Hello Fellow Physicists,

I am Aman Patel, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring session, so be sure to visit the tutoring center or visit [https://baylor.edu/tutoring](https://baylor.edu/tutoring).

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Wednesday from 6:45-7:45 pm in the Sid Richardson building basement, Room 74. See you there!

Over the last week, your professors will have covered Static Equilibrium. This week, you will explore Fluids.

**Keywords:** Fluids, Pascal’s Principle, Buoyancy, Bernoulli’s Equation

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**Topic of the Week: Fluids**

**Specific Gravity and Density**

Fluids are substances that can flow. This includes both liquids and gases. This includes air in our atmosphere and the blood in you body. We have studied fluids heavily and use them everywhere in day to day applications.

The important characteristic of fluids is density. Density is the mass per unit volume for a substance. All substances have their own unique densities. Density of an object is as follows:

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

The specific gravity of a substance is the ratio of the density of the substance to the density of water at 4°C. So, the mass of a liquid can be calculated using the product of the density of the substance and the volume of the substance observed. Using that we can calculate the weight of the fluid.

\[
m = \rho V
\]

\[
mg = \rho Vg
\]

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All Images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli
Highlight 1: Pressure:

Pressure is the force applied per unit area. The force exerted on a surface it perpendicular to the surface. All forces acting on a surface exert pressure on a surface.

$$\text{pressure} = P = \frac{F}{A}$$

This is highly important because we must consider this every day. Why do you sharpen knives? Why do nails have points? Why do divers dive into water in a vertical orientation? All of this is so that they exert the most pressure as you are confining the force applied to a smaller area.

When it comes to fluids, things get a lot more interesting. Due to the nature of fluids to fill the volume of their container, fluids exert pressure in every direction. It is still perpendicular to the surface it touches. The amount of pressure is affected by the volume of the liquid exerting the pressure. So, when a fluid is in a container, as the depth increases, so does the pressure exerted by the fluid. So, points at the same depth exert the same pressure in a liquid. We can quantify the pressure exerted by a fluid using the following equation

$$P = \rho gh$$

Using the same formula, we can also quantify the change in pressure by using the change in height.

Example:

The surface of the water in a storage tank 30 m above a water faucet in the kitchen of a house. Calculate the difference in water pressure between the faucet and the surface of the water in the tank.

Solution

$$P_2 - P_1 = \rho g (h_2 - h_1)$$

$$= (1000) (9.8) (30-0)$$

$$= 290000 \text{ N/m}^2$$

Atmospheric and Gauge Pressure:

As air is a fluid, it exerts pressure. So, all the air above our heads is continuously pushing down on us. But somehow, we aren’t crushed. That is because our bodies are built to withstand this pressure. The blood that is flowing in our body exerts an outward pressure that matches the atmospheric pressure. Some individuals experience nosebleeds when they go to higher altitudes because the pressure of blood is higher than the atmospheric pressure, their blood vessels

All Images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli
rupture. It's also one of the reasons why humans would not survive in space, the lack of pressure would cause major damage to our blood vessels. Due to the high magnitude of atmospheric pressure, we compare pressure with the atmospheric pressure.

\[ 1 \text{ atm} = 1.013 \times 10^5 \text{ N/m}^2 = 101.3 \text{ kPa}. \]

Many of the devices that we use to measure pressure remove atmospheric pressure. This is called the gauge pressure. The absolute pressure is the gauge pressure and the atmospheric pressure.

**Highlight 2: Pascal’s Principle:**

This principle states that if an external pressure is applied to a confined fluid, the pressure at every point within the fluid increases by that amount. So, at the same level,

\[ P_{\text{out}} = P_{\text{in}} \]

**Buoyancy:**

Objects float in water because they experience buoyant force from the fluid. This force exists due to the pressure exerted by the fluid on the object. Based on the depth of the object in the liquid, the buoyant force can be calculated as follows.

\[ F_B = F_2 - F_1 = \rho_F g A (h_2 - h_1) = \rho_F g A \Delta h = \rho_F V g = m g. \]

**Highlight 3: Archimedes Principle:**

The buoyant force on an object immersed in a fluid is equal to the weight of the fluid displaced by that object.

