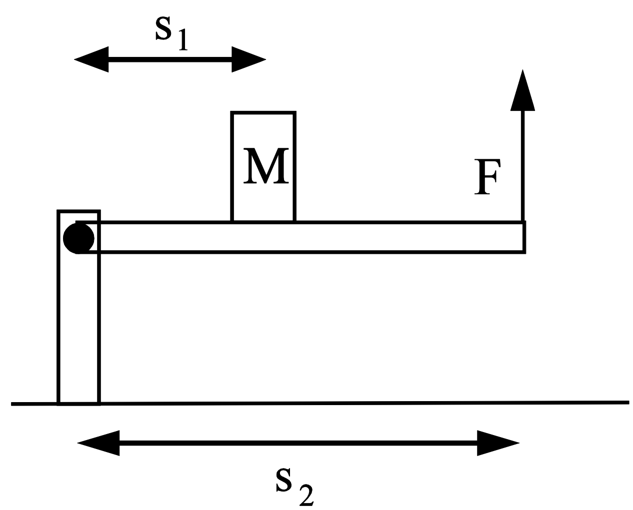
First Name:____________________ Last Name:________________________________

A mass *M* is placed on a massless board a distance s_1 from a frictionless pin. A force of magnitude *F* is applied vertically to the end of the board, a distance s_2 from the pivot, as shown below. In this configuration, the system is in static equilibrium. You will be using this figure for Questions #1-5.

1. Draw the forces acting on the board.



2. Determine the magnitude of the force *F* necessary for the board to be in static equilibrium. Specifically, use the rotational equilibrium condition $\Sigma\vec{\tau} = 0$.

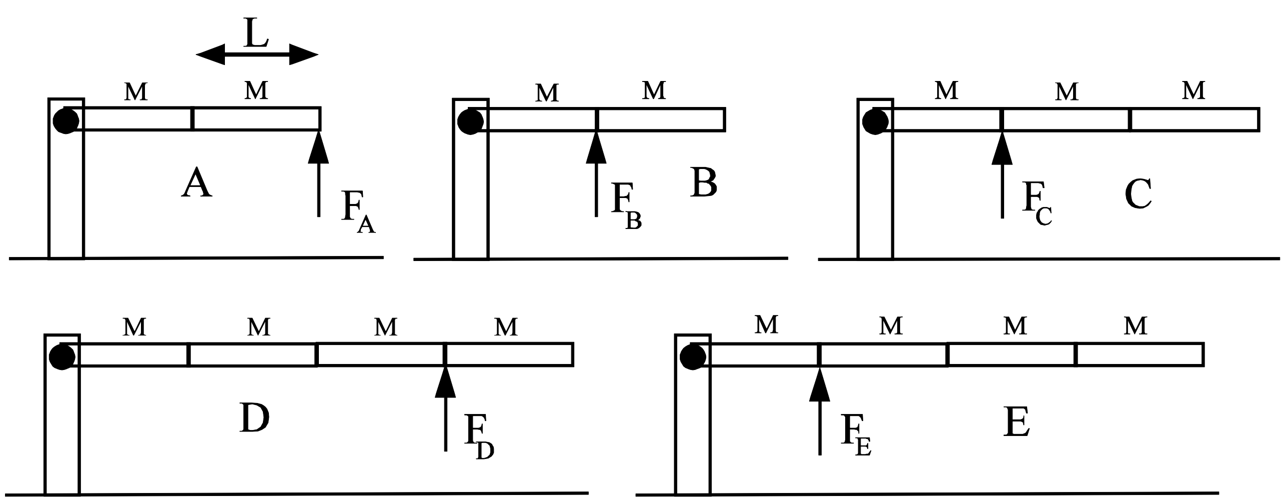
For the next three questions something in the original diagram will change and you will be asked whether the force must increase, decrease or stay the same to maintain static equilibrium. In each case, while you may certainly use equations you must also explain your answer using sentences that include a reference to torque or torques.

3. Imagine that the mass is moved to the right (so s_1 increases). Explain how and why *F* must change.

4. Imagine that the mass is increased. Explain how and why F must change.

5. Imagine that F is applied closer to the frictionless pin (so s_2 decreases). Explain how and why F must change.

6. In each of the five cases below (A-E), a uniform rod is attached to a support at one end with a pin. Each rod is kept horizontal by an upward force (F_A, F_B, etc.). These upward forces are not necessarily the same size. Each segment of the rod has a length L and a mass M.



