# ChEn 273

Class 1

- Course Introduction
- Units and unit conversions
- Significant figures
- Process Flow Diagrams
- Stream variables

We meet in 214 CTB

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# Course Objectives

A. Obtain a feel for what Chemical Engineers do
B. Learn about basic chemical process units
C. Learn to analyze and solve material balance problems (mass or mole balances)
D. Learn to analyze and solve energy balance problems
E. Learn to analyze more complex balance problems involving coupling of material and energy balances for multiple units

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http://www.arb.ca.gov/fuels/carefinery/crseam/crseam.htm

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In your ChE job you may use the skills from this class more than from any other ChE class

(based on feedback from many students)

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The biggest help from classes that I have taken came from Ch En 273 because the programming skills for Excel that I learned. Every day, I was recording hundreds of data points including temperatures, pressures, and mixture composition for the project that all had to be analyzed and summarized for the customer. The Excel sheets that I created were later used to reproduce the polymer under similar conditions to compare the numerous combinations and to even prove to the company that a certain mixture was better than another mixture that they were previously leaning towards.

Jennifer Robinson, Internship Report (2018)

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# BYU STEM Career Fair

- In-Person, Wed., Sept. 28
- Get your resume on BYU Handshake
- Learn which companies are coming
- Only 25-30% of our students obtain a job through the Career Fair
- **YOU** have to find a job
  - No one will do it for you
  - Time to start NOW!
- I am willing to give tips on your resume

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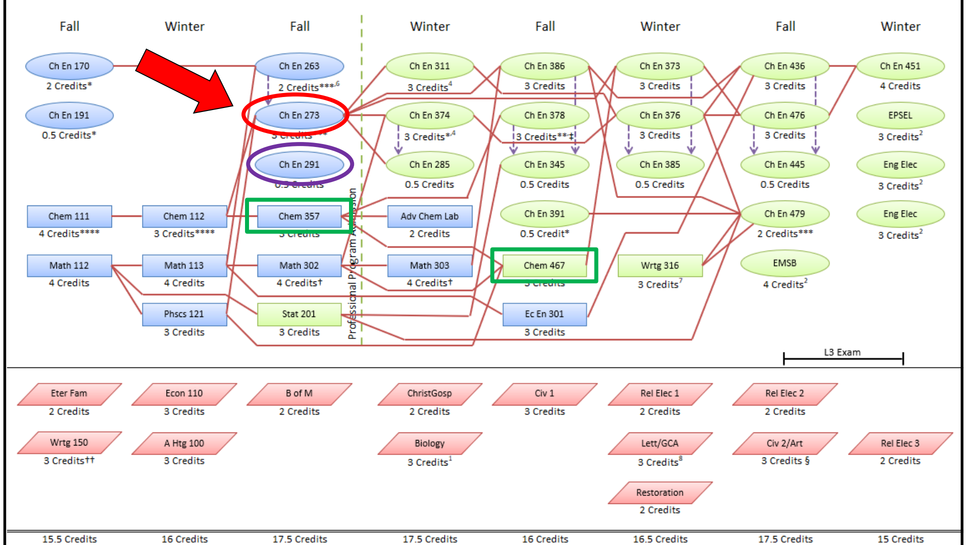


**Please take Fluid Dynamics (ChEn 374) in the Winter semester!**

**Please take Fluid Dynamics (ChEn 374) in the Winter semester! (also offered Spring & Fall)**

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# Prerequisites for ChEn 273

- **ChEn 263**
  - Concurrent enrollment is now encouraged
- **Calculus**
  - Know how to do simple derivatives and integrals (i.e., polynomials), which means **completed** Math 113
  - We will use one form of ordinary differential equations which will be solved like an integral
- **Physics**
  - You should have **completed** Physics 121
- **Chemistry**
  - You should have **completed** Chem 112 or 106

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## What You Need to Know from Excel

(from ChEn 263)

- Computing
- Fill down
- Solver
  - Iterative problems
  - Optimization
- Graphing
- Fitting simple equations
  - Linear
  - Power law, etc.

