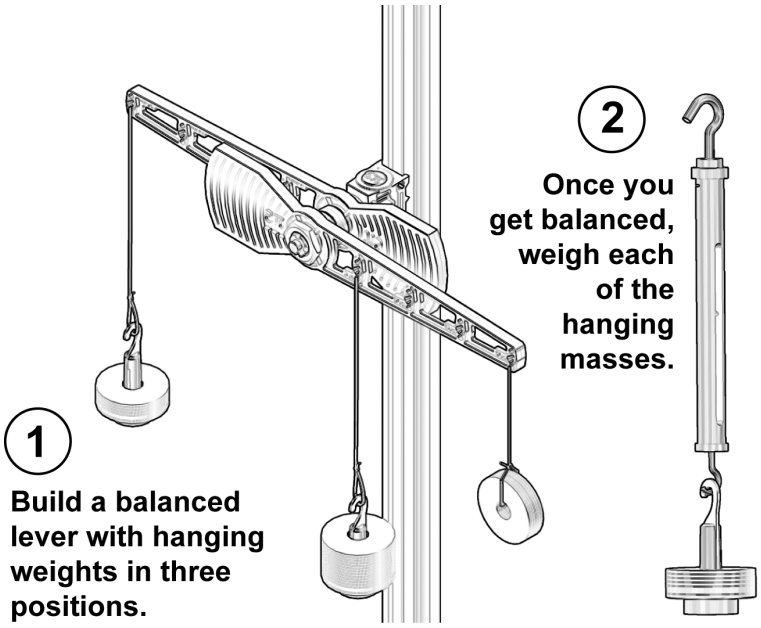
Investigation 12F: Torque

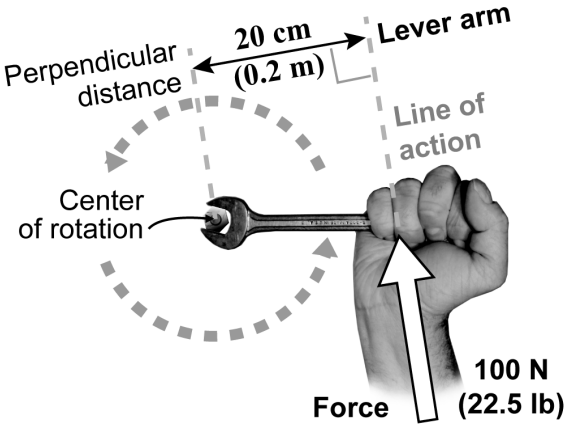
Essential question: How do forces affect rotating motion?

1. Build the lever in the diagram on the right adjusting the three hanging masses until the lever is balanced.
2. Measure and record the weight and distance for each hanging mass (Table 1).



A torque is a twisting action that may be created by forces. The torque created by a force depends on both the force and the *distance* the force acts from the center of rotation. This distance is called the *lever arm.* The same force applied with a longer lever arm created more torque.

The units of torque are force times distance, or newton-meters. A torque of 20 N·m is created by a force of 100 N acting with a lever arm of 0.2 m. Because torque is a product of two variables, it is possible to create the same torque with different forces. For example, a 20 N force applied with a lever arm of 1 m also produces a torque of 20 N·m.



The torque from a force

$$\begin{aligned} \tau &= r \times F \\ &= (0.2\ \text{m})(100\ \text{N}) \\ &= \mathbf{20\ N\ m} \end{aligned}$$

The sign of torques

Torques can be negative or positive depending on whether they tend to cause clockwise or counterclockwise rotation. By convention, *positive* torque increases the angle with the *x*-axis (*counterclockwise*). *Negative* torque decreases the angle with the *x*-axis (c*lockwise*).

