Chapter 8
Torque

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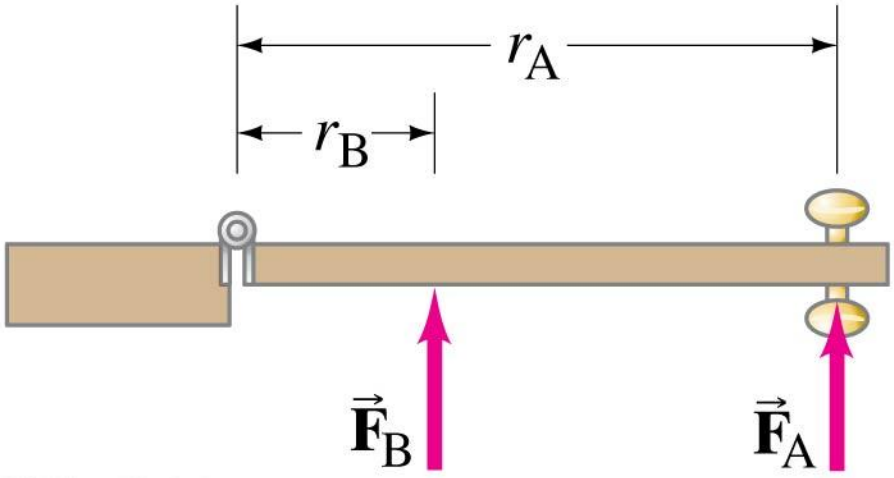
8-4 Torque

To make an object start rotating, a force is needed; the position and direction of the force matter as well.

The perpendicular distance from the axis of rotation to the line along which the force acts is called the lever arm.



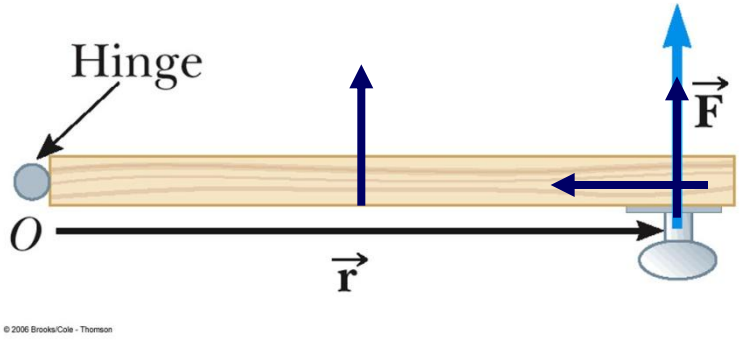
8-4 Torque

A longer lever arm is very helpful in rotating objects.

(a) (b)

Force vs. Torque

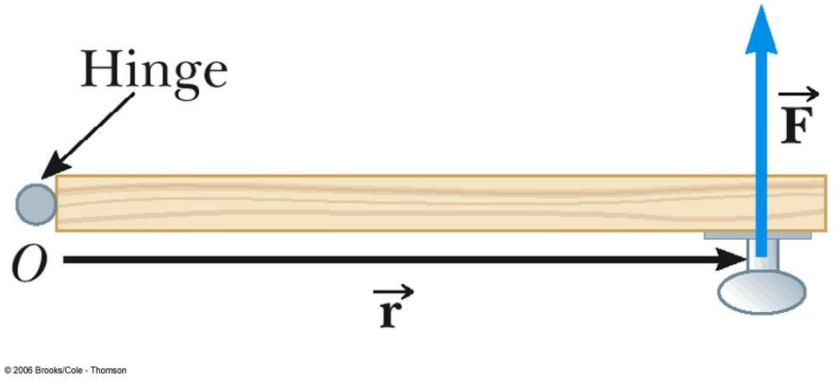
- Forces cause accelerations
- What cause angular accelerations ?
- A door is free to rotate about an axis through O
- There are three factors that determine the effectiveness of the force in opening the door:
  - The *magnitude* of the force
  - The *position* of the application of the force
  - The *angle* at which the force is applied



