College of Engineering

GE106:Introduction to Engineering Design

Need Analysis

By

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Outline

- Opening Statements
- The Big Picture
- Importance of Communication
- The Design Process
- Client's Need Statement
- Problem Statement
- How to Assess Needs (Need Analysis)
- Types of Specifications
- Design Objectives
- Design Constraints
- Design Criteria
- Problem Definition
- Summary

Opening Statements

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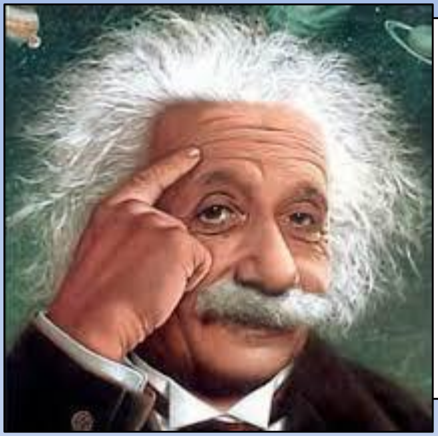


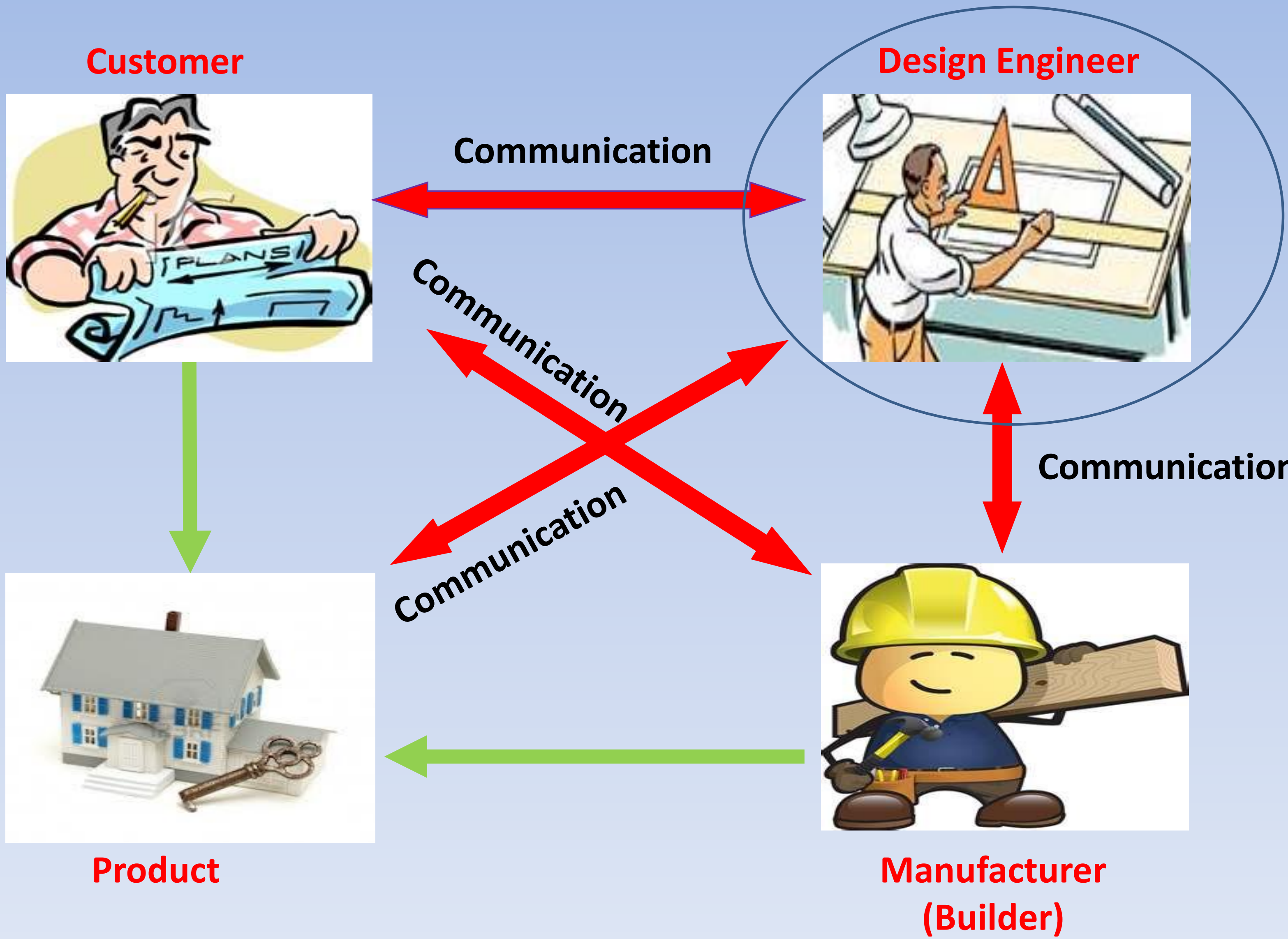
"If I had only one hour to save the world, I'd spend 55 min defining the problem and 5 minutes finding a solution"*

"A problem properly stated is half-solved"

Charles Kettering

(American inventor and the holder of over 300 engineering patents)

The Role Of The Design Engineer
in a civil engineering context



The Design Process

Customer **needs** a solution→
(Client statement)

Analyze the Needs → problem definition and formulation

This lecture

System Design
(Conceptual + Detailed)

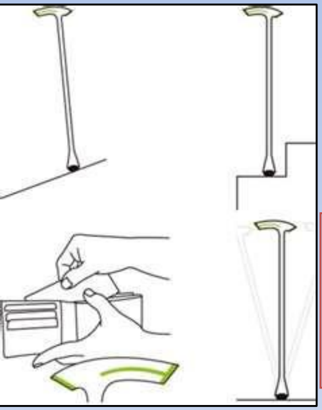
System integration and product test

Properly functioning system

Design Process

Customer needs a solution to a problem

Requirement analysis



System Design
(Conceptual Design + Preliminary Design)