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## ChEn Sophomore Course Scheduling

ChEn 291 and 391

- To satisfy graduation requirements, you must now take **ChEn 291** (0.5 credits) ***and*** **ChEn 391** (0.5 credits)
- ***You should be in ChEn 291 right now.***
  - ChEn 291 is only offered in Fall.
- ***You should take ChEn 391 fall or winter of next year***

O-chem

- If you have not taken O-chem (Chem 351/352) **you should be in Chem 357 right now**.
  - Chem 357 is a *Fall-only class*
  - You can still take 351/352, but this is only recommended for pre-med tracks.

- Please do not take ChE 170 concurrently with ChE 273

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## Grades

20% Homework problems, Quizzes, In-Class Activities

10% Case study

45% Three midterm exams (take-home, closed book with 3×5 note card) (10%-15%-20%)

25% Final Exam

– Must get 60% on final to avoid penalty!

**2 Dean's lectures this semester**

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## TAs are your friends

| | |
|---|---|
| **Dawson McCrea** | **Parker LaTour** |
| mccrea107@gmail.com | latour.parker@gmail.com |

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## My Schedule

| Time | M | T | W | Th | F |
|---|---|---|---|---|---|
| 8:00 | Class Prep | | Class Prep | | Class Prep |
| 9:00 | ChE273 214 CTB | Mahsa A. | ChE273 214 CTB | | ChE273 214 CTB |
| 10:00 | | | | | |
| 11:00 | | Devotional Marriott Center | | Graduate Seminar | |
| 12:00 | | | Faculty Mtg | | |
| 1:00 | | College Council | | | |
| 2:00 | | Dean's Office | | | |
| 3:00 | | | | | Danny G. |
| 4:00 | | | | | |

**Note that I am available most afternoons from 1-5 pm.**

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# Quiz next time:

1. Read the entire syllabus
2. Contact one TA before next class personally!!!
   - Email
   - Phone
   - In person

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# Advice

**Be Professional!**
- You are an apprentice engineer

**Treat this class like your job!**
**Keep up with the pace!**
**Come to class & pay attention!**
**Contact me!**

**Sense of Belonging**
- Please treat all students, faculty, & staff with respect
- Let me know if you have not been treated with respect

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# Homework rules:

- Homework problems are due at the beginning of class. Please don't be late to class because you are finishing homework.
- Homework may be turned in late until the next exam without excuse for up to 50% credit. You may look at the answer key in Learning Suite for guidance on late homework. Dr. Fletcher will excuse late homework on a case-by-case basis. Please work the homework early to avoid lateness due to computer crashes.
- Answer keys will be posted on Learning Suite after class.
- You may discuss with others how to begin working problems (in fact this is encouraged), but you must work the problem entirely yourself to hand in for credit. You may **not** share computer files for homework problems until the case study.
- Homework should be written on one side only of 8.5" x 11" paper. Neatness is essential in developing good problem-solving techniques. Points may be taken off for sloppiness.
- Use of Excel and Python is strongly encouraged. However, use the one that is most efficient for you!

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## Class Details

- Personal Info Sheet
  - Alias name used to post grades
  - Due Today!! (upload to Learning Suite)
- Schedule
- Competencies
- AIChE Code of Conduct
- Class web page
  - http://www.et.byu.edu/~tom/classes/273/273.html

