Energy balance via control volume-2
Steady State System

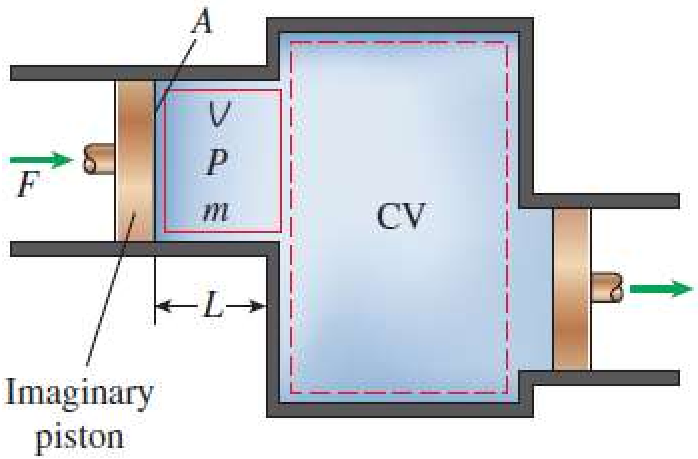
Raj Pala,
rpala@iitk.ac.in
Department of Chemical Engineering,
Associate faculty of the Materials Science Programme,
Indian Institute of Technology, Kanpur.

Energy balance: Closed system & Via Control Volume

- 1st TD law closed system: Conservation of energy; Q & W
- Most engineering systems: Flow systems
- Balances via control volume: Mass & energy