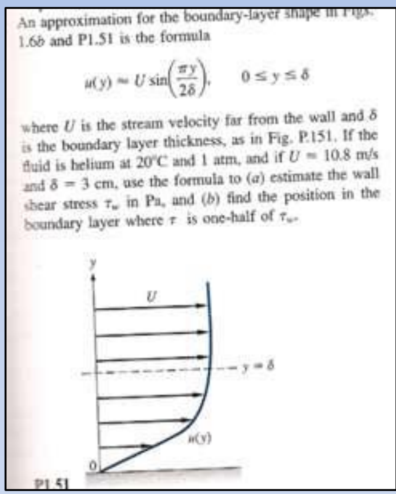
Detailed design and test

System integration and product test

Properly functioning system

Requirement Analysis

Requirement Analysis is usually done by upper management



An approximation for the boundary-layer shape in Figs. 1.6b and P1.51 is the formula

$$u(y) \approx U \sin\left(\frac{\pi y}{2\delta}\right), \qquad 0 \le y \le \delta$$

where U is the stream velocity far from the wall and δ is the boundary layer thickness, as in Fig. P.151. If the fluid is helium at 20°C and 1 atm, and if $U = 10.8$ m/s and $\delta = 3$ cm, use the formula to (*a*) estimate the wall shear stress τ_w in Pa, and (*b*) find the position in the boundary layer where τ is one-half of τ_w.

Exam Problem Definition

So What are my Requirements?

Customer needs a solution to a problem

↓

Assess needs

↓

Statement of problem

↓

Specify design requirements

↓

Requirement specifications

Requirement Analysis

Customer needs a solution to a problem

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Requirement specifications

What Do I Need?!

Needs Assessment

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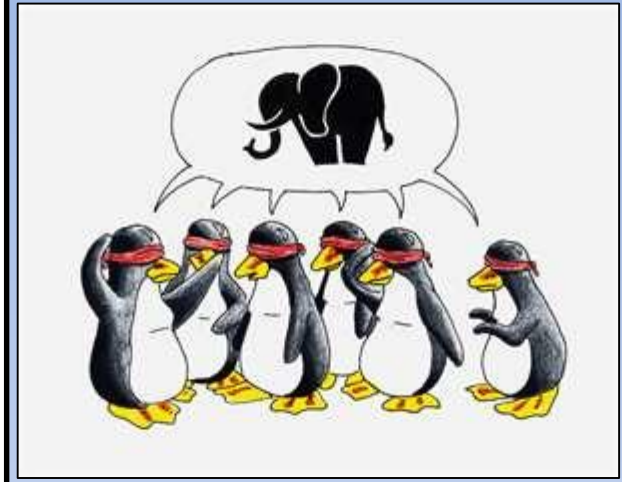
- **The aim is not to solve the problem but to understand what the problem is;**
  - **What does this client want?**
  - **What is the problem that the design is to solve?**

- **The objectives (goals) and constraints of the problem should be identified**
  - **Objectives: summary of the needs that the design is to satisfy**
  - **Constraints: what the design must satisfy. This limits the Engineers flexibility. (takes logical values 0 or 1, helps to decide acceptable or not)**



Who is my Neighbor?

Constraints!

Client's Need Statement

- First understand what the problem is (i.e. what does the customer want?)
- Often, the customer does not know exactly what he/she wants nor what is achievable.
- Client Statements usually have limitations such as:
  - Bias (e.g. reconsider admission strategy; whereas the problem could be managing classrooms)
  - Implied solutions (e.g., replace the door; whereas another solution can be better*)

- Make sure that the correct problem is being addressed

How to Assess Needs? (1/2)

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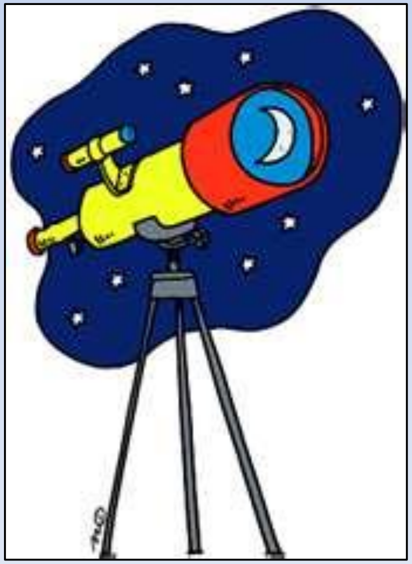
- Question the customer
  - To define the design problem
  - To understand budget and schedule constraints
  - Reliability and maintenance constraints

- Explore resources
  - Expertise (knowledge and experience)
  - Technical literature (books, journals,www)
  - Measurement and testing equipments (equipment suppliers)
  - Similar designs (competitors, patent search)



How to Assess Needs? (2/2)

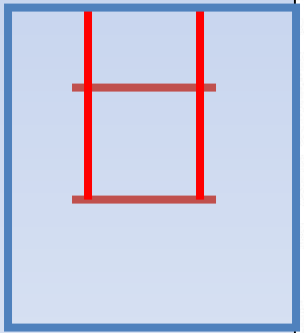
- Search legal and regulatory restrictions
  - Allocation of frequency bands
  - Restriction on tower heights
  - Environmental impacts
  - Safety

