To motivate what we will be learning in this course, let's talk about

What Some ChemEs Do For a Living

Immediately after graduation, most ChemE seniors will do one of the following:

1) Work for a Large Chemical, Petrochemical, Pulp & Paper, Plastics, or Textile Manufacturing Firm.

2) Work for a Govt Agency, Engineering Design Firm, or Environmental Consulting Firm.

3) Work for Pharmaceutical, Biotech, Electronics or specialty chemical Company.

4) Go to Graduate School in ChemE, Medicine, Law, or Business.

Take Home Message: The problem-solving skills you learn while getting a ChemE degree will contribute to your career successes regardless of the path you choose.

Even ChemE graduates who work in a traditional chemical manufacturing process, end up performing a wide variety of tasks.

Consider the following example:

A chemist in your company's research & development division has discovered that she obtains a very valuable product when two reactants are mixed in certain proportions at an elevated temperature.

The company contemplates manufacturing the product using a process based upon this reaction.

At this point, the matter becomes an engineering problem or, more precisely, hundreds of engineering problems. For example:

REACTOR TYPE

1. What type of reactor should be used? An extremely large test tube? A long pipe? A large tank?

SAFETY

2. Does the rxn supply its own heat? If so, can the reactor "runaway" and possibly explode? What kind of control measures should be put in place to prevent this?

SEPARATION

3. Should the product be separated and the reactants recycled? How should the separation be conducted?

MOVING MATERIAL

4. How should we move the reactants and product to and from the reactor and any other equipment in the process? By gravity? With pumps or blowers or compressors?

SAFETY

5. What can possibly go wrong and what can be done if and when it does?

ENVIRONMENT

6. Are waste products produced by the process? If so, how can we reduce their production? What is their toxicity? How would we separate them from our desired product?

ECONOMICS
7. How much is all of this going to cost? Who can we sell the product to and for how much? Will our net profit be sufficient to make the process worthwhile?

START-UP
8. What's the best way to start up the process? Once the process has been started up, why isn't it producing the same concentration as the lab experiments? Is it an equipment malfunction or some change in conditions between the plant and the lab?

TROUBLESHOOTING
9. All sorts of things are going wrong with the process. Why weren't they on the list of things that could possibly go wrong? What can we do about them?

OPERATION
10. When the process finally starts working perfectly, the next day an order comes down to change the product specifications, how can it be done without redesigning the entire process? Why didn't they think of this before they built the plant?

⇒ ChemEs are involved in answering all of these questions. To do this, they must know something about:

- physics
- chemistry
- biology
- environmental science
- medicine
- applied mathematics
- statistics
- computer science
- economics
- management and info. science
- research
- design
- construction
- sales and service
- production supervision
- business administration.

Even though many of these topics are learned after graduation, the fundamental techniques we teach in the curiculum can be readily applied to problems regardless of theis particular subject area. I'll be teaching you some of these techniques in this course.

INTRODUCTION TO ENGINEERING CALCULATIONS

One similarity among all of the questions I posed previously is that they involve processes that are designed to transform raw materials into desired products.

So, one of the problems can be stated as,

"Given the amounts & properties of the raw materials, Calculate the amounts & properties of the products, or vice versa."

Before we can solve these sorts of problems, we must be familiar with several concepts. Let's start with

Units and Dimensions

Measured values have both a value and a unit associated with it.

VALUE → 2 meters ← UNIT

VALUE → $\frac{1}{2}$ second ← UNIT

VALUE → 4.29 kgs ← UNIT

When using them in an equation, it's important to write both for each quantity present.

Units are treated like algebraic variables when quantities are added, subtracted, multiplied, or divided.

