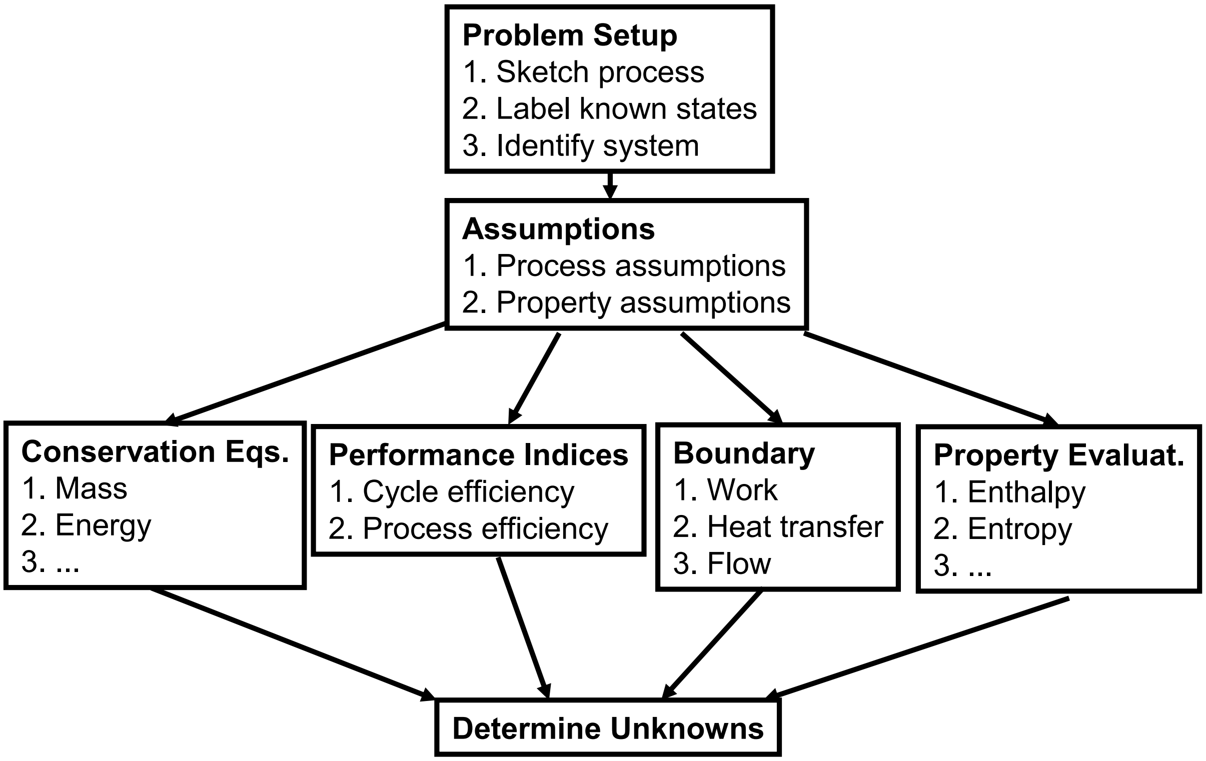
Exam 3 Reference Guide

Organizing your Solutions



Given: Make sure you understand what was given in terms of assumptions and data. Then restate in a simpler and easier to find format (e.g. list of assumptions, T_1=30 C, etc.)

Find: Make sure you understand what is asked for and express in a simpler and easier to find format (e,g. find P_2 = ?)

Energy Flow Diagram (EFD): Show your system boundary (dashed line) and indicate energy flows (work, heat transfer, fluid flow).

Assumptions: List both your "process" and "property" assumptions (e.g., SSSF, ideal gas)

Basic Equations: Select the basic equations that apply to this problem. Your basic equations should come from the ME 200 basic equation sheet. Often need 1) energy/mass/entropy balances, 2) performance indices/efficiencies, 3) boundary interaction equations (heat/work/flow), and 4) property relations (ideal gas, incompressible) and/orr data.

