Design and Engineering

(EST200)

S4 - EE

Overview

Introduction

- **Purpose**
  1. To introduce the fundamental principles of design engineering
  2. To understand the steps involved in the design process
  3. To familiarize the basic tools used and approaches in design
- Case studies and practical situations
- Design process according to the customer requirements, economics, reliability, aesthetics, ergonomics,sustainability etc.

Assessment Pattern

Continuous Internal Evaluation (CIE) Pattern:

- Attendance **: 10 marks**
- Continuous Assessment Test (2 numbers) **: 25 marks**
- Assignment/Quiz/Course project **: 15 marks**

End Semester Examination (ESE) Pattern:

- Part A **: 30 marks**
  - Part A contains 10 questions with 2 questions from each module, having 3 marks for each question
  - Students should answer all questions
- Part B **: 70 marks**
  - Part B contains 2 case study questions from each module of which student should answer any one
  - Each question carry 14 marks and can have maximum 2 sub questions

Mark Distribution

- Total Marks : 150 (CIE: 50, ESE: 100)
- ESE Duration : 3 hours

Module 1

- Design Process
  - Introduction to Design and Engineering Design
  - Defining a Design Process
  - Detailing Customer Requirements
  - Setting Design Objectives
  - Identifying Constraints
  - Establishing Functions
  - Generating Design Alternatives and Choosing a Design

Module 2

- Design Thinking Approach
  - Introduction to Design Thinking
  - Iterative Design
  - Thinking Process Stages: Empathize, Define, Ideate, Prototype and Test
  - Design Thinking as Divergent-Convergent Questioning
  - Design Thinking in a Team Environment

Module 3

- Design Communication
  - Communicating Designs Graphically
  - Communicating Designs Orally and in Writing
  - Mathematical Modeling In Design, Prototyping and Proofing the Design

Module 4

- Design Engineering Concepts
  - Project-based Learning and Problem-based Learning in Design
  - Modular Design and Life Cycle Design Approaches
  - Application of Biomimicry, Aesthetics and Ergonomics in Design
  - Value Engineering, Concurrent Engineering, and Reverse Engineering in Design

Module 5

- Expediency, Economics and Environment in Design Engineering
  - Design for Production, Use, and Sustainability
  - Engineering Economics in Design
  - Design Rights
  - Ethics in Design

4. Expected Outcome

After the successful completion of this course, the students will be able to

1. Explain the different concepts and principles involved in design engineering
2. Apply design thinking while learning and practicing engineering
3. Develop innovative, reliable, sustainable and economically viable designs incorporating knowledge in engineering

5. References

Text Books

- *'Engineering Design Process'* - Y. Haik, S. Sivaloganathan, T. M. Shahin
- *'Engineering by Design'* - Voland, G

Reference Books

- *'Exploring Engineering: An Introduction to Engineering and Design'* - P. Kosky, R. Balmer, W. Keat, G. Wise
- *'Engineering Design: A Project-Based Introduction'* - C. L. Dym
- *'Design Thinking: Understanding How Designers Think and Work'* - N. Cross
- *'Engineering Design: A Systematic Approach'* - Pahl, G. Beitz, W. Feldhusen, J. Grote

Thank You

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Module 1 I

Module 1 II

- Function-Means Trees

- Generating Design Alternatives
  - Design Space
  - Defining a Design Space by Generating a Morphological Chart
- Choosing a Design
  - Numerical Evaluation Matrices
  - Priority Checkmark Method
  - The Best-of-Class Chart
- Case Studies
  - Bicycle
  - Headphone
  - Helmet
  - Carry Bag
  - Wrist Watch

1. Introduction

- Engineering Design
  - When?
  - Why?
  - For whom?
- Definition by Accreditation Board for Engineering and Technology (ABET)
  - Engineering design is the process of devising a system, component, or process to meet desired needs
  - **Decision-making process** (usually iterative), in which the basic sciences, mathematics, and engineering sciences are applied to optimally convert resources to meet a stated **objective**

2. Engineering Design

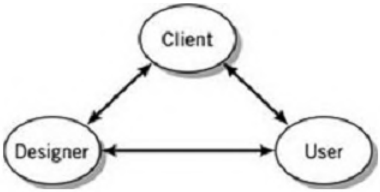
- **Design:** Scientific and creative process
- *Indeed, without a design, there would be no product!*
- Reason for failures in engineering designs:
  - Incorrect or overextended assumptions
  - Poor understanding of the problem to be solved
  - Incorrect design specifications
  - Faulty manufacturing and assembly
  - Error in design calculations
  - Incomplete experimentation and inadequate data collection
  - Errors in drawings
  - Faulty reasoning from good assumptions

2.1 Design Levels

1. **Adaptive Design**
   - Adaptation of existing designs
   - Only minor modifications usually dimensions
   - Ordinary technical training is sufficient
   - Eg: Elevator, Washing machine etc.
2. **Development Design**
   - More scientific training and design ability are needed
   - Designer starts from an existing design, but the final outcome may differ markedly from the initial product
   - Eg: Manual gearbox in a car to an automatic one, Tube-based television to the modern plasma, LCD and LED Televisions
3. **New Design**
   - Most difficult level
   - Generating a new concept involves mastering all the previous skills in addition to creativity and imagination, insight, and foresight
   - Eg: First automobile, airplane, wheel etc.

2.2 Roles in Design

1. **Client:** A person or group or company that wants a design conceived
2. **User:** Employ or operate whatever is being designed
3. **Designer:** Solve the clients problem in a way that meets the users needs



Designer Client - User triangle

- **Public** also has a stake in many designs eg: new interstate highway

2.3 Vocabulary for Engineering Design I

- **Engineering Design**
  - Systematic and 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
  - Thoughtful process for generating plans or schemes for devices, systems, or processes that attain given objectives while adhering to specified constraints
  - Designing new devices → **Artifacts** (artificial, man-made objects)

2.3 Vocabulary for Engineering Design II

- **Design Objective**
  - A feature or behaviour that we wish the design to have or exhibit
  - Objectives may be completely or partially achieved
- **Design Constraint**
  - A limit or restriction on the features or behaviours of the design
  - A proposed design is unacceptable if these limits are violated
  - Constraints must be satisfied or the design is not acceptable
- **Functions**
  - Things a designed device or system is supposed to do
  - Engineering functions almost always involve transforming or transferring energy, information, or material
  - It includes supporting and transmitting forces, the flow of current, the flow of charge, the transfer of material etc.

2.3 Vocabulary for Engineering Design III

- **Means**
  - A way or a method to make a function happen
  - Eg: Friction is a means of fulfilling a function of applying a braking force
  - 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
  - The *function* of a speaker is to produce sound by *means of* electro magnetic induction

2.3 Vocabulary for Engineering Design IV

- **Form**
  - The shape and structure of something as distinguished from its material
  - Same **function**, but different **forms**

2.3 Vocabulary for Engineering Design V

- **Accuracy** : The quality of being near to the true or desired value
- **Analysis** : Breaking an object or process into smaller parts to examine or evaluate systematically
- **Argument** : A persuasive defence for an explanation or solution based on evidence and reasoning
- **Assessment** : An evaluation of the cost, quality and/or ability of someone or something
- **Causation** : The relationship between cause and effect
- **Claim** : A response made to a question and in the process of answering that question
- **Communicate** : To share information orally, in written form and/or graphically through various forms of media
- **Control** : A variable that is kept the same across all tests for use as the comparison standard

2.3 Vocabulary for Engineering Design VI

- **Correlation** : A predictive dependent relationship between variables that may be positive or negative. Changing a variable creates a correspondi change in another but does not imply causation.
- **Criteria** : Attributes of a design that can be measured; a set of standards upon which a decision is based
- **Design** : To generate or to propose a possible solution; to create, fashion, execute, or construct
- **Diagram** : A visual representation of data or information
- **Effectiveness** : A determination of how well a solution meets the criteria
- **Efficiency** : The measurable relationship between a solution and the amount of resources it requires
- **Error** : The difference between a measured value and its true or accepted value

2.3 Vocabulary for Engineering Design VII

- **Evaluate** : To determine significance
- **Evidence** : Data used to support a claim
- **Failure** : The inability of a device, process, or system to perform a required function
- **Limit** : The minimum or maximum permissible value
- **Model** : A diagram, replica, mathematical representation, analogy, or computer simulation used to analyze a system for condition flaws, test a solution, visualize or refine a design, and/or communicate design features
- **Observation** : To become aware of an occurrence using the senses
- **Plan** : A systematic approach to solving a problem
- **Problem** : A situation to be changed; a question raised for inquiry, consideration, or solution

2.3 Vocabulary for Engineering Design VIII

- **Process** : A series of steps that form a pathway to a solution
- **Prototype** : A model that tests design performance
- Measuring the Success of an Engineered Design
  - Metric: a standard of measurement
  - Specifications: a scale on which the achievement of a designs functions can be measured

2.4 Learning and Doing Engineering Design I

- Engineering Design Problems are Challenging
  - Design problems are considered **ill structured**
    - Their solutions can not normally be found by applying mathematical formulas or algorithms in a routine or structured way
    - It is not possible to apply formulas to problems that are not well bounded or even defined
    - Experienced engineers
  - Design problems are **open-ended**
    - They typically have several acceptable solutions
    - Uniqueness does not apply to design solutions
    - Designers work to reduce or bound the number of design options they consider

2.4 Learning and Doing Engineering Design II

- Eg: To enable people to reach heights they would be otherwise unable to reach
  - Spiral Ladder, Step Ladder, Extension Ladder and Rope Ladder

- Learning Design by Doing

2.4 Learning and Doing Engineering Design III

Personal mobility devices to transport people unable to use their legs

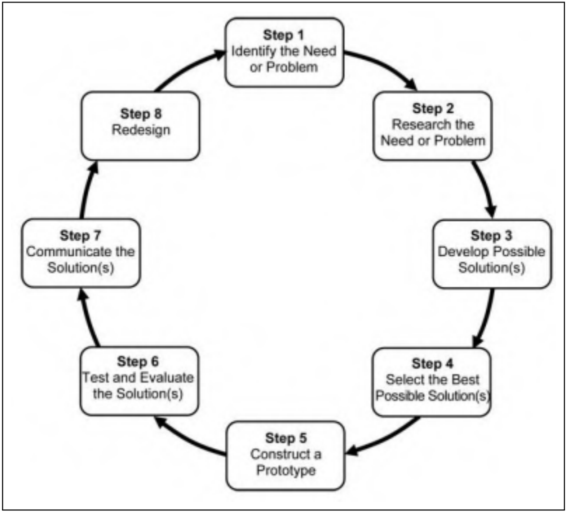
2.4 Learning and Doing Engineering Design IV

- There could be **trade-offs among design variables**
  - Eg: Design of a juice container
  - Material, thickness etc.
- Designers have obligations not only to clients and users, but also to their profession and to the public at large
- Design **Teams**
  - Many engineering problems are inherently **multidisciplinary**
  - eg: Design of medical instrument

3. Design Process I

- Design Process: A process of **questioning**
- Clarify what the client wants in order to translate those wishes into meaningful **objectives (goals), constraints(limits),** and **functions (what the design has to do)**
- Designer must fully understand what is needed from the final design
- The designer must be able to translate the clients wishes into the languages of engineering design (e.g., words, pictures, numbers, rules, formulas, and properties) in order to **model, analyze, test, evaluate, refine, optimize**, and finally **document** the design

3. Design Process II



3.1 Designing a Safe Ladder I

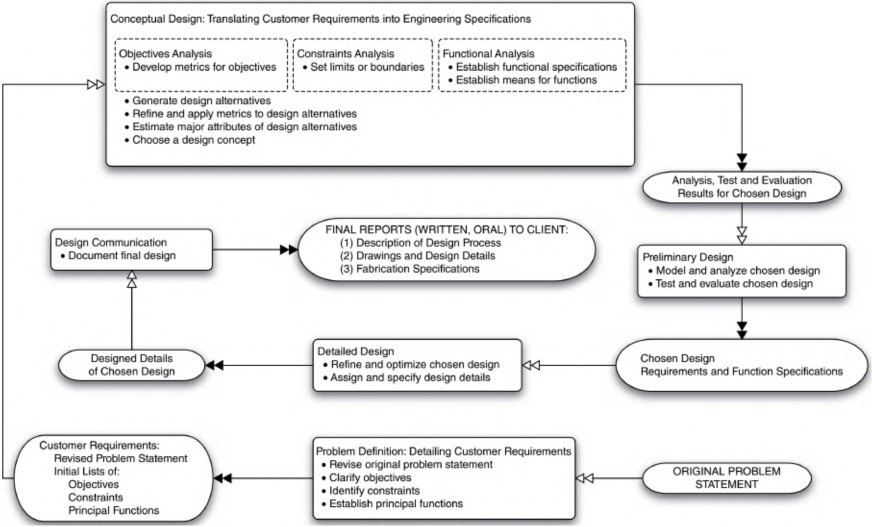
1. Establish clients **objectives**
   - Why do you want another ladder?
   - How will the ladder be used?
   - What market we are targeting?
2. Identify the **constraints** that govern the design
   - What does ‘safe’ mean?
   - Whats the most you are willing to spend
3. Establish **functions** that the design must perform and suggest **means** by which those functions can be performed
   - Can the ladder lean against a supporting surface?
   - Must the ladder support someone carrying something?
4. Establish **specifications** for the design
   - How much weight should a safe ladder support?
   - How high should someone on the ladder be able to reach?
5. Generate **design alternatives**

3.1 Designing a Safe Ladder II

- Could the ladder be a stepladder or an extension ladder?
- Could the ladder be made of wood, aluminum, or fiber glass?

6. **Model and analyze** the design
   - What is the maximum stress in a step supporting the ‘design load’?
   - How does the bending deflection of a loaded step vary with the material of which the step is made?
7. **Test and evaluate** the design
   - Can someone on the ladder reach the specified height?
   - Does the ladder meet OSHAs safety specification?
8. **Refine and optimize** the design
   - Are there other ways to connect the steps?
   - Can the design be made with less material?
9. **Document** the design process and **communicate** the completed design
   - What is the justification for the design decisions that were made?
   - What information does the client need to fabricate the design?

3.2 Prescriptive Model of the Design Process I



3.2 Prescriptive Model of the Design Process II

- *Checklist* to ensure that all of the *required steps* have done
- **Prescriptive Model**
  1. **Problem Definition**
     - Frame the problem by delineating the customer requirements
     - Clarify the clients objectives
     - Identify constraints
     - Establish functions before beginning conceptual design
     - eg: Safe Ladder
  2. **Conceptual Design**
     - Generate different concepts or schemes to achieve a clients objectives, satisfy constraints, and perform functions
     - Estimate costs, weights,overall dimensions etc
     - Translate the customer requirements into engineering specifications
     - eg:Extension of Ladder, a stepladder, or a rope ladder etc.
  3. **Preliminary Design**
     - Select and size the major subsystems, based on lower-level concerns that take into account the performance and operating requirements

3.2 Prescriptive Model of the Design Process III

- eg: For a stepladder, size the side rails and the steps, decide how to fasten the steps to the side rails etc.

