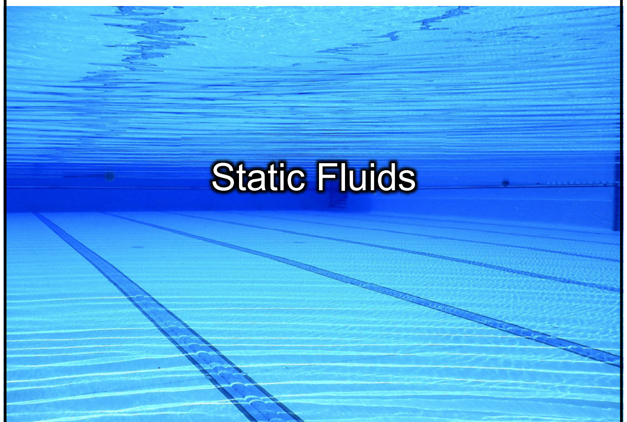
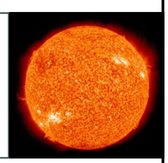


Static Fluids

Pixabay

What is a Fluid?

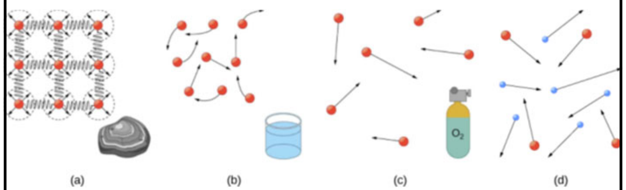
- Matter most commonly exists as a solid, liquid, gas, or plasma; these states are known as the common phases or states of matter.

Solid | Liquid | Gas | Plasma

Ice cubes – Bruno (Pixabay)
Drink – Kmeel.com (Pixabay)
Sun – WikiImages (Pixabay)

- Solids have a definite shape and a specific volume.
- Liquids have a definite volume but their shape changes depending on the container.
- Gases do not have a definite shape or volume as their molecules move to fill the container.
- Plasmas do not have a definite shape or volume.



a) Solid
b) Liquid
c) Gas
d) Plasma

- Liquids, gases, and plasmas are considered fluids because they yield to shearing forces, whereas solids resist them.
  - In other words, the molecules move in such a way that they can flow.

Artem Podrez (Pexels)

- Solids
  - The atoms are close together and the forces between them allow them to vibrate but not exchange places with each other.
  - A solid cannot really be deformed as the atoms cannot move freely.
  - A solid cannot really be compressed since the atoms are a fixed distance apart and cannot be pushed closer together.

- Liquids
  - Liquids deform easily because the atoms are free to slide about and change neighbors (they flow).
  - When a liquid is placed in a container with no lid on, it remains in the container.
  - Because the atoms are closely packed, liquids, like solids, resist compression.

- Gases
  - The atoms in gases separated by distances that are large compared with the size of the particles.
    - The forces between the particles are very weak.
  - Gases flow and are relatively easy to compress because there is much space and little force between the particles.
  - When placed in an open container gases, unlike liquids, will escape.

- Plasmas
  - The charges in plasmas are also separated by large distances compared to the size of the particles.
  - They behave like gases except they are very difficult to contain as the particles have large amounts of energy.

Density

- Density is mass per unit volume.

$$\rho = \frac{m}{V}$$

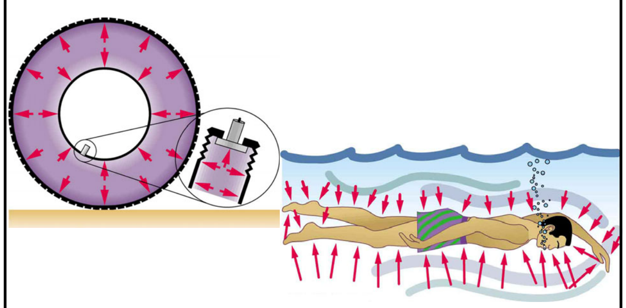
Pressure

- Pressure is defined as the force divided by the area perpendicular to the force over which the force is applied.

$$P = \frac{F_{\perp}}{A}$$

Units = $\frac{\mathrm{N}}{\mathrm{m}^2}$ = Pascal (Pa)

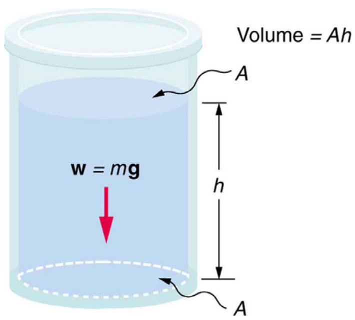
- Fluid pressure has no direction.
- The forces due to pressure are **always** exerted perpendicular to any surface.



