Physics 1408/1420 – General Physics 1

Week of October 17th, 2022

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Hello Fellow Physicists,

I am Jorge Martinez-Ortiz, 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.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Monday from 6:30pm-7:30pm in the Sid Richardson building basement, Room 75. 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

Important Notes

Important Conventions

Topic of the Week: Fluids

Specific Gravity and Density

Fluids are substances that can flow. These substances include both gases and liquids such as the air in our atmosphere and the blood in your body. Density is a very important property of fluids; it is the amount of mass per unit of volume, and it is unique to every fluid. Mathematically, it can be represented 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. 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 this fact, we can calculate the weight of the fluid.

$$m = \rho V \rightarrow mg = \rho V g$$

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Highlight 1: Pressure:

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

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

Pressure has to be considered in many situations in our daily life. 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.

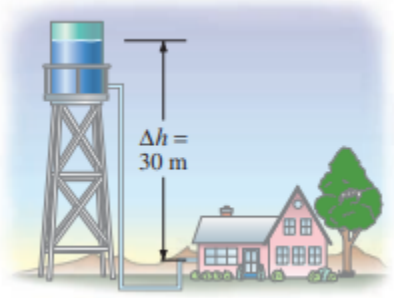
When it comes to fluids, things get a lot more interesting. Due to the nature of fluids to fill the volume of their container, fluids exert pressure in every direction. It is still perpendicular to the surface it touches. The amount of pressure is affected by the volume of the liquid exerting the pressure. When a fluid is in a container, as the depth increases, so does the pressure exerted by the fluid. Any two 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:

$$P = \rho g h$$

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

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

$= (1000)\,(9.8)\,(30\text{-}0)$

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

Atmospheric And Gauge Pressure:

Since air is a fluid, it exerts pressure. All the air above our heads is continuously pushing down on us, but somehow, we aren't crushed by the pressure it exerts. The reason behind that is because our bodies are built to withstand this pressure. The blood flowing in our body exerts an outward pressure that matches the atmospheric pressure. Some people experience nosebleeds when they go to higher altitudes because their blood pressure is higher than the atmospheric

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pressure, causing their blood vessels rupture, which is 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 do not consider the atmospheric pressure (called the gauge pressure). The absolute pressure is the gauge pressure and the atmospheric pressure.

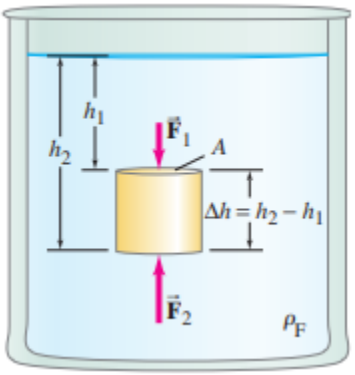
Highlight 2: Pascal's Principle:

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.



$$\begin{aligned} F_B = F_2 - F_1 &= \rho_F g A(h_2 - h_1) \\ &= \rho_F g A\,\Delta h \\ &= \rho_F V g \\ &= m_F g, \end{aligned}$$

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 measured the volume of an object without having to measure its dimensions. He used the following formula:

$$\frac{V_{\text{displ}}}{V_O} = \frac{\rho_O}{\rho_F}.$$

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Highlight 4: Fluid Dynamics:

So far, we have discussed fluids that are stationary, but we need to start talking about fluids in motion. The study of fluid dynamics is more complicated since it involves more factors that come into play. 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. This information is conveyed by the following equation, known as 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. If you compare the width of the stream at the tap to that at the sinkhole, you will notice that the width of the water gets smaller. This phenomenon occurs due to the presence of gravity. As gravity exerts is attractive force, it increases the velocity of the flow of water. The cross-sectional area of the flow decreases to adhere to the equation of continuity.

Highlight 5: Bernoulli's Equation:

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

$$\tfrac{1}{2}\rho v_2^2 - \tfrac{1}{2}\rho v_1^2 = P_1 - P_2 - \rho g y_2 + \rho g y_1$$

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

$v_2 = (v_1 A_1) / A_2$

$= (0.5) (\pi 0.02^2) / (\pi 0.013^2)$

$= 1.2$ m/s

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

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

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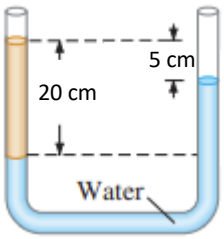
= 250000 Pa

CHECK YOUR LEARNING

1. Water and an unknow 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. In a fluid, the pressure is based on the height or level of a fluid. Pressure increases as you go deeper into the fluid. Therefore, as the distance from the surface of the fluid increases, the pressure exerted by the fluid at a given level increases. However, the pressure exerted on 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. You need to be able to understand 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, a force applied to a system will increase its pressure at every point. Additionally, the ratio of the forces and that of the areas must be the same, which means that changing the area where the fluid is exerting pressure can change how much force is exerted at that point.
3. Make sure that you know how to apply Archimedes principle and understanding buoyant force. An object that has been submerged experiences a force at all points where it is in contact with the fluid. The force that the fluid exerts is called the buoyant force, and it is dependent on the volume of water the object displaces.
4. Remember, the continuity equation and its relationship to the volume of the flow rate. The equation of continuity states that the volume of a fluid that is passing through a given area at a specific point in tame can be expressed as the product of velocity of the fluid and the cross-sectional area, and it should remain constant. In other words, area and velocity are inversely proportional. If the area is increased the velocity of the fluid must decreased and vice versa.

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/m^3 2. 23 bottles 3. 2.65 m/s

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