EST 200
Design and Engineering

Text Book

- Engineering Design: A Project-Based Introduction, Fourth Edition
  - Clive L. Dym

Module I

Design Process

Introduction

- Design

  The starting point in Engineering.

- Why do we design ?

  To meet a need / find a solution.

Introduction

- Types of needs
  - Individual needs
  - Organizational needs
  - National needs
  - Universal needs

Introduction

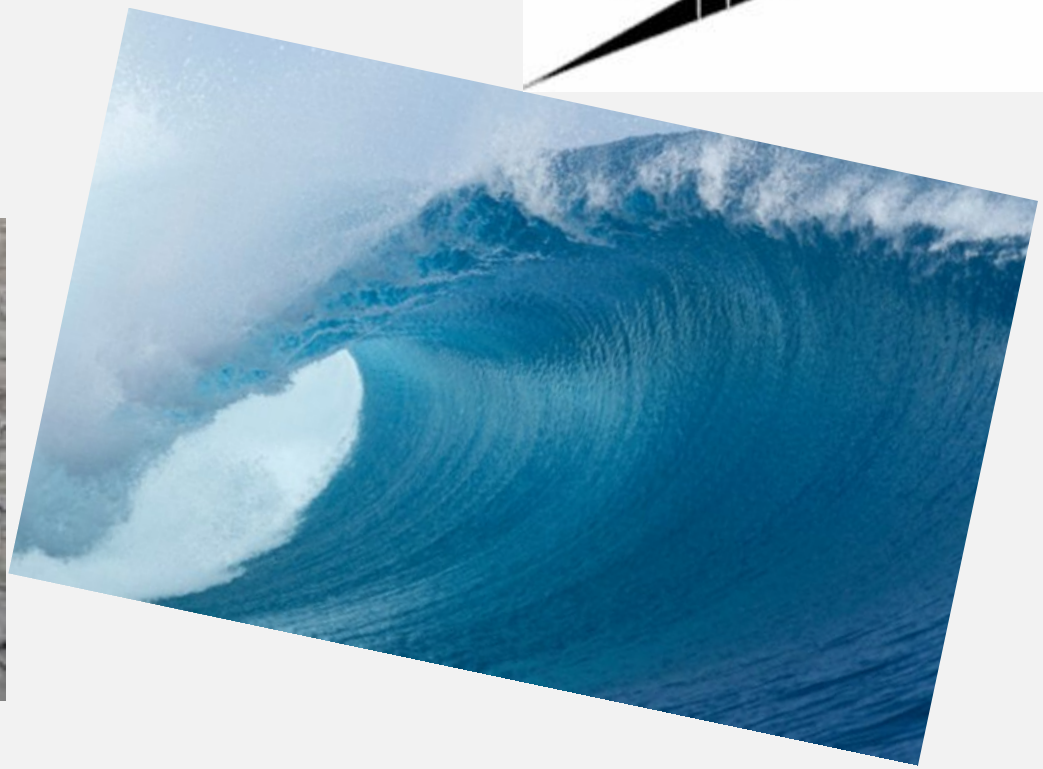
- Individual needs
  - Have shelter to stay
  - Prepare coffee quickly in the morning
  - Read the news paper

Introduction

- Organizational needs
  - Establish a modern restaurant
  - To have a modern curriculum in engineering
  - A plant to make bicycles

Introduction

- National needs
  - Warning for Tsunami
  - Buildings to withstand earth quakes
  - Draught relief



