Introduction to the Design Process

Accreditation Board for Engineering and Technology (ABET)

Definition of Design

- ***Engineering design*** is the process of devising a system, component, or process to meet desired needs.
- It is a decision-making process (often iterative), in which the engineering sciences and mathematics are applied to convert resources optimally to meet a stated objective.
- Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation.

Joseph Shigley (*Mechanical Engineering Design*)

Definition of Design

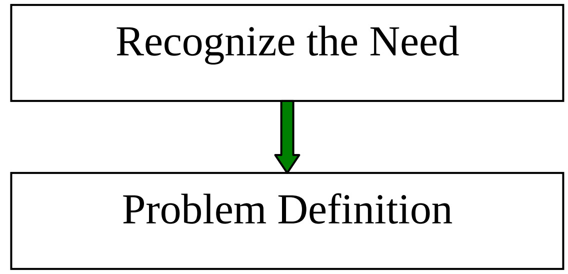
- ***Mechanical design*** means the design of components and systems of a mechanical nature—machines, products, structures, devices and instruments.
- For the most part mechanical design uses mathematics, materials, and the engineering-mechanics sciences.
- Additionally, it uses engineering graphics and the ability to communicate verbally to clearly express your ideas.
- ***Mechanical engineering design*** includes all mechanical design, but it is a broader study because it includes all the disciplines of mechanical engineering, such as the thermal fluids and heat transfer sciences too.
- Aside from the fundamental sciences which are required, the first studies in *mechanical engineering design* are in *mechanical design*, and that is the approach taken in this course.

Steps of the Design Process

1. Recognize the Need

- The first step is to establish the ultimate purpose of the project. Often, this is in the form of a general statement of the client's dissatisfaction with a current situation.
- example – "There is too much damage to bumpers in low-speed collisions."
- This is a general statement that does not comment on the design approach to the problem. It does not say that the bumper should be stronger or more flexible.
- Recognition and phrasing of the need are often very creative acts because the need may only be a sensing that something is not right. For this reason, sensitive people are generally more creative.
- example – the need to do something about a food packaging machine may be indicated by the noise level, variation in package weights, or by slight but perceptible variations in the quality of the packaging.

2. Problem Definition



- This is one of the most critical steps of the design process.
- There is an iteration between the definition of the problem and the recognition of need. Often the true problem is not what it first seems.
- The problem definition is more specific than recognizing the need. For instance, if the need is for cleaner air, the problem might be that of reducing the dust discharge from power-plant stacks, or reducing the quantity of irritants from automotive exhausts, or means for quickly extinguishing forest fires.
- The problem definition must include all the specifications for the thing that is to be designed. **Anything which limits the designer's freedom of choice is a specification.**
- It is imperative to write a formal problem statement which expresses what the design is to accomplish

    include:
        objectives and goals
          (musts, must nots; wants, don't wants)
        constraints
        criteria used to evaluate the design

- Example: Mobile Vehicle

  Design a vehicle which can maneuver in an indoor environment. The vehicle will be operated via remote control and must be able to:

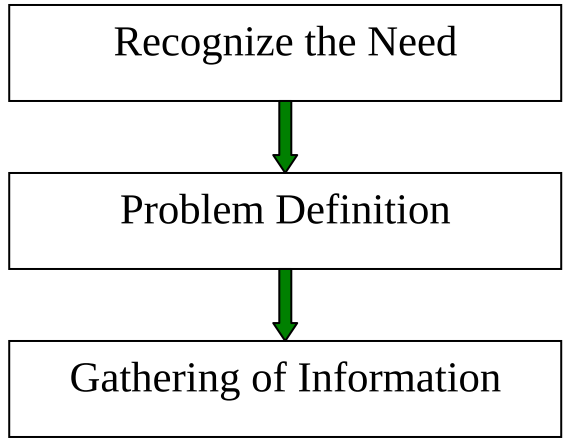
1) Travel up to a speed of 7 ft/sec on a flat, horizontal, dry, bare concrete surface.
2) Climb 5” high stairs at speeds up to 2 ft/sec.
3) Carry a payload of at least 20 lbs.
4) Fit through doorways.
5) Cross obstacles up to 20" high and up to 24" across within 20 seconds.
6) Climb a slope of up to 30 degrees and cross side slopes up to 20 degrees.
7) Rotate with zero turning radius.
8) Travel in any direction.
9) Total vehicle weight should be less than 275 lbs.

