WEEK 1

Engineering Calculations – Processes – Process Variables

2.1 Units and Dimensions

- Units and dimensions are important in science and engineering
- A measured quantity has a numerical value and a unit (ex: $25^{o}C$)
- Dimension: Length, time, mass or temperature - These are properties that can be measured <u>or</u> obtained by multiplying other dimensions (ex: velocity = Length/time; volume = $Length^3$)

Note: If the units are the same, they can be added or subtracted (ex: 3 cm- 1 cm). If they are different, conversion is required in order to obtain the same units.

2.2 Unit Conversion

- Measured quantity -→ Unit having appropriate dimension.

Ex: Volume--→ 3 cm^3 -→ $Length^3$

Measure quantity-→ numerical value, proper unit -→ proper dimension

Note: The numerical value depends on the unit.

(Inside cover of the book)

- To convert from one unit to another, we multiply by a “conversion factor”

Ex: 36 mg (1g/1000 mg) = 0.036 g

36 mg (0.001g/1 mg) = 0.036 g

Note: The old units should cancel out. All we have left is the desired unit.

- We also deal with compound units (Ex: miles/h). These units are formed by combining different dimensions (Ex: **to do in class**: 1 cm/s^2 in km/yr^2)

2.3 Systems of Units (SI, American Engineering System)

- Base units are units for mass, length, time, temperature, electrical current and light intensity (Page 11 in the textbook).

Ex1: Quantity: temperature, Base unit: Kelvin (SI), symbol: K.

Ex2: Quantity: time, Base unit: second, symbol: s.

- Multiple units: multiple or fraction of base units such as hours, milliseconds, year etc… Multiple unit prefixes are: Mega (M) = 10^6, Kilo (k) = 10^3, Centi (c): 10^{-2}, Milli (m) = 10^{-3}, Micro (μ) = 10^{-6}, Nano (n) = 10^{-9}.

Note: There are quantities which require derived units. It is imperative that we recognize units associated with quantities.

Ex: volume→ liter→l or L

Force→Newton (SI), dyne (CGS)→N

Pressure→pascal (SI) → Pa

Energy, work→ joule (SI) → J

Power→ watt→W

Conversion: W = 1 J/s = 1kg.m^2/s^3 ; 1 N = 1 kg.m/s^2

Example: Conversion between systems of units: 23 lbm.ft/min^2 in kg.cm/s^2

2.4 Force and Weight

- For now, we are interested in force and weight in the context of units and unit conversion
- Force is proportional to mass X acceleration

  SI: $kg.m/s^2$

CGS: $g.cm/s^2$

American engineering: $lbm.ft/s^2$

1 Newton (N) = 1 $kg.m/s^2$ (SI)

1 dyne = 1 $g.cm/s^2$ (CGS)

1 lbf = 32.174 $lbm.ft/s^2$ (American engineering)

(acceleration of gravity at sea level and 45^o latitude)

Conversion factors: 1 $kg.(m/s^2)/N$, 1 $g.(cm/s^2)/dyne$, 32.174 $lbm.(ft/s^2)/lbf$

- Weight is force exerted on an object by gravitational acceleration

  $W = m\ g$

$g = 9.8066\ m/s^2 = 980\ cm/s^2 = 32.174\ ft/s^2$

- There is a distinction between weight and mass (**Go over example 2.4-1 on page 13 in class**)

2.5 Numerical Calculations and Estimations

- Scientific notation, significant figures, and precision: $aX10^b$ (b is a negative or positive integer)
  Ex: 123,000,000=$1.23X10^8$; 0.000028=$2.8X10^{-5}$

Significant figures:

a) **There is a decimal point**: 0.000028 (2 significant figures)
<u>First nonzero digit on the left to the last digit (zero or nonzero) on the right</u>

b) **There is no decimal point**: 123000000 (3 significant figures)
<u>First nonzero digit on the left to the last nonzero digit of the number</u>
More examples: 2300 : 2; 2300. : 4; 2300.0 : 5; 23040 : 4; 0.035 : 2; 0.03500 : 4.
When using scientific notations, make sure that the significant digits are shown.
2.3×10^3; 2.300×10^3; 2.3000×10^3; 2.304×10^4; 3.5×10^{-2}; 3.500×10^{-2}.

Note: high precision: close to each other
High accuracy: very near the target

Significant figures have to do with precision of a reported (or measured) quantity.

Ex1: 3 significant figures: the value of the third of the figures may be off by ass much as one half.

Ex2: 8.3 g lies between 8.25 g and 8.35 g

Ex3: 8.300 g lies between 8.2995 g and 8.3005 g

2.5 Numerical Calculations and Estimations

- When doing <u>multiplication or division</u>, keep the lowest number of significant figures of any of the multiplicands or divisors.

Ex1: 3.57x4.286 = 15.30102 = 15.3

(3) (4) (3)

Ex2: $(5.2\times10^{-4})\ (0.1635\times10^{7})/2.67$ =

(2) (4) (3)

318.426966 = 3.2×10^{2}=320

(9) (2)

- <u>Addition and subtraction:</u> the number of decimal places in the answer = the number of decimal places in the *quantity with the smallest number of decimal places*

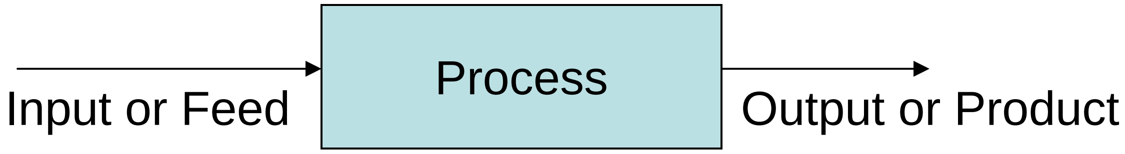
Ex: $(2.75\times10^{6}) + (3.400\times10^{4}) = 2.78\times10^{6}$