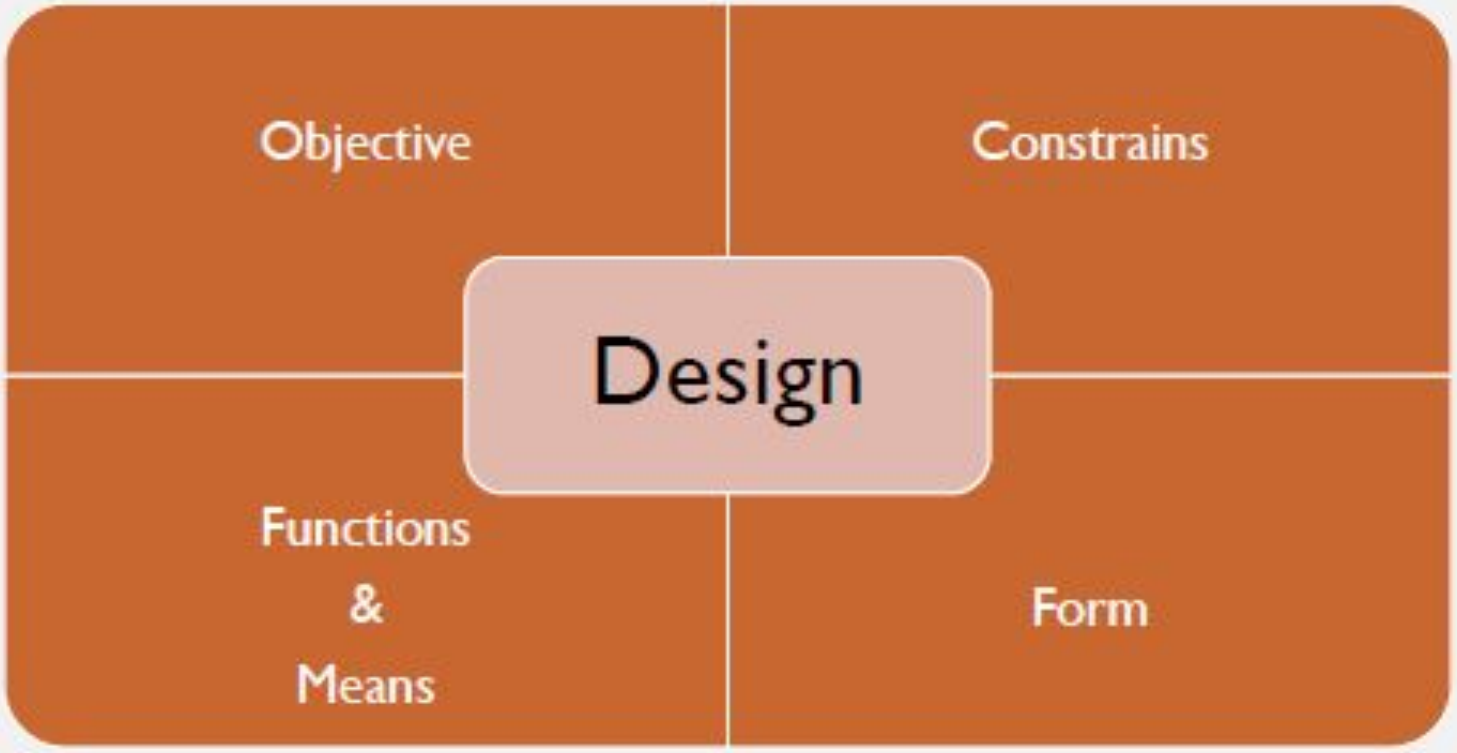
Introduction

- Universal needs
  - Prevent Global warming
  - Seamless transportation of goods

Introduction

- **Engineering design**
  - A systematic, intelligent process in which engineers generate, evaluate, and specify solutions for devices, systems, or processes whose form(s) and function(s) achieve clients' objectives and users' needs while satisfying a specified set of constraints.

Aspects of Design



Aspects of Design

❖ Design Objectives

- A feature or behavior that we wish the design to have or exhibit.
  - It defining the requirements of a design.

Aspects of Design

- Some generic objectives are
  - To identify the need of the user
  - To research about the possibilities of the problem solving
  - To formulate a working principle
  - To reduce the cost
  - To reduce the complexity
  - To make eco-friendly material

Aspects of Design

- Ex: Objective of a **portable ladder**
  - Ladder should be compact and portable
  - It should be stable on smooth surfaces
  - Should be reduce space requirements while packing by means of detachable parts

Aspects of Design

- Ex: Objective of a **portable ladder**
  - Ladder should be compact and portable
  - It should be stable on smooth surfaces
  - Should stand safely without a support
  - Can be used for house hold requirements
  - Should be reasonably stiff and comfortable for users
  - Must be safe and durable
  - Should be relatively economical
  - Should be reduce space requirements while packing by means of detachable parts

Aspects of Design

❖ Design Constrains

- Helps to shape the project to fit the exact needs of the client.
- Different types:
- Functional Constraints
  - Overall geometry
  - Kinematics
  - Energy requirement
  - Materials used
  - Control systems

Aspects of Design

- Safety constraints
- Quality constraints
- Manufacturing Constraints
- Time constraints
- Economical constraints
- Legal and ethical constraints