4. **Detailed Design**
   - Design with much greater detail, refining the choices made in preliminary design down to specific part types and dimensions
   - Use detailed design knowledge and procedures expressed in specific rules, formulas, and algorithms that are found in design codes (e.g., the ASME Pressure Vessel and Piping Code, the Universal Building Code), handbooks, databases, and catalogs.
5. **Design Communication**
   - Present the design process, the resulting final design, and its fabrication specifications
   - Tracking and organizing the work products and documents

3.3 Detailing Customer Requirements I

- Lists of Design Attributes → **Questioning**
- Design a new ladder for electricians or other maintenance and construction professionals working on conventional job sites
  - What features or behaviors would you like the ladder to have?
  - What do you want this ladder to do?
  - Are there already ladders on the market that have similar features?
  - How are you going to use it?
  - Are there things or circumstances you want us to avoid?

3.3 Detailing Customer Requirements II

Characteristics	O	C	F	M
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	✓			
Step deflections must be less than 0.05 in.		✓		
Must support weight of an average worker			✓	
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	✓			

3.4 Setting Design Objectives I

- 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

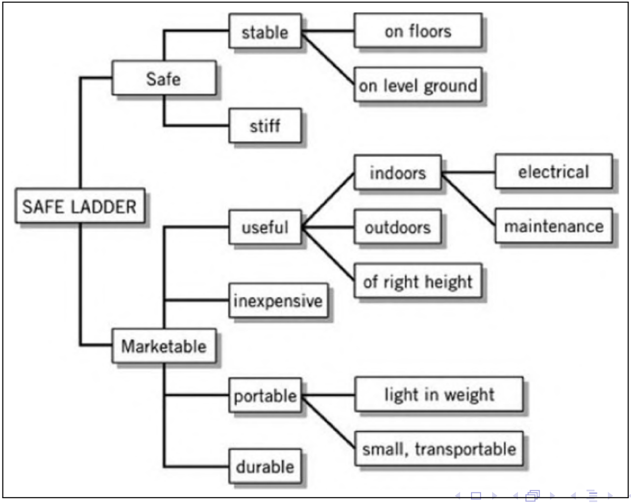
3.4 Setting Design Objectives II

- Indented list of the 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

3.4 Setting Design Objectives III

- Representing Lists of Objectives in Objectives Trees



3.4 Setting Design Objectives IV

- Rank Ordering Objectives with **Pairwise Comparison Charts**

Goals	Cost	Portability	Convenience	Durability	Score
Cost	••••	0	0	1	1
Portability	1	••••	1	1	3
Convenience	1	0	••••	1	2
Durability	0	0	0	••••	0

3.5 Identifying Constraints I

- **Constraint** : A limit or restriction on the designs behaviours or attributes
- Constraints are typically framed as a binary yes or no choice
  - A ladder material is a conductor or not
  - Step deflection is less than 1mm or not
- Any designs that violate these limits are unacceptable
- Constraints limit the size of a **design space** by forcing the exclusion of unacceptable alternatives

3.5 Identifying Constraints II

- Types of Constraints
  1. Functional Constraints (Overall geometry constraints, materials used, Control system etc.)
  2. Safety constraints
  3. Quality constraints
  4. Time constraints
  5. Economical constraints
  6. Ecological constraints
  7. Legal and Ethical Constraints
  8. Ergonomic and Aesthetic constraints

3.5 Identifying Constraints III

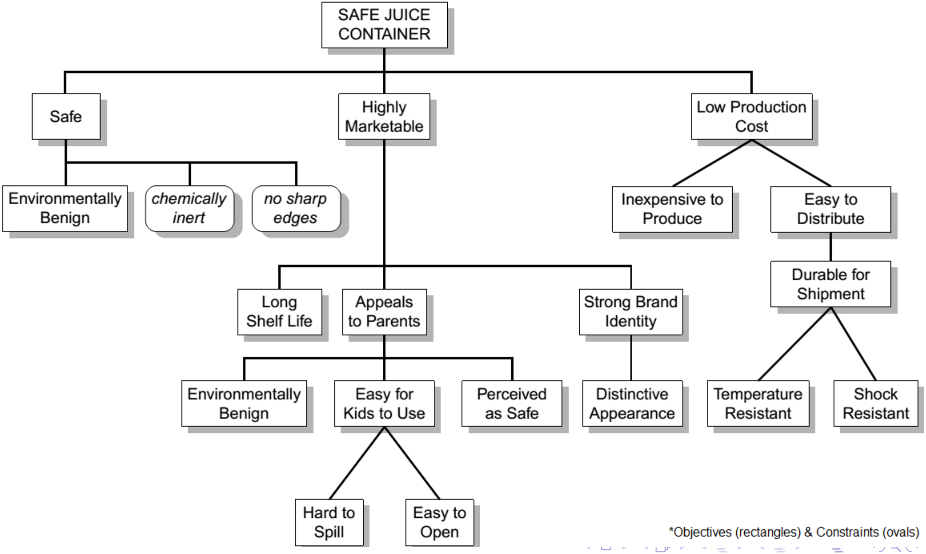
- Constraints for the design of safe ladder

Characteristic	O	C	F	M
Step deflections should be less than 0.05 in.		✓		
Must meet OSHA requirements		✓		
Must not conduct electricity		✓	✓	

- Constraints for the new juice container

Chemically Inert
No Sharp Edges

3.5 Identifying Constraints IV



*Objectives (rectangles) & Constraints (ovals)

3.6 Establishing Functions I

- **Function** : Those things a designed device or system is supposed to do
- *Transforming an input into an output*
- 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 etc

3.6 Establishing Functions II

- Classification of Functions
  1. **Basic Functions**
     - Specific, overall function that must be performed
  2. **Secondary Functions**
     - Other functions needed to perform the basic function or those that result from doing the basic function
     - **Required Secondary Functions**: Secondary functions those are needed for the basic function. For example, the basic function of an overhead projector is to project images. This requires several secondary functions, including converting energy, generating light and focusing images
     - **Unwanted Secondary Functions**: eg: For a projector, generating heat and generating noise etc.

3.6 Establishing Functions III

Design Specifications

1. **Prescriptive specifications**
   - Specify values for attributes of design
   - eg: "A juice container must be made of at least 50% recyclable plastic
   - "A ladder step shall be made from Grade A fir, have a thickness of at least 0.75 in., have a length that does not exceed 80 in., and be attached to the side rails through a full-width groove at each end"
2. **Procedural specifications**
   - Specify procedures for calculating attributes
   - eg: "The juice container must be disposable as stipulated by EPA standards"
   - "The maximum bending stress σ_{max} in a ladder step shall be calculated from $\sigma_{max} = Mc/I$"

3.6 Establishing Functions IV

3. **Performance specifications**
   - Specify performance levels that a function must demonstrate to be successful
   - eg: "A juice container must contain 75 ml"
   - "A ladder step shall support an 400 kg"

3.6 Establishing Functions V

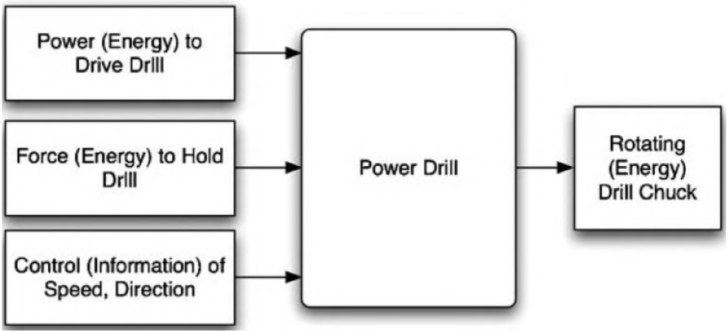
- Tools for establishing functions
  1. Black Boxes and Glass Boxes
  2. Dissection or Reverse Engineering
  3. Enumeration
  4. Function-Means Trees

3.6.1 Black Boxes and Glass Boxes I

- Used for understanding the connections between inputs and outputs
- A graphic of the system or object being designed, with inputs shown entering the box on its left hand side and outputs leaving on the right
- All of the known inputs and outputs should be specified, even undesirable by products that result from unwanted secondary functions
- eg: Black box for a power drill
  - Power drill transforms the controlled power input into a rotating chuck, in which we can insert a drill bit to drill a hole or a screwdriver blade to drive a screw
  - Inputs: a source of electrical power (electrical energy), a supporting force (mechanical work) that holds or grasps the drill, and the control of speed and direction (information) of the drill chuck's rotation
  - Outputs: a rotating chuck and a force holding the drill

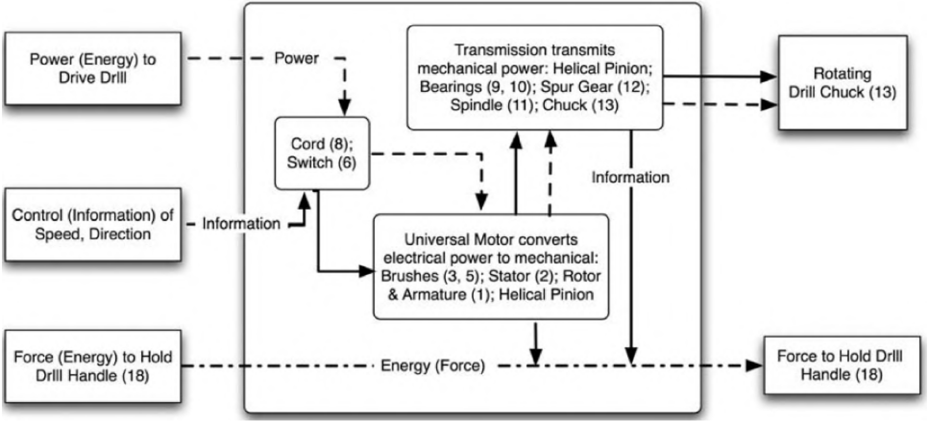
3.6.1 Black Boxes and Glass Boxes II

Black Box of Power Drill



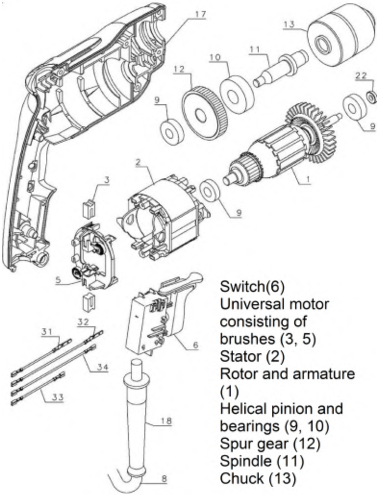
3.6.1 Black Boxes and Glass Boxes III

Glass Box of Power Drill



3.6.1 Black Boxes and Glass Boxes IV

Power Drill



3.6.2 Dissection or Reverse Engineering

- Dissect, deconstruct, or disassemble the product
- Find out the details how each part works and then apply it in the new design problem
- Reverse engineering: Looking at the parts (eg: gears, levers, circuit elements) that are used in a design or a device, and asking what functions those parts perform. Then look for alternative ways to do the same things

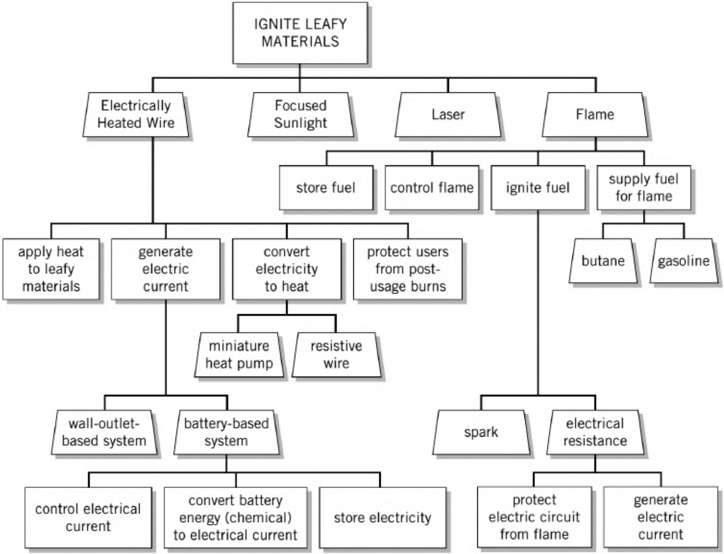
3.6.3 Enumeration

- Enumerate or list all of the functions that we can readily identify from a product $\rightarrow$ basic functions of the device

3.6.4 Function-Means Trees I

- Function-means tree is a graphical representation of a design's basic and secondary functions
- The tree's top level shows the **basic functions** to be met
- Each succeeding level alternates between showing the means (in trapezoids) by which the primary functions might be implemented and the secondary functions (in rectangles) necessitated by those means

3.6.4 Function-Means Trees II



3.7 Generating Design Alternatives

- Design Space
- Defining a Design Space by Generating a Morphological Chart

3.7.1 Design Space

- Design space: an imaginary intellectual region of design alternatives that contains all of the potential solutions to our design problem
- A large design space suggests a design domain with a large number of acceptable designs, or a design problem with a large number of design variables
- **Morphological Chart**: a formal tool for generating design spaces and for generating within those spaces a population of designs that perform the functions we specify

3.7.2 Defining a Design Space by Generating a Morphological Chart I

- Morphological chart is a matrix in which the leftmost column is a list of all of the **principal functions** that the design must perform and also some of the key features it must have
- The list should be of a manageable size, and all of the entries should be at the same level of detail to help ensure consistency
- Across from each of the functions or features, list each of the different means of realizing the function or feature

3.7.2 Defining a Design Space by Generating a Morphological Chart II

- Morphological chart for the juice container design problem

MEANS FUNCTION	1	2	3	4	5	6
Contain Liquid	Can	Bottle	Bag	Box	••••	••••
Fill and Seal Container	Fill and Heat Seal	Sealed Cap	Glue Container Material	Twist Top	Bottle Cap	
Empty Container	Pull Tab	Inserted Straw	Twist Top	Tear Corner	Unfold Container	Zipper
Resist Forces	Thick Walls	Flexible Materials				
Identify Product	Shape of Container	Distinctive Label	Color	••••	••••	••••

3.7.2 Defining a Design Space by Generating a Morphological Chart III

- Morphological chart for the juice container design problem with **two feasible design alternatives** whose means are dark and light shaded