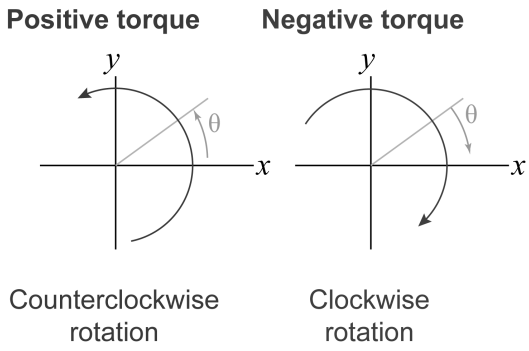


Table 1: Torque data

Distance (m)	Weight (N)	Torque (N·m)
	Sum	

Analysis

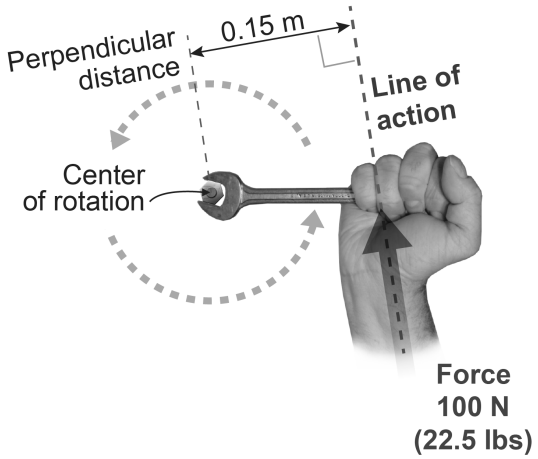
1. Calculate the torque in N·m and fill in the third column of Table 1.
2. Sum up the torques being careful to get the sign correct.

Questions

3. How does the sum of torques relate to the equilibrium of the lever? Can you state a rule for torque that applies to equilibrium?

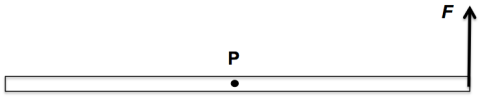
4. A wrench is used to apply a 100 N force at a distance 0.15 meters away from the center of a bolt. Calculate the torque created by this force.

5. Suppose the wrench in the diagram is 1.0 meter long. How much force is required to exert the same torque?

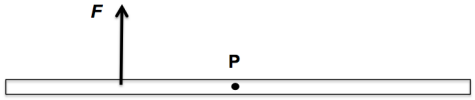


6. Mark each torque positive (CCW), negative (CW), or zero. The center of rotation is P and you may assume the force *F* acts on a uniform bar.

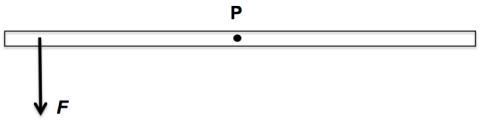
a) _____



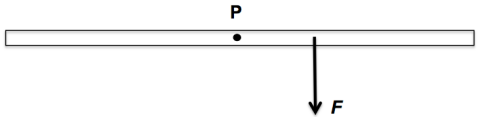
b) _____



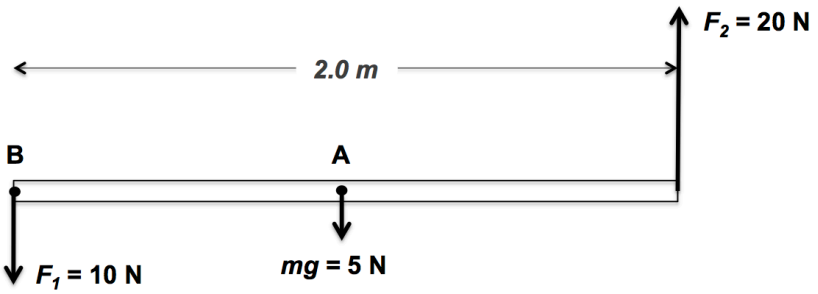
c) _____



d) _____



7. Three forces act upon a uniform horizontal rod: F_1, F_2, and weight mg. Calculate the magnitude and sign (+ or -) of the torque applied by each force for two possible pivot points, A and B. Add the torques to calculate the net torque.



	$F_1 = 10$ N	$F_2 = 20$ N	$mg = 5$ N	$\Sigma\tau$
Torque about A				
Torque about B				

8. Forces of magnitude F and $2F$ act on a uniform bar. Is the **net** torque about point P in the center of the bar positive (CCW), negative (CW), or zero?