$\Rightarrow$ Numerical values of two quantities may be added or subtracted <u>only if</u> the units are the same.

$$3 \text{ cm} - 1 \text{ cm} = 2 \text{ cm}$$

$$3 \text{ cm} - 1 \text{ mm} = ?$$

$\Rightarrow$ Numerical values and their corresponding units may always be combined by multiplication or division

$$(3 \text{ N}) \times (4 \text{ m}) = 12 \text{ N}\cdot\text{m}$$

$$\frac{5 \text{ km}}{2 \text{ hr}} = 2.5 \text{ km/hr}$$

$$(6 \text{ cm}) \times \left(5 \frac{\text{cm}}{\text{sec}}\right) = 30 \text{ cm}^2/\text{sec}$$

$$\frac{(5 \text{ kg/sec})}{(0.2 \text{ kg/m}^2)} = 25 \text{ m}^2/\text{sec}$$

Conversion of Units

A measured quantity can be expressed in terms of any units with the appropriate dimension. So, velocity could be expressed in

$$\mathrm{ft/s} \;,\quad \mathrm{miles/hr} \;,\quad \mathrm{cm/yr} \quad \text{or} \quad \frac{\text{any length unit}}{\text{any time unit}}$$

The velocity's numerical value depends on its units.

⟹ To convert a quantity expressed in terms of one unit to its equivalent in terms of another unit, multiply the quantity by the conversion factor (new unit / old unit).

$$(36\ \cancel{mg})\left(\frac{1\ g}{1000\ \cancel{mg}}\right) = 0.036\ g$$

Alternatively, you can use a vertical line instead of the multiplication symbol.

$$\frac{36\ \cancel{mg}}{} \Big| \frac{1\ g}{1000\ \cancel{mg}} = \frac{36}{1000}\ g = 0.036\ g$$

This technique helps you get your intended result by avoiding the common mistake of multiplying when you need to divide

$$\frac{36\ mg}{} \Big| \frac{1000\ mg}{1\ g} = 36000\ \frac{mg^2}{g} \leftarrow$$ Not what we want!

Example 2.2-1

Convert an accelaration of $1\ cm/s^2$ to its equivalent in km/yr^2.

$$\frac{1\ cm}{s^2}\left|\frac{3600^2\ s^2}{hr^2}\right|\frac{24^2\ hr^2}{day^2}\left|\frac{365^2\ day^2}{yr^2}\right|\frac{1\ m}{100\ cm}\left|\frac{1\ km}{1000\ m}\right.$$

$$= \frac{(3600 \times 24 \times 365)^2}{(100 \times 1000)} \frac{km}{yr^2} = 9.95 \times 10^9\ km/yr^2$$

<u>NOTE:</u> Raising a quantity to a power, raises its units to the same power.

Problem 2.1(b)

Convert 38.1 ft/s to miles/hr

$$\frac{38.1\ ft}{s}\left|\frac{3600\ s}{hr}\right|\frac{1\ mile}{5280\ ft} = \left(\frac{38.1 \times 3600}{5280}\right) miles/hr$$

$$= 26.0\ miles/hr$$

Systems of Units

Components of a System of Units:

1. <u>Base Units</u> for mass, length, time, etc. (e.g. seconds for time in SI)
2. <u>Multiple Units</u>, defined as multiples or fractions of the Base Units. These are defined for convenience rather than necessity (i.e. its easier to refer to 3 yrs than to 94,608,000 s)

3. <u>Derived Units</u>, obtained in one of two ways

   a) By multiplying or dividing base or multiple units (e.g. cm^2, ft/min, $kg\text{-}m/s^2$, etc). These are called <u>compound units</u>.

   b) As defined equivalents of compound units (e.g. $1 \text{ erg} \equiv 1 \text{ gm-cm/s}^2$, $1 \text{ lb}_f = 32.174 \text{ lb}_m\text{-ft/s}^2$)

Common Systems of Units	Base Units
SI (système Internationale d'Unités)	meter (m), kilogram (kg) second (s)
CGS	centimeter (cm), gram (g) Second (s)
American Engineering System	foot (ft), pound-mass (lb_m) second (s)

Conversion from one set to the other can be done by using the table on the inside front cover of your book.