MEANS / FUNCTIONS	1	2	3	4	5	6
Contain Liquid	Can	Bottle	Bag	Box	••••	••••
Fill and Seal Container	Fill and Heat Seal	Sealed Cap	Glue Container Material	Twist Top	Bottle Cap	
Empty Container	Pull Tab	Inserted Straw	Twist Top	Tear Corner	Unfold Container	Zipper
Resist Forces	Thick Walls	Flexible Materials				
Identify Product	Shape of Container	Distinctive Label	Color	••••	••••	••••

3.7.2 Defining a Design Space by Generating a Morphological Chart IV

- Morphological chart for the juice container design problem with **two infeasible design combinations** whose means are also dark and light shaded

MEANS / FUNCTIONS	1	2	3	4	5	6
Contain Liquid	Can	Bottle	Bag	Box	••••	••••
Fill and Seal Container	Fill and Heat Seal	Sealed Cap	Glue Container Material	Twist Top	Bottle Cap	
Empty Container	Pull Tab	Inserted Straw	Twist Top	Tear Corner	Unfold Container	Zipper
Resist Forces	Thick Walls	Flexible Materials				
Identify Product	Shape of Container	Distinctive Label	Color	••••	••••	••••

3.8 Choosing a Design

- Evaluate design alternatives and choose the best one
- Metrics are used as a way to measure the achievement of objectives
- Design alternatives that dont meet constraints must be immediately rejected as infeasible
- Types
  1. Numerical Evaluation Matrices
  2. Priority Checkmark Method
  3. The Best-of-Class Chart

3.8.1 Numerical Evaluation Matrices I

- Design of new juice container
  1. A glass bottle with a distinctive shape
  2. An aluminium can with a pull tab and a clever label
  3. A Mylar bag where the juice is accessed via a straw
  4. A polyethylene bottle with a screw cap

3.8.1 Numerical Evaluation Matrices II

- Numerical evaluation matrix for the design of juice container

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	×	×		
C: Chemically inert				
O: Environmentally benign			80	40
O: Easy to distribute			40	60
O: Long shelf life			90	100

- **Constraints** (upper rows) and **objectives** (lower rows) in the left-hand column
- Rule out glass bottles and aluminium containers because they violate a constraint because of their potential for sharp edges
- Choose the best design based on the **values of their clients**

3.8.2 Priority Checkmark Method I

- Rank objectives as high, medium, or low in priority
- Objectives with high priority are given three checks, those with medium priority are given two checks, while objectives with low priority are given only one check
- Metric results are assigned as 1 if they are awarded more than some arbitrary, but high value, such as 70 points (on a scale of 0-100), and as 0 if their award is less than the target value
- Easy to use, makes the setting of priorities rather simple, and is readily understood by clients and by other parties
- But priority checkmark loses considerable information that may be useful in differentiating between relatively close alternatives

3.8.2 Priority Checkmark Method II

Design Constraints and Objectives	Priority (✓)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges		×	×		
C: Chemically inert					
O: Environmentally benign	✓✓✓			1 × ✓✓✓	0 × ✓✓✓
O: Easy to distribute	✓			0 × ✓	1 × ✓
O: Long Shelf Life	✓✓			1 × ✓✓	1 × ✓✓

3.8.3 The Best-of-Class Chart I

- For each objective, assign scores to each design alternative that start from 1 for the alternative that meets that objective best, increasing to 2 for second-best, and so on, until the alternative that met the objective worst is given a score equal to the number of alternatives being considered
- eg: If there are seven alternatives, then the best at meeting a particular objective would receive a 1, and the worst a 7
- Ties are allowed (eg: two “firsts” would each get a score of $(1+2)/2 = 1.5$ and a tie between the “second” and “third” would get $(2+3)/2 = 2.5$)
- Check if a design that is Pareto optimal (best in all categories), or at least best in the most important (ie, highest ranked) objectives

3.8.3 The Best-of-Class Chart II

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	*	*		
C: Chemically inert				
O: Environmentally benign			1	2
O: Easy to distribute			2	1
O: Long shelf life			2	1

3.8.3 The Best-of-Class Chart III

- **Advantages**
  - It allows to evaluate alternatives with respect to the results for each metric, rather than simply treat as a binary yes/no decision as in case of priority checkmarks
  - It is relatively easy to implement and explain
  - The ranking methods also allow for qualitative evaluations and judgments
  - This method can also be done by individual team members or by a design team as a whole to make explicit any differences in rankings or approaches
- **Disadvantages**
  - Encourages evaluation based on opinion rather than testing or actual metrics
  - It shows only the rankings, but not the actual score
  - It do not reveal if the first and second results are close or not, which could be important information

3.9 Case Studies

- Bicycle
- Headphone
- Helmet
- Carry Bag
- Wrist Watch

3.9.1 Bicycle I

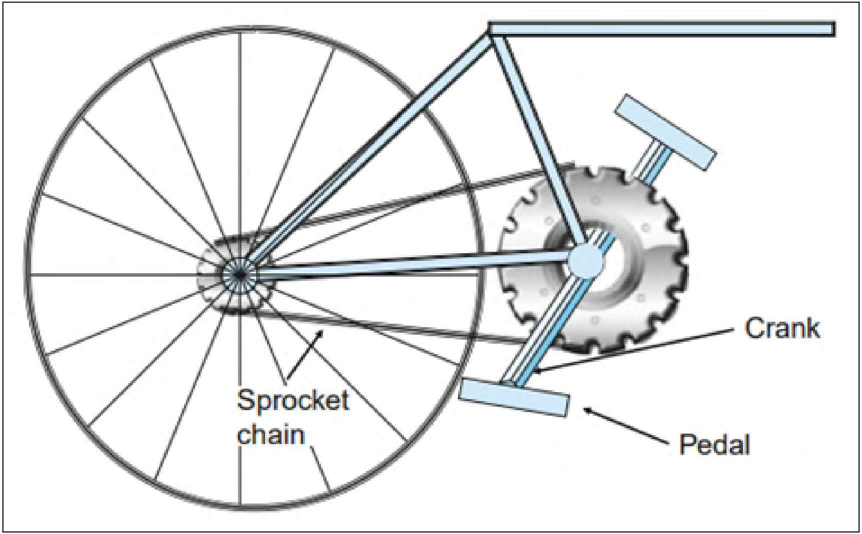
- Draw a conceptual sketch of what happens when you push on the pedal of a bicycle.

3.9.1 Bicycle II

Points to remember..

- What are the key components that connect the pedal to the wheel?
- Which ones are connected to each other?
- How does doing something to one of the components affect the others?
- What do those connections and changes have to do with accomplishing the task of accelerating the bicycle?

3.9.1 Bicycle III



3.9.1 Bicycle IV

- Pedal is connected to a crank, and the crank is connected to a sprocket
- A chain connects the sprocket to a smaller sprocket on the rear wheel
- Smaller sprocket is connected to some type of transmission with gears that turns the rear wheel

3.9.2 Headphone

- Write the **objectives**, **constraints**, **functions**, and **means**.

3.9.3 Helmet

- Write the **objectives**, **constraints**, **functions**, and **means**.

3.9.4 Carry Bag I

Identifying and detailing customer requirements

- Design an eco-friendly and biodegradable carry bag which can hold a weight of 5 kg.

3.9.4 Carry Bag II

- Objectives
  - To design an eco-friendly and biodegradable carry bag which can hold a weight of 5 kg
- Constraints
  - It should be eco-friendly and biodegradable
  - It should be able to carry a weight of 5 kg
- Functions
  - Cost estimation
  - Modeling and developing carry bag
- Generating design alternatives
  - Carry bag made of paper, plastic, cloth, jute etc.
- Choosing the best design

3.9.4 Carry Bag III





3.9.5 Wrist Watch I

- With the help of hand sketches, design a wrist watch showing the different design stages.

3.9.5 Wrist Watch II

- Identifying and detailing the customer requirements
  - Write the various possible requirements of the customer
  - Watch should show the time accurately
  - Wrist watch
- Setting objectives
  - Write all possible objectives
  - Ensure whether the design is possible using existing technology, allotted budget and time schedule
- Identifying design constraints
  - Identify the possible constraints while designing a wrist watch
  - It should have a strap or chain to tie on the wrist
  - Design should follow ISI/ISO standards
  - Weight should be less than 200 grams

3.9.5 Wrist Watch III

- Establishing functions
  - Write actual functions of the wrist watch
  - It should display time accurately
  - It should be a cell/battery/ solar powered
  - It should be able to tied on wrist
  - It should be pleasing, simple and light weighted
- Generating design alternatives
  - Analog watches, digital watches or smart watches
  - Leather strap or chain strap with different colours
  - Round, rectangle, oval or square shaped dial
  - Number pattern (Numeric, roman numbers etc.)
  - Draw free hand sketches to show the conceptual design

3.9.5 Wrist Watch IV

- Choose the best design
- Detailed design
- Design communication
  - Final report
  - Written or oral
  - Description of design process, drawings,design and fabrication details

3.9.5 Wrist Watch V

Thank You

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Design and Engineering

(EST200)

S4 - EE

1. Design Thinking

- Design Thinking is a design methodology that provides a solution-based approach to solving problems
- Design thinking is a **non-linear, iterative process** that teams use to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test
- **Design thinking is an iterative process in which we seek to understand the user, challenge assumptions, and redefine problems in an attempt to identify alternative strategies and solutions that might not be instantly apparent with our initial level of understanding.**
- Especially useful to tackle problems which are ill-defined

1.1 Importance of Design Thinking I

- The *'Norman Door'*: best illustration of why design thinking and a human-centred approach are important
- *'Norman Door'* is a figurative term for any product that is cumbersome to use and was designed poorly.
- A Norman Door has a handle that you can grab, so you think that you need to pull it. But when you pull you realize it's actually a push.

1.1 Importance of Design Thinking II

- While logically thinking, placing a handle on the door is perfectly normal. But in the world of real people and real experiences, the handle is obsolete and confuses the user.

1.1 Importance of Design Thinking III

- Design thinking revolves around a deep interest in developing an understanding of the people for whom we are designing the products or services. It helps us to observe and develop empathy with the target user.
- Design thinking helps us in the process of questioning (questioning the problem, questioning the assumptions, and questioning the implications).
- Design thinking is extremely useful in tackling problems that are **ill defined** or unknown, by **reframing** the problem in **human-centric ways**, creating many ideas in **brainstorming sessions**, and adopting a hands-on approach in prototyping and testing.
- Design thinking also involves ongoing experimentation: sketching, prototyping, testing, and trying out concepts and ideas.

1.2 Pillars of Design Thinking I

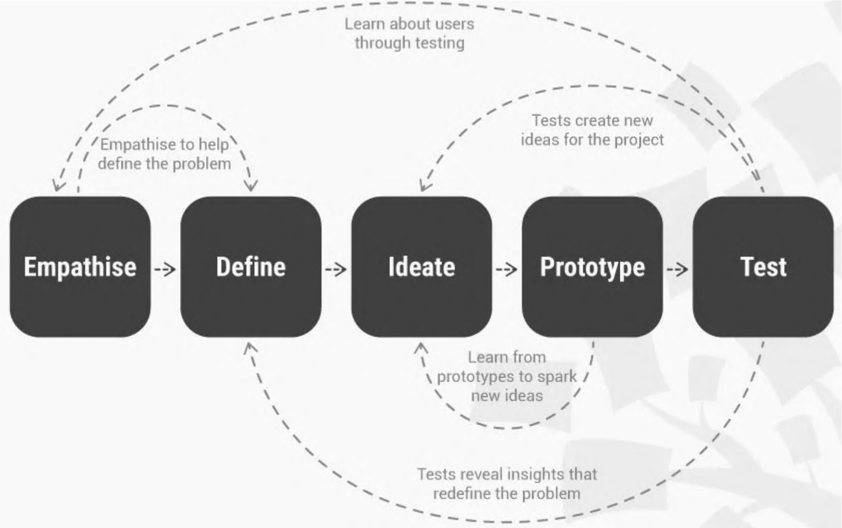
Three pillars of design thinking are

1. **Empathy**
   - Foundation of design thinking
   - Unless you get into the wants and needs of people you are designing for, what you're doing can't be considered design thinking
2. **Ideation**
   - Core of creative activities in the design thinking process
   - Multiple ideas are pitted against each other, where creativity is unleashed and innovation happens.
3. **Experimentation**
   - Are your assumptions correct?
   - Did you hit the right spot with your product?
   - What are users thinking about it?
   - Instead of guessing, **test it!**

2. Iterative Design Thinking Process Stages I

- Stages Iterative Design Thinking Process are not always **sequential**, and teams often run them in parallel, out of order and repeat them in an iterative fashion
- Stages of Iterative Design Thinking Process are
  1. Empathize
  2. Define
  3. Ideate
  4. Prototype
  5. Test

2. Iterative Design Thinking Process Stages II



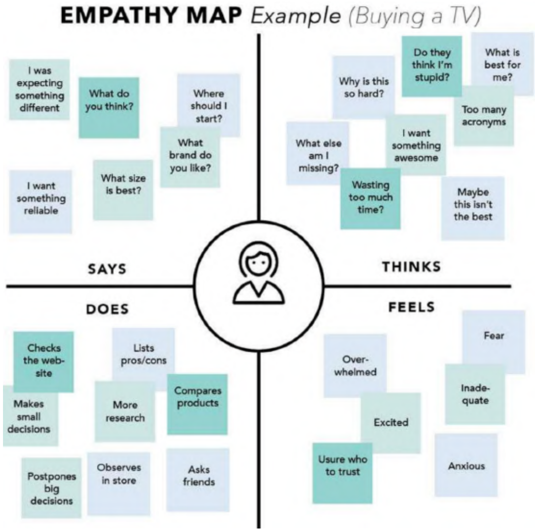
2.1 Empathize I

- First stage of the design thinking process
- Gain an empathetic understanding of the problem youre trying to solve, typically through user research
- Empathy is crucial to a human-centred design process because it allows you to set aside your own assumptions about the world and gain real insight into users and their needs
- Depending on time constraints, a substantial amount of information is gathered at this stage to use during the next stage and to develop the best possible understanding of the users, their needs, and the problems that underlie the development of that particular product

2.1 Empathize II

- Steps
  1. Observe
     - Observe how users interact with their environment
     - Capture quotes, behaviours and other notes that reflect their experience
     - Notice what they think, feel and need
  2. Engage
     - Interviews scheduled or ad-hoc
     - Learn how to ask the right questions
  3. Immerse
     - Find ways "to get into the users shoes"
     - Best way to understand the users needs

2.1 Empathize III



2.2 Define I

- State your users' needs and problems
- During the Define stage, you put together the information you have created and gathered during the Empathize stage.
- Analyze your observations and synthesize them to define the core problems you and your team have identified → **problem statements** - meaningful and actionable problem statements
  - Preserves emotion and needs of the individual you're designing for
  - Includes strong language
  - Uses sensible wording
  - Includes a strong insight
  - Generates lots of possibilities

2.2 Define II

- Problem statements are **concise descriptions** of design problems
- Design teams use them to define the current and ideal states, to freely find user-centered solutions
- eg: [User . . . (descriptive)] needs [need . . . (verb)] because [insight. . . (compelling)]

2.3 Ideate I

- Challenging assumptions and creating ideas for innovative solutions
- The solid background of knowledge from the first two phases means you can start to *"think outside the box"*, look for alternative ways to view the problem and identify innovative solutions to the problem statement you've created
- It is important to get as many ideas or problem solutions as possible at the beginning of the Ideation phase
- **Brainstorming** is particularly useful.
- Brainstorming is a method design teams use to generate ideas to solve clearly defined design problems.
- Find the best way to either solve a problem or provide the elements required to circumvent it.