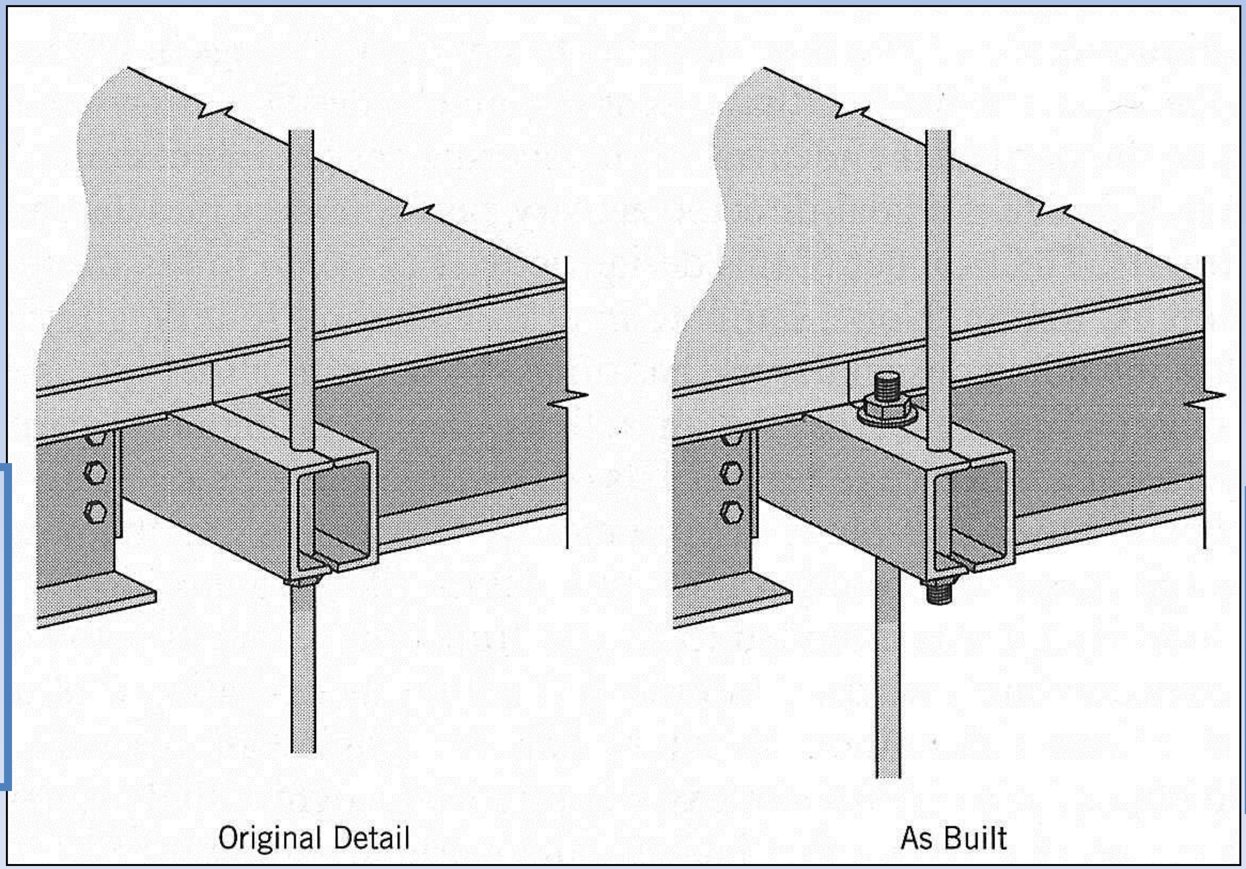
- Manufacturability issues: How easy it is to manufacture the design/product?

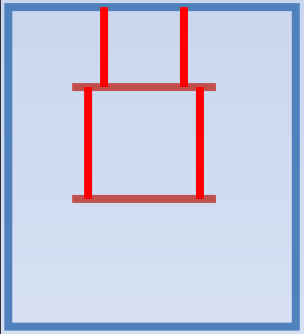
Environment

Importance of Manufacturability and Communication

A miscommunication within a building construction team lead to this accident due to the wrongful interpretation of the design.







Second floor collapsed, 114 people died

Requirement Analysis

<u>Homer:</u> Oh my God, I'm gonna be eaten alive be a *SHARK*!

<u>The SHARK:</u> Oh my God, Homer Simpson is gonna land on my head!!

Customer needs a solution to a problem

↓

Assess needs

↓

Statement of problem

↓

Specify design requirements

↓

Requirement specifications

Problem Statement

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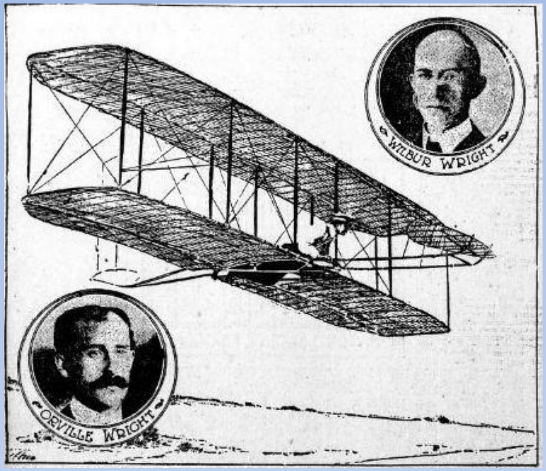
- **The statement is a *very* short paragraph providing answers to (What? Why? How?).**
  - **Written in the language of the customer.**
  - **Normally straightforward, non-technical and non-quantifiable.**
- **It is constructed in response to an expressed need. Engineer should identify, understand and validate the need before designing, failure to do this could lead to a failure of the design process.**

The Engineer must translate the Customer's need into engineering terms. The results are expressed as a **problem statement** and a **list of specifications**.

NOTE: Problem definition and problem statement are similar but problem definition has more details about the problem, while a problem statement is just a very short paragraph answering what, why and how a problem will be solved.

The Wright Brothers' Example

- The problem addressed by the Wright brothers at the turn of the 20th century was:
  Need a manned machine capable of achieving powered flight[1]



- This means that[2]:

1. They wanted to design a flying machine.
2. It must carry a person (which rules out model/prototype aircraft).
3. An onboard power source must be used to take off (which eliminates hot air balloons or gliders)

Statement of the Problem (1/3)

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- In the language of the customer, normally straightforward, non-technical and non quantifiable (measurable).

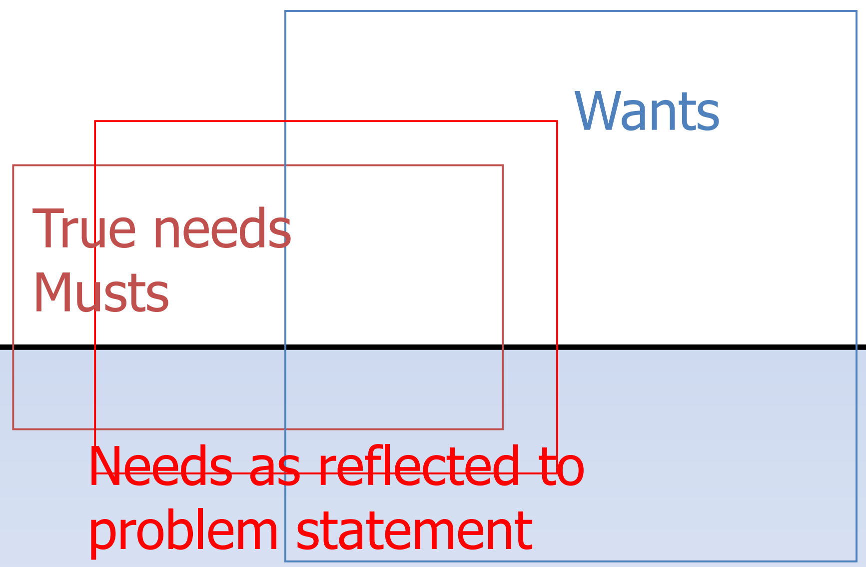
When Asked to Write a Problem Statement, the student should…

Problem Statement: Re-write the original problem in your own words without using highly technical terms (as if it's the language of the customer). However, since it is you the engineer who questioned the customer about what he/she wants exactly, more will be added that resemble parts of the objectives and the need analyses but in a paragraph format.

