Spring 2014

PHYS-2010

Lecture 37

Angular Momentum Demo: Bicycle Wheels

Announcements

- Read Giancoli **Chapter 9.**
- **CAPA # 13** due next Tuesday, April 22.
- **Written Homework # 9** due Friday, April 18.

Static Equilibrium

Static Equilibrium

Static Equilibrium: An object remains

(1) not translating (not moving up, down, left, right)

Not translating:

$$\vec{F}_{net} = 0 = \sum_i \vec{F}_i$$

(net force is zero)

$$\sum F_x = \sum F_y = 0$$

(each component of the net force is zero)

(2) not rotating (not spinning CW or CCW).

Not rotating:

$$\tau_{net} = 0 = \sum_i \tau_i$$

(net torque is zero)

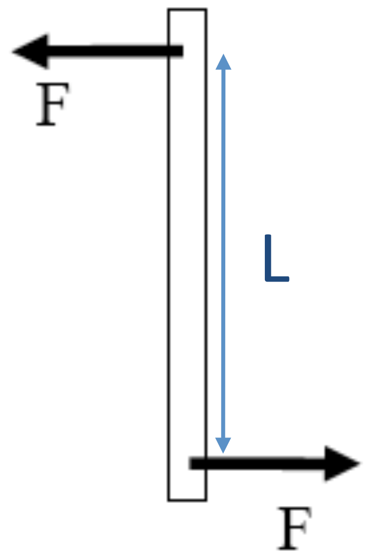
Both conditions are necessary!!!

Clicker Question

Room Frequency BA

Is the net force on the metal bar zero?

A) Yes   B) No



Is the the bar in static equilibrium?

A) Yes   B) No

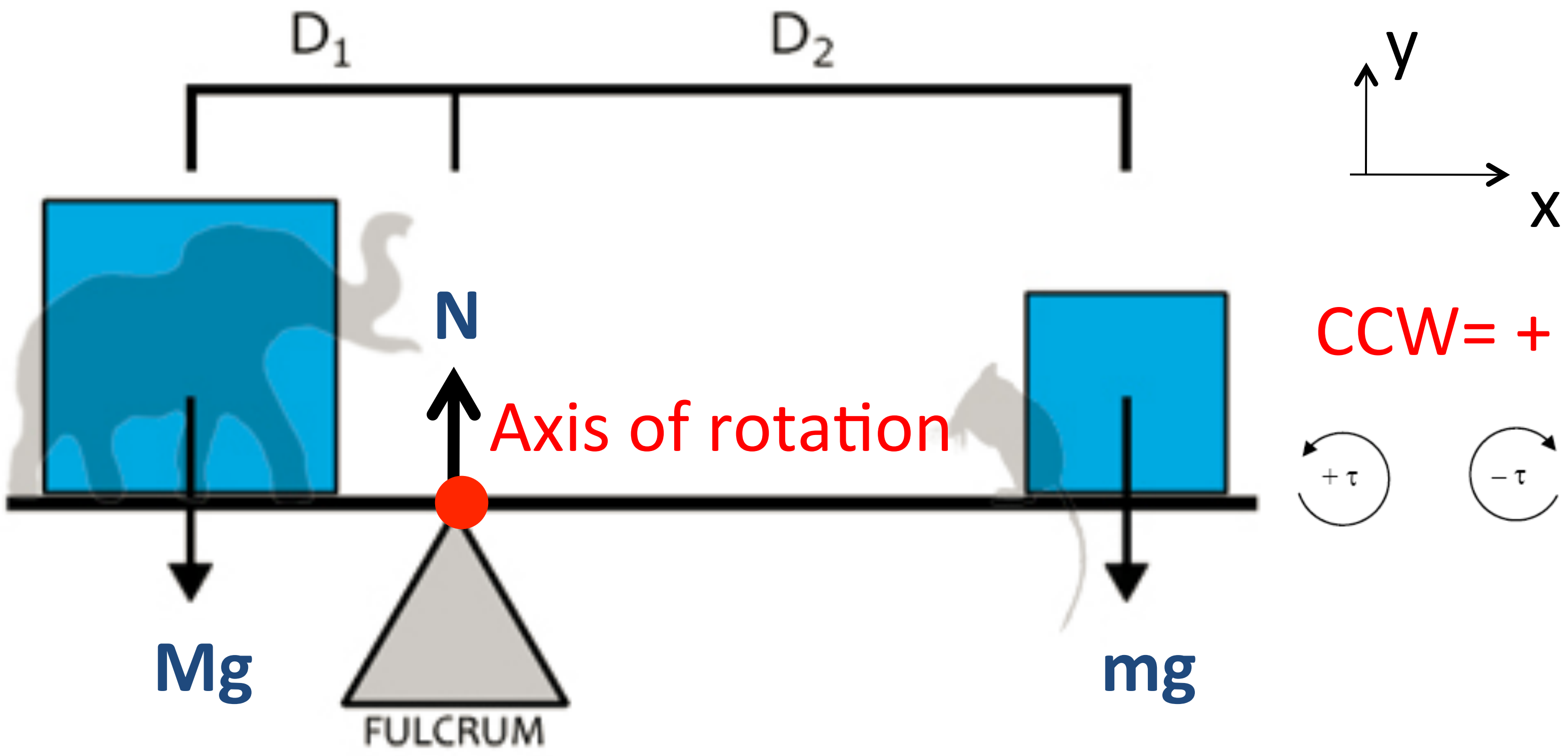
Consider rotations about the middle of the bar.