One of the most well-known stories in science is the story of how Archimedes and how he measured the volume of an object without having to measure its dimensions.

\[ \frac{V_{\text{displ}}}{V_O} = \frac{\rho_O}{\rho_F}. \]
**Highlight 4: Fluid Dynamics:**

Till now, we have been discussing fluids that are stationary. Now we look at moving fluids. This significantly complicates studying their flow due to the numerous factors that affect the flow. We will be looking at laminar flow, which refers to smooth and constant flow. The flow of a fluid is affected by changes in its path. We see this using the equation of continuity.

\[ A_1 v_1 = A_2 v_2. \]

You can see the effect of this in your sink. When you turn the water faucet on, you see the flow of water. But if you compare the width of the stream at the tap and then at the sinkhole, you will notice that the width of the water gets smaller. This is because of gravity. As gravity pulls on the water, it increases the velocity of the water flow. As that happens, the cross section of the stream decreases to adhere to the equation of continuity. Interesting right!

**Highlight 5: Bernoulli’s Equation:**

The Bernoulli principle states that where the velocity of a fluid is high, the pressure is low, and where the velocity is low, the pressure is high. David Bernoulli made the first major stride in fluid dynamics and devised an equation to express the principle.

\[ \frac{1}{2} \rho v_2^2 - \frac{1}{2} \rho v_1^2 = P_1 - P_2 - \rho g y_2 + \rho g y_1 \]

**Example:**

Water circulates throughout a house in a hot-water heating system. If the water is pumped at a speed of 0.5 m/s through a 4 cm diameter pipe in the basement under a pressure of 3 atm, what will be the flow speed and pressure in a 2.6 cm diameter pipe on the second floor 5 m above?

**Solution**

\[ v_2 = \frac{(v_1 A_1)}{A_2} \]

\[ = (0.5) \left( \pi 0.02^2 \right) / \left( \pi 0.013^2 \right) \]

\[ = 1.2 \text{ m/s} \]

\[ P_2 = P_1 + \rho g (y_1 - y_2) + (0.5) \rho ((v_1)^2 - (v_2)^2) \]

\[ = (3 \times 101300) + (1000) (9.8) (-5) + (0.5) (1000) (0.5^2 - 1.2^2) \]

\[ = 250000 \text{ Pa} \]
CHECK YOUR LEARNING

1. Water and an unknown fluid that doesn’t mix with water are poured into a U-shaped tube, open at both ends. They come to equilibrium as shown. What is the density of the unknown fluid?
2. A 45 kg child decides to make a raft out of empty 2 L soda bottles. What minimum number of soda bottles must the child use to stay dry on the raft?
3. Two 20 cm radius air duct is used to replenish the air of a room 10m x 5m x 8m every 10 min. How fast does the air flow in each duct?

THINGS YOU MAY STRUGGLE WITH

1. The pressure based on the level of the fluid you are at. Remember, in a fluid, the pressure increases as you go deeper into the fluid. So as the distance from the surface of the fluid increases, the pressure exerted by the fluid at the level increases. But the pressure exerted at different locations at the same depth is the SAME. If the object is at a particular depth, the object experiences force from the water at ALL sides as fluids exert pressure in all directions.
2. Pascal’s principle and how to apply it. This principle uses the properties of a fluid to analyze the effect on the fluid due to external pressure. Remember the force going into the system will increase pressure into the system and the pressure everywhere in the system. But the force and area ratios also follow the behavior. The ratio of the forces and the ratio of the areas must be the same. So changing the area where the fluid is exerting pressure can change how much force is exerted at that point.
3. Applying Archimedes principle and understanding buoyant force. The object experiences force on all sides of its that are submerged. The force that the fluid exerts is called the buoyant force which is dependent on the volume of water the object displaces.
4. The volume flow rate. All this means that a particular volume is flowing through a cross section in a given amount time. This can be rewritten as the product of velocity of the fluid flow and the area of the cross section, which is equal to a constant. Which also means that area and velocity are inversely proportional. So if the area is increases or decreased, the velocity of flow for the fluid will decrease or increase.

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: https://baylor.edu/tutoring

Answers: 1. 750 kg/m³  2. 23 bottles 3. 2.65 m/s