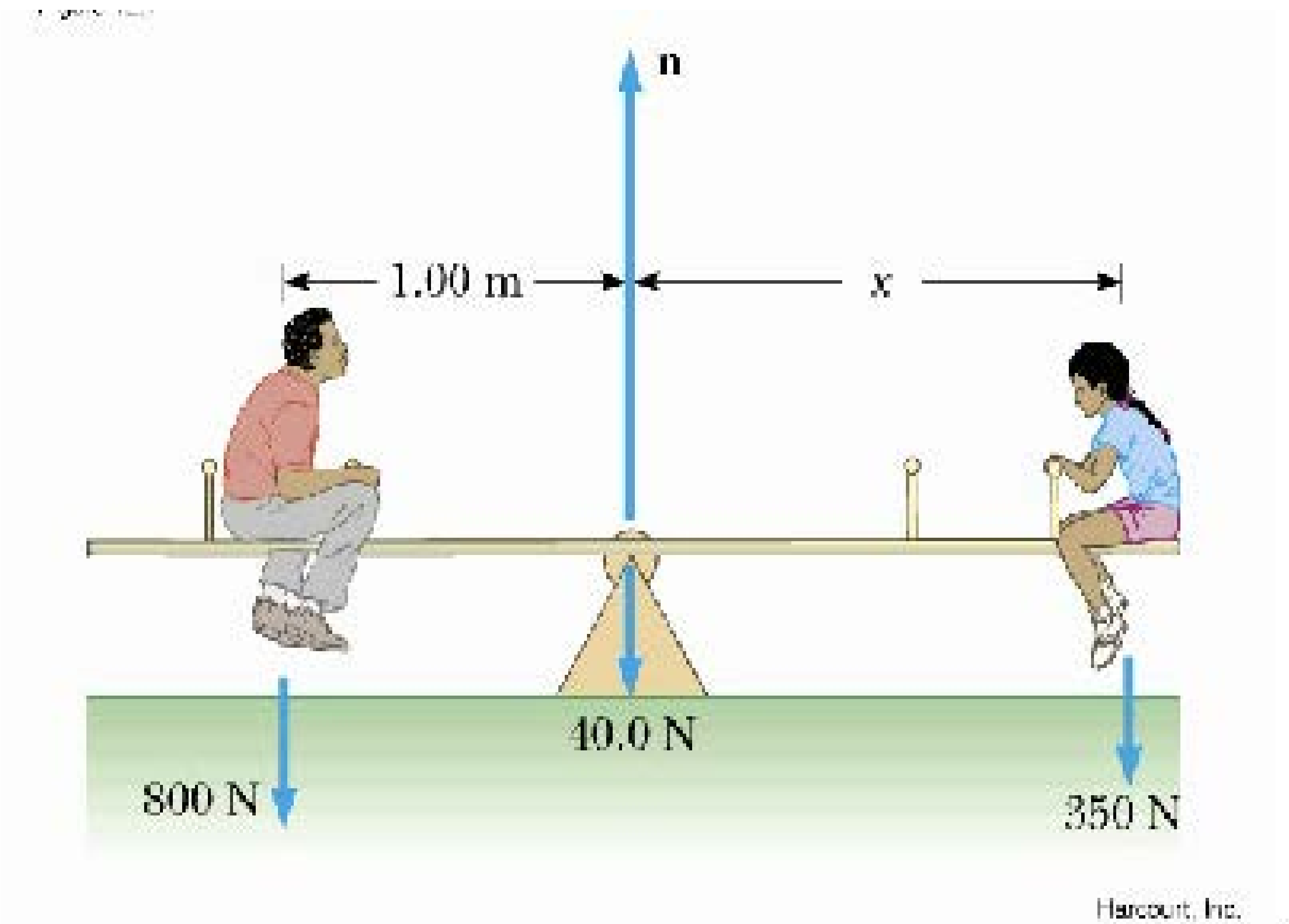


