Key Equations For ME211

$$n = m/M$$

$$T(^\circ C) = T(K) - 273.15$$

$$\Delta E = \Delta U + \Delta KE + \Delta PE$$

$$\Delta KE = KE_2 - KE_1 = \frac{1}{2}m(V_2^2 - V_1^2)$$

$$\Delta PE = PE_2 - PE_1 = mg(z_2 - z_1)$$

$$W = \int_{s_1}^{s_2} \mathbf{F} \cdot ds$$

$$\dot{W} = \mathbf{F} \cdot \mathbf{V}$$

$$W = \int_{V_1}^{V_2} p\,dV$$

$$E_2 - E_1 = U_2 - U_1 + m\left[\frac{1}{2}({V_2}^2 - {V_1}^2) + g(z_2 - z_1)\right]$$

$$E_2 - E_1 = Q - W$$

$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

CH1-2

$$W_{cycle} = Q_{in} - Q_{out}$$

$$\eta = \frac{W_{cycle}}{Q_{in}}$$

$$W_{cycle} = Q_{out} - Q_{in}$$

$$\beta = \frac{Q_{in}}{W_{cycle}}$$

$$\gamma = \frac{Q_{out}}{W_{cycle}}$$

1 liter $=10^{-3}$ m^3
1 atm =101.325 kPa
1 bar =100 kPa

CH 3

$$x = \frac{m_{vapor}}{m_{liquid} + m_{vapor}}$$

$$v = (1 - x)v_f + xv_g = v_f + x(v_g - v_f)$$

$$u = (1 - x)u_f + xu_g = u_f + x(u_g - u_f)$$

$$h = (1 - x)h_f + xh_g = h_f + x(h_g - h_f)$$

$$v(T, p) \approx v_f(T)$$

$$u(T, p) \approx u_f(T)$$

$$h(T, p) \approx h_f(T)$$

$$pv = RT$$

$$u = u(T)$$

$$h = h(T) = u(T) + RT$$

$$u(T_2) - u(T_1) = \int_{T_1}^{T_2} c_v(T)\,dT$$

$$u(T_2) - u(T_1) = c_v(T_2 - T_1)$$

$$h(T_2) - h(T_1) = \int_{T_1}^{T_2} c_p(T)\,dT$$

$$h(T_2) - h(T_1) = c_p(T_2 - T_1)$$

$$PV = mRT$$

$$R = \frac{\bar{R}}{M}$$

$$\bar{R} = 8.314\ kJ/kmolK$$

$$k = \frac{c_p}{c_v}$$

CH 4

$$\dot{m} = \frac{AV}{v}$$

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

$$\sum_i \dot{m}_i = \sum_e \dot{m}_e$$

(mass rate in) (mass rate out)

$$\frac{dE_{cv}}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \sum_i \dot{m}_i\left(h_i + \frac{V_i^2}{2} + gz_i\right) - \sum_e \dot{m}_e\left(h_e + \frac{V_e^2}{2} + gz_e\right)$$

$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + \sum_i \dot{m}_i\left(h_i + \frac{V_i^2}{2} + gz_i\right) - \sum_e \dot{m}_e\left(h_e + \frac{V_e^2}{2} + gz_e\right)$$

$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + \dot{m}\left[(h_1 - h_2) + \frac{(V_1^2 - V_2^2)}{2} + g(z_1 - z_2)\right]$$

$$0 = \frac{\dot{Q}_{cv}}{\dot{m}} - \frac{\dot{W}_{cv}}{\dot{m}} + (h_1 - h_2) + \frac{(V_1^2 - V_2^2)}{2} + g(z_1 - z_2)$$

$$m_{cv}(t) - m_{cv}(0) = \sum_i m_i - \sum_e m_e$$

$$U_{cv}(t) - U_{cv}(0) = Q_{cv} - W_{cv} + \sum_i m_i h_i - \sum_e m_e h_e$$

CH5

$$\eta_{\max} = 1 - \frac{T_C}{T_H} \qquad \beta_{\max} = \frac{T_C}{T_H - T_C} \qquad \gamma_{\max} = \frac{T_H}{T_H - T_C} \qquad \oint \left(\frac{\delta Q}{T}\right)_b = -\sigma_{\text{cycle}}$$

