

## Vibrations and Waves

**Problem A****HOOKE'S LAW****PROBLEM**

The pygmy shrew has an average mass of 2.0 g. If 49 of these shrews are placed on a spring scale with a spring constant of 24 N/m, what is the spring's displacement?

**SOLUTION****1. DEFINE**

**Given:**  $m =$  mass of one shrew  $= 2.0 \text{ g} = 2.0 \times 10^{-3} \text{ kg}$

$$n = 49$$

$$g = 9.81 \text{ m/s}^2$$

$$k = 24 \text{ N/m}$$

**Unknown:**

**2. PLAN Choose the equation(s) or situation:** When the shrews are attached to the spring, the equilibrium position changes. At the new equilibrium position, the net force acting on the shrews is zero. So the spring force (given by Hooke's law) must be equal to and opposite the weight of the shrews.

$$\mathbf{F}_{\text{net}} = 0 = \mathbf{F}_{\text{elastic}} + \mathbf{F}_g$$

$$F_{\text{elastic}} = -kx$$

$$F_g = -m_{\text{tot}}g = -nmg$$

$$-kx - nmg = 0$$

**Rearrange the equation(s) to isolate the unknown(s):**

$$x = \frac{-nmg}{k}$$

**3. CALCULATE Substitute the values into the equation(s) and solve:**

$$x = \frac{-(49)(2.0 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)}{(24 \text{ N/m})}$$

$$x = -4.0 \times 10^{-2} \text{ m}$$

**4. EVALUATE** Forty-nine shrews of 2.0 g each provide a total mass of about 0.1 kg, or a weight of just under 1 N. From the value of the spring constant, a force of 1 N should displace the spring by 1/24 of a meter, or about 4 cm. This indicates that the final result is consistent with the rest of the data.

**ADDITIONAL PRACTICE**

1. The largest meteorite of lunar origin reportedly has a mass of 19 g. If the meteorite placed on a scale whose spring constant is 83 N/m, what is the compression of the spring?

2. In 1952, a great rainfall hit the island of Reunion in the Indian Ocean. In less than 24 h, 187 kg of rain fell on each square meter of soil. If a 187 kg mass is placed on a scale that has a spring constant of  $1.53 \times 10^4$  N/m, how far is the spring compressed?
3. The largest tigers, and therefore the largest members of the cat family, are the Siberian tigers. Male Siberian tigers are reported to have an average mass of about 389 kg. By contrast, a variety of very small cat that is native to India has an average adult mass of only 1.5 kg. Suppose this small cat is placed on a spring scale, causing the spring to be extended from its equilibrium position by 1.2 mm. How far would the spring be extended if a typical male Siberian tiger were placed on the same scale?
4. The largest known crab is a giant spider crab that had a mass of 18.6 kg. The distance from the end of one of this crab's claws to the end of the other claw measured about 3.7 m. If this particular giant spider crab were hung from an elastic band so that the elongation of the band was equal to the crab's claw span, what would be the spring constant of the elastic band?
5. The CN Tower in Toronto, Canada, is 533 m tall, making it the world's tallest free-standing structure. Suppose an unusually long bungee cord is attached to the top of the CN Tower. The equilibrium length of the cord is equal to one-third the height of the tower. When a test mass of 70.0 kg is attached, the cord stretches to a length that equals two-thirds of the tower's height. From this information, determine the spring constant of the bungee cord.
6. The largest ruby in the world may be found in New York. This ruby is 109 mm long, 91 mm wide, and 58 mm thick, making its volume about  $575 \text{ cm}^3$ . (By comparison, the world's largest diamond, the Star of Africa, has a volume of just over  $30 \text{ cm}^3$ .)
  - a. If the ruby is attached to a vertically hanging spring with a spring constant of  $2.00 \times 10^2$  N/m so that the spring is stretched 15.8 cm what is the gravitational force pulling the spring?
  - b. What is the mass of the jewel?
7. Mauna Kea on the island of Hawaii stands 4200 m above sea level. However, when measured from the island's sea-submerged base, Mauna Kea has a height of 10 200 m, making it the tallest single mountain in the world. If you have a  $4.20 \times 10^3$  m elastic cord with a spring constant of  $3.20 \times 10^{-2}$  N/m, what force would stretch the spring to  $1.02 \times 10^4$  m?
8. Rising 348 m above the ground, La Gran Piedra in Cuba is the tallest rock on Earth. Suppose an elastic band  $2.00 \times 10^2$  m long hangs vertically off the top of La Gran Piedra. If the band's spring constant is 25.0 N/m, how large must a mass be if, when it is attached to the band, it causes the band to stretch all the way to the ground?