NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

COURSE MATERIALS

2019 SCHEME

EST 200 DESIGN ENGINEERING

VISION OF THE INSTITUTION

To mould true citizens who are millennium leaders and catalysts of change through excellence in education.

MISSION OF THE INSTITUTION

NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2002
- Course offered : B.Tech in Computer Science and Engineering

  M.Tech in Computer Science and Engineering

  M.Tech in Cyber Security
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to A P J Abdul Kalam Technological University.

DEPARTMENT VISION

Producing Highly Competent, Innovative and Ethical Computer Science and Engineering Professionals to facilitate continuous technological advancement.

DEPARTMENT MISSION

1. To Impart Quality Education by creative Teaching Learning Process
2. To promote cutting-edge Research and Development Process to solve real world problems with emerging technologies.
3. To Inculcate Entrepreneurship Skills among Students.
4. To cultivate Moral and Ethical Values in their Profession.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates will be able to Work and Contribute in the domains of Computer Science and Engineering through lifelong learning.

PEO2: Graduates will be able to Analyze, design and development of novel Software Packages, Web Services, System Tools and Components as per needs and specifications.

PEO3: Graduates will be able to demonstrate their ability to adapt to a rapidly changing environment by learning and applying new technologies.

PEO4: Graduates will be able to adopt ethical attitudes, exhibit effective communication skills, and Teamwork and leadership qualities.

PROGRAM OUTCOMES (POS)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO)

PSO1: Ability to Formulate and Simulate Innovative Ideas to provide software solutions for Real-time Problems and to investigate for its future scope.

PSO2: Ability to learn and apply various methodologies for facilitating development of high quality System Software Tools and Efficient Web Design Models with a focus on performance optimization.

PSO3: Ability to inculcate the Knowledge for developing Codes and integrating hardware/software products in the domains of Big Data Analytics, Web Applications and Mobile Apps to create innovative career path and for the socially relevant issues.

COURSE OUTCOMES

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

MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	2	1					1			1		
CO 2		2				1		1				2
CO 3			2			1	1		2	2		1

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

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: There will be two parts; Part A and Part B.
Part A : 30 marks
part B : 70 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 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	CIE	ESE	ESE Duration
150	50	100	3 hours

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	5	5	10
Understand	10	10	20
Apply	35	35	70
Analyse	-	-	-
Evaluate	-	-	-
Create	-	-	-

SYLLABUS`

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
			2	0	0	2
EST 200	DESIGN AND ENGINEERING					

Preamble:

The purpose of this course is to

i) introduce the undergraduate engineering studentsthe fundamental principles of design engineering,

ii) make them understand the steps involved in the design process and

iii) familiarize them with the basic tools used and approaches in design.

Students are expected to apply design thinking in learning as well as while practicing engineering, which is very important and relevant for today. Case studies from various practical situations will help the students realize that design is not only concerned about the function but also many other factors like customer requirements, economics, reliability, etc. along with a variety of life cycle issues.

The course will help students to consider aesthetics, ergonomics and sustainability factors in designs and also to practice professional ethics while designing.

Prerequisite:

Nil. The course will be generic to all engineering disciplines and will not require specialized preparation or prerequisites in any of the individual engineering disciplines.

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 Bio-mimicry,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 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

QUESTION BANK

Q.NO.	QUESTIONS	CO	KL
	MODULE 1		
1.	What does it mean to design something?	CO1	K2
2.	How Is engineering design different from other kinds of design?	CO1	K2
3.	Where and when do engineers design?	CO1	K2
4.	What is the basic vocabulary in engineering design?	CO1	K2
5.	How to learn and do engineering design.	CO1	K2
6.	How to do engineering design?	CO1	K2
7.	Illustrate the process with an example.	CO1	K4
8.	How to identify the customer requirements of design?	CO1	K3
9.	How to finalize the design objectives?	CO1	K3
10.	How to identify the design constraints?	CO1	K3
11.	How to express the functions a design in engineering terms?	CO1	K3
12.	How to generate or create feasible design alternatives?	CO1	K3
13.	How to identify the "best possible design"?	CO1	K2
14.	Design simple products going through the different stages of design process.	CO1	K4
	MODULE 2		
15.	How does the design thinking approach help engineers in creating innovative and efficient designs?	CO2	K2
16.	How can the engineers arrive at better designs utilizing the iterative design thinking process (in which knowledge acquired in the later stages can be applied back to the earlier stages)?	CO2	K2
17.	Describe how to create a number of possible designs and then how to refine and narrow down to the 'best design'.	CO2	K3
18.	How to perform design thinking as a team managing the conflicts?	CO2	K2
19.	Design thinking approach for 1 HUMANITIES designing any simple products within a limited time and budget	CO2	K3
	MODULE 3		
20.	How do engineering sketches and drawings convey designs?	C03	K2
21.	How can a design be communicated through oral presentation or technical reports efficiently?	C03	K2
22.	How do mathematics and physics become a part of the design process?	C03	K2
23.	How to predict whether the design will function well or not?	C03	K2
24.	Design communication through detailed 2D or 3D drawings of simple products with design detailing, material selection, scale drawings, dimensions, tolerances, etc.	C03	K3

