13.1: Fluid Pressure

Russian ocean submersible can withstand a great amount of pressure Figure 10.1.1

This is the Russian ocean submersible “Mir.” Submersibles like this are necessary for research or work at great depths in the ocean because of the massive pressure. This craft can operate as deep as 6000 meters below the surface. The pressure at 6000 meters below the ocean surface exceeds 8500 pounds per square inch.

Pressure in Fluids

Pressure is defined as force per unit area, where the force F is understood to be acting perpendicular to the surface area, A.

$\text{Pressure}=P=F/A$

The SI unit for pressure is N/m^2. This unit is also known as a **pascal** (Pa): 1 Pa = 1 N/m^2.

Example 10.1.1

Consider a 80.0 kg person whose two feet cover an area of 500. cm^2. Determine the pressure applied to the ground by his feet.

Solution

The force exerted by this person on the ground would be (80.0 kg)(9.80 m/s^2) = 784 N. The area over which this force is exerted would be 0.0500 m^2.

$P=F/A=784\ N/0.0500\ m^2=15{,}700\ Pa$

It has been determined experimentally that a **fluid** exerts pressure equally in all directions. In the sketch below, from any given point below the surface of the fluid, the pressure in all directions is the same. The fluid exerts the same pressure upward from this point as it does downward.

Fluid exterting pressure equally below the surface Figure 10.1.2

We can calculate how the pressure of a fluid varies with depth, assuming the fluid has uniform density.

Consider a gigantic tub filled with water as shown below. A column of water with a cross-sectional area of 1.00 m^2 is designated. If we multiply the cross-sectional area by the height of the column, we get the volume of water in this column. We can then multiply this volume by the density of water, 1000. kg/m^3, and get the mass of water in the column. We then multiply this mass by the acceleration due to gravity, g, to get the weight of the water in this column.

Volume of water in a column Figure 10.1.3

$F_{weight}=(\text{area})(\text{height})(\rho)(g)$

The pressure exerted by this force would be exerted over the area at the bottom of the column.

$P=F/A=\rho ghA/A=\rho gh$

Therefore, the pressure of a column of fluid is proportional to the density of the fluid and to the height of the column of fluid above the level. This is the pressure due to the fluid itself. If an external pressure is exerted at the surface, this must also be taken into account.

Volume of water in a column Figure 10.1.4

The surface of the water in a storage tank is 30.0 m above a water faucet in the kitchen of a house. Calculate the water pressure at the faucet.

The pressure of the atmosphere acts equally at the surface of the water in the storage tank and on the water leaving the faucet – so it will have no effect. The pressure caused by the column of water will be:

$P=\rho gh=(1000.\ kg/m^3)(9.80\ m/s^2)(30.0\ m)=294{,}000\ Pa$

The pressure of the earth’s atmosphere, as with any fluid, increases with the height of the column of air. In the case of earth’s atmosphere, there are some complications. The density of the air is not uniform but decreases with altitude. Additionally there is no distinct top surface from which height can be measured. We can, however, calculate the approximate difference in pressure between two altitudes using the equation $P=\rho g\Delta h$. The average pressure of the atmosphere at sea level is 1.013×10^5Pa. This pressure is often expressed as 101.3 kPa.

Dive into a SCUBA training pool in the simulation below to learn more about fluid pressure. Adjust the depth of the diver and note the differences between the water gauge pressure and the absolute pressure in the graph. Gauge pressure is the amount of pressure above 1 atmosphere. A gauge would read out 0 atm at normal pressure at sea level. It is used to measure pressures above atmospheric and doesn't include the 1 atmosphere of pressure we find at the Earth's surface.

Summary

- Pressure is defined as force per unit area, P=F/A.
- The SI unit for pressure is N/m^2 which has been named *pascal* (Pa).
- It has been determined experimentally that a fluid exerts pressure equally in all directions.
- The pressure of a column of fluid is proportional to the density of the fluid and to the height of the column of fluid above the level, P=ρgh.
- The average pressure of the atmosphere at sea level is 1.013×10^5 Pa, or 101.3 kPa.

Review

1. If you push the head of a nail against your skin and then push the point of the same nail against your skin with the same force, the point of the nail may pierce your skin while the head of the nail will not. Considering that the forces are the same, what causes the difference?
2. A brick of gold is 10.0 cm wide, 10.0 cm high, and 20.0 cm long. The density of gold is 19.3 g/cm^3.
   1. What pressure does the brick exert on the table if the brick is resting on its side?
   2. What pressure does the brick exert on the table if it is resting on its end?
3. What is the total force and the pressure on the bottom of a swimming pool 8.0 m by 15.0 m whose uniform depth is 2.0 m?
4. Calculate the pressure produced by a force of 800. N acting on an area of 2.00 m^2.
5. A swimming pool of width 9.0 m and length 24.0 m is filled with water to a depth of 3.0 m. Calculate pressure on the bottom of the pool due to the water.
6. What is the pressure on the side wall of the pool at the junction with the bottom of the pool in the previous problem?

Explore More

Use this resource to answer the questions that follow.

1. Why do the streams of water at the bottom of the bottle go the farthest?
2. Why does water stop flowing out of the top hole even before the water level falls below it?

Additional Resources

Study Guide: Fluids Study Guide

Real World Application: The Pressure Under Water

PLIX: Play, Learn, Interact, eXplore: Leaking tank

Videos: