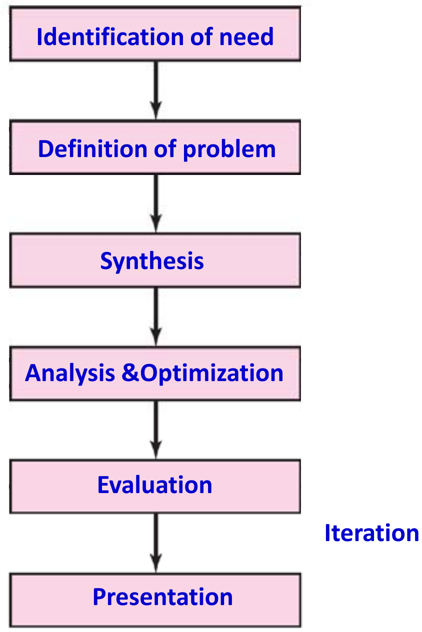
Design Process

- What is Design?
  - The formulation of a plan to satisfy a particular need, real or imaginary
  - To design is either to formulate a plan for the satisfaction of a specified need or to solve a problem
- Design is an interesting engineering activity that:
  - Affects almost all areas of human life
  - Uses the laws and insights of science
  - Builds upon special experience
  - Provides the prerequisites for the physical realisation of solution ideas
  - Requires professional integrity and responsibility

Design Process

- Characteristics of design process
  - Innovative
  - Highly iterative
  - Team work
  - Decision making with too little information or contradictory information
  - Communication intensive (oral, written, pictorial)
  - Multidisciplinary in nature (engineering, ergonomics, economics)
  - Multiple solutions possible (Optimum?)
- What is engineering design?
  - Accreditation Board for Engineering and Technology (ABET) definition: **Engineering design is the process of devising a system, component, or process to meet desired needs**

Stages in a design process



Identification of the need

- Involves recognition of a need, real or imagined and making a decision to do something about it
  - Develop capability to make missiles indigenously
    - Driven by national safety, regional threats, government initiative, sanctions by other countries
    - The statement is some what vague with respect to the payload type, weight, range etc.
  - Develop a car which costs Rs. 100,000/-
    - Observation by Tata that three to four members of a family travelling in a two-wheeler
    - Provide a safer but affordable mode of transport
    - The task has a clear constraint- the cost

Identification of the need

- Develop a portal for sharing taxi from IITK to Lucknow
  - Saving expenses
  - Reducing pollution
- Reduce the noise levels of a diesel generator
  - Reduce noise pollution
  - Profit
  - Here the task is to improve an existing system- so there will be constraints
- A system for cleaning glass panels in tall buildings
  - Less dangerous compared to humans climbing
  - Less cumbersome

Definition of the problem

- The “identification of need” is invariably not very well defined and may have contradictory objectives
- Before proceeding further, more clarity has to be evolved with respect to identifying the true requirements and constraints
- Design specifications are to be generated at this stage. Specification should be clear, correct and as complete as possible
- Identification of Need: “A system to cut grass”
- Specification:
  - Width of cut : 300 mm
  - Cut size: from 10 to 50 mm adjustable
  - Manually operated
  - Weight not to exceed 25 kg
  - Size not to exceed 1000 x 400 x 300 mm
  - Cost in the range of Rs. 4000-6000/- (?)

Lawn mowers

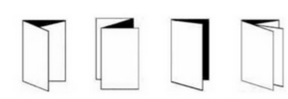




More examples

- Dustless hand drilling machine
- Dustless manual sweep
- Autonomous pipe inspection system
- Shredding documents
- Machine to fold an A4 sheet into three





Geared wheel chair

- Identification of need:
  - Normal wheel chairs work well on level surfaces (1:1 gear ratio)
  - Modify them for use on inclined surfaces (both up and down)
- Problem definition
  - Cruise on level surface like the conventional wheel chair
  - Shift to a lower gear for climbing up an inclined surface
  - The shoulder load should not increase while climbing
  - Should not roll back even if the hand rim is released
  - Assist in braking when going down the incline
  - Easily shift back to normal (1:1) gear on level surface

Definition of problem

- When design specifications are generated the following should be considered

- Geometry
- Energy
- Safety
- Economics
- Quality Assurance
- Maintenance
- Kinematics
- Materials
- Ergonomics
- Manufacture
- Transport
- Time scales
- Forces
- Signals
- Aesthetics
- Assembly
- Operation
- Environment

- As far as possible statements should be quantitative
  - Lawn mover should be light weight
  - Lawn mover should not weigh more than 30 kg
  - Lawn mover should be maintenance free
  - Service after every 1000 hours of use

Lawn mover specifications

Geometry	Minimum cut width 300 mm, Cutting height 5-50 mm adjustable, Overall size 600 x 600 x 400 mm^3
Kinematics	Cutting speed up to 2 m/s
Forces	Weight not to exceed 60 kg
Energy	Manual or powered, Noise level less than 60 dB
Material	Should not corrode within the life span of 5 years
Signals	Easy to start and stop, indicator for i) power on, ii) overload, iii) emptying grass collector
Safety	Cutting blade not exposed, No exposed sharp parts or electrical connections, overload protection
Ergonomics	Easy to operate, Easy to remove the grass collector for emptying, pleasant appearance
Economics	Price not more than Rs 8000/-