2.3 Ideate II

- Ideate - **Brainstorming**
  - Brainstorming is a group creativity technique by which efforts are made to find a conclusion for a specific problem by gathering a list of ideas spontaneously contributed by its members.
  - Participants write down their ideas on paper
  - They pass on their own piece of paper to another participant
  - The other participant elaborates on the first person's ideas and so forth.
  - Another few minutes later, the individual participants will again pass their papers on to someone else and so the process continues.
  - The process takes 15 minutes
  - Ideas are discussed afterwards

2.4 Prototype I

- **Experimental phase**
- The aim is to identify the best possible solution for each problem found.
- Prototypes may be shared and tested within the team itself, in other departments, or on a small group of people outside the design team.
- Team should produce some inexpensive, scaled-down versions of the product (or specific features found within the product) to investigate the ideas you've generated.

2.4 Prototype II

- The solutions are implemented within the prototypes, and, one by one, they are investigated and either **accepted**, **improved** and **re-examined**, or **rejected** on the basis of the users' experiences.
- By the end of this stage, the design team will have a better idea of the constraints inherent to the product and the problems that are present, and have a clearer view of how real users would behave, think, and feel when interacting with the end product.

2.4 Prototype III

- Types of Prototyping
  1. **Low Fidelity Prototyping**
     - Use basic models or examples
     - Just some features are included
     - Methods: Storyboarding, Sketching, Card sorting etc.
     - Quick and inexpensive but it lack realism
  2. **High Fidelity Prototyping**
     - Look and operate closer to the finished product
     - For example, a 3D plastic model with movable parts is having high fidelity in comparison to, say, a wooden block
     - Allows users to manipulate and interact with a device in the same manner as the final design
     - Likewise, an early version of a software system developed using a design program such as Sketch or Adobe Illustrator is high-fi in comparison to a paper prototype.
     - It has higher level of validity and applicability but it takes much longer to produce than low-fi prototypes.

2.5 Test I

- Final stage of iterative design thinking process
- Results generated during the testing phase are often used to redefine one or more problems and inform the understanding of the users, the conditions of use, how people think, behave, and feel, and to empathise.
- Evaluators rigorously test the prototypes
- Can return to previous stages to make further iterations, alterations and refinements - to find or rule out alternative solutions.
- Chance to gather feedback, refine solutions, and continue to learn about your users.
- *Prototype as if you know you're right, but test as if you know you're wrong*

2.5 Test II

- Design thinking is a **non-linear process**
  - For example, different groups within the design team may conduct more than one stage concurrently, or the designers may collect information and prototype during the entire project so as to enable them to bring their ideas to life and visualise the problem solutions.
  - Also, results from the testing phase may reveal some insights about users, which in turn may lead to another brainstorming session (Ideate) or the development of new prototypes (Prototype)

3. Divergent and Convergent Thinking I

- Divergent and convergent thinking are two complementary methods to explore ideas, work towards goals, and address challenges
- Both approaches are necessary and lead to unique solutions for challenges that require exploration and creativity

3. Divergent and Convergent Thinking II

Divergent Thinking

- Divergent thinking is taking a challenge and attempting to identify all the possible drivers of that challenge, then listing all of the ways those drivers can be addressed.
- It is a thought process or method used to generate creative ideas by exploring many possible solutions
- It typically occurs in a spontaneous, free-flowing, "non-linear" manner, such that many ideas are generated in an emergent cognitive fashion
- Divergent thinking uses the imagination to open the mind to new possibilities and solutions, and ultimately become more innovative
- Typically, divergent thinking means that everyone involved in this type of thinking will look for unexpected combinations and connections between remote associations

3. Divergent and Convergent Thinking III

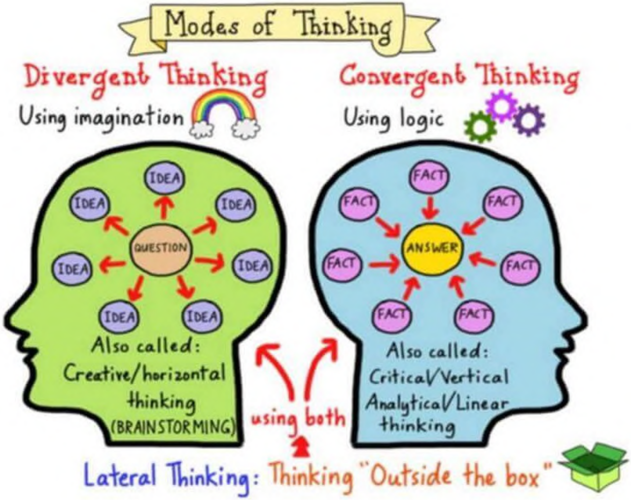
- Divergent thinking sparks creativity specifically because of its spontaneous non-linear nature.
- Divergent thinking is used in the initial stages of ideation on a project or task

3. Divergent and Convergent Thinking IV

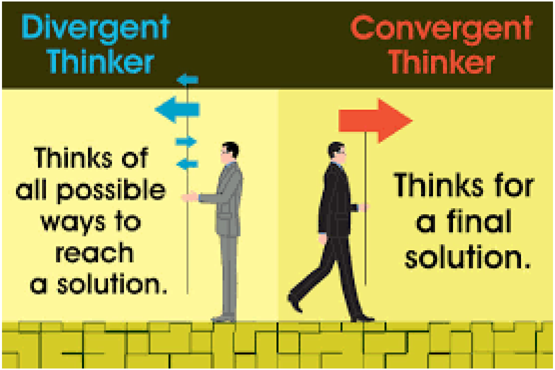
Convergent Thinking

- It is the opposite of divergent thinking
- It generally means the ability to give the "correct" answer to standard questions that do not require significant creativity, for instance in most tasks in school and on standardized multiple-choice tests for intelligence
- Convergent thinking moves from broad thoughts to concrete understanding
- Convergent thinking,is known as the practice of selecting the optimal solution from a finite set of ideas collected from different sources in order to solve a discrete challenge quickly and efficiently

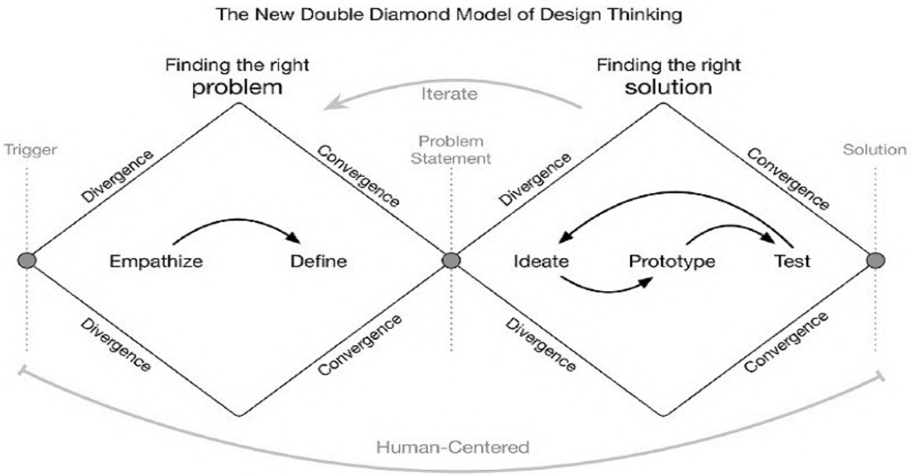
3. Divergent and Convergent Thinking V



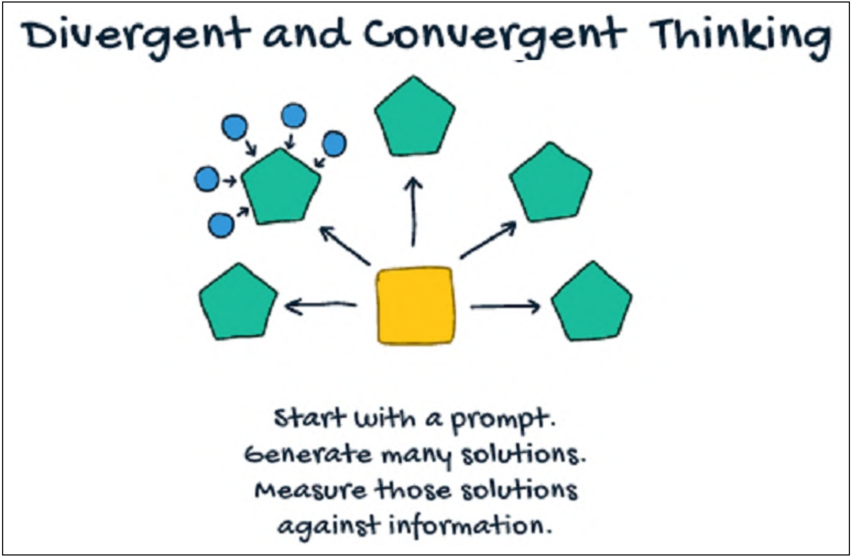
3. Divergent and Convergent Thinking VI



3. Divergent and Convergent Thinking VII



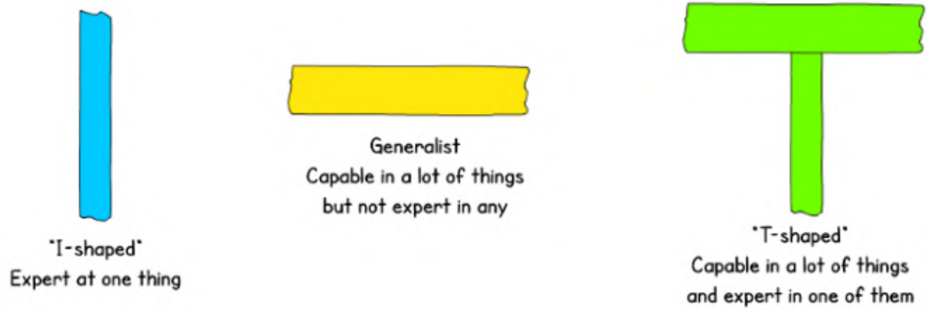
3. Divergent and Convergent Thinking VIII



4. Design Thinking in a Team Environment I

- Members of a Design Thinking team need to be open minded, curious, collaborative and allow their assumptions to be challenged, ready for change, and be adaptable.
- **Cross-disciplinary teams** will provide you with the best results.
- Teams may consist of people unfamiliar with each other, with external members brought on board either as specialists or facilitators depending on the availability of skills.
- To make a Design Thinking project successful, we need T-shaped people.
- T-shaped people have a depth of knowledge and experience in their own fields but they can also reach out and connect with others horizontally and create meaningful collaborations.
- All team members should be encouraged to respect each other's inputs, in order to discover deeper and to build upon each other's findings.

4. Design Thinking in a Team Environment II



4. Design Thinking in a Team Environment III

Characteristics of an Effective Team

- Team goals are as important as individual goals
- Team understands the goal and is committed to achieve them
- Trust replaces fear and teammates feel comfortable in taking risks
- Respect, collaboration and open mindedness are prevalent
- Team members communicate readily and diversity of options are encourage
- Decisions are made by consensus and have the acceptance and support of the members of the team

4. Design Thinking in a Team Environment IV

Steps in resolving conflicts

1. Prepare the resolution
   - Acknowledge the conflict
   - Discuss the impact
   - Agree to a cooperative process
   - Agree to communicate
2. Understand the situation
   - Clarify positions
   - List facts, assumptions and belief underlying each position
   - Analyse in small groups
   - Convene back as a team
3. Reach agreement

5. Case Studies I

Divergent Thinking - Case study of a pen

1. List out some of the uses of pen other than writing

- As a straw
- As a toy "telescope' for kids
- To rewind cassette tape
- Can be used as a paper punch
- Use as a ruler
- To make whistle

5. Case Studies II

2. List out some uses of fork other than as an eating aid

- To scramble things
- To mix things
- Scratcher
- To get something out of fire
- To open the bottle cap

5. Case Studies III

Question

- Illustrate the design thinking approach for designing a bag for college students within a limited budget. Describe each stage of the process and the iterative procedure involved. Use hand sketches to support your arguments.

5. Case Studies IV

Objective : To design a bag for college students in limited budget

1. Empathize
   - It should have a facility to carry books, tiffin box, water bottle and other small articles
   - It should be closed
2. Define
   - It should have separate racks for keeping books and tiffin box
   - It should have zips to close
   - It should be light weighted with sleek design
3. Ideate
   - Separate compartment to keep laptop
   - It should have a separate compartment outside to keep water bottle
   - It should have a small pouch on outside to keep necessary things like pen, keys, chargers etc
   - The shoulder strap should be of soft material
   - It should be water proof so that it can be used in rainy season too.

5. Case Studies V

- It should have an inner secret pouch to keep money or any other important thing

4. Prototype
   - Make the product

5. Case Studies VI

5. Test
   - Ensure that all the expected functionalities are incorporated in the product
   - The prototype shown in figure has separate racks for keeping books and laptop
   - It has water bottle holder outside
   - The shoulder strap is made of soft sponge material
   - The material used is waterproof polyester
   - It is light weighted and has sleek design

5. Case Studies VII

Question: Drug trolley in hospitals

- Construct a number of possible designs and then refine them to narrow down to the best design for a drug trolley used in hospitals. Show how divergent - convergent thinking helps in the design process. Provide your rationale for each step using hand sketches only.