Solution: Simplify your basic equations based on the system chosen and assumptions listed. Use them to solve for the unknown(s) in terms of the knowns.

Types of Assumptions

System/Process Assumption Examples: 1) closed/open system, 2) steady flow, steady state (SSSF) system, 3) negligible changes in kinetic and potential energy, 4) adiabatic process, 5) no work device, 6) quasi-equilibrium process, 7) no friction, 8) constant pressure (isobaric) process, 7) constant temperature (isothermal) process, 8) internally reversible process, 9) polytropic process, ….

Property Assumption Examples: 1) ideal gas behavior, 2) incompressible liquid/solid behavior, 3) constant specific heats, ..

"Conservation" Equations

Closed System Mass and Energy Balances

Rate Forms: $\frac{dE}{dt} = \dot{Q} - \dot{W}$, $\frac{dS}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \dot{\sigma}$, $\frac{dm}{dt} = 0$

$$E = U + PE + KE,\ U = m \cdot u,\quad PE = mgz,\ KE = \tfrac{1}{2} mV^2,\ \mathrm{S} = m \cdot s$$

Integrated over a Process: $\Delta U + \Delta PE + \Delta KE = Q - W$, $\Delta S = \sum_j \int_1^2 \frac{\delta Q_j}{T_j} + \sigma$, $\Delta m = 0$

$$\Delta U = m(u_2 - u_1),\ \Delta PE = mg(z_2 - z_1),\ \Delta KE = \tfrac{1}{2} m(V_2^2 - V_1^2),\ \Delta S = m(s_2 - s_1)$$

Open System Mass and Energy Balances

$$\frac{dE_{CV}}{dt} = \dot{Q}_{CV} - \dot{W}_{CV} + \sum_i \dot{m}_i \left(h + \tfrac{1}{2} V^2 + gz\right)_i - \sum_e \dot{m}_e \left(h + \tfrac{1}{2} V^2 + gz\right)_e$$

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

"Boundary Interaction" Equations

Work Relations: $W_b = \int p dV \quad W_e = -\xi i \Delta t \quad W_{spring} = \frac{k_s}{2}(x_2^2 - x_1^2) \quad W_{rot} = 2\pi n \tau$

$$w_{cv} = -\int_1^2 \mathrm{v}\, dp + (V_1^2 - V_2^2)/2 + g(z_1 - z_2)$$

Heat Transfer Relations: There are mechanistic relations for conduction, convection, and radiation but we don't use them in this class. You'll find these in a heat transfer class.

Mass Flow Relations: $\dot{m} = \rho A V = \frac{AV}{\mathrm{v}}$, $\dot{m} = \frac{\dot{V}}{\mathrm{v}}$

Polytropic Processes: $pv^n = \text{constant}$, $p = \dfrac{p_1 v_1^n}{v^n} = \dfrac{p_2 v_2^n}{v^n}$

Int. Rev. Boundary Work: $W_b = \int p dV = m \cdot p_1 v_1^n \int_{v_1}^{v_2} \dfrac{dv}{v^n} = p_1 V_1^n \int_{V_1}^{V_2} \dfrac{dV}{V^n}$ (integral depends on n)

Int. Rev. SSSF Work with *Δke=Δpe=0*: $w_{cv} = -\int_1^2 v dP = -P_1^{1/n} v_1 \int_1^2 \dfrac{dP}{P^{1/n}}$ (integral depends on n)

"Property" Equations

Enthalpy Definition: $h = u + p\mathrm{v}$

Ideal Gas Property Relations:

$$pV = n\bar{R}T, \quad pV = mRT, \quad pv = RT, \quad R = \bar{R}/M$$

$$\Delta u = \int c_{\mathrm{v}} dT, \ \Delta h = \int c_p dT, \ c_p - c_{\mathrm{v}} = R, \ \ k = c_p / c_{\mathrm{v}}$$

$$\Delta s = s_2^0 - s_1^0 - R\ln\frac{p_2}{p_1} = \int_{T_1}^{T_2} c_p \frac{dT}{T} - R\ln\frac{p_2}{p_1}, \quad \Delta s = \int_{T_1}^{T_2} c_v \frac{dT}{T} + R\ln\frac{v_2}{v_1}$$