The problem statement paragraph should be at least 3-5 lines long!

Statement of the Problem (2/3)

- Tools that help
  - Question the customer
  - Differentiate Needs and Wants



Most times the customer himself does not know what he wants exactly nor what is tangible in his case and the engineer therefore needs to clarify the situation…

Statement of the Problem (3/3)

- Make Input/Output Analysis

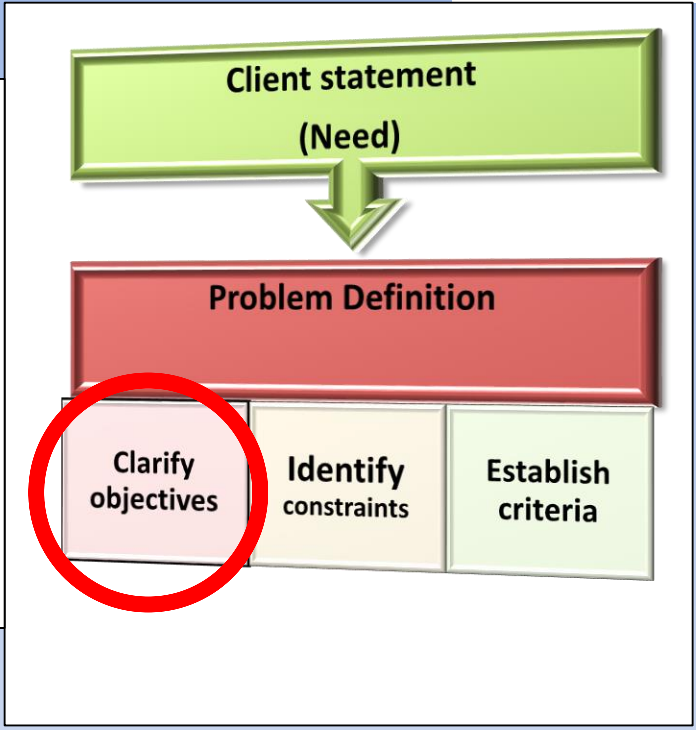
- Preview the user interface and operation of the device

Internet User Interface

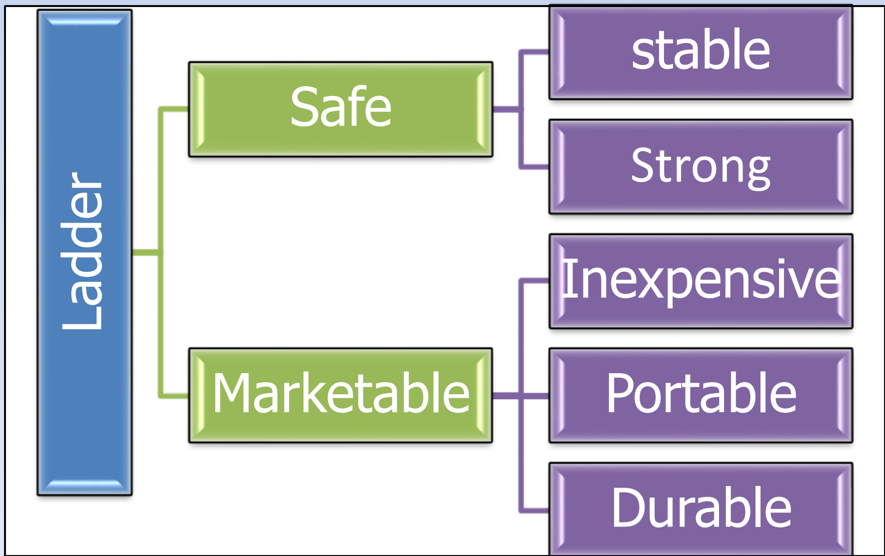
Design Objectives

<u>Objectives</u> are the <u>*requirements*</u> that the <u>design</u> must <u>satisfy</u> .

The objectives should be ***SMART***, i.e. (<u>S</u>pecific, <u>M</u>easurable, <u>A</u>chievable, <u>R</u>ealistic, <u>T</u>ime bound)



- Construct an <u>Objective Tree</u> by:
  - <u>Listing</u> objectives according to the assessed needs
  - <u>Grouping</u> the relevant objectives
  - <u>Forming</u> a hierarchical tree structure



Design Objectives: Need vs. Wish

- The Design Objectives can be divided into:
  - Primary (need/must)
  - Secondary (wish/want)

- The Primary Objective is what the customer/client really needs.
  - Without the primary objective the design is a failure.

- The Secondary (less important): objectives are not necessarily specified; but can have an added value to the product (e.g., safety, simplicity, beauty), etc.

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Requirement Analysis

Buildings zoning requirements

Some design requirements might be Enforceable by the State such as this western home earth quake requirements

Customer needs a solution to a problem

↓

Assess needs

↓

Statement of problem

↓

Specify design requirements

↓

Requirement specifications

Types of Specifications[1] (*Specs*)

- **Design Specifications : provide basis for evaluating the design**
  (e.g., safe, light, inexpensive, simple)
- **Functional Specifications : describe what the product must do**
  (e.g., drilling, grinding, polishing)
- **Performance Specifications: to judge how good is the design**
  (e.g., speed, energy, accuracy)

Specifications – "an act of identifying something precisely or of stating a precise requirement"
"a detailed description of the design and materials used to make something"

A specification often refers to a set of documented requirements to be satisfied by a material, design, product, or service. A specification is often a type of technical standard. There are different types of technical or engineering specifications, and the term is used differently in different technical contexts. Wikipedia

- ✓ **Use (but don't confuse) "Demanded" design elements and "Wished for[2]" design elements**
- ✓ **Be as specific as possible by using numbers where possible (e.g., not "heavy" but "2.5 kg")**