- Design considerations (in no particular order)

strength	**cost**	flexibility
reliability	safety	**control**
thermal properties	**weight**	**stiffness**
corrosion	life	surface finish
wear	noise	lubrication
friction	**styling**	maintenance
ergonomics	**shape**	**volume**
utility	**size**	liability
manufacturability	**speed**	feedrate
	ectetera	

Note: Design considerations in bold might be pertinent to the design project in EML2322L.

3. Gathering of Information



- Often, either no information is easily found, or there is an abundance of information
- Never-ending process for the best design engineers
- Info sources:

  textbooks
  trade journals & magazines
  technical reports from government sponsored R&D
  company catalogs, web pages and technical personnel
  handbooks
  company reports
  patents
  people

- Problems in gathering information:

  LAZINESS

  Where to find it?

  How to get it?

  How **accurate & credible** is the information?

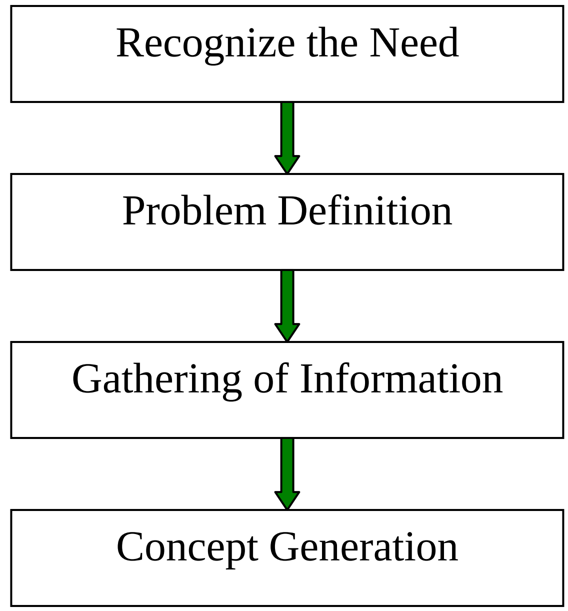
  How should the information be interpreted for my needs?

  When do I have enough information?

  What decisions result from the information?

  PLAGIARISM (integrity = giving others credit for their ideas)

4. Concept Generation



- This is the most creative part of the design process.
- Store ideas in a design notebook.
- Some approaches to concept generation:

  - **adaptation**

    a solution of a problem in one field is applied to a similar problem in another field (wine press → printing press → pistol grip)

  - **analogy**

    obstacle avoidance similar to potential fields

  - area thinking

    improve an existing product by concentrating on one of its important characteristics (cost, performance, function, appearance, safety, etc.)

  - **brainstorming**

    group of people who are familiar with the general nature of the problem;
    everyone says what comes to mind
    rules: (1) no judgements; (2) the more unconventional the better; (3) the more ideas the better

  - involvement

    visualize yourself as being part of the mechanism

- functional synthesis

  divide the system into subunits
  describe each subunit by a complete list of functional requirements
  list all the ways the functional requirements of each subunit can be realized
  study all combinations of partial solutions

Can Opener

Part	Function	Realization
Subunit 1	1. Separate metal	1. Shearing
		2. Tearing
		3. Fatigue
		4. Melting
		5. Drawing thin
		6. Chemical erosion
Subunit 2	1. Apply power	1. Hand
		2. Electric motor
		3. Hot wire
		4. Hydraulic motor
		5. Flame
		6. Chemical reaction
		7. Mechanical vibration
		8. Laser
	2. Position	1. Bring can to opener
		2. Bring opener to can
		3. Have opener built on can

- try inversion

  try reversing the ordering of things; i.e. an inversion is produced with an electric motor by holding the rotor stationary and permitting the field windings to rotate

