DESIGN AND ENGINEERING

NOTES AS PER KTU SYLLABUS

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B. Tech (CSE) M. Tech (SE) PhD (IT)

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Notes as per KTU syllabus

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B.Tech-COMPUTER SCIENCE & ENGINEERING

M. Tech-SOFTWARE ENGINEERING

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EST200 DESIGN AND ENGINEERING - SYLLABUS

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 (Languages of Engineering Design): 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

Text Books

1) YousefHaik, SangarappillaiSivaloganathan, Tamer M. Shahin, Engineering Design Process, Cengage Learning 2003, Third Edition, ISBN-10: 9781305253285,

2) Voland, G., Engineering by Design, Pearson India 2014, Second Edition, ISBN 9332535051

Reference Text Books

1.Philip Kosky, Robert Balmer, William Keat, George Wise, Exploring Engineering, Fourth Edition: An Introduction to Engineering and Design, Academic Press 2015, 4th Edition, ISBN: 9780128012420.

2. Clive L. Dym, Engineering Design: A Project-Based Introduction, John Wiley & Sons, New York 2009, Fourth Edition, ISBN: 978-1-118-32458-5

3. Nigel Cross, Design Thinking: Understanding How Designers Think and Work, Berg Publishers 2011, First Edition, ISBN: 978-1847886361

4. Pahl, G., Beitz, W., Feldhusen, J., Grote, K.-H., Engineering Design: A Systematic Approach, Springer 2007, Third Edition, ISBN 978-1-84628-319-2

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MODULE 1: DESIGN PROCESS

ENGINEERING

Engineering is the application of scientific, economic, social and practical knowledge in order to invent, build, design, develop and maintain various devices, systems, machines, structures and processes.

DESIGN

A plan or drawing produced to show the look and function or workings of an object before it is made.

ENGINEERING DESIGN

- Engineering design is the process of devising a system, component, or process to meet desired needs.
- It is an iterative design making process in which the basic sciences, mathematics and engineering sciences are applied to optimally convert resources to meet a stated objective.

DESIGN LEVELS

ADAPTIVE DESIGN

- Mostly designer's work will be concerned with the adaptation of existing designs.
- There are branches of manufacturing in which development has practically ceased, so that there is hardly anything left for the designer to do except make minor modifications, usually in the dimensions of the product.
- Design activity of this kind demands no special knowledge or skill, and the problems presented are easily solved by a designer with ordinary technical training.
- Example: Elevator, Washing Machine etc.

DEVELOPMENT DESIGN

- Considerably more scientific training and design ability are needed for development design.
- The designer starts from an existing design, but the final outcome may differ markedly from the initial product.
- Example: Development could be from a manual gearbox in a car to an automatic one, from the traditional tube-based television to the modern plasma and LCD versions, Wired telephone to mobile phone etc.

NEW DESIGN

- Only a small number of designs are new designs. This is possibly the most difficult level in that generating a new concept involves mastering all the previous skills in addition to creativity and imagination, insight, and foresight.
- Example: Design of the first automobile, airplane, camera etc.

CAUSE FOR FAILURES IN MOST 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
- Error in drawings
- Inadequate data collection

PHASES OF DESIGN PROCESS

Figure 1.1: Phases of Design Process

The phases involved in design process includes six phases as shown in Figure 1.1.

1. **Identifying Customer needs**: First identify what the customer is expecting the system. This can be done in the following ways.

Client request:

- A client may submit a request for developing a product or artifact.
- The customer need should be expressed clearly.
- The client may know only the type of product that they need.
- Example: I need a Table

Modification of an existing design

- Client may ask modifications in the existing product.
- They may ask for customization in certain products.
- They may ask to change shape, functionalities, material used etc.
- Example: Different coffee brands uses different flavours,

Generation of new product

- Profit oriented companies always do research to generate entirely new concepts and products so that they can rule the market.
- Example: Design variants of televisions with new features and build materials.

2. Setting design objectives – Identify the design objectives. Perform feasibility analysis, market study abd document the finalized design objectives.

Conduct feasibility analysis

- **Technical feasibility**: Ensuring whether the requirements can be implemented using the existing technology or not.
- **Economic feasibility:** Ensuring whether the requirements can be implemented within the allotted budget or not.
- **Schedule feasibility**: Ensuring whether the requirements can be implemented within the allotted time or not.
- **Social feasibility**: Ensuring whether the developing product may affect the society in a harmful manner or not.

Perform market analysis

- Analyze the market and identify the competing products and its exciting features.
- Identify the supplementary features that may be expected from this product.

Document the finalized design objectives

- Document all the finalized requirements / design objectives.
- This document act as an agreement between the customer and the manufacturer.
- Example: System Requirement Specification (SRS) document.

3. Identifying design constraints – Identify the various constraints that exist which may affect the design process.

Functional constraints

- These constraints impose a limit on the proposed working principle of the product
- Example: Energy requirement, Materials used, Overall geometry and aesthetics etc.

Manufacturing constraints

- The direct production limitations are due to equipment/raw materials deficiency, methods involved in manufacturing, labour shortage etc.

Safety constraints

- These constraints impose a direct threat to the product or to the user.
- Example: Operational safety constraints, Environmental constraints, Safety issues due to inevitable human errors etc.

Time and economic constraints

- Customer always expect quick delivery of the product with minimum cost.
- Demand of the product also leads to time and economic constraints. Example: Vaccine for COVID.

Legal Ethical and Quality constraints

- The end product should be approved by various organizations or Quality Control (QC) and Quality Assurance (QA) agencies to ensure its quality and safety
- Example: ISO, ISI, Food Safety and Standards Authority of India (fssai)

Ergonomics and Aesthetic constraints

- Product should be user friendly, attractive, visually pleasing and easy to use.

4. **Establishing functions –** Identify all the functionalities to be performed by the system.

- Identifying all the functions to be performed by the proposed product.
- Identifying the functions to be carried out to implement this product.
- Performing risk analysis in the implementation phases.
- Functions can be:
    1) **Engineering functions**: Cost estimation, Production design, Concept design, Simulation or 3D models etc.
    2) **Manufacturing functions:** Assembly, determination of tools and machineries for production, purchasing raw materials, Allotting labour etc.
    3) **Quality control functions:** Auditing, Check for regularity and safety, Design auditing, energy auditing etc.
    4) **Commercial functions**: Service-related aspects, Marketing, Sales, Warehousing, Packing and shipping etc.

5. **Generating design alternatives**

- For a design problem, there will be multiple solutions.
- For example: We can design a mobile phone in different modes: Touch screen phone, Keypad phone etc.
- Every design solution has its own pros and cons.

6. Choosing the best feasible design

- From the various design alternatives, the designer has to choose the best feasible design by considering the various trade-off aspects.

CASE STUDY 1 – CARRY BAG

CASE STUDY 2 – WRIST WATCH

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

<u>Solution</u>

1. Identifying and detailing customer requirements.

- ✓ It should show the accurate time.
- ✓ It can be tied on the wrist.

2. Setting design objectives

- ✓ Ensure whether we can design a wrist watch using existing technology, allotted budget and time schedule.

3. Identifying design constraint

- ✓ It should have a strap / chain to tie on the wrist.
- ✓ Should follow the quality guidelines like ISI / ISO standards.

4. **Establishing functions**

- ✓ It should display time accurately.
- ✓ It should be cell/battery/ solar powered.
- ✓ It should have a strap / chain to tie on the wrist.
- ✓ It should be simple and light weight.

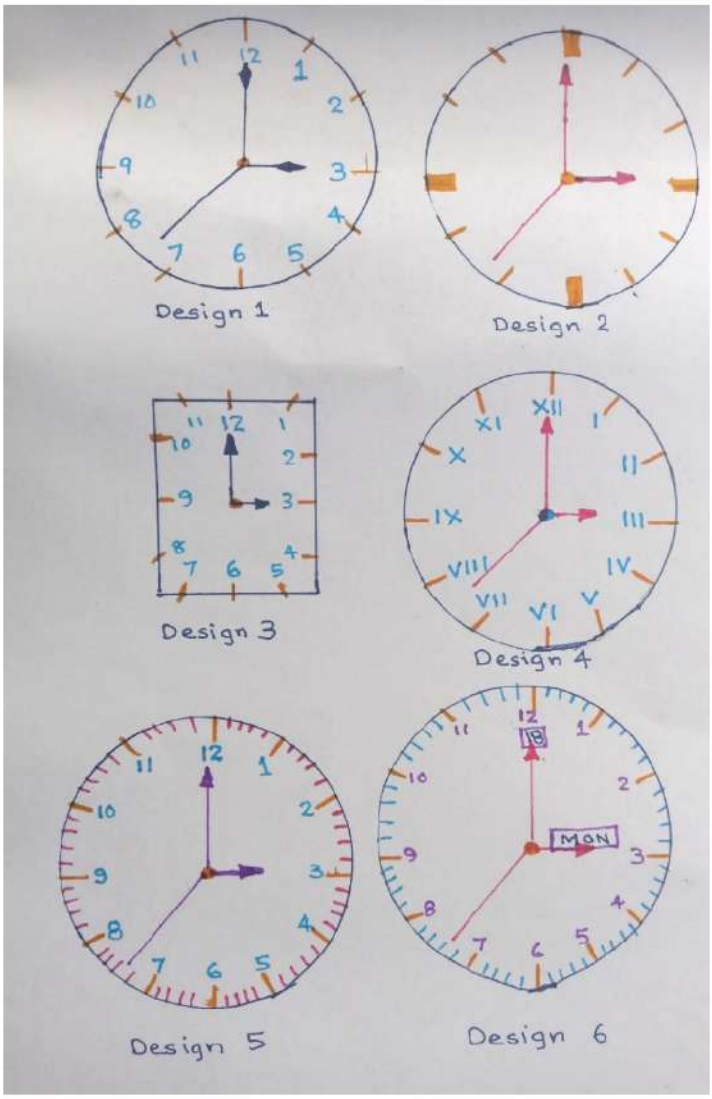
5. Generating design alternatives

Possible alternatives in mode: Analog watches, Digital watches, Smart watches

Possible alternatives in strap: Leather strap with different colors, Chain strap with different colors

Possible shapes of dial: Round, Rectangle, Oval, Square etc.

Number pattern in dial: Numbers like 1,2…12 or Roman numbers like I, II …. XII.