(3) (4) (3)

Note: Equations must be dimensionally homogeneous (End of Chapter 2)

Chapter 3

- Processes and process variables
- “Process”: any operation or series of operations that causes a physical or chemical change in a substance or a mixture of substances



- “Process Unit”: apparatus in which one of the operations that constitutes of a process is carried out

Examples of “process units”” reactors, distillation columns, heat exchanger

We need to introduce definitions and measurement techniques to help understand and design process units

Chapter 3

- Density: mass/volume of substance (kg/m^3, g/cm^3, lbm/ft^3)
- Specific volume of a substance: volume of substance/mass (m^3/kg, cm^3/g, ft^3/lbm)

Density of solid and liquid are weak functions of temperature and pressure.

Ex1: density of carbon tetrachloride: 1.595 g/cm^3

Ex2: mass of 20.0 cm^3 of carbon tetrachloride? 20.0 cm^3 x 1.595 g/cm^3 = 31.9 g

Ex3: volume of 6.20 lbm of tetrachloride: 6.20 lbm x (454g/1lbm) x (1cm^3/1.595 g) = 1760 cm^3

Chapter 3

- "Specific gravity" of a substance: SG = ρ/ρref. ρref(H_20, 4^oC) = 1.000 g/cm^3 = 1000 kg/m^3 = 62.43 lbm/ft^3 . SG = 0.6 $20^o/4^o$ (**Example 3.1-1 in class**)

- 3.2 Flow rate: Mass and volumetric flow rate

-Flow rate of a material = rate at which a material is transported through a process line. Mass flow rate (mass/time); volumetric flow rate (volume/time)

- How do we measure flow rate? (**Page 46: rotameter -** ***float*** **and orifice meter –** ***pressure drop***).

- 3.3 Chemical composition

Moles and molecular weights. Atomic weight of an element = mass of an atom. Molecular weight of a compound = sum of the atomic weights of all the atoms that make up the molecule of the compound

Ex: atomic weight (O): 16;   Molecular weight of O_2 is about 32.

Unit: 1 gram-mole (g-mole or mole in SI) = amount of that species (# moles) that is numerically equal to its molecular weight. Instead of g-mole, we may write moles (ex: 2 g-moles = 2 moles)

Ex: Carbon monoxide (CO) = 28 g/mole -> 1 g-mole of CO contains 28 g. Also 1 lb-mole of CO contains 28 lbm

Conversion: 34 kg NH_3 x (1 kmol/17 kg NH_3) = 2 kmol NH_3

4 lb-mole NH_3 x (17 lbm/1 lb-mole NH_3) = 68 lbm NH_3

In class Page 48 Example 3.3-1

Chapter 3

- Notes: Avogadro's number: 6.02×10^{23} molecules/mole
  - Molecular formula: CxOy means x mole of C and y mole of O. But we have 1 mole of Cx and 1 mole of Oy. Also: 1 mole of CxOy.

Mass, mole fractions and average molecular weight

Mass fraction = X_A = mass of A/total mass

Mole fraction = Y_A = mole of A/total moles

Example 3.3.2 to do in class

In this example, we use conversion of mass and mole fractions. You are giving mass %. 1) Use 100 (g, kg, lbm) basis, 2) Obtain the mass, 3) Convert mass to moles using molecular weight. When giving mole %, the procedure is similar.

Chapter 3

- Average molecular weight (or mean molecular weight) of a mixture: $\bar{M}$ (kg/Kmol or lbm/lbmol).

$$\bar{M} = y_1 M_1 + y_2 M_2 + ... = \sum y_i M_i$$

- M_i: molecular weight of compound i; y_i: mole fraction of compound i.

$$\frac{1}{\bar{M}} = \frac{x_1}{M_1} + \frac{x_2}{M_2} + ... = \sum \frac{x_i}{M_i}$$

x_i: mass fraction of i

- **Example 3.3-4 page 51 to do in class**

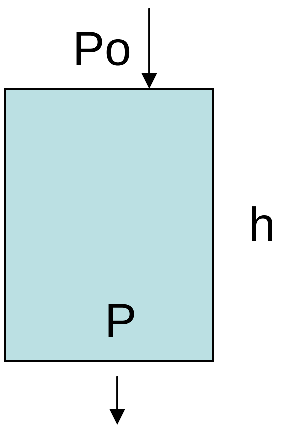
3.4 Pressure

- 3.4a Fluid pressure and hydrostatic head:

$P = F/A = N/m^2$; $dynes/cm^2$; lbf/in^2

$1\ N/m^2 = 1$ pascal (Pa)

$P = Po + \rho gh$



P is the hydrostatic pressure of the fluid

"Head" of a particular fluid $P_{head} = \rho_{fluid}gh$

Example 3.4-1 page 55 to do in class

We need to use $1\ N = 1\ kg.m/s^2$; $1\ dyne = 1\ g.cm/s^2$; $1 lbf = 32.174\ lbm.ft/s^2$ to obtain proper units.

- 3.4b Atmospheric pressure, absolute pressure and gauge pressure: $P_{abs} = P_{gauge} + P_{atmospheric}$
- 3.4c Fluid pressure measurement: Bourdon gauge; Manometer. **Read Page 58 and 59**

3.5 Temperature

- $T(K) = T(^oC) + 273.15$
- $T(^oR) = T(^oF) + 459.67$
- $T(^oR) = 1.8\ T(K)$
- $T(^oF) = 1.8\ T(^oC) + 32$

HMK: 2.2, 2.3, 2.8, 2.9, 3.2, 3.3, 3.14