Archimedes' principle is the law of buoyancy. It states that "any body partially or completely submerged in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body." The weight of an object acts downward, and the buoyant force provided by the displaced fluid acts upward. If these two forces are equal, the object floats. Density is defined as weight per volume. If the density of an object exceeds the density of water, the object will sink.

Archimedes Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

Hot air balloons rise into the air because the density of the air (warmer air) inside the balloon is less dense than the air outside the balloon (cooler air). The balloon and the basket displaces a fluid that is heavier than the balloon and the basket, so it has a buoyant force acting on the system. Balloons tend to fly better in the morning, when the surrounding air is cool.

Review Exercises (not homework):

1. Find the weight of the air in a room with dimensions of 20 ft x 12 ft x 15 ft. The weight density of air at sea level is 0.08 pounds/ft^3.

2. An iron anchor weighs 250 pounds in air and has a weight density of 480 lbs/ft^3. If it is immersed in sea water that has a weight density of 64 lbs/ft^3, how much force would be required to lift it while it is immersed?
2.15R (Buoyancy) A hot-air balloon weighs 500 lb, including the weight of the balloon, the basket, and one person. The air outside the balloon has a temperature of 80°F, and the heated air inside the balloon has a temperature of 150°F. Assume the inside and outside air to be at standard atmospheric pressure of 14.7 psia. Determine the required volume of the balloon to support the weight. If the balloon had a spherical shape, what would be the required diameter?

(ANS: 59,200 ft³; 48.3 ft)

For equilibrium,
\[ \sum F_{\text{vertical}} = 0 \]
so that
\[ F_B = W_a + W_b \]

Where:
- \( F_B \) = buoyant force
- \( W_a \) = weight of air inside balloon
- \( W_b \) = weight of basket and load

Thus,
\[ (\gamma_{\text{outside}}) V = (\gamma_{\text{inside}}) V + W_b \]

From the ideal gas law \( pV = nRT = \frac{m}{\gamma}RT \) or
\[ \gamma = \frac{pR}{m} \]

For outside air with \( T = 80°F = 460°F = 540°R \),
\[ \gamma_{\text{outside}} = \frac{(32.2 \text{ ft}^3/\text{slug})(14.7 \text{ lb/slug})}{(1716 \text{ ft} \cdot \text{lb/slug} \cdot \text{°R})(540°R)} = 0.07356 \text{ lb/ft}^3 \]

Similarly for inside air with \( T = 150°F = 640°F = 610°R \),
\[ \gamma_{\text{inside}} = \frac{(540°R)}{(610°R)} \left(0.07356 \text{ lb/ft}^3\right) = 0.06512 \text{ lb/ft}^3 \]

Thus, from Eq (1)
\[ V = \frac{W_b}{\gamma_{\text{outside}} - \gamma_{\text{inside}}} \]
\[ V = \frac{500 \text{ lb}}{0.07356 \text{ lb/ft}^3 - 0.06512 \text{ lb/ft}^3} = 59,200 \text{ ft}^3 \]

For spherical shape (with \( d = \) diameter),
\[ \frac{\pi}{6} d^3 = 59,200 \text{ ft}^3 \]
so that \( d = 48.3 \text{ ft} \)