Mechanical Analysis and Design
ME 2104

Lecture 4

Requirements

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www.staff.city.ac.uk/~ra600/intro.htm

Plan for today

- Design Process
- Customer requirements
  - » Objectives tree method
- Team meeting
- Project assignment
  - » Tennis ball server

The Engineering Design Process

Client Statement (Need)

Problem Definition
1. clarify objectives
2. establish user requirements
3. identify constraints
4. establish functions

Phase 1 - Vision

5. establish design specifications
6. generate alternatives

Conceptual Design

Phase 2 - Concept

Phase 3

7. model or analyze design
8. test and evaluate design

Preliminary Design

Phase 4 - Design

9. refine and optimize design

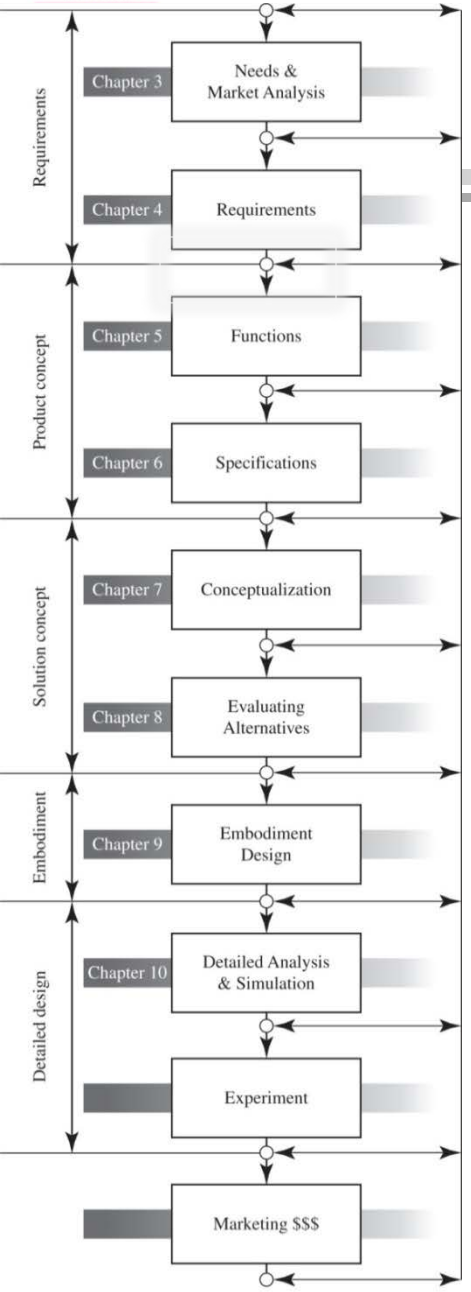
Detailed Design

Final Design (Fabrication Specs & Documentation)

Design Communication
10. document design

Phase 5

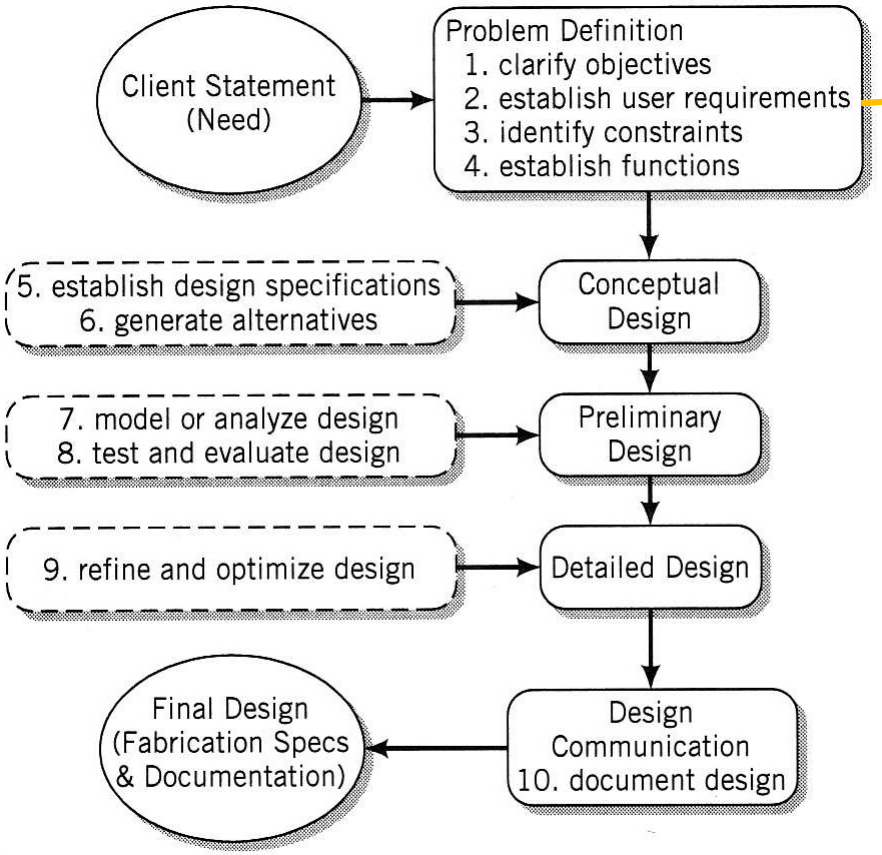
Product



Requirements

- Engineering Design Process 2nd Edition, Chapter 4
  - » Expand requirements from the needs statement
  - » Prioritize requirements according to importance
  - » Organize requirements into an objective tree

Phase 1: Clarify Problem



1. Clarify Objectives – The Objectives tree method
   - Prepare list of objectives
   - Order the list
   - Draw the objectives tree
2. Establish user requirements
3. Identify constraints
4. Establish functions
   - Create 'black box' model of the product
   - Break down overall function in sub-functions
   - Connect sub-function chains together
   - Define the system boundaries (Constrains)

Why Design is Important?

- Without Design, there is no product!
- With a poor design, no matter how good the manufacturing methods are, or quality control, etc, the end product will still be a bad idea and no one will buy
- Most people will buy something based on the design followed by the quality
- What about cost?

Why Design is Important?

