CHG 1125
Chemical Engineering Fundamentals

Chapter 1

The Chemical Engineer

Dr. Marc A. Dubé, P.Eng., FCIC, FEIC

uOttawa
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Canada's university

Outline

- Historical perspective
- Definition of chemical engineering
- The chemical engineering program
- A chemical engineering graduate's skills profile
- An overview of possible tasks
- Ethics & Professionalism
- Workplace Health & Safety

A historical perspective

- The chemical industry, like others, evolved rapidly over the course of the second half of the 19th century. However, different industries developed independently of each other.
- This rapid expansion increased the demand for scientists possessing basic knowledge about chemical processes.
- At the start, industrial chemists provided this knowledge. They were specialists in a particular production area (sulfuric acid, potash, phenol, etc.).

A historical perspective

- This remarkable evolution in the chemical industries brought forth the following question: *«Would it be possible to formulate, with the use of mathematics and physical principles, a set of general laws for production in chemical industries, analogous to those used in the pure sciences?»* Efforts to answer this question gave birth to a new discipline: **chemical engineering**.
- Slowly, this new discipline was born. In France, the term «**process engineer**» was employed to describe chemical engineering.

A historical perspective

- The first attempt to systematically organize the basic principles of chemical processes and to define the scope of chemical engineering was made in England by George E. Davis in 1880.
- The first course in chemical engineering in the United States was organized by Lewis Norton at MIT in 1888 and the AIChE (American Institute of Chemical Engineers) was founded in 1908.
- Despite being started in England, chemical engineering saw its most rapid growth in the United States.

The Canadian context

- 1720: A course in chemistry is offered at the Séminaire de Québec (the 1st course in Canada).
- 1850-60: Several universities begin offering courses in chemistry (Toronto, Laval, McGill).
- 1874: A course in applied chemistry is offered at McGill.
- 1904: The first course in chemical engineering is offered at the University of Toronto.
- 1914: A chemical engineering course is offered at McGill.
- 1916: The first chemical engineering department in Canada is created at the University of Toronto.

The Canadian context

- 1922: Chemical engineering department at Queen's University.
- 1934: … at the University of Saskatchewan
- 1940: … at l'Université Laval
- 1947: … at McGill University
- 1949: … at the Nova Scotia Technical College
- 1949: … at l'École polytechnique de Montréal
- 1955: There were 7 chemical engineering departments.
- 1961: There were 16 departments.
- 1966: The CSChE (or SCGCh) is founded.

Chemical Engineering at the University of Ottawa

- The University of Ottawa is founded in 1866.
- The School of Applied Sciences is created in 1946 and is reorganized in 1953 to form the Faculty of Pure and Applied Sciences.
- The Department of Chemical Engineering is started in 1954 and Professor Madonna is the first Chair.
- In 1986, the Faculty of Science and Engineering is split to form two distinct faculties: the Faculty of Science and the Faculty of Engineering.
- **In 2008, the Department changes its name to "Department of Chemical and Biological Engineering" to reflect the emerging role of the biological sciences in the discipline.**
- **In 2020…?**

