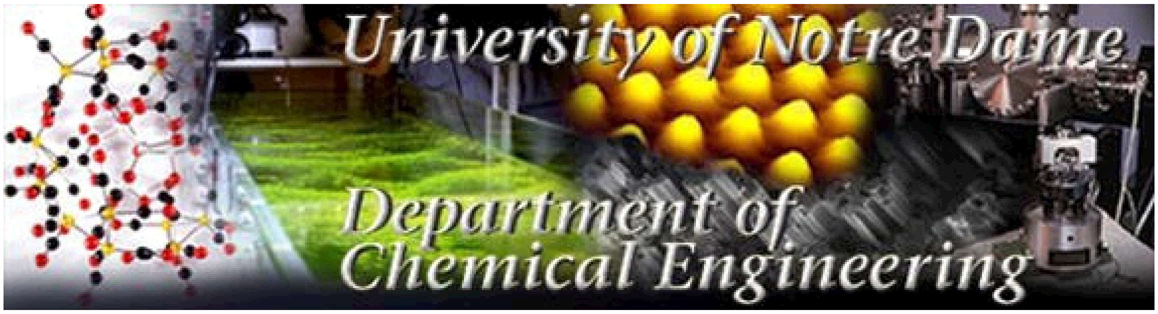

Engineering, Chemical Engineering, the Chemical Engineering Curriculum and Careers for Chemical Engineers

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Chemical Engineering originated with the need to transform raw materials into useful products through chemical reactions.

The reactions where discovered by chemists starting in the 1600's but by the end of the 1800's, there was a need to produce large quantities of an ever increasing number of materials.

The "scale-up" of a laboratory reaction (~grams) to a profitable commercial process 10^6 grams) is usually not a matter of just making bigger laboratory equipment (flasks, beaker and Bunsen burners).

Chemical engineers use the principles of engineering analysis and knowledge of chemistry to design, build and operate processes that provide society with items such as: petroleum fuels, toothpaste, low fat chips, paint, plastic for athletic shoes or carpeting, insecticides, pharmaceuticals, computer chips, etc. …

In the future we might expect: replacement bones, tendons, skin and other organs, superconducting integrated circuits, ceramic and plastic automobiles, nonmetallic bridges and building structures and clothes that don't get dirty!!

Outline

1. Engineers.
   (It is not what we do, but how we think about the world that makes us different)

2. Chemical Engineers.
   (the connection with chemistry makes this the most broad of the engineering fields)

3. What courses do students take to become chemical engineers?

4. Careers for chemical engineers.

What do engineers do?

You may have heard it stated that "engineers solve problems..."

What engineers really do is:

Engineers understand how to use techniques of engineering analysis to design (i. e., synthesize) substances, devices and processes even though they have an imperfect understanding of important physical, chemical or biological issues. Furthermore engineers operate under constraints caused by a need to produce a product or service that is timely, competitive, reliable, and consistent with the philosophy and within the financial means of their company.

An important part of this message is that it is not what engineers do that makes them different, it is who they are -- meaning how they think about the world.

We use all that we know to produce the best answer to a problem!!

Underlined words

1. Engineering analysis

Engineers use "mathematical models" to describe reality in sufficient detail to produce quantitative results.

(It is not engineering until we produce some numbers!!)

2. Imperfect understanding

Most significant engineering problems cannot be analyzed and solved exactly.

Thus we need our models or our understanding of phenomena gained by experiment to capture the important features and (usually) ignore a lot of unessential detail.

6.1 The Ideal solution

The history of modern science has shown repeatedly that a quantitative description of nature can often be achieved most successfully by first idealizing natural phenomena, i.e. by setting up a simplified model, either physical or mathematical, which crudely describes the essential behavior while neglecting details. **(In fact, one of the outstanding characteristics of great contributors to modern science has been their ability to distinguish between what is essential from what is incidental)** ..."

From: Molecular Thermodynamics of Fluid Phase Equilibria
John M. Prausnitz 1969.

This statement describes how an engineer often must do her job. You cannot waste your time on details that don't matter !!!!

Curveball vs. knuckle ball

We tried to make the argument that the imperfectness of a baseball is important to the pitching of a knuckleball, which does not spin and not important in the pitching of a curveball which spins fast. The same effect can either be important or incidental. This is because important issues always as ratios between competing effects. Engineers need to make the decision about what is important!!

3. Constraints

Problems that engineers need to solve invariably have more than one solution

Vehicle for transporting 1-5 people on paved highways:

Aspire ------------ BMW 740

Engineers find the *optimal* solution limited by constraints e.g., $$

"To define it rudely but not inaptly, engineering is the art of doing that well with one dollar which any bungler can do with two dollars." -Arthur M. Wellington, The Economic Theory of the Location of Railways, Introduction (6th ed., 1900).

