Chapter 9 - Fluids

After this you can
- discuss the states of matter.
- define a fluid and give examples.
- calculate density.
- define and calculate pressure.

solid

liquid

gas

fluids - material where it conforms to its container.

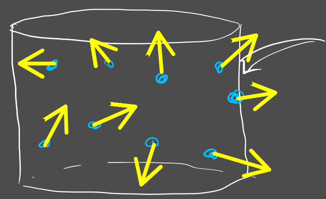
incompressible
ρ is constant

compressible
ρ is variable

volumetric mass density = $\frac{\text{mass}}{\text{volume}}$

"rho" $\rightarrow \rho = \frac{m}{V} \longrightarrow \rho \rightarrow$ intrinsic material property

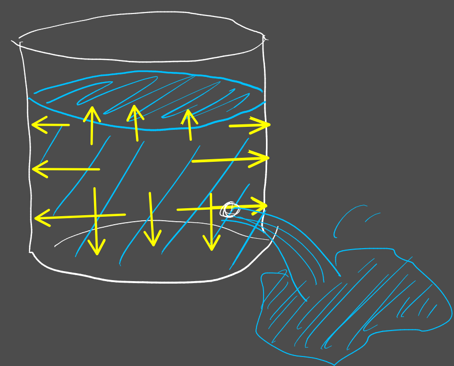
Hydrostatics - no flow of fluid
- atoms are still in motion
no average motion

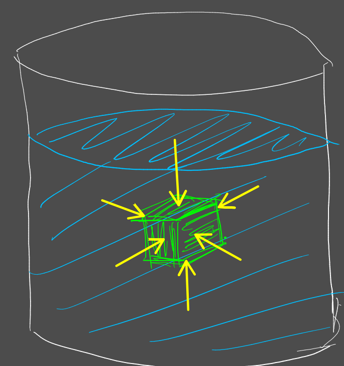


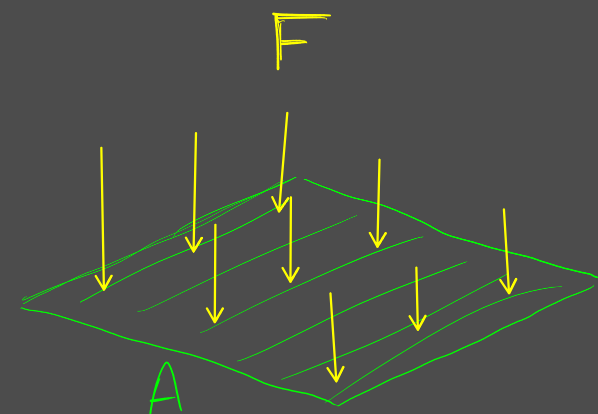
when this molecule collides

$$\Delta \vec{p} = F_{wall} \Delta t$$

$$F_{wall \to gas} = -F_{gas \to wall}$$







$$\boxed{\text{Pressure} = \frac{\text{Force}}{\text{Area}}}$$

$$\left[\frac{N}{m^2}\right] = [\text{Pascal}]$$

$101.3\ kPa = 1$ atmosphere

kilo Pascal

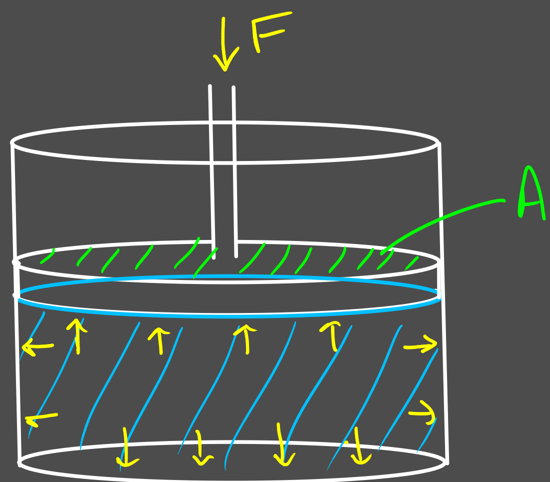
SI
- pascal
- atm — common
- psi — US customary
- mmHg — weather — health
- torr
- bar

