Course: **Introduction to Engineering**

Unit: **Engineering Basics**

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1. WHAT IS ENGINEERING?

1.1 DEFINITION OF ENGINEERING

There are various definitions of Engineering, e.g.:

- The profession in which scientific knowledge, gained by study, experience, and practice is applied with judgement, to develop ways to economically utilize the materials and forces of nature for the benefit of mankind.
- The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.
- The use of scientific knowledge to solve practical problems.

Let's analyse the first definition:

- ***profession*** - an occupation that requires considerable training and specialized study
- ***scientific knowledge*** – science is a branch of knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws, e.g. mathematics, physics, chemistry, economics, management, human behaviour, etc.
- ***study, experience, and practice*** – implies life-long learning
- ***applied with judgement*** - the ability to judge, make a decision, or form an opinion objectively, authoritatively, and wisely
- ***develop ways*** – implies creative thinking, development of new knowledge, and application of existing and new knowledge
- ***economically utilize*** – use resources optimally; must understand economics
- ***materials and forces of nature*** – must understand and apply the natural sciences
- ***for the benefit of mankind*** – must be ethical, and must understand social sciences.

Unfortunately, the terms *engineer* and *engineering* are some of the most misused terms around. It is not uncommon to see various kinds of workshops being called some sort of "engineering works"; and to see an engineer defined as "the operator of a railway locomotive", or "a person working on engines", or "the person looking after our computers".

It has become common practice to add importance to a job title by including "engineer" in it, e.g.:

- Sales Engineer (technical equipment salesman)
- Software Engineer (programmer)
- Systems Engineer (help desk operator)
- Computer Engineer (person assembling computers)
- Sanitary Engineer (plumber)
- Transport Engineer (truck driver's assistant)

- Domestic Engineer (housekeeper)
- Social Engineer (someone manipulating human interactions)

It will be up to you to study hard at university and to gain practical experience over many years, in order to join the engineering profession one day as a "real engineer", who can:

- apply scientific knowledge
- with judgement
- in order to develop ways to economically utilize the materials and forces of nature
- for the benefit of mankind.

1.2 ENGINEERING AND SCIENCE

It is important to distinguish between engineering and science:

- Scientists mainly investigate what exists; and systematically describe it in terms of theories, models and natural laws.
- Engineers utilize the scientific knowledge to create solutions for practical problems.
- Engineers must have a very good understanding of available scientific knowledge; while scientists don't need to know all about engineering and its processes.
- One of the most fundamental sciences used by engineers is **mathematics**.
- Mathematics is used as a *language* to describe scientific knowledge and engineering systems and processes.
- Remember, however: A mathematical description of a system is not the system itself – it is merely a model of the system.
- The better you can describe something mathematically, the better it can be analysed and improved.
- In order to describe a process or system mathematically, the basic scientific principles involved in the process or system must first be very well understood.
- Therefore, an engineer is only as good as his/her mathematical and scientific ability.

2. THE SPECTRUM OF ENGINEERING

2.1 WIDTH OF THE ENGINEERING TEAM

In order to have a successful engineering team, we need a variety of people with different knowledge, skills and qualifications:

	Professional Engineer	Engineering Technologist	Engineering Technician	Tradesman
Qualifications	4-year degree	3-year degree	2/3 year diploma	Apprenticeship followed by a trade test
Role	Design for new situations - with new and current technology	Design for standard situations - with current technology	Assembly, repair and testing	Manufacturing and installation
Skills	Design; innovation; system level and lateral thinking; documentation and communication; practical experience	Theoretical analysis; applied design; documentation	Practical problem solving; interpretation of documentation	Hands-on and manufacturing skills; interpretation of documentation
Knowledge Base	Foundations in various sciences; and a quest for new knowledge	Applications oriented; learn from current practices	Practical; learn from external observations	Manufacturing and installation processes and systems
Primary Roles	Problem solving; conception, design and development of new products and systems; prepare proposals and reports	Product development, manufacturing, product assurance and sales; prepare reports and user's manuals	Laboratory experiments, testing and repair; technical sales; prepare service manuals	Manufacture and install components and systems

The professional engineer's role can further be expanded on this spectrum, each with its own required knowledge and skills - e.g. to include roles such as:

- Design engineer
- Test and evaluation engineer
- Production engineer
- Maintenance engineer
- Project manager
- System engineer (someone with broad system engineering capabilities)
- Etc.