Torque Definition

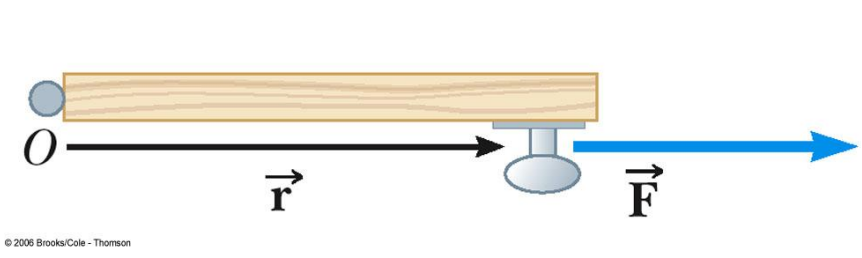
- Torque, τ, is the tendency of a force to rotate an object about some axis
- Let **F** be a force acting on an object, and let **r** be a position vector from a rotational center to the point of application of the force, with **F** perpendicular to **r**. The magnitude of the torque is given by

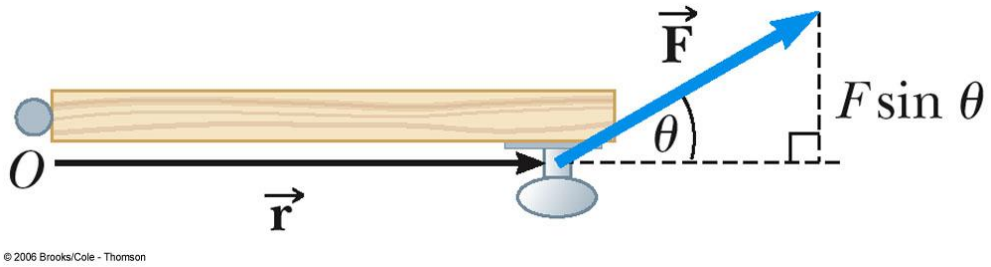
$$\tau = rF$$



General Definition of Torque

- The applied force is not always perpendicular to the position vector
- The component of the force *perpendicular* to the object will cause it to rotate
- When the force is parallel to the position vector, no rotation occurs
- When the force is at some angle, the perpendicular component causes the rotation

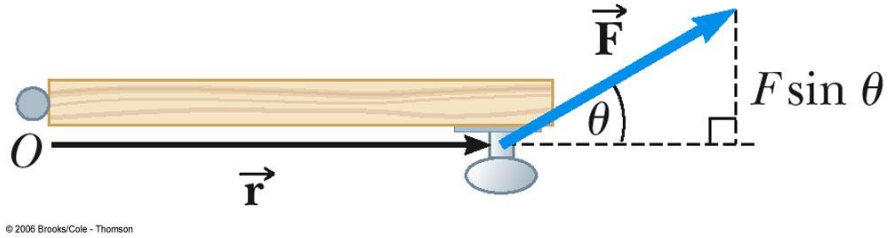




General Definition of Torque

- Let **F** be a force acting on an object, and let **r** be a position vector from a rotational center to the point of application of the force. The magnitude of the torque is given by

$$\tau = rF\sin\theta$$



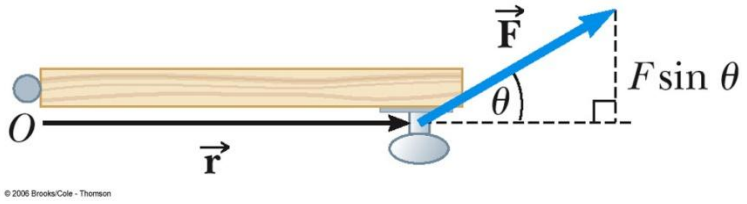
- $\theta = 0^\circ$ or $\theta = 180^\circ$: torque are equal to zero
- $\theta = 90^\circ$ or $\theta = 270^\circ$: magnitude of torque attain to the maximum