5. Case Studies VIII

Objective: To design a drug trolley that can be used in hospitals

- Intended users: Hospital staff like nurses
- Scope/Domain: Hospitals
- Apply divergent - convergent thinking process

Primary functionalities:

- It should have wheels as we need to move it from one room to another
- It should have racks to keep medicines
- It should be light weighted with sleek design so that we can move it easily

5. Case Studies IX

Secondary functionalities

- The wheel should have a lock such that it can be prevented from moving when not in use
- It should have racks with closing doors or lids
- It should have separate racks pr cells for keeping drugs for each room patients
- It should have a facility to dispose medicinal wastes like used cotton, syringe etc.
- It should have an open table on the top to keep case dairy of patients

5. Case Studies X

Design 1

- Merits
  - Simple and light weight
  - Easier to keep medicines and boundaries are provided in all three sides which prevents medicines falling down while moving
- Limitations
  - Difficult to sort out medicines for each room
  - No doors for racks and no open table
  - No lock for wheels

5. Case Studies XI

Design 2

- Merits
  - Simple and light weight
  - Easier to keep medicines
- Limitations
  - Difficult to sort out medicines for each room
  - No doors for racks and no open table
  - No lock for wheels
  - As there are nor boundaries, there is a high chance of falling down the medicines while moving

5. Case Studies XII

Design 3

- Merits
  - Simple and light weight
  - Easier to keep medicines as boundaries and lids are provide for each rack
- Limitations
  - Difficult to sort out medicines for each room
  - No lock for wheels

5. Case Studies XIII

Design 4

- Merits
  - Simple and light weight
  - Easier to keep medicines as drawers are used
  - An open table is provide at top to keep case dairy/charts of patients
- Limitations
  - Difficult to sort out medicines for each room
  - No option for disposing clinical wastes

5. Case Studies XIV

Design 5

- Merits
  - Simple and light weight
  - Easier to keep medicines as drawers are used
  - An open table is provide at top to keep case dairy/charts of patients
  - Have both open and closed racks to keep drugs accordingly
- Limitations
  - Difficult to sort out medicines for each room
  - No option for disposing clinical wastes
  - No lock for wheels

5. Case Studies XV

Design 6

- Merits
  - Simple and light weight
  - Easier to keep medicines and sort out medicines for each patient as different partitions are provided for each rack
  - Have both open and closed racks to keep drugs accordingly
- Limitations
  - No open table is there on the top to keep case dairy/charts of patients
  - No options for disposing clinical wastes
  - No lock for wheels

5. Case Studies XVI

Design 7

- Merits
  - Simple and light weight
  - Easier to keep medicines and sort out medicines for each patient as different partitions are provided for each rack
  - Have both open and closed racks to keep drugs accordingly
  - Have facility to dispose clinical wastes
  - Have open table to keep patient charts/records
  - Wheels have locks

5. Case Studies XVII

Choosing the best design

- **Design 7** can be chosen as the best design as it incorporates all the primary as well as secondary functionalities of a drug trolley.

5. Case Studies XVIII

Question

- Construct a number of possible designs and then refine them to narrow down to the best design for a trolley used in super markets. Show how the divergent - convergent thinking helps in the process. Provide your rationale for each step by using hand sketches only.

5. Case Studies XIX

Thank You

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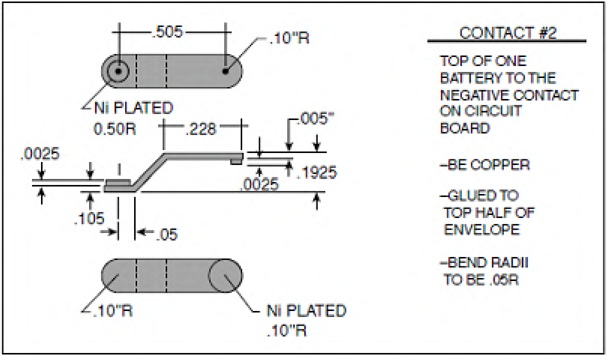
Design and Engineering

(EST200)

S4 - EE

1. Communicating Designs Graphically I

- A lot of information is created and transmitted in the engineering drawing process
- Design drawings: Sketches, Freehand drawings, Computer-aided design and drafting (CADD) models etc.



1. Communicating Designs Graphically II

- Graphic images are used to communicate with other designers, the client, and the manufacturing organization
- Sketches and drawings:
  - Serve as a launching pad for a brand-new design
  - Support the analysis of a design as it evolves
  - Simulate the behaviour or performance of a design
  - Record the shape or geometry of a design
  - Communicate design ideas among designers
  - Ensure that a design is complete
  - Communicate the final design to the manufacturing specialists

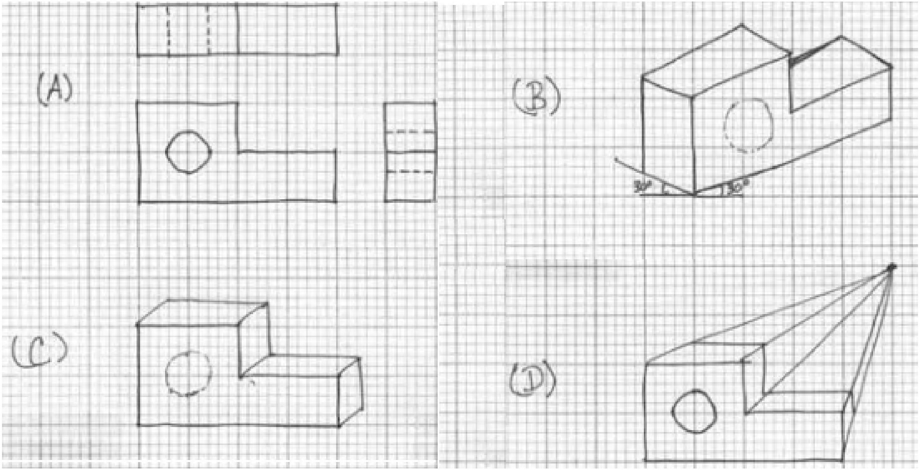
1.1 Engineering Sketches I

1. **Orthographic Sketches**
   - Lay out the front, right and top views of a part
2. **Axonometric Sketches**
   - start with an axis, typically a vertical line with two lines 30^o from the horizontal. This axis forms the corner of the part.
   - The object is then blocked in using light lines, with the overall size first.
   - Then vertical lines are darkened, followed by other lines.
   - All lines in these sketches are either vertical or parallel to one of the two 30^o lines.
   - Details of the part are added last.

1.1 Engineering Sketches II

3. **Oblique Sketches**
   - Front view is blocked in roughly first, depth lines are then added, and details such as rounded edges are added last.
4. **Perspective Sketches**
   - They are similar to oblique sketches in that the front view is blocked in first.
   - Then a vanishing point is chosen and projection lines drawn from the points on the object to the vanishing point.
   - The depth of the part is then blocked in using the projection lines.
   - Finally, the details are added to the part.

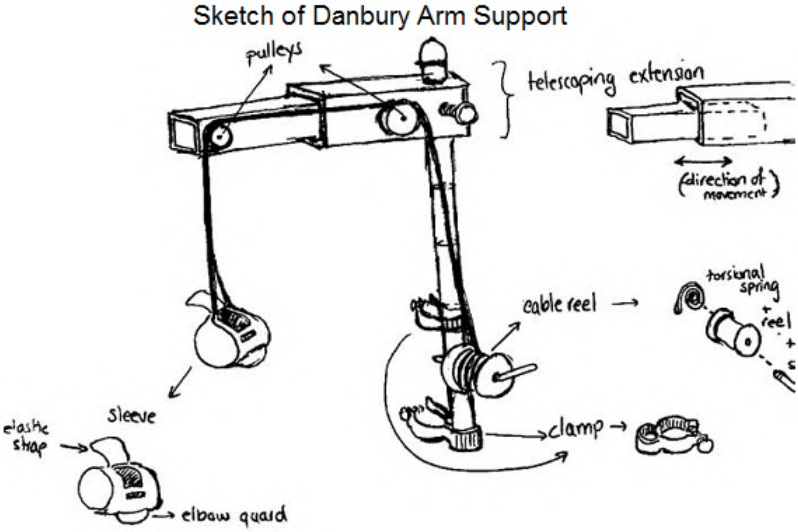
1.1 Engineering Sketches III



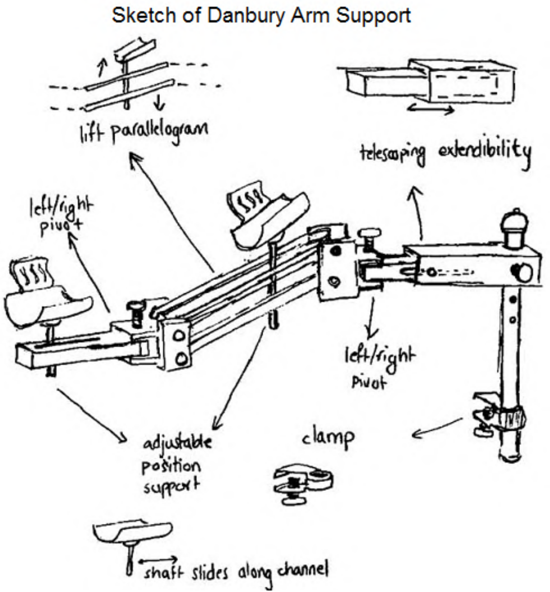
1.1 Engineering Sketches IV

- When we communicate design results to a manufacturer, we must think very carefully about the **fabrication specifications** that we are creating in drawings, as well as those we write
- We must ensure that our drawings are both appropriate to our design and prepared **in accordance with relevant engineering practices and standards**

1.1 Engineering Sketches V

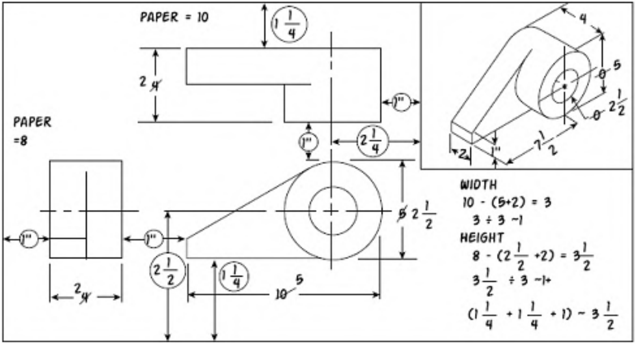


1.1 Engineering Sketches VI



1.2 Engineering Drawings I

1. Layout Drawings
   - Working drawings that show the major parts or components of a device and their relationship
   - They are usually drawn to scale, do not show tolerances, and are subject to change as the design process evolves



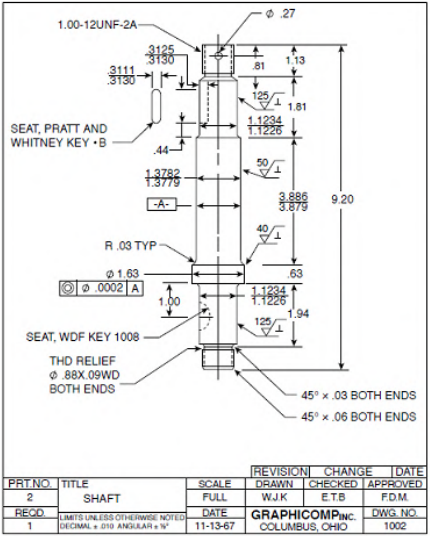
1.2 Engineering Drawings II

2. Detail Drawings
   - These drawings are used to communicate the details of our design to the manufacturer or machinist
   - They must contain as much information as possible while being both as clear and as uncluttered as possible
   - Show the individual parts or components of a device and their relationship
   - These drawings must show tolerances, and they must also specify materials and any special processing requirements
   - Detail drawings are drawn in conformance with existing standards, and are changed only when a formal change order provides authorization

1.2 Engineering Drawings III

- There are certain essential components that every drawing must have to ensure that it is interpreted as it is intended
  - standard drawing views
  - standard symbols to indicate particular items
  - clear lettering
  - clear, steady lines
  - appropriate notes, including specifications of materials
  - a title on the drawing
  - the designers initials and the date it was drawn
  - dimensions and units
  - permissible variations, or tolerances

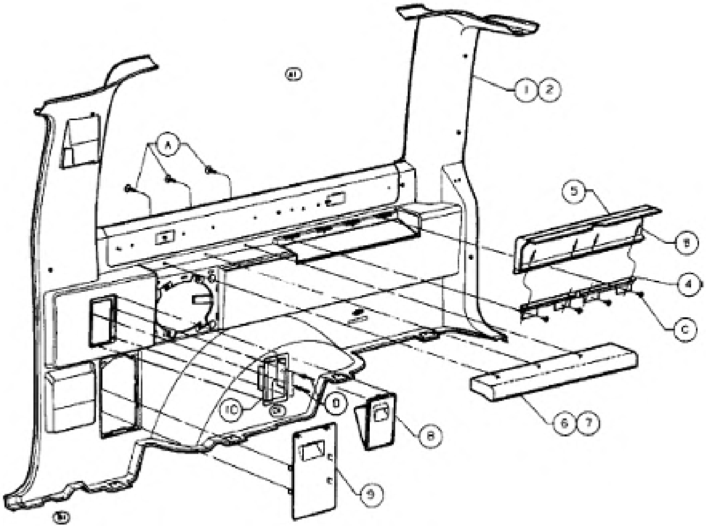
1.2 Engineering Drawings IV



1.2 Engineering Drawings V

3. Assembly Drawings
   - show how the individual parts or components of a device fit together
   - An exploded view is commonly used to show such “fit” relationships

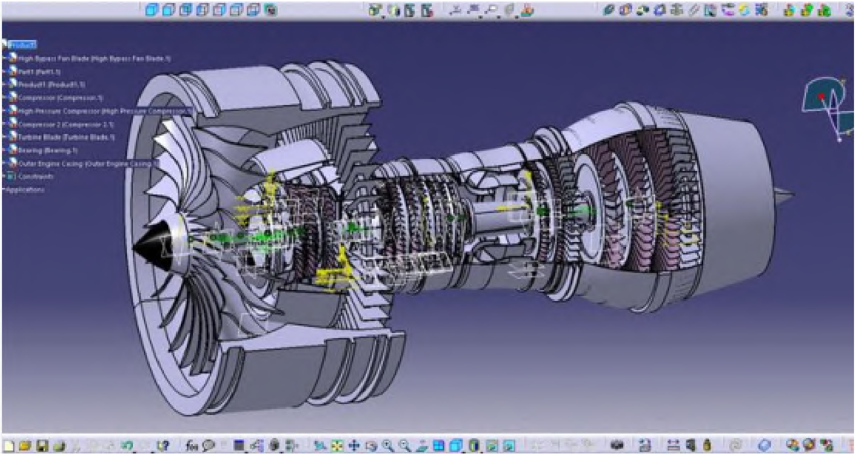
1.2 Engineering Drawings VI



1.2 Engineering Drawings VII

4. CADD Models
    - Good for digital visualization
    - The making of 3D models in computers software is called **geometric modelling**
    - CADD software provides many features such as colour rendering, shading, texting etc. to communicate the design more close to the reality
    - The modelled part can be rotated, sectioned and zoomed so that any complex shape can be communicated to the another person without confusion

