BASIC CONCEPTS:

THE MOST FUNDAMENTAL LAW OF NATURE IS THE CONSERVATION OF ENERGY PRINCIPLE, FROM WHICH WE GET OUR LAWS OF THERMODYNAMICS.

1^{ST} LAW: ENERGY & MATTER CANNOT BE CREATED NOR DESTROYED

2^{ND} LAW: ENTROPY NEVER DECREASES, IT CAN ONLY INCREASE. (A CUP OF HOT COFFEE LEFT ON A TABLE WILL NEVER GET HOTTER, THE HIGH-TEMP ENERGY ALWAYS IS DEGRADED ONCE ITS TRANSFERRED TO SURROUNDING AIR)

ZEROTH LAW: IF TWO BODIES ARE IN THERMAL EQUILIBRIUM W/ A THIRD BODY THEY ARE ALSO IN THERMAL EQUILIBRIUM W/ EACH OTHER

CHAPTER 1

FUNDAMENTAL LAWS OF NATURE: CONSERVATION OF ENERGY

FIRST LAW: ENERGY/MATTER CANNOT BE CREATED NOR DESTROYED

SECOND LAW: ENTROPY IS ALWAYS INCREASING. ENERGY HAS QUANTITY AND QUALITY.

ZEROTH LAW: IF TWO BODIES ARE IN THERMAL EQUILIBRIUM WITH A THIRD, THEY ARE ALL IN EQUILIBRIUM. $T_C = T_B$, $T_B = T_A$, $T_C = T_A$.

DIMENSION HOMOGENEITY:
- ALL OUR UNITS NEED TO MATCH IN EQUATIONS

PRIMARY UNITS: TIME, TEMP, LENGTH

SECONDARY UNITS: PRESSURE, DENSITY, ETC.

SYSTEMS:

CLOSED: FIXED MASS

OPEN: HAS MASS FLOW, CAN BE SIMPLIFIED W/ A CONTROL VOLUME.

SYSTEM PROPERTIES:

INTENSIVE: INDEPENDENT OF OUR SYSTEM, TEMP PRESSURE, DENSITY.

EXTENSIVE: VALUES THAT DEPEND ON OUR SYSTEM, TOTAL MASS, TOTAL VOLUME

EQUILIBRIUM:

PROCESS: CHANGE OF A SYSTEM OF STATE TO ANOTHER

PATH: THE SERIES OF STATES OUR PROCESS GOES THROUGH

QUASI-EQUILIBRIUM: SLOW MOVING PROCESS, THAT REMAINS CLOSE TO EQUILIBRIUM

STEADY PROCESS: DOES NOT CHANGE, CONSTANT.

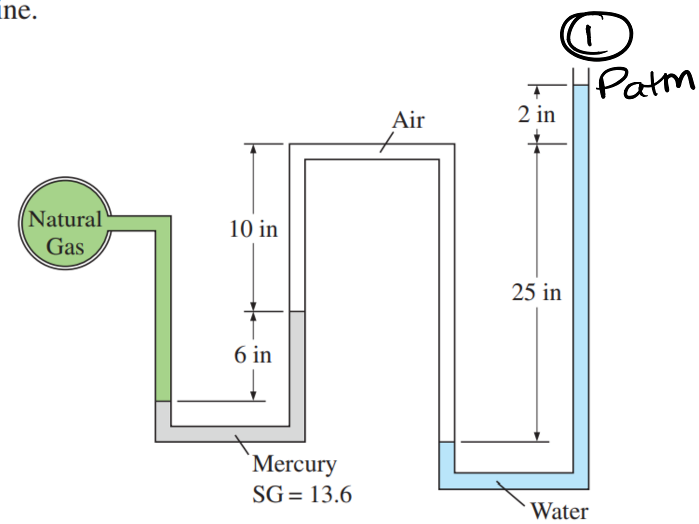
PRESSURE: NORMAL FORCE EXERTED BY A FLUID PER UNIT AREA. $P = \frac{F_n}{A}$

HYDROSTATIC EQUATION:

$$P_1 - P_2 = -\rho g (h_2 - h_1)$$

1–69E The pressure in a natural gas pipeline is measured by the manometer shown in Fig. P1–69E with one of the arms open to the atmosphere where the local atmospheric pressure is 14.2 psia. Determine the absolute pressure in the pipeline.

S. G. = SPECIFIC GRAVITY, MEASURE OF THE RELATIVE DENSITY OF A SUBSTANCE COMPARED TO THE DENSITY OF WATER AT A GIVEN TEMPERATURE.



$$\rho_{HG} = 13.6(\rho_w)$$

$$\rho_w = 62.4 \ \frac{lbm}{ft^3}$$

$$\rho_{HG} = 13.6(62.4) = 848.6 \ \frac{lbm}{ft^3}$$

$$P_1 - P_2 = -\rho g \Delta h$$

$$P_1 + \rho g \Delta h = P_{atm}$$

$$P_1 + \left[(62.4)(32.2)(-27/12) + (848.6)(32.2)(-6/12)\right]$$

$$\times \left(\frac{1}{32.2}\right)\left(\frac{1}{12}\right)^2 = 14.2 \text{ psia}$$

$$P_1 - 3.94 \text{ psia} = 14.2 \text{ psia}$$

$$P_1 = 18.14 \text{ psia.}$$

$$\left(\frac{lbm}{ft^3}\right)\left(\frac{ft}{s^2}\right)\left(\frac{ft}{ft}\right)$$