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Requirement Specifications

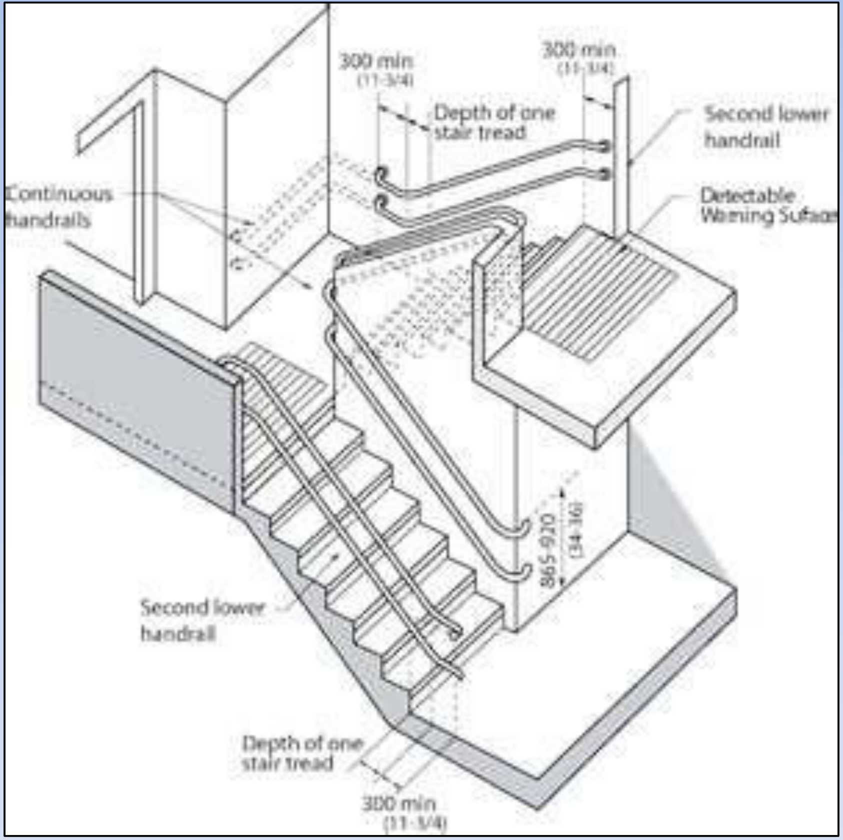
GARDEN EQUIPMENT COMPANY		DESIGN SPECIFICATION Grass Cutter Project	Issued: 11/1/1999 Page: 1
D/W	**Wt**	**REQUIREMENTS**	**Keyword**
		GEOMETRY	
W	M	• Maximum storage size: 600x600x300 mm	Storage
D		• Minimum width of cut: 300 mm	Cut width
W	M	• Adjustable cutting depth: 5 - 50 mm	Cut depth
		KINEMATICS	
W	H	• Easily manoeuvred	Manoeuvre
W	L	• Cutting speed up to 2 m/s	Cut speed
		FORCES	
W	H	• Maximum weight not greater than 100 N	Weight
W	M	• Force to move not greater than 50 N	Move force
W	M	• Withstand fall onto hard surface from 2 m	Robust
		ENERGY	
W	M	• Power requirement - maximum up to 1 kW	Power
W	M	• Power source - electricity	P/source
D		• Maximum noise level not to exceed 85 dB	Noise
		MATERIAL	
W	L	• Suitable for a life expectancy of 5 years	Life
W	L	• Must not corrode within design life	Corrosion
		SIGNALS	
D		• Simple to start/stop	Start/stop
W	L	• Indication when cuttings storage need emptying	Storage
W	L	• Maintenance instructions on the machine	Maint instr
		SAFETY	
D		• Electrical safety to BSI standards	Elec safety
D		• No accessible sharp edges or hot spots	Sharp/hot
D		• Cutting blade protection	Blade prot
W	M	• Automatic electrical cut-out	Auto cut-out
		ERGONOMICS	
D		• Easy to operate and control	Easy operation
W	M	• Simple cutting height adjustment in under 1 min	Cut adjust
W	H	• Pleasant appearance	Appearance
		ECONOMICS	
W	H	• Target selling price not more than £75	Price

Figure 9: Part of a design specification for a grass cutter

Can be a long list of required specifications detailing what is required from the design to achieve…

Specify Design Requirements

- Translating client and user needs into terminology that helps us find ways to realize those needs and measure how well we met them;
  - How will everyone that take part in the design know that it is done?
  - It turns the problem statement into a technical, quantified specification.
- Sets out criteria for verifying that the design meets its intended objectives.
- Describes the test for verification (confirmation).



Stair Design Criteria Sketched

Specifications

- How can I express what the client wants in terms that helps me as an engineer?
- Expressible as numbers and measures.
- Precise description of the properties of the object being designed.

Specification Types

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- **Design Specs :** provide basis for evaluating the design

Example: Pin Remover

The pin-remover is to be light.
The pin-remover must work in a wet, cold, and dusty environment.
The Pin-remover must be safe
The Pin-remover must have a 3-year warranty.
The Pin-remover is to be rugged.
… must work with air pressure.
… is be easy to use.
… is to pass "HTS" tests.
… is to last 5 years in normal usage.
… is to be easy to carry
… is to sell for less than $150.
… is to cost less than $50 to make.
… is to have low maintenance needs.
… is to be difficult to use as a hammer.
… must not infringe on patented devices.
… Production volume is to be 300 per year

Specification Types…

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- **<u>Functional Specs:</u>** what the thing must do?