2.2 DEPTH OF PROFESSIONAL ENGINEERING

The "depth" to which a professional engineer will develop after obtaining the four year degree

depends on factors such as:

- Completing advanced degrees (Master’s and Doctor’s degrees).
    - Different universities offer post-graduate degrees consisting of varying combinations of coursework and research.
    - Some of these degrees are purely research-based; and the advantage is that the student can often largely determine the direction of the research, in order to suit personal interest.
- Commitment to continued learning.
    - It is currently estimated that the doubling time of the world’s total knowledge pool is less than 10 years.
    - Therefore, a commitment to continued learning is essential for any engineer.
- Type of employer.
    - Some employers understand the spectrum of engineering and the role of different members of the engineering team; and some don’t.
    - Some employers call themselves engineering companies, while they are not.
- Type of work done. If you land in a job where engineering skills and knowledge are not used, it is up to you to ask for more to do, or to move on – otherwise you’ll stagnate and lose your engineering edge.

3. DISCIPLINES AND ORGANISATIONS

3.1 ENGINEERING DISCIPLINES

There is large variety of engineering disciplines, all requiring fundamental scientific knowledge plus some specialist knowledge. Engineering careers can vary from being highly specialized in a small part of one of the disciplines, to being multi-disciplinary. Where you will end up on this spectrum depends on your personal interests and your employer.

Examples of different engineering disciplines include the following (and there are even more!). Some of these are offered as undergraduate degree courses by various universities, while for others you either have to undertake postgraduate study or gain extensive postgraduate work experience.

- Aeronautical engineering
- Automotive engineering
- Agricultural engineering
- Biomedical engineering
- Chemical engineering
- Civil engineering
- Computer engineering (*not assembly of computers* or *working at the help desk*)
- Electrical engineering
- Electronics engineering

- Industrial engineering
- Instrumentation and Control
- Logistics engineering
- Maintenance engineering
- Mechanical engineering
- Mechatronic engineering
- Metallurgical engineering
- Mining engineering
- Software engineering
- Software Engineering (*not mere programming or working at the help desk*)
- System engineering (*not the help desk type, but large-scale system level work*)

Each of the above listed disciplines contains different areas of specialisation, e.g. an electronics engineer can further develop into robotics, automation, circuit design, telecommunications, power electronics, micro-electronics, instrumentation, computer technology, radar, radio frequency electronics, maintenance engineering, etc., etc.

3.2 PROFESSIONAL ORGANISATIONS

There is a huge variety of professional engineering organisations worldwide – one or more for each engineering discipline. (These can be searched on the internet.) Examples are:

- Engineers Australia: www.engineersaustralia.org.au
- Engineers Australia (Western Australia Division): www.wa.engineersaustralia.org.au
- Young Engineers Australia: www.youngengineers.com.au
- Young Engineers (Western Australia Division): http://wa.youngengineers.com.au
- The Association of Professional Engineers, Scientists & Managers, Australia: www.apesma.asn.au
- The Institute of Electrical and Electronics Engineers: www.ieee.org
- The Institution of Electrical Engineers: www.iee.org.uk
- The Society of Automotive Engineers: www.sae.org
- American Society of Agricultural and Biological Engineers: www.asabe.org

4. THE THREE "LEGS" OF ENGINEERING PROJECTS

- Any project "stands" on three interdependent legs: cost, schedule and functionality (performance).
- These are sometimes called *3S: Spending, Schedule, and Scope*.
- If the requirements (functionality) are increased, the cost and schedule will also likely increase.
- If the schedule is reduced, cost will likely increase, while performance can decrease.