After this you can

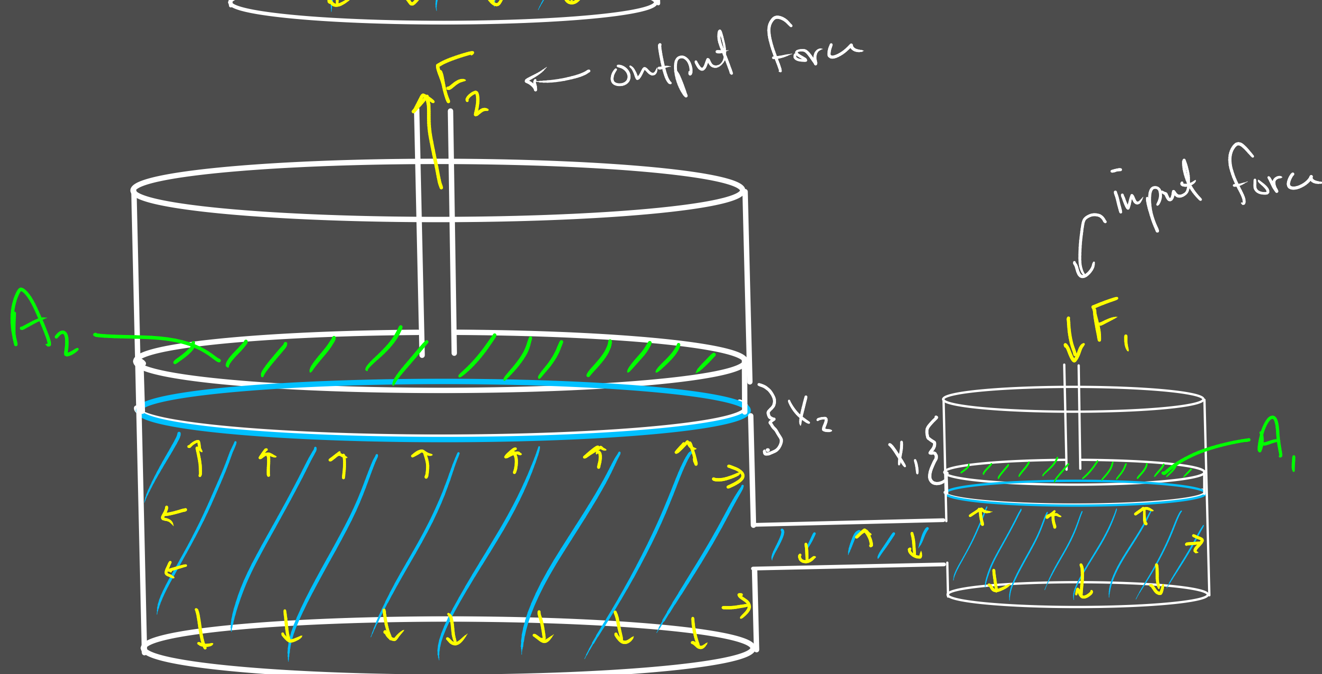
- use Pascal's principle to increase an applied force.

a change in pressure is transmitted throughout the fluid

- confined fluid
- ignore weight of fluid



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



$$\frac{F_1}{A_1} = P = \frac{F_2}{A_2}$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

could be very large ratio

$$F_2 = \frac{A_2}{A_1} \cdot F_1$$

But remember the Conservation of Energy

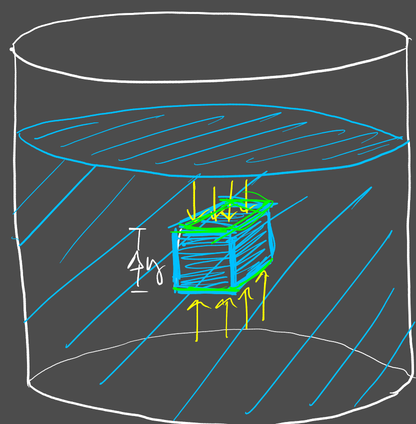
$$W_{in} = W_{out}$$

$$F_1 \cdot x_1 = F_2 \cdot x_2$$

large force $\qquad \dfrac{F_2}{F_1} = \dfrac{x_1}{x_2}$ $\qquad$ small displacement

After this you can

- discuss how pressure changes with under the force of gravity.
- discuss how heavy things float.