Example: Power Drill

- Functions

–Used with Drill Bits to create or enlarge holes

– Other uses including

- Grinding
- Buffing/Polishing
- Wire brushing
- Power screw driver

Functional Specification

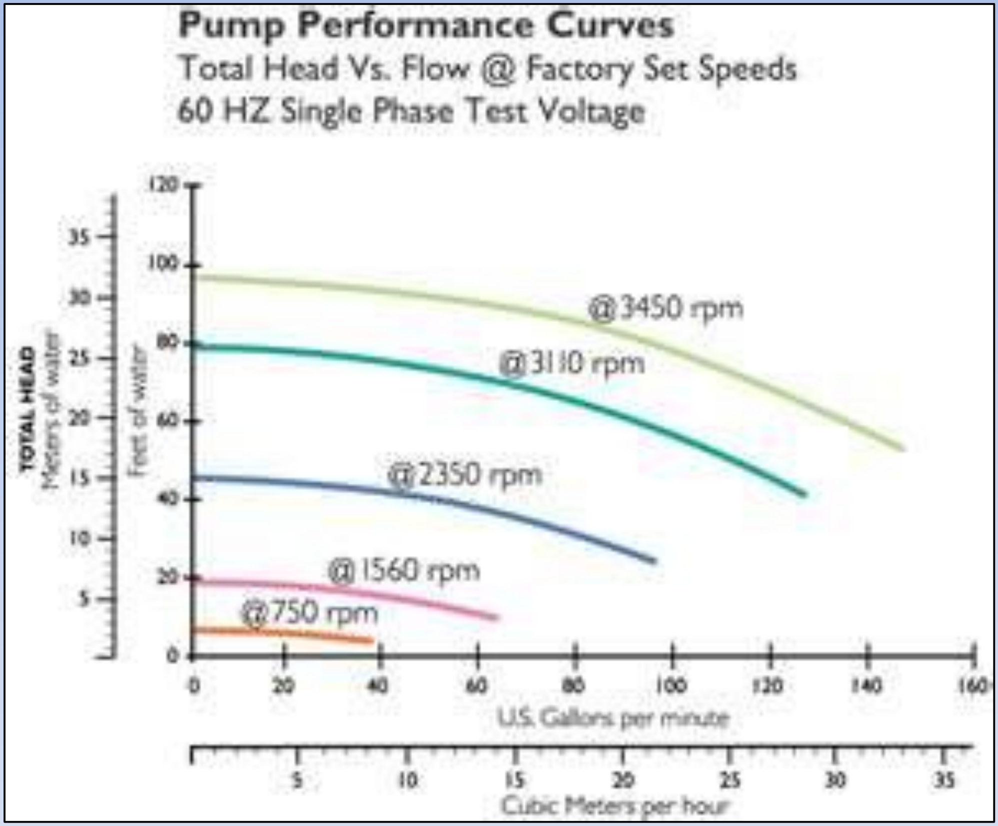
- Drill size
- Speed
- Power
- Size
- Weight
- Battery charging time
- Cost

Specification Types …

- **Performance specs:** tells us how well the design is

- **Metrics :** Tools for testing and measuring the performance

Metrics: Are indicators of performance



Water Pump Performance

Common Categories for Specifications*

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- Performance
- Geometry
- Materials
- Energy
- Time
- Cost

- Manufacturability
- Standards
- Safety
- Transport
- Ergonomics
- Weight

Example 1: Problem

- I don't want my iron to tip over easily causing water to spill out and possibly breaking the iron should it fall off the ironing table.

Example 1: Solution Need Analysis

- Can be retrofitted to existing irons
- Does not damage ironing table
- Easy to install and remove
- Cannot occupy a large area on ironing table
- Cannot interfere with operation of iron
- Cannot be damaged by iron (heat, water)
- Should not cost more than $2, should probably be included with ironing table or iron.

Target market: People who iron clothes on an unstable ironing surface

These could be the ideas coming to your mind on how to achieve the objective

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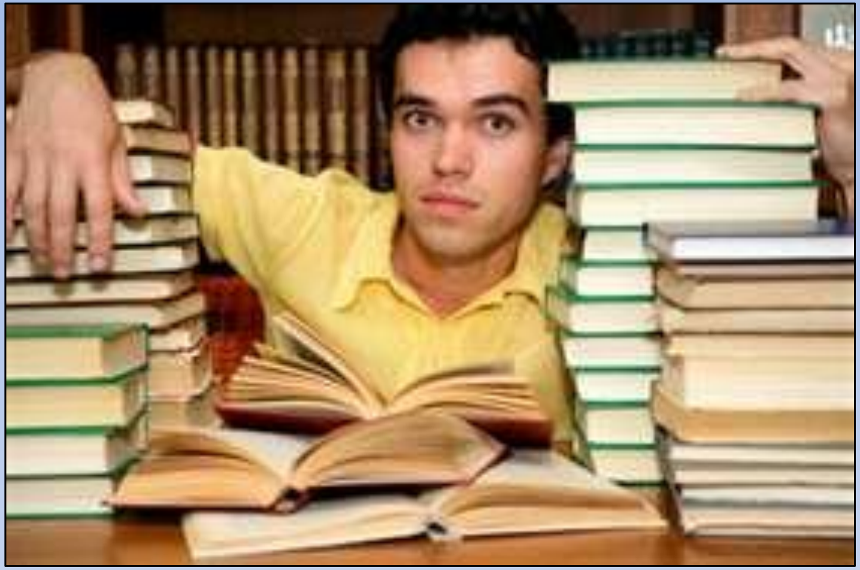
Example 2: Problem

- I want to store books in my car while providing plenty of room for passengers



A smart student wondering what to do with his books

Example 2: Solution

- Must store typical load and size of books for a college student (10 kg)
- Must resist degradation from sunlight, moisture, extreme cold and heat.
- Cannot occupy floor or seat space
- Cannot interfere with operation of any controls (radio, a/c, steering, gearshift, pedals, movement of seats) or passengers' freedom of movement.
- Easy to install and remove
- Cannot damage the car
- Should not allow books to eject during a severe crash
- Should not cost more than $15

These could be the ideas coming to your mind on how to achieve the objective

Target market: People who transport books and other people at the same time

Example 3: Problem

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- There is a need in underdeveloped countries for building materials. One approach is to make building blocks (10x15x30 cm) from highly compacted soil.

- Your assignment is to design a block-making machine with the capacity for producing 1000 blocks per day at a capital cost of less than SR 5000.

- Develop need analysis, a definitive problem statement, and a plan for the information that will be needed to complete the design.

Brick making in Pakistan

Brick making by a young boy

Example 3: Solution

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- **Needs Analysis:**
  - Must be capable of being constructed with local materials and labor.
  - Blocks of 10x15x30 cm
  - Total cost is less than SR 5000.
  - Should be easily transported to different locations.
  - Powered with human labor.
  - Cannot count on availability of electricity.
  - Hydraulic components may be invalid because cost and/or maintenance (sand in seals, etc.)

Notice how the need analysis is extracted from the problem while expanding it to include how the solution would be in this case, therefore, you will find some more information in it that was not given in the original problem!