- If costs are cut, less staff can mean a longer schedule, and less functionality.
- These three *project legs* must be balanced, planned in advance, and managed throughout the project's lifetime in order to have a successful project.
- Rigorous application of proper project management techniques greatly improves balancing of the three project legs, and the chances of project success.
- Many engineers become project managers in later stages of their careers.
- "Proper project management" involves *planning, organizing, staffing, directing* and *control* of the project.
- To do all these things successfully, a project manager must have good technical-, management-, and people skills.
- Over- or under emphasis of any of the project-, management- or skills elements will certainly result in a failed project.

5. PROFESSIONAL MATTERS

5.1 GENERIC ATTRIBUTES OF AN ENGINEER

Engineers Australia identifies the following attributes that a graduate in engineering should possess:

- Ability to apply knowledge of basic science and engineering fundamentals
- Ability to communicate effectively, not only with engineers but also with the community at large
- In-depth technical competence in at least one engineering discipline
- Ability to undertake problem identification, formulation and solution
- Ability to utilize a systems approach to design and operational performance
- Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member
- Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development
- Understanding of the principles of sustainable design and development
- Understanding of professional and ethical responsibilities and commitment to them, and
- Expectation of the need to undertake lifelong learning, and capacity to do so.

5.2 PROFESSIONAL DEVELOPMENT AND REGISTRATION

An engineering degree from an accredited university is only one of the two pre-requisites for registration as a Chartered Professional Engineer (or similar terms used in different countries). The other is the attainment of ***practice competencies*** through supervised formation in industry or other professional settings. Maintaining a ***professional log*** that documents where and how these various competencies have been attained is necessary in order to achieve recognition of these practice competencies. Hence, students are encouraged to develop the habit of maintaining a Professional

Developmental Log during their studies at university.

Countries that are signatories of the ***Washington Accord*** - http://www.washingtonaccord.org (currently Australia, Canada, Hong Kong, Ireland, Japan, New Zealand, South Africa, United Kingdom and United States), recognize the co-signatories' registration programmes.

6. BASICS OF ETHICS AND SAFETY

Engineers should:

- Be honest and trustworthy.
- Be punctual.
- Observe etiquette (good manners).
- Respect other people's rights (including copyright on software, books, etc.)
- Have a strong sense of what is right and what is wrong. (Even though this can be difficult in a multicultural society.)
- Always consider the full implications of their decisions, designs, and actions.
- Not make decisions for which they are not qualified and experienced.
- Always consider safety of people and equipment in any of their decisions, designs, and actions.

The engineering profession has a tradition of upholding ethical practices, and most engineering organizations have their own Code of Ethics. The following are the *Tenets of the Code of Ethics (Engineers Australia)*:

1. Members shall place their responsibility for the welfare, health and safety of the community before their responsibility to sectional or private interests, or to other members;
2. Members shall act with honour, integrity and dignity in order to merit the trust of the community and the profession;
3. Members shall act only in areas of their competence and in a careful and diligent manner;
4. Members shall act with honesty, good faith and equity and without discrimination towards all in the community;
5. Members shall apply their skill and knowledge in the interest of their employer or client for whom they shall act with integrity without compromising any other obligation to these Tenets;
6. Members shall, where relevant, take reasonable steps to inform themselves, their clients and employers, of the social, environmental, economic and other possible consequences which may arise from their actions;
7. Members shall express opinions, make statements or give evidence with fairness and honesty and only on the basis of adequate knowledge;
8. Members shall continue to develop relevant knowledge, skill and expertise throughout their careers and shall actively assist and encourage those with whom they are associated, to do likewise;
9. Members shall not assist in or induce a breach in these Tenets and shall support those who

seek to uphold them if called upon or in a position to do so.

- When safety is concerned, never:
  - Take any shortcuts.
  - Assume that things will be right (because *assume easily makes and ass of u & me*).
- Don't "over-kill", but always build safety-factors into your designs.
- Always thinking about safety must be a way of life for engineers.