6. Choosing the best design

In the above designs of analog watches, Design 6 can be considered as best as it uses number system 1,2…12 which is understood for common people. It has detailed minutes and seconds mapping of time. It shows the current date and day. It has all the three needles like second, minute and hour.

MODULE 2: DESIGN THINKING

DESIGN THINKING

- Design thinking is simply "a process for creative problem solving"
- 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.

ITERATIVE DESIGN THINKING PROCESS STAGES

- Consist of five phases—Empathize, Define, Ideate, Prototype and Test.
- It is most useful to solve problems that are ill-defined (unclear) or unknown.

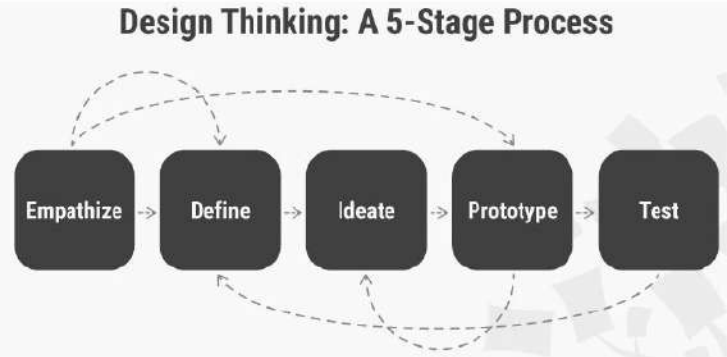


Figure 2.1: 5-stage process involved in design thinking

1. Empathize

- Designer should gain an empathetic understanding of the problem that they are trying to solve, typically through user research.
- Empathy is crucial to a human-centered design process such as design thinking because it allows you to set aside your own assumptions about the world and gain real insight into users and their needs.
- Place yourself as an end user and identify the user expectations and needs.

2. Define

- It's time to accumulate the information gathered during the Empathize stage.
- You then analyze your observations and synthesize them to define the core problems you and your team have identified. These definitions are called problem statements.
- The problem definition should be clear and unambiguous.
- Define the objectives or user requirements

3. Ideate

- 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.
- Brainstorming is particularly useful here.

4. Prototype

- This is an experimental phase. The aim is to identify the best possible solution for each problem found.
- Designer team should produce some inexpensive, scaled-down versions of the product (or specific features found within the product) to investigate and validate the ideas they generated.
- This could involve simply paper prototyping, simulations, 3D models, animations etc.

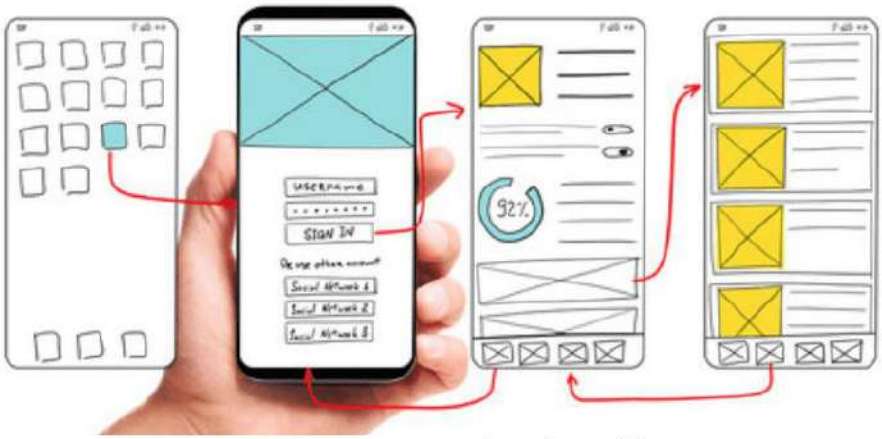


Figure 2.2: Paper prototyping of a Mobile app

Figure 2.3: 3D models

5. Test

- Evaluators rigorously test the prototypes.
- Although this is the final phase, design thinking is iterative: Teams often use the results to redefine one or more further problems.
- So, they can return to previous stages to make further iterations, alterations and refinements – to identify the best alternative solution.

DESIGN THINKING ITERATIVE APPROACH CASE STUDY – BAG FOR COLLEGE STUDENTS

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.

Solution:

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

1. Empathize

[1] It should have a facility to carry books, tiffin and other small articles.
[2] It should be closed.

2. Define

[1] It should have separate racks for keeping books and tiffin
[2] It should have zips to lock.
[3] It should be light weight with sleek design.

3. Ideate

[1] It should have separate racks for keeping books and tiffin
[2] It should have zips to lock.
[3] It should be light weight with sleek design.
[4] It should have a compartment to keep the laptop.
[5] It should have a compartment on the outer side to keep water bottles.
[6] It should have a small pouch on the outside to keep necessary things like pen, keys, chargers etc.
[7] The shoulder strap should be of soft material.
[8] It should be waterproof so that it can be used in rainy season too.
[9] It should have an inner secret pouch to keep money or any other important thing.

4. Prototype

The 2D prototype is shown on the right.

5. Test

Ensure that all the expected functionalities are incorporated in the product. The above prototype has separate racks for keeping books and laptop. It has a water bottle holder. The shoulder strap is made of soft sponge material. The material used is waterproof polyester. It is light weight and has sleek design.

DESIGN THINKING AS DIVERGENT – CONVERGENT QUESTIONING

- Design thinking is an iterative approach and we follows two generic patterns of design thinking: Divergent thinking and Convergent thinking.
- **Divergent thinking** is the process of thinking that explores multiple possible solutions in order to generate creative ideas. i.e. Think for all possible ways to reach a solution.
- **Convergent Thinking** is the process of figuring out a concrete solution to any problem. i.e. Thinks for a final solution.
- Table 2.1 shows the differences between divergent & convergent thinking.

Table 2.1: Difference between Divergent – Convergent thinking process

Convergent Thinking	Divergent Thinking
Convergent Thinking is the process of figuring out a concrete solution to any problem.	**Divergent thinking** is the process of thinking that explores multiple possible solutions in order to generate creative ideas.
It's a straight forward process that focuses on figuring out the most effective answer to a problem.	In contrast, divergent thinking refers to opening the mind in various directions and trying out multiple solutions for a problem.
Its characteristics include •Speed •Accuracy •Logic	Its characteristics include •Spontaneous •Free-flowing •Non-linear
Convergent thinking helps to find out the best possible answer to any problem, which are accurate most of the time, and no room for ambiguity is left.	Although Divergent thinking keeps the options open, a completely accurate answer isn't identified.

CONVERGENT – DIVEREGENT THINKING – CASE STUDY OF BULB

Figure 2.4: Convergent – Divergent thinking of electric bulb

DIVERGENT THINKING – CASE STUDY OF PEN

List out some uses of pen other than writing

- ✓ as a straw
- ✓ as a toy "telescope" for kids
- ✓ To rewind cassette tape
- ✓ as an improvised stabbing weapon
- ✓ As a paper punch
- ✓ Use as a ruler
- ✓ To make a smart phone stylus
- ✓ To make a whistle

DIVERGENT THINKING – CASE STUDY OF FORK

List out some uses of fork other than eating aid.

- ✓ Scramble things
- ✓ Mix things
- ✓ Stir stuff
- ✓ Poke things or people
- ✓ Give it to a small farmer as a pitch fork
- ✓ Scratcher
- ✓ Get something out of a fire
- ✓ Murder weapon
- ✓ Tool of torture
- ✓ Prop something open

DESIGN THINKING AS A TEAM

- ➢ In order to get best and creative solutions, design thinking process is generally performed as a team activity.
- ➢ Every member may raise their own ideas and solutions.
- ➢ The team will analyze the pros and cons of each solution or design and then finalize the best suitable solution.
- ➢ But during design thinking as a team activity, conflicts between team members may arise. So It is very important to resolve these conflicts.

CHARACTERISTICS OF AN EFFECTIVE TEAM

- ➢ Team goals are as important as individual goals.
- ➢ The team understands the goals and is committed to achieving them.
- ➢ Trust replaces fear, and people feel comfortable taking risks.
- ➢ Respect, collaboration, and open-mindedness are prevalent.
- ➢ Team members communicate readily; diversity of opinions is encouraged.
- ➢ Decisions are made by consensus and have the acceptance and support of the members of the team.

STEPS IN RESOLVING CONFLICTS

1. Prepare the resolution
2. Understand the situation
3. Reach agreement

Step 1: Prepare for resolution

- **Acknowledge the conflict** – The conflict has to be acknowledged before it can be managed and resolved. The tendency is for people to ignore the first signs of conflict, perhaps as it seems trivial, or is difficult to differentiate from the normal, healthy debate that teams can thrive on. If you are concerned about the conflict in your team, discuss it with other members. Once the team recognizes the issue, it can start the process of resolution.
- **Discuss the impact** – As a team, discuss the impact the conflict is having on team dynamics and performance.
- **Agree to a cooperative process** – Everyone involved must agree to cooperate in to resolve the conflict. This means putting the team first, and may involve setting aside your opinion or ideas for the time being. If someone wants to win more than he or she wants to resolve the conflict, you may find yourself at a stalemate.
- **Agree to communicate** – The most important thing throughout the resolution process is for everyone to keep communications open.

Step 2: Understand the situation

- **Clarify positions** – Whatever the conflict or disagreement, it's important to clarify people's positions. Whether there are obvious factions within the team who support a particular option, approach or idea, or each team member holds their own unique view, each position needs to be clearly identified and articulated by those involved.
- **List facts, assumptions and beliefs underlying each position** – What does each group or person believe? What do they value? What information are they using as a basis for these beliefs? What decision-making criteria and processes have they employed?
- **Analyze in smaller groups** – Break the team into smaller groups, separating people who are in alliance. In these smaller groups, analyze and dissect each position, and the associated facts, assumptions and beliefs.
- **Convene back as a team** – After the group dialogue, each side is likely to be much closer to reaching agreement. The process of uncovering facts and assumptions allows people to step away from their emotional attachments and see the issue more objectively. When you separate alliances, the fire of conflict can burn out quickly, and it is much easier to see the issue and facts laid bare.

Step 3: Reach agreement

- Now that all parties understand the others' positions, the team must decide what decision or course of action to take. With the facts and assumptions considered, it's easier to see the best of action and reach agreement.