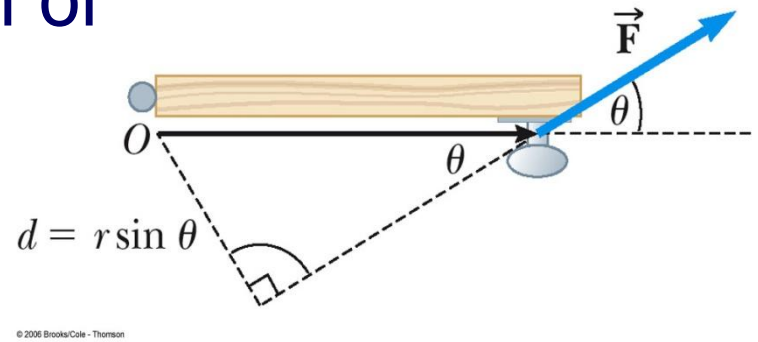
Understand sinθ

- The component of the force ($F\cos\theta$) has **no** tendency to produce a rotation
- The moment arm, *d*, is the *perpendicular* distance from the axis of rotation to a line drawn along the direction of the force

$$d = r\sin\theta$$

$$\tau = rF\sin\theta = Fd$$





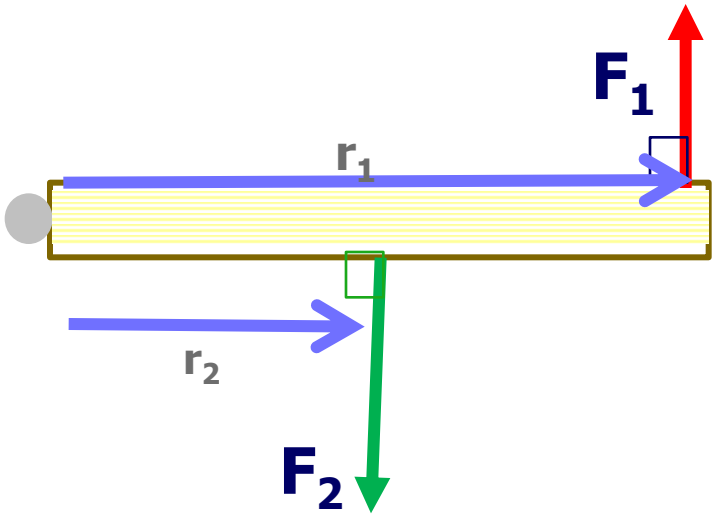
Torque Units and Direction

- The SI units of torque are N·m
- Torque is a vector quantity
- Torque magnitude is given by $\tau = rF\sin\theta = Fd$
- Torque will have direction
  - If the turning tendency of the force is counterclockwise, the torque will be positive (+)

  - If the turning tendency of the force is clockwise, the torque will be negative (-)

Net Torque

- The force $\vec{F}_1$ will tend to cause a counterclockwise rotation about *O*
- The force $\vec{F}_2$ will tend to cause a clockwise rotation about *O*
- $\Sigma\tau = \tau_1 + \tau_2 = F_1 r_1 - F_2 r_2$
- If $\Sigma\tau \neq 0$, starts rotating
- If $\Sigma\tau = 0$, rotation rate does not change



EXAMPLE 8-8 Biceps torque.

The biceps muscle exerts a vertical force on the lower arm, bent as shown in Figs. 8–14a and b. For each case, calculate the torque about the axis of rotation through the elbow joint, assuming the muscle is attached 5.0 cm from the elbow as shown.