7. FEEDBACK AND ITERATION

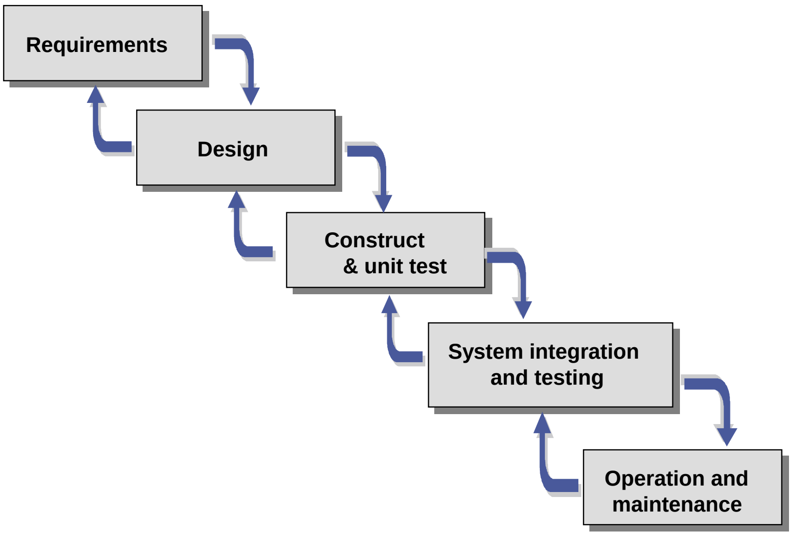
7.1 FEEDBACK

- Feedback is a very important, and a widely used concept in engineering.
- Feedback involves:
  - observation and/or measurement of actual events
  - comparing the actual events with the desired events
  - taking corrective action in order to ensure that desired results are achieved.
- It had been in use for thousands of years – e.g. for:
  - Controlled irrigation in ancient Egypt and Babylon
  - Control of Dutch windmills relative to wind direction (Andrew Meikle - 1750)
  - Speed control of steam engines (James Watt – 1788)
  - Stabilization of electronic amplifiers (Harold Black – 1927)
  - Speed control on vehicles
  - Climate control in buildings
- Feedback is essential to ensure that engineering solutions satisfy pre-defined needs.
- Feedback from students is also essential to ensure that my lecturing remains "on target".

7.2 ITERATION AND THE INCREMENTAL APPROACH

- Never try to solve a major problem all at once and on your own.
- Take time to understand the problem; and to consider how the problem can be split into a set of smaller problems (**analysis**).
- It is better to solve a well-defined problem halfway, than to solve the wrong problem in full.
- Solve the smaller problems, and then systematically combine the individual solutions (**synthesis**).
- Take small steps (**increments**) at a time, make sure that each step is the right one, and refer back to previous steps (**feedback**).
- The following diagram is one way to represent an engineering process from *requirements definition* to *operation and maintenance*.

- After each stage of the process, the results are compared with the goals of the previous stage (**feedback**).
- If the results are satisfactory, then move on to the next stage.
- If the results are not satisfactory, then review the goals and/or review the process followed to obtain the solution.
- This often involves a **trade-off** - a process of give and take, e.g. make the technical requirements less stringent in order to fit in with the available budget and the allowable schedule.
- Repeat this (**iteration**) until the actual result is the same as the desired result.



8. GUT FEELING AND COMMON SENSE

- It is very important for an engineer to have a "gut feeling" for what is realistic and possible; and to always apply common sense.
- Whenever an answer is obtained from a calculation, or when a design solution is proposed, the engineer must always ask questions such as:
  - Is this possible? Why / why not?
  - Is it realistic?
  - Is this the right order of magnitude? (E.g. mm instead of km.)
  - Does it make sense?
  - Does it feel right?
  - How can I verify this?
- If we put too much trust in our computers, without asking these questions, we might get answers accurate to 10 or more decimal points, but completely wrong!
- Always find ways to independently check your analysis, thoughts, solutions, etc.
- It is also very important to know when to use approximate numbers, and when to use high precision values, e.g.:

* In nanotechnology, there is as huge difference between 0.000 000 001 and 0.
* In civil engineering constructions, we can use this approximation without fear of landing in trouble.