PREVENTING CONFLICTS

- Dealing with conflict immediately – avoid the temptation to ignore it.
- Being open – if people have issues, they need to be expressed immediately.
- Practicing clear communication – articulate thoughts and ideas clearly.
- Practicing active listening – paraphrasing, clarifying, questioning.
- Practicing identifying assumptions – asking yourself "why" on a regular basis.
- Not letting conflict get personal – stick to facts and issues, not personalities.
- Focusing on actionable solutions – don't belabor what can't be changed.
- Encouraging different points of view – insist on honest dialogue and expressing feelings.
- Not looking for blame – encourage ownership of the problem and solution.
- Demonstrating respect – if the situation escalates, take a break and wait for emotions to subside.

DESIGN THINKING APPROACH CASE STUDY 1 – 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 process. Provide your rationale for each step using hand sketches only.

Solution:

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

Intended users: Hospital staff like nurses.

Scope / Domain: Hospitals

Expected functionalities:

[1] It should have wheels as we need to move it from one room to another.
[2] It should have racks to keep the medicines.
[3] It should be light weight with sleek design so that we can move it easily.

Exciting functionalities:

[1] The wheel should have a lock such that it can be prevented from moving when not in use.
[2] It should have racks with closing doors or lids.
[3] It should have separate rack for keeping drugs for each room patients.
[4] It should have a facility to dispose medicinal waste like used cotton, syringe etc.
[5] It should have an open table on the top to keep case diary/charts of patients.

Possible Designs using Divergent thinking process

Model 1:

Pros:

- Simple and Light weight
- Easier to keep medicines and boundaries are provided in all 3 sides which prevents from medicines falling down while moving.

Cons:

- Difficult to sort out medicines for each room.
- No doors for racks and no open table.
- Wheels have no locks

Model 2:

Pros:

- Simple and Light weight
- Easier to keep medicines

Cons:

- Difficult to sort out medicines for each room.
- No doors for racks and no open table.
- Wheels have no locks
- As there are no boundaries, there is a high chance of falling down the medicines while moving.

Model 3:

Pros:

- Simple and Light weight
- Easier to keep medicines as boundaries and lids are there for each rack.

Cons:

- Difficult to sort out medicines for each room.
- Wheels have no locks

Model 4:

Pros:

- Simple and Light weight
- Easier to keep medicines as drawers are used.
- An open table is there on the top to keep case diary/charts of patients.
- Wheels have locks

Cons:

- Difficult to sort out medicines for each room.
- No option for disposing clinical wastes.

Model 5:

Pros:

- Simple and Light weight
- Easier to keep medicines as drawers are used.
- An open table is there on the top to keep case diary/charts of patients.
- Have both open and closed racks to keep drugs accordingly.

Cons:

- Difficult to sort out medicines for each room.
- No option for disposing clinical wastes.
- No lock for wheels

Model 6:

Pros:

- Simple and Light weight
- Easier to keep medicines and sort out medicines for each patient as different partitions are provided for each room.
- Have both open and closed racks to keep drugs accordingly.

Cons:

- No open table is there on the top to keep case diary/charts of patients
- No option for disposing clinical wastes.
- No lock for wheels

Model 7:

Pros:

- Simple and Light weight
- Easier to keep medicines and sort out medicines for each patient as different partitions are provided for each room.
- Have both open and closed racks to keep drugs accordingly.
- Have facility to dispose clinical wastes.
- Have open table to keep patient charts / records.
- Have locks for wheels.

Choosing the best design

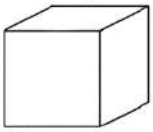
Model 7 can be chosen as the best design as it incorporates all the expected functionalities as well as exciting functionalities of a drug trolley.

MODULE 3: DESIGN COMMUNICATION

COMMUNICATING DESIGNS GRAPHICALLY

There are different modes of graphical designs to communicate our design to various stakeholders.

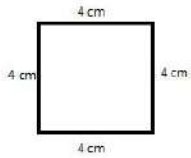
[1] **Sketching:** Sketching is a powerful tool in design because it enables us to convey our design ideas to others quickly and concisely. There are several types of sketches like Orthographic sketches, Axonometric sketches, Oblique sketches and Perspective sketches.

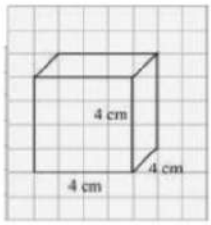


[2] **2D drawings/ 3D drawings:** They are the more formal representations of sketches. It includes proportion control and annotations.

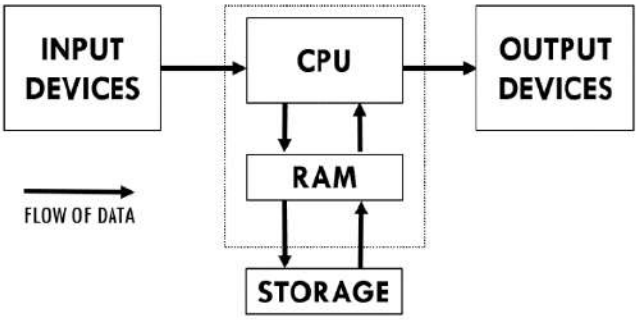
Annotations: They are clear and easily understandable notes provided on sketches for conveying the meaning behind the sketched ideas.

Proportions: It is extremely useful to show the relative sizes of parts, components, or features in a sketch. That's why it is generally a good idea to sketch designs on graph paper, because it is easier to control those relative sizes using the graph paper's grid pattern.

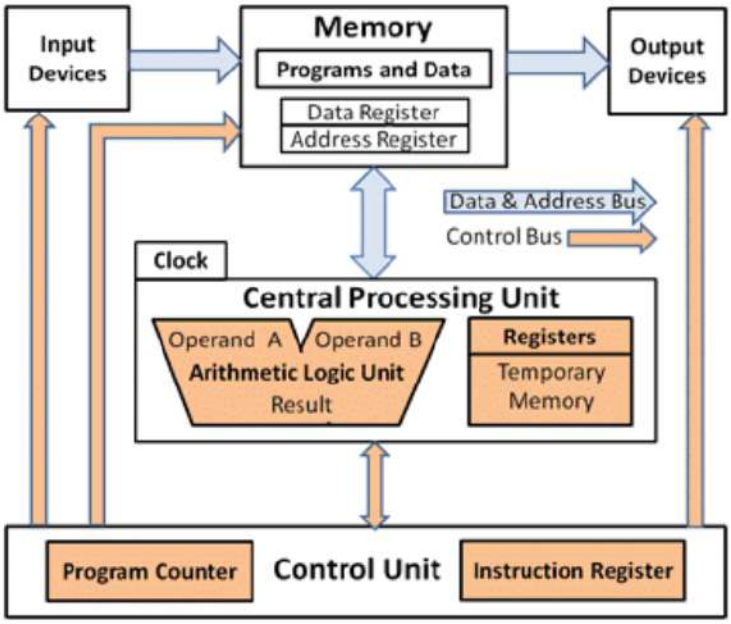




[3] **Block diagrams / Layout drawings:** It represents the various components in the system and their interrelationships. That is, it shows how the various components are connected together. Figure below shows the block diagram of digital computer.



[4] **Detailed drawing /Architecture diagram:** Architecture diagram of a system comprises of various components/elements of that system, interrelationship between them and the externally visible properties of those elements. These drawings must show tolerances, and they must also specify materials and any special processing requirements. Figure below shows the architecture diagram of Digital computer.



[5] **Assembly drawings / Component diagrams:** 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. Assembly diagram of digital computer is shown below.

[6] **Animations:** Animation within engineering becomes a clear way to study simulation of a whole system within its intended environment. This provides context for complicated issues, allowing engineering teams to find flaws or help explain complicated issues. Animation tools are used for developing animations. Example: Blender, Maya, Solidworks etc. are used for creating animations.

COMMUNICATING DESIGNS

- REPORTING is an essential part of a design project: We have not completed our project if we have not communicated our work and findings to our client and to other stakeholders the client may designate.
- Final design results can be communicated in several ways, including oral presentations, final reports (that may include design drawings and/or fabrication specifications), and prototypes and models.

COMMUNICATING DESIGNS ORALLY

The elements of an oral presentation are listed below:

- A **title slide** that identifies the client(s), the project, and the design team or organization responsible for the work being presented. This slide should include company logos.
- A **roadmap** for the presentation that shows the audience the direction that the presentation will take. This can take the form of an outline, a flowchart, a big picture slide, and so on.
- A **problem statement**, which includes highlights of the revised problem statement that the team produced after research and consultation with the client.
- **Background** material on the problem, including relevant prior work and other materials developed through team research. References should be included but may be placed in a slide at the end of the presentation.
- The **key objectives** of the client and users should be mentioned.
- The **key constraints** that the design must meet.
- **Functions** that the design must perform, focusing on basic functions, and means for achieving those functions.
- **Design alternatives**, particularly those that were considered at the evaluation stage, including diagrams and descriptions of each.
- **Highlights of the evaluation procedure and outcomes**, including key metrics or objectives that bear heavily on the outcome.
- The **selected design**, explaining why this design was chosen.
- **Features of the design**, highlighting aspects that make it superior to other alternatives and any novel or unique features.
- **Proof-of-concept testing**, especially for an audience of technical professionals for whom this is likely to be of great interest.
- **A demonstration of the prototype**, assuming that a prototype was developed and that it can be shown. Video or still photos may also be appropriate here.
- **Conclusion(s),** including the identification of any future work that remains to be done, or suggested improvements to the design.

ORAL PRESENTATION – CASE STUDY OF AUTOMATIC COFFEE MUG

Automatic Hot Coffee Mug

Project developed by
Johan Jacob Pratheesh
Ashish Mathew Varghese

Project Head: Dr. Pramod Mathew Jacob

PRAMOD'S ACADEMY
Learn to Apply Knowledge

OUTLINE

- Introduction
- Problem Statement
- Background
- Objectives
- Constraints
- Functions/Functional Requirements
- Design Alternatives
- Selected Design / Proposed Design
- Features of Design
- Testing
- Demonstration /Prototype/ Results
- Conclusions

PROBLEM STATEMENT

- To develop a portable coffee mug which will automatically heat the coffee inside it.

BACKGROUND

- Existing coffee mug designs varies in its shape and the build material.
- Build materials can be

Glass

Clay/Ceramics

Paper

Steel / Copper

Plastic

Wood etc.

OBJECTIVES

- To design a coffee mug which will check the temperature of coffee inside it.
- To develop a coffee mug which will automatically heat up the coffee if the temperature of coffee is less than a threshold temperature.
- To design a electric powered coffee mug to keep the coffee hot.

CONSTRAINTS

- Coffee mug should be portable.
- Coffee mug should be durable.
- It should be environmental friendly.