Variation of Pressure with Depth in a Fluid

- The pressure in a fluid varies with depth.
  - Air pressure is much higher at the surface of the Earth than at the top of a mountain.
  - The water pressure at the bottom of a pool is much greater than at the top of the pool.

- Consider the following container.



- Its bottom supports the weight of the fluid in it.

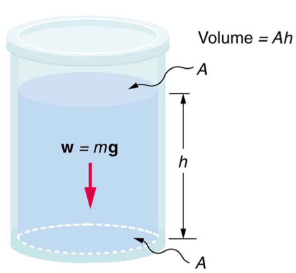
- The pressure is the weight of the fluid mg divided by the area A supporting it.

$$P = \frac{F_{\perp}}{A} = \frac{mg}{A}$$

$m = \rho V \qquad V = Ah$

$$P = \frac{\rho A h g}{A}$$

$$P = \rho g h$$



Note: This equation holds to great depths for liquids as they are not compressible. However, for gases, which are quite compressible, one can apply this equation if the density changes are insignificant over the depth considered.

- The pressure of the air in the atmosphere varies with altitude and as a result of the air movement due to the Earth's rotation.
- The average pressure at sea level is considered to be the standard atmospheric pressure.

$$P_0 = 1.0 \times 10^5 \ \mathrm{N/m^2} = 1.0 \times 10^5 \ \mathrm{Pa}$$

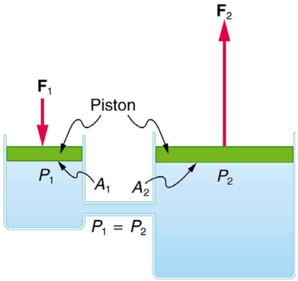
This standard pressure is also referred to as 1 atmosphere or 1 atm.

Pascal's Principle

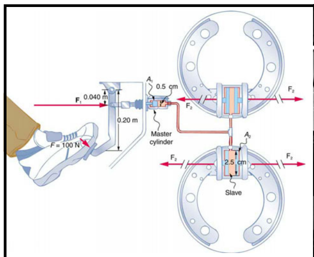
- Blaise Pascal, French (1623 – 1662)
  - A change in pressure applied to an enclosed fluid is transmitted undiminished to all portions of the fluid and to the walls of its container.

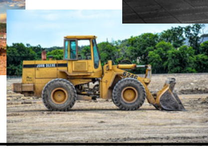
unknown; a copy of the painting of François II Quesnel, which was made for Gérard Edelinck en 1691 (CC BY 3.0)

- One of the most important technological applications of Pascal's principle is found in a *hydraulic system*, which is an enclosed fluid system used to exert forces.



OpenStax, Rice University (CC-BY 4.0)





Gauge and Absolute Pressure

- The atmosphere pushes down on everything.
- Therefore, anything that is open to the atmosphere is subject to atmospheric pressure.
- What is usually important, however, is the pressure relative to the atmospheric pressure.

- Gauge Pressure
  - The pressure relative to atmospheric pressure.
    - Gauge pressure is positive for pressures above atmospheric pressure, and negative for pressures below it.

$$P_{gauge} = \rho g h$$

- Absolute Pressure
  - The sum of gauge pressure and atmospheric pressure.

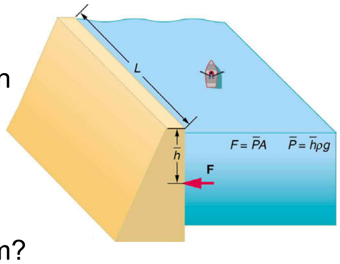
$$P = P_0 + \rho g h$$

Example

A dam is 500 m wide, and the water is 80.0 m deep at the dam.

(a) What is the average force on the dam due to the water?

(b) What is the average total force on the dam?