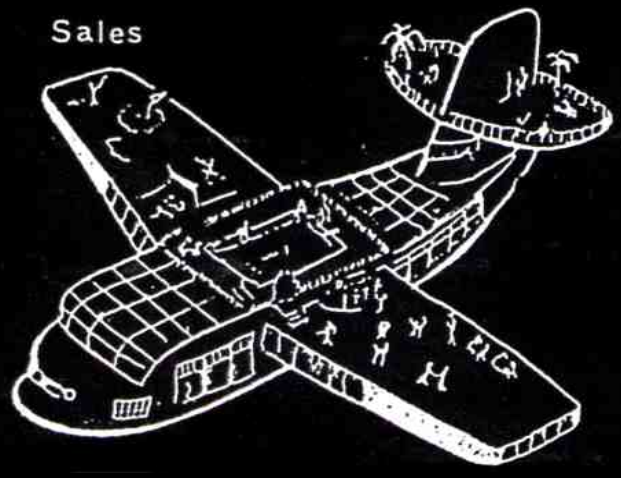
- Most end-users do not know/care about the details or technical features of a product.
- They look only at the design … both the functionality of the product and the way it looks.
- Think about how people choose to buy a kettle or even a mobile phone.

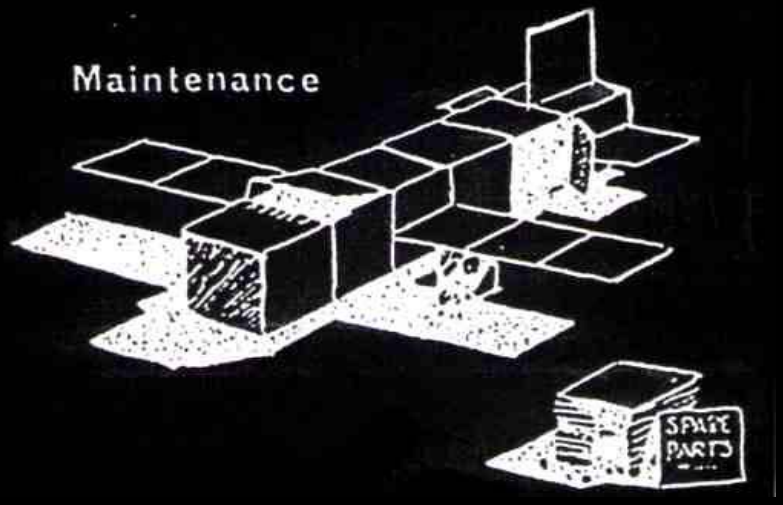
Identifying your Customers

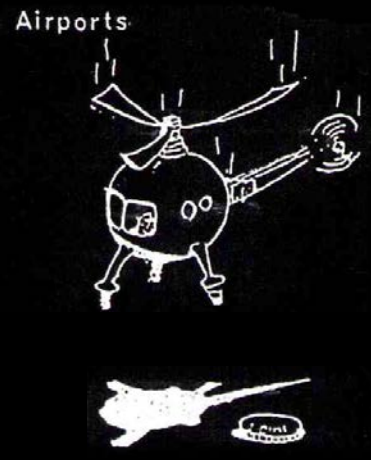
- Everyone has a different opinion / desire on how a product should be designed…
- Customers of a product are NOT just the end-users.
- Who do you think are customers of an airplane?
- Customers include the people that manufacture, maintain, sell, dissassemble… etc.

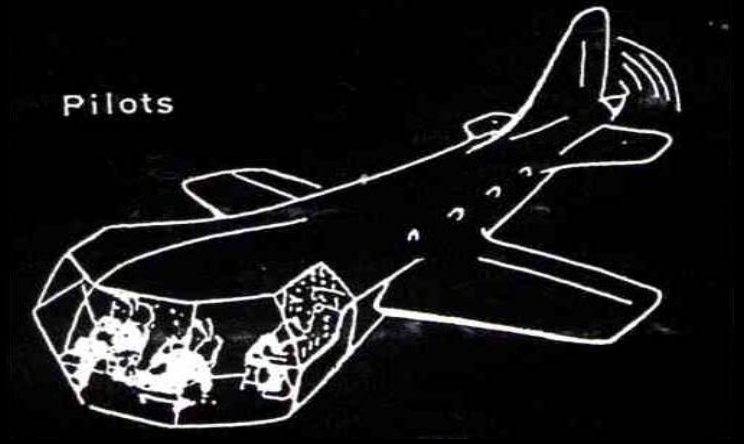
How an airplane should be designed..

According to:









Haik and Shahin, Engineering Design Process, 2nd Edition

How an airplane should be designed..

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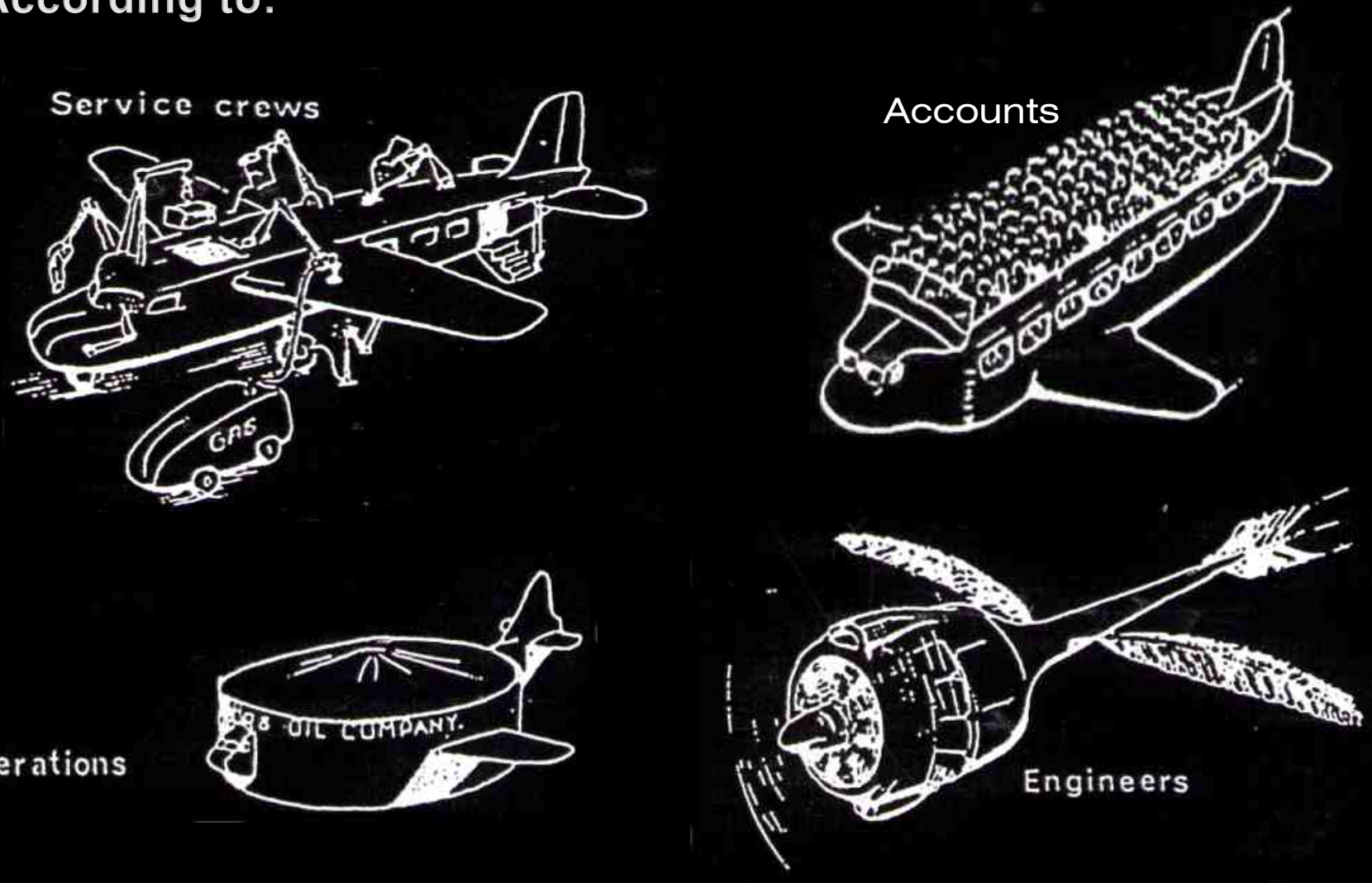


