Energy balance on closed system & Introduction to Enthalpy

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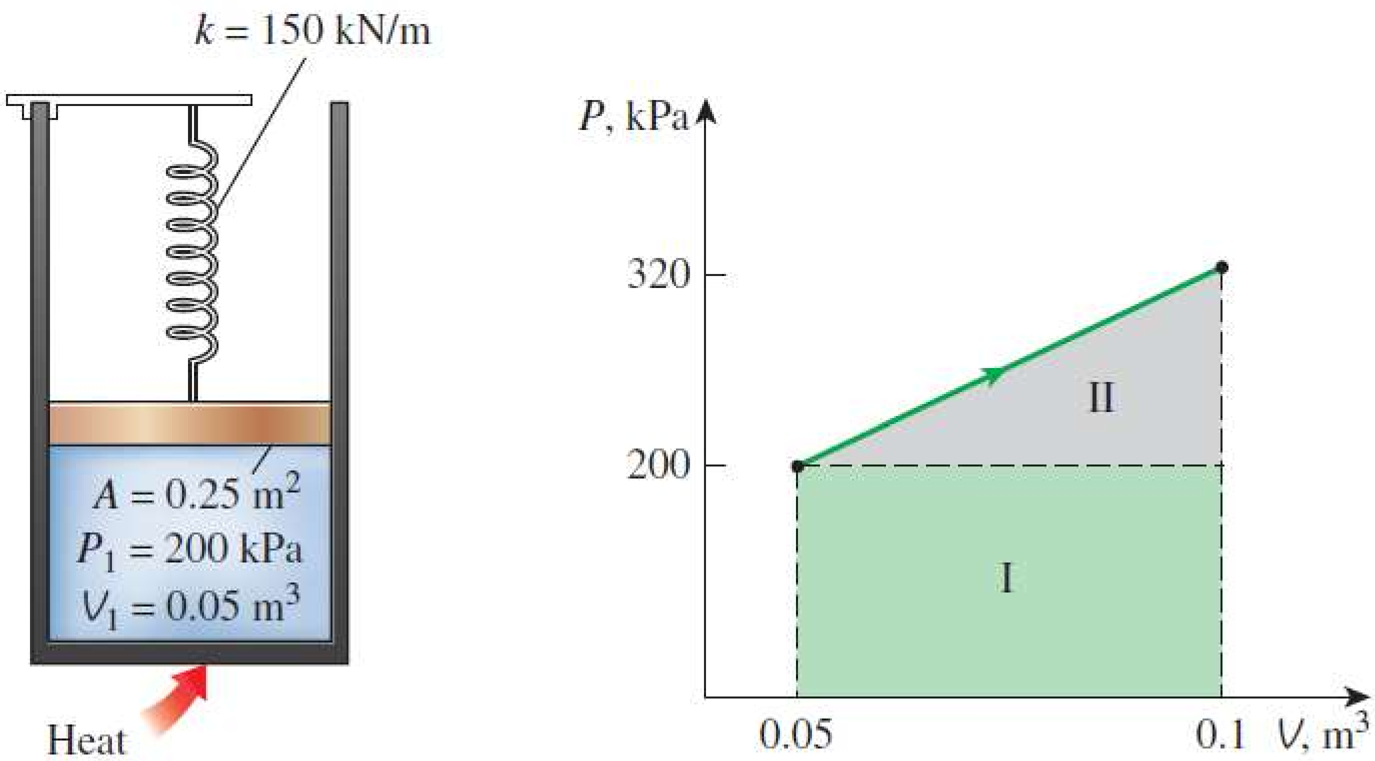
1st Law: Moving Boundary Work

- Work is a path fxn → Net work from cyclic processes!
- Constant P, Isothermal compression, Polytropic…
- Bounds for real processes

Expansion against spring



Figs: Cengel & Boles: TD

Energy Balance for Closed Systems

$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc., energies}}} \quad \text{(kJ)}$$

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{dE_{system}/dt}_{\substack{\text{Rate of change in internal,}\\ \text{kinetic, potential, etc., energies}}} \quad \text{(kW)}$$