Chemical Engineering: a definition

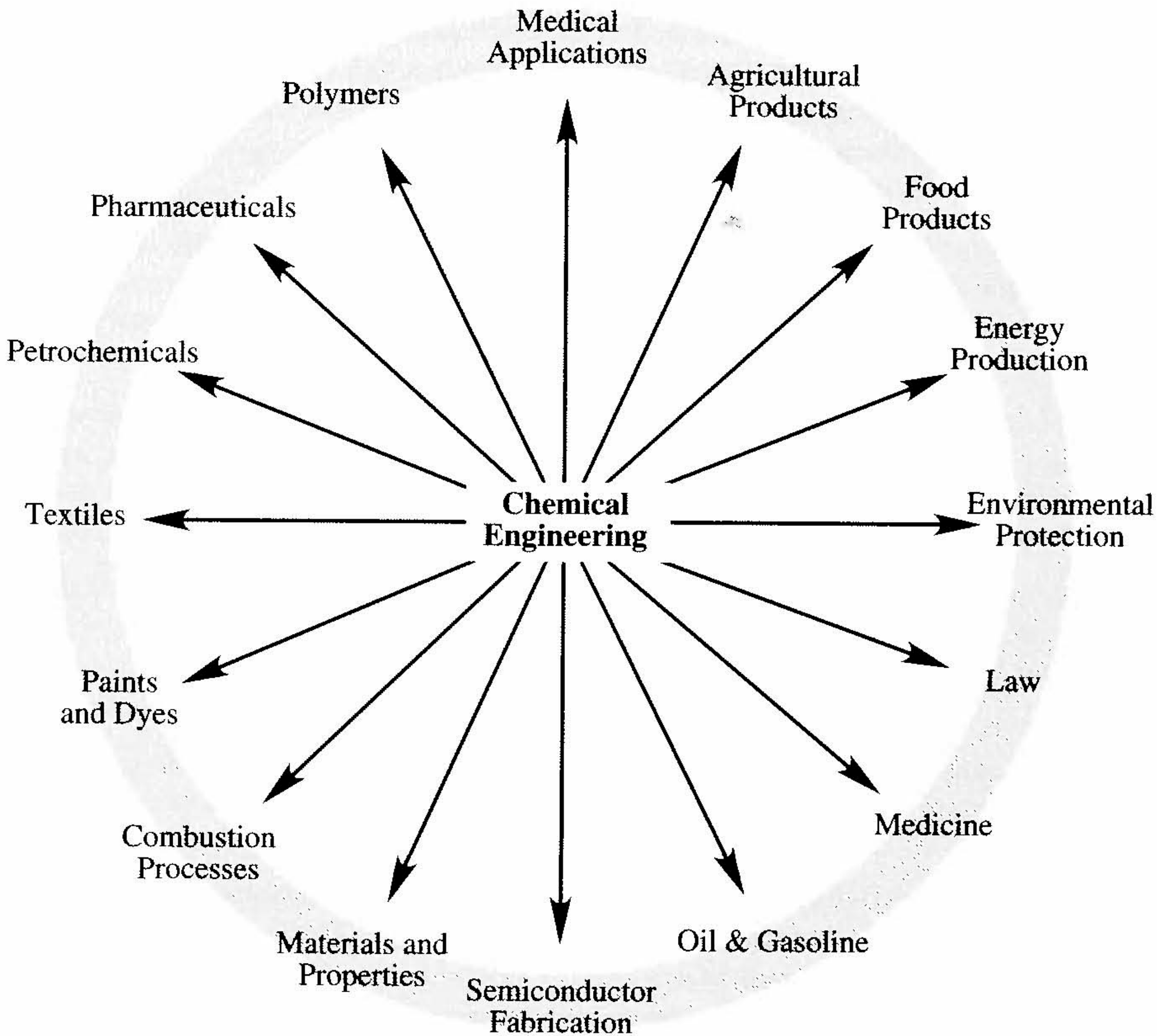
- **Chemical, or process engineering**, at the crossroads of many disciplines, brings together knowledge and know-how permitting the industrial scale **transformation** of raw natural or synthetic materials **into elaborate products** by way of a series of operations.
- The mission of chemical engineering is to **design** processes, **develop** industrial scale processes from laboratory experiments, and **maintain optimal process conditions**.

Chemical Engineering: a definition

- Chemical engineering involves the simultaneous application of principles from physics, chemistry and economics to areas directly related to processes and process equipment, wherein **materials undergo changes in state, energy and composition**.
- Because the chemical engineer often works alongside other engineers, scientists and trades people, he/she should maintain **good interpersonal skills**, demonstrate **leadership** and be able to **communicate** effectively.

Chemical Engineering: a definition

- In other words:
  - We heat things up or cool them down.
  - We mix things and separate things.
  - We make things react and stop things from reacting.


