Introduction to Engineering Professions
Chemical Engineering

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The universe
The World

= Chemical + “Spirit”

- Life is based on the existence of a very large number of chemical and biochemical reactions that take place continuously.

Photosynthesis:

\[ \text{CO}_2 + \text{H}_2\text{O} + (\text{sunlight}) \rightarrow (\text{CH}_2\text{O})_n + \text{O}_2 \]

Respiration:

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + 673 \text{ Kcal} \]
Engineering:

- Is the Profession in which a knowledge of the mathematical and natural sciences gained by study, experience and practice is applied with judgement to develop ways to economically utilize the materials and forces of nature for the progressive well being of mankind.
Chemical Engineering:
- Combines the principles of mathematics, physics, chemistry and biology with engineering practices in order to improve the human environment.

Continued . . .
- Chemical engineering is based on applications of chemistry, physics, mathematics, economics, and increasingly, biology and biochemistry.
- Because of this broad-based foundation .. the chemical engineer is considered the universal engineer. ...
A Chemical Engineer

- Mimics natural phenomena to produce materials that are useful for the well-being of humanity

1. Develops or designs a new process or
2. Re-designs, improves, or troubleshoots a process, in order to make or do something as economically, safely, and efficiently as possible.

Important terms

- A **process** is an operation (or group of any operations) which allow something to be which accomplished.

- A **chemical engineering process** is a process that takes one material or bit of energy (or a combination) and makes from it another material or bit of energy or combination.)
Life cycle of chemicals/Materials
Important responsibility in utilizing scarce natural resources:

- Maintaining a clean environment (air, water, earth)
- Providing for enough, clean energy (fossil fuels, wind, sun, hydraulic, geothermal, biomass, atomic, fuel cells...)
- Providing for enough, healthy food (animals, vegetables)
- Avoiding depletion of essential elements (C, N, O, P, K...) and minerals.

The dawn of Chemical Engineering

- English industrialists spent a lot of time, money, and effort in attempts to improve their processes for making bulk chemicals because a slight savings in production led to large profits because of the vast quantities of sulfuric acid consumed by industry.
- The term "chemical engineer" had been floating around technical circles throughout the 1880's,
  - But there was no formal education for such a person.
- The "chemical engineer" of these years was either a mechanical engineer who had gained some knowledge of chemical process equipment,
  - A chemical plant foreman with a lifetime of experience but little education, or an applied chemist with knowledge of large scale industrial chemical reactions.
Continued . . .

• In 1887 George Davis, an Alkali Inspector from the "Midland" region of England molded his knowledge into a series of 12 lectures on chemical engineering, which he presented at the Manchester Technical School.

• This chemical engineering course was organized around individual chemical operations, later to be called “unit operations”.

• Davis explored these operations empirically and presented operating practices employed by the British chemical industry.

A new profession “Chemical Engineering”

• For all intents and purposes the chemical engineering profession began in 1888 when Professor Lewis Norton of the Massachusetts Institute of Technology (MIT) initiated the first four year bachelor program in chemical engineering entitled "Course X" (ten).

• Soon other colleges, such as the University of Pennsylvania and Tulane University followed MIT’s lead in 1892 and 1894 respectively.
The "unit operations" concept had been latent in the chemical engineering profession ever since George Davis had organized his original 12 lectures around the topic.

But, it was Arthur Little who first recognized the potential of using "Unit Operations" to separate chemical engineering from other professions.

Before that:
- mechanical engineers focused on machinery,
- industrial chemists concerned themselves with products,
- applied chemists studied individual reactions

Continued . . .
- In advent of chemical engineers,
  - underlying processes common to all chemical products, reactions, and machinery identified and named as unit operations.
  - Unit operations could now make claim to industrial territory, and showing the uniqueness and worth of chemical engineering to the chemical manufacture across the globe.
  - Unit operations became a convenient manner of organizing chemical engineering knowledge.
- Additionally, the knowledge gained concerning a “unit operation” governing one set of materials can easily be applied to others.
  - *Driving a car is driving a car no matter what the make*
  - So, whether one is distilling alcohol for hard liquor or petroleum for gasoline, the underlying principles are the same!
Common Unit operations

- In transforming matter from inexpensive raw materials to highly desired products, chemical engineers became very familiar with the physical and chemical operations necessary in this metamorphosis.