FUNCTIONAL REQUIREMENTS

Functional Requirement (FR)

FR1: To sense the temperature of the coffee inside the mug
FR2: To automatically heat up the coffee if the coffee is cold (Based on threshold value)
FR3: To heat the coffee manually.

DESIGN ALTERNATIVES

SELECTED DESIGN & ITS FEATURES

- Portable
- Has lid so that coffee can be transported from one place to another.
- Made up of steel inner chamber.
- Environmental friendly.
- Powered by USB

DEMONSTRATION & TESTING

- The individual components like hot plate, sensors etc. are unit tested.
- After integration, the product was tested for its functionality.
- The product is tested by keeping hot coffee for a period of one hour.
- The threshold temperature is set as 60 degree Celsius.
- When the sensor value was less than 60, the coffee mug was automatically turned on heated up the coffee.
- The product is checked by manually turn on the switch and found working.

CONCLUSIONS

- An automatic hot coffee mug was modelled and developed.
- The coffee mug has two operating modes: Automatic and manual mode.
- In automatic mode, if the temperature of coffee is less than the threshold, it will automatically turn on the mug and heat up the coffee.
- In manual mode, user can heat the coffee whenever required.
- The coffee mug designed was portable and is made of environmental friendly materials.

COMMUNICATING DESIGNS -WRITING

- The usual purpose of a final or project report is to communicate with the client in terms that ensure the client's thoughtful acceptance of a team's design choices.
- The client's interests demand a clear presentation of the design problem, requirement analysis, design alternatives and decisions taken.
- The results should be summarized in clear and understandable language. Highly detailed or technical materials are often placed in appendices at the end of the report, in order to support clarity.
- The final report writing is a structured process similar to design process.

STRUCTURED PROCESS IN REPORT WRITING

- ❑ Determine the purpose and audience of the technical report.
- ❑ Construct a rough outline of the overall structure of the report.
- ❑ Review that outline within the team and with the team's managers or, in case of an academic project, with the faculty advisor.
- ❑ Construct a topic sentence outline (TSO) and review it within the team. (Example: Entries in Table of Contents)
- ❑ Distribute individual writing assignments and assemble, write, and edit an initial draft.
- ❑ Solicit reviews of the initial draft from managers and advisors.
- ❑ Revise and rewrite the initial draft to respond to the reviews.
- ❑ Prepare the final version of the report and present it to the client.

OUTLINE OF FINAL REPORT

- Abstract
- Table of Contents / Executive summary
- Introduction and overview
- Problem statement and problem definition or framing, including relevant prior work or research.
- Design alternatives considered.
- Evaluation of design alternatives and basis for design selection.
- Results of the alternatives analysis and design selection.
- Supporting materials, often set out in appendices, including.
- Drawings and details.
- Fabrication specifications.
- Supporting calculations or modelling results; and other materials that the client may require.

MATHEMATICAL MODELLING IN DESIGN

- Often when engineers analyse a system to be controlled or optimized, they use a mathematical model. In analysis, engineers can build a descriptive model of the system as a hypothesis of how the system could work, or try to estimate how an unforeseeable event could affect the system. Similarly, in control of a system, engineers can try out different control approaches in simulations.
- A mathematical model usually describes a system by a set of variables and a set of equations that establish relationships between the variables. Variables may be of many types; real or integer numbers, Boolean values or strings, for example.
- The variables represent some properties of the system, for example, the measured system outputs often in the form of signals, timing data, counters, and event occurrence. The actual model is the set of functions that describe the relations between the different variables.
- For example: The required resistance value 'R' in a circuit can be derived during the mathematical relationship between Voltage 'V' and current 'I'.

$$R = V/I$$

- Another simple activity is predicting the position of a vehicle from its initial position, direction and speed of travel, using the equation that distance travelled is the product of time and speed.
- In computer science, mathematical models may be used to simulate computer networks.
- In mechanics, mathematical models may be used to analyse the movement of a rocket model.
- The advantages of mathematical modelling are:
  i. Models exactly represent the real problem situations.
  ii. Models help managers to take decisions faster and more accurately.
  iii. They typically offer convenience and cost advantages over other means of obtaining the required information on reality.
  iv. Large and complex problems can be solved with ease.
  v. Models act as communicators to others by providing information and impact in changing conditions.

PROTOTYPING & PROOFING THE DESIGN

- A prototype in design thinking is "A simulation or sample version of a final product, which is used for testing prior to launch."
- The goal of a prototype is to test products (and product ideas) before spending lots of time and money into creating the final version of the sellable product.
- Prototyping serves to provide specifications for a real, working system rather than a theoretical one. In some design workflow models, creating a prototype (a process sometimes called materialization) is the step between the formalization and the evaluation of an idea.
- One of the best ways to gain insights in a Design Thinking process is to carry out some form of prototyping. This method involves producing an early, inexpensive, and scaled down version of the product in order to reveal any problems with the current design. Prototyping offers designers the opportunity to bring their ideas to life, test the practicability of the current design, and to potentially investigate how a sample of users think and feel about a product.
- Prototyping can be evolutionary prototyping or throwaway prototypes.

EVOLUTIONARY PROTOTYPE

- Evolutionary Prototyping build a robust prototype and constantly improve it.
- These prototypes are built only with well understood requirements instead of acknowledging all the requirements.
- It allows developers to add features or make changes that couldn't be devised during the requirements analysing and designing.
- Developers are helped to develop part by part of the system considering the usability aspects and this type of prototypes are delivered a working system to the end user.

THROWAWAY PROTOTYPE

- Throwaway prototypes are developed from the initial requirements but they are not used for the final product and not an alternative for written specification of the requirements.
- It enables quick prototyping and commit to throwing the prototype away. If the users can get quick feedback on their requirements, they may be able to refine the requirements early in the development of the software. Then changes can be done early in the development life cycle.
- Differences between Evolutionary and Throwaway prototyping

Criteria	Evolutionary Prototype	Throwaway Prototype
Definition	A robust prototype which is continuously refined	Builds in quick time and is later discarded.
Associated with	Refined products, Future concepts, State-of-the-art demonstrations	Early-stage design, Minimum viable product

ADVANTAGES OF PROTOTYPING

- Evaluate technical feasibility
- Enhance product quality
- Effectively present ideas to various stakeholders
- Test the product before building it.
- Can be used to identify the complexities and thereby reduce risks in development.
- Can be used for proper planning.

MODULE 4: DESIGN ENGINEERING CONCEPTS

PROBLEM BASED LEARNING

- **Problem-Based Learning** is a methodological approach to teaching in which learners solve problems of varying degrees of complexity with the application of knowledge they possess or need to possess.
- **Steps in problem-based learning:**
  - Presentation of an "ill-structured" (open-ended, "messy") problem
  - Problem definition or formulation (the problem statement)
  - Generation of a "knowledge inventory" (a list of "what we know about the problem" and "what we need to know")
  - Apply the knowledge and generate possible solutions.
  - Sharing of findings and solutions

PROJECT BASED LEARNING

- **Project –Based Learning** is an instructional method in which students learn a range of skills and subject matter in the process of creating their own projects. Sometimes, these projects are solutions to a real-world problem.
- **Steps in problem-based learning:**
  - Define the problem
  - Solution criteria
  - Solution research
  - Pick a solution
  - Create, run and inspect solution
  - Reflect on solution

PROJECT BASED vs PROBLEM BASED LEARNING

Project Based Learning	Problem Based Learning
Often multidisciplinary	Normally single subject
Often long-term projects	Often short-term projects
Includes the creation of product or performance	Product might only be a proposed solution or presentation or findings
Normally based on real world tasks and settings	Often use case studies, scenarios and ill-structured messy problems

MODULAR DESIGN

- A modular design is an approach for product designing which is used to produce a complete product by integrating or combining smaller parts that are independent of each other.
- With the modular design approach, a complex product (for example, a car) can be broken down or divided into smaller and simpler components that are independently designed and manufactured. Each of these components is then integrated (or assembled) to form the final product.

- Modular design is commonly used in various consumer products like cars, smartphones, computers, and televisions. Other modular design examples include software engineering, software product design, and even large websites (with each webpage as an individual component). A famous example of modularity is LEGO. These plastic toys contain elements that can easily be assembled and reused to develop different finished products.

MODULAR DESIGN PROCESS

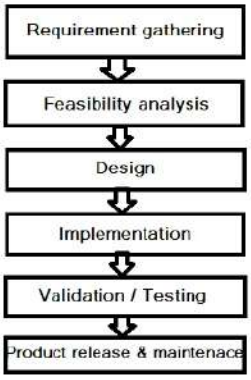
i) Clarify the task
ii) Establish function structure.
iii) Searching for solution principles and concept variants.
iv) electing and evaluating.
v) Preparing design and dimensioned layouts
vi) Preparing production document

BENEFITS OF MODULAR DESIGN

- **Easy to customize products:** Modular design products are easier to customize according to individual customer needs or preferences. For example, if you are looking for a smartphone with better battery life, you can easily include a high-power battery component (built by a third-party manufacturer) into your model.
- **Faster to market:** Modular products, including new ones, are faster to assemble and release. Each modular component is designed, manufactured, and tested separately to save time, and then assembled for the final product.
- **Cost efficiency:** The use of modularity can reduce product development and testing costs for the manufacturer, all thanks to shorter development cycles and modular components' reusability. Additionally, large manufacturers can outsource various components to smaller manufacturing firms, thus cutting down their costs.
- **Sustainability:** A modular design architecture, by definition, uses reusable components that can be used in many similar products; this reduces wastage and adds to the product's overall sustainability.
- **Allows incremental upgrades**: A modular system design or product can be easily upgraded (for example, for better performance of a smartphone or laptop). In non-modular products, it is harder to achieve incremental upgrades.
- **Reduces development & maintenance complexity:** It is easier to identify the source of defects and can replace the damaged module easily. Thus, it reduces the development and maintenance complexities.

PRODUCT DEVELOPMENT LIFE CYCLE

- The product development cycle is the process of taking a product from an idea through its market release and beyond.
- This cycle involves many departments in a company: product managers, developers, designers, QA testers, and others.
- The Product Development Life Cycle consists of 6 phases:



i) **Requirement gathering** – In this phase the requirements or features expected from the system is identified. Personnel interview with the end user, Questionnaire and field visits are some modes used for requirement gathering.

ii) **Feasibility analysis** – In this phase, the designer checks the technical, economical, schedule and operational feasibility of each of the identified requirements. Feasibility analysis is the process of ensuring that a particular requirement can be implemented within the project constraints.

iii) **Design:** In this phase the requirements are modelled into designs which include sketches, 2D plans, 3D models, Prototypes etc.

iv) **Implementation:** The design is transformed into product.

v) **Validation and Testing:** Testing is the process of verifying and validating a product. Validation ensures that the right product is developed whereas verification ensures that the product is developed in the right manner.

vi) **Product release:** Delivering the product to the customer od deploying the product in the target environment. Any changes made to the product after delivering to the customer is termed as maintenance.