Medical Applications
Agricultural Products
Polymers
Food Products
Pharmaceuticals
Energy Production
Petrochemicals
Chemical Engineering
Textiles
Environmental Protection
Paints and Dyes
Law
Combustion Processes
Medicine
Materials and Properties
Oil & Gasoline
Semiconductor Fabrication

Chemical Engineering Achievements

- Semiconductor fabrication
- Medicine (antibiotics, diagnostic devices, artificial organs)
- Environmental protection (catalytic converters, jet engines, scrubbers)
- Crude oil processing (cracking to fuels, plastics, pharmaceuticals)
- Plastics
- Synthetic fibers
- Synthetic rubber
- Gases from air (nitrogen, oxygen)
- Food (fertilizers, pesticides, food processing)
- Separation and use of isotopes (nuclear energy, medicine)
- **…and many others**

The Chemical Engineering program

- The **Bachelor's program in Chemical Engineering** has the goal of developing students for **immediate placement** in the workforce or to **undertake graduate studies**. Graduates of the program can work in chemical and chemical-related industries, in the public sector, in R&D and in engineering consulting.
- The program is **accredited** by the Canadian Engineering Accreditation Board (CEAB) and provides the education component for professional engineering designation (e.g., Professional Engineers Ontario or Ordre des ingénieurs in Québec). More on this later…

The Chemical Engineering program

- Program objectives:
  - To gain a basic understanding in the **fundamental sciences** in order to integrate that knowledge for the understanding of chemical engineering phenomena;
  - To **understand phenomena** linked to the fundamental **operations** characteristic of chemical engineering equipment and reactor design towards their utilization in industrial settings;
  - To master the **design** of chemical and chemical-related processes;
  - To acquire **good communication skills**;

The Chemical Engineering program

- Program objectives (cont.):
  - To **integrate physical and biological aspects** in a scientific way, into the **industrial activities** associated with chemical engineering, while respecting the **environment**;
  - To reinforce the **personal qualities** necessary for a fruitful career in chemical engineering;
  - To acquire the qualities of a **good manager**.

Fundamental topics in Chemical Engineering

- **Material** and Energy **Balances**
- Fluid Mechanics
- Heat Transfer
- Mass Transfer
- Reaction Engineering
- Process Control
- Materials
- Economics

The Chemical Engineering Program

Chemical Engineering Program 2019-2020

1A	1B	2A	2B	3A	3B	4A	4B
CHG 1125 Chemical Engineering Fundamentals	CHG 1371 Numerical Methods and Engineering Computation in Chemical Engineering	CHG 2312 Fluid Flow	CHG 2314 Heat Transfer Operations	CHG 3127 Chemical Reaction Engineering	CHG 3111 Unit Operations	CHG 4116 Chemical Engineering Laboratory	CHG 4250 Plant Design Project
CHM 1311 Principle of Chemistry	CHM 1321 Organic Chemistry I	CHG 2317 Introduction to Chemical Process Analysis and Design	CHG 2324 Fundamentals and Applications of Chemical Engineering Thermodynamics	CHG 3305 Advanced Materials in Chemical Engineering	CHG 3112 Process Synthesis, Design and Economics	CHG 4343 Computer-Aided Design in Chemical Engineering	CHG 4307 Process Risk Management and Sustainability
ENG 1112 Technical Report Writing	MAT 1322 Calculus II	CHM 2120 Organic Chemistry II	CHM 2330 Physical Chemistry: Introduction to Molecular Properties of Matter	CHG 3316 Transport Phenomena	CHG 3122 Chemical Engineering Practice	CHG 4381 Biochemical Engineering	GNG 4170 Engineering Law
GNG 1105 Engineering Mechanics	MAT 1341 Introduction to Linear Algebra	MAT 2322 Calculus III for Engineers	GNG 1103 Engineering Design	CHG 3335 Process Control	CHG 3326 Principles of Phase Equilibria and Chemical Reaction Equilibria	CHG 4900 Thesis and Seminars or Two Technical Electives	Technical Elective
MAT 1320 Calculus I	PHY 1122 Fundamentals of Physics II	MAT 2384 Ordinary Differential Equations and Numerical Methods	ECO 1192 Engineering Economics or GNG 2101 Introduction to Product Development and Management	CHG 3337 Data Collection and Interpretation	Complementary Elective		
		PHI 2394 Scientific Thought and Social Values (F) or	HIS 2129 Technology, Society and Environment since 1800 (W)	Technical Elective			
		Complementary Elective					
15 cr	15 cr	18 cr	18 cr	18 cr	15 cr	15 cr	18 cr

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A graduate's skills profile

- The chemical engineering graduate will be able to accomplish the following various tasks over the course of his/her career:

1. Control of a chemical process:
    - The group of activities suitable to ensure profitability, efficiency, process safety and product quality while respecting the environment.