- Examples of this include:
  - filtration
  - grinding
  - sedimentation
  - combustion
  - heat exchange
  - drying
  - Distillation/absorption
  - Extraction and leaching
  - Crystallization/adsorption
  - Catalysis
  - Coating
  - etc

The first paradigm: early success

- Became
  - Core of chemical engineering curriculum, unit operations, stoichiometry, thermodynamics
  - Process and plant design, process control dynamics
  - Principle to organize useful knowledge
  - Inspiration for research to fill in the gaps in knowledge

- Effective in problem solving
  - Graduates have a toolbox to solve processing problems in oil distillation, petrochemical, new polymer products
New paradigm: Product Engineering?

- Product engineering is innovation and design of useful products that people want
  1. Define a product, study the customers & needs
  2. Understand property-structure
  3. Design and innovate the product

Achievements of Chemical Engineering - The top 10

1. Splitting the atom, isolating isotopes (medicine, biology, archaeology)
2. The plastic age (bakelite, polyethylene, polystyrene...)
3. Human reactor, analogy with complex chemical processes
4. Wonder drugs for the masses (low price, high volume)
5. Synthetic fibers (textiles industry)
6. Liquified air (nitrogen, oxygen, argon)
7. Environmental protection (catalytic converters, waste treatment)
8. Food (fertilizers, biotechnology, food processing)
9. Petrochemicals (gasoline, plastics, rubber, synthetic fibers...)
10. Synthetic rubber (tires, gaskets, hoses, conveyor belts, shoes)
http://www.pafko.com/history/h_intro.html
Broad Spectrum of Chemical Engineering

Where do the chemical engineers work?

- 45% do “traditional” ChE: chemical, petroleum, plastic, paper, consumer goods
- 35% do “new” ChE: environment, consulting, microelectronics, biotechnology, nano technology, materials
- 10% go to ChE graduate school
- 10% go to other graduate school (law, business)
Percentage of Chemical Engineers per sector globally

- Process: 25%
- Other: 10%
- Oil: 17%
- Contract: 12%
- Pharmaceutical: 12%
- Food: 5%
- Power: 6%
- Water: 4%
- Education: 3%
- Consultants: 7%

Chemical products account for nearly 1/3 of material cost for a light vehicle

- Plastic Coatings: 25 €
- Infush Coatings: 20 €
- Celast: 5-30 €
- Pigments>Coatings: 3-40 €
- Pigments>Plastics: 15 €
- Fibers/Plies: 50 €
- Carbpol: Black: 10 €
- Lubricants: 8 €
- Carbontex: Black: 70 €
- Carbon Black: 10 €
- Leather Chemicals: 5 €
- Metal Treatment: 4 t
- Body Protection: 1 t
- Sealants: 20 €
- Rubber: 20 €

CEFIC 2004
Duties of Chemical engineers

• Production Supervision
• Scale-up of Laboratory Processes to Industrial Size
• Economic Analyses
• Pollution Control
• Health and Safety
• Automatic Control of Processes
• Computer Simulation of Plants for Optimum Operation
• Design of In-Plant Improvements for more Economical Operation
• Management
• Technical Marketing

A typical Chemical Engineering Curriculum

Aims to educate its graduates to:

- Obtain the necessary knowledge in mathematics, basic sciences, computing, and engineering that will enable them to solve problems in the analysis, design, optimization, and control of components, systems, and processes encountered in the practice of chemical engineering;

- Exercise their competence, creativity, and imagination in design and research and to synthesize their broad-based knowledge through applications to real-world engineering problems;
A typical Chemical Engineering Curriculum aims to educate its graduates to…

- Cultivate effective communication skills, both oral and written, especially in technical subjects;
- Develop the necessary attributes for constructive participation in and leadership of interdisciplinary teams; Understand and appreciate the professional and ethical responsibilities entailed in engineering practice and research; and
- Acquire a sufficiently broad, diverse, and rigorous education to excel in graduate work in chemical engineering as well as in a variety of other professional degrees.

