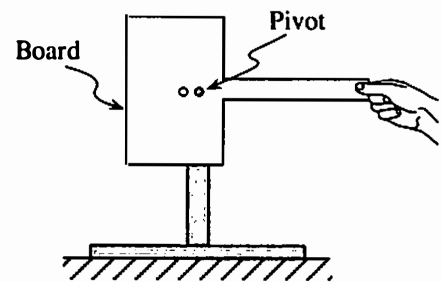
I. Interpreting center of mass

A. A T-shaped board of uniform mass density has two small holes as shown. Initially, the pivot is placed through the right hole, which corresponds to the *center of mass* of the board. The board is then held in place.



1. *Predict* the motion of the board after it is released from rest. Explain.

2. Check your prediction by observing the demonstration.

   a. Describe the angular acceleration of the board. Explain how you can tell.

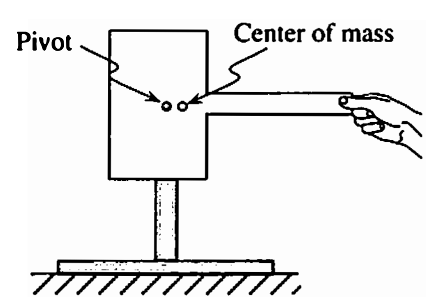
      What does your answer imply about the *net torque* about the pivot? Explain.

   b. Describe the acceleration of the center of mass of the board. Explain how you can tell.

      What does your answer imply about the *net force* acting on the board? Explain.

3. Explain how your answers about net torque and net force in question 2 would change, if at all, if there is *appreciable friction* between the board and the pivot and the board remains at rest.

B. Imagine that the board is now hung from the hole to the left of the center of mass.

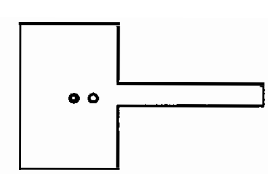


1. *Predict* the subsequent motion of the board after it is released. Explain.

2. On the diagram at right, draw and label an *extended free-body diagram* for the board just after it is released (*i.e.*, for each force, indicate explicitly a single point on the object at which the force can be regarded as acting).

   Explain how the diagram can be used to support your prediction for the motion of the board.

Extended free-body diagram for board



3. Obtain a T-shaped board and a pivot. Place the board on the pivot and check your predictions. Resolve any inconsistencies between your predictions and observations.

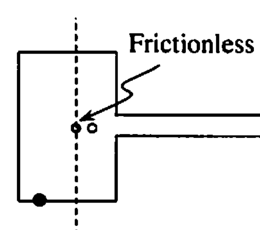
4. Place the board on the pivot with the center of mass directly above, directly below, and to the left of the pivot. Record your observations below.

An extended body can rotate freely about a fixed pivot if the friction between the object and the pivot is very small. A pivot that has negligible friction is sometimes referred to as a *frictionless pivot.* For all the following exercises and demonstrations in this tutorial, we will assume that the pivot is frictionless.

II. Applying the concept of center of mass

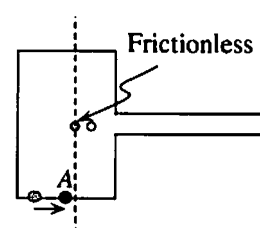
A. Attach clay to the bottom left side of the board so that it remains at rest when placed horizontally on the pivot. (The pivot should still be through the hole used in part B above.)

1. On the figure at right, mark the approximate location of the center of mass of the system composed of clay and board with an "x."



Is the center of mass of the system located *to the left of, to the right of,* or *along* the vertical line through the pivot? Explain.

2. Suppose that the piece of clay were moved to a new location (point *A*) closer to the pivot.



Predict whether the board would remain in equilibrium. Explain.

Would the total mass to the left of the pivot change when the clay is moved to point *A?*

Check your predictions.

3. Suppose the piece of clay were moved back to its original location and additional clay were added to it.

   Would the board remain in equilibrium?

   Is there any location along the bottom edge of the board at which this larger piece of clay could be placed so the board will be in equilibrium? If so, is the new location *closer to* or *farther from* the pivot?

   Check your prediction.

4. Generalize your observations from parts 1, 2, and 3:

   - Is it possible to keep the total mass to either side of the pivot unchanged yet change the system so that it is no longer in equilibrium?

   - Is it possible to change the *total mass* to one side of the pivot and still have the system in equilibrium?

   Is it enough to know the total mass to either side of the pivot in order to determine whether the system will be in equilibrium? Explain.

B. A student has balanced a hammer *lengthwise* on a finger. Consider the following dialogue between the student and a classmate.

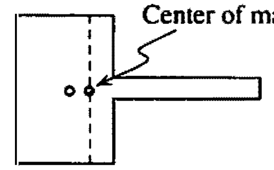
   Student 1: *"The hammer is balanced because the center of mass is above my finger. The mass is the same on both sides of the center of mass – that is what the center of mass means."*

   Student 2: *"It is not the mass, it is the torque that is the same for both parts of the hammer. If the torques weren't the same, the hammer would rotate."*

   With which statements, if any, do you agree? Explain.

   Explain how one of the students above misinterpreted the term "center of mass."

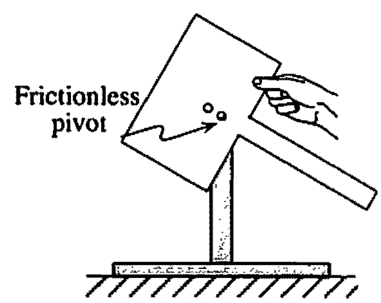
In part A of section I you observed that the board will remain in equilibrium when placed on the pivot through its center of mass and released from rest. The figure at right shows the board with a vertical line through its center of mass.



Is the mass of the piece of board to the left of the dashed line *greater than, less than,* or *equal to* the mass of the piece of board to the right of the dashed line? Explain.

➪ Obtain the necessary equipment from a tutorial instructor and check your answers. If necessary, resolve any inconsistencies. (*Hint:* Consider the areas of the pieces of board to the left and to the right of the pivot.)

C. Imagine that the T-shaped board (with no clay attached) were rotated as shown and then released from rest. The pivot passes through the center of mass of the board.



1. *Predict* the subsequent motion of the board.

2. Check your prediction by watching the demonstration. Record your observation below.

3. What does your observation imply about the net torque about the pivot? Explain.