1.2 Engineering Drawings VIII



2. Communicating Designs Orally and in Writing I

- **Reporting** is an essential part of a design project
- We communicate final design results in several ways, including oral presentations, final reports (that may include design drawings and/or fabrication specifications), and prototypes and models
- The primary purpose of such communication is to inform our client about the design, including explanations of how and why this design was chosen over competing design alternatives
- It is most important that we convey the results of the design process
- Presentations and reports should be lucid descriptions of design outcomes, as well as the processes with which those outcomes were achieved

2. Communicating Designs Orally and in Writing II

Guidelines

1. **Know your purpose**
   - This is the writing analog of understanding objectives and functions for a designed artefact
   - Design documentation seeks to inform the client about the features of a selected design
   - Design team may be trying to persuade a client that a design is the best alternative
   - A designer may wish to report how a design operates to users, whether beginners or highly experienced ones

2. Communicating Designs Orally and in Writing III

2. **Know your audience**
    - When documenting a design, it is essential that a design team structure its materials to its targeted audience
    - Taking time to understand the target audience will help ensure that its members appreciate your documentation

2. Communicating Designs Orally and in Writing IV

3. **Choose and organize the content around your purpose and your audience**
   - The key element is to structure the presentation to best reach the audience
   - There are many different ways to organize information
     - going from general concepts to specific details (analogous to deduction in logic)
     - going from specific details to general concepts (analogous to induction or inference)
     - describing devices or systems
   - Once an organizational pattern is chosen, no matter which form is used, the design team should translate it into a written outline. This allows the team to develop a unified, coherent document or presentation while avoiding needless repetition

2. Communicating Designs Orally and in Writing V

4. **Write precisely and clearly**
    - Effective use of short paragraphs that have a single common thesis or topic
    - Direct sentences that contain a subject and a verb; and active voice and action verbs that allow a reader to understand directly what is being said or done
    - Opinions or viewpoints should be clearly identified as such

2. Communicating Designs Orally and in Writing VI

5. **Design your pages well**
   - A long section divided into several subsections helps readers to understand where the long section is going, and it sustains their interest over the journey
   - Tables should be treated as a single figure and should not be split over a page break
   - Simple and direct slides encourage readers to listen to the speaker without being distracted visually
   - Text on a slide should present succinct concepts that the presenter can amplify and describe in more detail. A slide does not have to show every relevant thought
   - It is a mistake to fill slides with so many words (or other content) that audiences have to choose between reading the slide and listening to the speaker, because then the presenter's message will almost certainly be diluted or lost

2. Communicating Designs Orally and in Writing VII

6. **Think visually**
   - Visual representations are helpful to audiences to understand the idea clearly
   - A team should not allow their graphics' capabilities to seduce them into clouding their slides with artistic backgrounds that make the words illegible
   - Use the visual medium appropriately

2. Communicating Designs Orally and in Writing VIII

7. **Write ethically**
   - All results or test outcomes, even those that are not favourable, are presented and discussed
   - Ethical presentations also describe honestly and directly any limitations of a design
   - It is also important to give full credit to others, such as authors or previous researchers, where it is due

2. Communicating Designs Orally and in Writing IX

I. Introduction
II. Description of problem definition
  a. Problem statement
  b. Design objectives and constraints
III. Generation of design alternatives
  a. Morphological chart
  b. Description of design alternatives
  c. Description of subcomponents
IV. Design selection process
  a. Metrics description
  b. Metrics application
V. Final design
  a. Detailed description
  b. Prototype details
VI. Testing the design
VII. Conclusions
  a. Strengths and weaknesses of final design
  b. Suggestions for more advanced prototype
  c. Recommendations to the client
VIII. References
Appendix: Work breakdown structure
Appendix: Pairwise comparison chart

Outline of the Report

2. Communicating Designs Orally and in Writing X

Oral Presentations

- Knowing the audience: Who is listening?
- Presentation outline
    - Title slide
    - Roadmap for the presentation
    - Problem statement
    - Background material on the problem
    - Key objectives of the client and users
    - Key constraints
    - Functions
    - Design alternatives
    - Highlights of the evaluation procedure and outcomes
    - Selected design
    - Features of the design
    - Proof-of-concept testing
    - Demonstration of the prototype

2. Communicating Designs Orally and in Writing XI

  - Conclusions
- Visual events in presentation
- Practice
- Design reviews

3. Mathematical Modelling in Design I

- Mathematical Models are essential in design because we have to be able to predict the behaviour of the devices or systems that we are designing
- Representing the behaviour and function of real devices in mathematical terms
- How do we create mathematical models?
- How do we validate such models?
- How do we use them?
- Are there any limits on the use of mathematical models?

3. Mathematical Modelling in Design II

- Basic Principles of Mathematical Modelling
  - Why do we need a model?
  - For what will we use the model?
  - What do we want to find with this model?
  - What data are we given?
  - What can we assume?
  - What are the appropriate physical principles we need to apply?
  - What will our model predict?
  - Can we verify the model's predictions (i.e., are our calculations correct?)
  - Are the predictions valid (i.e., do our predictions conform to what we observe?)
  - Can we improve the model?

3. Mathematical Modelling in Design III

Dimensions and Units

- Every independent term that we use in equation has to be **dimensionally homogeneous or dimensionally consistent**, ie, every term has to have the same **net physical dimensions**
- The physical quantities used to model objects or systems represent concepts, such as time, length, and mass, to which we attach numerical measurements or values
- **Fundamental or primary quantities** can be measured on a scale that is independent of those chosen for any other fundamental quantities
  - eg: Mass, length, and time are usually taken as the fundamental mechanical dimensions or variables

3. Mathematical Modelling in Design IV

- **Derived quantities** generally follow from definitions or physical laws
  - eg : force is a derived quantity that is defined by Newton's law of motion
  - If mass, length, and time are chosen as primary quantities, then the dimensions of force are (mass $\times$ length)/(time)^2. We use the notation of brackets [ ] to read as "the dimensions of. "
  - If M, L, and T stand for mass, length, and time, respectively, then
    $$[F = force] = (M \times L)/(T)^2$$
  - $[\ A = \text{area}\ ] = (L)^2$
  - $[\ \rho = \text{density}\ ] = M/(L)^3$
- The units of a quantity are the numerical aspects of a quantity's dimensions expressed in terms of a given physical standard

3. Mathematical Modelling in Design V

Significant Figures

- The number of significant figures is equal to the number of digits counted from the first non-zero digit on the left to either
  - (a) the last non-zero digit on the right if there is no decimal point, or
  - (b) the last digit (zero or non-zero) on the right when there is a decimal point
- This notation or convention assumes that terminal zeroes without decimal points to the right signify only the magnitude or power of 10

3. Mathematical Modelling in Design VI

Measurement	Significant Figures	Assessment
5415	Four	Clear
5400	Two (54×10^2) or three (540×10^1) or four (5400)	Not clear
54.0	Three	Clear
54.1	Three	Clear
5.41	Three	Clear
0.00541	Three	Clear
5.41×10^3	Three	Clear
0.054	Two	Clear
0.0540	Two (0.054) or three (0.0540)	Not clear
0.05	One	Clear

3. Mathematical Modelling in Design VII

- We should always remember that the results of any calculation or measurement cannot be any more accurate than the least accurate starting value.
- Any calculation is only as accurate as the least accurate value we started with.

4. Prototyping and Proofing the Design I

- Focus on how to translate our design ideas into models and prototypes that can be used to test our design concepts and communicate our ideas to the client
- Prototypes are working models of designed artefacts
- They are tested in the same operating environments in which they're expected to function as final products
- Often the first step involves sketching or drawing of our design
- 3D representation
  - as an input to a computational modelling program to simulate the design's performance under specified conditions
  - as an input into a variety of rapid prototyping technologies, such as 3D printing
  - to generate detailed engineering drawings of the design
  - to guide the tool path in computer numerical-controlled (CNC) machining

4. Prototyping and Proofing the Design II

- Building a prototype depends on
  - the size and type of the design space
  - the costs of building a prototype
  - the ease of building that prototype
  - the role that a full-size prototype might play in ensuring the widespread acceptance of a new design
  - the number of copies of the final artefact that are expected to be made or built

4. Prototyping and Proofing the Design III

To construct a prototype:

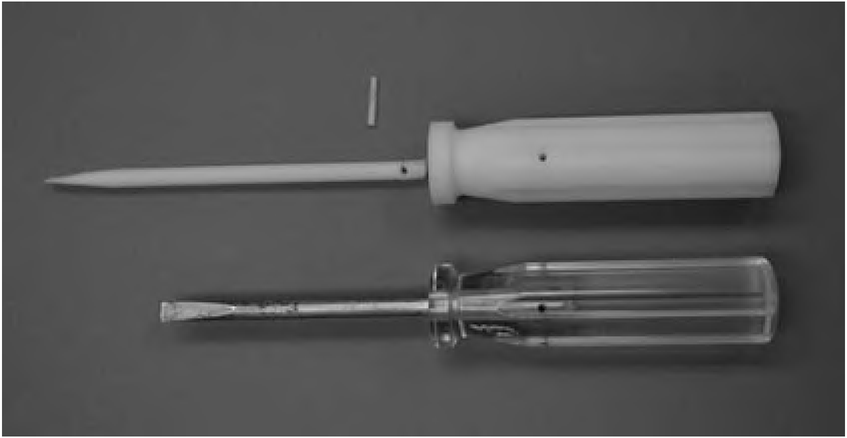
- Who is going to make it?
- Can we buy parts or components?
- How and from what, will the prototype be made?
- How much will it cost?

4. Prototyping and Proofing the Design IV

Techniques to construct a prototype:

- **Mock-ups**
  - Construct a mock-up of a 3D part from 2D cut-outs
  - 2D parts can be made using a vinyl cutter or a laser cutter, and parts are then assembled into 3D mock-ups of a design
  - Materials used for these mock-ups might be foam, thin plastic, or wood
- **Machining**
  - Machining parts or all of our prototypes ourselves in a machine shop
- **Rapid prototyping technologies**:
  - fast and cheap ways to fabricate prototypes
  - Rapid prototyping techniques use 3D CAD models as inputs, and convert these 3D files into thin 2D layers to build the 3D part
  - Rapid prototyping technologies include stereo-lithography and selective laser sintering, which involve using a laser to harden either a resin bath or a polymer powder in a particular configuration to build each layer

4. Prototyping and Proofing the Design V



3D printed (top) and machined (bottom) versions of a screwdriver

4. Prototyping and Proofing the Design VI

Prototypes, Models and Proof of Concept

- **Prototypes**
  - They are "original models on which something is patterned."
  - Also known as as "first full-scale and usually functional forms of a new type or design of a construction (such as an airplane)."
  - Prototypes are working models of designed artefacts.
  - They are tested in the same operating environments in which they're expected to function as final products.

4. Prototyping and Proofing the Design VII

- **Model**
  - It is "a miniature representation of something," or a "pattern of something to be made," or "an example for imitation or emulation."
  - Models are used to represent devices or processes.
  - Models may be paper models or computer models or physical models.
  - Models are used to illustrate certain behaviours or phenomena as we try to verify the validity of an underlying (predictive) theory.
  - Models are usually smaller and made of different materials than are the original artefacts they represent, and they are typically tested in a laboratory or in some other controlled environment to validate their expected behaviour.
- **Proof of Concept**
  - refers to a model of some part of a design that is used specifically to test whether a particular concept will actually work as proposed
  - doing proof-of-concept tests means doing controlled experiments to prove or disprove a concept

5. Case Studies

1. Prepare the 2D and 3D drawing of any two products with the following details
    - Design detailing
    - Material selection
    - Scale drawings with dimensions and tolerances(if any)

Thank You

*for internal private use only

Design and Engineering

(EST200)

S4 - EE

Module 4: Design Engineering Concepts I

1. Problem-based Learning and Project-based Learning in Design I

- There is growing evidence of the need to prepare engineering students for the future world in which they will practice as professionals.
- Educational practices that over-emphasise theory alone are outdated, as it is important for students to not only gain knowledge about engineering, but also to learn how to be an engineer.
- In order for students to practice as engineers, they need to have had exposure to a number of projects that offer real world problems, along with the complexity and uncertainty of factors that influence such problems
- Learning to apply theoretical principles is much better done when given real problems and hands-on activities in projects.

1. Problem-based Learning and Project-based Learning in Design II

- Design Engineering
  1. **Problem-based Learning**
  2. **Project-based Learning**

1.1 Problem-based Learning I

- How students can take up problems to learn design engineering?
- It empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem
- It is a teaching pedagogy which is **student-centred**
- Students learn about a topic through the solving of problems and generally work in groups to solve the problem
- Problem-based Learning crosses a broad spectrum of instructional patterns from total teacher control to more emphasis on self directed student inquiry.

1.1 Problem-based Learning II

Key Characteristics

1. **Problem-based:** It begins with the presentation of a real life (authentic) problem stated as it might be encountered by practitioners.
2. **Problem-solving:** It supports the application of problem-solving skills required in "practice". The role of the instructor is to facilitate the application and development of effective problem-solving processes.
3. **Student-centred:** Students assume responsibility for their own learning and faculty act as facilitators. Instructors must avoid making students dependent on them for what they should learn and know.
    - Strategies used: Using library resources, Using general reference text books, Preparing for class sessions, When working in groups, each person looks up one topic and then explains it to others etc

1.1 Problem-based Learning III

4. **Self-directed learning:** It develops research skills. Students need to learn how to get information when it is needed and will be current, as this is an essential skill for professional performance.
5. **Reflection:** This should take place following the completion of problem work, preferably through group discussion, and is meant to enhance transfer of learning to new problems.

1.1 Problem-based Learning IV

Typical steps in Problem-based Learning

1. Presentation of an “ill-structured” (open-ended and messy) problem
2. Problem definition or formulation of problem statement
3. Generation of a “knowledge inventory” (a list of ”what we know about the problem” and ”what we need to know”)
4. Generation of possible solutions
5. Formulation of learning issues for self-directed and coached learning
6. Sharing of findings and solutions

1.2 Project-based Learning I

- Project-based learning is an instructional approach where we learn by investigating a complex question, problem or challenge
- It promotes **active learning, engages students, and allows for higher order thinking**
- Students explore real world problems and find answers through the completion of a project
- Students also have some control over the project they will be working on, how the project will finish, as well as the end product

1.2 Project-based Learning II

- In project-based learning, teachers facilitate and guide students through the engineering design process, while students actively engage in research and problem solving activities within a team setting.
- The students need to produce **a solution to solve the problem** and are then required to produce **an outcome in the form of a report**.
- Teaching is considered as an input directing the learning process.
- The problem is open ended and the focus is on the application and assimilation of previously acquired knowledge.
- In a project, the **production of an end product is the focus of the students**.