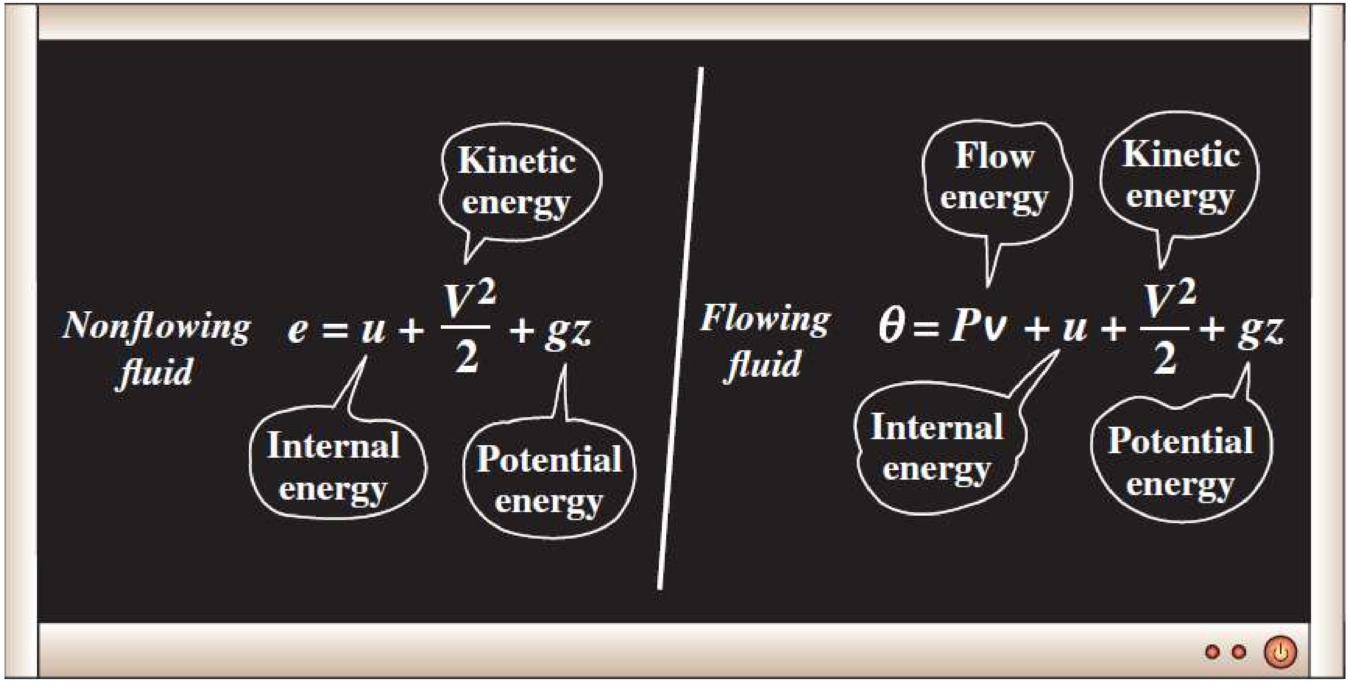
Work & Energy of Flowing Fluid

- "Flow work" done in pushing the fluid into or out of the control volume



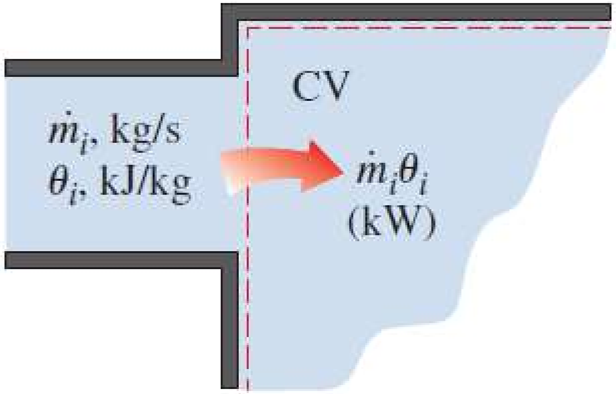
$$W_{\text{flow}} = FL = PAL = PV \qquad \text{(kJ)}$$

$$w_{\text{flow}} = Pv \qquad \text{(kJ/kg)}$$



Figs: Cengel & Boles: TD

Overall energy transport

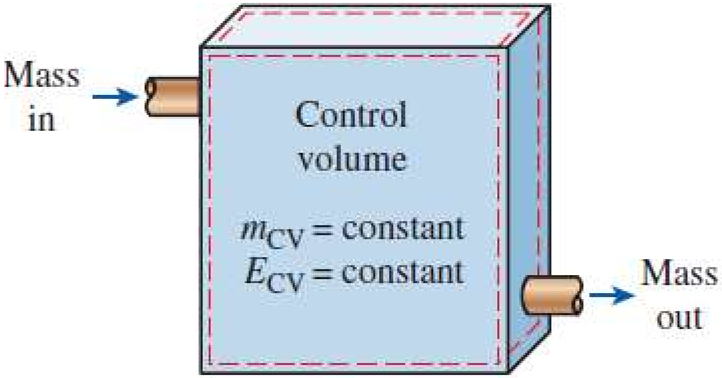


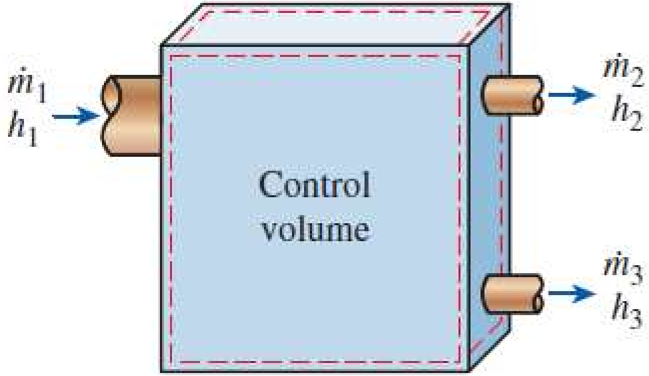
Amount of energy transport: $$E_{\text{mass}} = m\theta = m\left(h + \frac{V^2}{2} + gz\right) \qquad \text{(kJ)}$$

Rate of energy transport: $$\dot{E}_{\text{mass}} = \dot{m}\theta = \dot{m}\left(h + \frac{V^2}{2} + gz\right) \qquad \text{(kW)}$$

