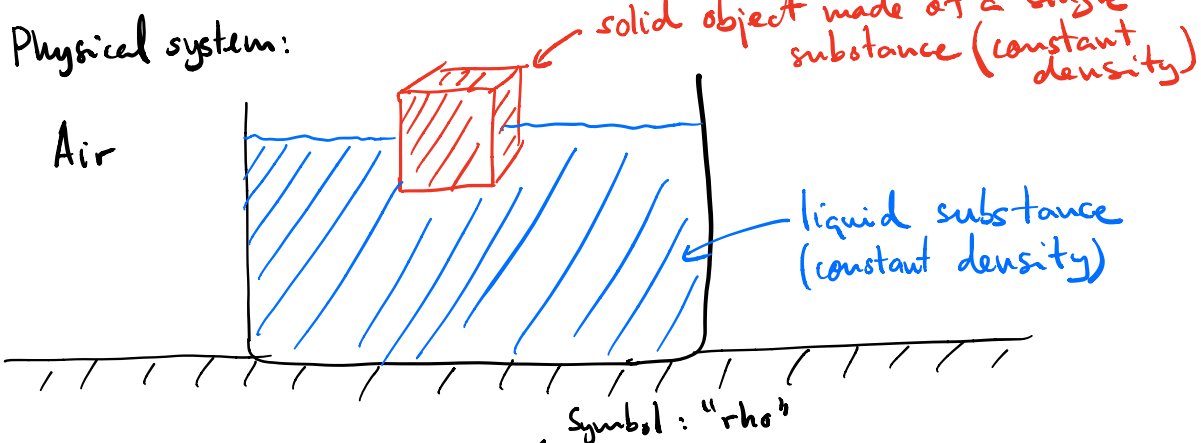
Lecture 9: Fluids: Buoyancy

Physical system:



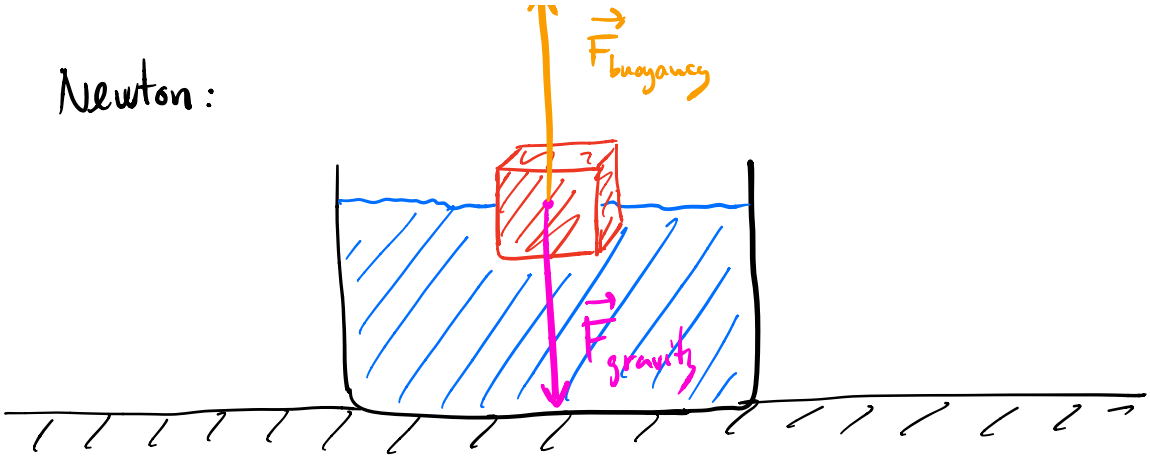
- **Density:** $\rho = \frac{m}{V}$

Symbol: "rho"

List of quantities that we could measure in this system:

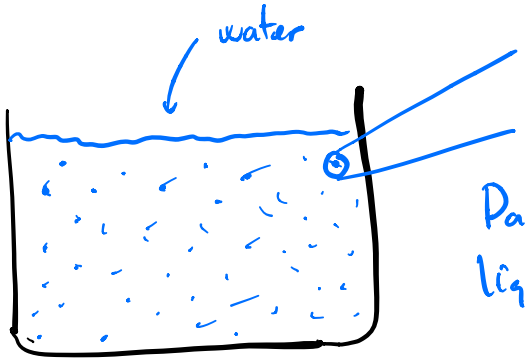
- Mass of the object.
- Volume of the liquid.
- "Buoyancy" of the object. (Buoyancy force on the object)
- Air pressure.
- Surface tension of fluid.
- Temperature of the fluid.
- Volume of the object.
- Shape of the container.
- Viscosity
- Density of the fluid.
- Density of the object.
- Force of gravity.
- Pressure of the fluid.
- ⋮

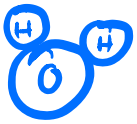
Newton:



Question: What is the cause of the buoyancy force?