Definition of problem

- The requirements can be classified as
  - Demands: Every solution should satisfy this, other wise the solution is not to be pursued
    - Minimum cut width 300 mm
    - Cutting height 5-50 mm adjustable
    - Weight should not exceed 60 kg
    - Cutting speed up to 2 m/sec
  - Wish: This is something desirable but not essential. Satisfying this will improve the value or quality of the solution
    - Easy to remove the grass collector for emptying
    - Pleasant appearance

Synthesis or Conceptual Design

- Once the problem definition or specifications are finalized, the following questions are raised
  - Is the need and specification sufficiently clear to allow the development of a solution in the form of a design?
  - Are there existing solutions that can be readily used or adapted? (adaptive or variant design) or a conceptual elaboration is really needed?
    - E.g. Dustless drilling machine: There are existing principles like that used in a vacuum cleaner which can be integrated with the drilling machine
  - If the above options are not viable, then a conceptual design stage is inevitable
- Conceptual design or synthesis stage is the most challenging stage

Conceptual design

- Goal at this stage is to generate as many ideas as possible that can provide the solution or design to meet the requirement (need elaborated through problem definition)
- This involves
  - Understanding the primary needs and specifications
  - Decompose or divide the problem into sub-problems that are easily understood
  - Search for solutions to these
  - Combine solutions to form concept variants or alternative designs
- Start by focusing on the most important need first
- Then iterate to satisfy secondary needs

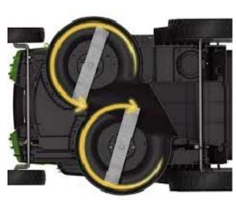
Lawn mower

- The primary purpose is to cut grass
- If the cut grass can be simultaneously collected, good
- The sub problems are as follows
  - Cutting system/mechanism
  - Prime mover and power source
  - Transmission
  - Locomotion and navigation
  - Grass collection system
  - Controls
- A lot of information collection and brainstorming takes place in conceptual design stage
- All ideas should be allowed to blossom but it is important to confront ideas
- Prejudiced verdict making at this stage should be avoided

Grass cutting mechanism

- Horizontal spinning blade
- Parallel blade
- Rotating wire
- Drum with cutting edges

- The principle used can have communalities and differences
- Science involved



Prime mover and power source for cutting mechanism

- Human
- Electric motor receiving power from main supply by wires
- Electric motor working on battery power
- Small internal combustion engine working on gasoline

Locomotion and navigation

- Human
- Powered- Separate prime mover, same prime mover

Grass collection

- Gravity based
- Kinetic energy
- Vacuum assisted
- Air pressure

Grass storing

- Bag
- Box

Concept generation

- In this stage out of the several solutions available for each sub-problem, choices are made and combined together to generate concept solutions
- The selection criteria is based on satisfying the demands
  - Horizontal blade, electric motor powered from mains, manual locomotion, kinetic energy based collection in a bag
  - Drum type blade, manual powered, manual locomotion, kinetic energy based collection in a bag
  - Horizontal blade, electric motor powered from battery, manual locomotion, kinetic energy based collection in a bag
  - Horizontal blade, IC engine powered cutting and locomotion, kinetic energy based collection in a bag

Concept evaluation

- All combinations are not possible as some combinations may be incompatible
  - Manual locomotion and 2 m/s speed may not be feasible
  - Battery powered and maximum weight up to 60 Kg may not be feasible
- Each of these concept solutions are evaluated against the wishes
- In the evaluation stage we determine the set of combination that will give additional features and competitive advantage
- At the end of this exercise one concept emerges as the optimal one called the principal solution

Embodiment design

- In the embodiment design phase, the chosen product concept (principal solution) is further developed
- Separate functions the product (system) should accomplish are taken into consideration
- The assemblies or modules required for this are identified
- Function, position and geometry of assemblies or modules are to be described
- Interactions between modules and integration of subassemblies is also taken into consideration
- This stage involves analysis and modeling and many decisions regarding

Embodiment design

- This stage involves analysis and modeling and many preliminary decisions regarding the following are to be made
  - Choice of components
    - Whether standard or custom (specialized)
  - Component interfaces
  - Materials
  - Geometry (dimensions, shape and tolerances)
  - Surface finish, fasteners and connectors
  - Manufacturing processes
  - Assembly processes
- This the stage where engineers apply their skills in mathematics and applied science

Embodiment design

- Design is viewed from many angles as listed below
  - Failure modes
    - Strength, stiffness and stability
  - Design for manufacture
  - Design for assembly
  - Design for environment
  - Design for service
  - Robustness of design
  - Scalability
- A change in one subsystem can propagate changes in other modules so this stage is highly iterative and done in parallel
- **Prototyping and testing**
  - Make the real product and test to see if it satisfies all the requirements