Chapter 2: Energy, Energy Transfer, & Energy Analysis

- Forms of Energy:
  - Thermal, Kinetic, Potential, Electric-Magnetic, etc.
  - internal energy: U [kJ], u [kJ/kg]
  - kinetic energy: $KE = \frac{1}{2}mV^2$ [kJ]
    $ke = \frac{1}{2}V^2$ [kJ/kg]
  - potential energy: $PE = mgh$ [kJ]
    $pe = gh$ [kJ/kg]
  - total energy: $E = U + KE + PE$ [kJ]
    $e = u + ke + pe$ [kJ/kg]
- Heat & Work
  - $Q \equiv$ heat; $Q = 0$ for an adiabatic process
  - Similarities:
    1) boundary phenomena
    2) not properties
    3) associated w/ a process
    4) path function
- Energy Conservation
  - Energy Balance $\equiv \Delta E = E_{in} - E_{out}$
    - open system: $Q + W + \dot{m}$
    - closed system: $Q + W$
  - $E_{in} - E_{out} = (Q_{in} - Q_{out}) + (W_{in} - W_{out}) + (E_{mass_{in}} - E_{mass_{out}}) = \Delta E_{sys}$
    - steady: $\dot{E}_{in} - \dot{E}_{out} = \boxed{\frac{dE_{sys}}{dt} = 0}$

Example:

A vertical piston-cylinder device contains water and is being heated on top of a range. During the process, 65 Btu of heat is transferred to the water, and heat losses from the side walls amount to 8 Btu. The piston rises as a result of evaporation, and 5 Btu of work is done by the vapor. Determine the change in energy of the water for this process.

Known:

$Q_{in} = 65\,[Btu]$

$Q_{out} = 8\,[Btu]$

$W_{out} = 5\,[Btu]$

Find:

$\Delta E_{water} = ?$

$$\Delta E_{water} = E_{in} - E_{out} = (Q_{in} - Q_{out}) + (\cancel{W_{in}}^{0} - W_{out}) + \cancel{(E_{mass_{in}} - E_{mass_{out}})}^{0}$$

$$\Delta E_{water} = Q_{in} - Q_{out} - W_{out}$$

$$= 65\,[Btu] - 8\,[Btu] - 5\,[Btu]$$

$$\boxed{\Delta E_{water} = 52\,[Btu]}$$

Chapter 3

Pure Substance - A pure Substance is a Substance that has a fixed Chemical Composition through out.

