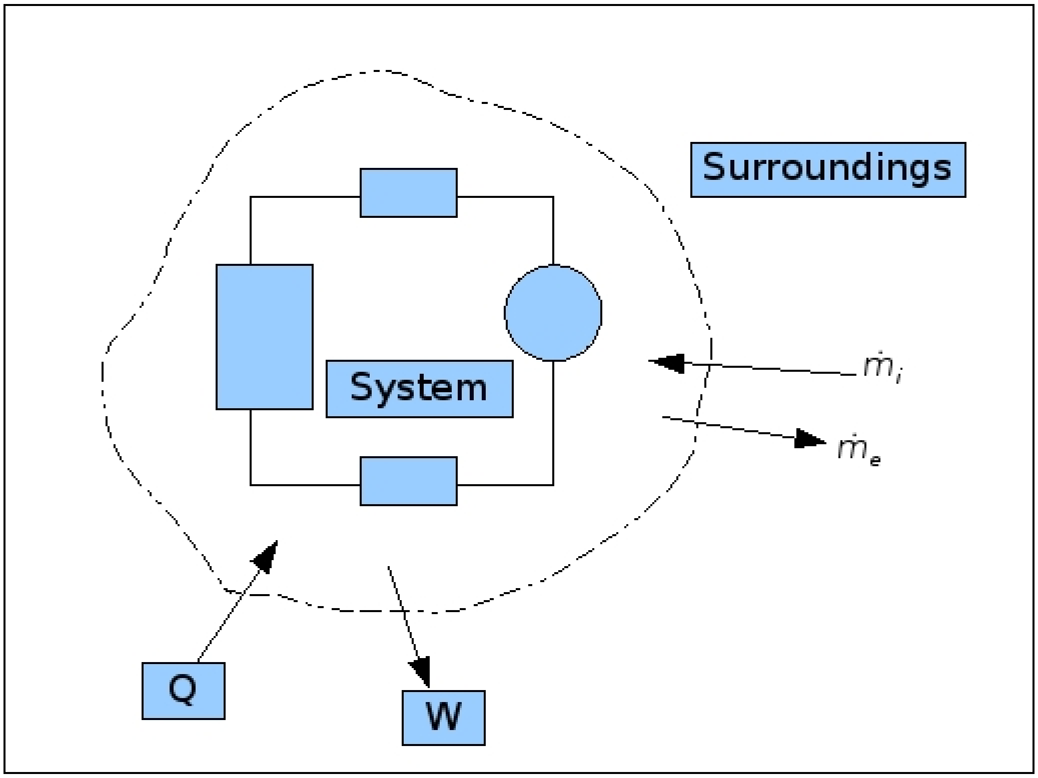
ENGR 3203
Thermo Concepts and Definitions

Thermo = Science of conservation of energy and accounting of entropy.

Thermo System – thermo devices and substances are inside the system and the surroundings (environment or ambient conditions) exist outside the system.



Mass Flow Rate: $\frac{dm}{dt} = \dot{m} \quad [\frac{kg}{s}, \frac{lb_m}{s}]$

Heat Transfer Rate: $\frac{dQ}{dt} = \dot{Q} \quad [\frac{kJ}{s}, \frac{Btu}{s}]$

Work Rate: $\frac{dW}{dt} = \dot{W} \quad [\frac{kJ}{s}, \frac{ft-lb_f}{s}]$

Open System: $\dot{m}_i \neq 0$ OR $\dot{m}_e \neq 0$

Closed System: $\dot{m}_i = 0$ AND $\dot{m}_e = 0$

Adiabatic System: $\dot{Q} = 0$

Isolated System: $\dot{m}_i = 0$ AND $\dot{m}_e = 0$ AND $\dot{Q} = 0$ AND $\dot{W} = 0$

Thermo Phases

Solid, Liquid, Vapor, Solid-Liquid (example: saturated ice-water mix), Solid-Vapor (example: saturated CO_2 (dry ice) mix), Liquid-Vapor (example: steam-liquid water saturated mix).

Formation:

Sublimation

Melting:

Evaporation/Vaporization:

Thermo States

State of substance identified by set of properties (i.e. temperature, pressure, volume, etc...). It takes 2 independent properties to identify state. If a substance is a saturated mix, pressure and temperature are **NOT** independent so one property in addition to pressure or temperature are required to identify the state.

Intensive/Extensive Properties

Intensive properties are those that **DO NOT** depend on the amount of the substance, i.e. temperature, pressure, density. *Extensive properties* are those that **DO** depend on the amount of the substance, i.e. mass, volume, weight.

Thermo Equilibrium

We will work with systems in equilibrium or undergoing very slow changes such that they are in equilibrium at all times (sometimes called quasi-equilibrium). Real systems are frequently not in equilibrium, so later on we will have to correct our results based on experimental evidence or predicted performance (these are due to inefficiencies and irreversibility in real systems).

