

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.

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

$$\begin{aligned}\rho &= \text{density (kg/m}^3\text{)} \\ m &= \text{mass (kg)} \\ V &= \text{volume (m}^3\text{)}\end{aligned}$$

Example 1: Mercury is the only metal that is a liquid at room temperature. It has a density of 1.36×10^4 kg/m³. If you had 27.0 g of mercury, **determine** the volume it would take up.

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

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

$$V = \frac{0.027}{1.36 \times 10^4}$$

$$V = 1.99 \times 10^{-6} \text{ m}^3$$

The density of water at 4°C is often used as a standard by which we compare other densities.

- The density of water is $1.000\text{e}3 \text{ kg/m}^3$.
- 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 $1.36\text{e}4 \text{ kg/m}^3$.

$$\begin{aligned} \text{Specific gravity} &= \frac{\rho_{\text{mercury}}}{\rho_{\text{water}}} \\ \text{Specific gravity} &= \frac{1.36\text{e}4}{1.000\text{e}3} \\ \text{Specific gravity} &= 13.6 \end{aligned}$$

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 $5.20\text{e}-3 \text{ m}^3$ of blood, **determine** the weight of the blood.

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

$$\begin{aligned} \text{Specific gravity} &= \frac{\rho_{\text{blood}}}{\rho_{\text{water}}} \\ \rho_{\text{blood}} &= \rho_{\text{water}} (\text{specific gravity}) \\ \rho_{\text{blood}} &= 1.000\text{e}3 (1.06) \\ \rho_{\text{blood}} &= 1.06\text{e}3 \text{ kg/m}^3 \end{aligned}$$

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

$$\begin{aligned} F_g &= mg \leftarrow \rightarrow \rho = \frac{m}{V} \\ F_g &= mg \leftarrow \rightarrow m = \rho V \\ F_g &= \rho V g \\ F_g &= 1.06\text{e}3 (5.20\text{e}-3) (9.81) \\ F_g &= 54.1 \text{ N} \end{aligned}$$

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