- change the normal position and character of things

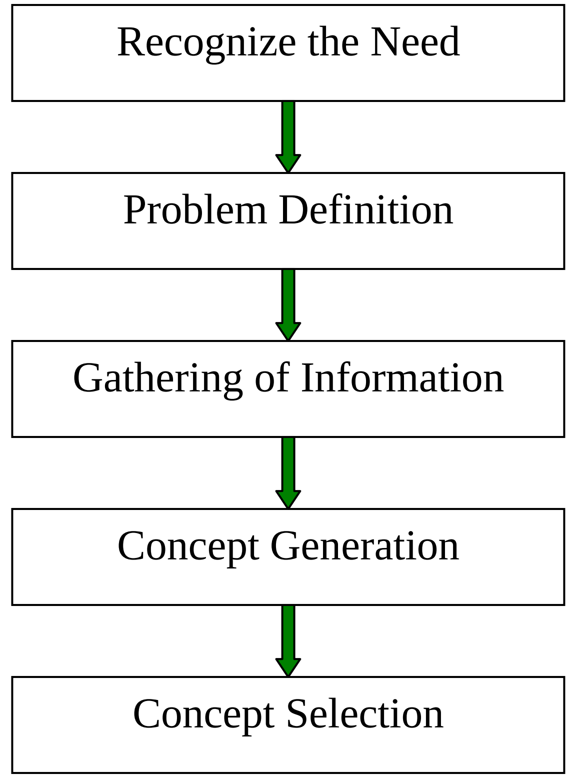
  if it operates horizontally, try operating it vertically. If it's round, try making it square. For example, doors hinged at top or bottom, a horizontal drill press, etc.

- **talk it over**

  If the designer has followed these suggestions thus far, he/she is now quite familiar with the problem. Many solutions have been found but none are quite satisfying. Having worked to this point, the designer's mind is in a receptive condition and will instantly recognize a solution. The problem is to bridge a gap between two groups of ideas—to make an association of ideas. It is generally conceded that this association occurs by pure chance. This event is most likely to occur when the problem is being discussed with another person or group of persons.

5. Concept Selection

- form **decision matrix** to unbiasedly evaluate different ideas based on a weighted set of objectives the design team decides are important for the solving the problem



Decision matrix for the design of a crane hook

CRANE HOOK			Welded Plates			Riveted Plates			Cast Hook		
Objective	Weighting Factor	Parameter	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Material Cost	0.10	$	2500	8.8	0.9	2500	8.8	0.9	2200	10.0	1.0
Manufacturing Cost	0.20	$	1500	8.0	1.6	1200	10.0	2.0	2400	5.0	1.0
Manufacturing Time	0.10	hours	40	6.3	0.6	25	10.0	1.0	50	5.0	0.5
Durability	0.15	experience	great	10	1.5	good	8	1.2	good	8	1.2
Reliability	0.30	experience	good	8	2.4	great	10	3.0	okay	6	1.8
Repairability	0.15	experience	good	8	1.2	great	10	1.5	fair	4	0.6
Overall value					**8.2**			**9.6**			**6.1**