A. Draw a free body diagram for the beam in picture C.

B. Rank the cases based on the magnitude of the upward force F_A, F_B, etc.

Largest Smallest

Explain your reasoning and show your calculations.

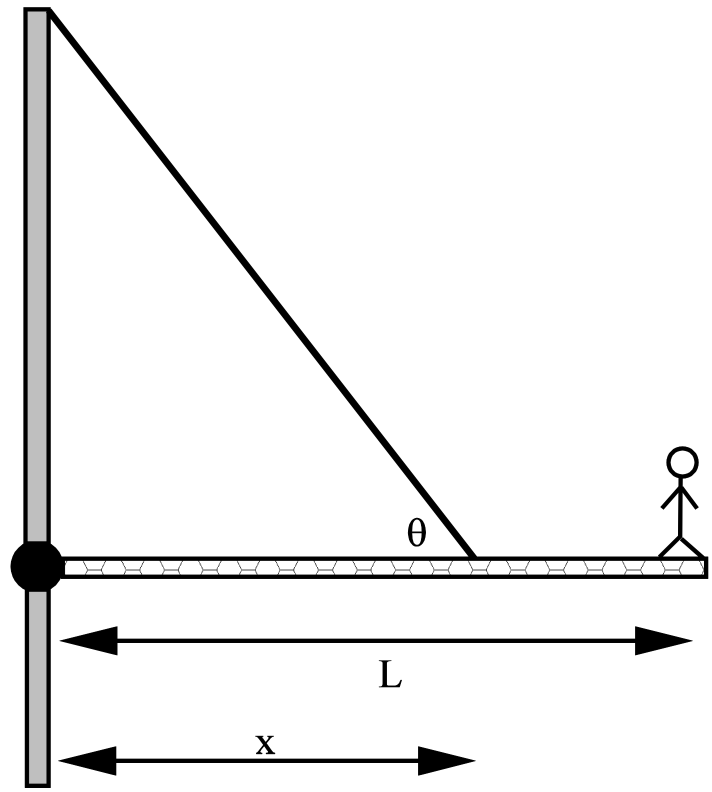
C. Rank the cases based on the force that the pin exerts on the rod (call this n_A, n_B, etc.), from the greatest upward force to the greatest downward force. If the force exerted by the pin is zero in any of the cases, explicitly indicate that and also make sure you distinguish which forces are upward and which are downward.

Greatest Upward Greatest Downward

Explain your reasoning and show your calculations.

7. A beam of mass M_B is hinged to a wall and also connected to the wall by a stiff cable. The cable can be connected to the beam at various locations, so the distance *x* in the diagram and the corresponding angle θ can be varied. A child of mass M_C can walk back and forth along the beam.

A. Draw the forces acting on the bar.



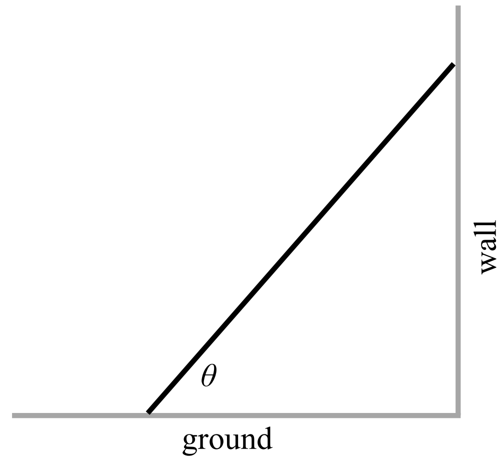
B. Write Newton's laws for the bar along the x-axis, along the y-axis, and also the rotational version.

C. Imagine that the child is originally at the left end of the beam and then begins walking (or crawling) to the right. Describe how each force in your free body diagram changes and why it changes.

D. Assuming that $x = \frac{2}{3}L$, $\theta = 53.1°$ and that the child is at the right end of the beam, determine M_C (in terms of M_B) if the vertical force exerted by the hinge on the beam is zero.

8. A ladder in static equilibrium leans against a *frictionless* wall.

   A. Draw the forces acting on the ladder.



Someone moves the ladder closer to the wall (so θ increases). The ladder is again in static equilibrium. For each force below, has that force increased in magnitude, decreased in magnitude or stayed the same. Explain your reasoning in each case.

   B. The normal force exerted by the ground on the ladder.

   C. The normal force exerted by the wall on the ladder.

   D. The static friction force exerted by the ground on the ladder.