A fluid is defined as substances that can flow and change its shape since its particles can move around with respect to one another.

We know that particles in solid are fixed in a lattice, resulting in their definite shape, hence this is not a fluid. Liquids and gases, however, are fluids since their particles can move freely.

In this reviewer, we are going to learn about fluid mechanics and its properties.

Density.

All fluids exhibit density, which is the **mass per unit volume.**

Mathematically,

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

Note that density is represented by the Greek letter, rho, not p. The SI unit for density is kg/cm^3.

Objects made of the same material have the same density, regardless of their mass and volume.

Sample Problem.

If your room has dimensions 3.0 m x 4.0 m and a ceiling 5.0 m high, determine the mass and the weight of the air.

$$(\rho = 1.20\ \text{kg/m}^3)$$

Solution.

We know that

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

Looking for mass, we will have

$$m = \rho v$$

The volume of the room is equal to the product of the length, width, and height of the room. Hence,

$$v = (3.0\ m)\ (4.0\ m)\ (5.0\ m)$$

$$v = 60\ m^3$$

Calculating for the mass,

$$m = \rho v$$

$$m = (1.20\ kg/m^3)\ (60\ m^3)$$

$$\mathbf{m = 72\ kg}$$

Calculating for the weight,

$$w = mg$$

$$w = (72\ kg)\ (9.8\ m/s^2)$$

$$\mathbf{w = 705.6\ N}$$

Pressure.

We usually use the term “pressure” to describe the feeling of being pushed whether by a stressful situation or a physical force. In physics, it almost means the same.

We usually define ***pressure* as *the force per unit area***. The SI unit for pressure is the pascal (Pa), named after the scientist Blaise Pascal.

The pressure of the earth’s atmosphere is known as *atmospheric pressure*. This pressure varies with weather changes and with elevation. The normal atmospheric pressure at sea level (an average value) is 1 atmosphere (atm) which is equal to 101,325 Pa.

Pressure in a Liquid.

The pressure in a liquid describes how the fluid's pressure pushes on the walls of the surrounding container, as well as on all parts of the fluid itself. This applies to gases as well since they are both fluids, but the pressure in a liquid is a little different from that of a gas.

When you swim underwater, you have probably noticed that the deeper you swim, the greater the pressure you feel since there is more water above you. Hence, **the pressure a liquid exerts depends on the depth.**

Liquid pressure also increases with depth because of gravity. The liquid at the bottom must bear the weight of all the liquid above it, as well as all the air above that!

You probably do not notice the weight of the air around you because your body is 'pressurized' the same as the atmosphere, but any liquid under that atmosphere feels it.

The pressure in the liquid also depends on the density of the liquid. The denser the fluid, the greater the pressure would be.

When a liquid is at rest (not flowing), we can calculate its pressure at the given depth using the formula

$$\boldsymbol{p = p_0 + \rho g h}$$

where

- $\boldsymbol{p}$ is the pressure at depth **h** in a fluid of uniform density
- $\boldsymbol{p_0}$ is the pressure at the fluid's surface
- **ρ** is the uniform density of the fluid
- **g** is the acceleration due to gravity
- **h** is the depth below the surface.

When you increase the pressure at the fluid's surface, the pressure at any depth increases at the same amount. This is known as **Pascal's law**.

Sample Problem.

Find the density of the gasoline if the pressure inside a tank 8 meters deep is 113,640 Pa. Note that the top of the tank is open to the atmosphere.

Solution.

We know that $p = p_0 + \rho g h$.

Looking for density, we will have

$$p - p_0 = \rho g h$$

Dividing both sides by gh, we will get

$$\rho = p - p_0/gh$$

Calculating for the density,

$$\rho = (113640 \text{ Pa} - 101{,}325 \text{ Pa})/(9.8 \text{ m/s}^2)\ (8 \text{ m})$$

$$\rho = 12315 \text{ Pa}/78.4 \text{m}^2/\text{s}^2$$

$$\boldsymbol{\rho = 157.08 \text{ kg/m}^3}$$

Buoyancy.

Have you ever wondered why is it so hard to push down an object underwater? That is because an upward force exerted by a fluid counteracts with your applied force. **This upward force is known as *buoyancy***.

If buoyancy exists, *how come other objects sink while others float? Does it have something to do with its size?*

The answer lies in the **Archimedes principle which states that objects submerged in a fluid will experience an upward buoyant force equal in magnitude to the weight of the fluid being displaced**. Meaning, the buoyant force supports an object if it is less dense than the fluid since the object's weight is less than the weight of an equal volume of the fluid.

For example, the cruise ship floats in the ocean because it is less dense compared to the ocean. It may be made up of very dense material like steel, but the air in all the cabins is not dense.