<u>Example 2.3-1</u>

Convert $23 \text{ lb}_m\text{-ft/min}^2$ to its equivalent in $kg\text{-cm/s}^2$

$$\frac{23 \text{ lb}_m\text{-ft}}{\text{min}^2} \bigg| \frac{\text{min}^2}{60^2 \text{sec}^2} \bigg| \frac{\text{kg}}{2.20462 \text{ lb}_m} \bigg| \frac{100 \text{ cm}}{3.2808 \text{ ft}}$$

$$= \frac{(23 \times 100)}{(60^2 \times 2.20462 \times 3.2808)} \frac{\text{kg-cm}}{\text{s}^2}$$

$$= 8.83 \times 10^{-2} \text{ kg-cm/s}^2$$

Force and Weight

From Newton's 2nd Law, Force is proportional to the product of mass and acceleration.

System	Natural Force Units	Derived Force Units
SI	$kg\text{-}m/s^2$	N (Newton)
CGS	$g\text{-}m/s^2$	dyne
American Engineering System	$lb_m\text{-}ft/s^2$	lb_f (pound-force)

Conversion factors :

$$1\ N = 1\ kg\text{-}m/s^2$$

$$1\ dyne = 1\ g\cdot cm/s^2$$

$$1\ lb_f = 32.174\ lb_m\text{-}ft/s^2$$

product of a unit mass & gravitational acceleration at sea level ($32.174\ ft/s^2$)

Example 1

Determine the force in Newtons required to accelerate a 4 kg mass at a rate of $9.00\ m/s^2$.

$$F = \frac{4\ kg}{} \Big| \frac{9.00\ m}{s^2} \Big| \frac{N}{kg\text{-}m/s^2} = 36.0\ N$$

Example 2

Determine the force in pounds-force required to accelerate a 4 lb_m mass at a rate of 9.00 ft/s^2

$$F = \frac{4\ lb_m \;\big|\; 9.00\ ft \;\big|\; 1\ lb_f}{\;\big|\; s^2 \;\big|\; 32.174\ lb_m\text{-}ft/s^2} = 1.12\ lb_f$$

An objects weight is the force exerted on the object by gravitational attraction.

$W = mg$ where m is object's mass

$$\left.\begin{aligned} g &= 9.8066\ m/s^2 \\ &= 980.66\ cm/s^2 \\ &= 32.174\ ft/s^2 \end{aligned}\right\} \text{for weight determination on earth.}$$

Numerical Calculation & Estimation

⇒ Scientific Notation - a number is expressed as the product of another number and a power of 10.

$$123{,}000{,}000 = 1.23 \times 10^8 \quad \text{or} \quad 0.123 \times 10^9$$

⇒ Significant Figures - number of digits from the first nonzero digit on the left to either

a) the last digit (zero or nonzero) on the right if there is a decimal point

or

b) the last nonzero digit of the number if there is no decimal point.

2300 or 2.3×10^3 - 2 significant figures

2300. or 2.300×10^3 - 4 significant figures

2300.0 or 2.3000×10^3 - 5 significant figures.

The number of significant figures is an indication of the measured or calculated quantity's precision. The last of the significant figures may be off by as much as a half-unit.

<u>Example:</u> By reporting a mass at 8.3 g, you are indicating the mass lies between 8.25 and 8.35.

Q: If you reported a mass at 8.300 g, where are you indicating the mass lies between?

A: Between 8.2995 and 8.3005.

<u>NOTE:</u> This rule applies only to measured quantities or numbers calculated from measured quantities. It doesn't apply if the value is known precisely - like an integer or counted item rather than measured quantity.

Q: How many significant figures are in the result when we do arithmetic with measured quantities having different numbers of significant figures?

A: For multiplication/division, the result has the same significant figures as the lowest number of significant figures of the quantities being multiplied or divided.