Figs: Cengel & Boles: TD

Most engineering systems operate at steady state

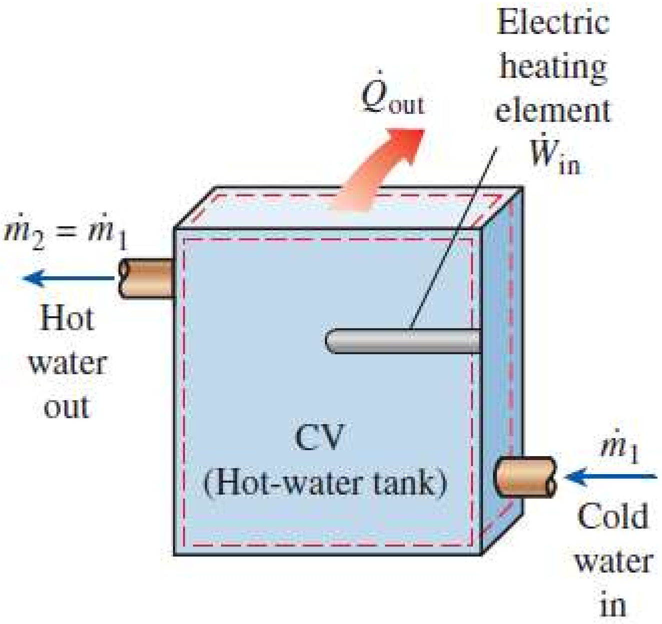




Boundary Work=0 as V_{cv}=Constant

Figs: Cengel & Boles: TD

Steady state balances



$$\sum_{in} \dot{m} = \sum_{out} \dot{m} \qquad \text{(kg/s)}$$

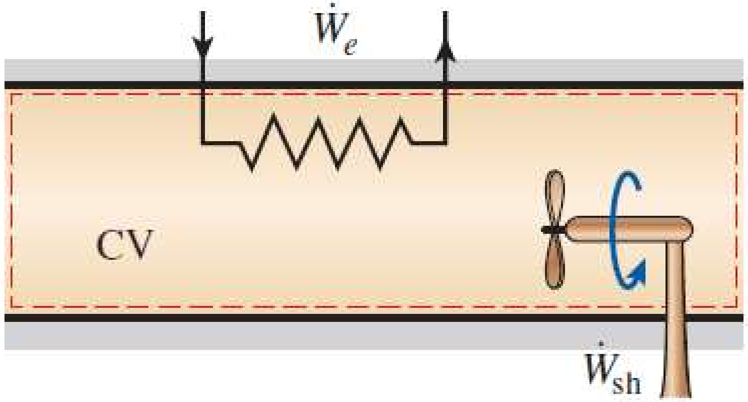
$$\underbrace{\dot{E}_{in}}_{\substack{\text{Rate of net energy transfer in} \\ \text{by heat, work, and mass}}} = \underbrace{\dot{E}_{out}}_{\substack{\text{Rate of net energy transfer out} \\ \text{by heat, work, and mass}}} \qquad \text{(kW)}$$

$$\dot{Q}_{in} + \dot{W}_{in} + \sum_{in} \dot{m}\theta = \dot{Q}_{out} + \dot{W}_{out} + \sum_{out} \dot{m}\theta$$

$$\dot{Q}_{in} + \dot{W}_{in} + \sum_{in} \underbrace{\dot{m}\left(h + \frac{V^2}{2} + gz\right)}_{\text{for each inlet}} = \dot{Q}_{out} + \dot{W}_{out} + \sum_{out} \underbrace{\dot{m}\left(h + \frac{V^2}{2} + gz\right)}_{\text{for each exit}}$$

Figs: Cengel & Boles: TD

1^{st} TD law for flow systems



$$\dot{Q} - \dot{W} = \sum_{\text{out}} \underbrace{\dot{m}\left(h + \frac{V^2}{2} + gz\right)}_{\text{for each exit}} - \sum_{\text{in}} \underbrace{\dot{m}\left(h + \frac{V^2}{2} + gz\right)}_{\text{for each inlet}}$$

$$q - w = h_2 - h_1$$

Figs: Cengel & Boles: TD

What's next?

- Applying 1^{st} TD in engineering flow devices operating at steady state