

First Condition of Equilibrium

- Equilibrium means no _____
- First condition of equilibrium
- $net F = 0$
 - _____ and _____
 - They can still _____, so...

Torque

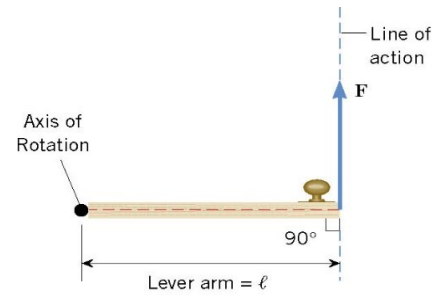
$$\tau = F \times r$$

This means we use the component of the _____ that is _____ to the _____ arm

$$\tau = F_{\perp} r$$

$$\tau = Fr \sin \theta$$

- Where θ is the angle between the _____ and the _____
- Unit: Nm
- CCW: _____
- CW: _____



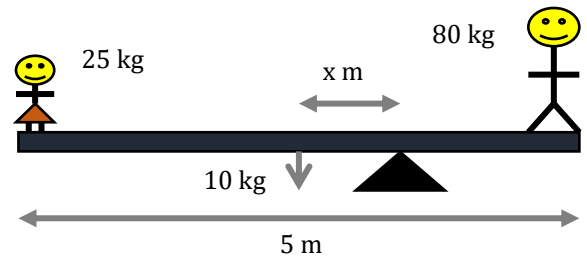
You are meeting the parents of your new “special” friend for the first time. After being at their house for a couple of hours, you walk out to discover the little brother has let all the air out of one of your tires. Not knowing the reason for the flat tire, you decide to change it. You have a 50-cm long lug-wrench attached to a lugnut as shown. If 900 Nm of torque is needed, how much force is needed?



Second condition of equilibrium

- _____

A 5 m, 10 kg seesaw is balanced by a little girl (25 kg) and her father (80 kg) at opposite ends as shown below. How far from the seesaw’s center of mass must the fulcrum be placed?



How much force must the fulcrum support?

Practice Work

1. What can you say about the velocity of a moving body that is in dynamic equilibrium? Draw a sketch of such a body using clearly labeled arrows to represent all external forces on the body.
2. Under what conditions can a rotating body be in equilibrium? Give an example.
3. What three factors affect the torque created by a force relative to a specific pivot point?
4. A wrecking ball is being used to knock down a building. One tall unsupported concrete wall remains standing. If the wrecking ball hits the wall near the top, is the wall more likely to fall over by rotating at its base or by falling straight down? Explain your answer. How is it most likely to fall if it is struck with the same force at its base? Note that this depends on how firmly the wall is attached at its base.
5. Mechanics sometimes put a length of pipe over the handle of a wrench when trying to remove a very tight bolt. How does this help? (It is also hazardous since it can break the bolt.)
6. (a) When opening a door, you push on it perpendicularly with a force of 55.0 N at a distance of 0.850 m from the hinges. What torque are you exerting relative to the hinges? (b) Does it matter if you push at the same height as the hinges? (OpenStax 9.1) **46.8 Nm**
7. When tightening a bolt, you push perpendicularly on a wrench with a force of 165 N at a distance of 0.140 m from the center of the bolt. (a) How much torque are you exerting in newton \times meters (relative to the center of the bolt)? (b) Convert this torque to footpounds. (OpenStax 9.2) **23.1 Nm, 17.0 ft lb**
8. Two children push on opposite sides of a door during play. Both push horizontally and perpendicular to the door. One child pushes with a force of 17.5 N at a distance of 0.600 m from the hinges, and the second child pushes at a distance of 0.450 m. What force must the second child exert to keep the door from moving? Assume friction is negligible. (OpenStax 9.3) **23.3 Nm**
9. The two children shown in the are balanced on a seesaw of negligible mass. (This assumption is made to keep the example simple—more involved examples will follow.) The first child has a mass of 26.0 kg and sits 1.60 m from the pivot. (a) If the second child has a mass of 32.0 kg, how far is she from the pivot? (b) What is F_{\perp} , the supporting force exerted by the pivot using the second condition for equilibrium (net $\tau = 0$), employing any data given or solved for in part (a). (OpenStax 9.4) **1.30 m, 568 N**
10. Repeat the previous problem with the center of mass of the seesaw 0.160 m to the left of the pivot (on the side of the lighter child) and assuming a mass of 12.0 kg for the seesaw. The other data given in the example remain unchanged. (OpenStax 9.5) **1.36 m, 686 N**