Aspects of Design

❖ Design Functions

- Functions are **the behaviors** that expected from the design.
- A design should perform certain functions for convert given input to required output.
- They describe what the design will "do" or accomplish, with an emphasis on input-output transformations.
- The statement of a function typically couples an action verb to a noun or object:
  - Eg: lift a book, support a shelf, transmit a current, measure a temperature, or switch on a light

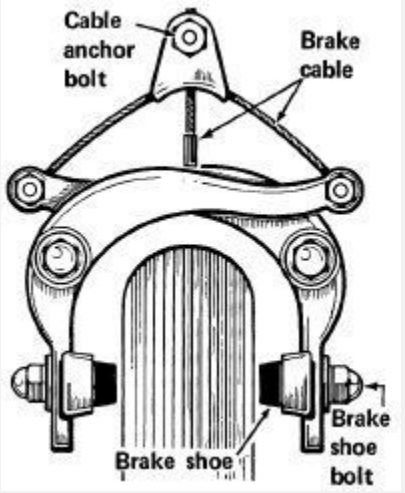
Aspects of Design

- Research function - Identifying the need, working principle, collection of data.
- Engineering function - Main product design, 3D model, concept, simulation, etc.
- Manufacturing function - Element production, assembly, cost, purchases, raw materials, etc.
- Quality control function - Regulation of product, check for safety, design auditing, energy auditing, etc.
- Commercial function - Cost and service related aspects

Aspects of Design

❖ Design Means

- It is the way in which a design **executes** a desired function.



- Eg: The **function** of a *bicycle brake* is **stop the wheel** when applying the brake lever by **means** of **frictional force** between rim and brake pad.

- Eg: The function of a *speaker* is to produce sound by means of electro magnetic induction.

Aspects of Design

❖ Design Form

- An area or mass to define objects in space
  - Two dimensional
  - Three dimensional

conceptual design is the stage at which basic questions of form and content for a design are established.(i.e., the nature of goals of the designed item)

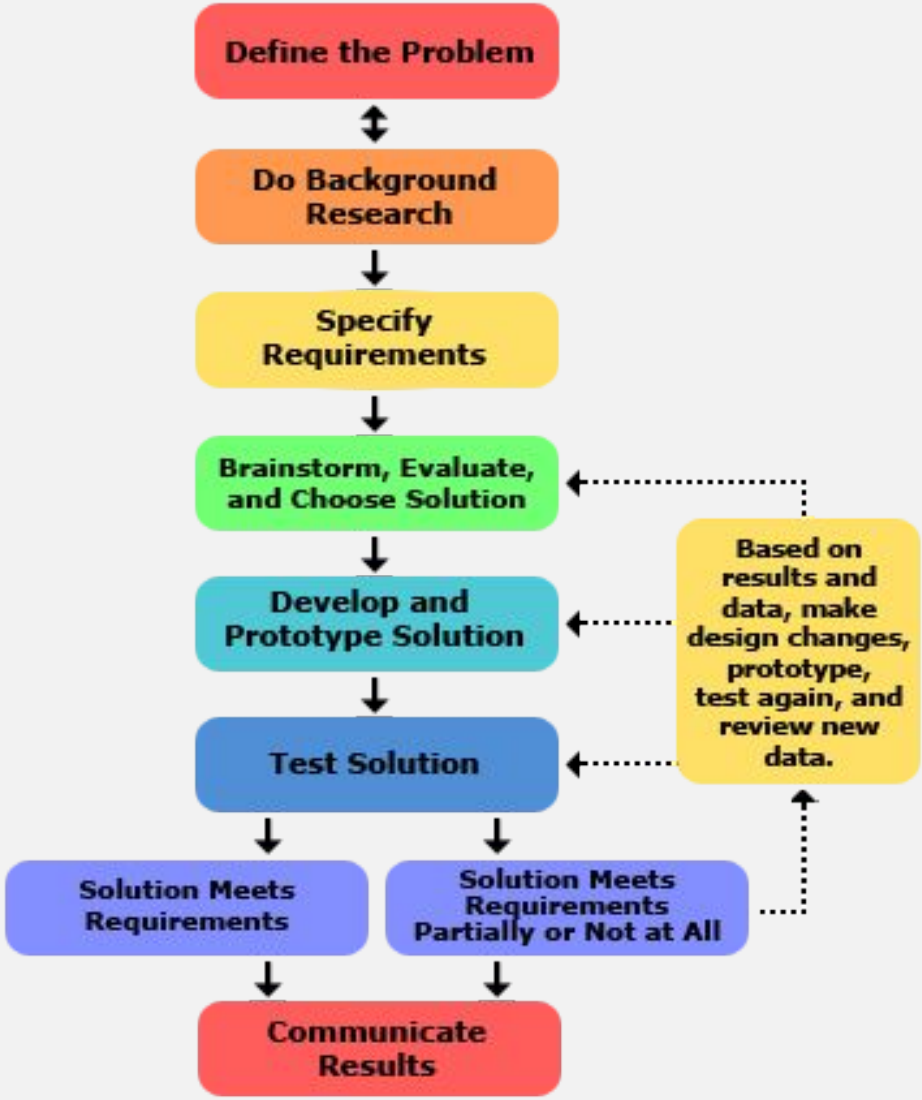
detailed design is the stage in the design process after conceptual design(and after preliminary and embodiment design), when specific details particular to the design are resolved

