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.

The **four states of matter** are solid, liquid, gas, and plasma. Of these four, gases and liquids are considered to be fluids.

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.

$$\rho = \frac{m}{V}$$

ρ = density (kg/m^3)
m = mass (kg)
V = 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/m^3. If you had 27.0 g of mercury, **determine** the volume it would take up.

$$\rho = \frac{m}{V}$$

$$V = \frac{m}{\rho}$$

$$V = \frac{0.027}{1.36\text{e}4}$$

$$V = 1.99\text{e-}6\, m^3$$

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/m^3.
- 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/m^3.

$$Specific\ gravity = \frac{\rho_{mercury}}{\rho_{water}}$$

$$Specific\ gravity = \frac{1.36e4}{1.000e3}$$

$$Specific\ gravity = 13.6$$

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 m^3 of blood, **determine** the weight of the blood.

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

$$Specific\ gravity = \frac{\rho_{blood}}{\rho_{water}}$$

$$\rho_{blood} = \rho_{water}(specific\ gravity)$$

$$\rho_{blood} = 1.000e3(1.06)$$

$$\rho_{blood} = 1.06e3\, kg/m^3$$

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

$$F_g = mg \leftarrow\rightarrow \rho = \frac{m}{V}$$

$$F_g = mg \leftarrow\rightarrow m = \rho V$$

$$F_g = \rho V g$$

$$F_g = 1.06e3(5.20e\text{-}3)(9.81)$$

$$F_g = 54.1\, N$$

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