Isentropic: $\left(p_2/p_1\right)_s = p_{r2}/p_{r1}$, $\left(\mathrm{v}_2/\mathrm{v}_1\right)_s = \mathrm{v}_{r2}/\mathrm{v}_{r1}$, $T_2/T_1 = \left(p_2/p_1\right)^{(k-1)/k} = \left(\mathrm{v}_1/\mathrm{v}_2\right)^{k-1}$

Incompressible Substance Property Relations:

$$\Delta u = \int c \cdot dT, \ \ \Delta h = \Delta u + \mathrm{v}\Delta p, \ \Delta s = \int_{T_1}^{T_2} c \frac{dT}{T}$$

SLVM Property Relations:

$$x = m_g/(m_f + m_g), \ \ y = (1-x)y_f + xy_g = y_f + xy_{fg}, \ \ y_{fg} = y_g - y_f$$

Approx. for Compressed Liquids from SL Properties (not quite treated as incompressible)

$$h(T,p) \cong h_f(T) + \mathrm{v}_f(T)[p - p_{sat}(T)], \ u(T,p) \cong u_f(T), \ v(T,p) \cong v_f(T), \ \mathrm{s}(T,p) \cong s_f(T)$$

"Performance Indice" Equations

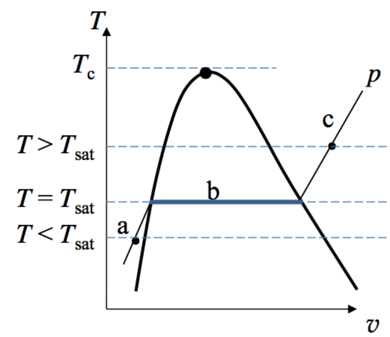
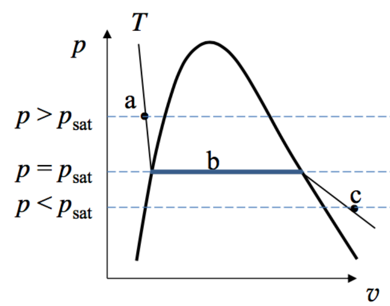
Device Efficiencies: $\eta_T = w/w_s$, $\eta_C = \eta_P = w_s/w$, $\eta_N = V_2^2/V_{2s}^2$

Cycle Efficiencies: $\eta_{th} = W_{net,out}/Q_H$, $\beta = Q_C/W_{net,in}$, $\gamma = Q_H/W_{net,in}$

Carnot (Reversible) Cycle Efficiencies:

$$\eta_{th,rev} = 1 - T_C/T_H, \ \ \beta_{rev} = T_C/\left(T_H - T_C\right), \ \ \gamma_{rev} = T_H/\left(T_H - T_C\right)$$

General Rules for Evaluating the Condition of Real Fluids

Given Properties	Test to Determine Region of Vapor Dome	Vapor Dome Diagram
1. p 2. T	**Look up p in Saturation Properties - P tables:** a. If $T < T_{sat}$, Compressed liquid b. If $T = T_{sat}$, Two-phase, liquid-vapor mixture c. If $T > T_{sat}$, Superheated vapor d. If T > T_c, Superheated vapor	
1. p 2. T	**Look up T in Saturation Properties - T tables:** a. If $p > p_{sat}$, Compressed liquid b. It $p = p_{sat}$, Two-phase, liquid-vapor mixture c. If $p < p_{sat}$, Superheated vapor	
1. T 2. v, u, h, or s	**Look up T in Saturation Property - T tables:** a. If $v < v_f$, Compressed liquid b. If $v_f < v < v_g$, Two-phase, liquid-vapor mixture c. If $v > v_g$, Superheated vapor **Apply the same procedure if u, h, or s is given.**