Qualitative Score Assignments:	
great	10
good	8
okay	6
fair	4
poor	2

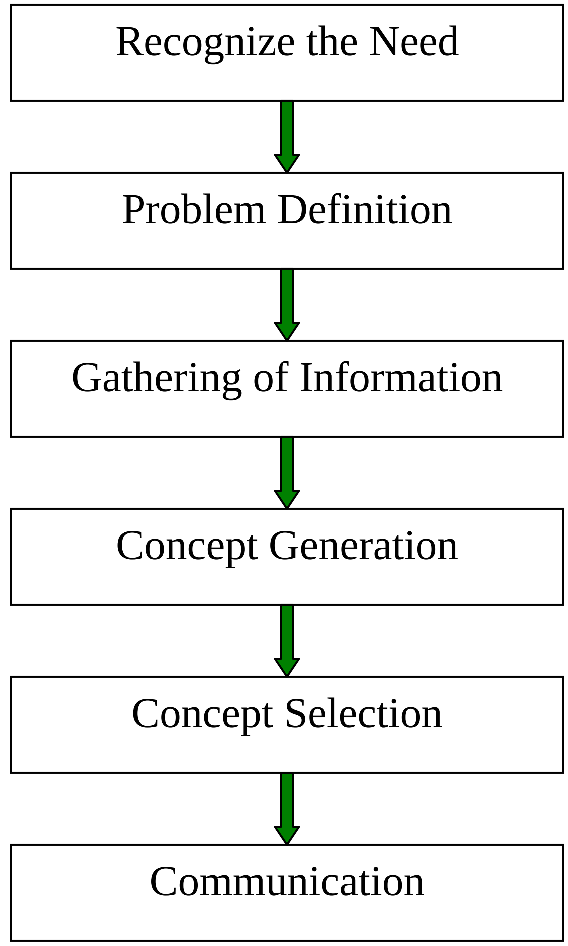
CRANE PHOTO

CRANE HOOK PHOTO

BAD DAY AT WORK FOR CRANE OPERATOR PHOTO

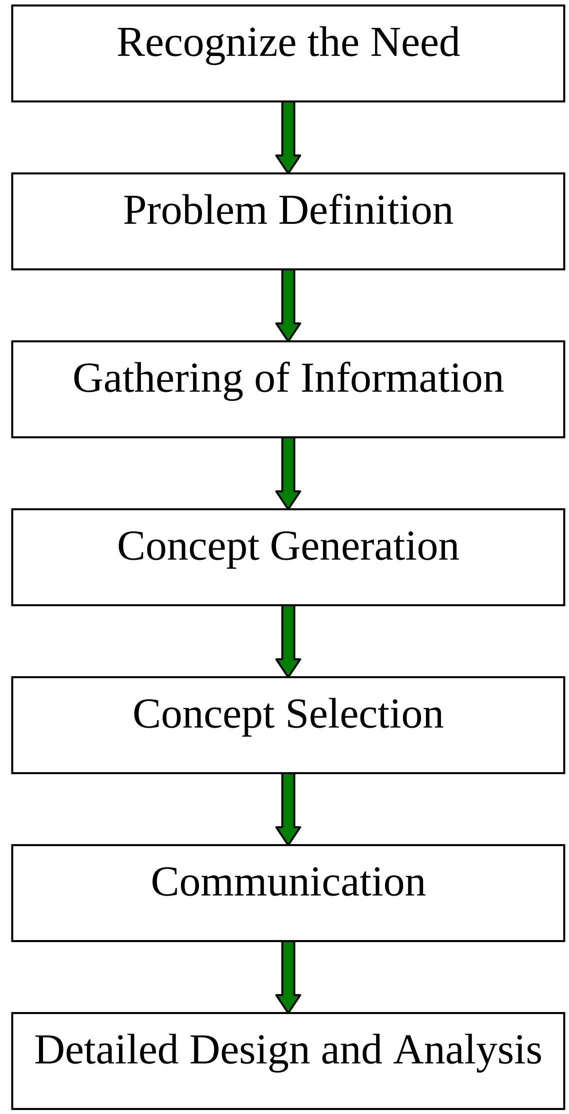
CLICK HERE FOR THE SAME EXAMPLE WITH PRINTABLE (AS OPPOSED TO DIGITAL) COMMENTS

6. Communication of the Design



- The purpose of the design is to satisfy the needs of the client.
- Designer must provide oral presentations and written design reports.
- Continuous communication is important in order to avoid surprises.
- Many great designs and inventions have been lost simply because the originator was unable or unwilling to explain his/her accomplishments to others.
- There are only 3 forms of communication available to us: written, oral and graphical. The successful engineer will be technically competent and versatile in all three. Competency only comes from practice.
- Ability in writing can be acquired by writing letters, reports, memos, and papers. It doesn't matter whether the articles are published or reviewed—the practice is the important thing. Ability in speaking can be obtained in educational, fraternal, civic, church and professional activities. To acquire drawing ability, pencil sketching should be employed to illustrate every idea possible. **CAD work should complement this, not replace it.**
- Importance of sketches, drawings, visual aids, computer graphics and models in the communications process.

7. Detailed Design and Analysis



- The principal goal of your engineering studies is to enable you to create mathematical models which accurately simulate the real physical world.
- All real physical systems are complex. Creating a mathematical model of the system means we are simplifying the system to the point that it can be analyzed. The terms *rigid body* and *concentrated force* are examples. The rule in making such *assumptions*, is that, in creating the model, the model must be meaningful—i.e. a good and appropriate model given the design constraints involved.
- The nature of the problem, its economics, the computational facilities available and the ability and working time of the engineer, all play a key role in the formulation of the model.
- **The designer's time investment typically increases exponentially with regard to model accuracy.**

8. Prototype Development and Testing

- Initial exposure in EML2322 lab and design project.

9. Manufacturing

- Initial exposure in EML4321 course.

10. Life Cycle Maintenance

- Learned from experience and industry standards.