$$\tau_{net} = \sum_i \tau_i = +F(L/2) + F(L/2) = +FL \neq 0$$

Net positive torque will cause the bar to rotate (CCW).

$F_{net} = 0$ but the bar will rotate anyway.

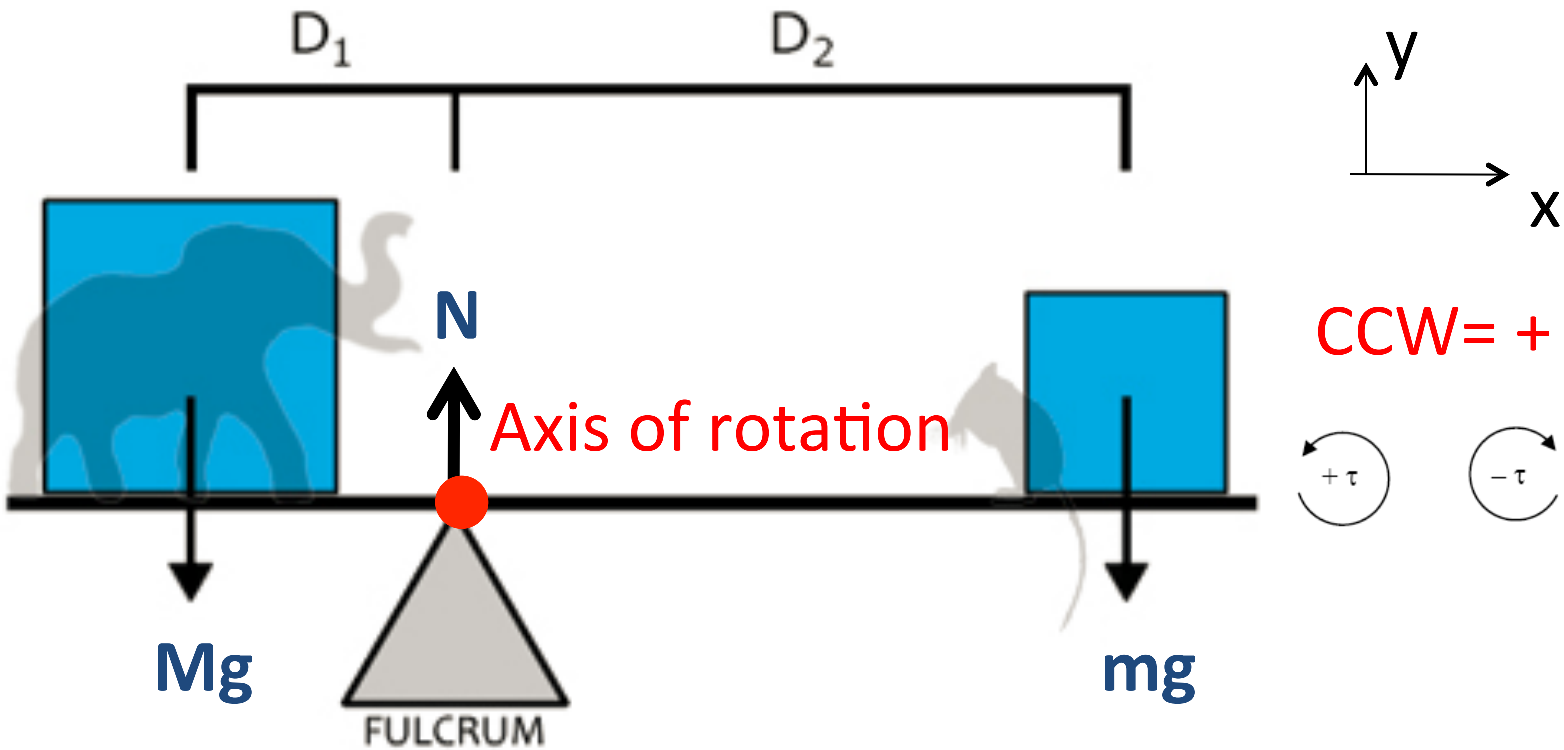
Static Equilibrium Problem: 4 Step Process



#1 – Draw the free body diagram identifying all forces and exactly where they act.

