Physics 1408/1420

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Hello Fellow Physicists

I am Aman Patel, the Master Tutor for Physics this semester. I have created this resource document to help you review some of the topics you have been introduced to this semester to better prepare for your Final in physics.

Keywords: Fluids, Pascal's Principle, Buoyancy, Bernoulli's Equation

Important Notes
Important Conventions

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.

$$m = \rho V \qquad mg = \rho V g.$$

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.

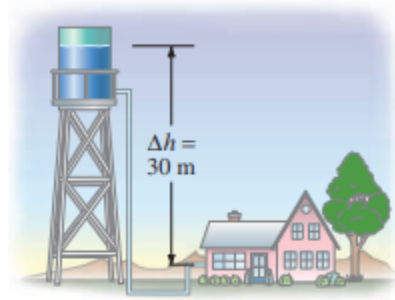
When it comes to fluids, things get a lot more interesting. Due to the nature of fluids to fill the volume of their container, fluids exert pressure in every direction. It is still perpendicular to the surface it touches. The amount of pressure is affected by the volume of the liquid exerting the pressure. 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

$$P = \rho g h$$

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

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

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

$= 290000\ N/m^2$

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 rupture. Its 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.

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

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.

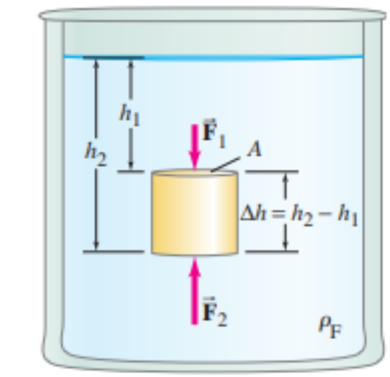
Pascal's Principle:

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.



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

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.

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

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!

<u>Bernoulli's Equation:</u>

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.

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

<u>Example:</u>

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

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

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

$= 250000$ Pa

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