This is how we can assess how good did you understand the problem "Scenario" which is why open ended problems are usually disliked by some students!

Example 3: Solution (Analyses of Need)

- Musts
  - Cost less than SR 5000
  - Weight less than 700 N.
  - Human powered
  - Made from local materials
  - Easily manufactured.
  - Produce 10x15x30 cm blocks
  - Produce 600 blocks/day

- Wants
  - Able to make tiles of 5x15x30 cm
  - Easily maintained.
  - Easy and safe operation.
  - Available to a variety of soil mixes.

Analyses of the need to determine what we must have and what is nice to have!

Example 3: Solution (Problem Definition)

The objective of this project is the design and construction of a prototype model of a block-making machine. The blocks are to be made of soil cement and are 10 x15 x 30 cm. The machine must be human powered, weigh less than 700 N, cost less than SR 5000, and be capable of producing 1000 blocks per day with a 5 person crew. The machine should be easily constructed of local materials with local labor. The machine also should be capable to a variety of soil cement mixtures and to making tiles 5cmx10 cmx30 cm. A crew of three persons should be capable of operating the machine to produce 600 blocks per day.

Notice how the problem statement when it is to be written by you, the student is simply re-writing the original problem with added information that you probably obtained from the imaginary customer.

Note how some of the points added are really suitable to be objectives and others may have come from the need analyses!!

Example 3: Solution (Information Needed)

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- Determination of the processing conditions for making blocks.
  - What pressures must be generated? Curing temperature and time? Effect of different soil mixes on pressure.
- Mechanism for generating pressure.
- Human factors in design: Magnitude of force that can be exerted without causing human fatigue.
- Materials handling.
- Available construction materials and properties.

What manufacturing, product, safety, legal, market and technical information do we need to succeed in our design?

Example 4: Problem

- Customer needs a solution to a problem

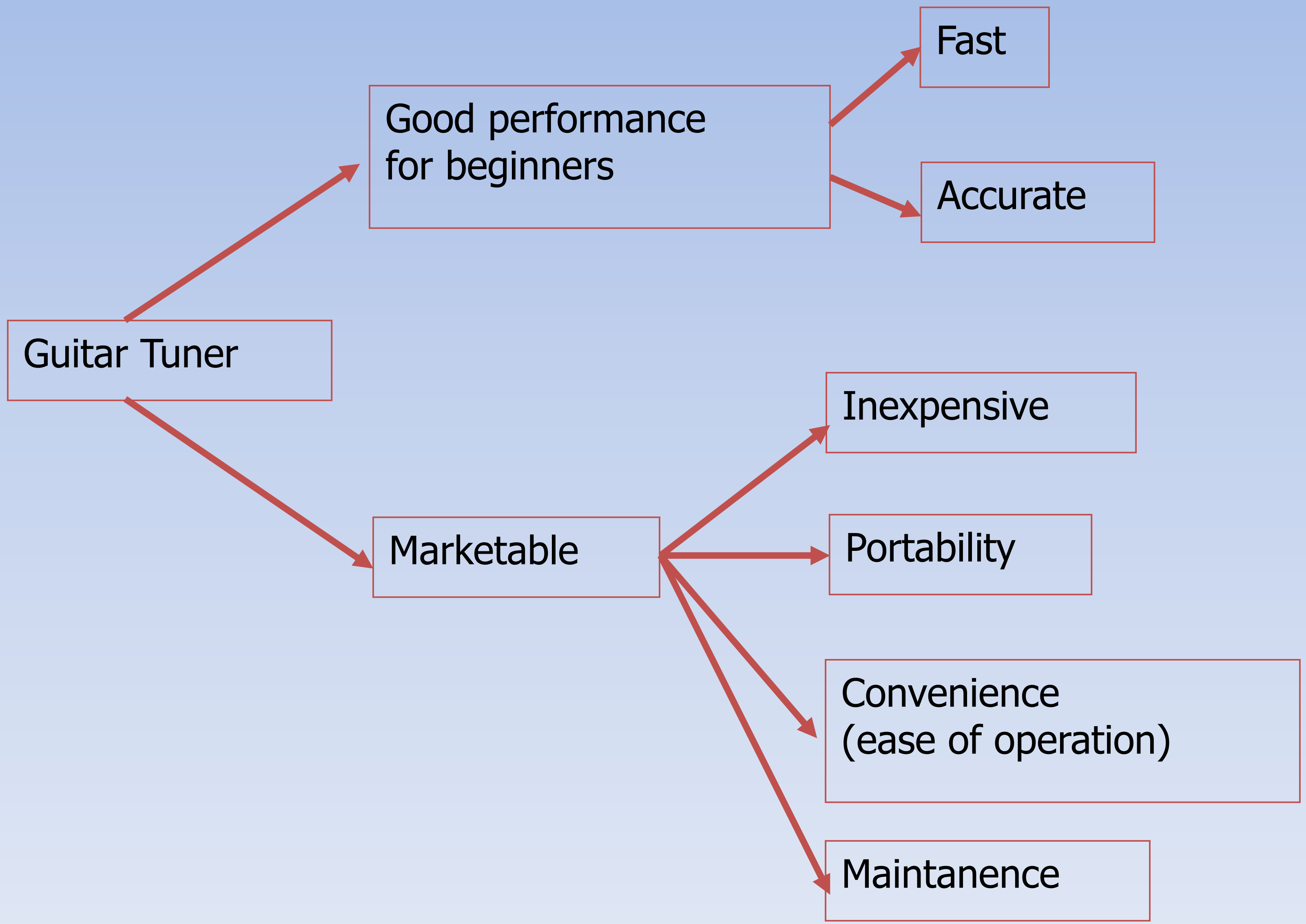
  of designing a guitar tuner

Example 4: Solution (Problem Statement)

- The accuracy of the device will be measured by the difference between the pitch of a tuned string and the correct pitch. The limits should be well within those of a guitar that has been professionally tuned and then played for one week without further tuning (correction).