Haik and Shahin, Engineering Design Process, 2nd Edition

Requirements

- Requirements are a ‘wish list’ that the product needs to do.
- This is usually given by the customers or sponsors or even as a list of requirements in the designer’s mind
- They are not usually technical
- E.g. for a coffee cup … ‘something that will hold coffee’ etc..

TABLE 4.2 Aluminum Can Crusher Requirements

List of requirements in no particular order					
Pleasing to eye (stylish and fashionable)	W	5	Stand-alone unit	D	10
Internal parts totally enclosed: safe from ambient environment	D	10	Large capacity feeder and refuse container	W	4
Blends with surrounding	W	5	Cans automatically removed	D	10
Dimensions $1 \times 1.5 \times 1.5$	D	10	Low peripheral force	W	8
Inconspicuous	W	5	Easy to start	W	9
Many colors available	W	1	Shock absorption	W	8
Built from polymer	W	2	Easy cleaning	W	3
Housing constructed from molded polymer	W	2	Durable refuse container	W	4
Paintable surface	W	3	Can counter	W	2
Ability to reset after kill switch has been used	W	9	Receiving containers on casters	W	3
Plexiglass window to view operation	W	1	Sealed bearings	W	7
Low noise	W	7	Ability to mount to various surfaces	D	10
Machine rendered inoperable when opened	W	10	Compact size	D	10
Operable by elementary students	D	10	Ability to crush various sizes of containers	W	3
Total Cost $<$ \$200	D	10	Operator-free operation	W	6
Automatic kill switch and reset button within easy reach	W	10	Enough force to crush cans	D	10
Wiring kept away from moving parts	D	10	Starts immediately	W	7
Crushing mechanism inaccessible from feeder & dispenser	W	10	High efficiency engine	W	9
Yellow light to indicate improper use of machine	W	3	Light weight	W	3
Internal parts safe from liquid damage	W	8	Low loading height	W	7
Stops easily and immediately	W	9	Flip open lid	W	1
Little heat produced	W	6	Solvents unable to hurt finish	W	6
No sharp corners	W	8	Limit # of light tolerances	W	7

Excerpt – See book for full table

Aluminum Can Crusher – Objective Tree

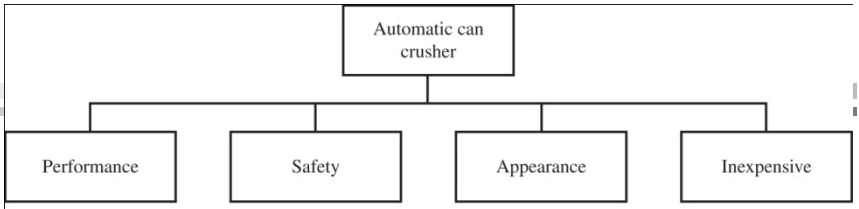
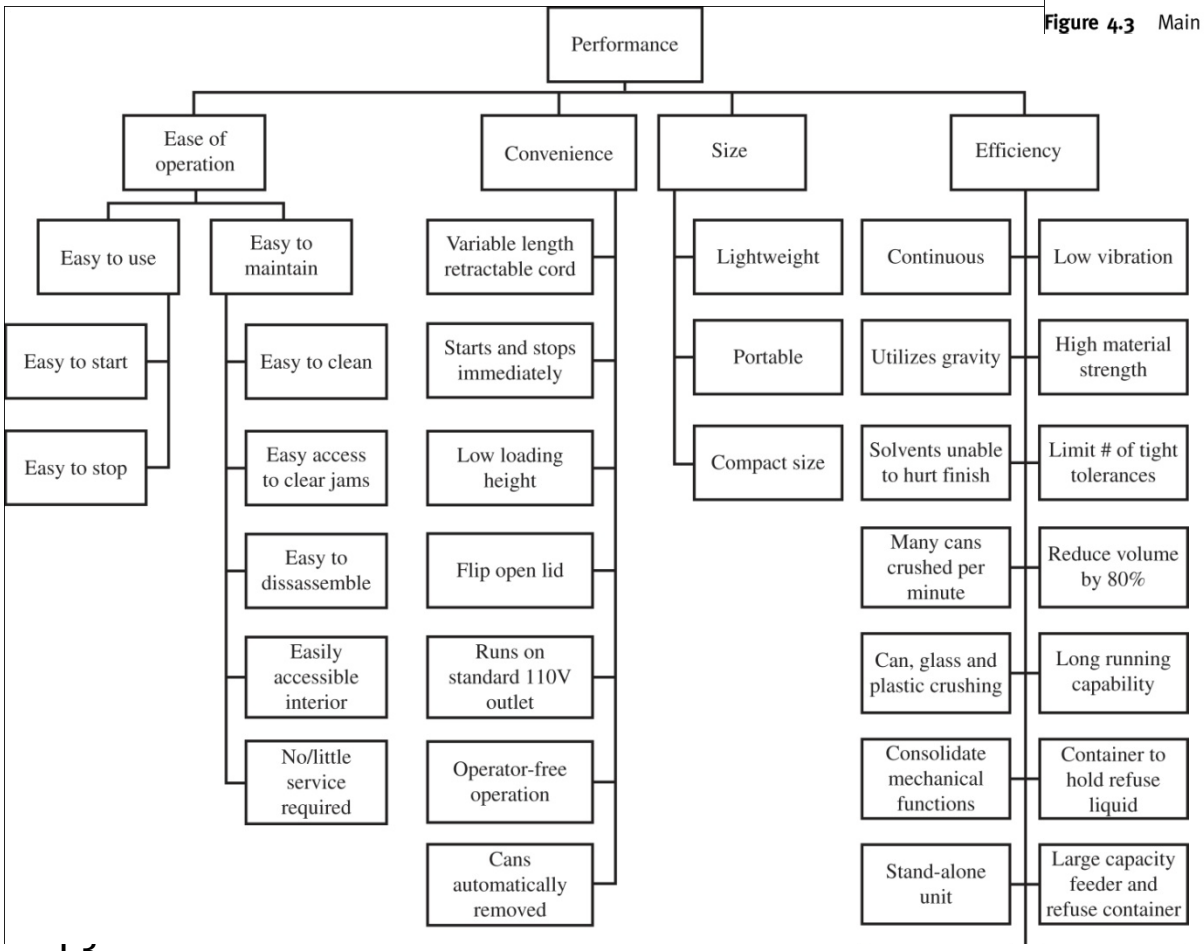