#2 – Label the coordinate axis and axis of rotation being considered (and the sign convention)

Static Equilibrium Problem: 4 Step Process



#3 – Write out $F_{net} = ma$ and $\tau_{net} = I\alpha$ equations…

$F_{net,x} = (M+m)a_x = 0$ (no forces in this direction)

$F_{net,y} = (M+m)a_y = 0 = +N - Mg - mg$

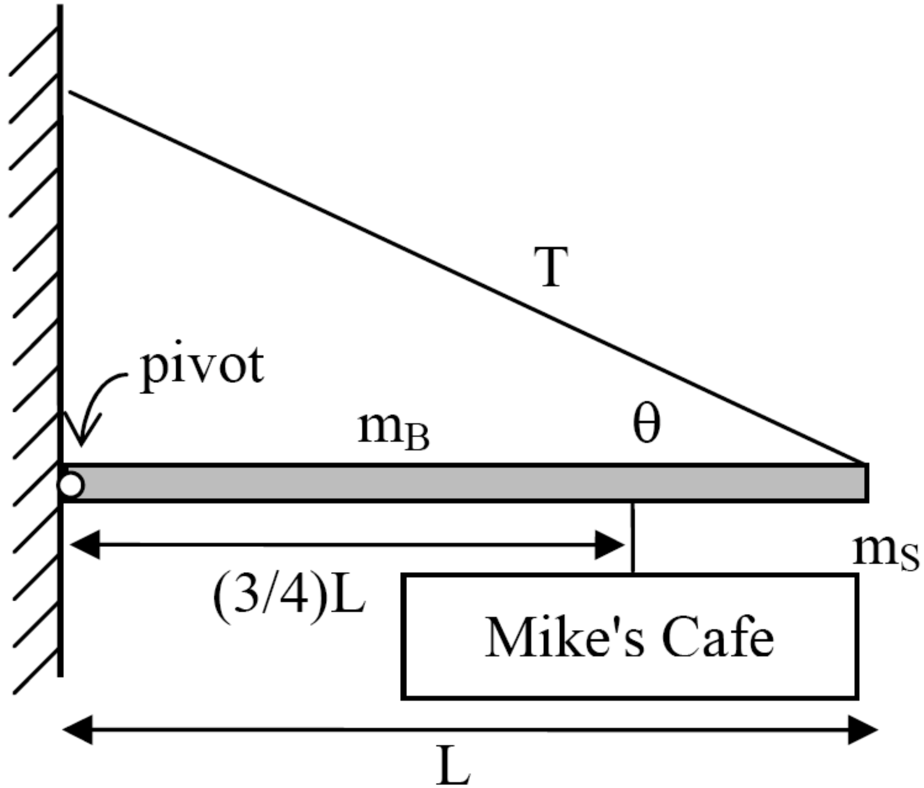
$\tau_{net} = I\alpha = 0 = +(Mg)D_1 - (mg)D_2$

#4 – Solve…

EXAMPLE: A sign with mass $\mathbf{m_s}$ is hung from a uniform bar of mass $\mathbf{m_b}$ and length **L**.