SOLUTION (a) $F = 700\,\text{N}$ and $r_\perp = 0.050\,\text{m}$, so

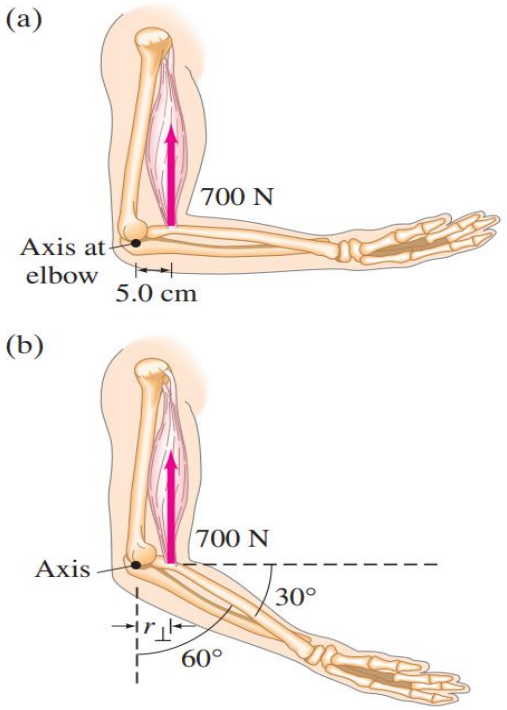
$$\tau = r_\perp F = (0.050\,\text{m})(700\,\text{N}) = 35\,\text{m}\cdot\text{N}.$$

(b) $$r_\perp = (0.050\,\text{m})(\sin 60°)$$

$$\tau = r_\perp F$$

$$\tau = (0.050\,\text{m})(0.866)(700\,\text{N}) = 30\,\text{m}\cdot\text{N}.$$

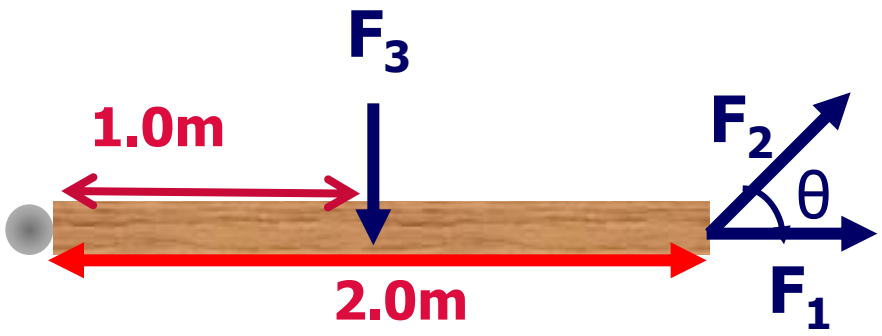
FIGURE 8–14 Example 8–8.



The Swinging Door

- Three forces are applied to the door, as shown in figure. What is the net torque ? Assume

  $F_1 = 150$ N, $F_2 = 300$ N, $F_3 = 300$ N, $\theta = 30^\circ$



Problem 24

A 52-kg person riding a bike puts all her weight on each pedal when climbing a hill. The pedals rotate in a circle of radius 17 cm. (a) What is the maximum torque she exerts? (b) How could she exert more torque?

Problem 25

Calculate the net torque about the axle of the wheel shown in Fig. 8–42. Assume that a friction torque of 0.60 m.N opposes the motion.

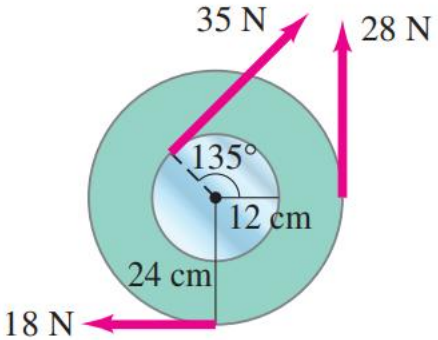


FIGURE 8–42 Problem 25.

Problem 27

Two blocks, each of mass m, are attached to the ends of a massless rod which pivots as shown in Fig. 8–43. Initially the rod is held in the horizontal position and then released. Calculate the magnitude and direction of the net torque on this system when it is first released.

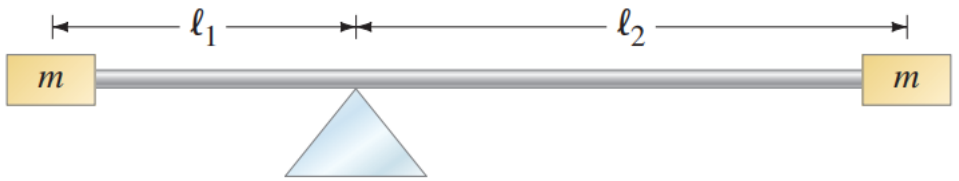


FIGURE 8–43 Problem 27.