

# Fluid Dynamics #1

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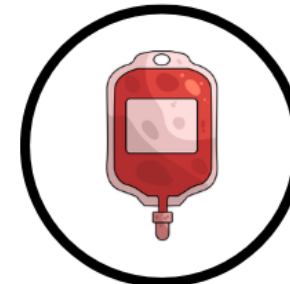
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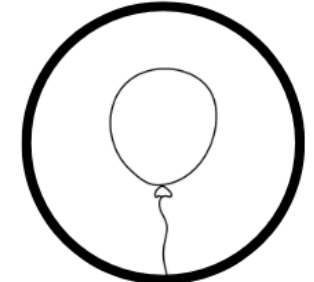
# What is a fluid?

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- A fluid is a substance that can flow and take the shape of its container
- Fluids cannot resist shear stress
  - Even a small force causes continuous deformation (flow)
- They do not have a fixed shape
- They exert pressure in all directions
- They can be:
  - Liquids (fixed volume)
  - Gases (compressible, no fixed volume)



Blood



Helium



Oil



Air

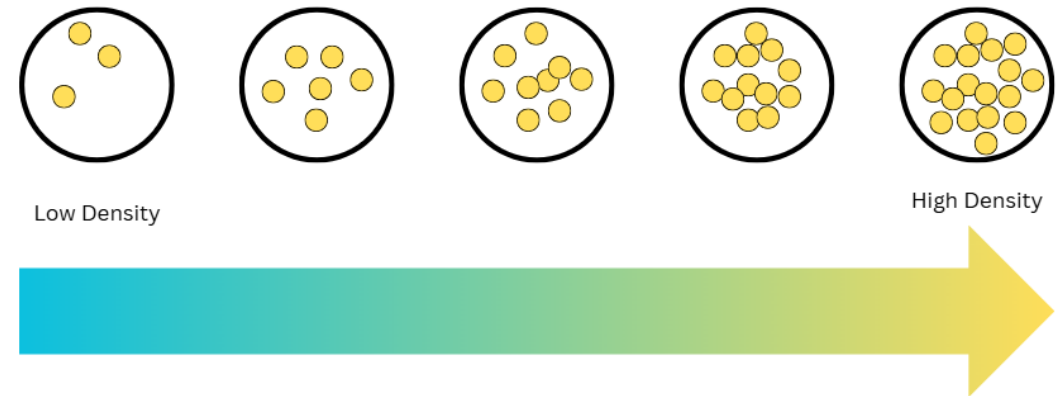


Water

# Density

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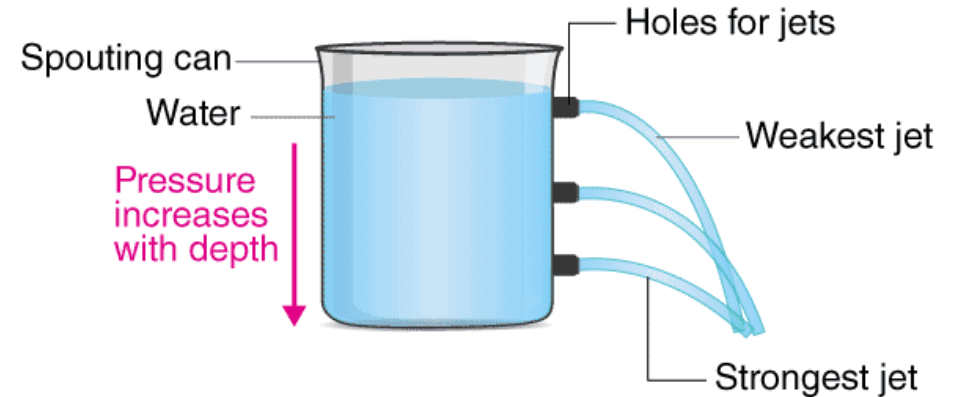
- Density is how much mass is contained in a given volume
- It tells us how “packed” a material or fluid is
- Higher density → heavier for same volume
- Liquids generally have higher density than gases
- We can calculate density using:  $\rho = \frac{m}{V}$
- Where:
  - $\rho$  = Density ( $kg/m^3$ )
  - $m$  = mass ( $kg$ )
  - $V$  = volume ( $m^3$ )



# Pressure in Fluids

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- Pressure is force acting over an area
- Pressure is given in pascals (Pa)
- Pressure increases with:
  - Depth ( $h$ )
  - Density ( $\rho$ )
- We have two equations we use for pressure:
  - We use  $P = \frac{F}{A}$  when given force ( $F$ ) and Area ( $M^2$ )
    - Used for: Solid surfaces, Hydraulic systems, Contact forces
  - We use  $P = \rho gh$  when given a fluid with density ( $\rho$ ) and a depth ( $h$ )
    - Used for: Liquids at rest, Tanks, Dams, Underwater systems



# Your Turn

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1. A tank contains  $0.015\text{m}^3$  of oil with a mass of 12kg. Calculate the density of the oil.
2. Seawater has a density of  $1025\text{kg/m}^3$ . A tank contains 205kg of seawater. Calculate the volume of seawater in the tank.
3. Two fluids are stored to the same depth:
  - Fluid A:  $800\text{ kg/m}^3$
  - Fluid B:  $1200\text{ kg/m}^3$
  - Explain which fluid produces greater pressure at the bottom and why.
4. Oil floats on top of water in a container. Explain what this tells you about the density of oil compared to water.
5. Water is stored in a vertical tank to a depth of 4 m. Calculate the pressure at the bottom of the tank.

