Hydrostatic Pressure

Unit: Pressure & Fluid Mechanics

NGSS Standards: N/A

MA Curriculum Frameworks (2006): N/A

AP Physics 2 Learning Objectives: 1.E.1.1, 1.E.1.2

Knowledge/Understanding:

- hydrostatic pressure

Skills:

- calculate pressure exerted by a column of fluid

Language Objectives:

- Understand and correctly use the term "hydrostatic pressure."
- Accurately describe and apply the concepts described in this section using appropriate academic language.
- Set up and solve word problems relating to hydrostatic pressure.

Labs, Activities & Demonstrations:

- Bottle with hole (feel suction, pressure at exit)
- Buret & funnel manometer
- Syphon hose
- Cup of water & index card
- Magdeburg hemispheres
- Shrink-wrap students

Notes:

hydrostatic pressure: the pressure caused by the weight of a column of fluid. For clarity, in these notes hydrostatic pressure will be denoted P_H.

The force of gravity pulling down on the molecules in a fluid creates pressure. The more fluid there is above a point, the higher the pressure at that point.

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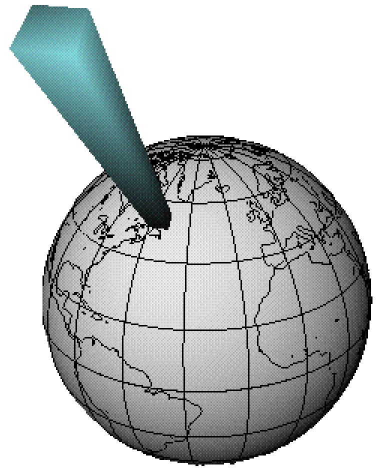
The atmospheric pressure that we measure at the surface of the Earth is caused by the air above us, all the way to the highest point in the atmosphere, as shown in the picture at right:



Assuming the density of the fluid is constant, the pressure in a column of fluid is caused by the weight (force of gravity) acting on an area. Because the force of gravity is *mg* (where $g = 10\,\frac{\text{m}}{\text{s}^2}$), this means:

$$P_H = \frac{F_g}{A} = \frac{mg}{A}$$

where:

- P_H = hydrostatic pressure
- g = acceleration due to gravity ($10\,\frac{\text{m}}{\text{s}^2}$ on Earth)
- A = area of the surface the fluid is pushing on

We can cleverly multiply and divide our equation by volume:

$$P_H = \frac{mg}{A} = \frac{mg \cdot V}{A \cdot V} = \frac{m}{V} \cdot \frac{gV}{A}$$

Then, recognizing that density, ρ*, is mass divided by volume, we can substitute:

$$P_H = \rho \cdot \frac{gV}{A}$$

Finally, if the volume of an object is the area of the base times the height (*h*), we can rewrite the equation as:

$$P_H = \frac{\rho g \cancel{A} h}{\cancel{A}} = \rho g h$$

* Note that physicists use the Greek letter ρ ("rho") for density. You need to pay careful attention to the difference between the Greek letter ρ and the Roman letter "p".

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Finally, if there is an external pressure, P_o, above the fluid, we have to add it to the hydrostatic pressure from the fluid itself, which gives us the equation:

$$P = P_o + P_H$$

Substituting $\rho g h$ for P_H gives the more familiar form of the equation:

$$P = P_o + \rho g h$$

where:

- P_o = pressure above the fluid (if relevant)
- ρ = density of the fluid (this is the Greek letter "rho")
- g = acceleration due to gravity ($10\,\frac{\text{m}}{\text{s}^2}$ on Earth)
- h = height of the fluid above the point of interest

Sample Problem

Q: What is the water pressure in the ocean at a depth of 25 m? The density of sea water is $1025\,\frac{\text{kg}}{\text{m}^3}$.

A: $P = \rho g h = (1025\,\frac{\text{kg}}{\text{m}^3})(10\,\frac{\text{m}}{\text{s}^2})(25\,\text{m}) = 256\,250\,\text{Pa} = 2.56\,\text{bar}$

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Homework Problems

For all problems, assume that the density of fresh water is $1000\frac{kg}{m^3}$.

1. 1. A diver dives into a swimming pool and descends to a maximum depth of 3.0 m. What is the pressure on the diver due to the water at this depth? Give your answer in both pascals (Pa) and in bar.

   Answer: 30 000 Pa or 0.3 bar

2. The specifications for the wet/dry vacuum cleaner that Mr. Bigler used for his hovercraft state that it is capable of creating enough of a pressure difference to lift a column of water to a height of 1.5 m at 20°C. How much pressure can the vacuum cleaner apply?

   Answer: 15 000 Pa

3. A standard water tower is 40 m above the ground. What is the resulting water pressure at ground level? Express your answer in pascals, bar, and pounds per square inch. (1 bar = 14.5 psi)

   Answer: 400 000 Pa, 4 bar, or 58.8 psi

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