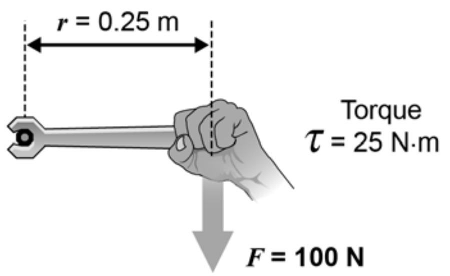
Name: ______________________________ Date: __________

5G Torque

Read:

In this skill sheet, you will practice solving problems that involve torque. Torque is an action that is created by an applied force and causes an object to rotate. Any object that rotates has a torque associated with it.



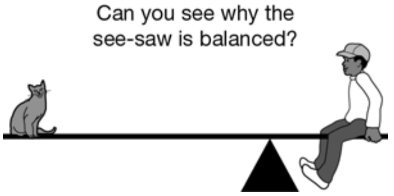
Torque, τ, can be calculated by multiplying the applied force, F, by r. The value, r, is the perpendicular distance between the point of rotation and the line of action of the force (the line along which the force is applied).

$$\tau = F \times r$$

The unit of torque is newton·meter (N·m).

For many situations the distance r is also called the lever arm. The lever arm length in the graphic above and to the right is 0.25 m. The force applied to this lever arm is 100 N.

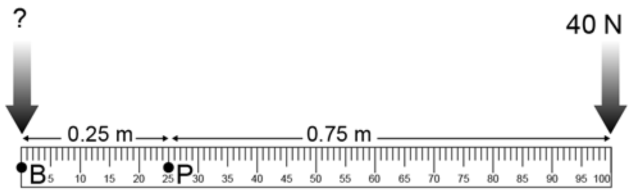
A see-saw works based on torque. As you know, the lighter person (or a cat!) has to sit further out for the see-saw to be level. You know now that this is because the only way to make the torque of the heavy person equal to the torque of the light person is to increase the lever arm of the light person.



Example:

For an object to be in rotational equilibrium about a certain point, the total torque about this point must be zero.

For the example shown in the figure, calculate the magnitude and direction of a force that must be applied at point B for rotational equilibrium about point P.

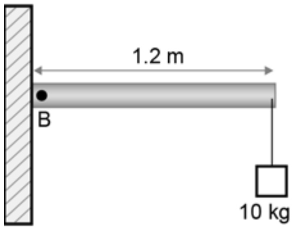


<table>
<tr><td>Looking for
Magnitude and direction of the force that must be applied at point B for rotational equilibrium</td><td rowspan="3">Solution
$F_{left} \times r_{left} = F_{right} \times r_{right}$
$F_{left} \times 0.25\text{ m} = 40\text{ N} \times 0.75\text{ m}$
$F_{left} = \dfrac{30\text{ N-m}}{0.25\text{ m}}$
$F_{left} = 120\text{ N}$
For rotational equilibrium, 120 N must be applied downward at point B.</td></tr>
<tr><td>Given
Let the force at point B equal F_{left}.
r_{left} = 0.25 meter
F_{right} = 40 newtons
r_{right} = 0.75 meter</td></tr>
<tr><td>Relationship
Torque to the left of P = Torque to the right of P
$F_{left} \times r_{left} = F_{right} \times r_{right}$</td></tr>
</table>

Skill and Practice

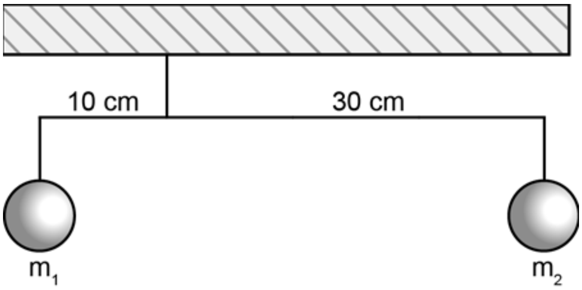
Practice:

1. A 10-kilogram mass is suspended from the end of a beam that is 1.2 meters long. The beam is attached to a wall. Find the magnitude and direction (clockwise or counterclockwise) of the resulting torque at point B. Hint: Remember that force is measured in newtons, not kilograms.



2. Two masses m_1 and m_2 are suspended at the ends of a rod. The rod is hung from the ceiling at a point which is 10 centimeters from mass m_1 and 30 centimeters from mass m_2.

   a. If m_1 = 6 kg, what does m_2 have to be for the rod to be in rotational equilibrium?

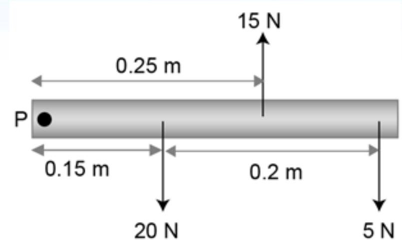


   b. Calculate the ratio of $\frac{m_1}{m_2}$ so that the rod will be horizontal.

   c. Suppose m_1 = 10 kg and m_2 = 2 kg. You wish to place a third mass, m_3 = 5 kg, on the bar to make it balance. Should m_3 be placed to the right or to the left of the rod's suspension point? Explain your answer.

   d. Calculate the exact location where m_3 should be placed.

3. Forces are applied on the beam as shown on the figure at right.



   a. Find the torque about point P produced by each of the three forces.

   b. Find the net torque about point P.

   c. A fourth force is applied to the beam at a distance of 0.30 m to the right of point P. What must the magnitude and direction of this force be to make the beam in rotational equilibrium?

4. Calculate the clockwise and counter clockwise torques for the lever diagramed below. Weights are given in newtons and distances in centimeters. Determine whether the lever is in rotational equilibrium. If it is not, determine the direction of rotation. If it is in equilibrium, can it be rotating? Explain.