Code of Ethics is based on:

- upholding and advancing the integrity, honor and dignity of the engineering profession by:
  - being honest and impartial and serving with fidelity employers, clients, and the public;
  - striving to increase the competence and prestige of the engineering profession;
  - using knowledge and skill for the enhancement of human welfare.
Main Components

1. Engineering core courses (math, phys, chem, hum, bio, economics)
2. Chemical engineering fundamentals
3. Chemical engineering science and analysis
4. Chemical engineering synthesis and design
5. Specialization options (biomolecular, catalyst technology and reaction, process, polymer and biopolymer science and eng.)
Chemical Engineering Fundamentals

Physicochemical Systems

Chemical Engineering Calculations
✓ Calculation methods used in the chemical industry based on the principles of material and energy balances. Application of equations of state, heat capacity, enthalpy, chemical reactions, two-phase systems, enthalpy-concentration diagrams, heats of solution; crystallization, vaporization, melting, etc. Concepts of simultaneous material and energy balance calculations of chemical engineering unit operations, unit processes and related applications.

Chemical Engineering Fundamentals---

Probability and Statistics in Chem.Eng.Applications
➢ Fundamental concepts in probability; probability distributions, mathematical expectations; statistical methods including sampling distributions, point and interval estimation, hypothesis testing, linear regression, analysis of variance, as applied in chemical engineering problems. Factoral design of experiments.

Mathematical Modeling
➢ Utilization of mass, energy and momentum balances and rate processes to describe the behavior of chemical engineering systems. Distributed, lumped parameter, steady and transient systems. Block diagrams, development of mathematical models and solution techniques.
Chemical Engineering Science and Analysis

Fluid Mechanics

Chemical Engineering Laboratories

Chemical Engineering Thermodynamics

Chemical Engineering Science and Analysis...

Heat Transfer

Mass Transfer Operations

Chemical Reaction Kinetics and Reactor Design
Chemical Engineering Synthesis and Design

Design of Chemical Processing Units
- Basic engineering concepts and accepted procedures as applied to the design of main process units and auxiliary equipment. Operating principles of various processing equipment to critically evaluate, specify and design the most appropriate unit(s) among available alternatives for specific tasks.

Chemical Plant Design and Economics
- Study of fundamental concepts in chemical plant design, organization of chemicals manufacturing plants and the economic considerations associated with the investment, feasibility and operation of such plants. Independent and group projects covering the above topics related to the existing Turkish conditions.

Chemical Engineering Synthesis and Design

Process Dynamics and Control

Project
- Inter-disciplinary project undertaken by a student, either together with a small team of other students or individually, under the supervision of a faculty member. The object is to enable the student to apply as much of his/her education as possible to the solution of a specific realistic problem. Students are required to meet on a regular basis for consultation with, and report orally to their project supervisor. A written midterm progress report and a final report are required of each student together with at least one oral report to his/her classmates.
The strong scientific, mathematical, and technical background found in chemical engineering education is allowing the profession to enter new fields.

The largest growth in employment is occurring in up-and-coming fields which show tremendous potential.

- Biotechnology, polymers, electronics, catalyst design, food processing, pharmaceuticals, environmental clean-up, biomedical implants and nano technologies.
- All offer possibilities for chemical engineers.

The chemical engineering education needs to respond to the industrial realities of the profession.

Current Trends:

Specialization Options

I. Engineering
1. Process Engineering
2. Biochemical/Biomolecular Engineering
   - Enzyme technology
   - Biomedical engineering
3. Catalyst Technology and Reaction Eng.
4. Polymer and Biopolymer Science and Eng.

II. Technology
1. Food Technology
2. Pharmaceutical Technology
3. Leather Technology
4. Silicate technology
5. Chemical Technology
   - Sanitary chemicals, cosmetics, paints, dyes, etc.
Thank you
The emergence of Chemical Engineering as Engineering profession
• Industrial Revolution & Industrialization
• Competition & least cost of production
• Optimum Large scale operation
• Continuous production

Chemists were not able to cope the engineering advancement made in the above systems for which they are unprepared and unqualified

On the other hand the detailed physical and chemical knowledge required by the above advancement are not known by mechanical engineers and other Engineers except chemical engineers

It is because of this fact that chemical engineering profession capable of designing and operating the increasingly complex engineering and chemical operations of industries were required and rapidly emerged particularly in USA and Canada.

Chemical Engineering profession = Engineering

Chemical Engineering = Industrial Chemistry + Economics
The emergence of a new profession “Chemical Engineering”

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Chem. Eng. Departments in the USA
First Canadian Chemical Engineering education

- 1902 Queen’s (Department of Chemical Engineering)
- 1914 McGill
- 1926 Alberta
- 1958 Ecole Polytechnique (Department of chemical Engineering)