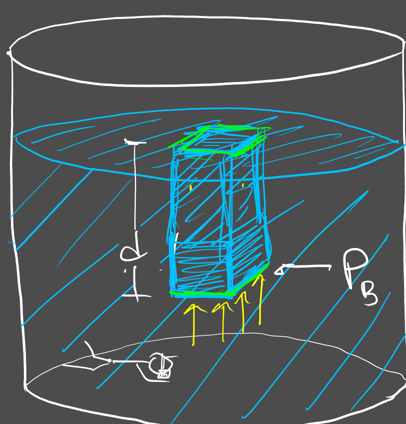
$$-F_{Above} + F_{Below} - mg = 0$$

$$-P_A \cdot A + P_B \cdot A - mg = 0$$

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

$$-P_A A + P_B A - \rho V \cdot g = 0$$

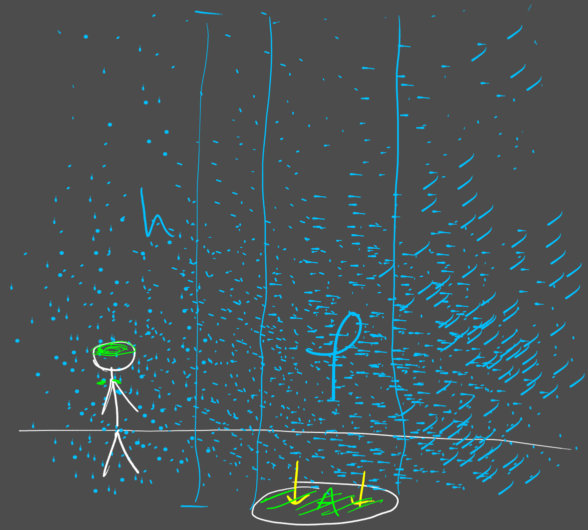
$$V = A \cdot \Delta y$$



$$\frac{-P_A \cancel{A} + P_B \cancel{A} - \rho \cancel{A} \cdot \Delta y \cdot g}{\cancel{A}} = \frac{0}{A}$$

$$-P_A + P_B - \rho \Delta y \cdot g = 0$$

$$P_B = P_A + \rho g \Delta y$$

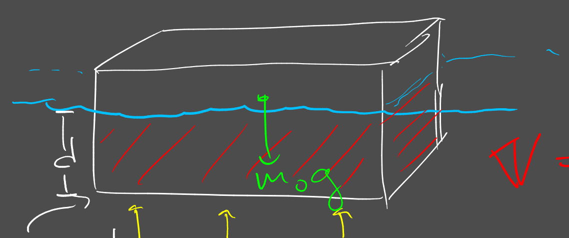


for an open container

$$P_B = P_{ATM} + \rho g d$$

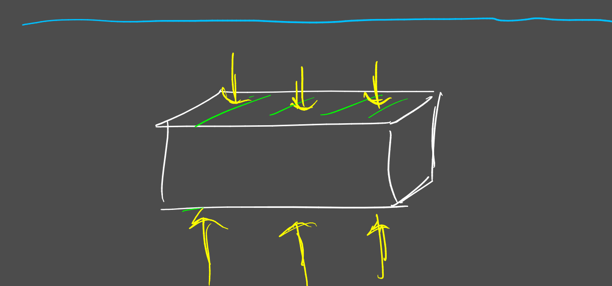
$$\frac{\text{Weight of air above}}{\text{Area}} = \underline{1 \text{ atm}} = 101.3 \text{ kPa} = \underbrace{1.013 \cdot 10^5 \text{ Pa}}_{\approx 10^5 \text{ Pa}}$$

$$\approx 15 \frac{\text{lb}}{\text{sq}^2}$$



$$\mathbb{V} = A \cdot d$$

$$P = \rho g d$$



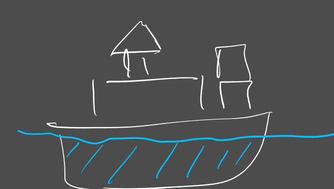
$$F_B = P_B \cdot A = \rho_f g \cdot d \cdot A$$

$$F_B = \rho_f g \mathbb{V} = g m_f$$

$$F_B = \rho_f \mathbb{V} \cdot g$$

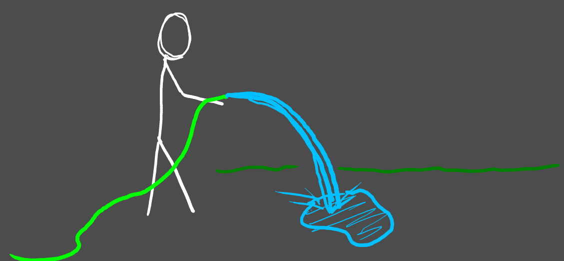
floating object

$$\hookrightarrow -m_o g + \rho_f g \cdot A \cdot d = 0$$



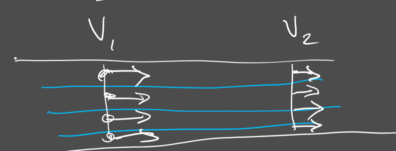
After this you can
- discuss flow rate in terms of volume and mass trasfer
- discuss Bernoulli's principle using the conservation of energy

