ChEn 374
Fluid Mechanics

Mechanical Energy

Spiritual Thought

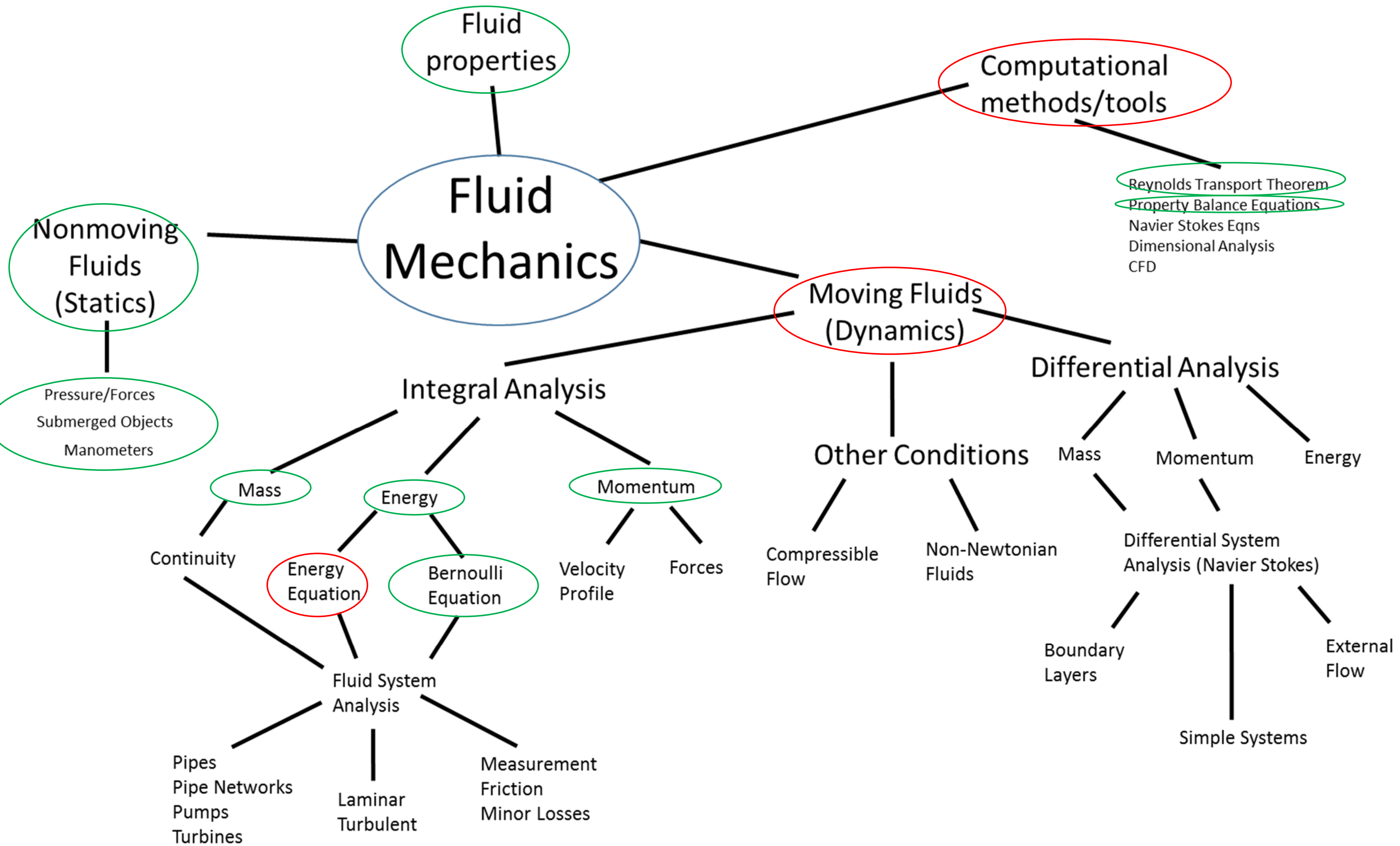
Matthew 5:14-16

Ye are the light of the world. A city that is set on a hill cannot be hid.

Neither do men light a candle, and put it under a bushel, but on a candlestick; and it giveth light unto all that are in the house.

