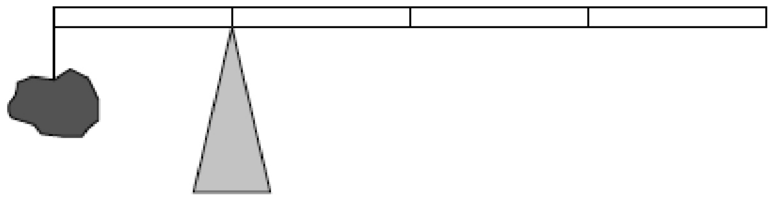
Static Equilibrium
Concept Questions

Question 1 A 1-kg rock is suspended by a massless string from one end of a 1-m measuring stick. What is the weight of the measuring stick if it is balanced by a support force at the 0.25-m mark?



1) 0.25 kg

2) 0.5 kg

3) 1.0 kg

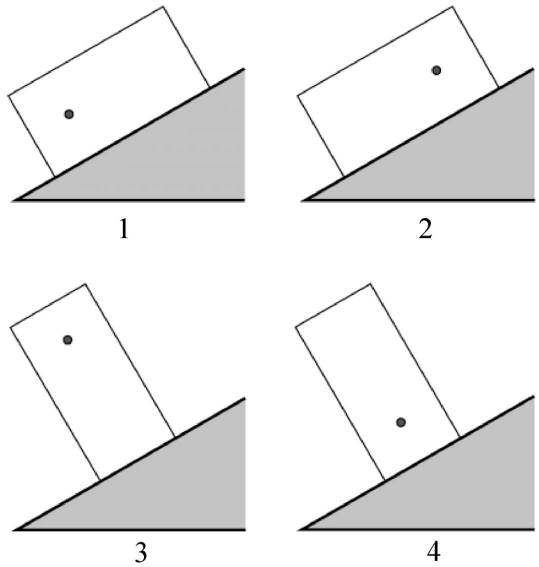
4) 2.0 kg

5) 4.0 kg

6) impossible to determine

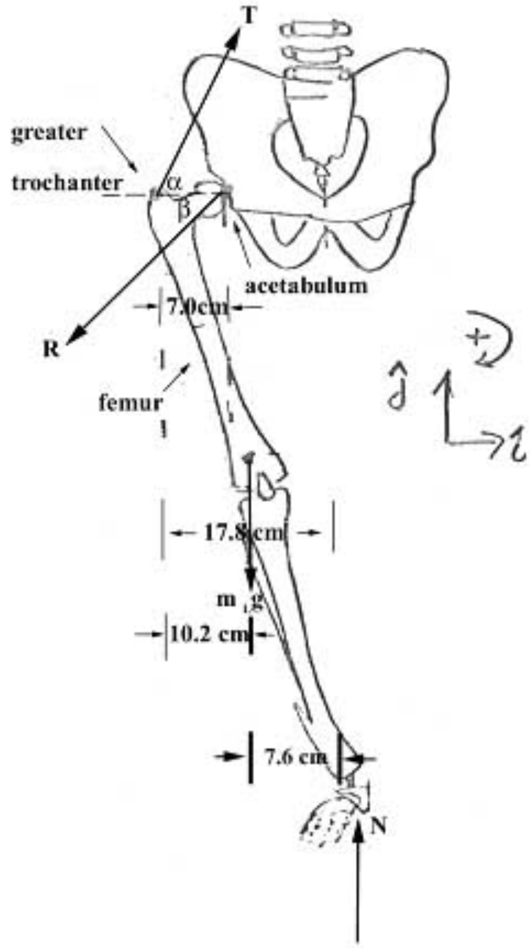
Answer 3. Because the stick is a uniform, symmetric body, we can consider all its weight as being concentrated at the center of mass at the 0.5-m mark. Therefore the point of support lies midway between the two weights, and the system is balanced only if the total weight on the right is also 1 kg.

Question 2 A box, with its center-of-mass off-center as indicated by the dot, is placed on an inclined plane. In which of the four orientations shown, if any, does the box tip over?



Answer 3. In order to tip over, the box must pivot about its bottom left corner. Only in case 3 does the torque about this pivot (due to gravity) rotate the box in such a way that it tips over.