The Design Process

- The engineering design process is a series of steps that engineers follow to come up with a solution to a problem.
- The solution involves designing a product that meets certain criteria and/or accomplishes a certain task.
- If your project involves designing, building, and testing something, you should probably follow the Engineering Design Process.

The Design Process

Steps of the Engineering Design Process



The Design Process

1. Define the Problem

- Finding an idea for your engineering project requires you to identify the ***needs*** of yourself, another person, or a group of people.
- The act of looking at the world around you to identify these needs **need finding**.
- To help you find an idea for your engineering project:
  - Create a list of all the things that annoy or bother the people around you and record this bug list.
  - Mind Map possible design problems, ideas, or areas of interest to you.

The Design Process

- Once you have found an idea for your engineering project, describe the problem by writing a **problem statement**. Your problem statement must answer three questions:
  - **What** is the problem or need?
  - **Who** has the problem or need?
  - **Why** is it important to solve?
- The format for writing a problem statement uses your answers to the questions and follows these guidelines:
  - **Who** need(s) **what** because **why**

The Design Process

2. Do Background Research

- Learn from the experiences of others — this can help you find out about existing solutions to similar problems, and avoid mistakes that were made in the past.
- So, for an engineering design project, do background research in two major areas:
  - Users or customers
  - Existing solutions

The Design Process

 Users or Customers

- **Research your target user or customer.**
  - Everything humans design is ultimately for the use of another human
  - Your choice of target user will sometimes have a big impact on your design requirements.
  - For example, if you design something for a toddler, you need to make sure that there are no small parts that could be swallowed. Some customers are more sensitive to the cost than others, and so forth.

The Design Process

- You might describe your target user in any number of ways. Here are some examples:
  - Age (old, young, infant)
  - Gender
  - Occupation
  - Hobby interests
  - Whether users have disabilities and require accommodations
  - First-time user or experienced user etc..

The Design Process

 Existing Solutions

- **Research the products that already exist to solve the problem you defined or a problem that is very similar.**
  - No one wants to go to all the trouble of designing something they think is new, only to find that several people have already done it.
  - You want to investigate what's already out there. Only then can you be sure that you're making something that more effectively fills a need.
  - And keep in mind that what is "better" depends on your requirements.

The Design Process

- **Research how your product will work and how to make it.**
  - When it comes time to build their solution, savvy designers also want to use their research to help them find the best materials and way to do things, rather than starting from scratch.
  - Background research is also important to help you understand the science or theory behind your solution.
  - If you are entering a science fair, judges like to see that you understand why your product works the way it does and what causes it to perform better than other products.

The Design Process

3. Specify Requirements

- State the important characteristics that your design must meet in order to be successful.
- One of the best ways to identify the design requirements for your solution is to use the concrete example of a similar, existing product, noting each of its key features.

The Design Process

- Here is how to analyze:
  - A physical product
  - A software product or website
  - An environment
  - An experience

The Design Process

4. Brainstorm Solutions

- There are always many good possibilities for solving design problems.
- If you focus on just one before looking at the alternatives, it is almost certain that you are overlooking a better solution.

The Design Process

- Good designers try to generate as many possible solutions as they can before choosing one that they feel is the best. This creative process of developing ideas is called ***ideation***.
- Methods of ideation include:
  - Examining existing solutions
  - Creating and using analogies
  - Conducting brainstorming sessions
  - Sketching and doodling

The Design Process

5. Choose the Best Solution

- Look at whether each possible solution meets your design requirements.
- Some solutions probably meet more requirements than others.
- Reject solutions that do not meet the requirements.