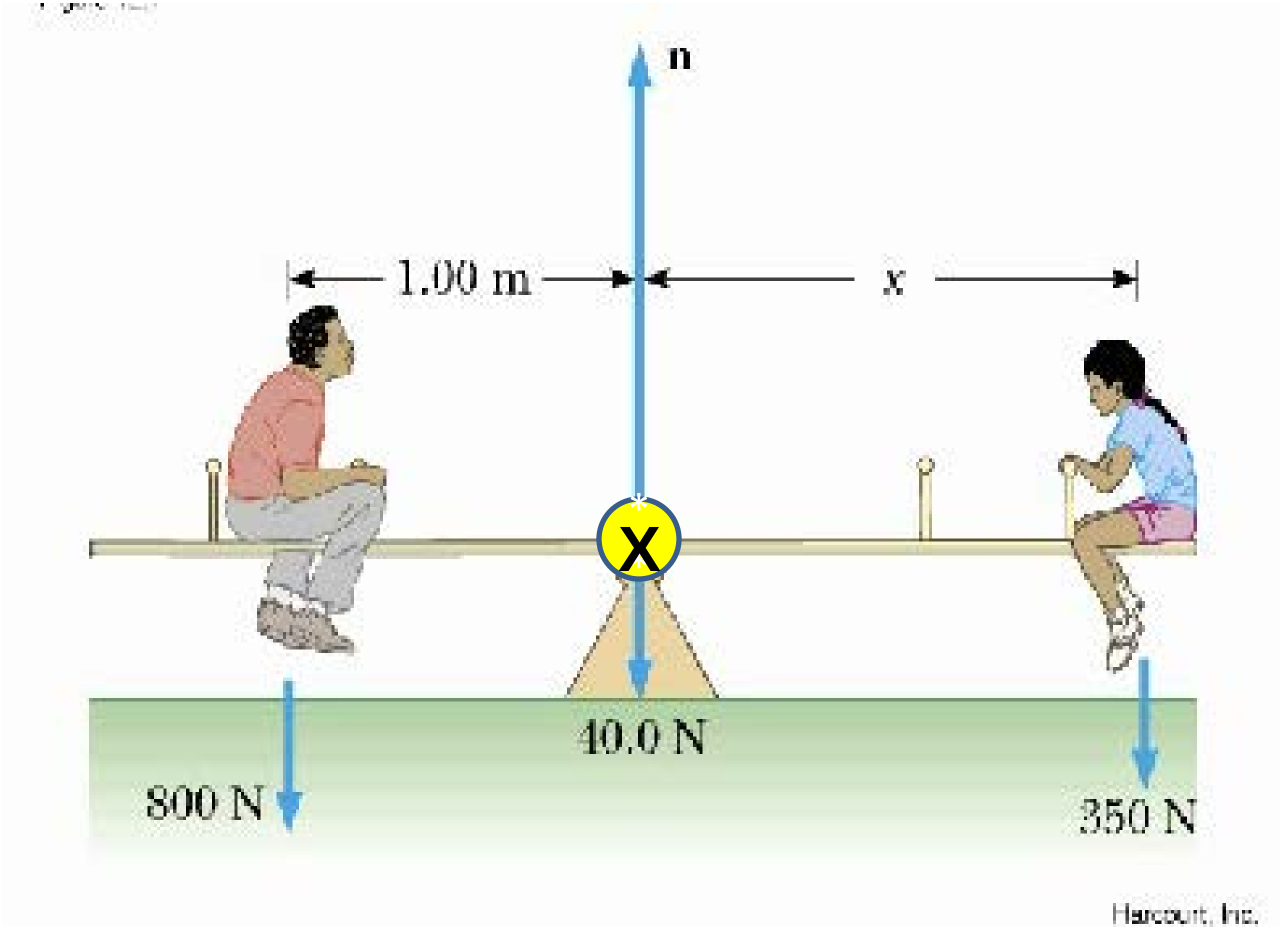
Support ***above*** CM:



