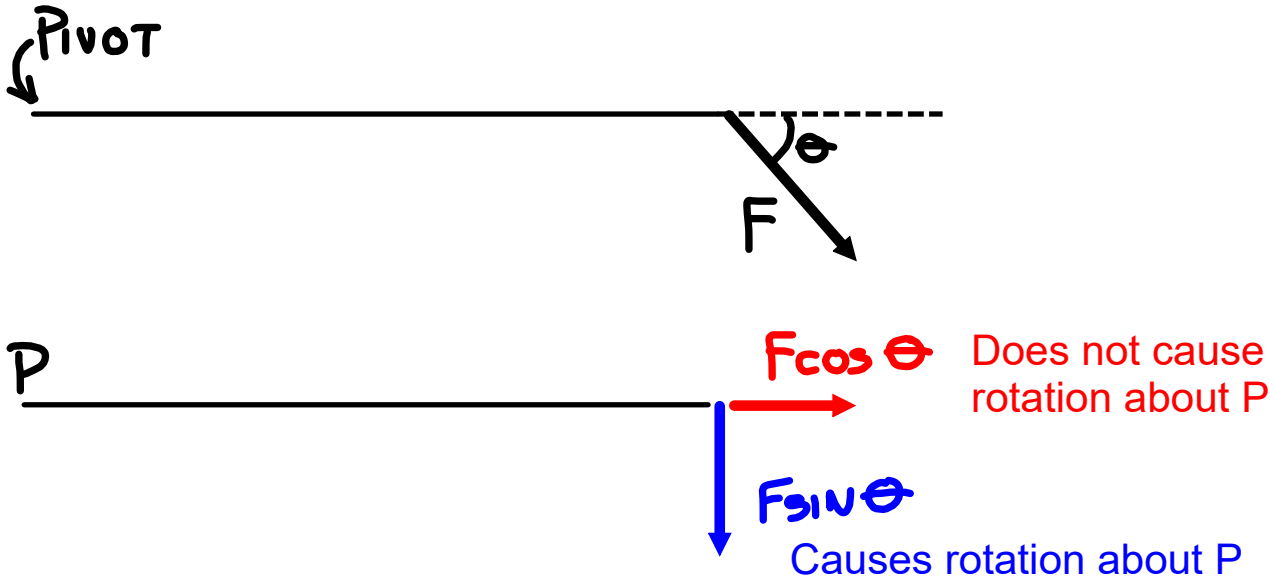
Torque and Rotational Equilibrium

Objectives:

- Students will understand what torque is and how it relates to forces.
- Students will know what rotational equilibrium is and what it implies about torques.
- Students will be able to use the concepts of torque and rotational equilibrium to solve statics problems.

Torque:

A torque is required to cause something to rotate.



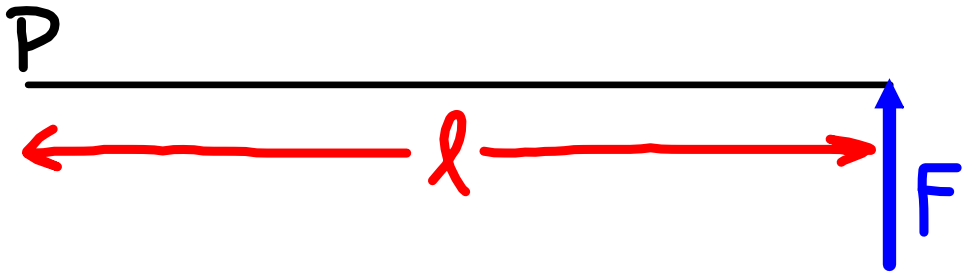
In general:

$$\text{Torque} = \tau = F \times \ell$$

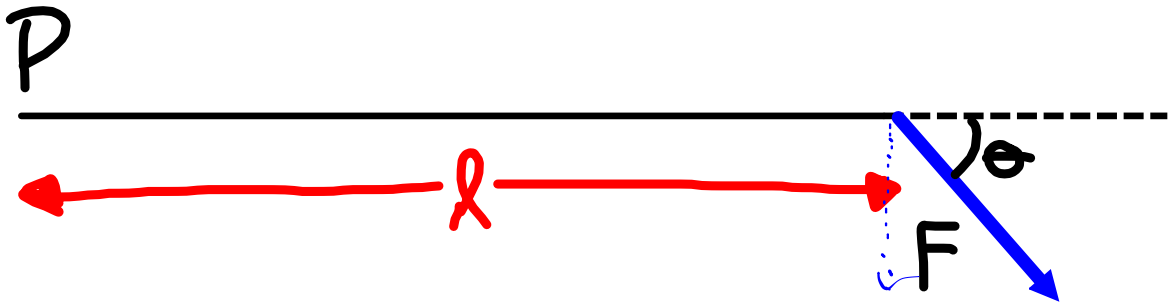
F = A Force ⊥ To ℓ

ℓ = Lever Arm (The displacement between the "pivot" and the location where the force is being applied)

Examples of determining torque:



$\tau = F \times l$



$\tau = F \sin\theta \times l$

Rotational Equilibrium

When considering cases of **translational** equilibrium, the location on a body at which a force acts is not important.

$$\Sigma F_x = 0$$

$$\Sigma F_y = 0$$

When considering cases of **rotational** equilibrium, the location at which a force acts is important.

