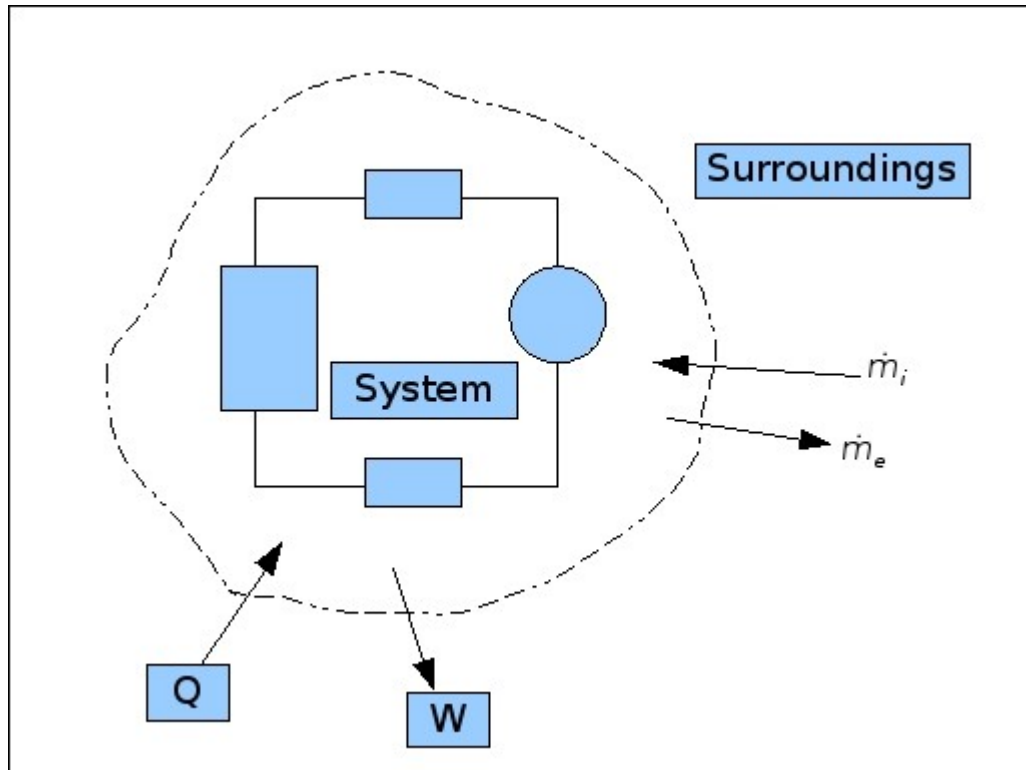


## ENGR 3203

### 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.



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:  $Q = 0$

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

### Thermo Phases

Solid, Liquid, Vapor, Solid-Liquid (example: saturated ice-water mix), Solid-Vapor (example: saturated CO<sub>2</sub> (dry ice) mix), Liquid-Vapor (example: steam-liquid water saturated mix).

### 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<sub>f</sub>, lb<sub>m</sub>, ft, s ---  $F = \frac{ma}{g_c}$  where  $g_c = 32.174 \frac{lb_m ft}{lb_f s^2}$

### **Specific Volume**

There is a minimum size for which density makes sense ( $\delta V_{min}$ ). Density can be defined as

$\rho = \lim_{\delta V \rightarrow \delta V_{min}} \frac{\delta m}{\delta V}$  The specific volume is just  $v = \frac{1}{\rho}$ .  $\delta V_{min}$  is just the minimum volume for which the substance is a continuum.

### **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<sub>m</sub> of air one needs to know that

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

Note that a molar specific volume is sometimes useful as well (an overline is often 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**

$P = \lim_{\delta A \rightarrow \delta A_{min}} \frac{\delta F}{\delta A}$  where  $\delta A_{min}$  is the smallest area for which the substance is a continuum and

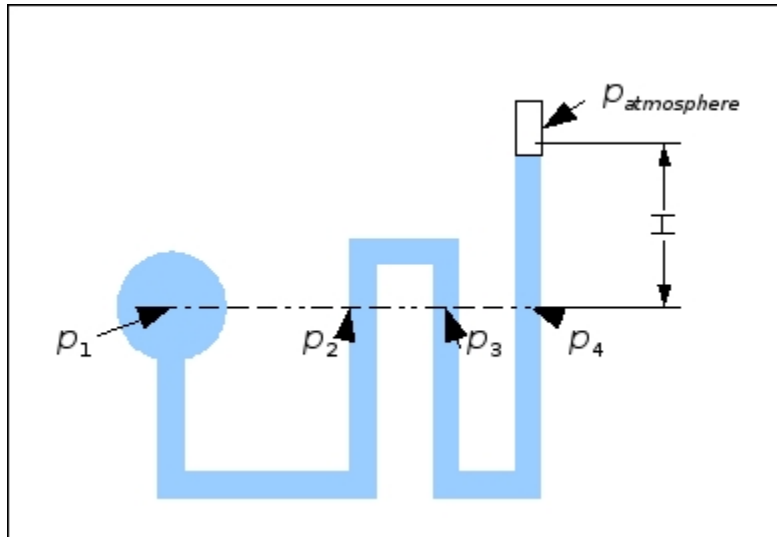
$\delta F$  is the normal force to  $\delta A$ . Note that 1 bar =  $10^5$  Pa and 1 atm = 101325 Pa = 14.696

$\frac{lb_f}{in.^2}$ . When pressure is absolute it may be denoted *abs* as a subscript or on the unit itself

(e.g  $p_{abs}$  and/or psia). Absolute pressure exists when there is no atomic or molecular motion and equates to absolute zero temperature as well. Gauge 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:

$$T(\text{Celsius}) = T(\text{Kelvin}) - 273.15$$

$$T(\text{Rankine}) = 1.8 T(\text{Kelvin})$$

$$T(\text{Fahrenheit}) = T(\text{Rankine}) - 459.67$$