Answer: A pressure gradient.

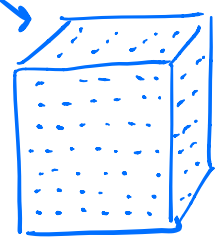




water molecule
H_2O

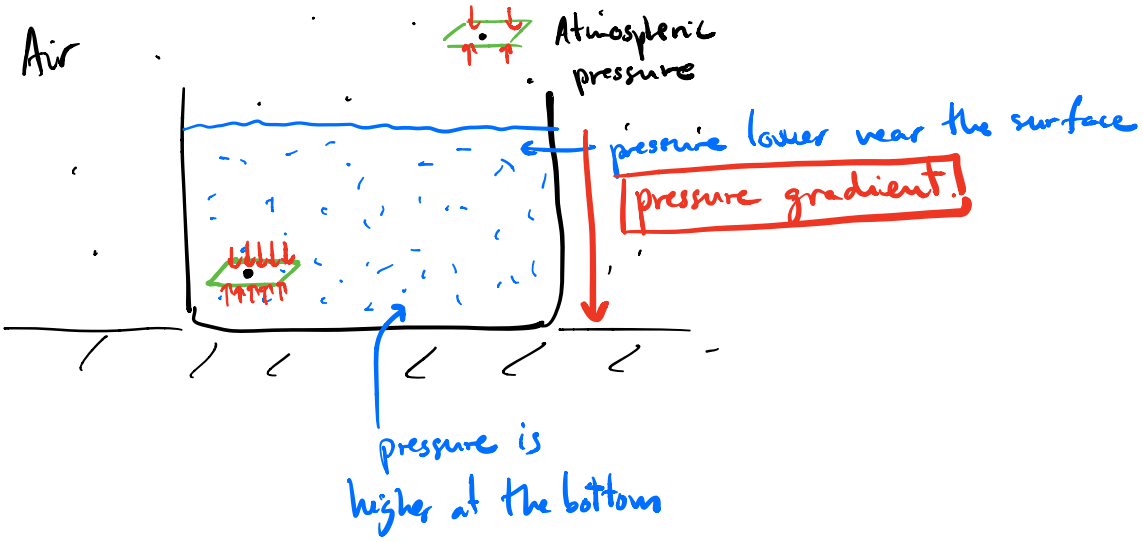
Particles move freely in liquid water.

ice cube (solid water)



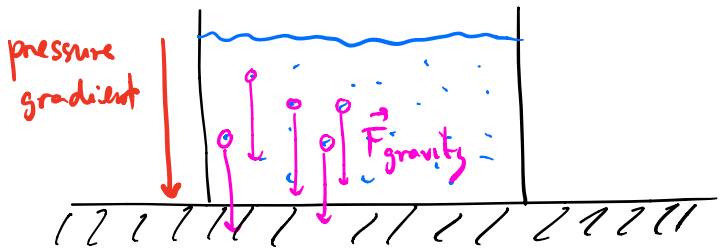
Particles are fixed in place (they can vibrate)

- Pressure in a fluid: Is the number of particle collisions per unit time against an imaginary surface.