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## Schedule

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# Class Outcomes

- Students will be able to perform unit conversions.
- Students will be able to ensure dimensional consistency when evaluating equations.
- Students will exhibit critical and creative thinking skills for analysis and evaluation of problems and cause-effect relationships.
- Students will be able to make order of magnitude estimates, assess reasonableness of solutions, and select appropriate levels of solution sophistication.
- Students will be able to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- Students will be able to calculate the work of pumps, turbines, and/or compressors.
- Students will be able to design multiple-unit processes.
- Students will understand and commit to practice the AIChE code of ethics.
- Students will function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- Students will understand process variables (e.g., P, T, flow rate, conc.) including procedures and equipment for their measurement.
- Students will be able to set up and solve steady state material balances.
- Students will be able to set up and solve steady state energy balances (1st law of thermodynamics) for closed and open systems.
- Students will be able to set up and solve transient mass balances.
- Students will be able to solve simple fluid statics problems.
- Students will be able to apply solution thermodynamics fundamentals to solve phase equilibrium problems including bubble point, dew point and flash calculations.
- Students will understand and be able to use the extent of reaction in material balances for systems involving chemical reactions.
- Students will understand and be able to apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation.
- Students will be able to read and understand phase diagrams and use these to determine physical phenomena.
- Students will be able to solve problems related to pure-component phase behavior including vapor pressure, critical point, freezing line, triple point, etc.
- Students will be able to explain how molecular and continuum phenomena give rise to macroscopic behavior, processes, and properties.
- Students will be able to calculate internal energy, enthalpy, and entropy at system conditions assuming ideal behavior.

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# AIChE Code of Ethics

**A. Fundamental Principles**

Engineers shall uphold and advance the integrity, honor and dignity of the engineering profession by:

1. Using their knowledge and skill for the enhancement of human welfare;
2. Being honest and impartial and serving the engineering profession with fidelity;
3. Striving to increase the competence and prestige of the engineering profession.

**B. Fundamental Canons**

1. Engineers shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties.
2. Engineers shall perform services only in areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
5. Engineers shall build their professional reputations on the merits of their own service.
6. Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession.
7. Engineers shall continue their professional development throughout their careers and shall provide opportunities for the professional development of those engineers under their supervision.

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# Dean’s Lectures

- Students are required to attend two Dean’s lectures
  - May view recorded lectures
- Held in JSB Auditorium at 11 am
  - Oct 13
  - Nov 17
- Will count for ½ grade (A vs A-)

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# Learning Philosophy

- There are way too many problems in ChE to try to go through an example on each type of problem, like perhaps in a Math class
- **We will learn the basic principles in class, and then give a few HW problems to reinforce those principles**
  - **“Learn to fish”**
- The goals are to learn the basic principles and be able to apply those principles to solve engineering problems
- This method is kind of like being on a job:
  - You will be given a problem and told to solve it with whatever method you can

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# Learning Philosophy

- Re-reading the chapter(s) just before the exam has been shown to do **no good**
- Learn the **concepts**
  - Do they make sense?
  - Apply to real life
  - Review throughout the semester (more frequent quizzes?)
- Homework with a purpose
  - Why was the problem given?
  - Does my answer make sense?
  - Debugging skills
    - Pieces of problem can be debugged
  - Check vs. answer key to learn what you did wrong!
- **Education vs. Degree**
  - Job skills vs. a piece of paper (Opportunity vs Drudgery)

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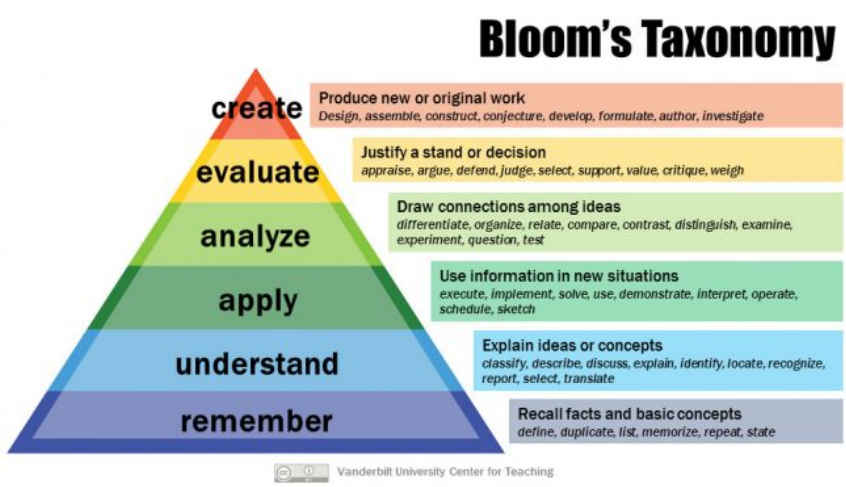
# Learning Philosophy