25.	How engineering students can learn design engineering through projects?	CO4	K3
26.	How students can take up problems to learn design engineering?	CO4	K2
27.	What is modular approach in design engineering? How it helps?	CO4	K3
28.	How the life cycle design approach influences design decisions?	CO4	K2
29.	How do aesthetics and ergonomics change engineering designs?	CO4	K2
30.	How do the intelligence in nature inspire engineering designs?	CO4	K2
31.	What are the common examples of bio-mimicry in engineering?	CO4	K3
32.	How do concepts like value engineering, concurrent engineering and reverse engineering influence engineering designs?	CO4	K2
33.	Develop new designs for simple 1 HUMANITIES products using bio-mimicry and train students to bring out new nature inspired designs.	CO4	K4
34.	How designs are finalized based on the aspects of production methods, life span, reliability and environment?	CO5	K2
35.	How to estimate the cost of a particular design and how will economics influence the engineering designs?	CO5	K2
36.	What are design rights and how can an engineer put it into practice?	CO5	K3
37.	How do ethics play a decisive role in engineering design?	CO5	K2
38.	Conduct exercises using simple products to show how designs change with constraints of production methods, life span requirement, reliability issues and environmental factors.	CO5	K4

Module 1
Notes

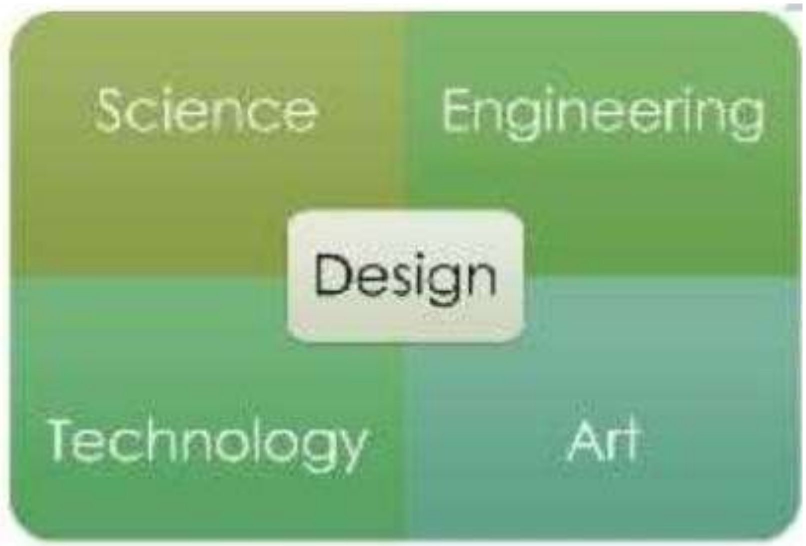
Introduction

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

Thus, although engineers are not the only people who design things, it is true that the professional practice of engineering is largely concerned with design; it is often said that design is the essence of engineering. To design is to pull together something new or to arrange existing things in a new way to satisfy a recognized need of society.

“Design establishes and defines solutions to and pertinent structures for problems not solved before, or new solutions to problems which have previously been solved in a different way.” The ability to design is both a science and an art. The science can be learned through techniques and methods to be covered in this text, but the art is best learned by doing design. It is for this reason that your design experience must involve some realistic project experience.

Science, Technology, Engineering & Art



In a nutshell, a Scientist studies nature, a Technologist manipulates nature, and an Engineer exploits technology for human purposes. While Scientists may, at times, may conduct scientific studies for the sake of discovery, Engineers and Technologists always try to have in mind the ultimate benefit of humankind and results of their work are invariably beneficial for human purposes.

Engineering is the art of optimally using technology and is primarily concerned with how to direct to useful and economical ends the natural phenomena which scientists discover and formulate into acceptable. Engineering therefore requires the creative imagination to innovatively apply technology in order to obtain useful applications of natural phenomena.

It seeks newer, cheaper, better technologies of using natural sources of energy and materials.

Science Is very concerned with what is (exists) in the natural world. Whereas technology deals with how humans modify, change, alter, or control the natural world. And, Engineering attributes of design which let us develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

- Science is knowledge of the natural world put together, Engineering is creation based on the scientific knowledge put together, and Technology is the set of engineered creations put together.

