EXERCISE B On the hydrometer of Example 10–9, will the marks above the 1.000 mark represent higher or lower values of density of the liquid in which it is submerged?

Archimedes principle is also useful in geology. According to the theories of plate tectonics and continental drift, the continents float on a fluid "sea" of slightly deformable rock (mantle rock). Some interesting calculations can be done using very simple models, which we consider in the Problems at the end of the Chapter.

Air is a fluid, and it too exerts a buoyant force. Ordinary objects weigh less in air than they do if weighed in a vacuum. Because the density of air is so small, the effect for ordinary solids is slight. There are objects, however, that *float* in air—helium-filled balloons, for example, because the density of helium is less than the density of air.
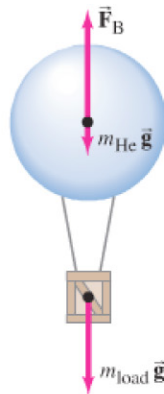
FIGURE 10–18 Example 10–10.

EXAMPLE 10–10 **Helium balloon.** What volume V of helium is needed if a balloon is to lift a load of 180 kg (including the weight of the empty balloon)?

APPROACH The buoyant force on the helium balloon, F_B, which is equal to the weight of displaced air, must be at least equal to the weight of the helium plus the weight of the balloon and load (Fig. 10–18). Table 10–1 gives the density of helium as 0.179 kg/m^3.

SOLUTION The buoyant force must have a minimum value of

$$F_B = (m_{He} + 180 \text{ kg})g.$$

This equation can be written in terms of density using Archimedes' principle:

$$\rho_{air} V g = (\rho_{He} V + 180 \text{ kg})g.$$

Solving now for V, we find

$$V = \frac{180 \text{ kg}}{\rho_{air} - \rho_{He}}$$

$$= \frac{180 \text{ kg}}{(1.29 \text{ kg/m}^3 - 0.179 \text{ kg/m}^3)} = 160 \text{ m}^3.$$

NOTE This is the minimum volume needed near the Earth's surface, where $\rho_{air} = 1.29 \text{ kg/m}^3$. To reach a high altitude, a greater volume would be needed since the density of air decreases with altitude.