A graduate's skills profile

2. Management
   - The group of activities with a goal to plan, organize, direct and control human, financial, material and technical resources within the framework of the construction, start-up or operation of a chemical or chemical-related factory.
3. Technical support
   - The group of activities aimed at ensuring the correct use of raw materials and services, as well as providing effective day-to-day operation.

A graduate's skills profile

4. Process design and improvement
   - The group of activities including the design and profitability of a new process and/or the optimization of an existing one, in whole or in part.
5. Quality control of the environment
   - The group of activities including the prevention, diagnosis, measurement and correction of environmental problems of various origins and in various locations.

A graduate's skills profile

6. Communication
   - The group of attitudes and actions aimed at ensuring the good transmission of information and knowledge in professional work.
7. Research and development
   - The group of activities seeking to enhance knowledge and to develop new processes, equipment and products.

A graduate's skills profile

8. Sales and marketing
   - The group of activities used for evaluating the needs of a customer, promoting equipment, products, processes and services, while supporting their implications.

An outline of possible tasks

- A chemist in the laboratory of your company discovers that **mixing two products** at high temperature results in a product of great value. The company wishes to manufacture this product. At this moment, this becomes an engineering problem and actually, a multitude of engineering problems, which can be summarized as a series of design choices.

An outline of possible tasks

1. Reactor:
   - Which type of reactor should be used?
   - A long pipe? A large tank? Several small tanks in series or parallel? Of which dimension?
   - Made of which material? Material able to withstand corrosion? Will the selected material be subject to pressure?
   - Is the reaction endothermic or exothermic? If endothermic, how will we provide the heat necessary to the reaction? Do we use internal or external electric heating? A hot fluid passing through a coil located in the reactor?

An outline of possible tasks

1. Reactor (cont.):
   - Do we need to heat the reagents before feeding them to the reactor? Is there a danger of a loss of control of the reaction, even an explosion? If so, which steps should be taken?
2. Reagents:
   - Where should one get the reagents? Should one buy or manufacture them? If so, which quantity of each one and in which proportion should they be supplied to the reactor?

An outline of possible tasks

3. Product recovery:
   - Can the residual product and reagents be sold directly? Does one have to purify the product by a method of separation? Which method of separation does one have to choose? Distillation? Extraction with solvent? Adsorption? Crystallization?
   - What dimensions will the equipment need to be? Of what material of construction?
   - Heating and/or cooling?
   - Does it require an automatic control device?

An outline of possible tasks

4. Reagent and product transport:
   - How will the reagents be fed to the reactor and how will the product be transported to the reactor's exit?
   - By gravity? With the aid of a pump, compressor, fan, or conveyor belt? Which type? Which dimensions? How much energy will be necessary? Which material of construction?
5. Preliminary experiments:
   - Is the reaction sufficiently well-known? Does one have to make additional tests to evaluate its kinetics? Does one have to build a pilot scale reactor?
   - Do we need to design a set of experiments?

An outline of possible tasks

6. Safety measures:
   - What are the safety considerations? Could something function badly?
   - What can one do in the event of problems?
7. Pollution prevention:
   - Is there any waste from the process? In which quantities? What is their impact on the environment?
   - Can one make changes to the process?
   - How can the waste be treated? Does a waste treatment unit need to be built? Can we incinerate the waste?

An outline of possible tasks

8. Control and instrumentation:
   - What level of automatic control will be necessary? What instrumentation will be necessary?
9. Economic survey:
   - To make a complete study of the costs. Costs of purchasing the reagents? Selling price of the product? Construction costs? Operating and labour costs?
   - Should the factory be built?
10. Process operation:
    - Which procedure should be followed for start-up? If something does not function as planned, then what?
    - Which improvements could one make to the process?

What can you expect when you graduate?