BIOMIMICRY – DESIGNS INSPIRED FROM NATURE

- Biomimicry is a practice that learns from and mimics the strategies found in nature to solve human design challenges.
- Biomimicry is learning from and then emulating nature's forms, processes, and ecosystems to create more sustainable designs.
- When translating nature's strategies into design, the science of the practice involves three essential elements: Emulate, Ethos, and (Re)Connect. These three components are infused in every aspect of biomimicry and represent these core values at its essence.

  i) **Emulate:** The scientific, research-based practice of learning from and then replicating nature's forms, processes, and ecosystems to create more regenerative designs.

  ii) **Ethos:** The philosophy of understanding how life works and creating designs that continuously support and create conditions conducive to life.

  iii) **(Re)Connect:** The concept that we are nature and find value in connecting to our place on Earth as part of life's interconnected systems. (Re)Connect as a practice encourages us to observe and spend time in nature to understand how life works so that we may have a better ethos to emulate biological strategies in our designs.

BIOMIMICRY- EXAMPLES

Case 1: Sharkskin = Swimsuit

Sharkskin-inspired swimsuits received a lot of media attention during the 2008 Summer Olympics when the spotlight was shining on Michael Phelps. Seen under an electron microscope, sharkskin is made up of countless overlapping scales called dermal denticles (or "little skin teeth"). The denticles have grooves running down their length in alignment with water flow. These grooves disrupt the formation of eddies, or turbulent swirls of slower water, making the water pass by faster. The rough shape also discourages parasitic growth such as algae and barnacles.

Scientists have been able to replicate dermal denticles in swimsuits (which are now banned in major competition) and the bottom of boats. When cargo ships can squeeze out even a single percent in efficiency, they burn less bunker oil and don't require cleaning chemicals for their hulls. Scientists are applying the technique to create surfaces in hospitals that resist bacteria growth — the bacteria can't catch hold on the rough surface.

Case 2: Beaver – Wet Suite

Beavers have a thick layer of blubber that keeps them warm while they're diving and swimming in their water environments. But they have another trick up their sleeves for staying toasty. Their fur is so dense that it traps warm pockets of air in between the layers, keeping these aquatic mammals not only warm, but dry. Engineers at the Massachusetts Institute of Technology thought surfers might appreciate that same ability, and they created a rubbery, fur-like pelts they say could make "bioinspired materials," such as wetsuits.

Case 3: Termite den – Office building

Termite dens look otherworldly, but they are surprisingly comfortable places to live. While the temperature outside swings wildly throughout the day from lows in the 30s to highs over 100, the inside of a termite den holds steady at a comfortable (to a termite) 87 degrees. Mick Pearce, architect of Eastgate Centre in Harare, Zimbabwe, studied the cooling chimneys and tunnels of termite dens. He applied those lessons to the 333,000 square-foot Eastgate Centre, which uses 90 percent less energy to heat and cool than traditional buildings. The building has large chimneys that naturally draw in cool air at night to lower the temperature of the floor slabs, just like termite dens. During the day, these slabs retain the coolness, greatly reducing the need for supplemental air conditioning.

Case 4: Burr-Velcro

Velcro is widely known example of biomimicry. You may have worn shoes with Velcro straps as a youngster and you can certainly look forward to wearing the same kind of shoes in retirement. Velcro was invented by Swiss engineer George de Mestral in 1941 after he removed burrs from his dog and decided to take a closer look at how they worked. The small hooks found at the end of the burr needles inspired him to create the now ubiquitous Velcro.

Case 5: Whales- Turbines

Whales have been swimming around the ocean for a long time, and evolution has crafted them into a super-efficient form of life. They are able to dive hundreds of feet below the surface and stay there for hours. They sustain their massive size by feeding on animals smaller than the eye can see, and they power their movement with über-efficient fins and a tail. Scientists at Duke University, West Chester University and the U.S. Naval Academy discovered that the bumps at the front edge of a whale fin greatly increase its efficiency, reducing drag by 32 percent and increasing lift by 8 percent. Companies are applying the idea to wind turbine blades, cooling fans, airplane wings and propellers.

Case 6: Birds-Jets

Birds have been able to boost the distance they're able to fly by more than 70 percent though the use of the V-shape. Scientists have discovered that when a flock takes on the familiar V-formation, when one bird flaps its wings, it creates a small updraft that lifts the bird behind. As each bird passes, they add their own energy to the stroke helping all the birds maintain flight. By rotating their order through the stack, they spread out the exertion.

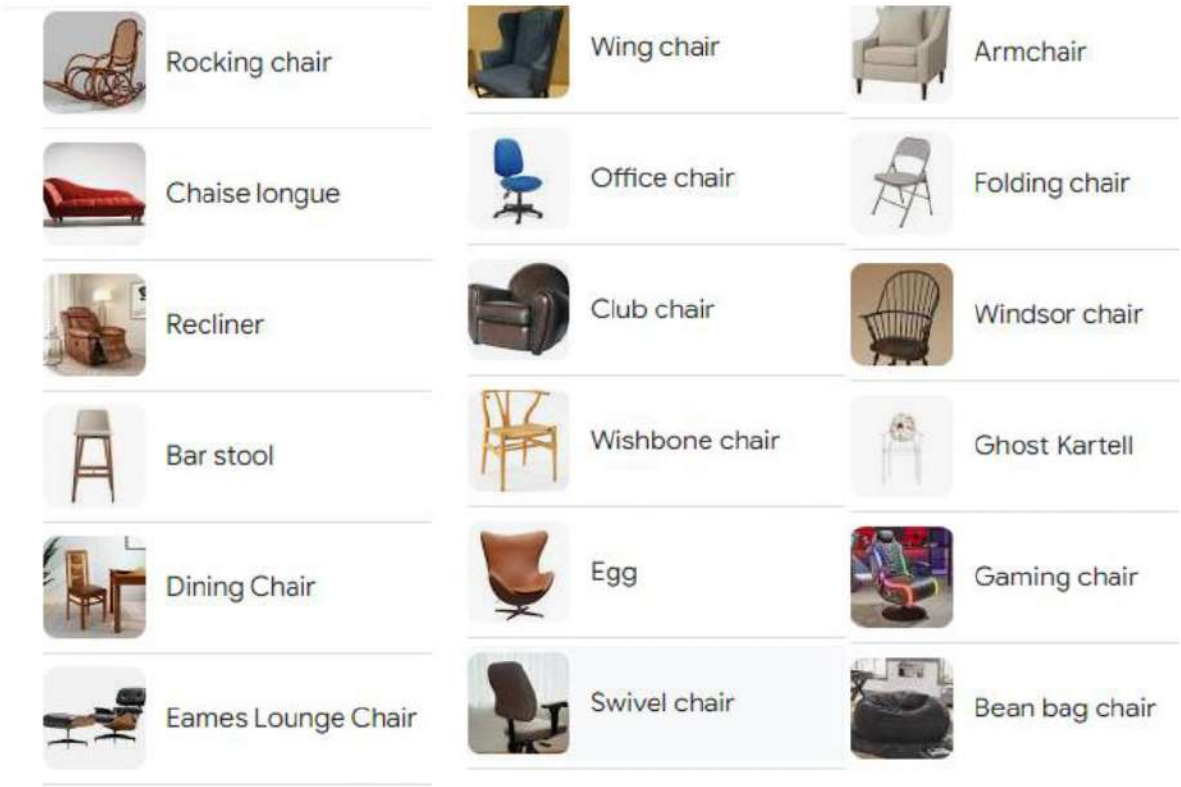
Case 7: Lotus- Paint

The lotus flower is sort of like the sharkskin of dry land. The flower's micro-rough surface naturally repels dust and dirt particles, keeping its petals sparkling clean. If you've ever looked at a lotus leaf under a microscope, you've seen a sea of tiny nail-like protuberances that can fend off specks of dust. When water rolls over a lotus leaf, it collects anything on the surface, leaving a clean leaf behind. A German company, Ispo, spent four years researching this phenomenon and has developed a paint with similar properties. The micro-rough surface of the paint pushes away dust and dirt, diminishing the need to wash the outside of a house.

ERGONOMICS IN DESIGN

- The practice of ergonomics can be summed up simply as "fitting a workplace to an employee's needs," or "making people more comfortable at work."
- The process of ergonomic design involves designing products, workspaces, and environments to fit the physical and mental capabilities of people.
- **Definition of ergonomics:** The ergonomic design discipline focuses on designing products and environments that are comfortable, efficient, and safe for humans to use. It is a multidisciplinary field drawing on knowledge from engineering, psychology, and physiology, to improve the interaction between humans and their environment.
- **Importance of ergonomic design:** Ergonomic design is essential in all industries to help reduce workplace injuries, improve productivity, and increase employee satisfaction. Products and environments designed with ergonomic principles in mind are easier and safer for people to use, reducing the risk of injury and increasing productivity.
- **Principles of ergonomic design:** The principles of ergonomic design – designing products and environments that are easy to use, comfortable, and safe – can be achieved by considering factors such as:
    - the physical and mental capabilities of people
    - the layout and design of workspaces
    - the type of work being performed

CASE STUDY 1: DESIGN ERGONOMICS OF CHAIR



CASE STUDY 2: DESIGN ERGONOMICS OF BOTTLE

BENEFITS OF ERGONOMIC DESIGN

- **Improved Productivity:** Ergonomic design can help to improve productivity by reducing the time and effort required to complete tasks. Products and environments designed with ergonomic principles in mind are easier and more comfortable for people to use, allowing them to work more efficiently.
- **Reduced Workplace Injuries:** Ergonomics reduce workplace injuries by reducing the physical strain and stress placed on workers.
- **Better Employee Satisfaction:** Improve employee satisfaction by creating a more comfortable and enjoyable work environment.
- **Improved Quality of Work:** When workers are comfortable and focused, they are more likely to produce high-quality work that meets or exceeds expectations.