Analysis of stability:

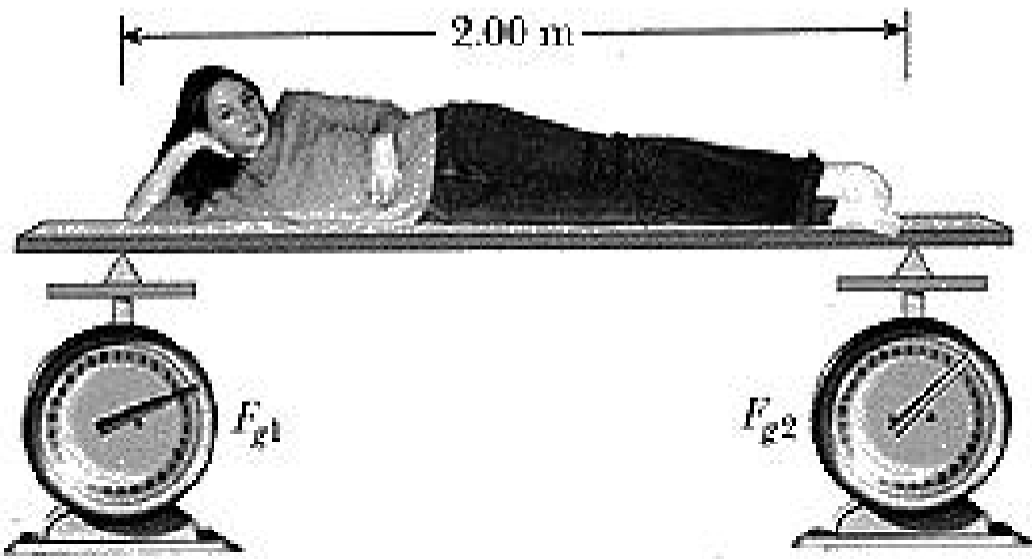
$$\sum_i \mathbf{F}_i = 0 \quad \sum_i \boldsymbol{\tau}_i = 0$$



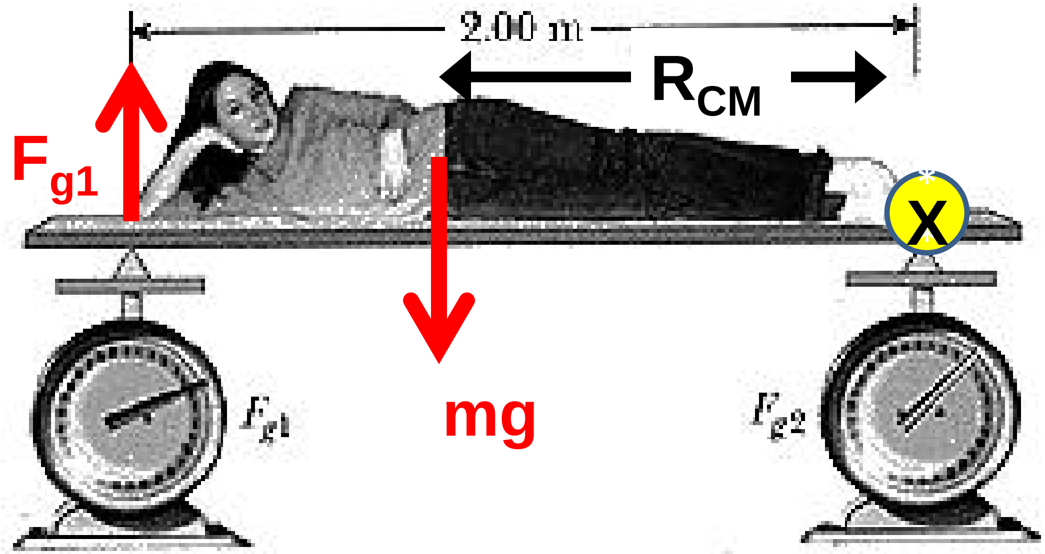


$$\text{Forces}: \quad n - M_D g - m_c g - m_P g = 0$$

$$\text{Torques}: \quad M_D g(1m) - m_c g x = 0$$



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.)