Figure 4.3 Main heading.



Aluminum Can Crusher – Objective Tree

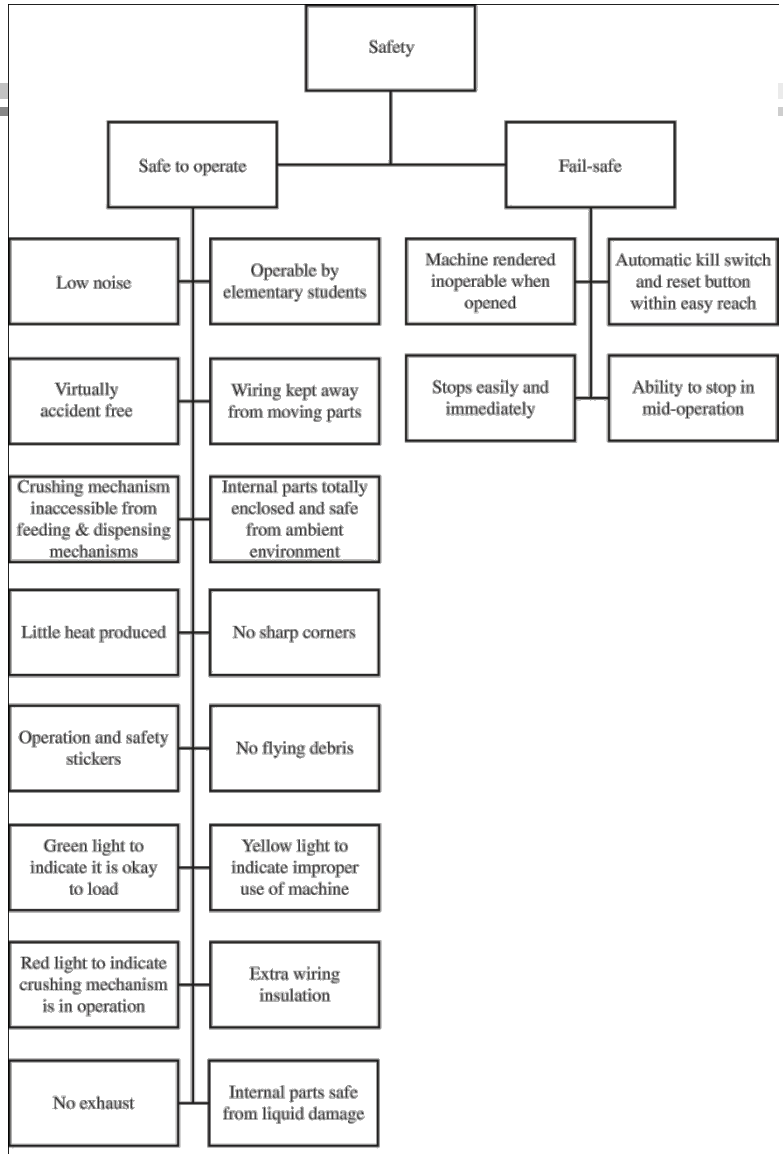


Figure 4.5 Safety branch.

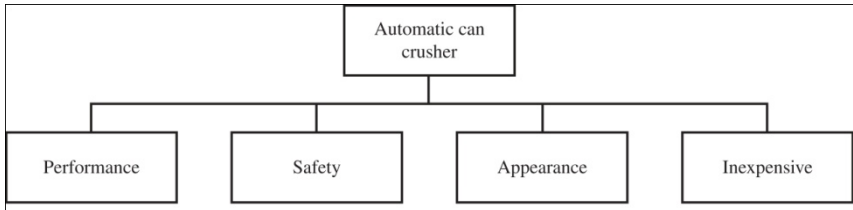


Figure 4.3 Main heading.

Aluminum Can Crusher – Objective Tree

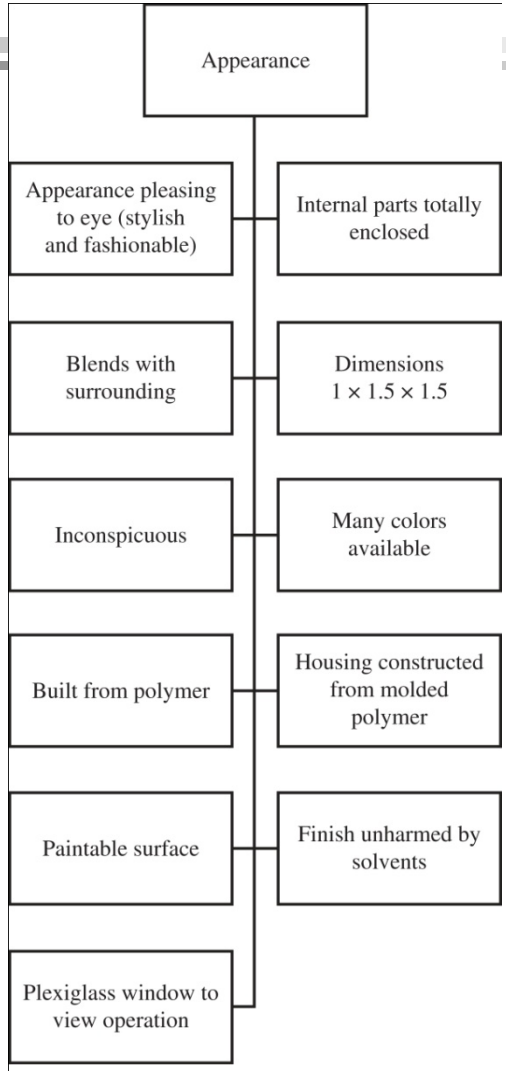


Figure 4.6 Appearance branch.