Buoyant force can also be expressed as the gravitational force of the displaced fluid, which is also equal to the mass of the displaced fluid times acceleration due to gravity. In the case of the ship, it weighs less than the water it displaces, causing it to float.

A floating object displaces fluid based on its mass, while a sinking object displaces fluid based on its volume.

Apart from the principle of buoyancy, Archimedes was also the first to understand that when any object submerged in the water, regardless of its shape, the volume of the water displaced is equal to the volume of the object submerged. His discovery made him run out of the bathtub, shouting *"Eureka,"* which means *"I have found it."*

Buoyant force can also be expressed mathematically. In terms of the equation,

$$\mathbf{B = \rho g v}$$

where

- **B** is the buoyant force
- **ρ** is the density of the displaced fluid
- **g** is the acceleration due to gravity
- **v** is the volume of the displaced fluid

Sample Problem.

Find the buoyant force of a 10 m^3 block that is placed in the water. Note that the density of water is 1000 kg/m^3.

Solution.

We know that $B = \rho g v$.

Substituting the values, we will get

$$B = (1000\ kg/m^3)(9.8\ m/s^2)(10\ m^3)$$

$$\mathbf{B = 98000\ N}$$

The Continuity Equation.

Fluids rarely stay at rest; hence, it is important to understand how they flow.

There are varieties of ways a fluid can move, so to understand fluids in a very specific way, we are going to make assumptions. In this lesson, we are going to assume that fluids are incompressible, flows in a steady and constant manner, and non-viscous (no resistance to flow).

When you are watering your plants, you probably have noticed how the water in the hose comes out faster when you block the opening partially. That is because the same volume of water has to travel through the hose, regardless of how small or large the opening is.

The relationship between the area inside the hose (the hose's internal diameter) and the velocity of the fluid is expressed in the *equation of continuity*, written mathematically as

$$\mathbf{A_1v_1 = A_2v_2}$$

where A is the area that fluid travels through and v is the velocity of the fluid.

Sample Problem.

A hose has an initial cross-sectional area of 1.5 cm^2 that expands into a 3 cm^2 area. Initially, the velocity of the water through the smaller cross-sectional area of the pipe is 10 cm/s. Find the velocity of the water through the larger cross-sectional area section of the pipe.

Solution.

We are given the following quantities:

- $A_1 = 1.5\ cm^2$
- $v_1 = 10\ cm/s$
- $A_2 = 3\ cm^2$

Calculating for the v_2,

$$v_2 = A_1v_1/A_2$$

$$v_2 = (1.5\ cm^2)(10\ cm/s)/3\ cm^2$$

$$\mathbf{v_2 = 5\ cm/s}$$

Bernoulli's Principle.

Like energy, fluids can also be conserved. This idea is shown in ***Bernoulli's principle*****, which states that a quantity involving the pressure p, flow speed v, and height h has the same value anywhere in a flow tube**, assuming steady flow in an ideal fluid.

Mathematically,

$$\mathbf{p_1 + \rho g h_1 + \tfrac{1}{2}\rho v_1^{\ 2} = p_2 + \rho g h_2 + \tfrac{1}{2}\rho v_2^{\ 2}}$$

where

- **p** is the fluid pressure
- **ρ** is the fluid density
- **g** is the acceleration due to gravity ($9.8\ m/s^2$)
- **h** is the height of the fluid off the ground
- **v** is the velocity of the fluid

Sample Problem.

Water flows through a Z-shaped pipe. At one end, the water in the pipe has a pressure of 175 kPa, a speed of 15.0 m/s, and a height of 3.0 m. At the other end, the speed of the water is 5 m/s, and the height is 1.0 m. Find the pressure at this point in terms of kPa. Note that the density of water is 1000 kg/m^3.

Solution.

Based on Bernoulli's principle,

$$\mathbf{p_1 + \rho g h_1 + ½\rho v_1{}^2 = p_2 + \rho g h_2 + ½\rho v_2{}^2}$$

To find p_2,

$$p_2 = p_1 + \rho g(h_1 - h_2) + ½\rho(v_1^2 - v_2{}^2)$$

Substituting the values, we will get

$$p_2 = 175 \text{ kPa} + (1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(3 \text{ m} - 1 \text{ m}) + ½(1000 \text{ kg/m}^3)[(15.0 \text{ m/s})^2 - (5.0 \text{ m/s})^2]$$

$$p_2 = 175 \text{ kPa} + 19600 \text{ Pa} + 100000 \text{ Pa}$$

$$p_2 = 175 \text{ kPa} + 19.6 \text{ Pa} + 100 \text{ kPa}$$

$$\mathbf{p_2 = 294.6 \text{ kPa}}$$