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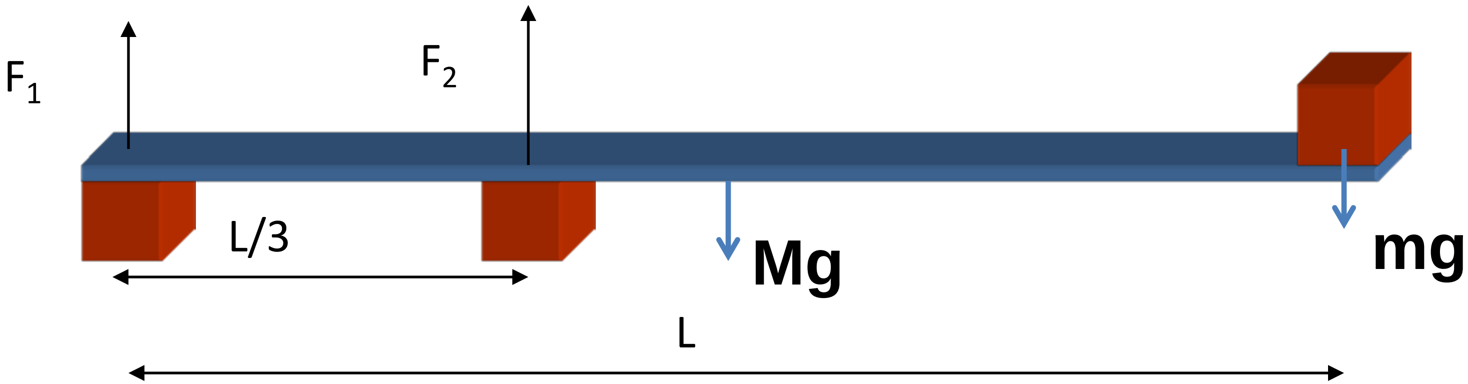
$$\text{Torques:} \quad -F_{g1}(2m) + mg(R_{CM}) = 0$$

iclicker question:

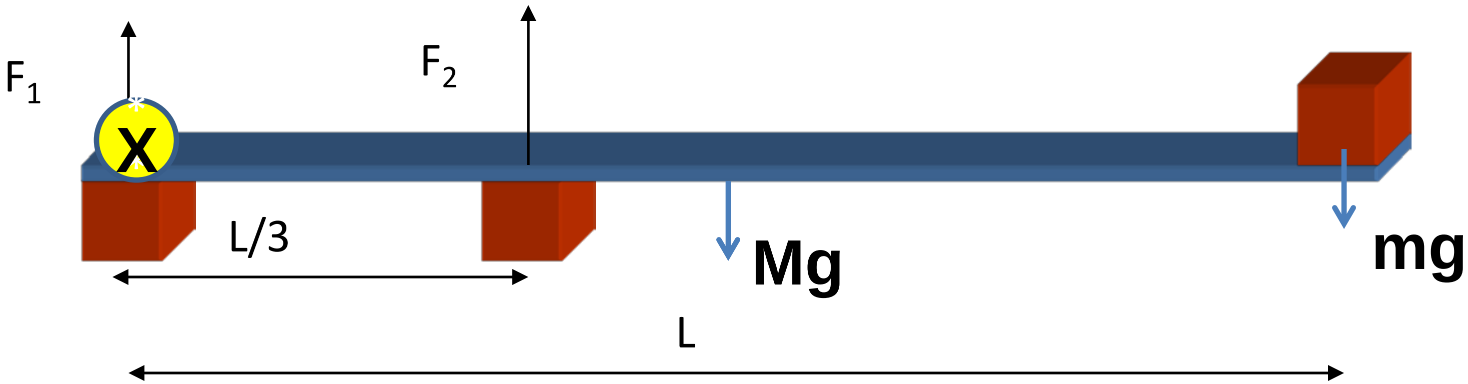


Consider the above drawing of the two supports for a uniform plank which has a total weight Mg and has a weight mg at its end. What can you say about F_1 and F_2?