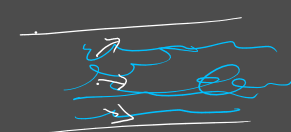
hydrodynamics – moving fluids; flows

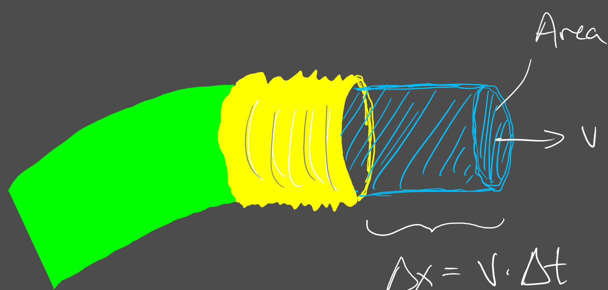


ideal flow (steady flow) → laminar

nonideal (unsteady) → extreme turbulance







volumetric flow

$$V = A \cdot \Delta x$$

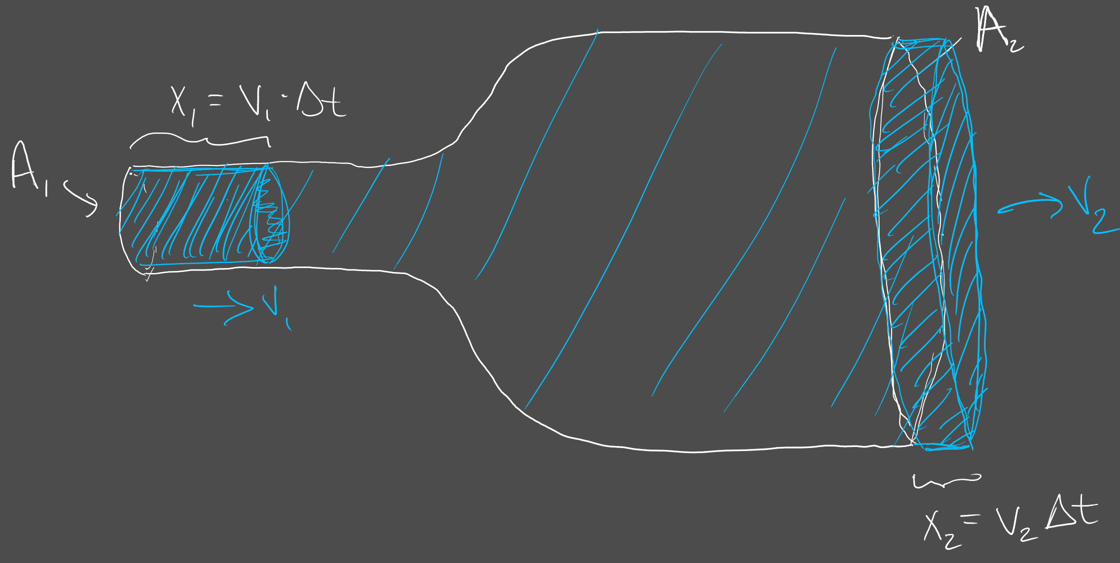
$$V = A \cdot v \cdot \Delta t$$

$$\boxed{\frac{V}{\Delta t} = A \cdot v}$$ rate of volume flow

mass flow rate

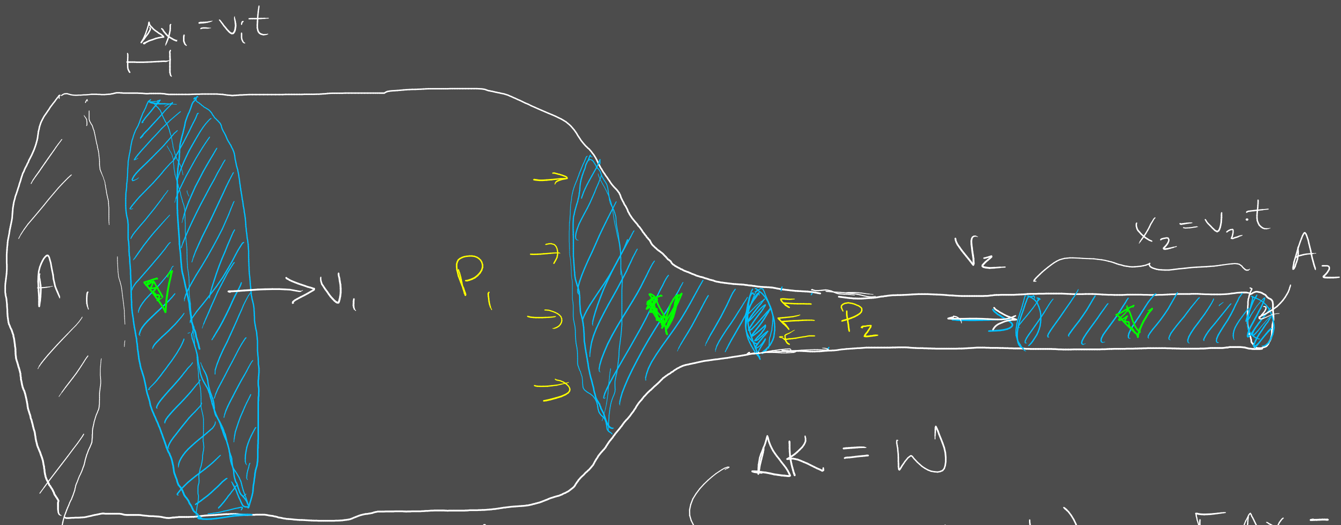
$$\rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho}$$

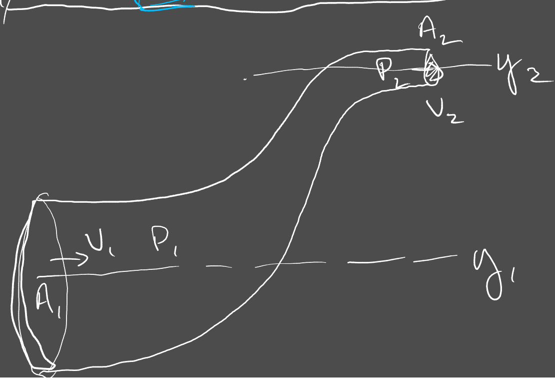
$$\frac{m}{\rho \Delta t} = A \cdot v \Rightarrow \boxed{\frac{m}{\Delta t} = \rho \cdot A \cdot v}$$ mass flow rate



$$\underbrace{A_1 v_1}_{\text{what comes in}} = \underbrace{A_2 v_2}_{\text{what goes out}} \leftarrow \text{continuity equation}$$

$$\begin{array}{l} \text{constriction} \to \\ \text{widening} \to \end{array} \underbrace{\frac{A_1}{A_2}}_{<1} = \underbrace{\frac{v_2}{v_1}}_{<1} \begin{array}{l} \leftarrow \text{slow velocity} \\ \leftarrow \text{faster} \end{array}$$





$$\Delta K = W$$