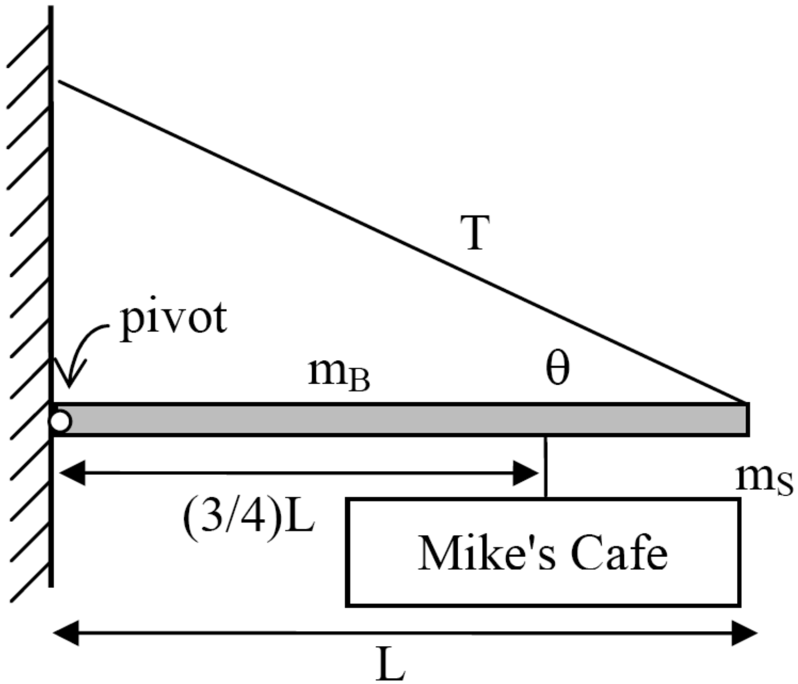
The sign is suspended ¾ of the way from the pivot.

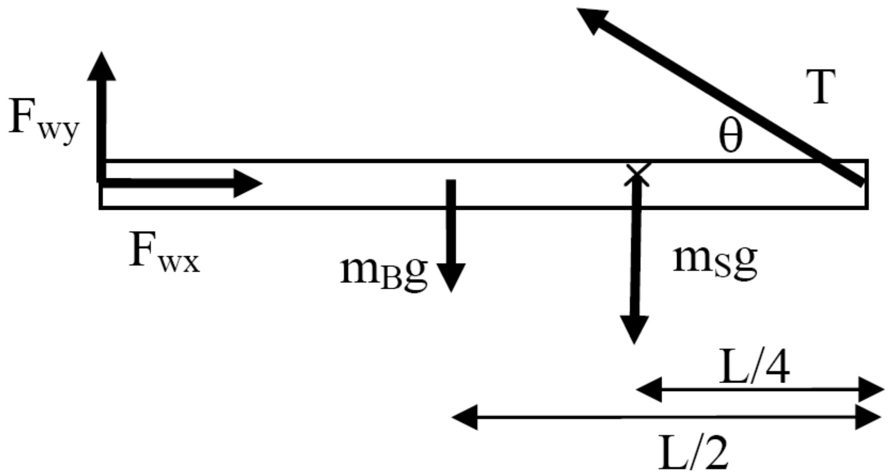
The sign is held up with a cable at an angle **θ**.



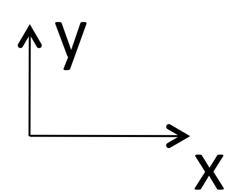
How strong a cable is required (i.e. what is tension T)?