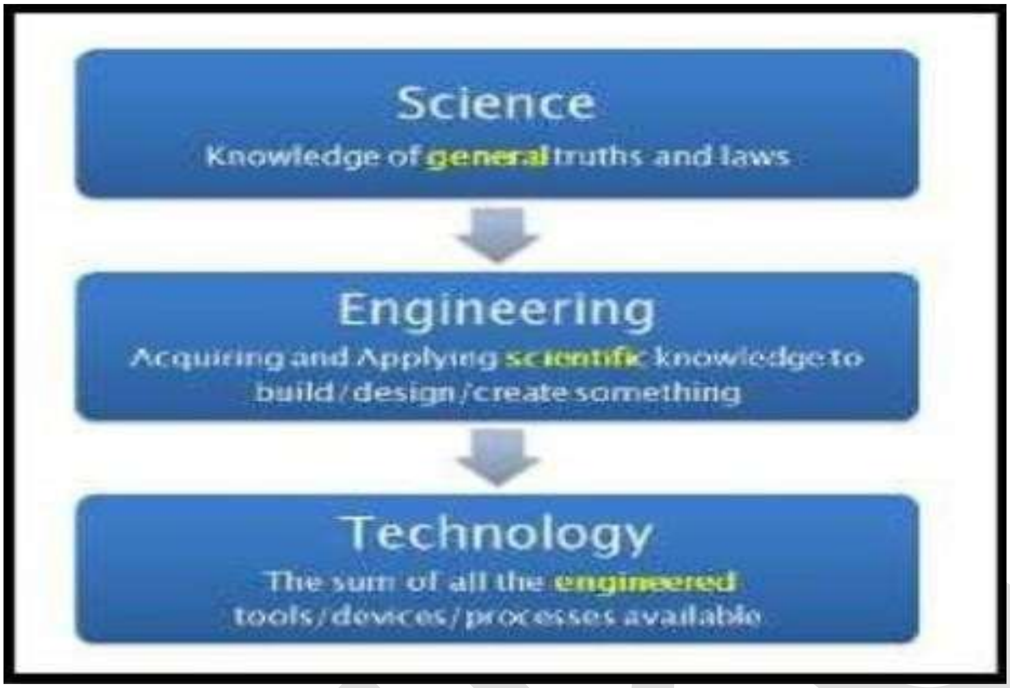
- ❖ Science comes from observation of the world, Engineering comes from acquiring and applying knowledge, and Technology comes from repeated application and approval of the engineered tools.
- ❖ Science is about creating meaning of natural phenomenon, Engineering is about creating new devices, tools and processes, and Technology is about creating a collection of engineered and tested tools for the mankind.

*Eg-1: **Science** is based on observation: The friction between a sphere and a flat surface is minimum, allowing the sphere to roll with the slightest deviation from the horizontal position of the surface. Given the weight of the sphere and the tilt angle, all parameters of the sphere motion can be calculated, including the rolling friction.*

Technology: A wheel hub with ball bearings ensures long life and effortless wheel motion(e.g. cart wheel, etc.), by exploiting the minimum rolling friction principle.

Engineering: Modern vehicles wheel hubs are fitted with specially designed ball bearings which usually last well beyond the average life span of the vehicle.

Note: The intriguing behaviour of a ball on a tilted flat surface triggers the curiosity of the scientist who derives the physical and mathematical laws underpinning that behaviour. The technologist finds (invents) the application(s) exploiting the laws governing the scientific phenomenon (whether he knows them or not). The engineer finds the most appropriate design for each specific technological application of the scientific principle.



Eg-2:

Science: Burning wood produces heat, water, and carbon dioxide. Heat denatures proteins in food.

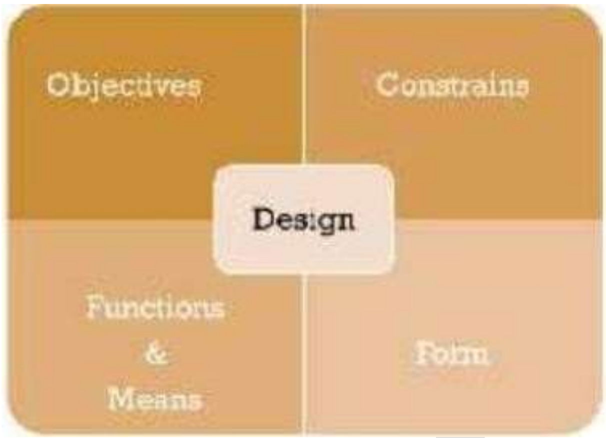
Technology: Fire can be used to cook food.

Engineering: Building a fireplace and chimney makes it easier to cook with fire without filling the room with smoke.

Hence it can be concluded that in every designs you can find the elements of science, engineering, technology and art.

Characteristics of Design or Aspects of Design

Having a defined engineering design and some vocabulary, we now define a process of design, that is, how we actually do a design. This may seem a bit abstract, because we will break down a complex process into smaller, more detailed design tasks. However, as we define those design tasks, we will identify specific design tools and methods that we use to implement a design process. Keep in mind that we are not presenting a recipe for doing design. Instead, we are outlining a framework within which we can articulate and think about what we are doing as we design something. Further, it is important to keep in mind that our overall focus will be on what we will identify as conceptual design, the early stage where different design ideas or concepts are developed and analyzed.



