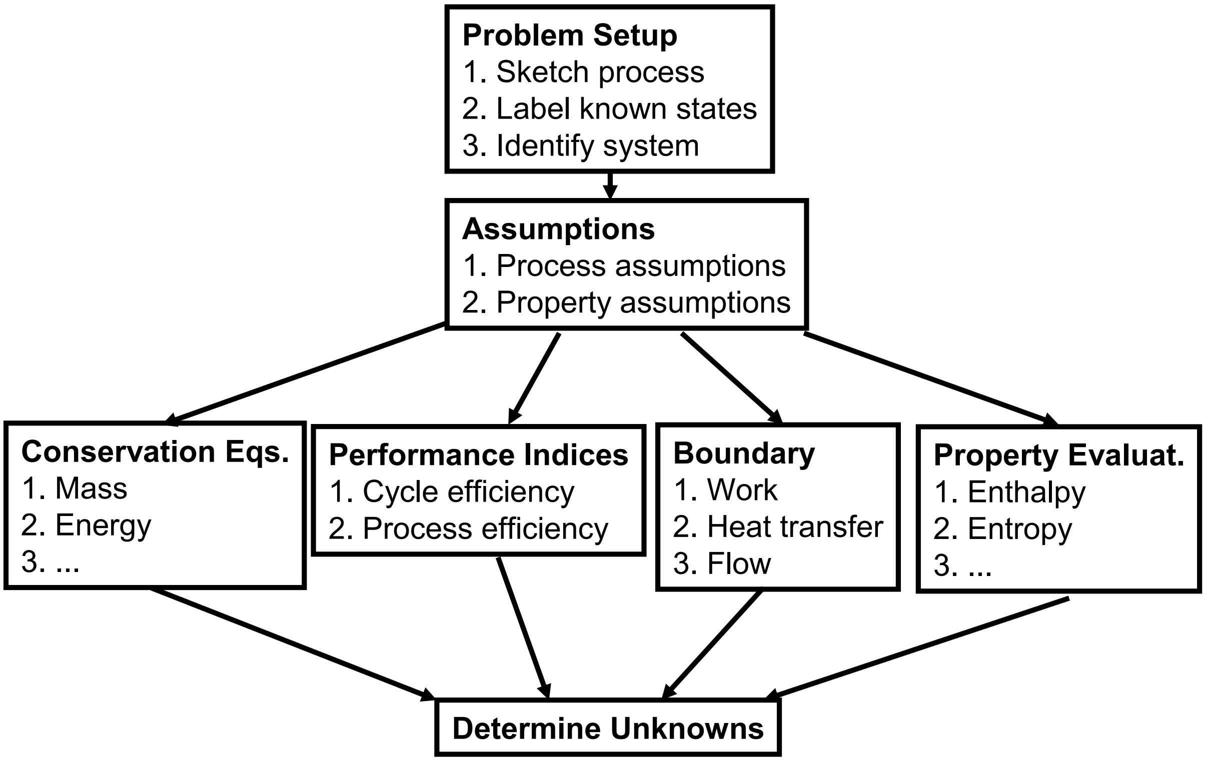
Exam 1 Reference Guide

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 $P_2 = ?$)

System: 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., constant pressure, 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, ..

Mass and Energy Conservation Equations

From ME 200 Equation Sheet

$$\left.\frac{dm}{dt}\right|_{system} = \sum_{in} \dot{m}_{in} - \sum_{out} \dot{m}_{out}$$

$$\left.\frac{dE}{dt}\right|_{system} = \sum_{in} \dot{m}_{in}\,(h + ke + pe)_{in} - \sum_{out} \dot{m}_{out}\,(h + ke + pe)_{out} + \dot{Q} - \dot{W}$$

Simplifications for Closed Systems

$$\dot{m}_{in} = \dot{m}_{out} = 0 \rightarrow \frac{dE}{dt} = \dot{Q} - \dot{W}, \quad \frac{dm}{dt} = 0$$

Integrated over a process (initial to final conditions) $E_2 - E_1 = Q - W, \; m_2 - m_1 = 0$

"Boundary Interaction" Equations

Work Relations:

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

Note: boundary work equation requires assumption of quasi-static process

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.

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

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

“Property” Equations

General Relations:

$$E = m(u + ke + pe), ke = V^2/2, pe = gZ,\ h = u + p\mathrm{v}$$

Ideal Gas Property Relations:

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

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

Notes: *u* and *h* only depend on temperature for an ideal gas, c_v and c_p are intensive properties, ideal gas tables contain integrals for internal energy and enthalpy changes evaluated between a reference temperature and the temperature at each table entry

Incompressible Substance Property Relations:

$$v = \text{constant},\ \Delta u = \int c \cdot dT,\ \ \Delta h = \Delta u + \mathrm{v}\Delta p$$

Notes: *u* only depends on temperature for an incompressible substance, c is an intensive property, *h* depends on both temperature and pressure for an incompressible substance

SLVM Property Relations:

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

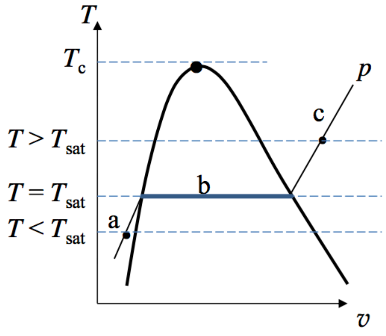
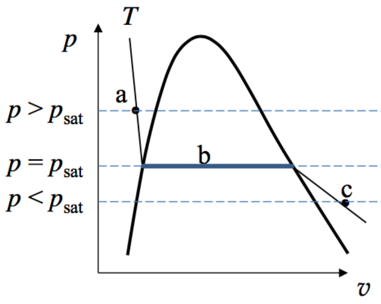
Notes: mixture quality is only defined for a two-phase mixture (not for a compressed liquid or a superheated vapor), determination of mixture properties requires utilization of mixture quality (this is not interpolation)

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

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

Notes: this approximation is a slightly better alternative to determining internal energy and enthalpy than the incompressible assumption of v = constant.

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.**