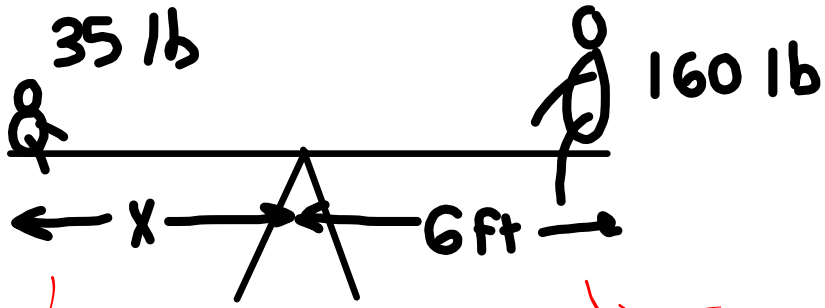
$$\Sigma F_x = 0$$

$$\Sigma F_y = 0$$

$$\Sigma \tau = 0$$

(No matter what point is taken to be the pivot. Rotational equilibrium exists only when the sum of the torques about ALL points on an object is zero).

Example: What does *x* need to be for the seesaw to be in rotational equilibrium?



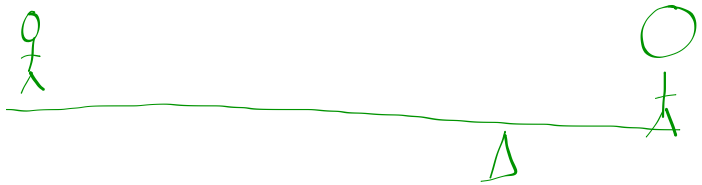
$\tau = 35\,lb \cdot x$

$\tau = 160\,lb \cdot 6\,ft$

$= 960\ ft \cdot lb$

$960 = 35x$

$x = 27.43\ ft$



System for Solving Rotational Equilibrium problems:

1. Draw a FBD.

2. Identify a point to serve as a pivot. (Note: if in equilibrium, the object will either not be rotating or will be rotating with a constant speed. In either case, ANY pivot point will work.)

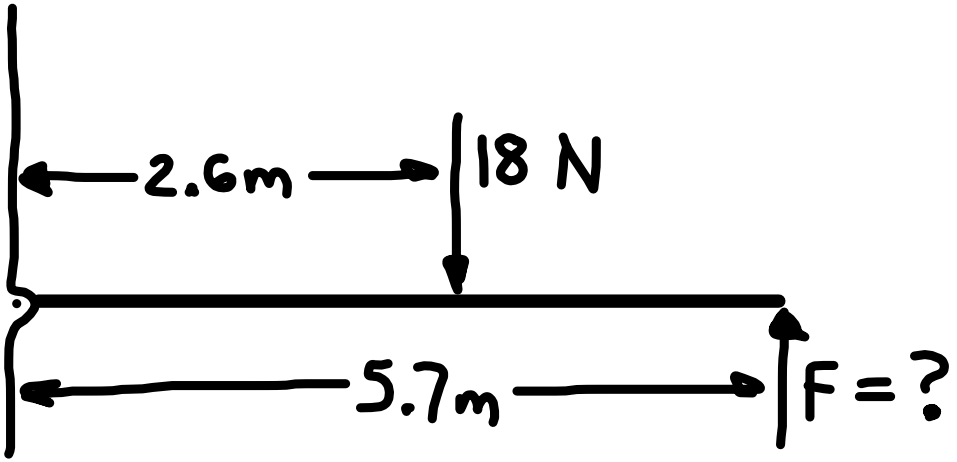
3. Establish a reference rotation (+/-).

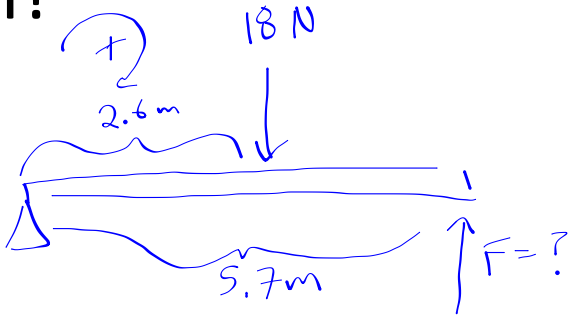
4. Resolve all forces into components:
   - One perpendicular to the lever arm
   - One parallel to the lever arm

5. The sum of all torques about the pivot point (and every point) on the object must equal zero.
   - If an object is causing the force, the location of the force is at the object's "center of mass" (C.O.M.)

