SOME FORMULAS

First law for closed systems

$$dE = \delta Q - \delta W$$

For an ideal gas

$$PV = mR_s T \qquad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

First law for open systems

$$\frac{dE_{CV}(t)}{dt} = \dot{Q} - \dot{W}_{shaft} + \sum_i \dot{m}_i (h_i + V_i^2/2 + gZ_i) - \sum_e \dot{m}_e (h_e + V_e^2/2 + gZ_e)$$

Conservation of mass

$$\frac{dm_{CV}}{dt} = \sum_i \dot{m}_i - \sum_e \dot{m}_e$$

Second law of thermodynamics (entropy)

$$\Delta S_{\text{isolated system}} \geq 0$$

$$\oint \frac{\delta Q}{T} \leq 0 \qquad \textit{Clausius Inequality}$$

Isentropic relationships

$$\left(\frac{P_2}{P_1}\right)_{s=cte} = \left(\frac{v_1}{v_2}\right)^k \qquad \left(\frac{T_2}{T_1}\right)_{s=cte} = \left(\frac{v_1}{v_2}\right)^{k-1} \qquad \left(\frac{T_2}{T_1}\right)_{s=cte} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

Tds (Gibbs) equations

$$Tds = du + Pdv$$

$$Tds = dh - vdP$$

For an ideal gas
constant specific heats

$$s_2 - s_1 = c_V \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{v_2}{v_1}\right) \qquad s_2 - s_1 = c_P \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$$

Specific heat relations of ideal gases

$$c_p = c_v + R \qquad c_v = \frac{R}{k-1}$$

$$k = \frac{c_p}{c_v} \qquad c_p = \frac{k \cdot R}{k-1}$$

Compressibility Factor

$$Z = \frac{P \cdot v}{R \cdot T} \qquad Z = \frac{v_{\text{actual}}}{v_{\text{ideal}}}$$

$$P_R = \frac{P}{P_{\text{cr}}} \qquad T_R = \frac{T}{T_{\text{cr}}} \qquad v_R = \frac{v_{\text{actual}}}{RT_{\text{cr}}/P_{\text{cr}}}$$

Isentropic efficiencies

$$\eta_{compressor} = \frac{\text{Isentropic compressor work}}{\text{Actual compressor work}} = \frac{h_{2s} - h_1}{h_2 - h_1}$$

$$\eta_{turbine} = \frac{\text{Actual turbine work}}{\text{Isentropic turbine work}} = \frac{h_2 - h_1}{h_{2s} - h_1} \qquad \eta_{Nozzle} = \frac{\text{Actual KE at nozzle exit}}{\text{Isentropic KE at nozzle exit}} = \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$$