1.2 Project-based Learning III

- Project based learning involves
  1. Knowledge
  2. Critical thinking
  3. Collaboration
  4. Communication

1.3 Problem-based Learning Vs Project-based Learning I

Similarities

- Focus on open ended task or question
- Provide authentic applications on content and skills
- Emphasize student independence and inquiry
- Longer and more multifaceted than traditional lessons and assignments

1.3 Problem-based Learning Vs Project-based Learning II

Differences

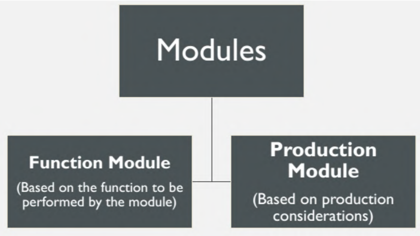
- Problem-based Learning
  - More likely to be a single subject and shorter
  - Often share the outcomes and jointly set the learning goals and outcomes
  - Provides specific steps
  - Uses scenarios and cases that are perhaps less related to real life
- Project-based Learning
  - Goals are set and quite structured
  - Often multidisciplinary and longer
  - Follows general steps
  - Incudes creation of a product or performance
  - Involves authentic tasks that solve real world problems

2. Modular Design

- Module means separate elements
- Modular design is an approach in which a product is designed for **assembling in module-wise fashion**
- Modular products are the artefacts that are composed of many modules
- These modules function together to get the overall function of the product
- Modular products can be machines, assemblies and components that fulfil various overall functions through the combination of distinct building blocks or modules
- In a **modular product** (or modular system), the overall function performed by the product is the results achieved through a combination of discrete units (**modules**)

2.1 Modularization

- Dividing a product into discrete units based on some criteria is called as modularization of a product
- Modular products or modular Systems are built up on separable or inseparable units called as modules
- The basic idea behind modular design is to organize a complex system as a set of distinct component that can be developed independently and then assembled together to perform a function



2.2 Modular Design Process I

Stages

1. Clarify the task
2. Establish function structure
3. Searching for solution principles and concept variants
4. Selecting and evaluating
5. Preparing design and dimensioned layouts
6. Preparing production document

2.2 Modular Design Process II

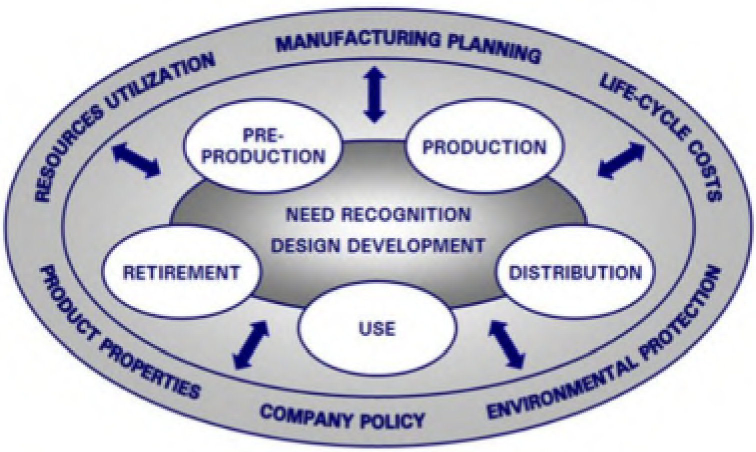
Advantages

- Minimizing cost
- Design of a singe part is easier as designer can concentrate only in one section
- Module can be separately improved without affecting the entire product
- A part of module can be updated
- Replacement of a parts becomes cheaper
- Shorten the design cycle
- Improves reliability and quality

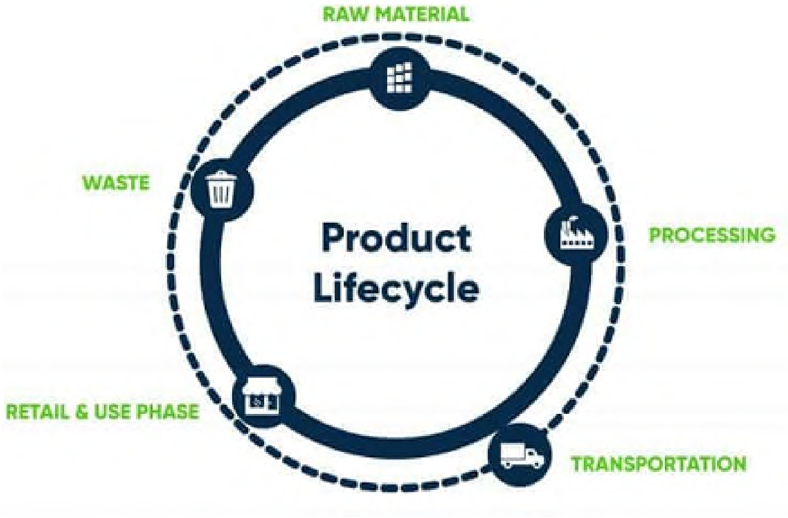
3. Life Cycle Design Approaches I

- The application of the **life cycle concept** to the design phase of the product development process is known as **Life Cycle Design (LCD)**
- It is a design process which takes into consideration of all the phases of a product's life cycle
  - Development
  - Production
  - Distribution
  - Use
  - Maintenance
  - Disposal
  - Recovery

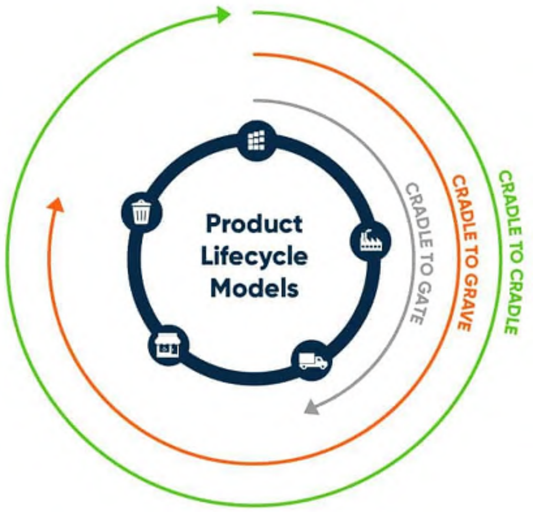
3. Life Cycle Design Approaches II



3. Life Cycle Design Approaches III



3. Life Cycle Design Approaches IV



3. Life Cycle Design Approaches V

- Life Cycle Design is characterized by three main aspects
    1. The perspective broadened to include the entire life cycle
    2. The assumption that the most effective interventions are those made in the first phases of design
    3. The simultaneity of the operations of analysis and synthesis on the various aspects of the design problem

3. Life Cycle Design Approaches VI

- The selection of design alternatives must be guided by considering the main factors of product success (design targets), in relation to all the phases of the life cycle:
  - Resources utilization
  - Manufacturing planning
  - Life cycle cost
  - Product properties (ease of production, functionality, safety, quality, reliability, aesthetics)
  - Company policies
  - Environmental protection

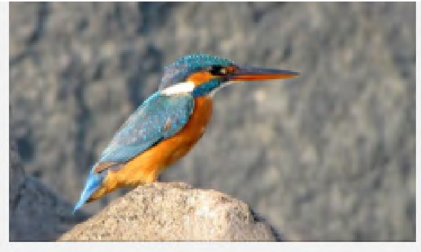
3. Life Cycle Design Approaches VII

LCA has three essential steps:

1. **Inventory analysis:**
   - Lists all inputs (raw materials and energy) and outputs (products, wastes, and energy), as well as any intermediate outputs
2. **Impact analysis:**
   - Lists all of the effects on the environment of each item identified in the inventory analysis, and quantifying or qualitatively describing the consequences (e.g., adverse health effects, impacts on ecosystems, or resource depletion)
3. **Improvement analysis:**
   - Lists, measures, and evaluates the needs and opportunities to address adverse effects found in the first two steps.

4. Application of Bio-mimicry in Design I

- **"Biomimicry"** borrows nature's blueprints, recipes, processes, and ecosystem strategies and then comes up with design principles to solve our own problems
- **An approach to innovation that seeks sustainable solutions to human challenges by emulating natures patterns and strategies.**
- **Kingfisher and Bullet Train**



5. Application of Aesthetics in Design I

- The meaning of the word **'aesthetics'** is sensory perception
- Aesthetics is the feel that a human being perceives
- Humans have five basic senses: **touch, sight, hearing, smell and taste**
- When a person perceives a sense of pleasure through any of the senses while using a product, then we can say that the product is aesthetically appealing

5. Application of Aesthetics in Design II

- Aesthetically appealing products are intentionally designed to generate a defined perception in potential customers


- Aesthetics of a product (that is how a customer feels about a product) is a very important aspect for its business merit and acceptability
- Aesthetic feel (or perception) enables the customer to distinguish and choose a product from similar products

5. Application of Aesthetics in Design III

- Examples for demarcation of percept ions are;
  - hot and cold
  - smooth and rough
  - soft and hard
  - heavy and light
  - dark and bright
  - sweet and sour
  - loud and quiet
  - sharp and dull
  - spacious and congested
- Customers generally combine few of these feels (or attributes) and arrive at conclusion of a product as reliable, enjoyable and precise

5. Application of Aesthetics in Design IV

6. Application of Ergonomics in Design I

- **Ergonomics** is basically the science of analyzing work and then designing items (tools, equipment, products etc.) and methods to most appropriately fit the capabilities of the user
- Ergonomics design approach focuses on **human comfort** and **decreased fatigue** *through product design*
- During the design phase of a product, all the aspects of the product that can cause discomfort while using that product are identified. After analyzing the causes of the discomfort, appropriate solutions are incorporated in the product design

6. Application of Ergonomics in Design II

- Ergonomic design applied to an office chair will focus on how much it is comfortable for a person who sits on it during office work

6. Application of Ergonomics in Design III

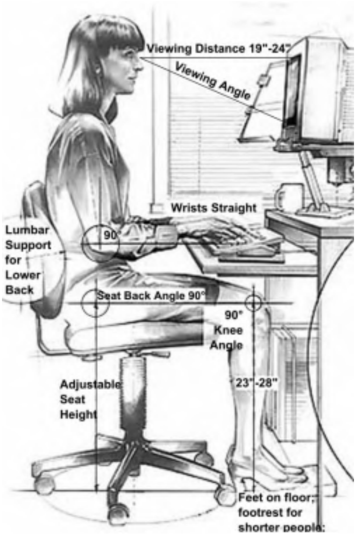
- A chair ergonomically designed for dining purpose and a chair meant for relaxed sitting at beach will be different
- It is, because, the kind of comfort and function to be provided by the chairs in these situations are different

6. Application of Ergonomics in Design IV

- To develop an ergonomic design (for a product or system), the designer will have to consider and analyse anthropometric data (dimensions of human body), posture of working while using the product, kind of movements and kind of workspace
- Ergonomic design involves every aspect of user-product interaction, for the comfortable utilization of a product

6. Application of Ergonomics in Design V

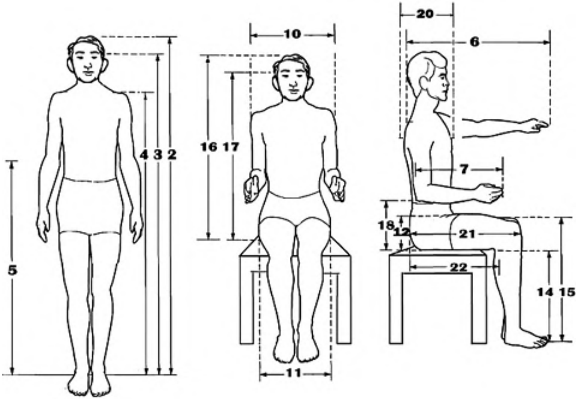
6. Application of Ergonomics in Design VI



6. Application of Ergonomics in Design VII

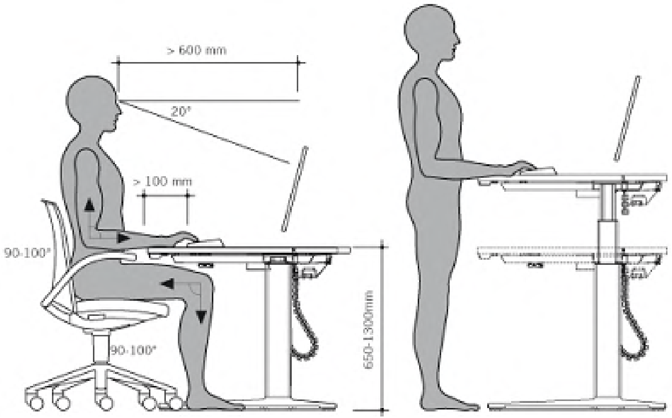
Ergonomic Design Factors

1. Anthropometry
   - Systematic measurements of human body
   - Variations in humans according to race, age, occupation etc.