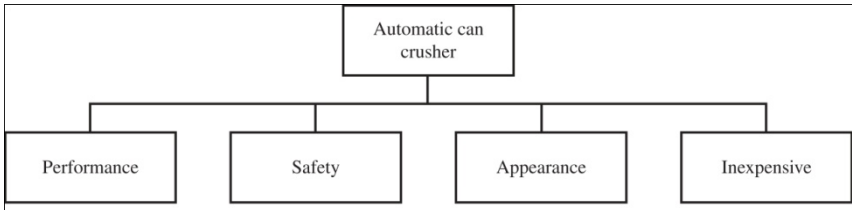


Figure 4.3 Main heading.

Aluminum Can Crusher – Objective Tree

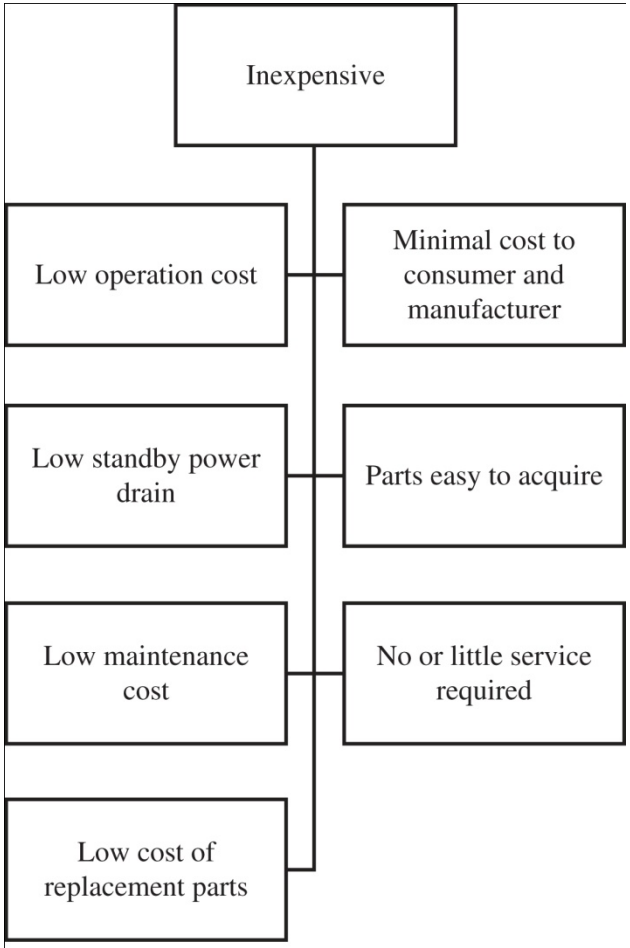


Figure 4.7 Inexpensive branch.

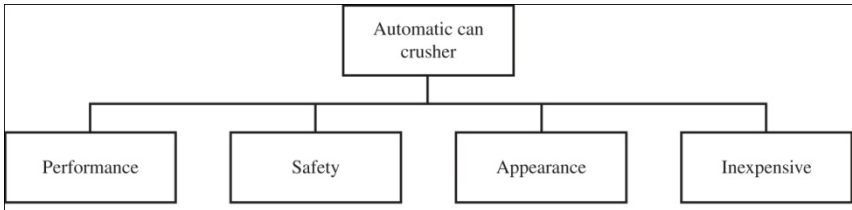


Figure 4.3 Main heading.

The Objectives Tree Method

- The objectives tree method is an approach to transform vague design statements into more specific customer requirements
- Make vague statements more specific by asking:
  - *What is meant by that statement?*
- Other useful questions to ask when expanding and clarifying design objectives:
  - *Why? How? What?*

The Objectives Tree Method (1)

- Three step procedure:
  1. Prepare a list of design objectives
  2. Order the list into sets of higher-level and lower-level objectives
  3. Draw a tree of objectives, showing hierarchical relationships and interconnections

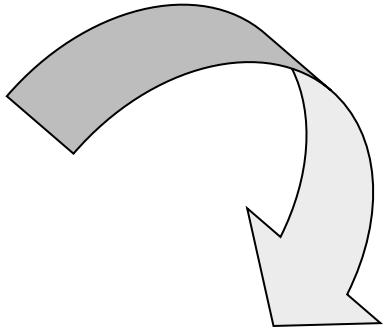
Step 1: Listing the Objectives

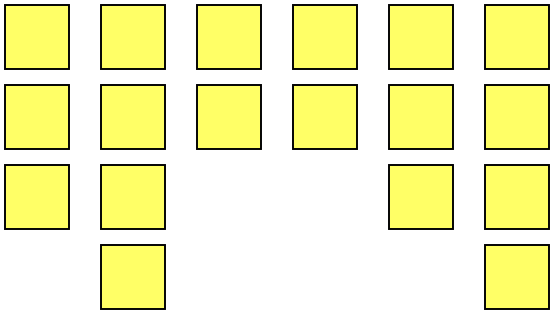
- This can be done by:
  - » Talking with (interviewing) customer
  - » Thoroughly reading any written design statements and requirements
- Take vague statements and make them clearer by asking “what is *meant* by this statement”