It's not a big surprise that a whole bunch of questions immediately come to mind. Typically, design projects start with a statement that talks about a client's intentions or goals, the design's form or shape, its purpose or function, and perhaps some things about legal requirements. That statement then leads to the designer's first task: to 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). This clarification task proceeds as the designer asks the client to be more precise about what she really wants. Asking questions is an integral part of the design process. Aristotle noted long ago that knowledge resides in the questions that can be asked and the answers that can be provided. By looking at the kinds of questions that we can ask, we can articulate the design process as a Series of design tasks.

Thus the basic characteristics of any designs can be explained as follows:

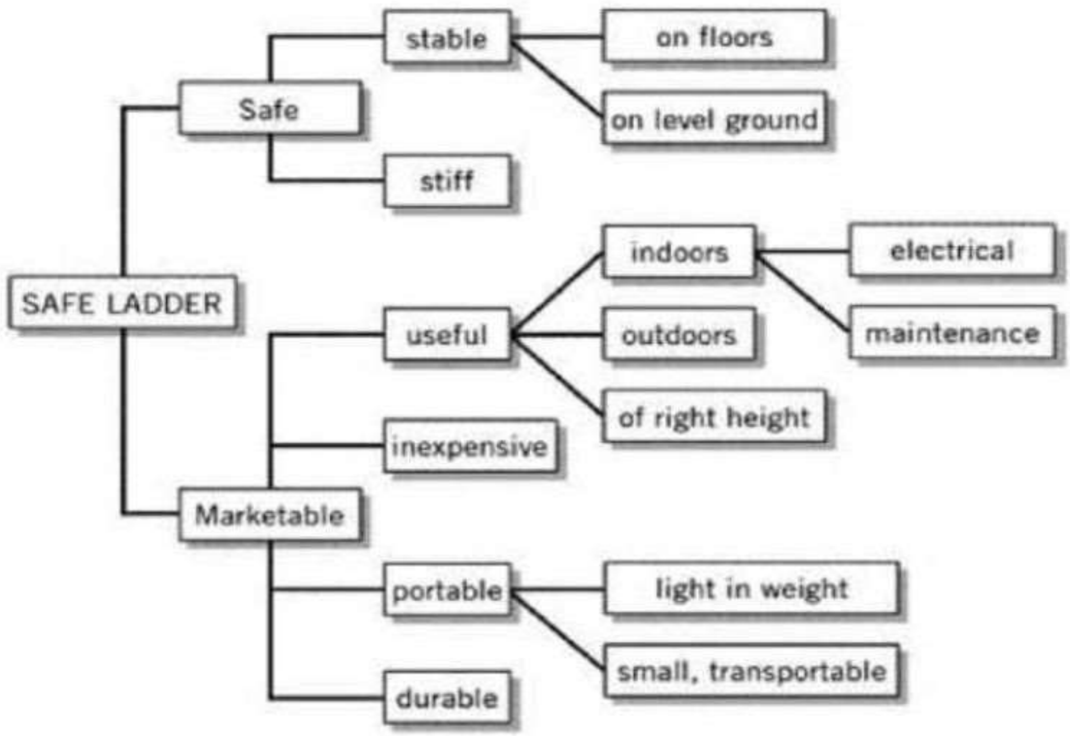
Objective: a feature or behavior that the design should have or exhibit. Objectives are normally expressed as adjectives that capture what the design should be, as opposed to what the design should do. For example, saying that a ladder should be portable or lightweight expresses an attribute that the client wants the ladder to have. These features and behaviors, expressed in the natural languages of the client and of potential users, make the object "look good" in the eyes of the client or user.

Constraint: a limit or restriction on the design's behaviors or attributes. Constraints are clearly defined limits whose satisfaction can be framed into a binary choice (e.g., a ladder material is a conductor or it is not). Any designs that violate these limits are unacceptable. For example, when we say a ladder must meet OSHA standards, we are stating a constraint.

Function: a specific thing a designed device or system is expected to do. Functions are typically expressed as “doing” terms in a verb—noun pairing. Often they refer to engineering functions, such as the second function in Table 3.1: “Must not conduct electricity.” Note that this function is also a constraint.

Means: a way or method to make a function happen. Means or implementations are often expressed in very specific terms that, by their nature, are solution-specific. Means often come up because clients or others think of examples of things they’ve seen that they think are relevant. Because they are so strongly function-dependent, they should be pruned from our attribute list for the time being, but we will revisit them after we have looked at functions.

Form: It represents the shape of the design or otherwise how a design look like. Aesthetic and ergonomics of a design is depends upon the form of that design.