The Design Process

- Good designers consider these **universal design criteria** when choosing which possible solution to implement:
  - Elegance
  - Robustness
  - Aesthetics
  - Cost
  - Resources
  - Time
  - Skill required
  - Safety

The Design Process

- It helps to compare solutions in a ***decision matrix***—a chart with the requirements and criteria on one axis and the different solutions on the other.
- If your requirements and solutions are relatively simple, you can sometimes just list the **pros** and **cons** for each solution.

The Design Process

6. Develop the Solution

- Involves the refinement and improvement of a solution.
- It continues throughout the design process, often even after a product ships to customers.
- The goals of development work are to:
  - Make it work!
  - Reduce risk.
  - Optimize success.

The Design Process

- **Methods** of development work include:
  - Drawings
  - Modeling
  - Prototyping
  - Storyboards
  - Analysis

The Design Process

7. Build a Prototype

- A prototype is an operating version of a solution.
- Prototypes are a key step in the development of a final solution, allowing the designer to test how the solution will work.

The Design Process

- A **prototype** is an operating version of a solution. It is often made with different materials (cheaper and easier to work with) than the final version.
- Prototypes allow you to test how your solution will work and even show the solution to users for feedback.
- Creating prototypes may involve using readily available materials, construction kits, storyboards, or other techniques that help you to create your solution quickly and with little cost.

The Design Process

8. Test and Redesign

- The design process involves multiple iterations and redesigns of your final solution.
- You will likely test your solution, find new problems, make changes, and test new solutions before settling on a final design.
- At this point, you have created prototypes of your alternative solutions, tested those prototypes, and chosen your final design.

