**Density** ($\rho$) - Ratio of Mass to Volume

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

**Units** [kg/m$^3$]

\[ \rho_{H_2O} = \frac{1\text{ g}}{c.c.} = \frac{1\text{ g}}{mL} = \frac{1000\text{ g}}{m^3} = \frac{1\text{ kg}}{L} \]

**Specific Gravity** ($SG$) - Ratio of a substance's density to the density of water

\[ SG = \frac{\rho_{\text{object}}}{\rho_{H_2O}} \]

*ICE* : $SG = 0.917$

"less dense" $\rho_{\text{ice}} = 0.917 \frac{g}{m^3}$

*SILVER* : $SG = 10.5$

"more dense" $\rho_{\text{Ag}} = 10.5 \frac{g}{mL} = 10.5 \frac{g}{L} = 10500 \frac{g}{m^3}$

*SPECIFIC GRAVITY IS PERCENTAGE OF THE OBJECT THAT WILL BE SUBMERGED IN WATER.*

**Pressure** ($P$) - Quantity of Force to Area

- What causes things to split/burst/puncture

\[ P = \frac{F}{A} \]

**Units** [Pa]

**OTHER COMMON UNITS** atm, psi, mmHg, torr

\[ 1 \text{ Pascal} = \frac{1\text{ N}}{1\text{ m}^2} \]

\[ P = \frac{mg}{A} \]
Pressure at Depth

When you go to the bottom of a fluid... pressure increases because you have the weight of all the fluid on top of you pushing on you... this is why your ears pop.

\[ P = \rho gh + P_0 \]

- \( P \) - Absolute Pressure
- \( \rho \) - Density of Fluid
- \( g \) - Accel. of Gravity (9.8 \( \text{m/s}^2 \))
- \( h \) - Depth
- \( P_0 \) - Air Pressure

\[ P_0 = 1.01 \times 10^5 \text{ Pa} \]
\[ = 14.7 \text{ psi} \]

\[ = 15 \text{ psi} \]

Gauge Pressure (\( P_g \)) - Ignore Air Pressure

Absolute Pressure (\( P = \rho gh + P_0 \)) - Use Air Pressure

Straws

Siphon

Barometer
PASCAL’S PRINCIPLE - WHEN A PRESSURE \( \frac{F}{A} \) IS APPLIED TO AN ENCLOSED FLUID... THAT PRESSURE IS APPLIED TO ALL PARTS OF THE FLUID \& THE CONTAINING VESSEL.

\[
\frac{F_A}{A_A} = \frac{F_B}{A_B}
\]

PRINCIPLE BEHIND ALL OF HYDRAULICS

\[
\frac{F_A}{A_A} = \frac{F_B}{A_B} \Rightarrow \frac{F_A}{\pi r^2} = \frac{F_B}{\pi r^2}
\]

BOUYANCY \& THE BOYANT FORCE \( F_B \) - UPWARD FORCE ON AN OBJECT BY A FLUID WHEN THE OBJECT IS COMPLETELY OR PARTIALLY SUBMERGED IN THE FLUID.

ARCHIMEDE’S PRINCIPLE - THE MAGNITUDE OF THE BOYANT FORCE \( F_B \) IS EQUAL TO THE WEIGHT OF THE FLUID DISPLACED.

\[
F_B = \rho g V
\]

\[
\rho \text{ - Density of Fluid}
\]

\[
V \text{ - Volume of Fluid Displaced}
\]

\[
g = 9.8 \text{ m/s}^2
\]

FLOATING VS. SUNK

FLOATING \( \rightarrow \)

\[
F_B = \rho g V
\]

\[
F_0 = mg
\]

\[
F_B = \rho g \cdot V_{FLUID}
\]

\[
F_0 = mg
\]

\[
\rho g V_{FLUID} = \rho g V_{OBJECT}
\]

SUNK \( \rightarrow \) VOLUME OF OBJECT SUNK EQUALS VOLUME OF LIQUID DISPLACED FLUID

LARGEST \( F_B \)?

\[
F_{B_A} > F_{B_C} > F_{B_B}
\]
Ship Conceptual Problems

What happens to the water level in a lock (big bath tub) when...

A boat sinks?

Go down

Ice Berg melts?

Stay the same

Throw a boulder overboard?

Go down

Ice Berg, full of rocks melts?

Go down

Throw an ice ball, what happens?

Stay the same

9.6 Buoyant forces and Archimedes Principle

29. A table-tennis ball has a diameter of 3.80 cm and an average density of 0.0810 g/cm³. What force is required to hold it completely submerged underwater?

\[ F_B = \frac{4}{3} \pi r^3 \rho g \]

\[ F_B = \frac{4}{3} \pi (0.019)^3 (0.0810) (9.8) \]

\[ F_A = \rho g V_v - \rho g V_D \]

\[ F_A = (1000)(9.8)(0.019^3) (9.8) - (21)(3.14)(0.019^3) (9.8) \]

Where is pressure the greatest?

A B C D

Same \( \Rightarrow P = P_o + \rho gh \)
### Moving Fluids

**Equation of Continuity** - In a hose or pipe, the flow rate must remain constant at all points in the hose/pipe.

- Fluid must travel faster at B than A.

\[
\text{Volume} = \text{flow rate} \times \text{time}
\]

- Same at A, B, and all points in the pipe.

\[
A = \text{cross sectional area of pipe}
\]

\[
v = \text{velocity of the fluid at that point}
\]

**Bernoulli's Equation** - "Conservation of Energy" of Fluids

For a pipe/hose, the following equation remains constant throughout the entire pipe/hose:

\[
P + \frac{1}{2} \rho v^2 + \rho gh = \text{constant}
\]

- \(P\) - Absolute Pressure
- \(\rho\) - Density of the fluid
- \(v\) - Velocity of fluid
- \(h\) - Height above/below \(h = 0\)
- \(g\) - \(9.8\) m/s\(^2\)

**Ideas:**

\[
P_A + \frac{1}{2} \rho v_A^2 + \rho g h_A = P_B + \frac{1}{2} \rho v_B^2 + \rho g h_B
\]

\[
P_A + \frac{1}{2} \rho v_A^2 = P_B + \frac{1}{2} \rho v_B^2
\]

Slow moving fluids have greater pressures than fast moving fluids.

Bernoulli effect:

- Slow \(\rightarrow\) Higher Pressure \(\triangleright\)
- Fast \(\rightarrow\) Lower Pressure \(\triangleleft\)
### Problem Types:

**PEEKING BUCKET:**

- \( P_{A} = \rho g h = \frac{1}{2} \rho V_{A}^{2} \)
- \( P_{B} = P_{0} + \frac{1}{2} \rho V_{B}^{2} + \rho gh \)

**Fou - Tank / Water Main Break:**

- \( P_{\text{inside}} + P_{0} + \frac{1}{2} \rho V_{C}^{2} + \rho gh \)
- \( P_{\text{inside}} + P_{0} + \frac{1}{2} \rho V_{D}^{2} + \rho gh \)

**Closed System:**

- \( \frac{\nu_{A}}{T} = A_{A} \nu_{A} \)

\( P_{\text{inside}} + P_{0} + \frac{1}{2} \rho V_{B}^{2} + \rho gh \)

### Notes:

- Yes moving - Radios of Pipe given
- No moving - Radios of Pipe not given

- \( P_{\text{inside}} \rightarrow \text{Absolute Pressure} \)
- If asked for gauge pressure, subtract air pressure

\( P_{g} = P_{\text{inside}} - P_{0} \)