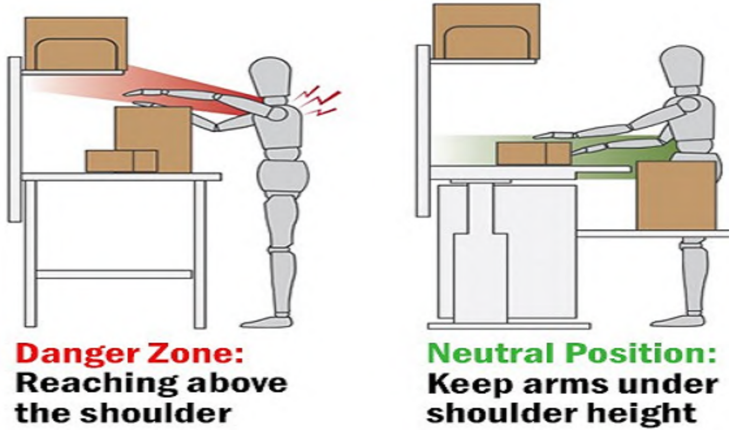
6. Application of Ergonomics in Design VIII

2. Posture while using product
   - Standing, sitting, reaching, moving and combinations of these.



6. Application of Ergonomics in Design IX

3. Movements while using product



6. Application of Ergonomics in Design X

4. Kind of workspace

6. Application of Ergonomics in Design XI

- **Universal Design Concept**
  - The designer must recognize the special needs of different users, including the individuals with disabilities
  - The disability can be temporary or permanent
  - Few examples for disabilities include broken bones, sprained joints, pregnancy handicap, differently able, aging, etc.
  - Universal design is an approach in ergonomics design, which considers all people; common and special people; who are potential users of a product

6. Application of Ergonomics in Design XII

6. Application of Ergonomics in Design XIII

Advantages of Ergonomic Design

- Proper consideration of ergonomic design can bring lots of advantages in working environment
  - health issues can be solved
  - Increase savings because of productive, sustainable and effective work environment
  - Reduce medical expenditure

7. Value Engineering in Design I

- Technique for **improving the value of the product**, project and process
- Value engineering is a systematic and organized approach to **providing the necessary functions in a project at the lowest cost**
- Value engineering promotes the substitution of materials and methods with less expensive alternatives, without sacrificing functionality
- It is focused solely on the functions of various components and materials, rather than their physical attributes

7. Value Engineering in Design II

- **Product value** is defined as the ratio of function to cost
- The function of an item is the specific work it was designed to perform, and the cost refers to the cost of the item during its life cycle
- The ratio of function to cost implies that the **value of a product can be increased by either improving its function or decreasing its cost**
- In value engineering, the cost related to production, design, maintenance, and replacement are included in the analysis

7. Value Engineering in Design III

- eg1: Consider that a new product is being designed and is slated to have a life cycle of only two years
  - The product will thus be designed with the least expensive materials and resources that will serve up to the end of the products life cycle, saving the manufacturer and the end-consumer money
  - This is an example of improving value by reducing costs

7. Value Engineering in Design IV

- eg2: A bottle of dishwashing liquid that becomes slippery after some of the soap has leaked to the sides, may be improved by redesigning the shape of the bottle and the opening spout to improve grip and minimize leakage
  - This improvement could lead to increased sales without incurring additional advertising costs
  - This is an example of improving value by increasing function

8. Concurrent Engineering in Design I

8. Concurrent Engineering in Design II

- It is an approach in product design process in which people from various functional areas works together simultaneously to develop a product
- **Concurrent engineering is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively**
- Since people from various fields are working simultaneously for the development, this kind of engineering is also known as **Simultaneous Engineering or Parallel Engineering**
- This approach is adopted to improve the efficiency of product design and reduce the product development cycle time

8. Concurrent Engineering in Design III

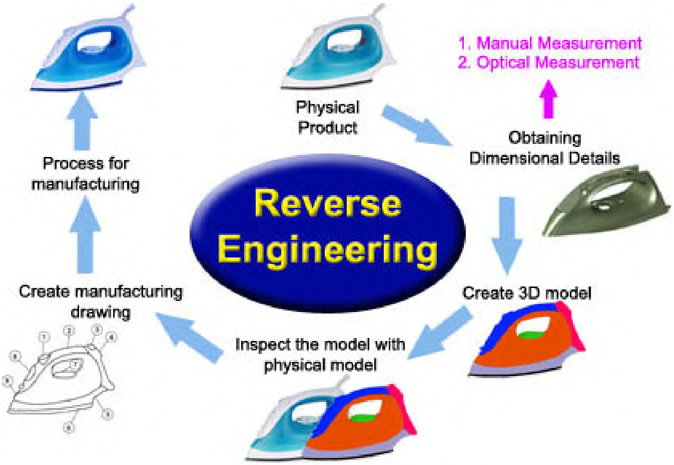
Advantages

- It encourages multi-disciplinary collaboration
- Reduces design time
- Reduces component manufacturing
- Reduces cost for design changes
- Enhanced quality
- Ensures correct data and information transfer between various sections
- Simultaneous thinking leads to amazing innovations
- Every person has the feel of belongingness to the product

Disadvantages

- Complex to manage
- Relies on everyone working together hence communication is critical
- Room for mistakes is small as it impacts all the departments or disciplines involved

9. Reverse Engineering in Design I



9. Reverse Engineering in Design II

- **Reverse Engineering is an approach in which an existing product is analyzed and another product is developed in light of the analysis**
- The product that is analyzed can be own product of the producer or a product from a competitor
- In reverse engineering, a product is **dissected or dis-assembled**to find out in detail how a part works an why is it used. This information obtained by this process can then be applied to solve own design problem or develop a new product
- Reverse Engineering is essentially a functional decomposition process in the reverse direction
- An existing product is analyzed into subsystems, which are further analyzed into deep to ultimately establish the product concept
- This analysis will help the designer to identify weak side of the design and it can be improved later

10. Case Studies I

Problem based learning

1. Design a new waste management system in your residence area, especially for plastic wastes
2. How can you market your own product within limited budget?
3. Plan your relative's wedding by following covid protocol

Project based learning

1. Analyse three most popular social media platforms for people and then design a new platform based on existing trends and past trajectory of changes.
2. Imagine and discuss about the possible higher education system in 2050.

Application of Ergonomics in Design

1. Ergonomically design a vegetable knife for your kitchen, consider gripping material, shape, safety and placement of knife

10. Case Studies II

Application of Bio-mimicry in Design

- **Mosquito and Syringe**


- **Fireflies and LED Light Bulbs**


10. Case Studies III

- **Tree-Climbing Robot and Worm**

10. Case Studies IV

- **Burr and Velcro**

10. Case Studies V

- **Whale and Wind Turbine**

10. Case Studies VI

- **Birds and Jets**


1. Find out bio-mimetic products and explain how bio-mimicry is useful in designing new products.

10. Case Studies VII

Reverse Engineering

1. Propose a new design for screw driver based on reverse engineering method.
   - Design requirement: conventionally for different screws different heads are available. Present requirement is to develop a screw driver that can handle any screws without changing the heads. You can change the designs as per your wish.

Thank You

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Design and Engineering

(EST200)

S4 - EE

Module 5: Expediency, Economics and Environment in Design Engineering I

1. Design for Production, Use, and Sustainability

- Concurrent engineering: A multidisciplinary design team works simultaneo and in parallel to design a product, a manufacturing approach, a distributio scheme, user support, maintenance, and ultimately disposal.

1.1 Design for Production I

- **Design for manufacturing (DFM)** is design based on minimizing the costs of production and/or the time to market for a product, while maintaining an appropriate level of quality
- DFM begins with the formation of the design team
- In commercial settings, design teams committed to DFM tend to be multidisciplinary, and they include engineers, manufacturing managers, logistics specialists, cost accountants, and marketing and sales professional Each brings particular interests and experience to a design project
- Design for manufacturing (DFM) is the design based on minimizing the costs of production and/or the time to market for a product, while maintaining an appropriate level of quality.
- The importance of maintaining an appropriate level of quality cannot be overstated because without an assurance of quality, DFM is reduced to simply producing the lowest cost product.

1.1 Design for Production II

- Manufacturing and design tend to interact iteratively during product development. That is, the design team itself discovers a possible problem in producing a proposed design or learns of an opportunity to reduce production costs or timing, and the team then reconsiders its design.
- Similarly, a design team may be able to suggest alternative production approaches that lead manufacturing specialists to restructure processes.
- Basic methodology for DFM:
    1. Estimate the manufacturing costs for a given design alternative
    2. Reduce the costs of components
    3. Reduce the costs of assembly
    4. Reduce the costs of supporting production
    5. Consider the effects of DFM on other objectives
    6. If the results are not acceptable, revise the design once again

1.2 Design for Assembly I

- Assembly refers to the way in which the various parts, components, and subsystems are joined, attached, or otherwise grouped together to form the final product.
- Handles parts or components (i.e., retrieves and positions them appropriate relative to each other)
- Inserts (or mates or combines) the parts into a finished subsystem or system
- The assembly process can be done in a number of ways, and the designer needs to consider approaches that will make it possible for the manufacturer to reduce the costs of assembly while maintaining high quality in the finished product. Clearly then, assembly is a key aspect of manufacturing and must be considered either as part of design for manufacturing or as a separate, yet strongly related design task.

1.3 Design for Use I

- **Reliability**
  - Reliability is defined as the probability that an item will perform its function under stated conditions of use and maintenance for a stated measure of a variate
  - Reliability of a component or system can be properly measured only under the assumption that it has been or will be used under some specified conditions
  - Appropriate measure of use of the design, called the variate, may be something other than time

1.3 Design for Use II

- **Maintainability**
  - Maintainability can be defined as the probability that a failed component or system will be restored or repaired to a specific condition within a period of time when maintenance is performed within prescribed procedures
  - Designing for maintainability requires that the designer take an active role in setting goals for maintenance, such as times to repair, and in determining the specifications for maintenance and repair activities in order to realize these goals.
  - It includes
    - Selecting parts that are easily accessed and repaired
    - Providing redundancy so that systems can be operated while maintenance continues
    - Specifying preventive or predictive maintenance procedures
    - Indicating the number and type of spare parts that should be held in inventories in order to reduce downtime when systems fail

1.4 Design for Sustainability I

- The American Society of Mechanical Engineers (ASME) stipulates that Engineers shall consider environmental impact in the performance of their duties
- Environmental Issues and Design
  - Environmental implications of a design in terms of the effects on air quality, water quality, energy consumption, and waste generation

1.4 Design for Sustainability II

- Environmental Life-Cycle Assessments
  - Life-cycle assessment is a tool that was developed to help product designers understand, analyse, and document the full range of environmental effects of design, manufacturing, transport, sale, use, and disposal of products.
  - LCA has three essential steps:
    1. **Inventory analysis** lists all inputs (raw materials and energy) and outputs (products, wastes, and energy), as well as any intermediate outputs.
    2. **Impact analysis** lists all of the effects on the environment of each item identified in the inventory analysis, and quantifying or qualitatively describing the consequences (e.g., adverse health effects, impacts on ecosystems, or resource depletion).
    3. **Improvement analysis** lists, measures, and evaluates the needs and opportunities to address adverse effects found in the first two steps.

2. Engineering Economics in Design I

- **Cost Estimation:** How much does this particular product design cost?
- In practice, cost estimation is a complex business that requires skill and experience.
- Cost structure of a device: estimation of labour, materials, overhead costs etc.

2. Engineering Economics in Design II

- **Labour Costs**:
  - Costs include payments to the employees who build the designed device, as well as to support personnel who perform necessary but often invisible tasks such as taking and filling orders, packaging, and shipping the device.
  - Labour costs also include a variety of **indirect costs** that are less evident because they are generally not paid directly to employees.
  - Indirect costs are sometimes called **fringe benefits** and include health and life insurance, retirement benefits, employers contributions to Social Security, and other mandated payroll taxes
  - A simple starting point for estimating costs is to keep good records or the activities needed to build our designs prototype.

2. Engineering Economics in Design III

- **Material Costs**
  - It include those items and inputs directly used in building the device, along with intermediate materials and inventories that are consumed in the manufacturing process.
  - A key tool for estimating the materials cost of an artifact is the **bill of materials (BOM)**, the list of all of the parts in our design, including the quantities of each part required for complete assembly
  - The BOM is particularly useful since it is usually developed directly from the assembly drawings, and so it reflects our final design intentions.
  - Materials costs can often be reduced significantly by using commercial off-the-shelf materials rather than making our own.
  - This is because outside vendors have the machinery and expertise to make very large numbers of parts for a lot of customers

2. Engineering Economics in Design IV

- **Overhead Costs**
  - The costs incurred by a manufacturer that cannot be directly assigned to a single product are termed overhead.
  - Estimating the costs of producing a design requires careful consultation with clients or their suppliers.
  - In practice, each engineering discipline has its own approaches to cost estimating that are captured by general guidelines

2.1 Cost of Design and Cost of Designed Device I

- There is an important distinction between the cost of designing, prototypin and testing a product and the cost of the product after manufacturing and distribution.
- Costing is an important element in the profitability of a design. But it is generally not a key factor in the pricing of the artifact.
- Revenues are determined by the price charged for an item multiplied by the number of items sold.
- For most profit maximizing firms, prices are not set on the basis of costs, but rather in terms of what the market is willing to pay.
- The responsibilities of marketing professionals on a design team usually include identifying design attributes that make consumers willing to pay a high price for a new product design.

2.2 Time Value of Money

- **Time value of money:** Money obtained sooner is more valuable than money obtained later, and money spent sooner is more costly than money spent later
- $V_f = (1 + r)V_p$
  -
  - V_f = Future value of money (a year from now)
  - V_p = Present value of money
  - r = Discount rate
  - Rs. 100 today is Rs 110 a year later at 10% annual discount rate
- $V_p = V_f/(1 + r)$
  - Rs. 100 a year later at 10% annual discount rate is Rs. 90.91 today
- For case of more than 1 year: $V_p = V_f/(1 + r)^t$
  - t = time period measured in years over which a cost is incurred or benefit is realised
  - Rs. 100, 3 years later at 10% annual discount rate is Rs. 75.13 today

3. Design Rights

- What is a design right?
  - If you have created a new design, its worthwhile considering registering it to effectively prevent others from copying or exploiting your design.
  - A registered design is an excellent and cost-effective tool to protect your rights against copying and counterfeiting.
- A design registration means you can register the look of your product. It gives you an exclusive right to your design for a limited time
- Designs can be registered to protect the look of your whole product, a part of your product, or even just a small detail. Your product might be something functional, like a mobile phone, a drill, or a toothbrush, or something more decorative like a vase or a piece of jewellery
- You can also protect graphical symbols, logos, computer icons, user interface graphics, even typefaces with a registered design.
- The design must be new and have individual character over prior design registrations in order to be registered

4. Ethics in Design I

- To design means to accept responsibility for creating designs
- Designers are influenced by the society in which they work, and designed products influence society
- Words like ethics, morals, obligations, and duty are used in a variety of ways in everyday life

4. Ethics in Design II

- **Ethics**
  - Discipline dealing with what is good and bad and with moral duty and obligation
  - A set of moral principles or values
  - A theory or system of moral values
  - Principles of conduct governing an individual or group
- **Moral**
  - Relating to principles of right or wrong in behaviour
  - Expressing or teaching a conception of right behaviour
- These definitions define ethics as a set of guiding principles or a system that people can use to help them behave well.

4.1 Codes of Ethics I

- **Professional Obligations**
- The professional societies undertake activities, including promulgating design standards, and providing forums for reporting research and innovatio in practice.
- The professional engineering societies continue to play a leading role in setting ethical standards for designers and engineers.
- Ethical standards clearly speak to the various and often conflicting obligations that an engineer must meet.
- The societies also provide mechanisms for helping engineers to resolve conflicting obligations
- Most professional engineering societies have published codes of ethics.

4.1 Codes of Ethics II

- The differences in the codes reflect different styles of engineering practice in the various disciplines much more than differences in their views of the importance of ethics.
- The professional societies, not withstanding their promulgation of codes of ethics, have not always been seen as active and visible protectors of whistleblowers and other professionals who raise concerns about specific engineering or design instances.
- The codes of ethics that described are not necessarily the same as those in all parts of the world.
- Ethics are intensely personal

5. Questions

1. Examine the changes in the design of a foot wear with the constraints of 1) production methods, 2) life span requirement, 3) reliability issues and 4) environmental factors. Use hand sketches and give proper rationalization for the changes in design.
2. Describe how to estimate the cost of the following design products
   - A website
   - Elevator used in a 5 storied building
   - A car

   Show how economics will influence the engineering designs. Use hand sketches to support your arguments.

Thank You

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