Step 2: Ordering the List

- Group the statements into related topics using an *affinity diagram*

Design Objective



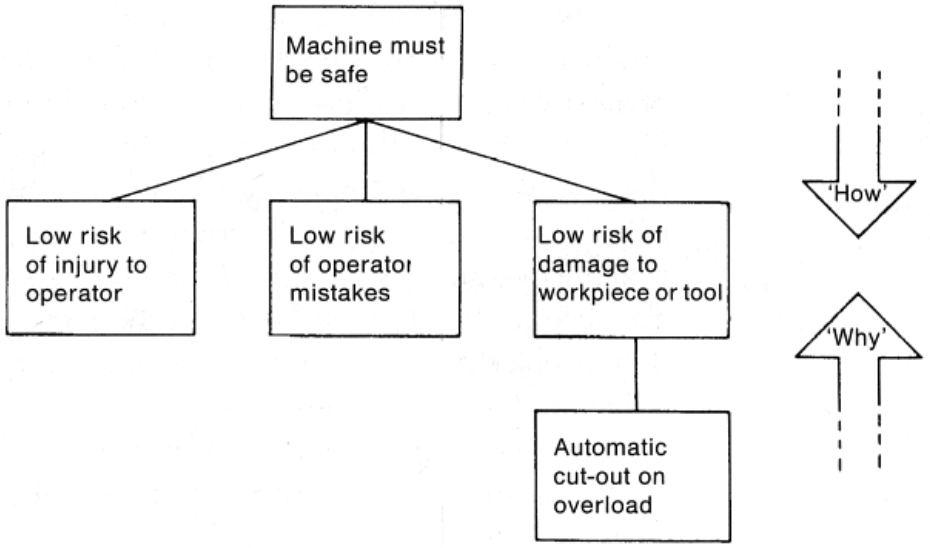


Affinity Diagram

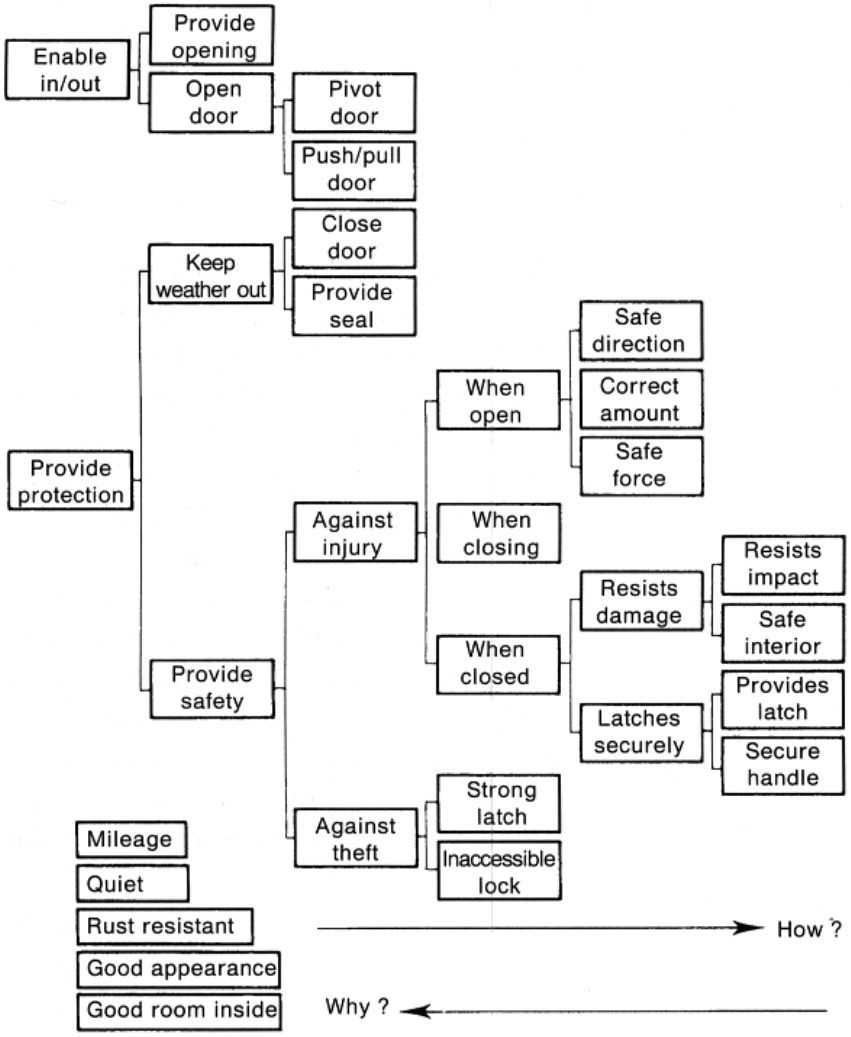
- Copy design objectives to post-it® notes
- Place one on a board
- Compare next objective card to the first
  - » If different, begin a new column
  - » If similar intent, place under the first column
- Repeat for all design objective cards
- Result: Objectives sorted by similar statement
  - » Within each column there may be levels of objectives
  - » Lower-level objectives answer the question “How?”
  - » Higher-level objectives answer the question “Why?”

Step 3: Draw the Tree

- The Objectives Tree diagram looks like an "upside-down" tree
  - » The overall objective of the tree is at the top
  - » Underneath it, branches break the objective into more detailed objectives
  - » Can have many levels and interconnections



Step 3: Draw the Tree (1)



- The objectives tree diagram may alternatively be drawn on its side
- Example: Car door

Example: Bumble Ball

- As a team, generate a list of objectives for the bumble ball toy
- Complete the affinity method for ordering the objectives in class
- Draw an objectives tree for the bumble ball

FIGURE OF MERIT

Teams will have 6 servers to set the machines before testing. After the machine is set, no manual adjustment of the machine will be allowed during testing. Testing will consist of 6 serves alternating between two targets,

The performance of the serving machine will be computed by the following figure of merit (FOM):

$$FOM = Z \cdot \left[10 \cdot (50 - C) + 100 \cdot \left(1.8 - {(d_C + d_D)}/{2} \right) + 100 \cdot T + 20 \cdot (25 - W) \right] + 20 \cdot A + 20 \cdot E + 200 \cdot DI + 30 \cdot OI$$

Where:

Z Multiplier based on above net zone ball passes through
Z=1.1 for zone E, 1.0 for zone F, 0.9 for zone G, and 0.8 for zone H.

C Cost of materials in £

d_C, d_D Minimum distances (m) from the corner of service court to the ball landing location for best serves.

T Total number of tries to hit landing zones C and D

W Total weight of machine plus any stand or structure needed (kg)

A A number ranging from 0 -4 assessing the workmanship and aesthetic appeal of the machine. Aesthetics also includes the ease and reliability of operation.