- Source: https://www.payscale.com/college-salary-report/majors-that-pay-you-back/bachelors (US dollars)

Major	Early Career Pay	Mid-Career Pay
Petroleum Engineering	**$82,700**	**$183,600**
Operations Research & Industrial Engineering	$79,600	$166,300
Actuarial Mathematics	$54,700	$158,100
Chemical & Biomolecular Engineering	**$71,900**	**$138,100**
Public Accounting	$60,700	$135,000
Building Science	$50,700	$135,000
Aeronautics & Astronautics	$71,400	$133,300
Systems Engineering	$70,800	$131,200
Business Analysis	$53,400	$129,800
Economics and Mathematics	$63,200	$126,900
Chemical Engineering	**$71,800**	**$126,900**
Marine Engineering	$72,600	$126,500
Actuarial Science	$62,700	$123,500
Aeronautical Engineering	$67,900	$122,500
Electrical Power Engineering	$71,300	$122,300
Nuclear Engineering	$70,700	$121,700
Ocean Engineering (OE)	$68,900	$121,200
Electrical & Computer Engineering (ECE)	$71,100	$120,400
Computer Science (CS) & Engineering	$74,000	$120,100
Computer Engineering (CE)	$72,600	$120,000
Engineering Physics	$65,400	$119,100
Construction Engineering Management	$64,000	$118,200
Electrical Engineering (EE)	$69,900	$118,100
Engineering Science	$63,900	$118,000
Managerial Economics	$60,800	$117,800

CHG's of the future…

- Dealing with information proliferation:
  - Easy to acquire/huge amounts of data
  - Important to develop a critical mind
  - Artificial intelligence + CHG
- Technological development:
  - Key: multi-disciplinarity (CHG's are in a good position to deal with this)
- Market globalization:
  - Appreciate other cultures
  - Knowledge of second (more?) languages

CHG’s of the future…

- Climate change and other environmental issues - “The Natural Step” process has 4 guiding principles:
  - Substances extracted from the earth’s crust (e.g., oil, fossil fuels) **must not systematically accumulate in the ecosphere** (i.e., rate of mining must not occur at a pace faster than reintegration of a species into the earth’s crust).
  - Substances produced by society **must not systematically increase in the ecosphere** (i.e., synthetic substances must not be produced at a rate faster than they can be broken down and integrated into natural cycles).

CHG's of the future…

- Climate change and other environmental issues - "The Natural Step" process has 4 guiding principles:
  - **Physical conditions** for productivity and assimilation within the ecosystem **cannot be systematically diminished** (e.g., forests, wetlands, agricultural land, animals cannot be systematically destroyed).
  - Since resources are limited, basic human needs must be met with the **most resource-efficient methods** available. Industrialized nations cannot use the resources to create luxuries while the basic needs of people in underdeveloped nations are not being met.

CHG's of the future…

- Our social responsibility:
  - Threats to public health
  - Depletion of non-renewable natural resources
- Rapid rate of change:
  - Because technology changes so quickly, people need to be trained in a way that facilitates **lifelong learning** and other skills needed to **manage change** rather than simply adapt to it.
  - CHG's must learn the **fundamental building blocks** that can be applied to a broad range of technologies.

The World's Challenges

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning

See also: www.chemicalengineering.org

CHG 1125
Chemical Engineering Fundamentals

Professional Engineering Ethics

What is a profession?

- All professions are occupations, but not all occupations are professions.
- One can take a broad or narrow view of what is a “profession”.
- A “self-regulated occupational group capable of legally prohibiting others (including incompetent or unethical members) from practicing” is one definition.

What is a profession?

- Group identified by extensive training and possessing a special uncommon knowledge, mastery of a subject.
- Knowledge used in the service of society.
- Professional association with standards and codes.
- Often self-regulating, via certifications and licensing.
- Involves individual judgment, (some) autonomy in decisions.
- Penalties for substandard performance (accountable to society).

What is a professional engineer?

- Has a bachelor's degree in engineering from an accredited school (CEAB).
- Passed exams in Engineering Law and Professional ethics.
- Performs engineering work.
- Is a registered P.Eng. in a provincial professional engineering association; pays dues.
- Acts in a morally responsible way while practicing engineering.

What is ethics?