9. SELF-ASSESSMENT

9.1 TRUE / FALSE QUESTIONS

Indicate which of the following statements are TRUE and which are FALSE.

1. Engineers and scientists always do the same work.
2. There is only one unique definition of engineering.
3. “The operator of a railway locomotive” is a suitable definition of an engineer.
4. After completion of a four year degree in engineering, you are set up for life, and you never have to worry about studying again.
5. Not all employers understand the spectrum of engineering and the role of different members of the engineering team.
6. Any project “stands” on three legs: cost, schedule and functionality (performance).
7. In terms of the *Washington Accord*, an engineer from Australia cannot work in Washington.
8. There are about nine professional organisations worldwide for engineers.
9. Honesty and etiquette are personal matters, and not something that engineers should worry about.
10. Feedback and iteration are important concepts used to ensure that engineering solutions satisfy pre-defined needs.

9.2 MULTIPLE CHOICE QUESTIONS

Choose the one most correct answer for each of the following questions:

1. Engineering can best be defined to involve:
    a. The use of scientific knowledge.
    b. Solving practical problems.
    c. Utilizing the materials and forces of nature for the benefit of mankind.
    d. All of the above.
2. Which of the following terms is not in the same category as the others?
    a. The operator of a railway locomotive.
    b. A person working on engines.
    c. Professional engineer.
    d. Sales engineer.
3. An important difference between scientists and engineers is:
    a. Scientists wear white coats.
    b. Engineers must have a very good understanding of available scientific knowledge; while

scientists don't need to know all about engineering and its processes.
    c. Engineers should earn more money than scientists.
    d. Engineers make things happen, while scientists wonder what had happened.

4. The following are essential skills for an engineer:
    a. Manufacturing skills.
    b. Workshop skills.
    c. Design; innovation; systems level and lateral thinking; documentation and communication; practical experience.
    d. None of the above.
5. Any project "stands" on three legs – of which the most important is:
    a. Cost.
    b. Schedule.
    c. Functionality.
    d. That these three *project legs* must be balanced, planned in advance, and managed throughout the project's lifetime in order to have a successful project.
6. An engineering degree from an accredited engineering program is only one of the two pre-requisites for registration as a Chartered Professional Engineer. The other is:
    a. Completing a post-graduate degree.
    b. Joining a professional organization.
    c. The attainment of practice competencies through supervised formation in industry or other professional settings.
    d. Signing the Washington Accord.
7. Engineers should:
    a. Be honest and trustworthy; and have a strong sense of what is right and what is wrong.
    b. Always consider the full implications of their decisions, designs, and actions.
    c. Not make decisions for which they are not qualified and experienced.
    d. All of the above.
8. Feedback is:
    a. A technique used by pre-historic people for controlling their windmills.
    b. A useful engineering concept to ensure that engineering solutions satisfy pre-defined needs.
    c. An opportunity for students to get even with lecturers.
    d. None of the above.
9. Iteration in engineering involves:
    a. A method to solve a major problem all at once.
    b. Necessary to understand problems.
    c. Solving only small problems.
    d. Repeating the process of problem definition and finding solutions until the actual result is the same as the desired result.
10. In engineering:
    a. There is no place for "gut feeling" and "common sense".

b. There is always only one correct answer.

c. There is no need to verify answers obtained from a computer.

d. None of the above.

9.3 SHORT ESSAY QUESTIONS

(Typically for 10 marks.)

1. Define engineering, and analyse the definition in your own words.
2. Give a brief discussion of the concepts *width and depth of engineering*.
3. Name the “legs” of an engineering project, and discuss their interdependence.
4. Define “feedback” and discuss how it is applicable to engineering in general.
5. Discuss the role of gut feeling and common sense in the engineer’s life.

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