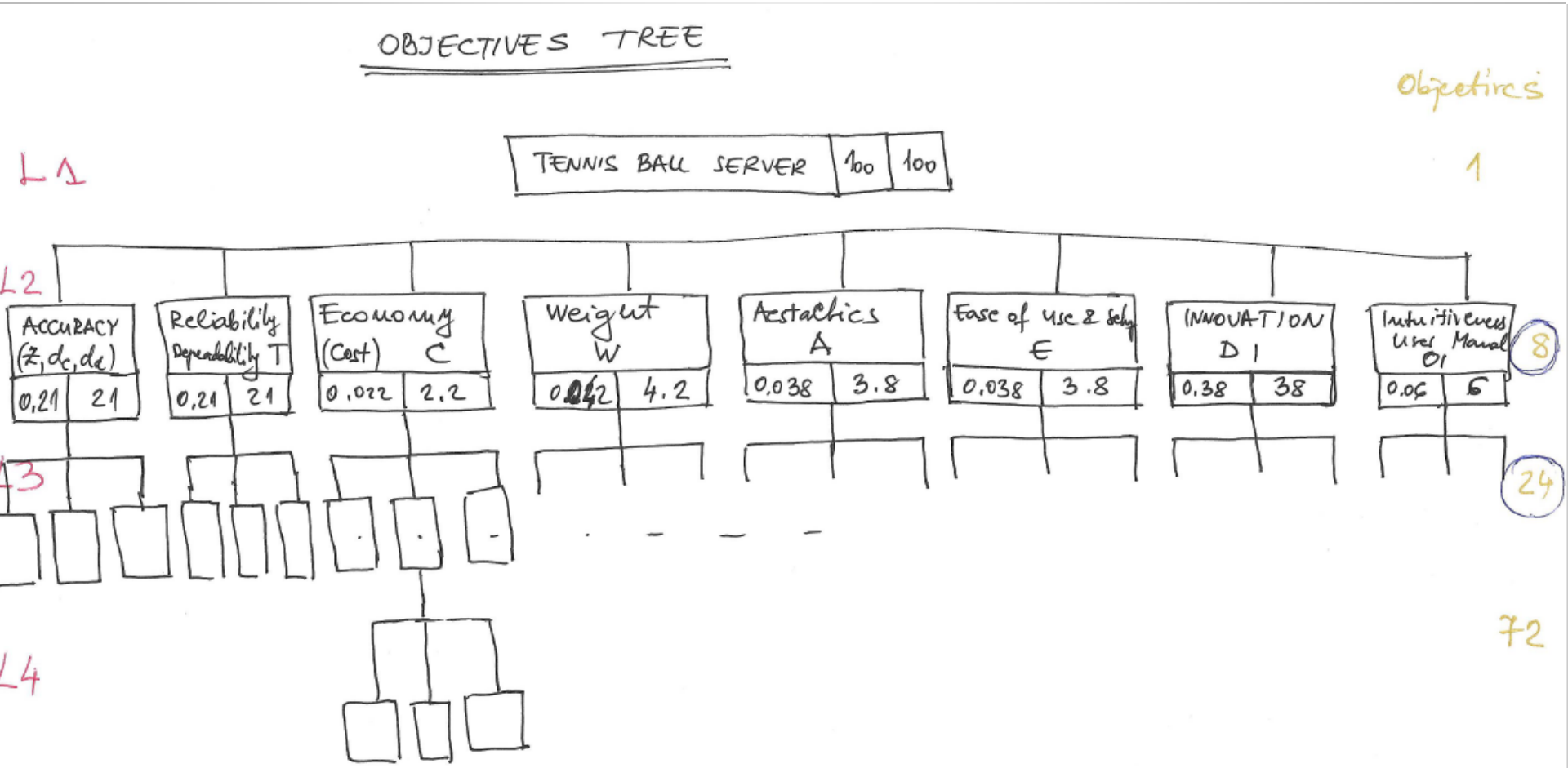
E A number ranging from 0 - 4 assessing the ease of set-up and use of the machine.

DI A number ranging from 1 - 4 measuring the creativity and/or innovation of the design. The innovation will be evaluated for sealing, aiming, feeding and storing of balls.

OI A number ranging from 0 - 4 assessing the quality of the operating instructions.

FOM to Objectives Tree

Objective	Symbol	Value	Utility Value	Importance [%]
Accuracy	Z, d_C, d_D	100 x 1.1	110	21.0
Reliability (Repeatability)	T	100 x 1.1	110	21.0
Economy (Cost)	C	10 x 1.1	11	2.2
Weight	W	20 x 1.1	22	4.4
Aesthetics	A	20	20	3.8
Ease of setup and use	E	20	20	3.8
Innovation	DI	200	200	38.0
User manual (intuitiveness)	OI	30	30	6.0
TOTAL			**523**	**100**


OBJECTIVES TREE
Objectives
L1
TENNIS BALL SERVER 100 100
1
L2
ACCURACY (Z, dc, de) 0,21 21
Reliability Dependability T 0,21 21
Economy (Cost) C 0.022 2.2
Weight W 0.042 4.2
Aestathics A 0,038 3.8
Ease of use & safety E 0,038 3.8
INNOVATION D1 0.38 38
Intuitiveness User Manual O1 0.06 6
8
L3
24
72
L4

Deliverables for Week 4

» Notebook, Work agreement
» WBS, Calendar, Gantt Chart
» Meeting minutes from last week
» Objectives tree
» Functional model