<u>Objective Tree</u>

Objectives trees are hierarchical lists of the client's objectives or goals for the design that branch out into tree-like structures. We build objectives trees in order to clarify and better understand a client's project statement. The objectives that designs must attain are clustered by sub-objectives and then ordered by degrees of further detail.**Objective Tree for Step Ladder Design**

The graphical tree display is very useful for portraying design issues, and for highlighting things we need to measure, since these objectives will provide our basis for choosing between alternatives. The tree format also corresponds to the mechanics of the process that many designers follow: One of the most useful ways of "getting your mind around" a large list of objectives is to put them all together, and then move them around until the tree makes sense. Note, too, that process just outlined—

from lists to refined lists to indented outlines to trees— has a lot in common with outlining, a fundamental skill of writing. A topical outline provides an indented list of topics to be covered, together with the details of the subtopics corresponding to each topic. Since each topic represents a goal for the material to be covered, the identification of an objectives tree with a topical (or an indented) outline seems logical.

In addition to their use in depicting design objectives, objectives trees are valuable in several other ways. First, and perhaps foremost, note that as we work down an objectives tree (or further in on the levels of indentation of an outline), we are not only getting more detail. We are also answering a generic how question for many aspects of the design.

"How are you going to do that?" Conversely, as we move up the tree, or further out toward fewer indentations, we are answering a generic why question about a specific objective: "Why do you want that?" This may be important if, when selecting a design, we find that one alternative is better with respect to one objective, but weaker with respect to another.

But if we're working downward as we construct and organize a tree, where do we stop? When do we end our list or tree of objectives? One simple answer is: We stop when we run out of objectives and implementations begin to appear. That is, within any given cluster, we could continue to parse or decompose our objectives until we are unable to express succeeding levels as further objectives. The argument for this approach is that it points the objectives tree toward a solution-independent statement of the design problem. We know what characteristics the design has to exhibit, without having to make any judgment about how it might get to be that way. In other words, we determine the features or behaviors of the designed object without specifying the way the objective is realized in concrete form. We can also limit the depth of an objectives tree by watching for verbs or "doing" words because they normally suggest functions. Functions do not generally appear on objectives trees or lists.

Obviously, it is important to take notes when we are generating our lists of objectives, because we are generating a lot of information, to ensure that all suggestions and ideas are captured, even those that seem silly or irrelevant at the moment. Then it becomes important to organize the information we're getting so we can use it effectively: It's always easier to prune and throw away things than to recapture spontaneous ideas and inspirations. Also, get the substance of the objectives down first: Once a rough outline of an objectives tree has emerged, it can be formalized and made to look presentable and pretty with any number of standard software packages for constructing organization charts, or similar graphical displays.

Finally, do we build an objectives tree as soon as we start a design job, or after doing some homework and learning more about the design task we're undertaking? There's no hard and fast answer to these questions, in part because building an objectives list or tree is not a mathematical problem with an attendant set of initial conditions that must be met.

Also, building a tree is not a one-time, let's-get-it-done kind of activity. It's an iterative process, but one that a design team should start with at least some degree of understanding of the design domain. Thus, some of the questioning of clients, users, and experts should have begun, and some of the tree building can go on episodically while more information is being gathered.

Initiating Creative Designs

Our time appreciates rationality and logic. We think that these qualities are the only functions in science, and together with carefully gathered knowledge those are the most powerful tools in our technical, economic and social progress. But in the case of design work we realize that these tools are quite dull and we have got into a tight place with them. All remarkable creative inventions are rational and logical, when we look at them afterwards, but in order to find something new in front of us more powerful tools are needed. The tools are sensations and intuition. Because of their subconscious nature, we often do not take them seriously in our scientific work. All practical designers, however, are acquainted with those subconscious functions of the mind and they use them in those phases of work, when we have to go ahead of present knowledge. The rationality and logic of the new results are checked afterwards and, in a favorable case, a new piece of science is attained.

A despising attitude towards pictures remained a prominent attitude. Science was still based on logical thinking described by words, and by admiring it, the preceding ideas and images were ignored. During the present century and even earlier the technique in the form of concrete machines has revolutionized our everyday life, and still we consider that machine inventions are based barely on scientific mechanics and economical needs. According to this point of view we teach our future engineers and even engineering design we have described using strictly logical systematics. This way of teaching is producing successful engineering designers less frequently because the engineering design is essentially reading and producing pictures and images. The stressing of systematics and the lack of training in pictorial thinking have led to the fact that concrete design work especially drafting, is carried out by designers having a lower technical education. The enormous development of electronics and physics has further increased the appreciation of sharp logic. Because modern products based on this technology have brought the technical services nearer the man, these sciences have got admiration and value without criticism. At the same time there is a tendency to underestimate drafting and to think that engineering design has already reached its maturity and that its value is now in decline. The mechanical machines have been considered to represent the polluting chimney industry and they are attributed with all the disadvantages due to industry, whereas electronics and automation represent the new un-polluting communication society. It has not been realized that this is a false image without any basis.

Creative thinkers are distinguished by their ability to synthesize new combinations of ideas and concepts into meaningful and useful forms. A creative engineer is one who produces a lot of ideas. These can be completely original ideas inspired by a discovery. More often, creative ideas result from putting existing ideas together in novel ways. A creative person is adept at breaking an idea down to take a fresh look at its parts, or in making connections between the current problem and seemingly unrelated observations or facts.

