TORQUE

Vocabulary **Torque:** A measurement of the tendency of a force to produce a rotation about an axis.

$$\textbf{torque} = \textbf{perpendicular force} \times \textbf{lever arm} \qquad \text{or} \qquad \tau = F \times d$$

The lever arm, d, is the distance from the pivot point, or fulcrum, to the point where the component of the force perpendicular to the lever arm is being exerted. The longer the lever arm, the larger the torque. This is why it is easier to loosen a tight screw with a long wrench than with your hand or a short pair of tweezers.

If a torque causes a counterclockwise rotation of an object around the fulcrum, it is positive. If the torque causes a clockwise rotation of an object around the fulcrum, it is negative. This convention works even if the object remains balanced and the torques just *attempt* to cause a rotation.

The SI unit for torque is the **newton·meter (N·m)**. However, unlike work, which is measured in the same unit, torque is not a form of energy and is not equivalent to a joule.

In most of the exercises in this book, all the torques are balanced. For example, if two people are sitting on either side of a seesaw and they want to remain level, they can position themselves so that all the torques on one side of the seesaw equal all the torques on the other side. The total torque on a system equals the sum of all the individual torques, or

$$\tau = (F_1 \times d_1) + (F_2 \times d_2) + \ldots$$

The ... means that there may be more than only two torques acting on a system at any one time. Keep in mind that when an object is balanced, all the torques must also balance. Therefore, the total torque, τ, is zero.

Vocabulary **Center of Gravity:** The point on any object that acts like the place at which all the weight is concentrated.

The weight of an object, which acts as if it is concentrated at the center of gravity, is one of the forces that can cause it to rotate. The weight produces a torque if the object is not supported at its center of gravity.

Solved Examples

Example 5: Ned tightens a bolt in his car engine by exerting 12 N of force on his wrench at a distance of 0.40 m from the fulcrum. How much torque must Ned produce to turn the bolt?

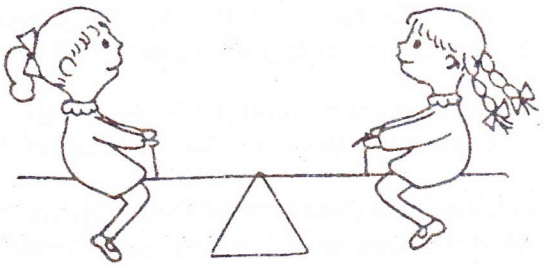
Given: $F = 12\ N$
$d = 0.40\ m$

Unknown: $\tau = ?$
Original equation: $\tau = F \times d$

Solve: $\tau = F \times d = (12\ N)(0.40\ m) = \mathbf{4.8\ N \cdot m}$

Example 6: Mabel and Maude are seesawing on the school playground and decide to see if they can move to the correct location to make the seesaw balance. Mabel weighs 400. N and she sits 2.00 m from the fulcrum of the seesaw. Where should 450.-N Maude sit to balance the seesaw?

Solution: It helps to draw a diagram of the situation to allow yourself to visualize what is happening.



Given: $F_1 = 400.\ N$
$F_2 = 450.\ N$
$d_1 = 2.00\ m$

Unknown: $d_2 = ?$
Original equation: $\tau = (F_1 \times d_1) + (F_2 \times d_2)$

Solve: If 400.-N Mabel makes the seesaw turn in a counterclockwise direction, then 450.-N Maude makes the seesaw turn in a clockwise direction. Therefore, $\tau = (F_1 \times d_1) + -(F_2 \times d_2)$. If the seesaw is balanced, then $\tau = 0$ and the equation becomes $\tau = (F_1 \times d_1) + -(F_2 \times d_2) = 0$, or $(F_1 \times d_1) = (F_2 \times d_2)$. Therefore,

$$d_2 = \frac{(F_1 \times d_1)}{F_2} = \frac{(400.\ N)(2.00\ m)}{450.\ N} = \mathbf{1.78\ m}\ \text{from the fulcrum.}$$

Practice Exercises

Exercise 13: A water faucet is turned on when a force of 2.0 N is exerted on the handle, at a distance of 0.060 m from the pivot point. How much torque must be produced to turn the handle?

Exercise 14: Nancy, whose mass is 60.0 kg, is working at a construction site and she sits down for a bite to eat at noon. If Nancy sits on the very end of a 3.00–m–long plank pivoted in the middle on a saw horse, how much torque must her co–worker provide on the other end of the plank in order to keep Nancy from falling on the ground?

Exercise 15: Barry carries his tray of food to his favorite cafeteria table for lunch. The 0.50–m–long tray has a mass of 0.20 kg and holds a 0.40–kg plate of food 0.20 m from the right edge. Barry holds the tray by the left edge with one hand, using his thumb as the fulcrum, and pushes up 0.10 m from the fulcrum with his finger tips. How much upward force must his finger tips exert to keep the tray level? b) How might Barry make the tray easier to carry if he still chooses to use only one hand?

Exercise 16: Tracey is building a mobile to hang over her baby's crib. She hangs a 0.020–kg toy sailboat 0.010 m from the left end and a 0.015–kg toy truck 0.20 m from the right end of a bar 0.50 m long. If the lever arm itself has negligible mass, where must the support string be placed so that the arm balances?

Exercise 17: Orin and Ann, two paramedics, rush a 60.0–kg man from the scene of an accident to a waiting ambulance, carrying him on a uniform 3.00–kg stretcher held by the ends. The stretcher is 2.60 m long and the man's center of mass is 1.00 m from Ann. How much force must Orin and Ann each exert to keep the man horizontal?