# Flow rate

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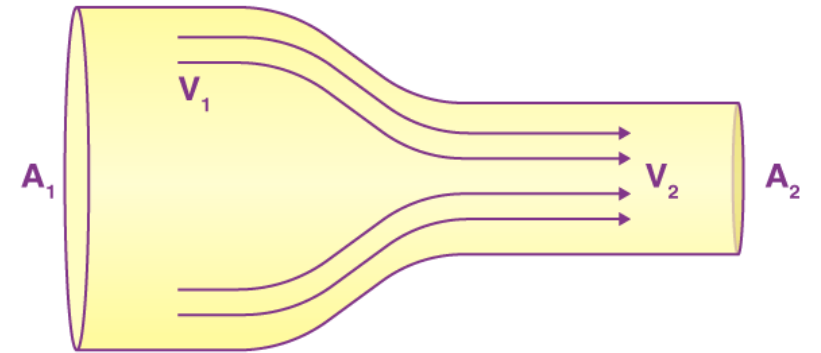
- Flow rate is the volume of fluid passing a point per second
- Flow rate in a pipe stays constant
- We can work out flow rate using:  $Q = Av$
- Where:
  - $Q$  = flow rate ( $\text{m}^3/\text{s}$ )
  - $A$  = cross-sectional area ( $\text{m}^2$ )
  - $v$  = velocity ( $\text{m}/\text{s}$ )



# Continuity Equation

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- In any fluid system what goes in must come out (steady flow)
- If area decreases  $\rightarrow$  velocity increases
- If area increases  $\rightarrow$  velocity decreases
- The continuity equation is:
  - $Q_1 = Q_2 \rightarrow A_1 v_1 = A_2 v_2$
- Where:
  - $A$  is area ( $m^2$ )
  - $v$  is velocity ( $m/s$ )



Narrow pipe  $\rightarrow$  faster fluid

Wide pipe  $\rightarrow$  slower fluid

# Solving a Continuity Equation Problem

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- Water flows through a horizontal pipe with a cross-sectional area of  $0.08\text{m}^2$  at a velocity of  $2.5\text{m/s}$ . The pipe then narrows to a cross-sectional area of  $0.02\text{m}^2$ . Calculate the velocity of the water in the narrower section.
- $0.08 * 2.5 = 0.02 * v$
- $\frac{0.08*2.5}{0.02} = 10$
- Velocity in the narrower section must be  $10\text{m/s}$

# Your Turn

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1. Water flows through a pipe with an area of  $0.06\text{m}^2$  at a velocity of  $3\text{m/s}$ . The pipe narrows to  $0.02\text{m}^2$ . Calculate the velocity in the narrower section.
2. Water flows at  $12\text{m/s}$  through a pipe with an area of  $0.01\text{m}^2$ . The pipe widens and the velocity reduces to  $3\text{m/s}$ . Calculate the new cross-sectional area.
3. Water flows through a pipe of diameter  $0.2\text{m}$  at  $2\text{m/s}$ . The pipe narrows to a diameter of  $0.1\text{m}$ . Calculate the new velocity.
4. Oil floats on top of water in a container. Explain what this tells you about the density of oil compared to water.
5. Water is stored in a vertical tank to a depth of  $4\text{ m}$ . Calculate the pressure at the bottom of the tank.

# Energy in a fluid

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- When working with fluids our energy calculations change
- We use density instead of mass

- Kinetic Energy:

- $K_e = \frac{1}{2}pv^2$

- Where:
- $p$  = density (kg/m<sup>3</sup>)
- $v$  = velocity (m/s)

- Gravitational Potential Energy:

- $E_p = pgh$

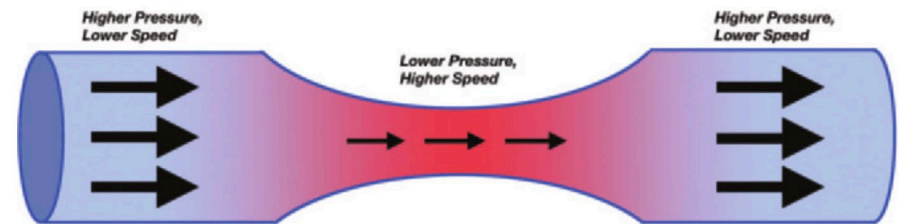
- Where:
- $p$  = density (kg/m<sup>3</sup>)
- $g$  = gravitational field strength (9.81m/s<sup>2</sup>)
- $h$  = height (m)

# Bernoulli's Principle

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- In a flowing fluid, **total energy is conserved**
  - Energy is shared between:
    - Pressure energy
    - Kinetic energy
    - Gravitational potential energy
- This means we can equate all 3 values into one equation:

- $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$



- $P$  = Pressure
- $\rho$  = Density ( $\text{kg/m}^3$ )
- $v$  = Velocity ( $\text{m/s}$ )
- $g$  = gravitational field strength ( $9.81\text{m/s}^2$ )
- $h$  = height