CH6

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma$$

$$\frac{dS}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \dot{\sigma}$$

$$s(T_2, v_2) - s(T_1, v_1) = \int_{T_1}^{T_2} c_v(T)\frac{dT}{T} + R \ln \frac{v_2}{v_1}$$

$$s(T_2, v_2) - s(T_1, v_1) = c_v \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1}$$

$$\frac{dS_{cv}}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e + \dot{\sigma}_{cv}$$

$$0 = \sum_j \frac{\dot{Q}_j}{T_j} + \sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e + \dot{\sigma}_{cv}$$

$$s(T_2, p_2) - s(T_1, p_1) = \int_{T_1}^{T_2} c_p(T)\frac{dT}{T} - R \ln \frac{p_2}{p_1}$$

$$s(T_2, p_2) - s(T_1, p_1) = s^\circ(T_2) - s^\circ(T_1) - R \ln \frac{p_2}{p_1}$$

$$\eta_t = \frac{\dot{W}_{cv}/\dot{m}}{(\dot{W}_{cv}/\dot{m})_s} = \frac{h_1 - h_2}{h_1 - h_{2s}}$$

$$s(T_2, p_2) - s(T_1, p_1) = c_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1}$$

$$\eta_{\text{nozzle}} = \frac{V_2^2/2}{(V_2^2/2)_s}$$

$$\eta_c = \frac{(-\dot{W}_{cv}/\dot{m})_s}{(-\dot{W}_{cv}/\dot{m})} = \frac{h_{2s} - h_1}{h_2 - h_1}$$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{(k-1)/k} \qquad \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} \qquad \frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^{k}$$

$$\frac{p_2}{p_1} = \frac{p_{r2}}{p_{r1}} \qquad \frac{v_2}{v_1} = \frac{v_{r2}}{v_{r1}}$$

CH7

$$\mathsf{E} = (U - U_0) + p_0(V - V_0) - T_0(S - S_0) + \text{KE} + \text{PE}$$

$$\mathsf{e} = (u - u_0) + p_0(v - v_0) - T_0(s - s_0) + V^2/2 + gz$$

$$\mathsf{E}_2 - \mathsf{E}_1 = (U_2 - U_1) + p_0(V_2 - V_1) - T_0(S_2 - S_1) + (\text{KE}_2 - \text{KE}_1) + (\text{PE}_2 - \text{PE}_1)$$

$$\mathsf{E}_2 - \mathsf{E}_1 = \mathsf{E}_q - \mathsf{E}_w - \mathsf{E}_d$$

$$0 = \sum_j \left(1 - \frac{T_0}{T_j}\right)\dot{Q}_j - \dot{W} - \dot{\mathsf{E}}_d$$

$$0 = \sum_j \left(1 - \frac{T_0}{T_j}\right)\dot{Q}_j - \dot{W}_{cv} + \sum_i \dot{m}_i \mathsf{e}_{fi} - \sum_e \dot{m}_e \mathsf{e}_{fe} - \dot{\mathsf{E}}_d$$

$$\mathsf{e}_f = h - h_0 - T_0(s - s_0) + \frac{V^2}{2} + gz$$

$$\varepsilon = \frac{\dot{W}_{cv}/\dot{m}}{\mathsf{e}_{f1} - \mathsf{e}_{f2}}$$

$$\varepsilon = \frac{\mathsf{e}_{f2} - \mathsf{e}_{f1}}{(-\dot{W}_{cv}/\dot{m})}$$

$$\varepsilon = \frac{\dot{m}_2(\mathsf{e}_{f3} - \mathsf{e}_{f2})}{\dot{m}_1(\mathsf{e}_{f1} - \mathsf{e}_{f3})}$$

$$\varepsilon = \frac{\dot{m}_c(\mathsf{e}_{f4} - \mathsf{e}_{f3})}{\dot{m}_h(\mathsf{e}_{f1} - \mathsf{e}_{f2})}$$