Chemical Engineers

The special role of chemical engineers is their ability to analyze, design and operate processes where

- chemical (i.e. reactions)
- physical (phase change)
- biological (reactions inside cells)

transformations of matter occur.

Most all of the products of the world are made of materials that are in a different form from the raw materials from which they were made.

Chemical engineers must be able to deal with matter from atomic up to process scales.

This requires a strong understanding of chemistry and the ability to apply physical laws over very broad range of length scales.

Soda pop example

We discussed that soda pop fizzes when shaken, and not if not shaken, because shaking makes lots of small bubbles which serve as "surface area" for the CO_2 to go from the liquid to gas phase. The change in the equilibrium state is the same with or without shaking.

The (approximate) phase equilibria equation is for this process is

$$x_i H_i = y_i P$$

where x_i is the liquid phase mole fraction, y_i is the gas phase mole fraction, H_i is the "Henry's Law" coefficient and P is total pressure. Inside the bottle, the CO_2 should be in equilibrium and shaking will have the minor effect of raising the temperature slightly.

Once the bottle is opened, the total pressure, P, drops slightly (~10%) and the mole fraction in the outside air (but not inside a bubble) also decreases. This change in equilibrium can lead to either a mild effect, if the surface area is limited, or a large effect (fizzing out of the bottle) if there is a large area available for interphase transport. The reason that the difference is so large is because phase change does not easily occur unless "interface" is already available. That is, a bubble will not spontaneously form in a liquid phase (this would be called *homogeneous nucleation*), unless the concentration driving force is much larger than would occur for a soda bottle. Note as an aside, the same effect occurs in boiling also where the vapor bubbles form at nucleation sites which are usually chips or scratches in the pan. Bubble nucleation at a solid site is called *heterogeneous nucleation*.

The process of a chemical constituent is being transferred from one phase to another is called *mass transfer*. Chemical engineering processes are typically designed to make mass transfer as fast as possible by providing sufficient *transfer area* for mass transfer to occur.

I have been mentioning that engineers need to use ratios of important effects to make comparisons.

Here are three ratios that define *happiness*

$$\frac{\tau_{consume}}{\tau_{desorption}} << 1$$

$$\frac{\tau_{consume}}{\tau_{warm\ up}} << 1$$

$$\frac{L_{thirst}}{L_{in\ glass}} < 1$$

If I asked how you how far it was to Chicago you would not answer, 5 Kg!

Your answer would involve length, ~ 100 miles or 5,702,400 inches!

I can use the idea that quantities must have the correct dimensions to do some other comparisons,

A cooking time scale for the interior of something is

$$t \sim \frac{C_p l^2 \rho}{k}$$

in this equation k is the thermal conductivity, ρ is the density, C_p is the heat capacity and l is the length scale of the object.

The surface time scale can be the chemical reaction time scale. The exterior cooking could be a chemical reaction time scale for dehydrolysis (removal of water from sugars and starches) If we have

$$\text{Rate} = K\,\text{C}$$

where C is the concentration for a first order reaction and K is the first order rate constant, we can construct a *dimensionless* group (i.e. ratio of important effects) that will tell us how to cook something.
The (interior to exterior) cooking ratio is:

$$\frac{K C_p l^2 \rho}{k}$$

How can I use this to decide how to cook different items?

As the object grows larger, it will take longer for the inside to get cooked. To avoid burning the outside, we need to alter the value of *K* to keep the ratio roughly the same. This can be done by reducing the temperature because we expect that *K* will follow Arhenius kinetics as

$$K = A \text{ Exp}[-E_a/RT]$$

Where E_a is the activation energy, *A* is a constant that depends on the reaction, *R* is the gas constant in appropriate units and *T* is absolute temperature.

From this expression we find that we can reduce the temperature and the reaction (outside cooking) rate will go down!!

Thus, we would expect this equation in every cookbook!!

(We may not be able to make a muffin much bigger that the current ones that are softball size!)

What other problems have chemical engineers solved?

The McGraw-Hill "Encyclopedia of Science and Technology" continues with its description saying: "The American Institute of Chemical Engineers (AIChE) has identified the 10 most outstanding achievements of chemical engineering as being:

1. production of fissionable isotopes,
2. production of synthetic ammonia,
3. production of petrochemicals,
4. production of chemical fertilizers,
5. commercial-scale production of antibiotics,
6. establishment of the plastics industry,
7. establishment of the synthetic fibers industry
8. establishment of the synthetic rubber industry,
9. development of high-octane gasoline,
10. electrolytic production of aluminum.

"Chemical engineering is also involved in a major way in nuclear energy, medicine, materials science, food production, space, undersea exploration, and, above all, in energy production and the development of new sources of energy.

What do chemical engineers study to become chemical engineers?