Let your light so shine before men, that they may see your good works, and glorify your Father which is in heaven.

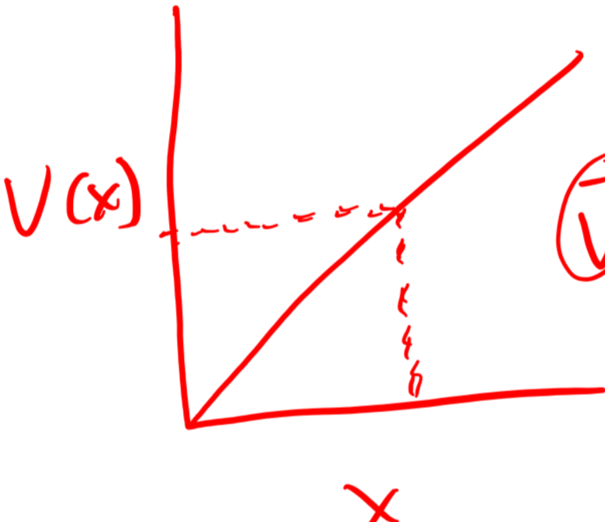
Fluids Roadmap



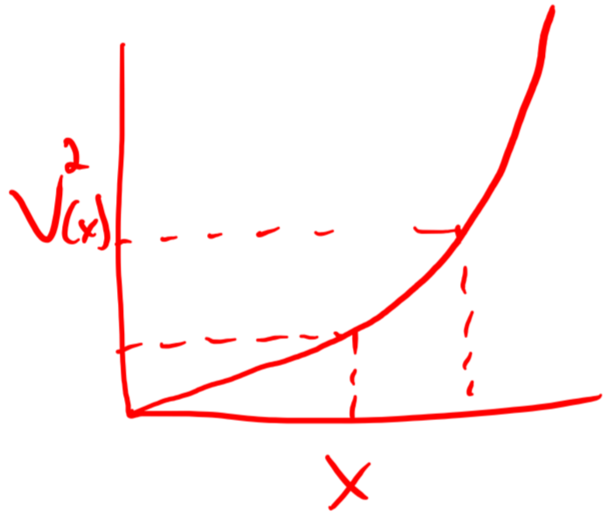
Key Points

- Kinetic Energy Correction Factor (α)
- Friction, Shaft work
  - F is positive
    F decreases e_{mech}
    F = $\dot{Q} - \dot{m}\Delta u$
- Examples

Kinetic Energy Correction Factor



$\bar{V} = V(\bar{x})$



- Correct with a fudge factor - $KE = \frac{1}{2}\alpha m\bar{v}^2$
  - α=2 for laminar flow 
  - α = 1.04 – 1.11 for turbulent flow 
- Often ignored
  - most flows turbulent
  - KE small vs p or height

Friction/Losses

- SS Energy Equation:

$$\dot{Q} + \cancelto{0}{\dot{W}_s} = \dot{m}\Delta u + \dot{m}\left(\cancelto{0}{\frac{\Delta P}{\rho}} + \cancelto{0}{\frac{\Delta v^2}{2}} + \cancelto{0}{g\Delta z}\right)$$

  - Been ignoring $\dot{Q}, \dot{W}_s$, Δu, now add $\dot{W}_s$, losses
- If $\dot{Q}, \dot{W}_s$, Δu are constant?
    - B.E.
- Heater, no friction?
    - $\dot{m}\Delta u = \dot{Q}$
    - Heat goes to Δu!

- Friction → Δ e_{mech} to Δu

- Energy Eq. adjusted for friction:

$$\dot{W}_s + \underbrace{\left(\dot{Q} - \dot{m}\Delta u\right)}_{-\,F} = \dot{m}\left(\frac{\Delta P}{\rho} + \frac{\Delta v^2}{2} + g\Delta z\right)$$

  - F is positive
  - Decreases e_{mech}
  - Sometimes called $\dot{E}_{mech,loss}$

- Head form:

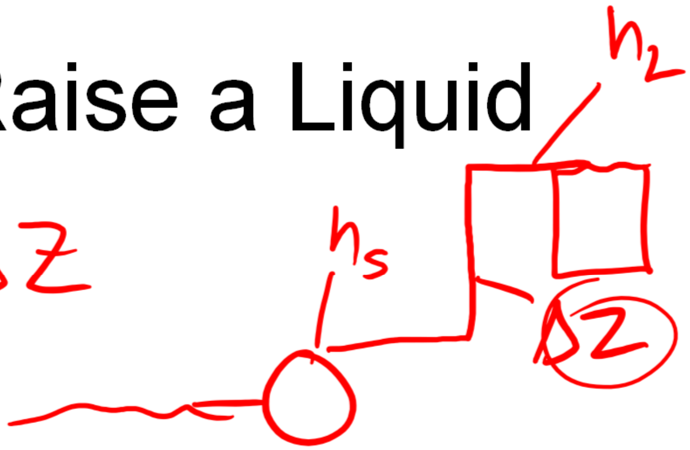
$$\left(\frac{\Delta P}{\rho g} + \frac{\Delta v^2}{2g} + \Delta z\right) = h_s + h_L$$

  - $\dot{W}_s - F = \dot{W}_u$ →usable work

Example 1

- Raise a Liquid

ΔZ

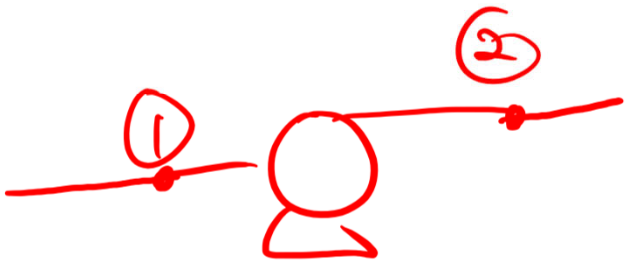


$$\frac{\cancel{\Delta P}^{0}}{\rho g} + \frac{\cancel{\Delta v^2}^{0}}{2g} + \Delta z = h_s - h_L$$

$$h_s = \underline{\Delta z} + h_L$$

Example 2

- Pump a liquid



$h_s = ?$

$$\frac{\Delta P}{\rho g} + \cancel{\frac{\Delta v^2}{2g}}^{\,0} + \cancel{\Delta z}^{\,0} = h_s - h_L$$

$$h_s = \frac{\Delta P}{\rho g} + h_L$$

Example 3

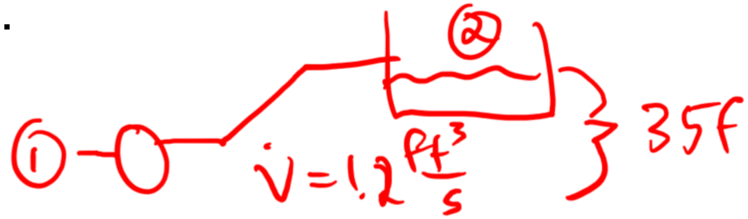
- Nozzle

$$\frac{\Delta P}{\rho g} + \frac{\Delta V^2}{2g} + \cancel{\Delta z}^{\,0} = \cancel{h_s}^{\,0} - h_L$$

$$\frac{\Delta P}{\rho g} = \boxed{-h_L - \frac{\Delta V^2}{2g}}$$

Example 4

A 73% efficient pump is pumping water from a lake to a nearby pool at a rate of 1.2 ft3/s through a constant diameter pipe. The free surface of the pool is 35 ft above that of the lake. Determine the irreversible head loss of the piping system, in ft. and the mechanical power used to overcome it.



$$W_s - F = \dot m\left(\cancel{\frac{P_2}{\rho}}^{\,0} + \cancel{\frac{V_2^2}{2}}^{\,0} + gz_2\right)$$
$$-\dot m\left(\cancel{\frac{P_1}{\rho}}^{\,0} + \cancel{\frac{V_1^2}{2}}^{\,0} + \cancel{gz_1}^{\,0}\right)$$

↑
$\eta = 0.73$
$\dot W = 12\,hp$

$-h_L$?
$-P$ to overcome it

$z_2 = h = 35ft$

$$W_s - F = \dot m g h$$
↳ head form divide by $\dot m g$

$$\frac{W_s}{\dot m g} - h_L = h$$

$$h_L = \frac{W_s}{\dot m g} - h = \boxed{29.4\ ft}$$

$$\text{Power} = \dot m g h_L = \boxed{4.0\ hp}$$