(a) $P = \rho g h$ To calculate average pressure, we use the average height.

$$\bar{P} = \rho g \bar{h}$$

$$\bar{P} = (1000)(9.8)(40)$$

$$\bar{P} = 3.92 \times 10^5 \text{ Pa}$$

$$\bar{F} = \bar{P}A$$

$$\bar{F} = (3.92 \times 10^5)(500)(80)$$

$$\bar{F} = 1.6 \times 10^{10} \text{ N}$$

(b) $P = P_0 + \rho g h$ To calculate average pressure, we use the average height.

$\bar{P} = P_0 + \rho g \bar{h}$

$\bar{P} = 1.0 \times 10^5 + (1000)(9.8)(40)$

$\bar{P} = 4.92 \times 10^5 \text{ Pa}$

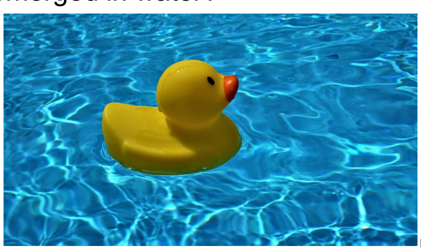
$\bar{F} = \bar{P} A$

$\bar{F} = (4.92 \times 10^5)(500)(80)$

$\bar{F} = 2.0 \times 10^{10} \text{ N}$

Archimedes' Principle

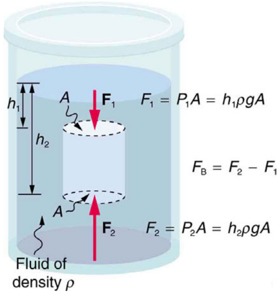
- Why do some things float?
- What do objects feel lighter when submerged in water?



Myléne (Pixabay)

- There is a net upward, or **buoyant force** on any object in any fluid.
  - If the buoyant force is greater than the object's weight, the object will rise to the surface and float.
  - If the buoyant force is less than the object's weight, the object will sink.
  - If the buoyant force equals the object's weight, the object will remain suspended at that depth.

- Consider a cylinder with cross-sectional area A and height h completely submerged in a fluid of density ρ.



$$F_B = F_2 - F_1$$

$$F_B = h_2\rho gA - h_1\rho gA$$

$$F_B = \rho gA\Delta h$$

$$\boxed{F_B = \rho Vg}$$

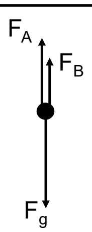
$$F_B = mg$$

The buoyant force is equal to the weight of the fluid displaced.

- Archimedes, Greek (287–212 BCE) stated this principle long before concepts of force were well established.
- The buoyant force on an object equals the weight of the fluid it displaces.
- This principle holds whether the object is totally or partially submerged.

Example 1

- An ancient statue lies at the bottom of the sea. The statue is estimated to have a mass of 70 kg and a volume of 3.0×10^{-2} m^3. How much force is required to lift it? The density of sea water is 1.025×10^3 kg/m^3.



$$\Sigma F = ma$$

$$F_A + F_B - F_g = 0$$

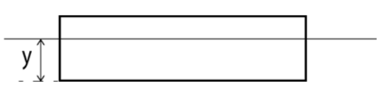
$$F_A = -F_B + F_g$$

$$F_A = -\rho V g + mg$$

$$F_A = -(1.025 \times 10^3)(3.0 \times 10^{-2})(9.8) + (70)(9.8)$$

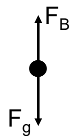
$$F_A = 380 \text{ N}$$

Example 2



- A wooden platform of thickness, h, and surface area, A, is placed in water. The distance, y, represents the amount of the platform that is submerged. Calculate the ratio $\frac{y}{h}$.

$$\rho_{\text{water}} = 1000 \text{ kg/m}^3$$
$$\rho_{\text{wood}} = 640 \text{ kg/m}^3$$



$$\Sigma F = ma$$
$$F_B - F_g = 0$$
$$F_B = F_g$$
$$\rho V g = mg$$
$$\rho_{water} A y g = \rho_{wood} A h g$$
$$\frac{y}{h} = \frac{\rho_{wood}}{\rho_{water}}$$
$$\frac{y}{h} = \frac{640}{1000}$$
$$\frac{y}{h} = 0.64$$