- Ethics refers to **standards of conduct** that indicate how one should behave based on principles (determined by society) of **right and wrong**.
- For engineers, ethics is often about how we meet the challenge of doing the right thing.
- Ethics are not directly enforced by law. However, **the code** can be directly **enforced by the law**. It is a systematically arranged and comprehensive **collection of laws**. It is a systematic collection of regulations and rules of procedure or conduct.

Code of Ethics

- The **code of ethics** is used as a **guide** to reach a decision or course of action when an engineer comes across an ethical issue and there are no existing laws or codes that directly address it.

Engineering Code of Ethics

- In fulfillment of their professional duties, engineers shall:
  1. Hold public safety, health and welfare paramount.
  2. Perform services only in **areas of their competence**.
  3. Issue public statements only in an objective and truthful manner.
  4. Act for each employer or client as faithful agents or trustees.
  5. Avoid deceptive acts.
  6. Conduct themselves honourably, responsibly, ethically, and lawfully so as to enhance the honour, reputation, and usefulness of the profession.

See Appendix C

Issues addressed by Engineering Professional Codes

- Responsibility (acknowledging mistakes)
- Conflicts of interest (bribes, kickbacks)
- Environmental concerns (pollution)
- Product liability (safety)
- Quality control (reliability)
- Whistle-blowing

- Codes of Ethics – See the following documents on the course Web site:
  - **Professional Engineering Practice Guideline PEO.pdf**
  - **Ontario-Code-of-Ethics.pdf**
  - **The code of ethics of engineers OIQ.pdf**

1- Safety, Health, Welfare of Public

- Notify client and appropriate authority of circumstances that endanger life or property.
- Approve only engineering documents that conform with applicable standards.
- Report alleged Code violations to appropriate professional bodies and, when relevant, to public authorities

2- Work Only in Area of Competence

- Undertake assignments only when qualified by specific technical education or experience.
- Do not sign plans or documents when you lack competence or supervisory control.

3- Issue Truthful and Objective Public Statements

- Be objective and truthful in professional reports, statements, or testimony.
- Publicly express technical opinions founded upon facts and competence.

4- Act as Faithful Agent

- Disclose all known or potential conflicts of interest
- Do not accept compensation from more than one party for services pertaining to the same project, without full disclosure and agreement.

5- Avoid Deceptive Acts

- Do not falsify or misrepresent qualifications or pertinent facts pertaining to you or your associates.
- Do not offer, give, solicit or receive, (directly or indirectly) a bribe or “kick-back.”
- Avoid any appearance of impropriety.

6- Personal Conduct

- Public behaviour; behaviour when representing engineering profession.
- Personal integrity, honesty…