Phase: Solid/Liquid/Vapor

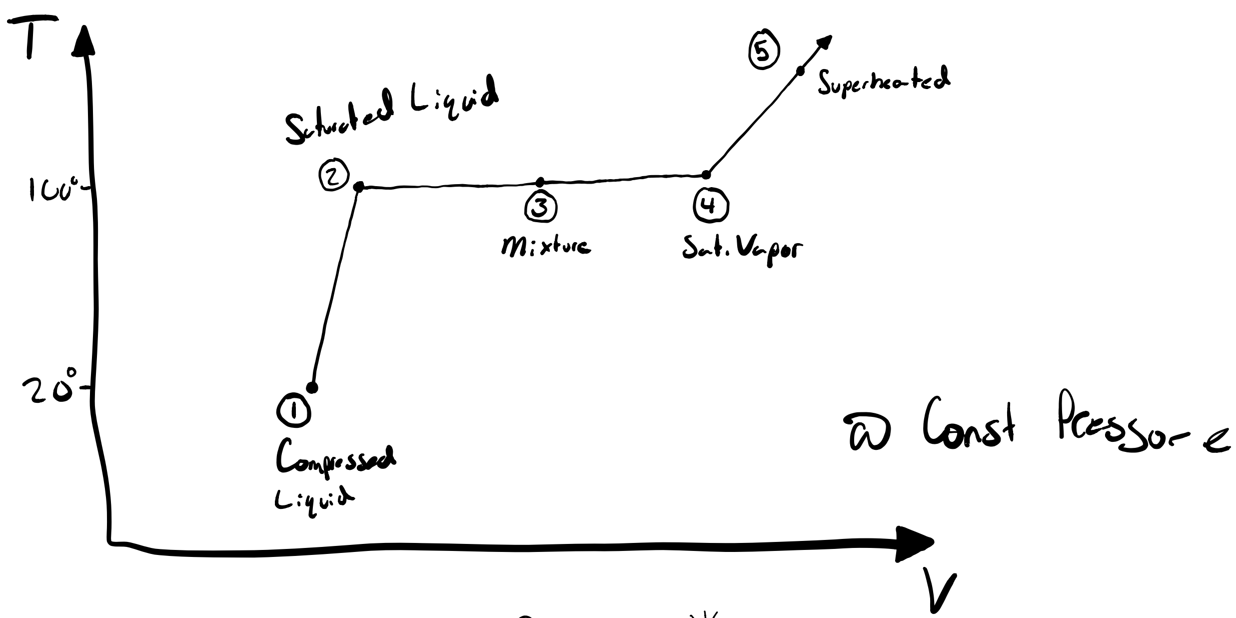
Add energy: Solid → Liquid → Vapor

Remove Energy: Vapor → Liquid → Solid

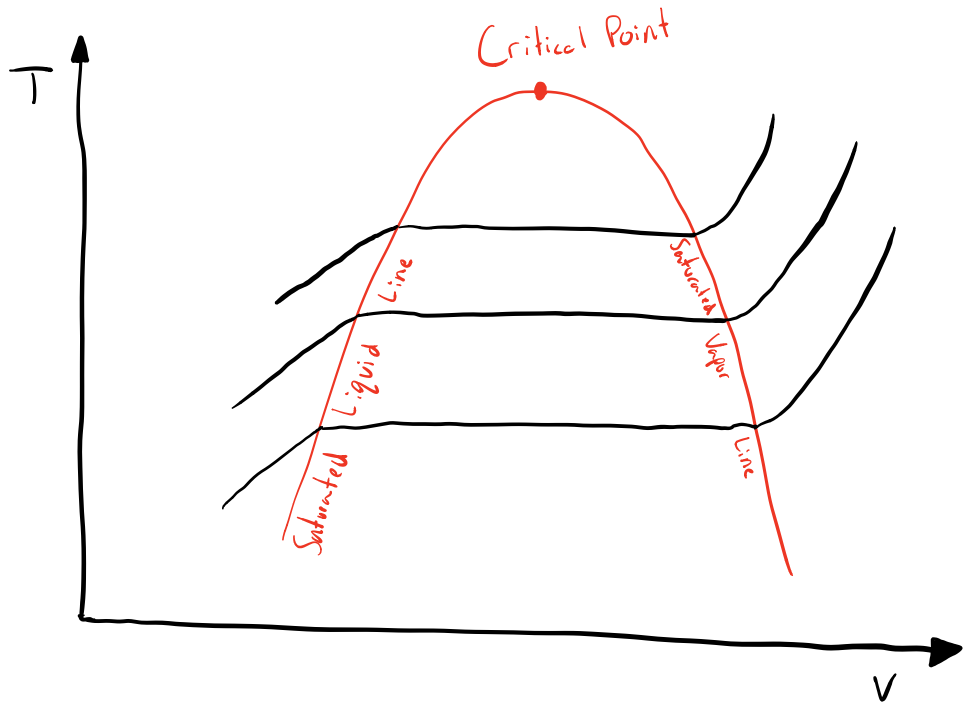
Saturated Liquid: A Liquid about to vaporize (ie. Water @ 100°C)

Saturated Vapor: A Vapor about to condense

Superheated Vapor: A Vapor not about to condense



* Constant Pressure *



Critical Point: Where the saturated Liquid & Saturated Vapor States are identical

Saturated Liquid-Vapor mixture:

quality: $X = \frac{m_{vapor}}{m_{total}}$; $0 \leq X \leq 1$

for any intensive property, y:

$$y = y_f + X y_{fg}$$

w/o Compressed Liquid data, use Saturated Value

$$y = y_{f@T}$$

Equation of State

$$PV = RT$$

Alternatives:

- Van Der Waals
- Beattie - Bridgeman
- Benedict - Webb - Rubin

(Pg 151)

Compressibility Factor:

$$Z = \frac{PV}{RT} \rightarrow PV = ZRT$$

$$Z = \frac{V_{actual}}{V_{ideal}}$$

Reduced Pressure + Temperature

$$P_R = \frac{P}{P_{cR}} \qquad T_R = \frac{T}{T_{cR}}$$

Problem 3-63

3–63 A rigid tank initially contains 1.4-kg saturated liquid water at 200°C. At this state, 25 percent of the volume is occupied by water and the rest by air. Now heat is supplied to the water until the tank contains saturated vapor only. Determine (*a*) the volume of the tank, (*b*) the final temperature and pressure, and (*c*) the internal energy change of the water.

FIGURE P3–63

get from A-4

a) $V_{h2o} = m \, v_{h2o,f}$

$= 1.4\,kg \left(.001157 \frac{m^3}{kg}\right)$

$V_{h2o} = 1.6198e-3 \; m^3$

$V_{tank} = 4 \, V_{h2o}$

$= 4 \cdot (1.6198e-3 \; m^3)$

$\boxed{V_{tank} = 6.4792e-3 \; m^3}$

b)

$v_g = \frac{V_{tank}}{m}$

$= \frac{6.4792e-3 \, m^3}{1.4 \, kg}$

$v_g = .004628 \frac{m^3}{kg}$

Interpolate

$T_2 = 371°C$

$P_2 = 21.3 \; kPa$

c)

$$\Delta u = u_2 - u_1$$

$$= (2224 - 850.46)$$

$$\Delta u = 1373.54 \frac{kJ}{kg}$$