We would all like to be called “creative,” yet most of us, in our ignorance of the subject, feel that creativity is reserved for only the gifted few. There is the popular myth that creative ideas arrive with flash-like spontaneity—the flash of lightning and clap of thunder routine. In keeping with the view of association, students of the creative process assure us that most ideas occur by a slow, deliberate process that can be cultivated and enhanced with study and practice.

A characteristic of the creative process is that initially the idea is only imperfectly understood. Usually the creative person senses the total structure of the idea but initially perceives only a limited number of its details. There ensues a slow process of clarification and exploration as the entire idea takes shape. The creative process can be viewed as moving from an amorphous idea to a well-structured idea, from the chaotic to the organized, from the implicit to the explicit. Engineers, by nature and training, usually value order and explicit detail and abhor chaos and vague generality. Thus, we need to train ourselves to be sensitive and sympathetic to these aspects of the creative process. We need also to recognize that the flow of creative ideas cannot be turned on upon command. Therefore, we need to recognize the conditions and situations that are most conducive to creative thought. We must also recognize that creative ideas are elusive, and we need to be alert to capture and record our creative thoughts.

Improving Creativity

Creative cognition is the use of regular cognitive operations to solve problems in novel ways. One way to increase the likelihood of positive outcomes is to apply methods found to be useful for others. Following are some positive steps you can take to enhance your creative thinking.

- **Develop a creative attitude**: To be creative it is essential to develop confidence that you can provide a creative solution to a problem. Although you may not visualize the complete path through to the final solution at the time you first tackle a problem, you must have self-confidence; you must believe that a solution will develop before you are finished. Of course, confidence comes with success, so start small and build your confidence up with small successes.
- **Unlock your imagination:** You must rekindle the vivid imagination you had as a child. One way to do so is to begin to

question again. Ask “why” and “what if,” even at the risk of displaying a bit of naiveté. Scholars of the creative process have developed thought games that are designed to provide practice in unlocking your imagination and sharpening creative ability.

- **Be persistent:** We already have dispelled the myth that creativity occurs with a lightning strike. On the contrary, it often requires hard work. Most problems will not succumb to the first attack. They must be pursued with persistence. After all, Edison tested over 6000 materials before he discovered the species of bamboo that acted as a successful filament for the incandescent light bulb. It was also Edison who made the famous comment, “Invention is 95 percent perspiration and 5 percent inspiration.”

- **Develop an open mind**: Having an open mind means being receptive to ideas f rom any and all sources. The solutions to problems are not the property of a particular discipline, nor is there any rule that solutions can come only from persons with college degrees. Ideally, problem solutions should not be concerned with company politics. Because of the NIH factor (not invented here), many creative ideas are not picked up and followed through.
- **Suspend your judgment:** We have seen that creative ideas develop slowly, but nothing inhibits the creative process more than critical judgment of an emerging idea. Engineers, by nature, tend toward critical attitudes, so special forbearance is required to avoid judgment at an early stage of conceptual design.
- **Set problem boundaries:** We place great emphasis on proper problem definition as a step toward problem solution. Establishing the boundaries of the problem is an essential part of problem definition. Experience shows that setting problem boundaries appropriately, not too tight or not too open, is critical to achieving a creative solution.

Brainstorming

Brainstorming is the most common method used by design teams for generating ideas. This method was developed by Alex Osborn 18 to stimulate creative magazine advertisements, but it has been widely adopted in other areas such as design. The word brainstorming has come into general usage in the language to denote any kind of idea generation.

Brainstorming is a carefully orchestrated process. It makes use of the broad experience and knowledge of groups of individuals. The brainstorming process is structured to overcome many of the mental blocks that curb individual creativity in team members who are left to generate ideas on their own. Active participation of different individuals in the idea generation process overcomes most perceptual, intellectual, and cultural mental blocks. It is likely that one person’s mental block will be different from another’s, so that by acting together, the team’s combined idea generation process flows well.

A well-done brainstorming session is an enthusiastic session of rapid, free- flowing ideas. To achieve a good brainstorming session, it is important to carefully define the problem at the start. Time spent here can help us to avoid wasting time generating solutions to the wrong problem. It is also necessary to allow a short period for individuals to think through the problem quietly and on their own before starting the group process.

Participants in brainstorming sessions react to ideas they hear from others by recalling their own thoughts about the same concepts. This action of redirecting a stream of thought uncovers new possibilities in the affected team member. Some new ideas may come to mind by adding detail to a recently voiced idea or taking it in different, but related, directions. This building upon others’ ideas is known as piggy-backing or scaffolding, and it is an indicator of a well- functioning brainstorming session. It has been found that the first 10 or so ideas will not be the most fresh and creative, so it is critical to get atleast 30 to 40 ideas from your session. An important attribute of this method is that brainstorming creates a large number of ideas, some of which will be creative.

