When the spring's compression is equal to the distance the spring was originally stretched away from the equilibrium position (x), as shown in **Figure 1(c),** the mass is at maximum displacement, and the spring force and acceleration of the mass reach a maximum. At this point, the speed of the mass becomes zero. The spring force acting to the right causes the mass to change its direction, and the mass begins moving back toward the equilibrium position. Then the entire process begins again, and the mass continues to oscillate back and forth over the same path.

In an ideal system, the mass-spring system would oscillate indefinitely. But in the physical world, friction retards the motion of the vibrating mass, and the mass-spring system eventually comes to rest. This effect is called *damping.* In most cases, the effect of damping is minimal over a short period of time, so the ideal mass-spring system provides an approximation for the motion of a physical mass-spring system.

In simple harmonic motion, restoring force is proportional to displacement

As you have seen, the spring force always pushes or pulls the mass toward its original equilibrium position. For this reason, it is sometimes called a *restoring force.* Measurements show that the restoring force is directly proportional to the displacement of the mass. This relationship was determined in 1678 by Robert Hooke and is known as *Hooke's Law.* The following equation mathematically describes Hooke's Law:

HOOKE'S LAW

$$F_{elastic} = -kx$$

spring force = −(spring constant × displacement)

The negative sign in the equation signifies that the direction of the spring force is always opposite the direction of the mass's displacement from equilibrium. In other words, the negative sign shows that the spring force will tend to move the object back to its equilibrium position.

As mentioned in the chapter "Work and Energy," the quantity k is a positive constant called the *spring constant.* The value of the spring constant is a measure of the stiffness of the spring. A greater value of k means a stiffer spring because a greater force is needed to stretch or compress that spring a given amount. The SI units of k are N/m. As a result, N is the unit of the spring force when the spring constant (N/m) is multiplied by the displacement (m). The motion of a vibrating mass-spring system is an example of **simple harmonic motion.** Simple harmonic motion describes any periodic motion that is the result of a restoring force that is proportional to displacement. Because simple harmonic motion involves a restoring force, every simple harmonic motion is a back-and-forth motion over the same path.

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simple harmonic motion

vibration about an equilibrium position in which a restoring force is proportional to the displacement from equilibrium

Why it Matters

Conceptual Challenge

1. Earth's Orbit

The motion of Earth orbiting the sun is periodic. Is this motion simple harmonic? Why or why not?

2. Pinball

In pinball games, the force exerted by a compressed spring is used to release a ball. If the distance the spring is compressed is doubled, how will the force exerted on the ball change? If the spring is replaced with one that is half as stiff, how will the force acting on the ball change?