Sign Convention: $\dot{m}$ is positive for mass entering the system, $\dot{Q}_{cv}$ is positive for heat transfer to the system, and $\dot{W}_{cv}$ is positive for work done by the system.

Energy Balance: system with mass crossing the boundary at multiple points, neglecting kinetic and potential energy effects

$$\frac{dU}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \sum_{j=1}^{N} \dot{m}_j h_j$$

Entropy Balance: system with mass and heat crossing the boundary at multiple points

$$\frac{dS}{dt} = \sum_{j=1}^{N} \frac{\dot{Q}_j}{T_j} + \sum_{j=1}^{N} \dot{m}_j s_j + \dot{\sigma}$$

Boundary Work:

$$\delta W = pdV \text{ or for a process } W = \int_1^2 pdV$$

Gibbs Relations

$$ds = du + pdv = dh - vdp$$

Efficiency

$$\eta_{turbine} = \frac{\dot{W}_{act}}{\dot{W}_{ideal}} \qquad \eta_{pump} = \frac{\dot{W}_{ideal}}{\dot{W}_{act}}$$

Carnot Efficiency for Heat Engine

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H}$$

Ideal Gas Property Evaluation:

Changes in enthalpy and internal energy

$$dh = c_p(T)dT \quad \text{and} \quad du = c_v(T)dT$$

$$c_p - c_v = R = \frac{R_u}{MW}$$ and R_u=8.314 kJ/kmol-K

Gibbs Relations

$$ds = c_v dT + pdv = c_p dT - vdp$$

$$ds = c_p \frac{dT}{T} - R\frac{dp}{p}$$

Ideal gas with constant specific heat

$$h_2 - h_1 = c_p\left(T_2 - T_1\right)$$

$$u_2 - u_1 = c_v\left(T_2 - T_1\right)$$

$$s_2 - s_1 = c_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{p_2}{p_1}\right)$$