CHALLENGES IN IMPLEMENTING ERGONOMIC DESIGN

- **Cost:** Ergonomic design may require additional resources and training, which can be costly and time-consuming.
- **Resistance to change:** Some organizations may resist implementing changes to their current work practices or equipment.
- **Lack of Expertise:** Some organizations may lack the experience and training required to effectively implement ergonomic design principles.

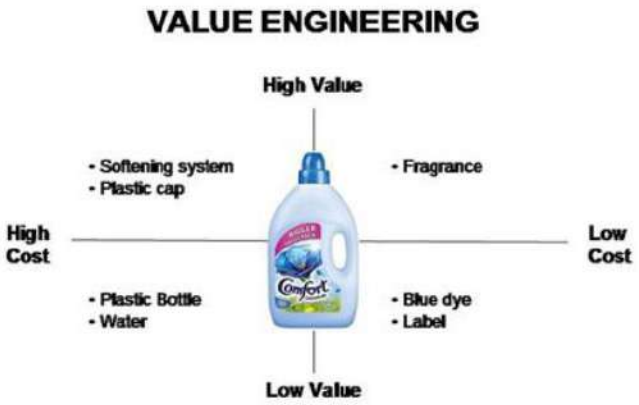
DESIGN AESTHETICS

- Aesthetic design is influencing how people think and feel. It influences how much pleasure we feel from the product.
- Aesthetics are not just about pleasing the eye; they're about pleasing the senses. A good designer creates the right balance of aesthetics and usability.
- As a general rule, an aesthetic design consists of: three dimensional features:
    - Shape of a product
    - Dimensional features such as ornamentation, patterns, lines or colour of a product
    - Combination of one or more such features.

VALUE ENGINEERING

- Value engineering is a systematic analysis of the functions of various components and materials to lower the cost of goods, products and services with a tolerable loss of performance or functionality.
- Value, as defined, is the ratio of function to cost. **Value = Function/Cost**
- Value engineering is a creative perspective utilized in the project life cycle to increase productivity and quality, and to make the project more lucrative.

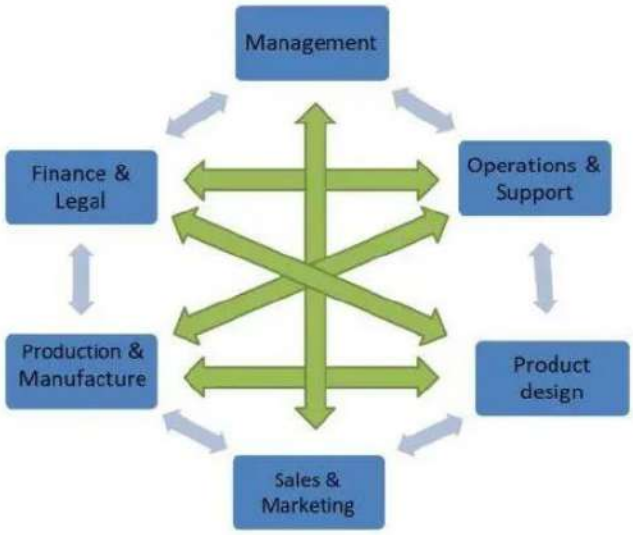
CASE STUDY: VALUE ENGINEERING IN FABRIC CONDITIONER



- The components of cost divide into four segments:
  i) **High value to the customer and high cost** – for these items, a company would rigorously analyse small changes in the specification of each component of cost in order to optimise the relationship between the value to the customer and the cost.
  ii) **High value to the customer and low cost** – for these items, a company would seek to invest more cost in order to increase the value to the customer i.e. in the example, either by increasing the amount of fragrance in the product or by upgrading to a superior quality fragrance.
  iii) **Low value to customer and high cost** – for these items, a company would seek to reduce the cost i.e. in the example, this could be achieved by either reducing the amount of plastic in the bottle or by reducing the amount of blue pigment in the bottle and or by introducing a quadruple concentrated formulation. Any cost saved can either be used to increase margin or to reinvest in high value low-cost items.
  iv) **Low value to the customer and low cost** – a company would typically ignore these items.
- The win-win from value engineering is to increase the customer perceived value whilst reducing the total cost. Whilst often overlooked, pricing is the single most important part of value engineering. This is because:
  - Price is the only element of the marketing mix that directly produces revenue. All the other elements produce cost.
  - Small changes in price can have significant effects on volume, market share and profitability.

CONCURRENT ENGINEERING

- Concurrent engineering, also known as simultaneous engineering, is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively. It decreases product development time and also the time to market, leading to improved productivity and reduced costs.
- The process flow diagram is shown below:



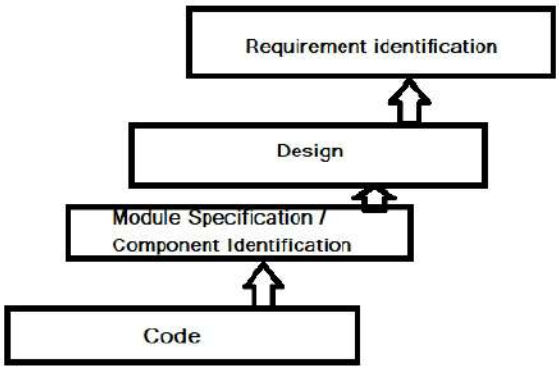
- The major perceived disadvantage of concurrent engineering is that it increases the time spent in preliminary design, when the design staff is anxious to finalize details and release drawings.

ADVANTAGES OF CONCURRENT ENGINEERING

- It encourages multi-disciplinary collaboration.
- Reduces product cycle time.
- Reduces cost.
- Increases quality by supporting the entire project cycle – enhanced quality.
- Increases productivity by stopping mistakes in their tracks.
- It gives a competitive edge over the competitors.

REVERSE ENGINEERING

- Reverse engineering, sometimes called back engineering, is a process in which software, machines, aircraft, architectural structures and other products are deconstructed to extract design information from them. Often, reverse engineering involves deconstructing individual components of larger products.
- The purpose of reverse-engineering is to find out how an object or system works. There are a variety of reasons to do this. Reverse-engineering can be used to learn how something works and to recreate the object or to create a similar object with added enhancements.
- The phases of reverse engineering are illustrated below:



ADVANTAGES OF REVERSE ENGINEERING

- Reduce cost while developing products.
- Lesser maintenance costs.
- Quality improvement
- Competitive advantages

MODULE 5: EXPEDIENCY, ECONOMICS AND ENVIRONMENT IN DESIGN ENGINEERING

DESIGN FOR PRODUCTION

- Design for Production includes two categories:
  - Design for Manufacturing (DFM)
  - Design for Assembly

DESIGN FOR ASSEMBLY

- Assembly refers to the way in which the various parts, components and sub systems are joined, attached or grouped together to form the final product.
- Assembly can be characterized as consisting of a set of processes by which the assembler
  (1) handles parts or components (i.e., retrieves and positions them appropriately relative to each other)
  (2) inserts (or mates or combines) the parts into a finished subsystem or system.

DESIGN FOR MANUFACTURING

- DFM begins with the formation of design team.
- Teams committed to DFM are multidisciplinary – they include engineers, manufacturing managers, logistics specialists, cost accountants, marketing and sales professionals etc.
- Basic methodology of DFM consist of six steps:

  1. Estimate the manufacturing cost of a given design alternative.
  2. Reduce the costs of components.
  3. Reduce the costs of assembly.
  4. Reduce the cost of supporting production.
  5. Consider the effects of DFM on other objectives.
  6. If the results are not acceptable, revise the design once again.

DESIGN FOR USE

- Design for use ties together the designer–client–user triangle in a powerful way.
- The product designed or developed should be 'user-friendly'.
- The term 'user-friendly should be made specific. This specificity may include interfaces between the designed system and the user, skills requirements, physical demands on the user (captured in the field of ergonomics), and even how well the system works relative to unintended applications.
- Design for use deals with reliability and maintainability.
- **Reliability:** Reliability means the probability that an item will perform its function under stated conditions of use and maintenance for a stated measure of a variate (time, distance, etc.).
- **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.

DESIGN FOR SUSTAINABILITY

- Sustainable design creates long-term solutions and helps societies ensure the well-being of their people and harmony with the environment for generations. Designers reduce waste by making products that are recyclable, compostable and even better - endlessly reusable.
- Sustainability is broken into four distinct areas, known as the four pillars of sustainability: Human, Social, Economic, and Environmental Sustainability
- Sustainable design principles aim to:
  i) Optimize site potential.
  ii) Minimize non-renewable energy consumption and waste.
  iii) Use environmentally preferable products.
- There are examples of eco-design in all kinds of consumer goods, such as biodegradable furniture, recycled tableware, edible coffee cups and bamboo sunglasses or toothbrushes, as well as clothes and shoes made with plastic recovered from the ocean and ecological gold jewellery.

ENGINEERING ECONOMICS IN DESIGN

- The engineering economics is concerned the systematic evaluation of the benefits and costs of projects involving engineering design and analysis.
- Engineering economics quantifies the benefits and costs associating with engineering projects to determine if they save enough money to warrant their capital investments.
- The simplest method for cost estimation is to estimate labour, materials and overhead costs.

LABOUR COST

- Labor 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.
- Labor costs also include a variety of indirect costs that are less evident because they are generally not paid directly to employees. These 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.

MATERIAL COST

- Materials 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.
- BOM specifies all of the ingredients that we need, as well as the exact quantities needed to make a specified lot size (i.e., the number of the designed devices we want to make).

- Sample BOM is shown below:

Sl. No.	Component Name	Count	Cost in INR
1	DHT11 Sensor	1	180
2	12V DC Cooling Fan	1	100
3	60W Filament Bulb	1	20
4	12V 2A DC Power Supply Adapter	1	240
5	Transparent PVC Box with Lid	1	200
6	Jumper wires	20	60
7	Lolin Node MCU ESP8266	1	400
		Total amount in INR	1200
		Amount in words: One thousand and two hundred only	

OVERHEAD COST

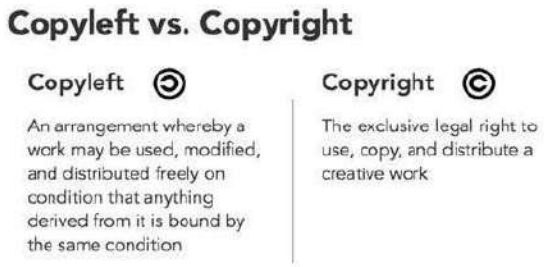
- The costs incurred by a manufacturer that cannot be directly assigned to a single product are termed overhead. If, for example, a company makes a product in a factory that also produces 20 other products, the cost of the building, the machines, the janitorial staff, the electricity, and so on, must somehow be shared or distributed among all of the 21 items.
- If the company ignored these overhead costs in setting its product's prices, it would soon find itself unable to pay for the building and the services necessary to maintain it.
- Overhead cost categories include building cost, Utilities, Office supplies, rent, Advertising and marketing, Technology expenses, Property taxes, Administration cost, Legal fees, Travel costs etc.