Curriculum

1. Basic sciences

   - Mathematics (5 courses)
   - Physics (3 courses)
   - Chemistry (7 courses + labs)

2. Engineering sciences

   - Thermodynamics

     Heat -- work conversion
     phase equilibria

   - Transport Phenomena

     Heat transfer, fluid mechanics, mass transfer

   - Numerical Analysis

3. Engineering Design

- Chemical Reaction Engineering
- Separation Processes
- Process Control
- Process Design

DEPARTMENT OF CHEMICAL ENGINEERING
UNDERGRADUATE CURRICULUM
CLASS OF 2000 - FIRST CLASS TO FOLLOW THIS CURRICULUM

FRESHMAN YEAR

First Semester	Cr.	Second Semester	Cr.
MATH 125, Calculus I	4	MATH 126, Calculus II	4
CHEM 115, Gen Chem I	3	CHEM 116, Gen Chem II	3
PHYS 127, Gen Phys I	3.5	CHEM 116L, Gen Chem Lab	1
Arts and Letters I/EG 120	3	PHYS 128, Gen Phys II	3.5
ENGL 110/Univ. Sem. 180 (A&L II)	3	Arts and Letters I/EG 120	3
Physical Education	0	Univ. Sem180/ENG110 (A&L, III)	3
	16.5	Physical Education	0
			17.5

SOPHOMORE YEAR

First Semester	Cr.	Second Semester	Cr.
MATH 225, Calculus III	3.5	MATH 226, Calculus IV	3.5
CHEM 223,Org Chem I	3	CHEM 224, Org Chem II	3
CHEM 223L, Organic Chem Lab I	1	Arts and Letters V	3
PHYS 229, Gen Phys III	3.5	CHEG 258, Computer Mtds	3
CHEG 255, Intro Chem Eng	3	CHEG 327, Thermo I	3
Arts and Letters IV	3		
	17		15.5

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JUNIOR YEAR

First Semester	Cr.	Second Semester	Cr.
MATH 325, Diff Eqns	3	CHEM 322A, Physical Chem	3
CHEM 333, Analytical Chem	2	CHEG 356, Transport Phen II	3
CHEM 333L, Analytical Chem Lab	2	CHEG 225, Materials	3
Arts and Letters VI	3	CHEG 358, Chem Eng Lab I	3
CHEG 343, Thermo II	3	Elective	3
CHEG 355, Transport Phen I	3	Arts and Letters VII	3
	16		18

SENIOR YEAR

First Semester	Cr.	Second Semester	Cr.
CHEG 438, Chem Proc Control	3	CHEG 448, Proc Design	3
CHEG 459, Chem Eng Lab II	3	ENG/#Chemistry elective	3
CHEG 443, Separation Proc	3	Chemical Engineering Elective	3
CHEG 445, Chem Rxn Eng	3	*Technical Elective	3
ENG/#Chemistry elective	3	Elective	3
Arts and Letters VIII	3		15
	18		

total:133.5 credits

What chemical engineers do

Opportunities in traditional fields:

1. Petroleum and Chemical Industries
2. Graduate/Professional school
3. Food processing companies
4. Consumer product companies

Opportunities in nontraditional fields

1. Non-traditional fields that have an inherent chemical engineering component

i. Cleanup of contaminated ground water

   a. Will reaction proceed at a fast enough rate and cause desired decomposition ??

   b. Can the necessary mass transfer (diffusion and convection) occur sufficiently rapidly ??

ii. Production of high density integrated circuit chips

   How much unwanted dissolution, that will undercut small paths, will occur during etching ??

iii. Production of "genetically engineered" pharmaceuticals

How can we get the product which is present in dilute concentrations in a fermentation broth, into a concentration and chemical form that is useful for injection or ingestion ??

iv. Biomedical engineering

Drug dosage and delivery

2. Business analysis

a. Predicting oil/commodity prices,
b How much should Walmart charge for VCR's ??
c. Investment Banking
d. Real Estate Pricing

3. Political advising

A broadly based science education is ideal for understanding important environmental issues that the world faces !!

How can you tell if you could be good at and like chemical engineering?

1. Enjoy and be good at chemistry

2. Enjoy and be good at mathematics

3. Your curiosity focuses on *how nature works*!

Summary

Chemical engineers are the people who design, build and operate the processes that produce the materials of modern society.

As with all engineers we do this by using the tools of engineering analysis to design processes even though there are limits to our understanding of possibly key issues, while providing a *solution* that meets the required constraints

Its incorporation of chemistry, and for may people biology, gives chemical engineering the broadest academic base of all fields of engineering and allows for contributions in many different fields.

Chemical engineers typically are people who have a strong interest and ability in chemistry and mathematics and curiosity into the chemical workings of nature.

One last favorite quote:

Sufficiently complex technology is indistinguishable from magic
(Engineers from Shell Development Co.)

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