https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

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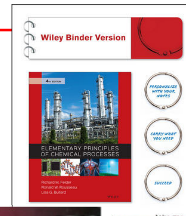
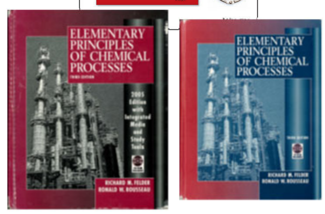
# Textbook

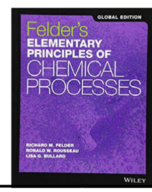
- 4th Edition
  - 3-ring binder (get it spiral bound)
  - Online (this may only be available for one semester)




- 3rd Edition
  - Black & Red cover better
  - Blue and Red cover okay
  - Workbook available




- International Edition
  - Purple paperback
  - Now for sale in the U.S.

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# Ethics (see Syllabus)

- Only look at previous semester exam
  - I will post the previous year exam with final answers
- Take-home exams should be worked ALONE!
- Illegal online HW answer keys
  - How much is your integrity worth?
  - Education vs. degree
- Turn in your own computer work
  - Don't share group computer file

https://www.ilscorp.com/saskatchewan-council-approved-ethics-courses/

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Questions?

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# Chapter 2

Units

Estimation

Significant Figures

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**FACTORS FOR UNIT CONVERSIONS**

| Quantity | Equivalent Values |
|---|---|
| **Mass** | 1 kg = 1000 g = 0.001 metric ton = 2.20462 $lb_m$ = 35.27392 oz<br>1 $lb_m$ = 16 oz = $5 \times 10^{-4}$ ton = 453.593 g = 0.453593 kg |
| **Length** | 1 m = 100 cm = 1000 mm = $10^6$ microns ($\mu$m) = $10^{10}$ angstroms (Å)<br>= 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile<br>1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm |
| **Volume** | 1 $m^3$ = 1000 L = $10^6$ $cm^3$ = $10^6$ mL<br>= 35.3145 $ft^3$ = 220.83 imperial gallons = 264.17 gal<br>= 1056.68 qt<br>1 $ft^3$ = 1728 $in.^3$ = 7.4805 gal = 0.028317 $m^3$ = 28.317 L<br>= 28,317 $cm^3$ |
| **Force** | 1 N = 1 kg·m/$s^2$ = $10^5$ dynes = $10^5$ g·cm/$s^2$ = 0.22481 $lb_f$<br>1 $lb_f$ = 32.174 $lb_m$·ft/$s^2$ = 4.4482 N = $4.4482 \times 10^5$ dynes |
| **Pressure** | 1 atm = $1.01325 \times 10^5$ N/$m^2$ (Pa) = 101.325 kPa = 1.01325 bar<br>= $1.01325 \times 10^6$ dynes/$cm^2$<br>= 760 mm Hg at 0°C (torr) = 10.333 m $H_2O$ at 4°C<br>= 14.696 $lb_f$/$in.^2$ (psi) = 33.9 ft $H_2O$ at 4°C<br>= 29.921 in. Hg at 0°C |
| **Energy** | 1 J = 1 N·m = $10^7$ ergs = $10^7$ dyne·cm<br>= $2.778 \times 10^{-7}$ kW·h = 0.23901 cal<br>= 0.7376 ft-$lb_f$ = $9.486 \times 10^{-4}$ Btu |
| **Power** | 1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·$lb_f$/s = $9.486 \times 10^{-4}$ Btu/s<br>= $1.341 \times 10^{-3}$ hp |

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# Expectation:

- You will be able to convert all kinds of units
  - American companies work in American units, not SI units!