Step #1: Force Diagram

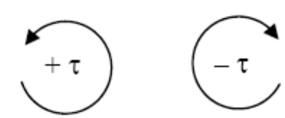


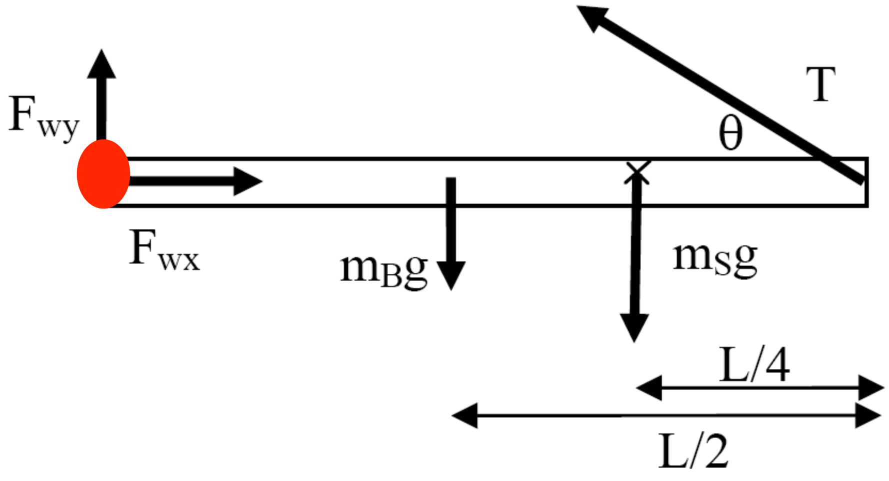


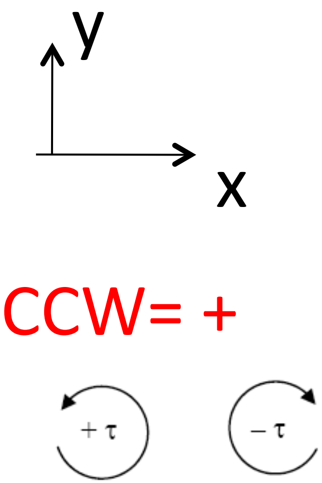
Step #2: Coordinate System



CCW= +







Step #3: Static Equilibrium conditions *F*=*ma*=0 and τ=*I*α=0

$$F_{net,x} = ma_x = 0 = F_{wx} - T\cos\theta$$

$$F_{net,y} = ma_y = 0 = F_{wy} + T\sin\theta - m_B g - m_s g$$

Not enough information to solve for T, F_{wx}, F_{wy}
(2 constraint equations and 3 unknowns)

$$\tau_{net} = I\alpha = 0 = -(m_B g)(L/2) - (m_s g)(3L/4) + (T\sin\theta)(L)$$

Step #4: SOLVE!

$$\tau_{net} = I\alpha = 0 = -(m_B g)(L/2) - (m_s g)(3L/4) + (T\sin\theta)(L)$$

Notice here that there is no dependence on the hinge force!

$$T = \frac{(2m_B + 3m_s)g}{4\sin\theta}$$

$$F_{net,x} = ma_x = 0 = F_{wx} - T\cos\theta$$

$$F_{wx} = T\cos\theta = \frac{(2m_B + 3m_s)g}{4}\left(\frac{\cos\theta}{\sin\theta}\right)$$

$$F_{net,y} = ma_y = 0 = F_{wy} + T\sin\theta - m_B g - m_s g$$

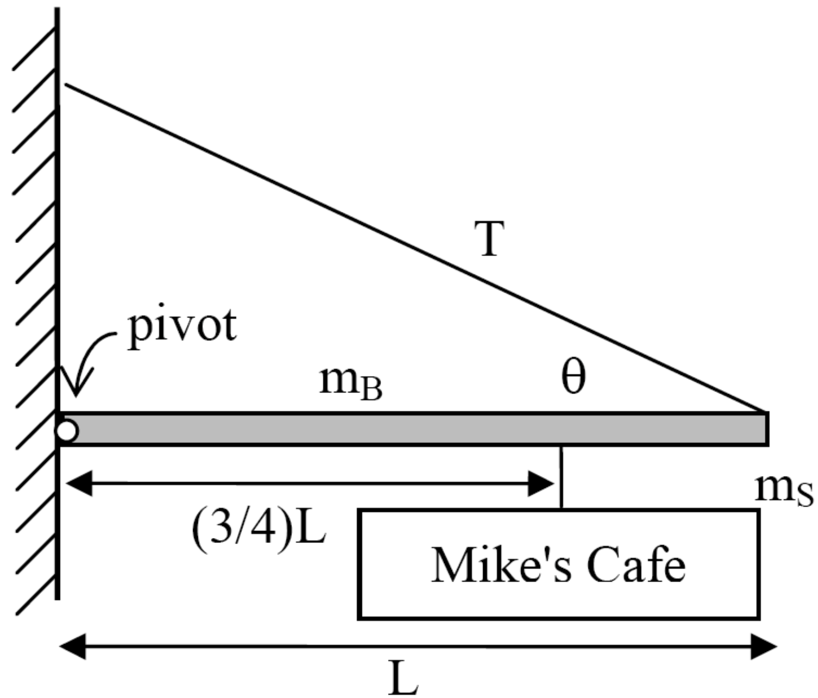
$$F_{wy} = (m_B + m_s)g - T\sin\theta = (m_B + m_s)g - \frac{(2m_B + 3m_s)g}{4}$$

Clicker Question

Room Frequency BA

In the problem about finding the tension in a support wire for a beam and sign in static equilibrium, where is the correct point to use as the axis of rotation when calculating the net torque?

A) The pivot
B) The end of the beam
C) The point where the sign is attached
D) Any of the above
E) None of the above



In static equilibrium, the net torque is zero around *any* axis of rotation!

Clicker Question

Room Frequency BA

Two movers pick up a couch that weighs 1000 N. One holds each end as shown.

To hold the couch in equilibrium each mover needs to provide an upward force of 500 N. Suppose the mover on the **left** provides a force of **400 N** while the mover on the **right** continues to provide a force of **500 N**. What happens?

A) The center of mass of the couch will accelerate downward.

B) The couch will start to rotate counter-clockwise.

C) Both A and B.

D) Neither A nor B.