Question 3 Torque on the right leg We want to find the magnitude of the tension in the hip abductor muscles $\vec{\mathbf{T}}$ shown in the figure below.



The direction α is given. After drawing your free body diagram for the right leg, you are trying to decide what point to compute the torques about. Explain the disadvantages /advantages if you chose each of the points listed below.

a) The center of mass of the leg where the gravitational force $m_l\vec{\mathbf{g}}$ acts
b) The contact point with the ground where the normal force $\vec{\mathbf{N}}$ acts
c) The point of contact between the acetabulum and the femur where the reaction force $\vec{\mathbf{R}}$ acts
d) The point where the tension in the hip abductor muscles $\vec{\mathbf{T}}$ act

Answers: An important aspect of this problem, which is a part of a more involved problem, is that we want the tension in the hip abductor muscle, not the reaction force $\vec{\mathbf{R}}$ (magnitude R and angle β).

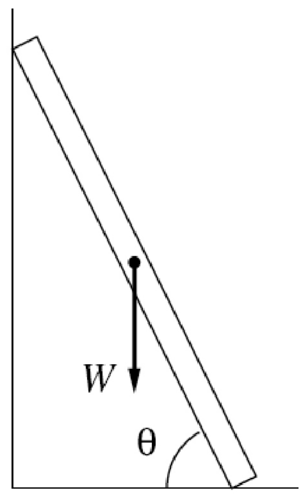
a) Using the center of the system is often a good idea, but in this case the leg is only one part of the larger system (the entire body). Specifically, we would need to include $\vec{\mathbf{R}}$ in both the force and torque calculations. This can be done, of course, and a decided advantage would be that we obtain $\vec{\mathbf{R}}$ from the resulting algebra.

b) Using the contact point with the ground would mean that the normal force $\vec{\mathbf{N}}$ (and any friction force, not included in the problem but a great aid in standing on one foot) would not exert any torque. However, as in (a), $\vec{\mathbf{R}}$ is then part of the problem.

c) Since the stated goal is to find T, using this contact point for determination of torques means that $\vec{\mathbf{R}}$ does not enter the torque calculation. If the weight $N = \left|\vec{\mathbf{N}}\right|$ is known or given, then only the torque equation, not any force equations, is needed.

d) Using this point takes $\vec{\mathbf{T}}$ out of the torque equation entirely, but T is what we want, so this would involve extra calculations and determination of $\vec{\mathbf{R}}$.

Question 4 A uniform ladder (one whose center of mass is at its geometrical center) of weight W leans against a wall at an angle $\theta \approx 60^o$ up from the ground. The coefficient of friction between the ladder and the ground is μ_G, and between the ladder and the wall is μ_W. The magnitudes of these two coefficients are about equal. In order to keep the ladder from slipping:



1) The magnitude of the torque about the center of mass due to the normal force between the ground and the base of the ladder is greater than the magnitude of the torque about the center of mass due to the frictional force of the wall on the ladder.
2) The magnitude of the torque about the center of mass due to the normal force between the ground and the base of the ladder is equal to the magnitude of the torque about the center of mass due to the frictional force of the wall on the ladder.
3) The magnitude of the torque about the center of mass due to the normal force between the ground and the base of the ladder is less than the magnitude of the torque about the center of mass due to the frictional force of the wall on the ladder.

4) Not enough information is given to answer this problem.

Answer 1. The torque about the center of mass due to the normal force between the ground and the base of the ladder is in the opposite direction from the torques about the center of mass due to (i) the normal force of the wall on the ladder, (ii) the friction force of the ground on the ladder and (iii) the frictional force of the wall on the ladder. Hence the torque about the center of mass due to the normal force between the ground and the base of the ladder must be larger in magnitude than the other three order to keep the ladder in static equilibrium.

Question 5 You are trying to open a door that is stuck by pulling on the doorknob in a direction perpendicular to the door. Assume the doorknob is at the same height as the center of mass of the door. If instead you tie a rope to the door and then pull perpendicularly with the same force, the torque about the center of mass of the door you exert is

1) increased
2) decreased
3) the same
4) unsure

Answer 3. Because you have not changed the moment arm about the center of mass and you are pulling with the same force, the torque is the same.