Thermo Units (brief and not complete)

SI – meter-kilogram-second – Newton (N), Pascal (Pa) $1\,Pa = 1\,N/m^2$, Joule (J) $1\,J = 1\,N\cdot m$, Watt (W) $1\,W = 1\,J/s$

English Engineering – lb_f, lb_m, ft, s --- $F = \frac{ma}{g_c}$ where $g_c = 32.174 \frac{lb_m ft}{lb_f s^2}$

Weight of 10.0 lb_m would be: $F = \frac{10.0\ lb_m\ x\ 32.174\ \frac{ft}{s^2}}{32.174\ \frac{lb_m\ ft}{lb_f\ s^2}} = 10.0\ lb_f$

Density Definition

There is a minimum size for which density makes sense (δV_{min}). Density can be defined as $\rho = \lim_{\delta V \to \delta V_{min}} \frac{\delta m}{\delta V}$. δV_{min} is just the minimum volume for which the substance is a continuum.

Bulk Density and Specific Volume

Density: $\rho = \frac{m}{V}$ $[\frac{kg}{m^3}, \frac{lb_m}{ft^3}]$

The specific volume is just $v = \frac{1}{\rho}$

Where can you look up v values in your book?

At standard conditions 25 ˚C and 100 kPa, $\rho_{H_2O} \approx \quad \frac{kg}{m^3}$, $\rho_{air} \approx \quad \frac{kg}{m^3}$

Molar Quantities

n = # of moles (these are usually *kgmoles*, but can be *lbmoles* too). One can determine *n* using $n = \frac{m_x}{M_x}$ where m_x is the mass of substance *x*, and M_x is the molecular mass of substance *x*. So for example to determine *n* for 2 lb_m of air one needs to know that

$$M_{air} = 28.97 \frac{kg}{kgmol} = 28.97 \frac{lb_m}{lbmol} \quad \text{so} \quad n = \frac{2\, lb_m}{28.97 \frac{lb_m}{lbmol}} = 0.069\, lbmol \quad .$$

Where can you look up *M in your book*?

Note that a molar specific volume is sometimes useful as well (an overline is used to denote molar quantities).

$\bar{v} = \frac{V}{n} = \frac{V}{m/M} = \frac{V}{m} M = v\, M$ so determining the molar specific volume once one knows the specific volume only involves multiplying by the molar mass.

Pressure

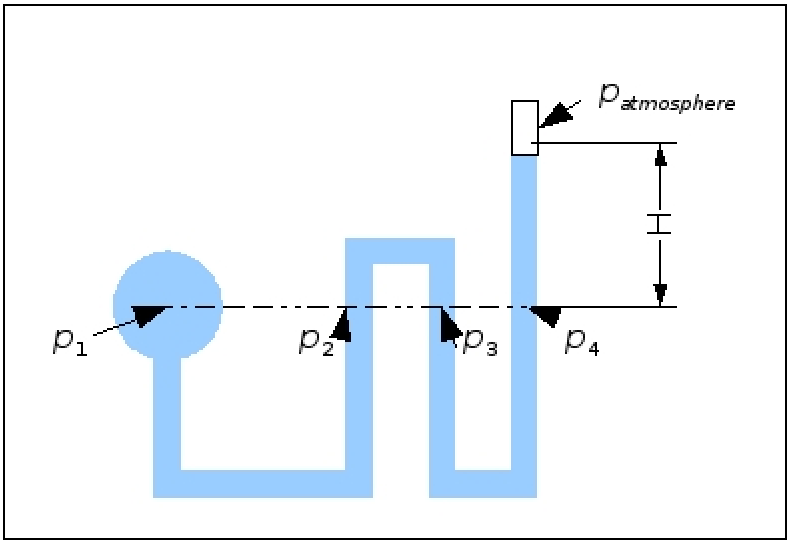
$P = \lim_{\delta A \to \delta A_{min}} \frac{\delta F}{\delta A}$ where δA_{min} is the smallest area for which the substance is a continuum and δF is the normal force to δA.

1 bar = 10^5 Pa and 1 atm = 101325 Pa = 14.696 $\frac{lb_f}{in.^2}$.

When pressure is <u>absolute</u> it may be denoted *abs* as a subscript or on the unit itself (e.g p_{abs} and/or psia). Absolute zero pressure exists when there is no atomic or molecular motion and equates to absolute zero temperature as well. <u>Gauge</u> pressure is relative to atmospheric air pressure and may be denoted *g* as a subscript or on the unit itself (e.g p_g and/or psig). So to find gauge pressure use $P_{gauge} = P_{absolute} - P_{atm}$.

Manometers

Manometers are a way to measure pressure (see below)



In this case because the fluid in the manometer is continuous $p_1 = p_2 = p_3 = p_4$. If the density is constant for the fluid (a liquid almost always satisfies this condition for a given temperature) then one can find the pressure p_4 using $p_4 = \rho g H + p_{atmosphere}$.

Zeroth Law of Thermo

Two bodies that are initially in thermal equilibrium with a third body are in thermal equilibrium with each other. This is the basis of thermometry, where if two objects are in thermal equilibrium with a third (let's say a thermometer) then the two objects have the same temperature. So basically two things at the same temperature are in thermal equilibrium.

Temp Units

Absolute Units are Kelvin (K) and Rankine (R). Conversions to relative temp. scales are:

$$T(Celsius) = T(Kelvin) - 273.15$$
$$T(Rankine) = 1.8\,T(Kelvin)$$
$$T(Fahrenheit) = T(Rankine) - 459.67$$