6. Solve for unknowns.

Example: What does *F* need to be in order for the bar to be in rotational equilibrium?



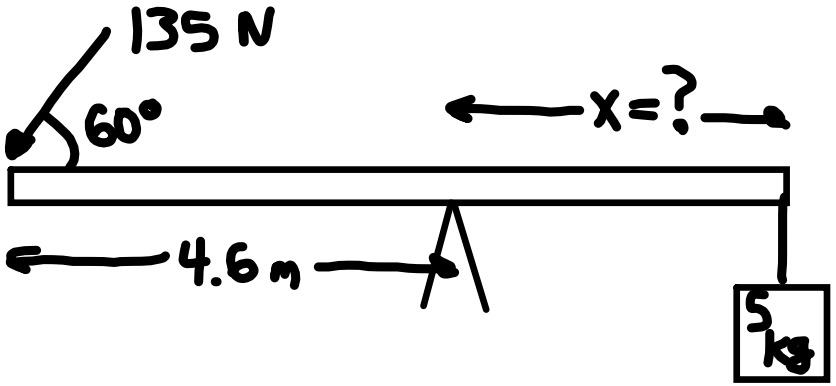


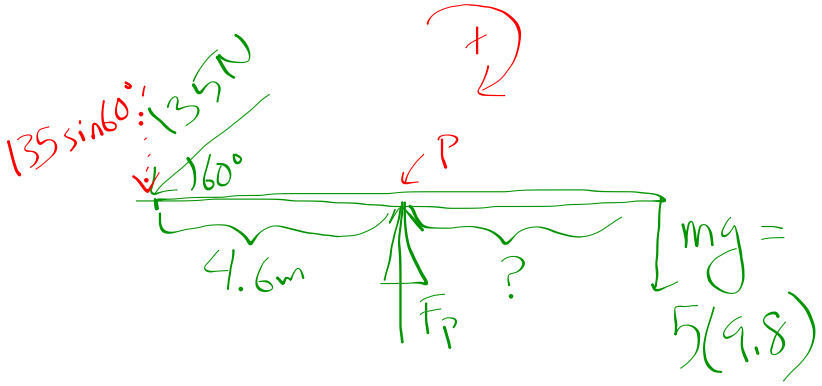
$$\Sigma\tau = 0$$

$$(18)(2.6) + -(F)(5.7) = 0$$

$$F = \frac{(18)(2.6)}{5.7}$$

Example: What does *x* need to be in order for the bar to be in rotational equilibrium?

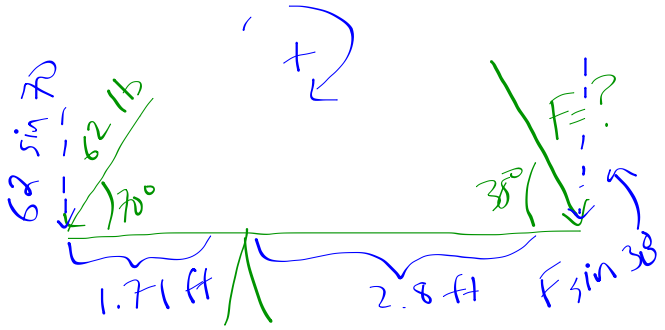




$$\Sigma\tau = \emptyset$$

$$-(135\sin 60)(4.6\text{ m}) + (F_p)(\emptyset) + (5)(9.8)(x) = \emptyset$$

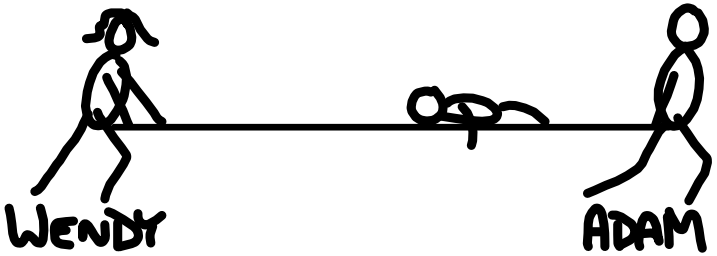
Example: What does *F* need to be in order for the bar to be in rotational equilibrium?



$$\Sigma\tau = 0$$

$$-(62\sin 70)(1.71) + F_p(0) + (F\sin 38)(2.8) = 0$$

Example: What are the forces that Adam and Wendy need to apply in order to keep the stretcher in rotational equilibrium?



- The stretcher has a mass of 1.3 slugs and is 7.0 ft long
- Foster weighs 35 lbs and his center of mass is 2.0 ft from Adam