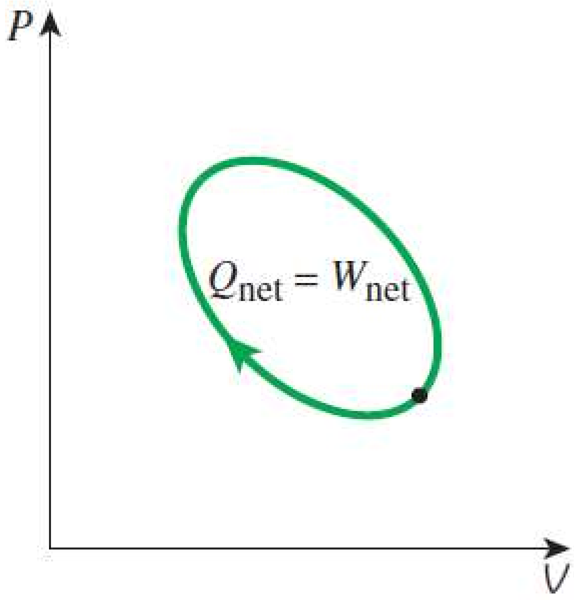
$$Q = \dot{Q}\,\Delta t, \quad W = \dot{W}\,\Delta t, \quad \text{and} \quad \Delta E = (dE/dt)\Delta t \qquad \text{(kJ)}$$

$$e_{in} - e_{out} = \Delta e_{system} \qquad \text{(kJ/kg)}$$

$$\delta E_{in} - \delta E_{out} = dE_{system} \quad \text{or} \quad \delta e_{in} - \delta e_{out} = de_{system}$$

Figs: Cengel & Boles: TD

Cyclic Processes in a Closed Systems

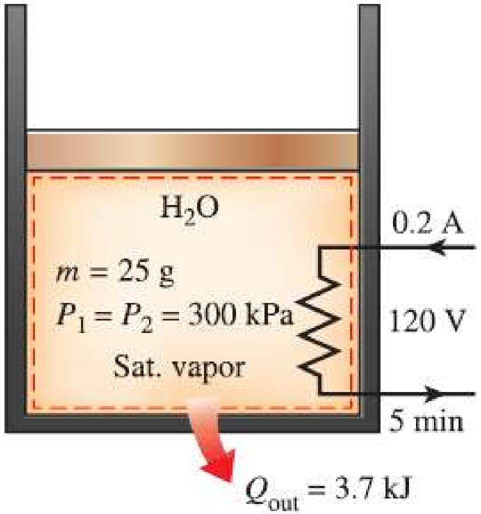


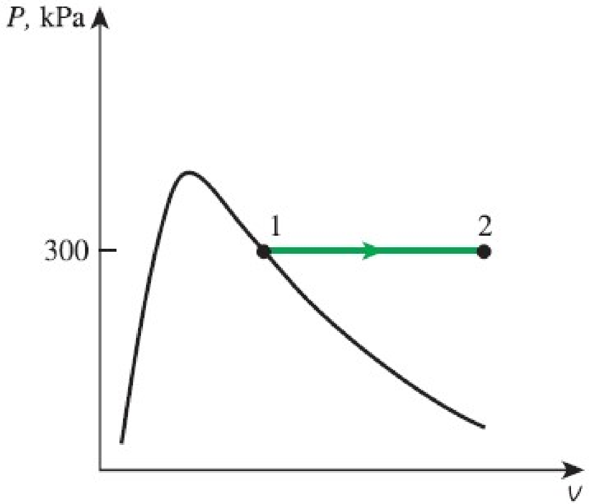
For a cycle $\Delta E = 0$, thus $Q = W$.

$$W_{net,out} = Q_{net,in} \quad \text{or} \quad \dot{W}_{net,out} = \dot{Q}_{net,in}$$

Figs: Cengel & Boles: TD

Welcoming Enthalpy-Energy Balance at constant P





$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc., energies}}}$$

$$Q - W = \Delta U + \cancel{\Delta KE}^{\,0} + \cancel{\Delta PE}^{\,0}$$

$$Q - W_{other} - W_b = U_2 - U_1$$

$$Q - W_{other} - P_0(V_2 - V_1) = U_2 - U_1$$

$$Q - W_{other} = (U_2 + P_2V_2) - (U_1 + P_1V_1)$$

$$H = U + PV$$

$$Q - W_{other} = H_2 - H_1$$

For a constant-pressure expansion or compression process:

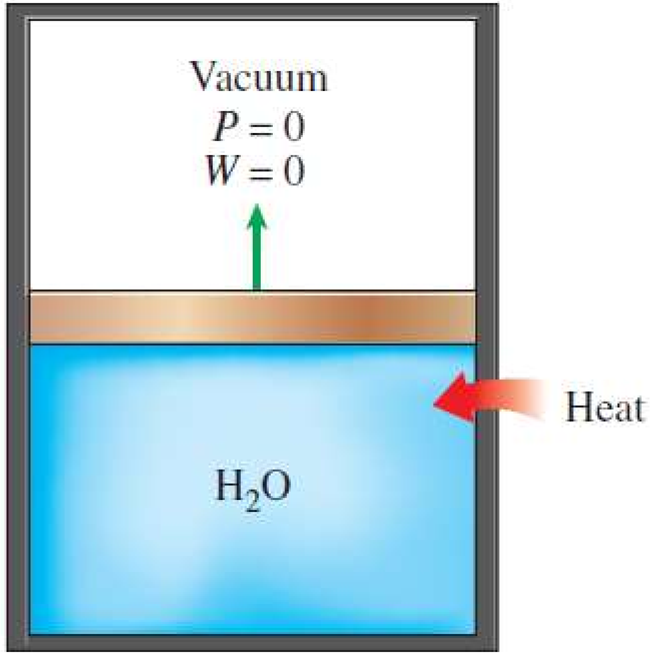
$$\Delta U + W_b = \Delta H$$

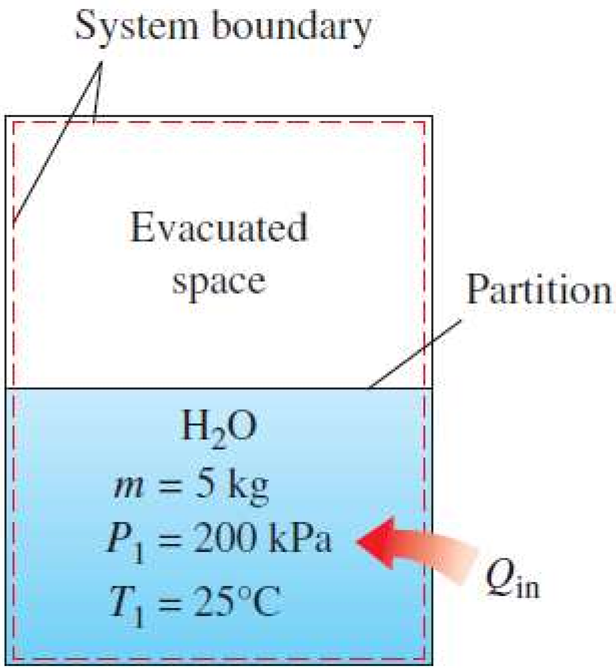
$$W_{e,in} - Q_{out} - W_b = \Delta U$$

$$W_{e,in} - Q_{out} = \Delta H = m(h_2 - h_1)$$

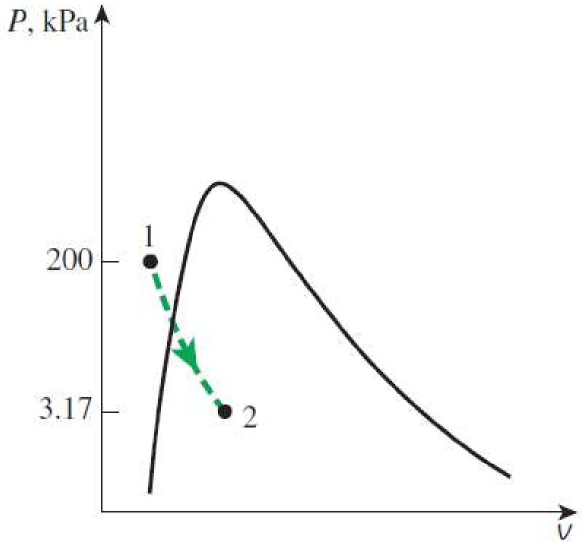
Figs: Cengel & Boles: TD

Expansion at constant P=0





- Unrestrained expansion of water



$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc., energies}}}$$

$$Q_{in} = \Delta U = m(u_2 - u_1)$$

Figs: Cengel & Boles: TD