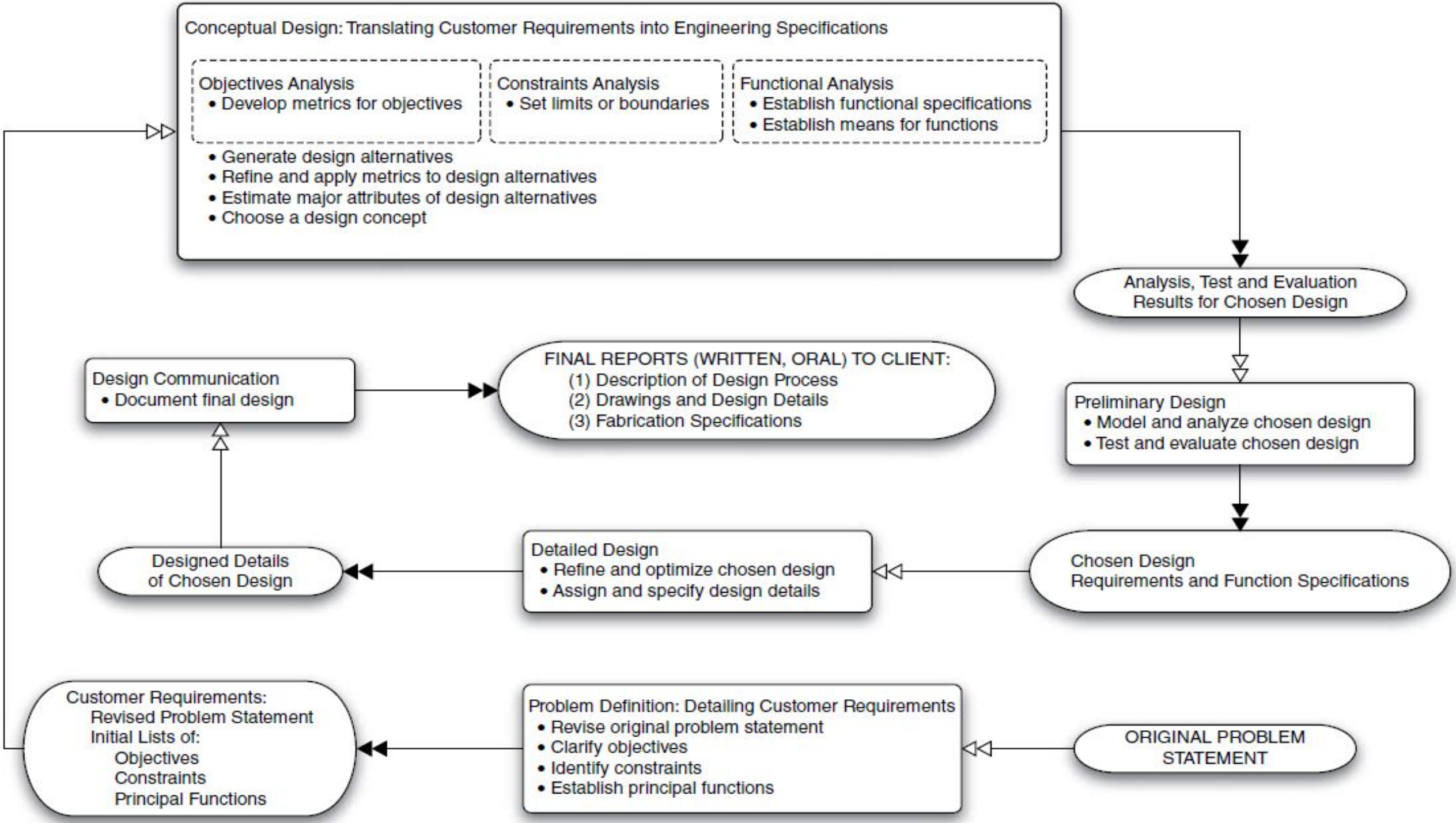
The Design Process

- Test and redesign requires you to go out and test your final design with your users.
- Based on their feedback and their interaction with your solution, you will redesign your solution to make it better.
- Repeat this process of testing, determining issues, fixing the issues, and then retesting multiple times until your solution is as successful as possible.

The Design Process

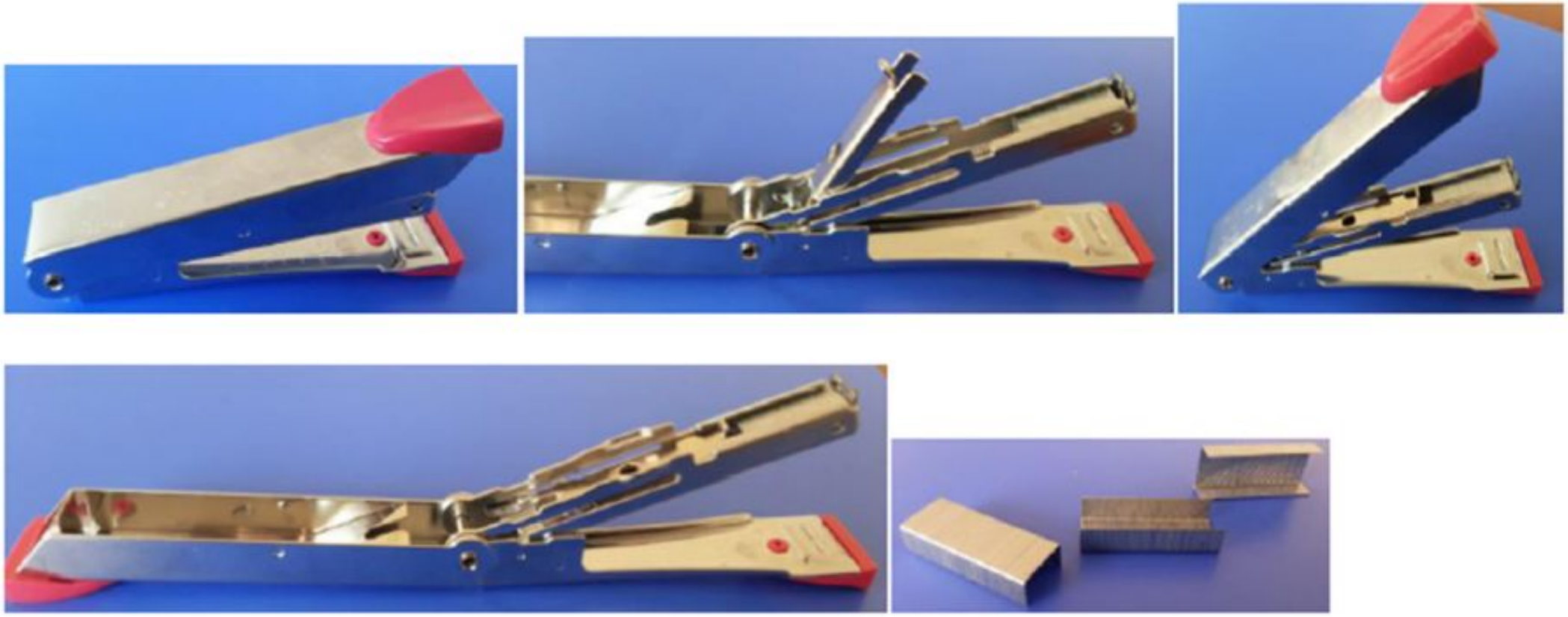
9. Communicate Results

- To complete your project, communicate your results to others in a final report and/or a display board.
- Professional engineers always do the same, thoroughly documenting their solutions so that they can be manufactured and supported.