DESIGN RIGHTS

- Design rights include patents, trademarks, trade secrets and copyright.
- Copyright, trademarks, patents, and trade secrets are types of intellectual property (IP).
- Patent protects new inventions, processes, or scientific creations, a trademark protects brands, logos, and slogans, and a copyright protects original works of authorship.

COPYRIGHT

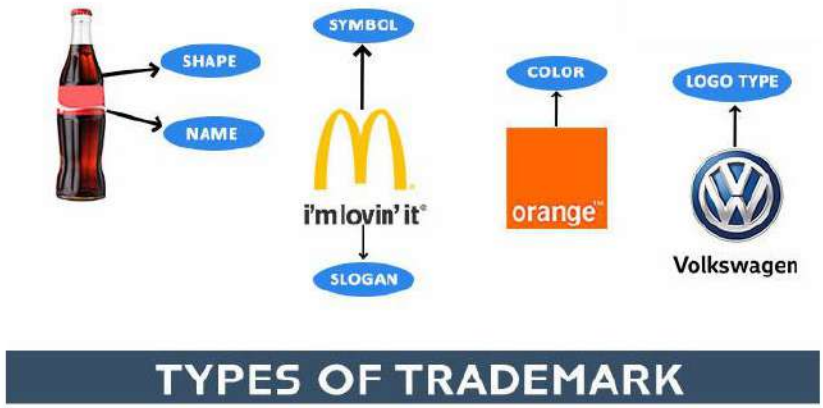
- A copyright is a collection of individual rights that you automatically have once you create an original work that is fixed in a tangible medium like a photograph, a book, or an mp3 file.
- These rights include the right to reproduce the work, to prepare derivative works, to distribute copies, to perform the work publicly, and to display the work publicly.



- As the copyright owner, you can transfer an individual right or multiple rights to one or more people or collectively transfer them to one or more people. This can be accomplished through licensing, assigning, and other forms of transfers.
- Being a copyright owner also allows you to control whether and how your work is made available to the public.

TRADE MARK

- A trademark is a word, phrase, symbol, and/or design that identifies and distinguishes the source of the goods of one party from those of others.
- A service mark is a word, phrase, symbol, and/or design that identifies and distinguishes the source of a service rather than goods. Examples include brand names, slogans, and logos.
- The term "trademark" is used in a general sense to refer to both trademarks and service marks.

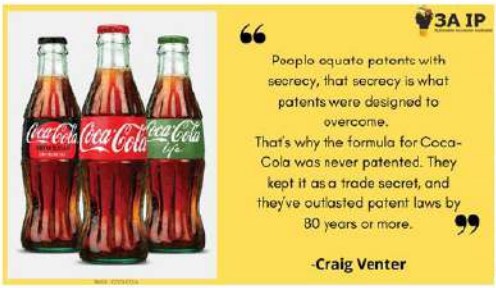


PATENT

- A patent protects inventions. These inventions can include new and useful processes, machines, manufactures, compositions of matter as well as improvements to them.
- The primary goal of the patent law is to encourage innovation and commercialization of technological advances. Patent law incentivizes inventors to publicly disclose their inventions in exchange for certain exclusive rights.
- Inventors can apply for and be granted a patent from the respective patent offices in each nation. (Example: US patent, Indian Patent etc.)

TRADE SECRET

- Trade secret protection protects secrets from unauthorized disclosure and use by others.
- A trade secret is information that has an economic benefit due to its secret nature, has value to others who cannot legitimately obtain it, and is subject to reasonable efforts to maintain its secrecy.
- The protections afforded by trade secret law are very different from others forms of IP.
- Example: KFC, Coco Cola composition etc.



ETHICS IN DESIGN

- **Definition:** The discipline dealing with what is good and bad and with moral duty and obligation.
  - i) A set of moral principles or values.
  - ii) A theory or system of moral values.
  - iii) The principles of conduct governing an individual or group.
- Moral means principles of right or wrong in behaviour
- Engineering Professional societies/ bodies has released the code of ethics for engineers.
- Example: IEEE code of ethics, ASCE code of ethics (American Society of Civil Engineers)

ETHICS IN ENGINEERING DESIGN

- Engineering design ethics concerns issues that arise during the design of technological products, processes, systems, and services. This includes issues such as safety, sustainability, user autonomy, and privacy.
- Universal ethical values such as honesty, integrity, promise-keeping, fidelity, fairness, respect for others, responsible citizenship, pursuit of excellence and accountability is followed in engineering.
- **Role of ethics in engineering:** The engineers' code of ethics demands that professionals do their best to promote equity in the field and sustainability efforts in the building trade. Ethically, engineers are obligated to issue public statements, arguments, criticisms, or opinions that: Only address technical matters.

HIERARCHY OF ETHICAL OBLIGATIONS

Primary: Ethical Obligations to the Public

Secondary: Ethical Obligations to Employer or Client

Tertiary: Ethical Obligations to Other Professionals and Other Parties

7 PRINCIPLES IMPACTING PRIMARY, SECONDARY & TERITIARY OBLIGATIONS

1. Protecting The Public Health, Safety and Welfare
2. Demonstrating Professional Competence
3. Maintaining Objectivity/Truthfulness
4. Addressing Conflict of Interest
5. Preserving Confidentiality
6. Receiving and Providing Valuable Consideration
7. Emerging Areas/Emerging Challenges

QUESTION BANK

PART A QUESTION OF 3 MARKS

MODULE 1

1. Discuss the importance of design constraints?
2. Describe how to select the "best possible design" from the generated design alternatives.
3. Outline the significance of understanding customer requirements in design process
4. Describe any three constraints that can occur in design process of a lunch box.
5. What is engineering design? Draw a diagram to represent the engineering design process?
6. Explain and differentiate conceptual design and detailed design?
7. List the objectives and constrains for designing a school bag for school students.
8. State how engineering design is different from other kinds of design.
9. How is engineering design different from other kinds of design?
10. Explain how to identify customer requirements of design.

MODULE 2

11. Discuss how to manage the conflicts in a team executing the design thinking process.
12. How does the design thinking approach help engineers in creating innovative and efficient designs?
13. Explain convergent questioning in design thinking.
14. Explain how conflict in team environment helps in better design of products .
15. How prototype will help to identify the best possible solution for the problem?
16. Compare convergent thinking and divergent thinking?
17. How to perform design thinking as a team managing the conflicts?
18. Explain divergent-convergent questioning in design thinking.
19. Explain the term design functions as applicable to engineering design.
20. How does design thinking approach help engineers in creating innovative and efficient designs?

MODULE 3

21. Clarify the part of mathematics and physics in the design engineering process.
22. What are factors to be considered in preparing technical reports to communicate a design efficiently?
23. Describe how prototyping helps in design process
24. Explain any three advantages of communicating designs in writing.
25. “Sketching is a powerful tool in design engineering”. Justify this statement.
26. What is a mathematical model? State the significance?
27. List the factors to be considered in preparing oral presentations to communicate designs effectively to clients.
28. How does prototyping help to predict whether the design will function well or not?
29. Briefly explain the role of basic principles of mathematical modelling in design.
30. What are the factors considered in communicating designs through oral presentation?

MODULE 4

31. Describe the use of value engineering in the design process.
32. How does intelligence in nature inspire engineering designs?
33. Illustrate advantages of reverse engineering in design.
34. Explain bio mimicry in design with an example.
35. Write and differentiate problem based and project based learning?
36. Compare sequential design and modular design techniques?
37. Relate how designs are inspired from nature.
38. How the life cycle design approach influences design decisions?
39. Examine how engineering students can learn design engineering through projects.
40. Distinguish how aesthetics and ergonomics change engineering designs.

MODULE 5

41. How to estimate the cost of a particular design?
42. How do ethics play a decisive role in engineering design?
43. Describe ethics to be followed in engineering design.
44. Explain the significance of sustainability in engineering design
45. Explain the cost factor calculation of a particular design?
46. Write the role of economics in engineering design?
47. What are design rights and how can an engineer put it into practice?
48. Describe the role of ethics in the design of any two products.
49. Show how designs are finalized based on the aspects of production methods.
50. Tell how ethics play a decisive role in engineering design.

PART B QUESTIONS OF 14 MARKS

MODULE 1

1. Design a study table for a child upto 5 years old specifying objectives, functions and constraints through various stages of design processes. Use hand sketches to illustrate the process.
2. Choose the best design for a laptop stand for avoiding overheating, also incorporate the customer requirements. Show how design objectives were finalized considering the constraints also.
3. Design two alternatives of a chair suitable for a five-year-old child, and then to narrow down to the best design based on objectives and constraints. Sketch both the designs.
4. Identify the objectives, functions and constraints for designing a water level indicator. Illustrate the various stages of the design process. Provide suitable sketches.
5. Explain the design process through designing a handbag for women of age group of 15 to 25 years. Use hand sketches to support your idea.
6. Describe the concept of generating design alternatives and choosing a design through designing a coffee mug with the help of sketches
7. Design the interface of a simple calculator explaining each stage in the design process. Use hand sketches wherever necessary.
8. An electric car recharging station has to be designed. Find the customer requirements and explain how it can be materialised. Include the detailed layout of the station?

9. Show the designing of a length adjustable mop to clean ceiling fan. Use hand sketches to illustrate the various stages of the design process.
10. In certain situations, users require extra length for their mobile charger cable. But offering extra cable length becomes an issue while normal usage. Develop a design to effectively solve this problem. Use necessary hand sketches. Also give the objectives and constraints of your design.