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# Practice Unit Conversions

- Pressure is 1300 psi ($lb_f$/sq. in.)
  - What is the pressure in atmospheres?
  - $(1300\ psi) \cdot \left(\frac{1\ atm}{14.696\ psi}\right) = 88.46\ atm$
  - What is the pressure in mm Hg?
  - $(1300\ psi) \cdot \left(\frac{760\ mm\ Hg}{14.696\ psi}\right) = 6.723 \times 10^4\ mm\ Hg$

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# Units of Force

| System | Mass | Length | Time | Force | $g_c$ | g | $g/g_c$ |
|---|---|---|---|---|---|---|---|
| SI (System International d'unites) | kg | m | s | N | 1 kg-m/s²-N | 9.807 m/s² | 9.807 N/kg |
| CGS | g | cm | s | dyne | 1 g-cm/s²-dyne | 980.7 cm/s² | 980.7 dyne/g |
| FPS | $lb_m$ | ft | s | poundal | 1 ft-$lb_m$/s²-poundal | 32.17 ft/s² | 32.17 poundal/$lb_m$ |
| British (physics) | slug | ft | s | $lb_f$ | 1 ft-slug/s²-$lb_f$ | 32.17 ft/s² | 32.17 slug/$lb_m$ |
| AES (American Engineering System) | $lb_m$ | ft | s | $lb_f$ | 32.17 ft-$lb_m$/s²-$lb_f$ | 32.17 ft/s² | 1 $lb_f$/$lb_m$ |

Bottom line: 1 $lb_m$ weighs 1 $lb_f$ (under normal gravity), but 1 kg weighs 9.807 N!

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## Alternate Way of Thinking

- Force = mass times acceleration (F = m · a)
- 1 Newton = 1 $\frac{kg \cdot m}{s^2}$
- 1 Dyne = 1 $\frac{g \cdot cm}{s^2}$

However, in American Units,

- 1 $lb_f$ = 32.17 $\frac{lb_m \cdot ft}{s^2}$

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## New Concepts

- Pounds mass ($lb_m$)
- Pound moles (lb moles)

- 1 $lb_m$ = 454 grams
- 1 lb mol = 454 gram moles

- 1 gmol contains $6.02 \times 10^{23}$ molecules
- How many molecules are in a lb-mol?

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# LeBron James

- Weighs 250 pounds
- Is this 250 $lb_m$ or 250 $lb_f$?


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# Derivation of $g_c$

250 $lb_m$ weighs 250 $lb_f$ (on earth with earth's gravity)

But $W = m \cdot g/g_c$

250 $lb_f$ = (250 $lb_m$ × 32.17 ft/s²)/$g_c$

Solving for $g_c$, $\boxed{g_c = 32.17\ (lb_m \cdot ft)/(lb_f \cdot s^2)}$

**Always need to use $g_c$ when converting between $lb_m$ and $lb_f$**

**Note: $g_c$ defined based on earth gravity only, and is a constant!**

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# Example

- What would a LeBron James weigh in a tight fighter jet turn that pulls 4 g's? (i.e., g = 4 times that of earth)

Solution:

- $g = 4(32.17\ ft/s^2) = 128.7\ ft/s^2$
- $m = 250\ lb_m$
- $W = mg/g_c = \dfrac{(250\ lb_m)(128.7\frac{ft}{s^2})}{\boxed{32.17\frac{lb_m\ ft}{lb_f\ s^2}}} = \mathbf{1000\ lb_f}$

**Note: value of $g_c$ does not change with g!**

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# Estimation

- How much coal is in a train car?
  - Length = 20 ft
  - Width = 6 ft
  - Depth = 10 ft
  - Density = 1.4 times density of water
  - Water Density = $62.4\ lb_m/ft^3$
  - Packing factor = 0.7

- 20 x 6 x 10 x 1.4 x 62.4 x 0.7 =?
  - $2\times10^1 \cdot 6 \cdot 10 \cdot 1 \cdot 6\times10^1 \cdot 1 = 72\times10^3\ lb_m$
  - 36 tons (real answer = 36.6 tons)

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# Significant Figures

- **Addition/Subtraction**: Compare position of last significant figure relative to the decimal point. The position farthest left is the last permissible significant figure for the sum or difference.

