# Unit 1: Fluids

## 1.1 - Fluid Systems

- fluids:
  - includes liquids and gases
    - liquids have constant mass and constant volume, take the shape of a container, and have uniform density
    - gases have constant mass but variable volume and density, and it fills the container entirely
  - can flow
  - has pressure
- systems:
  - collections of objects that can be treated as a whole
  - properties of systems are determined by the properties and interactions of its particles
- **density:** represented by $\rho$, measured in $\frac{kg}{m^3}$, and calculated by $\rho = \frac{m}{V}$, is the measurement of how much matter per space

> 📢 - **Density:** represented by $\rho$ and calculated by $\rho = \frac{m}{V}$, is the measurement of how much matter per unit of space

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## 1.2 - Density

- density is a property of a material
- to experimentally determine density, you need mass and volume
- for experimental procedures, use a best fit line to find the average ratio between quantities
  - when calculating the slope, never use your data points — use two points on the best fit line instead
  - convert the data points to a unit you actually want to use

> 📢 - You'll be asked questions related to experimental procedures on the AP exam

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## 1.3 - Fluids - Pressure and Forces

- **Newton's Third Law:** every action has an equal an opposite reaction
  - force is always the same between two objects, even if the objects are in motion
- **pressure:** represented by $P$, measured in $\text{Pascals}$, and calculated by $P = \frac{F}{A}$, is how force affects an entire area
  - the pressure is higher for a smaller area if the force applied stays constant

- hydrostatic or gauge pressure:
  - pressure exerted by the fluid, calculated by $P_G = \rho g h$
- absolute pressure:
  - the sum of atmospheric pressure and hydrostatic pressure calculated by $P_0 + \rho g h$
    - atmospheric pressure is denoted by $P_0 = 100,000 \text{ Pa}$

- pressure is equal at the same depth
- **Pascal's Principle:** changing the pressure at any point in an incompressible fluid causes the same pressure change at all points in that fluid

    - if you add something on top of the fluid, all points of pressure within the fluid change by the pressure of what you just added on top
- if a fluid of unknown density is added to one side of a U-shaped tube, the pressure at the same depth is still equal, meaning you can solve for the density of the unknown fluid with $\rho_1 h_1 = \rho_2 h_2$
    - the taller column of fluid is less dense

> 📢 - **Pressure ($\mathrm{Pa}$):** represented by $P$ and calculated by $P = \frac{F}{A}$, is how force affects an entire area
> - **Pascal's Principle:** changing the pressure at any point in a fluid cases the same pressure change at all points in that fluid
> - Absolute pressure is just hydrostatic pressure plus the atmospheric pressure

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# 1.4 - Fluids and Free-Body Diagrams

- a free-body diagram is a drawing that shows the forces acting on an object
    - the object is denoted by a dot and all forces are represented by arrows
    - only draw forces affecting the object and every force gets its own arrow that points away from the dot
- **Newton's Second Law:** $F = ma$
    - you have to take the vector sum of the forces before plugging them into the equation
    - you can only find the vertical $\sin\theta$ or horizontal $\cos\theta$ acceleration at a time, not both

> 📢 - A free-body diagram shows how forces affect an object

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# 1.5 - Buoyancy

- **Archimedes' Principle**: $F_b = \rho V g$ calculates the buoyant force on an object using the density of the liquid $\rho$, the volume of the object submerged $V$, and gravity $g$
    - liquids with higher densities have higher buoyant forces
    - bigger volume means larger buoyant force
    - object density doesn't affect buoyant force, because the density in the equation is of the liquid
    - depth, orientation, and object mass don't affect buoyant force
- to find the density of an object that's  partially submerged in a fluid, use the equation $\frac{V_f}{V_o} = \frac{\rho_o}{\rho_f}$
    - the density is the object is just the percentage submerged multiplied by the density of the fluid

> 📢 - **Archimedes' Principle:** $F_b = \rho V g$ which calculates the buoyant force on an object
> - The density of an object that's partially submerged in a fluid is calculated by $\frac{V_f}{V_o} = \frac{\rho_f}{\rho_o}$

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# 1.6 - Conservation of Energy in Fluid Flow

- speed of the fluid stays the same as the water moves up and down
    - a difference in pressure accounts for the change in graviatational potential energy
- **Bernoulli's Equation:** $P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$ where $\rho g y$ is gravitational potential energy and $\frac{1}{2}\rho v^2$ is kinetic energy
    - energy is conserved in a closed fluid flow system

- as liquid flows into a narrower tube, velocity increases and pressure decreases
- as liquid flows into a wider tube, velocity decreases but pressure increases
- tips for doing these types of questions on the AP exam:
  - set the lower height $y_1$ or $y_2$ as 0
  - write out your steps so you don't get lost
  - these questions take lots of time, so it might be good to just come back to it later
- **Torricelli's Theorem:** $v = \sqrt{2gh}$, calculates the speed at which water exits a hole in a container
  - depth affects the speed of the water and its range
  - range (how far a projectile travels) is calculated by $R = v_x \cdot \sqrt{\frac{2d}{g}}$

> 📢 - **Bernoulli's Equation:** $P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$ which is basically the conservation of energy equation
> - **Torricelli's Theorem:** $v = \sqrt{2gh}$ which calculates the speed at which water exits a hole
> - The range of a projectile is $R = v_x \cdot \sqrt{\frac{2d}{g}}$

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# 1.7 - Conservation of Mass Flow Rate in Fluids

- **continuity equation:** $A_1 v_1 = A_2 v_2$, states the relationship between cross-sectional area and velocity in a tube of water
  - volume of water passing through a tube is conserved meaning that the same amount coming in at a velocity must be equal to the same amount exiting at a velocity
  - when speed increases, pressure decreases, and when speed decreases, pressure increases
- if the speed is unknown, use the continuity equation to get spee, and then use Bernoulli's equation
- the Venturi effect is when air is blown through a tube connected to water, and the pressure within the tube towards the water is less than the atmospheric pressure outside of the tube pressing on the water

> 📢 - Continuity equation: $A_1 v_1 = A_2 v_2$ which calculates cross-sectional area and velocity of water moving through a tube