$$\Delta K + \Delta U = W_{nc} = F_1 \Delta x_1 - F_2 \Delta x_2$$

$$K_2 - K_1 + U_2 - U_1 = P_1 \underbrace{A_1 \Delta x_1}_{V} - P_2 \underbrace{A_2 \Delta x_2}_{V}$$

$$= P_1 V - P_2 V = (P_1 - P_2) V = W$$

higher lower

$$\frac{\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 + mgy_2 - mgy_1}{\mathbb{V}} = \frac{(P_1 - P_2)\cancel{\mathbb{V}}}{\cancel{\mathbb{V}}}$$

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

$$\frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g y_2 - \rho g y_1 = P_1 - P_2$$

$$\underbrace{\boxed{\frac{1}{2}\rho v_1^2 + \rho g y_1 + P_1}}_{\underline{\text{energy before}}} \boxed{=} \underbrace{\boxed{\frac{1}{2}\rho v_2^2 + \rho g y_2 + P_2}}_{\underline{\text{energy after}}}$$

$$\underline{\text{energy before}} = \underline{\text{energy after}}$$

Bernoulli's Law

- ideal flow

$$\underbrace{\frac{1}{2}\rho v_1^2 + \rho g y_1 + P_1} = \underline{\underline{\text{constant}}}$$

$$\boxed{\begin{array}{l}\underline{\text{non ideal}}: \\ \quad \underline{\underline{\text{viscous fluid}}}\end{array}}$$