P = 0

76 cm

P = 1 atm

FIGURE 10–9 A mercury barometer, invented by Torricelli, is shown here when the air pressure is standard atmospheric, 76 cm-Hg.

Barometer

Atmospheric pressure can be measured by a modified kind of mercury manometer with one end closed, called a mercury **barometer** (Fig. 10–9). The glass tube is completely filled with mercury and then inverted into the bowl of mercury. If the tube is long enough, the level of the mercury will drop, leaving a vacuum at the top of the tube, since atmospheric pressure can support a column of mercury only about 76 cm high (exactly 76.0 cm at standard atmospheric pressure). That is, a column of mercury 76 cm high exerts the same pressure as the atmosphere[†]:

$$P = \rho g \, \Delta h$$
$$= (13.6 \times 10^3 \, \text{kg/m}^3)(9.80 \, \text{m/s}^2)(0.760 \, \text{m}) = 1.013 \times 10^5 \, \text{N/m}^2 = 1.00 \, \text{atm}.$$

Household barometers are usually of the aneroid type, either mechanical (Fig. 10–8b) or electronic.

A calculation similar to that above will show that atmospheric pressure can maintain a column of water 10.3 m high in a tube whose top is under vacuum (Fig. 10–10). No matter how good a vacuum pump is, it cannot lift water more than about 10 m. To pump water out of deep mine shafts with a vacuum pump requires multiple stages for depths greater than 10 m. Galileo studied this problem, and his student Torricelli was the first to explain it. The point is that a pump does not really suck water up a tube—it merely reduces the pressure at the top of the tube. Atmospheric air pressure *pushes* the water up the tube if the top end is at low pressure (under a vacuum), just as it is air pressure that pushes (or maintains) the mercury 76 cm high in a barometer.

FIGURE 10–10 A water barometer: a full tube of water is inserted into a tub of water, keeping the spigot at the top closed. When the bottom end of the tube is uncovered, some water flows out of the tube into the tub, leaving a vacuum between the water's upper surface and the spigot. Why? Because air pressure can not support a column of water more than 10 m high.

CONCEPTUAL EXAMPLE 10–5 | **Suction.** You sit in a meeting where a novice NASA engineer proposes suction cup shoes for Space Shuttle astronauts working on the exterior of the spacecraft. Having just studied this Chapter, you gently remind him of the fallacy of this plan. What is it?

RESPONSE Suction cups work by pushing out the air underneath the cup. What holds the cup in place is the air pressure outside the cup. (This can be a substantial force when on Earth. For example, a 10-cm-diameter cup has an area of $7.9 \times 10^{-3} \, \text{m}^2$. The force of the atmosphere on it is $(7.9 \times 10^{-3} \, \text{m}^2)(1.0 \times 10^5 \, \text{N/m}^2) \approx 800 \, \text{N}$, about 180 lbs!). But in outer space, there is no air pressure to hold the suction cup onto the spacecraft.

We sometimes mistakenly think of suction as something we actively do. For example, we intuitively think that we pull the soda up through a straw. Instead, what we do is lower the pressure at the top of the straw, and the atmosphere *pushes* the soda up the straw.

[†]This calculation confirms the entry in Table 10–2, 1 atm = 76 cm-Hg.