(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.



$$\text{Forces}: \quad F_1 + F_2 - Mg - mg = 0$$

$$\text{Torques}: \quad F_2 \frac{L}{3} - Mg\frac{L}{2} - mgL = 0$$

$$F_2 = \frac{3}{2}Mg + 3mg \qquad\qquad F_1 = -\frac{1}{2}Mg - 2mg$$

iclicker question:

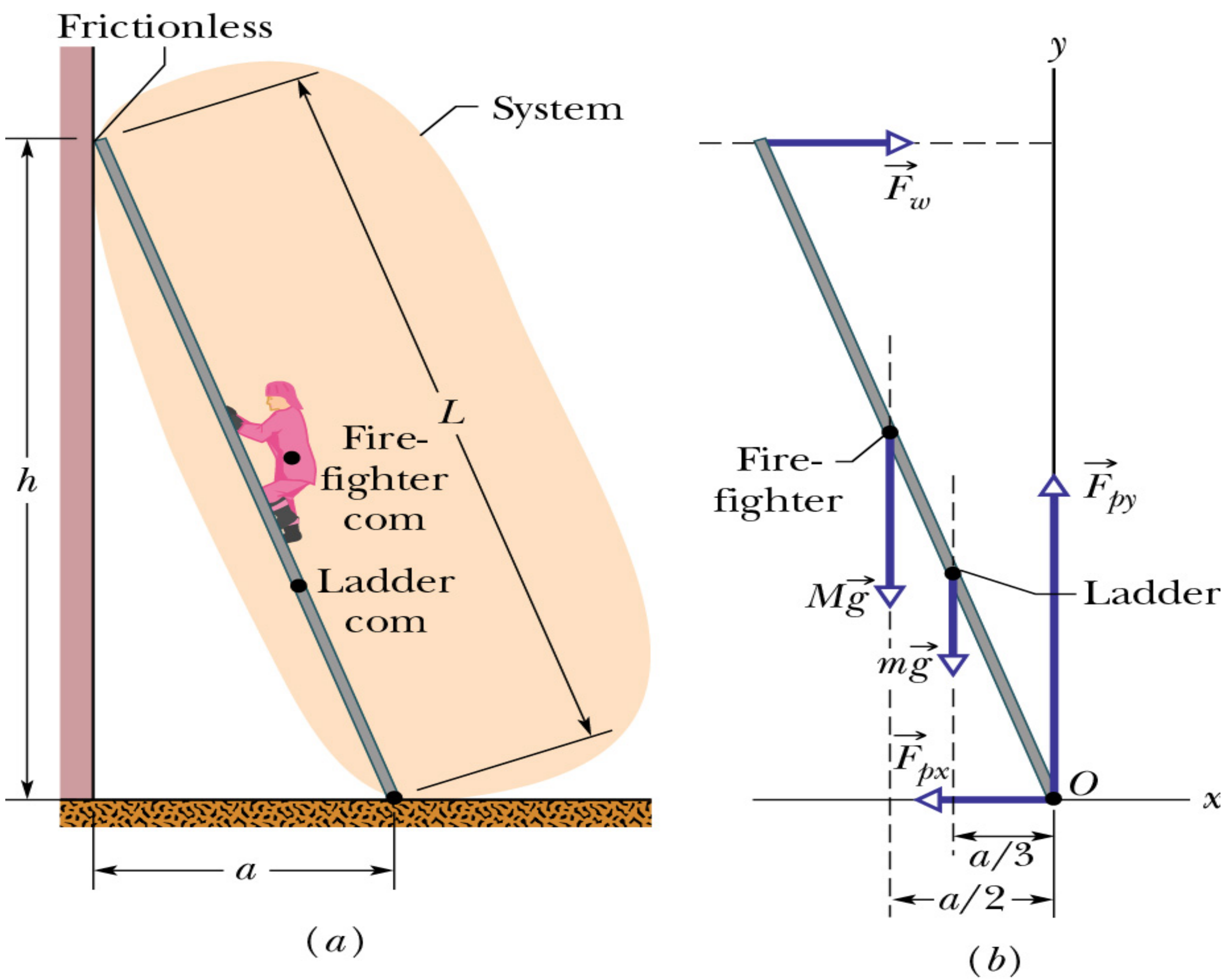
The fact that we found $F_1 < 0$ means:

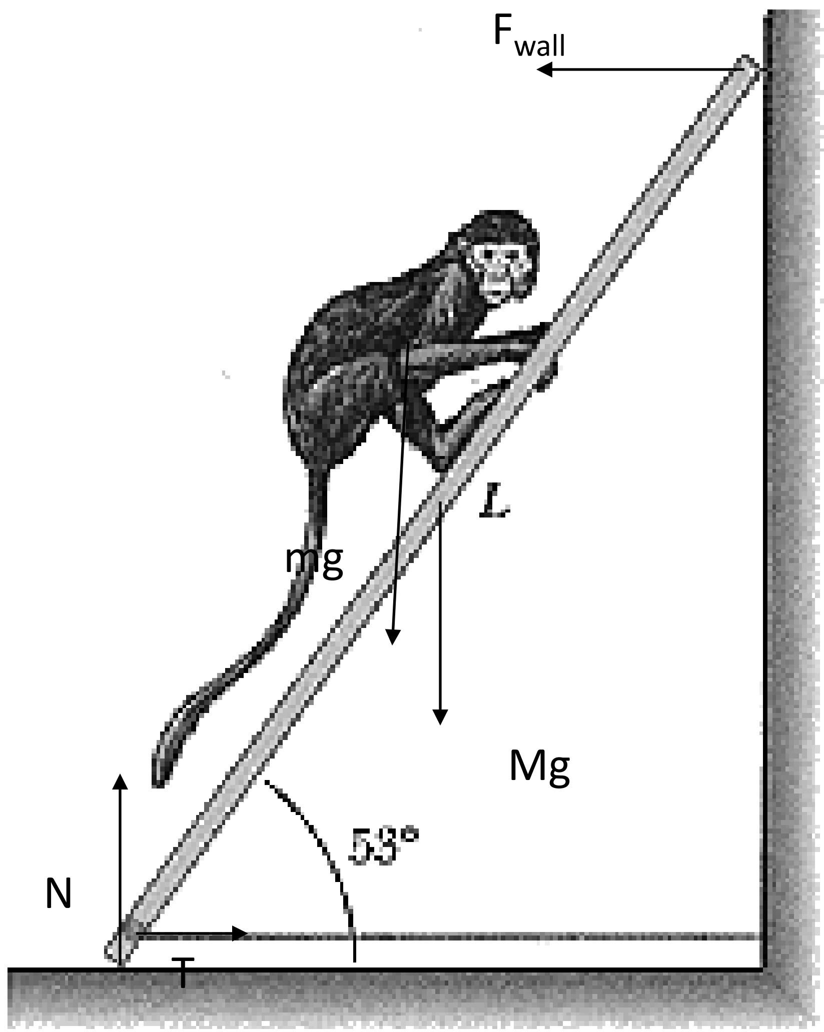
A. **We set up the problem incorrectly**
B. **The analysis is correct, but the direction of F_1 is opposite to the arrow**
C. **Physics makes no sense**

iclicker question:

What would happen if we analyzed this problem by placing the pivot point at F_1 ?:

A. **The answer would be the same.**
B. **The answer would be different.**
C. **Physics makes no sense**


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



Mg = 120 N

mg = 98 N

T < 110 N