Conceptual Design: Translating Customer Requirements into Engineering Specifications
Objectives Analysis
• Develop metrics for objectives
Constraints Analysis
• Set limits or boundaries
Functional Analysis
• Establish functional specifications
• Establish means for functions
• Generate design alternatives
• Refine and apply metrics to design alternatives
• Estimate major attributes of design alternatives
• Choose a design concept
Analysis, Test and Evaluation Results for Chosen Design
Preliminary Design
• Model and analyze chosen design
• Test and evaluate chosen design
Chosen Design Requirements and Function Specifications
Detailed Design
• Refine and optimize chosen design
• Assign and specify design details
Designed Details of Chosen Design
Design Communication
• Document final design
FINAL REPORTS (WRITTEN, ORAL) TO CLIENT:
(1) Description of Design Process
(2) Drawings and Design Details
(3) Fabrication Specifications
ORIGINAL PROBLEM STATEMENT
Problem Definition: Detailing Customer Requirements
• Revise original problem statement
• Clarify objectives
• Identify constraints
• Establish principal functions
Customer Requirements:
Revised Problem Statement
Initial Lists of:
Objectives
Constraints
Principal Functions

The picture of a stapler is given below (different views are shown).The user has the complaint that he does not know how much of stapler pins are left in the stapler. His need is to know whether there are enough stapler pins in the stapler before he uses it.

Can this be solved through any design modification to the stapler? If so, what design modification to the stapler can be done to achieve this? Sketch the solution and explain it briefly (ten lines only).



- Show the designing of a wrist watch going through the various stages of the design process. Use hand sketches to illustrate the processes.

- Design a safe ladder

- Problem statement

  “Design a new ladder for electricians or other maintenance and construction professionals working on conventional job sites.”

TABLE 3.1 A starting list of safe ladder attributes (O = objectives; C = constraints; F = functions; M = means)

Characteristics	O	C	F	M
Ladder should be useful	✓			
Used to string conduit and wire in ceilings	✓			
Used to maintain and repair outlets in high places	✓			
Used to replace light bulbs and fixtures	✓			
Used outdoors on level ground	✓			
Used suspended from something in some cases	✓			
Used indoors on floors or other smooth surfaces	✓			
Could be a stepladder or short extension ladder				✓
A folding ladder might work				✓
A rope ladder would work, but not all the time				✓
Should be reasonably stiff and comfortable for users	✓			

Characteristics	O	C	F	M
Step deflections must be less than 0.05 in.		✓		
Should allow a male of medium height to work safely up to 11-ft. heights				
Must support weight of an average worker			✓	
Must be safe	✓			
Must meet OSHA requirements		✓		
Must not conduct electricity		✓	✓	
Could be made of wood or fiberglass, but not aluminum				✓
Should be relatively inexpensive	✓			
Should be portable between job sites	✓			
Should be light	✓			
Must be durable	✓			

TABLE 4.1 A pruned list of objectives for a safe ladder

Ladder should be useful
Used to string conduit and wire in ceilings
Used to maintain and repair outlets in high places
Used to replace light bulbs and fixtures
Used outdoors on level ground
Used suspended from something in some cases
Used indoors on floors or other smooth surfaces
Should be reasonably stiff and comfortable for users
Should allow a person of medium height to reach and work at levels up to 11 ft.
Must be safe
Should be relatively inexpensive
Must be portable between job sites
Should be light
Must be durable

TABLE 4.2 An indented list of the pruned objectives for a safe ladder

0. ***A safe ladder for electricians***
    1. **The ladder should be safe**
        1.1 The ladder should be stable
            1.1.1 Stable on floors and smooth surfaces
            1.1.2 Stable on relatively level ground
        1.2 The ladder should be reasonably stiff
    2. **The ladder should be marketable**
        2.1 The ladder should be useful
            2.2.1 The ladder should be useful indoors
                2.2.1.1 Useful to do electrical work
                2.2.1.2 Useful to do maintenance work
            2.2.2 The ladder should be useful outdoors
            2.2.3 The ladder should be of the right height
        2.2 The ladder should be relatively inexpensive
        2.3 The ladder should be portable
            2.3.1 The ladder should be light in weight
            2.3.2 The ladder should be small when ready for transport
        2.4 The ladder should be durable