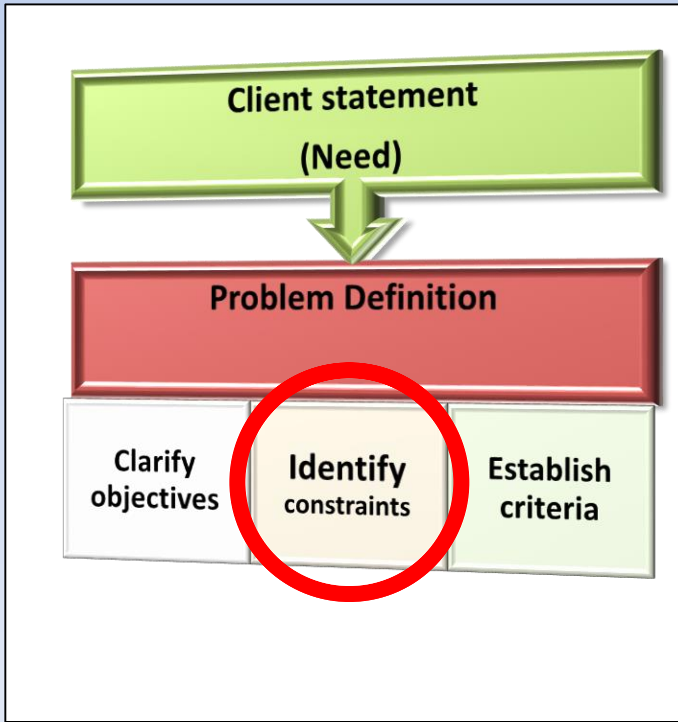
Notice how little information the original problem gave you about the tuner and yet this is the answer. Therefore, you need to be creative in your answers, un-limited in your thinking, and of course, it doesn't hurt if you knew how to play the guitar to answer the problem!

Example 4…Objective trees



Constraints

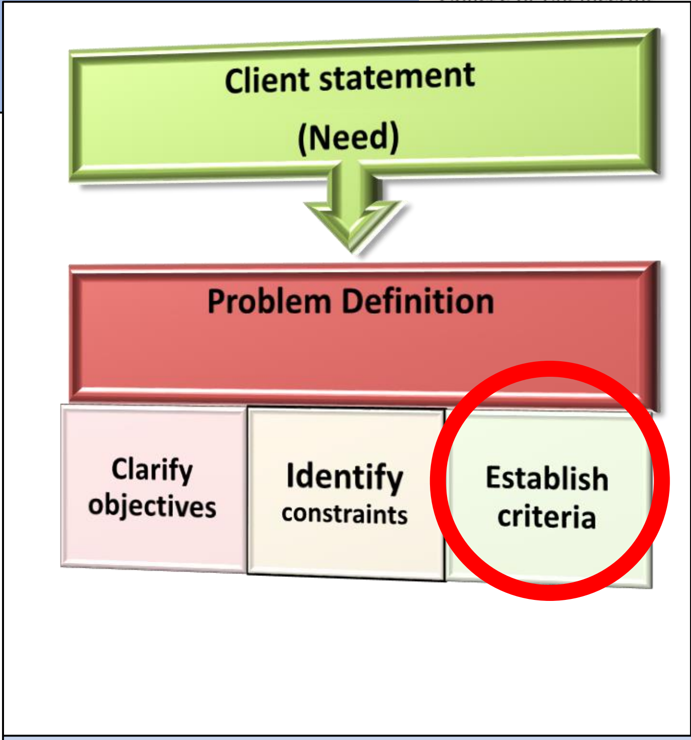
- Constraints are ***boundaries*** that limit the engineer's **flexibility**; they form the **design envelope** (feasible design **space**).
- They help to identify **acceptable designs**
- Should be **measurable**
- Should be **answered with:** True/False; **Yes/No**
  - Example: Cost <1000 SAR?
    Weight <500 N?
    Flexible system (yes/no)?



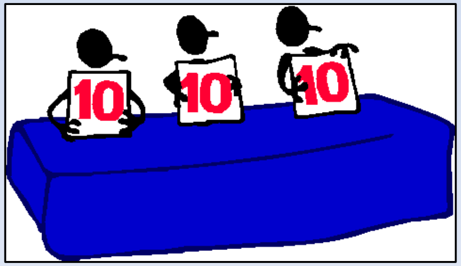
Sources of Constraints

- **Cost**: cost of design, production, maintenance, support
- **Time**: delivery dates, processing, time to market
- **Legal, ethical**: patents, intellectual property, product reliability, safety requirements
- **Physical**: size, weight, power, durability
- **Natural factors**: topography, climate, resources
- **Company practices**: common parts, manufacturing processes
- **Human Factors/Ergonomics**
- **Sustainability**
- **Environment**: bio-degradable materials, recycled materials, green energy

Design Criteria



- Criteria are indicators defining the success of achieving the objectives.
- Criteria define the product physical and functional characteristics.
- They represent descriptive adjectives that can be qualified on a *given scale*: examples: beautiful, low cost, low noise, smart, low weight.
- Might be used for judging between different designs.



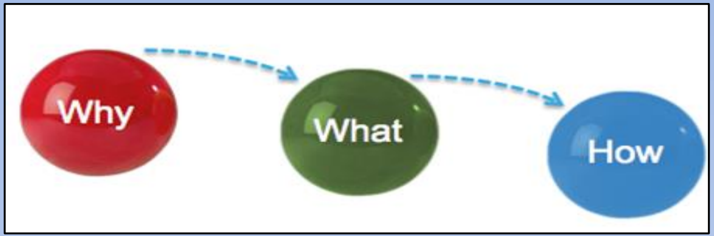
Examples of Criteria

- High safety
- Environment friendliness
- Public Acceptance
- Performance
- Ease of operation
- Durability
- Cost

- Ease of Maintenance
- Ease of Manufacturing
- Aesthetic design (Appearance)
- Geometry
- Physical Features
- Reliability
- Use Environment

These criteria (or whatever criteria you have) are to be qualified (ranked) say *on a scale 1 to 10, where* 1 (worst) and 10 (best) *

Problem Definition



Need Analysis

- ***Specifications***

Problem Definition

- ***Objectives***
- ***Constraints***
- ***Criteria***

Problem Formulation

- ***A paragraph compiling the above points***

Summary

Need Analysis

- Needs that are well understood
- A well stated objective
- A list of Demanded and Wished for Specifications
- A set of criteria
- A set of constraints

Problem Definition

- Turn the problem statement into a technical, quantified problem definition
- Precise description of the properties of the object being designed
- Can be a long list

Problem Formulation

- A compiled carefully written paragraph

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Need Analysis

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