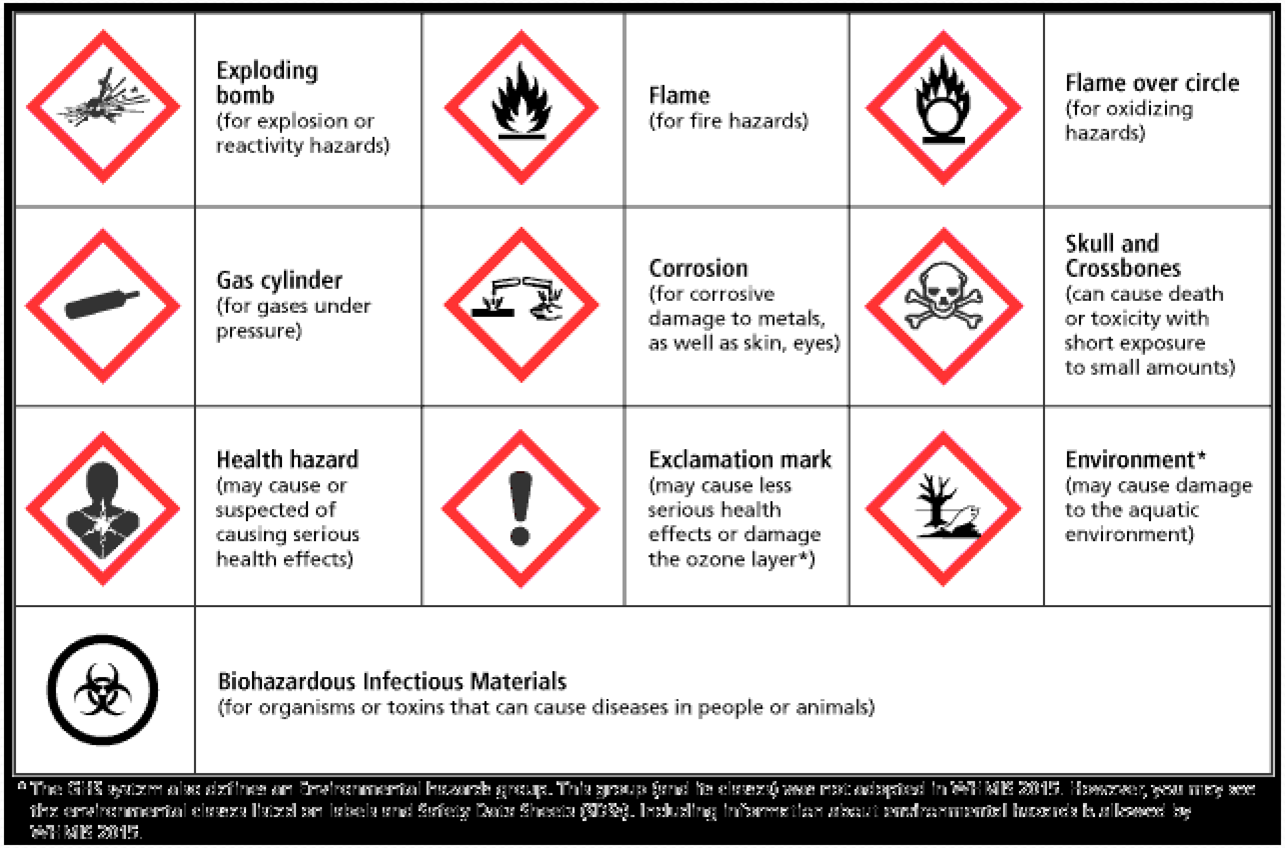
Ethical Dilemmas

- Situations evolving from conflicts between sets of moral considerations
  - Loyalty to employer, customer, general public
- Due to varying groups with differing interests within the "general public", the concept of public welfare may be vague.
- Guidelines for resolution of these ethical dilemmas come from personally adopting one of several Codes of Ethics.

Workplace health and safety

- **<u>REMINDER: Mandatory assignment</u>**
  - WHMIS: https://orm.uottawa.ca/whmis/
  - WHSA: https://web47.uottawa.ca/en/lrs/node/1481
- **Due Thursday September 26**
  - **Download your certificates and upload them to Brightspace**

Workplace health and safety: WHMIS



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Line failure, naphtha leak caused explosion at Syncrude upgrader, company says

Injured worker remains in stable condition in an Edmonton hospital

CBC News
March 15, 2017

A fire broke out Tuesday at the Syncrude plant north of Fort McMurray, Alta. (Pete Potipcoe/Facebook)

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U of A research building evacuated after chemical explosion

200 people evacuated from building, no injuries reported

CBC News Posted: Jan 24, 2018 2:38 PM MT | Last Updated: Jan 24, 2018 2:38 PM MT

Edmonton fire crews are on the scene of a chemical explosion Wednesday afternoon on the main University of Alberta campus.

The nitric acid explosion was in the Electrical and Computer Engineering Research building near 116th Street and 91st Avenue.

There were no injuries.

Firefighters got a call about alarms ringing in the building at 1:40 p.m. and arrived on scene within six minutes, Edmonton Fire Rescue Services spokesperson Maya Filipovic told CBC News.

By that time, 200 people had been evacuated from the building, Filipovic said.

Three people were in the room where the explosion happened, she said. All three were wearing proper protective equipment and were able to get out of the room safely.

The ventilation system was functioning properly and helped get rid of any fumes, Filipovic said. A hazardous materials crew remains on scene.

According to the PubChem open chemistry database, nitric acid is a colourless liquid used in the manufacture of inorganic and organic nitrates and nitro compounds for fertilizers, dye intermediates, explosives and many organic chemicals.

Weather