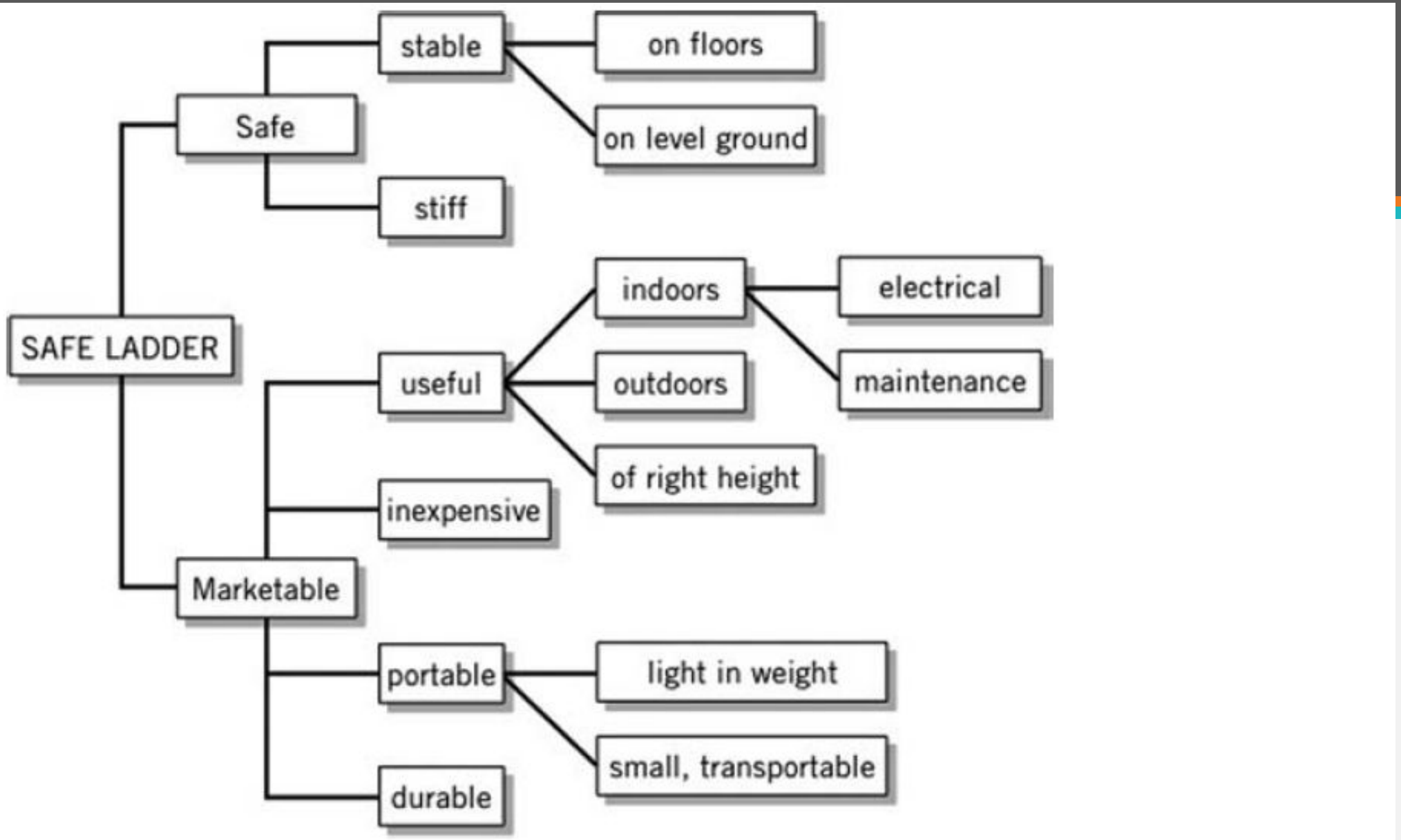


Figure 4.1 The objectives tree for the design of a safe ladder. Note the hierarchical structure and the clustering of similar ideas.

- Design a bottle for a new children’s juice product