Lesson 54: Fluids (AP Only)

**Fluids**

The word **fluid** will most often make people think about some kind of liquid.

- In physics, fluid can refer to either a gas or a liquid.
  - This is because, although they are different, both gases and liquids can flow and will change shape to match whatever container they are in.
- The biggest difference between them is that we usually think of a liquid as **incompressible**, whereas gases are **compressible**.
  - This just means that if I have a liquid in a container and try to squish it to a smaller volume, I won't be able to. If it was a gas in the container I would probably have a lot more luck getting it to squish at least a bit.

**Hydrostatics**

Hydrostatics is the study of fluids at rest.

- We know that at a microscopic level the molecules are in constant motion (at least a bit), but we are looking at the fluid at a macroscopic level.
  - Imagine a cup of water sitting on the table. The water appears to be at rest, since we do not see it flowing. This is a **static fluid**.
- We will also assume that any solid in contact with a static fluid is also at rest.
  - This could be the sides of a container holding the fluid, or any solid that we put in the fluid.

**Density**

The same volume of two different fluids can have very different masses because they have different densities.

- Density is the mass (in kilograms) of an object per volume (in metres cubed).
- The symbol for density is the Greek letter rho, ρ, which looks like a lower case p.

\[
\rho = \frac{m}{V}
\]

\[\rho = \text{density (kg/m}^3)\]

\[m = \text{mass (kg)}\]

\[V = \text{volume (m}^3)\]

**Example 1**: Mercury is the only metal that is a liquid at room temperature. It has a density of 1.36e4 kg/m³. If you had 27.0 g of mercury, **determine** the volume it would take up.

\[
\rho = \frac{m}{V}
\]

\[V = \frac{m}{\rho}\]

\[V = \frac{0.027}{1.36e4}\]

\[V = 1.99e-6 m³\]
The density of water at 4°C is often used as a standard by which we compare other densities.

- The density of water is 1.000e3 kg/m³.
- If you want to compare another substance's density to water, you divide its density by the density of water.
  - This value is called the **specific gravity**.
  - Specific gravity has no units (since they cancel out in the division).
  - It's just a way of saying how many times heavier a substance is compared to water.

**Example 2:** Determine the specific gravity of mercury.

From the last example we know that mercury has a density of 1.36e4 kg/m³.

\[
Specific \ gravity = \frac{\rho_{\text{mercury}}}{\rho_{\text{water}}} \\
Specific \ gravity = \frac{1.36e4}{1.000e3} \\
Specific \ gravity = 13.6
\]

**Example 3:** Blood has a specific gravity of 1.06, just slightly higher than the density of water itself. If the average adult body has about 5.20e-3 m³ of blood, determine the weight of the blood.

First convert the specific gravity to a regular measurement of density...

\[
\rho_{\text{blood}} = \rho_{\text{water}} \times (\text{specific gravity}) \\
\rho_{\text{blood}} = 1.000e3 \times (1.06) \\
\rho_{\text{blood}} = 1.06e3 \text{ kg/m}^3
\]

Now we can use our formula for calculating weight (\(F_g\)) and a little substitution to get the final answer...

\[
F_g = mg \quad \Rightarrow \quad \rho = \frac{m}{V} \\
F_g = mg \quad \Rightarrow \quad m = \rho V \\
F_g = \rho V g \\
F_g = 1.06e3 \times (5.20e-3) \times (9.81) \\
F_g = 54.1 \text{ N}
\]

By solving the density formula for mass, we can substitute it into the weight formula.