The evaluation of your ideas should be done at a meeting on a day soon after the brainstorming session. This removes any fear that criticism or evaluation is coming soon and keeps the brainstorming meeting looser. Also, making the evaluation on the day after the idea generation session allows incubation time for more ideas to generate and time for reflection on what was proposed. The evaluation meeting should begin by adding to the original list any new ideas realized by the team members after the incubation period. Then the team evaluates each of the ideas. Hopefully, some of the wild ideas can be converted to realistic solutions.

Need Identification and Problem Statement

During the course of human development, different kinds of needs existed. For instance, there has always been and always will be a need for improving and making new designs. Lincoln Steffens wrote. “The world is yours, nothing is done and nothing is known. The greatest poem isn’t written, the best railroad isn’t built yet, the perfect state hasn’t been thought of. Everything remains to be done right, everything.” The engineer is a person who applies scientific knowledge to satisfy humankind’s needs. It should be emphasized that the ability to design is a characteristic of an engineer.

One serious difficulty that engineers must overcome deals with the form in which problems are often presented to them. Even if some goals are given to the engineer, they often are not specifically stated. Problems may be presented vaguely: “The shaft is breaking.” “The controls aren’t producing the desired effect.” “It costs too much to operate this engine.” Thus, the first task of the engineer involves determining the real problems. Then, the engineer must determine the extent and confines of the goals. It is necessary to formulate a clear, exact statement of the problem in engineering words and symbols. It is also necessary to isolate the problem form the general situation and to delineate its form. This definition should clearly identify every aspect of the problem on which attention should be concentrated. The nonessential should be stripped away, and the individual characteristics of the problem should be differentiated. It should be determined whether or not the immediate problem is part of the larger problem. If it is, its relationship to the total part should be determined.

Consider the following examples.

- A designer is presented with a situation involving the waste of irrigation water in public parks. The park keepers forget to turn off the water. A general formulation of the problem would be "What can we do to minimize the possibility of workers forgetting to turn off the water before the end of their shit? Ah engineer could ask the following questions. "Why do workers continue to forget to turn off the water?" "What is the sequence of events that workers use during their daily activities?" "What will happen if a keeper does not show up for his/her shift?" "Do we need to manually turn on and off the water?" A more precise form of the problem statement would be "How do we prevent irrigation water waste in public parks?"
- A company has proposed to use the density gradient to isolate red blood cells from whole blood and thus to treat white blood cells with a light-activated drug. The designer should ask questions such as the following. "Is it necessary to use the density gradient if other methods of separation would be capable of isolating the red blood cells from the whole blood?" "If the white cells are being treated, why don't we isolate the white cells from the whole blood rather than isolate red blood cells?" "Why don't we impede the light into the blood and reduce the need for separation?"
- An engineer is presented with a problem caused by the formation of ice on roofs. The ice forms during certain types of weather, falls away from the roofs, and causes damage to vehicles and people below. A general formulation of this problem might be "How do we prevent ice from forming on roofs?" However, further questions may be asked. "What would happen if ice did form?" "What will cause the ice to fall?"

"What harm would such formation do?" These questions determine that the first definition was much too narrow. A much broader definition was "How do we prevent ice that forms on roofs from doing harm or damage to people and equipment below?"

Designers need to abstract the need statement from its current state to a statement that they can base their design on. Vague statements from the customer usually result in a bad design.

Before an engineer can define the problem properly, he or she must recognize all of the problems that exist. Most of the failures in machines do not occur because we make mistakes in analysing the problem, but because we fail to recognize that there is a problem.

So, it is evident that the needs should be identified clearly, otherwise a vague statement of need will lead to a vague understanding of the product to be designed. A vague understanding cannot give a solution that addresses the specific problem. Asking the right question requires engineering knowledge, practice, and common sense.

Market Survey

Establishing who your customers are is one of the most important initial steps that a designer needs to take. One of the vital concepts to grasp is that customers are not only the end users. Customers of a product are everyone who will deal with the product at some stage during its lifetime. This includes the person who will manufacture the product, the person who will sell the product, the person who will service the product, the person who will maintain the product during its lifetime in operation, etc.

Consider an example: Discuss with your colleagues who the possible customers of a golf cart are. Here are a few ideas to start you off.

- The golf player
- The golf country club (Institution)
- The transportation company that will transport-the cart
- The golf club (Equipment) manufacturers for storage of their clubs in the cart

Once all possible customers have been identified, their needs should be considered, and more often than not, their needs can conflict with each other. It is the responsibility of the designer to recognize all of these needs in a prioritized manner and later arrive at a feasible solution that is an optimal combination of all these 'desires'. One good way to identify the needs in a prioritized manner is to conduct a market survey. There are a number ways in which this can be carried out.

