Block A in Figure 13.46 hangs by a cord from spring balance D and is submerged in a liquid C contained in beaker B. The mass of the beaker is 1.00 kg; the mass of the liquid is 1.80 kg. Balance D reads 3.50 kg and balance E reads 7.50 kg. The volume of block A is $3.80 \times 10^{-3}$ m$^3$. (a) What is the density of the liquid? (b) What will each balance read if block A is pulled up out of the liquid?

![Figure 13.46 Problem 66.](image)

The spring scale D exerts a tension force $F_D$ up but the read out reported is $F_D/g = 3.50$ kg. The balance scale E exerts a force $F_E$ up on the bottom of the beaker, but the read out reported is $F_E/g = 7.50$ kg.

The system consisting of block A, beaker B and liquid C has a total weight

$$W_{ABC} = (m_A + m_B + m_C)g$$

The system is in equilibrium.

$$F_D + F_E - W_{ABC} = 0$$

$$F_D + F_E - (m_A + m_B + m_C)g = 0$$

$$m_A = \frac{F_D}{g} + \frac{F_E}{g} - m_B - m_C$$

$$m_A = 3.50\text{ kg} + 7.50\text{ kg} - 1.00\text{ kg} - 1.80\text{ kg}$$

$$m_A = 8.20\text{ kg}$$

Now consider just mass A. The forces acting on $m_A$ are its weight, the tension force $F_D$ and a buoyant force $F_{buoyant}$ because it displaces some of the liquid.
\[ F_D + F_{\text{buoyant}} - W_A = 0 \]

The buoyant force is

\[ F_{\text{buoyant}} = \rho_{\text{lg}} \cdot V \cdot \text{displaced} \cdot \text{lg}. \]

But \( V \cdot \text{displaced} \cdot \text{lg} = V_A = 3.80 \times 10^{-3} \text{m}^3 \)

since the block A is totally submerged.

Thus

\[ 3.50 \text{kg} \cdot g + \rho_{\text{lg}} \cdot g \cdot V_A = m_A \cdot g \]

\[ \rho_{\text{lg}} = \frac{m_A - 3.50 \text{kg}}{V_A} = \frac{8.20 \text{kg} - 3.50 \text{kg}}{3.80 \times 10^{-3} \text{m}^3} \]

a.) \( \rho_{\text{lg}} = 1.024 \times 10^3 \text{kg/m}^3 \)

b.) When the block is out of the liquid

\( F_D \cdot g \) reads \( m_A \), i.e. 8.20 kg

and \( F_E \cdot g \) reads \( m_B + m_C = 2.80 \text{kg} \).

Why was \( F_{\text{buoyant}} \) not involved when we initially analysed the system consisting of the block, beaker, and liquid?

For the system, it was an internal force. \( F_{\text{buoyant}} \) acts up on the block (\( m_A \)) but acts down on the liquid (\( m_C \)). These are action/reaction pairs (Newton's Law #3) but since internal to the system, not involved in the system's equilibrium.