MODULE 2

1. Design a suitable product for easy cleaning of dust from the chalkboards in a classroom. Illustrate the various stages involved in design thinking. Sketch the final design.
2. Construct two possible designs of a dining table set that occupies minimum space when not in use and then refine them to narrow down to the best design. Show how the divergent-convergent thinking helps in the process. Provide your rationale for each step by using hand sketches only.
3. Design a water bottle that can be opened with one hand. Illustrate the various stages involved in design thinking. Sketch the final design.
4. During the Covid-19 pandemic, people have to wear a mask, but wearing a mask is not comfortable. Empathize about this design problem and arrive at a solution using the design thinking process, so that people can select the level of protection provided by masks according to different situations. Illustrate the solution using sketches.
5. Illustrate the design thinking process through designing a walking stick for elderly people.
6. Design a parachute mechanism for safe landing an egg which is dropped from a height of 3 meters using iterative design thinking process with the help of sketches.
7. Explain the five different stages of design thinking? Illustrate it with the help of a face mask design
8. Show how divergent and convergent thinking process will help to choose the best design from a list of possible solutions, considering water jug as a case study.
9. Construct a number of possible designs and then refine them to narrow down to the best design for a baby seater in a car. Show how convergent-divergent thinking helps in the process. Illustrate with hand sketches.
10. Design a carry bag for shopping purposes. Illustrate the various stages involved in design thinking. Sketch the final design.

MODULE 3

1. Graphically communicate the design of a foldable ladder for electricians. Draw the detailed 2D drawings of the same with design detailing, material selection, scale drawings and dimensions. Use only hand sketches.
2. Describe the role of mathematical modelling in design engineering. Show how mathematics and physics play a role in designing a simple paper cutting scissor.
3. Design a foldable steel table. Draw the detailed 2D drawings of the same with design detailing, scale drawings and dimensions. Use only hand sketches.
4. Prepare a technical report for a newly designed website for online training of students with neat diagrams for presenting to a client.
5. Design an office chair and communicate your design using sketches with design detailing, material selection, scale drawings and dimensions.
6. Describe the role of mathematical modelling in design engineering citing an example.
7. Explain the general guidelines for technical communication. Justify each point with an example.

8. A web page has to be maintained to store the details of covid patients in Kerala district wise. Design a web page and its popups with neat sketches and necessary documentation. The design must include the specification of softwares required for the page development.
9. Draw the detailed drawing of a foldable bed with design detailing, scale drawings and dimensions. Use hand sketches.
10. Explain the steps for oral presentation for marketing your own product within limited budget? Illustrate with an example and suitable figures.

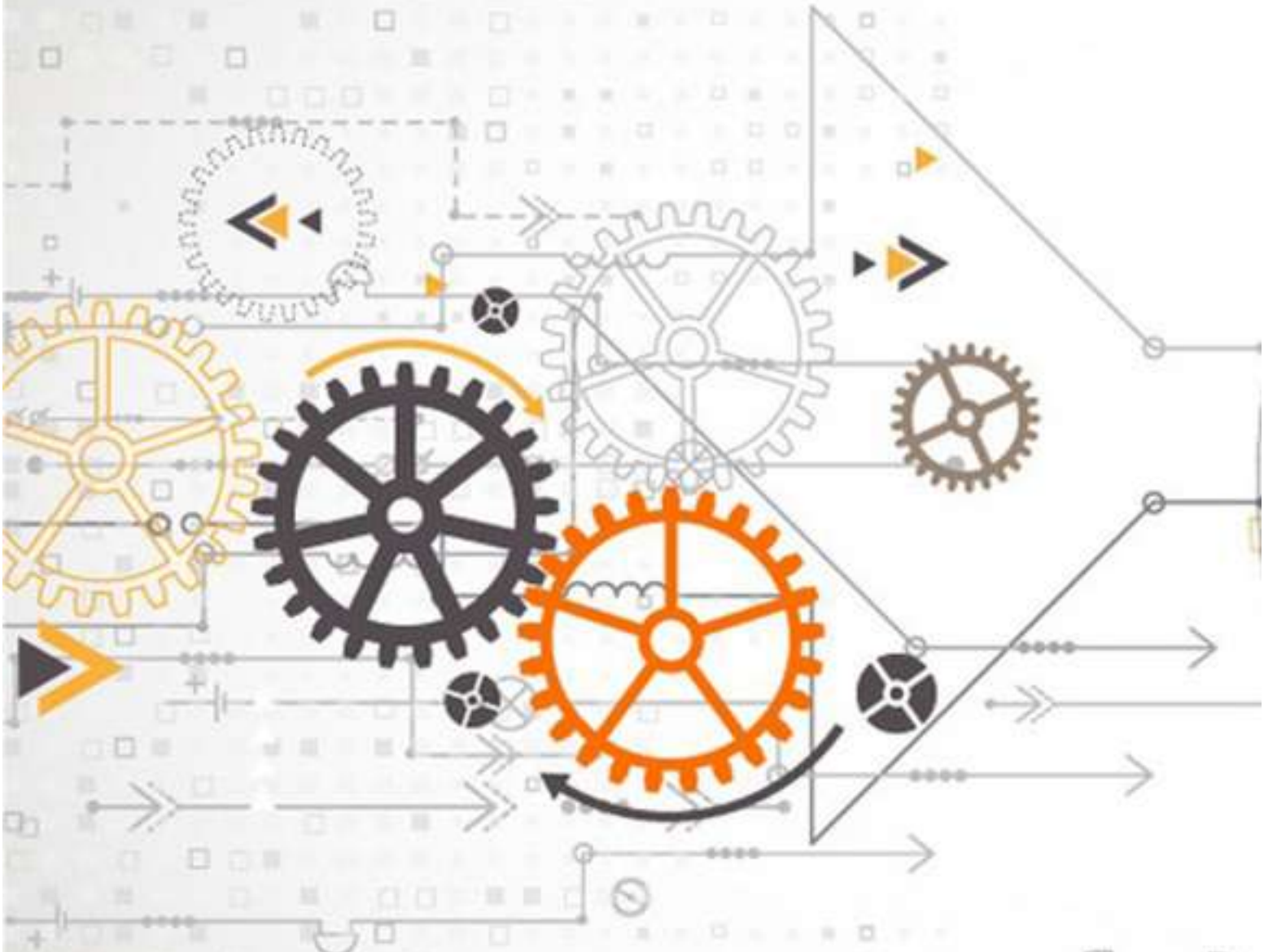
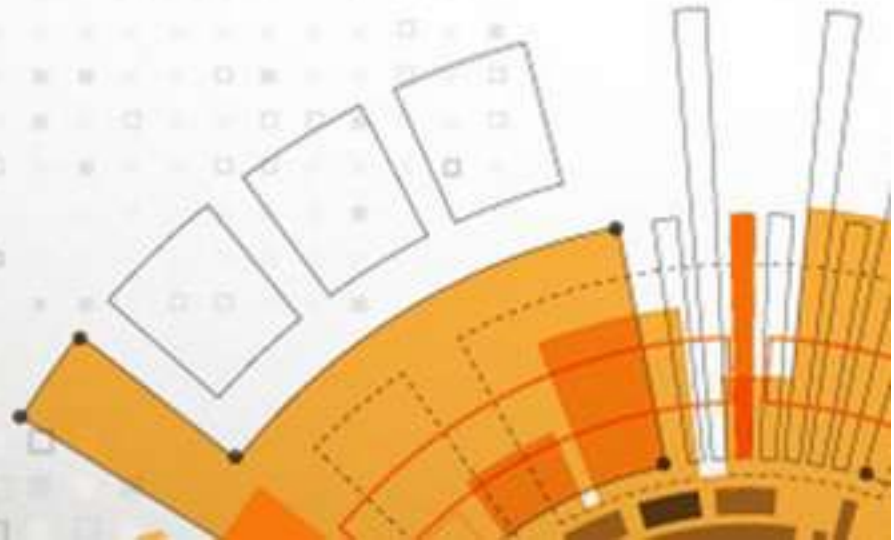
MODULE 4

1. Apply value engineering to a pen, and design a lightweight pen torch. Illustrate the solution using sketches.
2. Design waste bins to be kept at bus stops for waste collection enabling source separation. The bin should be theft-resistant and protect the contents of the bin from external weather conditions. Design the bins with ergonomic consideration for waste collection workers. Sketch the design using hand drawings.
3. Illustrate modular design approach for designing of desktop computers.
4. Demonstrate the concept of ergonomics through design of a table lamp.
5. A class room has to be designed in such a way that it should support the faculty for taking both online and offline mode class in the same room. Prepare a bill of material and draw a neat sketch showing the seating arrangement, cable layout, projector and smartboard position, podium, camera and the teacher position. aesthetic, ergonomics and convenience must be considered.
6. (a) Write the significance of life cycle design?
   (b) Apply the ergonomic design concepts to design a knife for various purposes. Illustrate each design with a neat sketch?
7. Design a nature inspired solar lamp for the students residing in urban areas. These students do not have proper availability of electricity and cannot afford highly priced products. Illustrate your design with sketches.
8. Apply modular engineering to a conventional bicycle and design a bicycle which can used in different terrains. Illustrate the design using sketches.
9. Show the design of a kid friendly craft and then depict how the design changes when considering 1) aesthetics and 2) ergonomics into consideration. Give hand sketches and explanations to justify the changes in designs.
10. Design a smart umbrella which has automatically folding and unfolding mechanism during heavy rain and sunlight with the concept of bio mimicry and sustainability. Use hand sketches to support your arguments.

MODULE 5

1. Design a fan which automatically reduces speed or stops when the temperature reduces during the night for energy conservation. Use hand sketches to support your design.
2. Describe how to estimate the cost of a pen and list the various parts. Show how the economics will influence the engineering designs. Use hand sketches to support your arguments.
3. Illustrate the changes in design of disposable tea cup in terms of production, use and sustainability
4. Describe the how to estimate the cost of a table in design stage? Show how economics will influence the engineering designs.

5. A table has to be designed as a study table, but it must include a provision to place your computer. Calculate the cost difference if you want to convert it as a dining table. The cost calculation must include labor, material and overhead costs.
6. An umbrella has to be designed for daily use. Show how the cost will vary based on material, design and labor using suitable neat hand sketches?
7. Examine the changes in the design of a footwear in terms of production methods, reliability issues and environmental factors. Use hand sketches and give proper rationalization for the changes in design.
8. Describe how to estimate the cost of a residence house in design stage. Show how the economics will influence its design. Use hand sketches to support your arguments.
9. Examine the changes in the design of a hand purse with 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 change in design
10. Describe how to estimate the cost of a particular design of a smart bus for public use with wi-fi and proper cleaning facility. List the various components used. Show how economics will influence the engineering designs, use hand sketches to support the arguments.

DESIGN AND ENGINEERING

Dr. Pramod Mathew Jacob