  $3.23 + 4.125429 = 7.39$

- **Multiplication/Division**: The number of significant figures in the product or quotient is equal to the lowest number of significant figures of any of the numbers being multiplied or divided. $3.23 \times 4.125429 = 13.33$

**Bottom line: Be Reasonable!**

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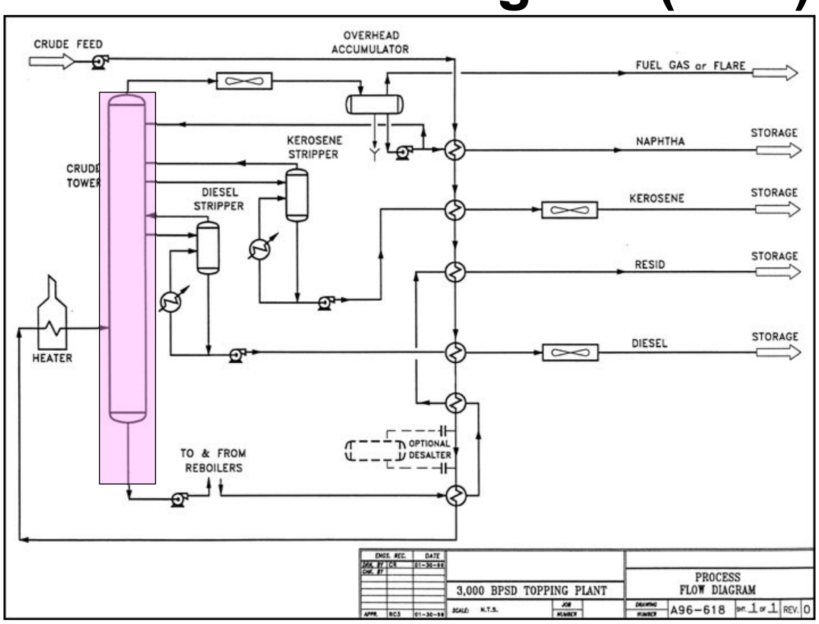
# Process Flow Diagram (PFD)

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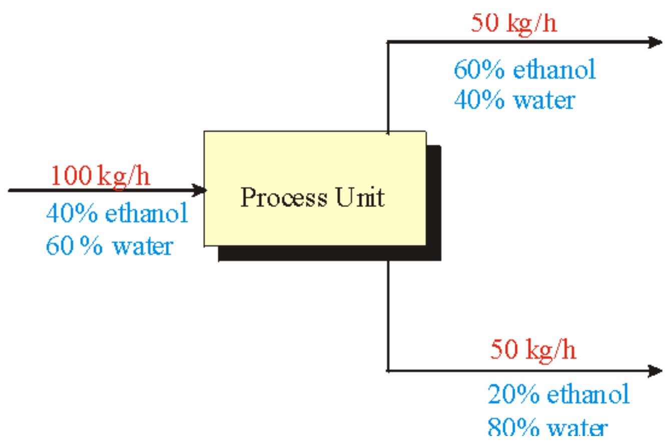
# Simple PFD

(with information on diagram)

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# Stream Variables

- **Extensive-** depend on the amount of material (e.g., flow rate, mass, moles)
- **Intensive-** do not depend on amount (e.g., mole fraction or temperature)

- Precision of numbers- significant figures
- Numbers must have units!

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# HW for next time

- HW 2 (see learning suite)
  - Look at Case Study (see learning suite)

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