

## Section Summary

### 9.1 The First Condition for Equilibrium

- Statics is the study of forces in equilibrium.
- Two conditions must be met to achieve equilibrium, which is defined to be motion without linear or rotational acceleration.
- The first condition necessary to achieve equilibrium is that the net external force on the system must be zero, so that  $\mathbf{F} = 0$ .

### 9.2 The Second Condition for Equilibrium

- The second condition assures those torques are also balanced. Torque is the rotational equivalent of a force in producing a rotation and is defined to be
- $\tau = rF \sin \theta$

where  $\tau$  is torque,  $r$  is the distance from the pivot point to the point where the force is applied,  $F$  is the magnitude of the force, and  $\theta$  is the angle between  $F$  and the vector directed from the point where the force acts to the pivot point. The perpendicular lever arm  $r_{\perp}$  is defined to be

$$r_{\perp} = r \sin \theta$$

so that

$$\tau = r_{\perp} F.$$

- The perpendicular lever arm  $r_{\perp}$  is the shortest distance from the pivot point to the line along which  $\vec{F}$  acts. The SI unit for torque is newton-meter ( $\text{N} \cdot \text{m}$ ). The second condition necessary to achieve equilibrium is that the net external torque on a system must be zero:
- $\tau_{\text{net}} = 0$

By convention, counterclockwise torques are positive, and clockwise torques are negative.

### 9.3 Stability

- A system is said to be in stable equilibrium if, when displaced from equilibrium, it experiences a net force or torque in a direction opposite the direction of the displacement.
- A system is in unstable equilibrium if, when displaced from equilibrium, it experiences a net force or torque in the same direction as the displacement from equilibrium.
- A system is in neutral equilibrium if its equilibrium is independent of displacements from its original position.

#### **9.4 Applications of Statics, Including Problem-Solving Strategies**

- Statics can be applied to a variety of situations, ranging from raising a drawbridge to bad posture and back strain. We have discussed the problem-solving strategies specifically useful for statics. Statics is a special case of Newton's laws, both the general problem-solving strategies and the special strategies for Newton's laws, discussed in Problem-Solving Strategies, still apply.

#### **9.5 Simple Machines**

- Simple machines are devices that can be used to multiply or augment a force that we apply – often at the expense of a distance through which we have to apply the force.
- The ratio of output to input forces for any simple machine is called its mechanical advantage
- A few simple machines are the lever, nail puller, wheelbarrow, crank, etc.

#### **9.6 Forces and Torques in Muscles and Joints**

- Statics plays an important part in understanding everyday strains in our muscles and bones.
- Many lever systems in the body have a mechanical advantage of significantly less than one, as many of our muscles are attached close to joints.
- Someone with good posture stands or sits in such a way that the person's center of gravity lies directly above the pivot point in the hips, thereby avoiding back strain and damage to disks.