1. Focus group meetings
2. Telephone interviews
3. One-on-one interviews
4. Questionnaires

Each method cited has its advantages and disadvantages. In a focus group meeting, a group of 6 to 12 potential 'customers' meet and discuss their needs and other aspects of the product. If the product already exists, the discussion usually focuses on a 'satisfaction' based feedback in terms of what they liked, what they disliked, and what they would like to see improved. However, for a new product, the discussion usually focuses on their wishes and desires in a particular market segment, what they would like to see introduced to improve their lives, or what current problems exist in the similar products on the market. It is important to ensure that any potential solutions are filtered out at this stage and converted into a neutral need. However, this method is an expensive process, and the sample size is relatively small. It is however a good starting point and is frequently used as a precursor to sending out a larger survey in the form of questionnaires. Telephone and one-on-one interviews can eliminate some of the ambiguities that arise for questionnaires. However, they are very expensive to run and also have a potential disadvantage of the interviewer 'leading' the interview and causing bias. For example, a question can be asked: "Would you really walk a long distance in the cold, rainy weather, in the middle of rush hour to get to your office early in the morning, or would you prefer taking the cheap, fast, and comfortable public transport?" An unbiased question could be "What is your preferred mode of transport to your office in the morning?"

The questionnaire format is one of the most popular survey methods, as it involves taking the opinion of a large number of people (sample) at a relatively low cost. It is important to construct a questionnaire carefully in order to provide meaningful, useful, and unbiased feedback. Here are some points to follow when creating a questionnaire:

- ✓ Develop a standard set of questions. The main goal of a questionnaire is to ascertain potential needs, problems, likes, and dislikes. It is useful at this stage to also identify which (if any) market segment would be most interested in the product as well as to gain an estimate of how much they would be willing to spend.
- ✓ Ensure that the questionnaire is easy to read and complete. Use simple language and simple formatting. Try to keep the writing to a minimum, and offer multiple choice questions or yes/no answers where possible. Leave an opportunity for writing for those who wish to do so.
- ✓ Identify the demographic you want to target. Mailing lists can be purchased from market research companies. KY Wee.com
- ✓ Test the questionnaire initially on a pilot sample (friends, family, or small group of people) before sending it out to the entire sample. This is an opportunity to iron out any ambiguous questions and to observe whether or not you are obtaining the desired information.
- ✓ Introduce only one issue per question.
- ✓ Similar to interviews, you do not want to give your questions a bias. Ensure all questions are unbiased.
- ✓ Avoid negative questions, which cause confusion. For example, a question such as “Do you not like to travel in the morning” may result in the answer “No, I do not like to travel in the morning”. Reading this carefully reveals a double-negative answer which means “I do like to travel in the morning.”

✓

- ✓ Ask a few conflicting questions and compare the answers to ensure that the person who has completed the questionnaire actually read the questions. For example ask "Do you ALWAYS switch off the electricity from the mains?" Later on ask "Do you forget to switch off the electricity from the mains?" If the person completing the questionnaire replied the same yes or no to both questions, then this particular feedback is not reliable.

Preliminary Research on Customer Needs

In a large company, the research on customer needs for a particular product or for the development of a new product is done using a number of formal methods and by different business units. The initial work may be done by a marketing department specialist or a team made up of marketing and design professionals. The natural focus of marketing specialists is the buyer of the product and similar products. Designers focus on needs that are unmet in the marketplace, products that are similar to the proposed product, historical ways of meeting the need and technological approaches to engineering similar products of the type under consideration. Clearly, information gathering is critical for this stage of design.

Design teams will also need to gather information directly from potential customers. One way to begin to understand needs of the targeted customers is for the development team to use their own experience and research to date. The team can begin to identify the needs that current products in their area of interest do not meet and those that an ideal new product should meet. In fact, there's no better group of people to start articulating unmet needs than members of a product development team who also happen to be end users of what they are designing.

Design attributes and customer requirements

Not all customer requirements are equal. This essentially means that customer requirements have different values for different people. The design team must identify those requirements that are most important to the success of the product in its target market and must ensure that those requirements and the needs they meet for the customers are satisfied by the product. This is a difficult distinction for some design team members to make because the pure engineering viewpoint is to deliver the best possible performance in all product aspects. A Kano diagram is a good tool to visually partition customer requirements into categories that will allow for their prioritization.

Kano recognized that there are four levels of customer requirements: **(1) expecters, (2) spokens, (3) unspokens, and (4) exciters.**

Expecters: These are the basic attributes that one would expect to see in the product, i.e., standard features. Expecters are frequently easy to measure and are used often in benchmarking.

Spokens: These are the specific features that customers say they want in the product.

Because the customer defines the product in terms of these attributes, the designer must be willing to provide them to satisfy the customer.

Unspokens: These are product attributes the customer does not generally talk about, but they remain important to him or her. They cannot be ignored. They may be attributes the customer simply forgot to mention or was unwilling to talk about or simply does not realize he or she wants. It takes great skill on the part of the design team to identify the unspoken requirements.

Exciters: Often called delighters, these are product features that make the product unique and distinguish it from the competition. Note that the absence of an exciter will not make customers unhappy, since they do not know what is missing.