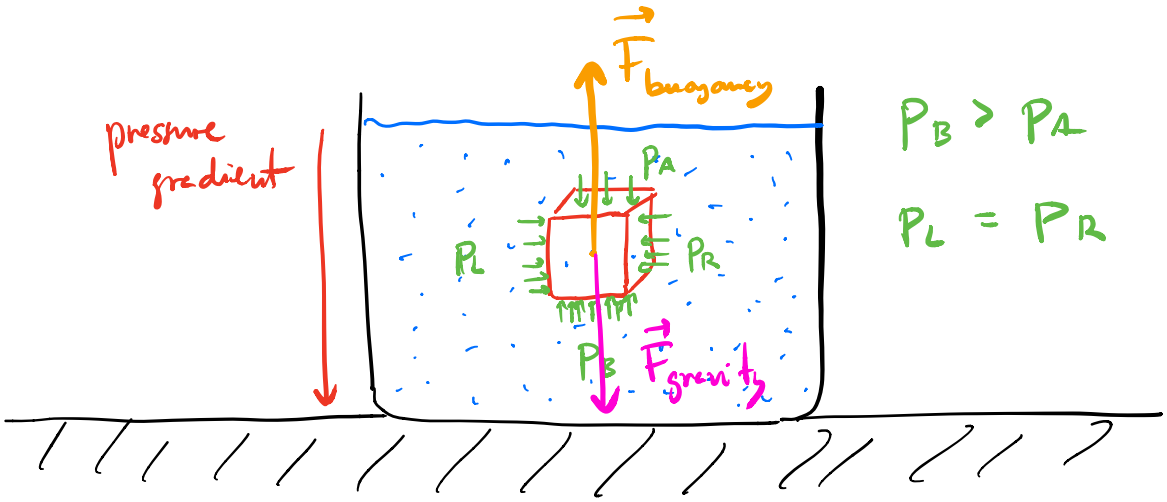


Question: What is causing the pressure gradient?

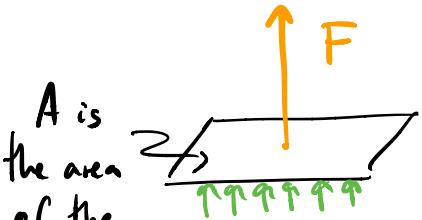
Answer: The force of gravity acting on the fluid particles.



Putting things together:



How to deduce the force from pressure p?

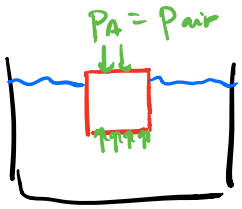


A is the area of the surface.

$$F = p \cdot A$$

3 possible outcomes

- $|\vec{F}_{buoyancy}| > |\vec{F}_{gravity}| \Rightarrow$ object rises.
- $|\vec{F}_{buoyancy}| = |\vec{F}_{gravity}| \Rightarrow$ object remains where it was
- $|\vec{F}_{buoyancy}| < |\vec{F}_{gravity}| \Rightarrow$ object sinks.



The principle (law) underlying this phenomena is called "Archimedes principle"

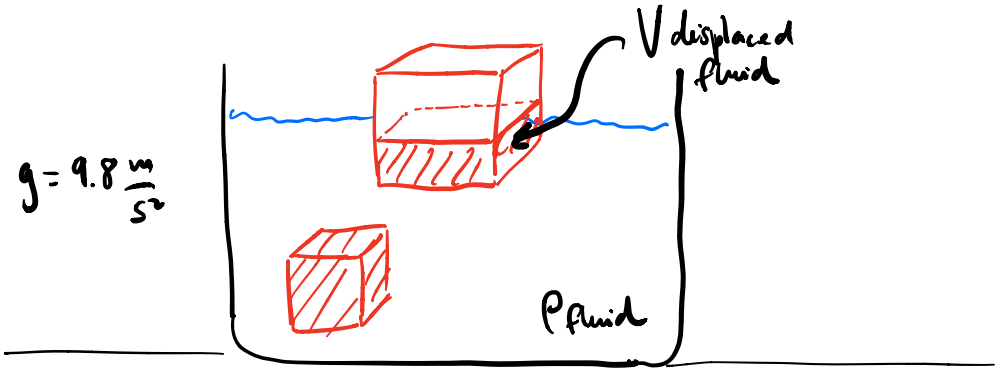
- Archimedes 287-212 BC. Syracuse.
- Work "On floating bodies" ~ 250 BC
- Other inventions: lever, Archimedes screw.
- "Eureka".

- Archimedes principle: Any object, totally or partially immersed in a liquid, is buoyed up by a force equal to the weight of the displaced fluid.

$$F_{buoyancy} = m_{\substack{displaced \\ fluid}} \cdot g \qquad (g = 9.8\ m/s^2)$$

$|\vec{F}_{buoyancy}|$

$$\boxed{F_{buoyancy} = \rho_{fluid} \cdot V_{\substack{displaced \\ fluid}} \cdot g}$$



The volume displaced $V_{displaced\ fluid}$ is the same as the volume of the object that is <u>immersed</u>.