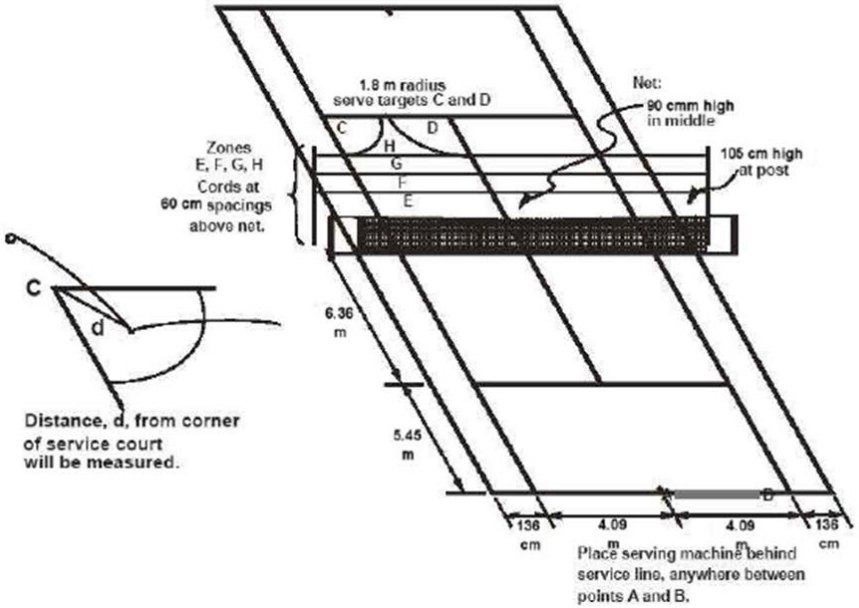
Team meeting

Project assignment

GENERAL PROJECT DESCRIPTION

Design team is asked to design, build, and demonstrate a tennis ball serving machine that uses standard liquid CO2 3kg bottle as source of energy. The device must be capable of serving a regulation tennis ball from behind the service line to the opposite service court shown in Figure 1. The ball should pass over the net with as little clearance height as possible. Serves should alternate between corners C and D so that one serve lands in the quarter circle area C and the next one in the quarter circle D. The alteration between one and the other target should be automatic.

The machine should be of a reasonable size but shipping volume should be less than 500 x 500 x 1000 mm. It should be easy to assemble and use. The machine must be completely portable, preferably on wheels and independent of any external source of energy. If electrical power is to be used for any function of the machine it must be supplied from 12V batteries which will be provided. The machine must have ball storage capable of holding at least 12 balls. For launching a ball must be placed in the machine from the storage automatically. The operator should actuate the machine for each serve by use of a button, switch, or lever to initiate the serve. The energy storage and energy conversion system will be provided to the students. The remaining parts of the machine and the enclosure should be built within the budget of £50 per team. Purchasing of the required materials will be arranged through the University. All required materials should be ordered not later than the end of Week 5 in Term 2.



Testing

FIGURE OF MERIT

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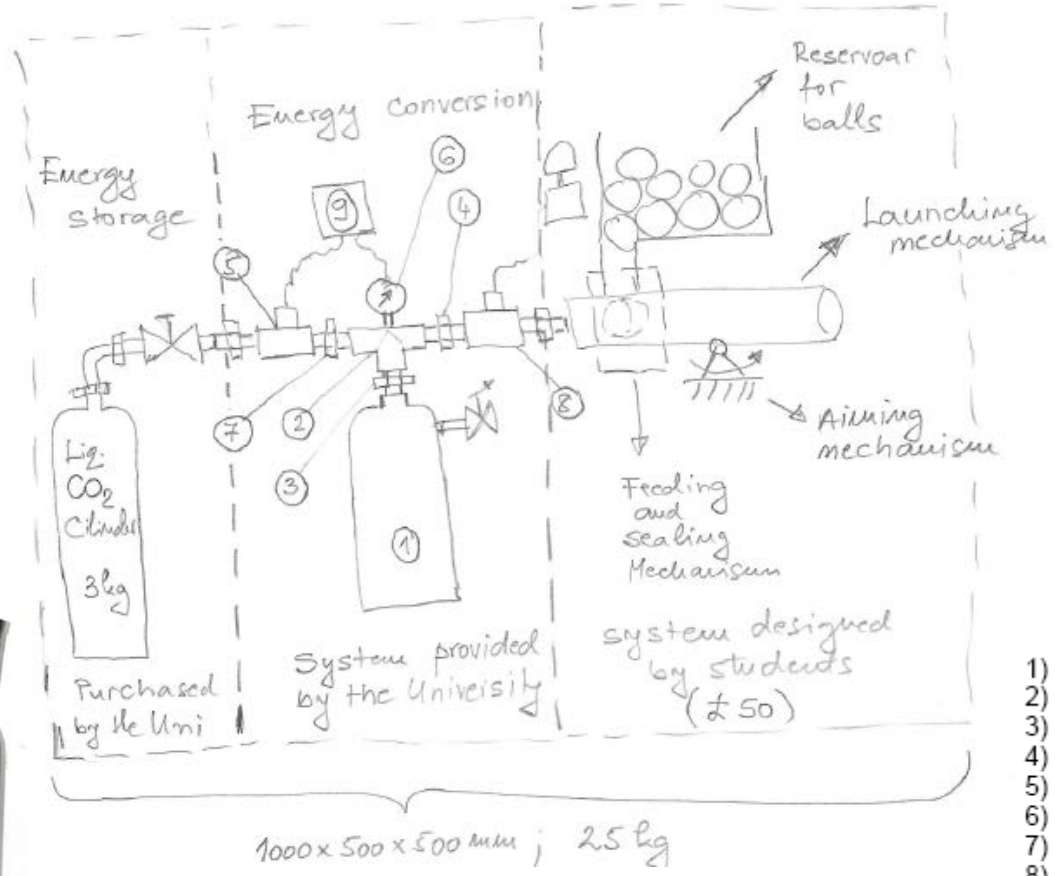
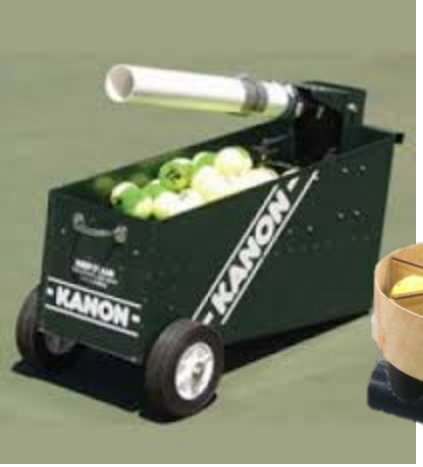
What to do



1) CO_2 fire extinguishers to use as pressure vessel
2) BSP T piece 1"
3) 1" BSP male – 3/8"BSP female bush
4) 1" BSP male/male nipple
5) 10 bar 3/8"BSP female solenoid valve
6) 0 - 10 bar pressure gauge
7) 3 x 3/8"BSPP male /male fittings
8) 1" BSP Rinpro 200 series solenoid valve
9) Pressure control system

Deliverables

- Teams will provide weekly memo reports documenting their progress
  - » Group notebook and Personal logbooks
- Teams will have three design reviews, and the final presentations on dates specified in the Timetable.
  - » Project review 1 – Vision & Concepts (Report and PPT Presentation)
  - » Project review 2 – Embodiment (Report and PPT presentation)
  - » Project review 3 – Detail design (Report and PPT presentation)
  - » Final report – ‘Dragons den’
    (Prototype, Report – Marketing, business, technical, PPT presentation, poster and user manual)


KANON
KANON


LOBSTER

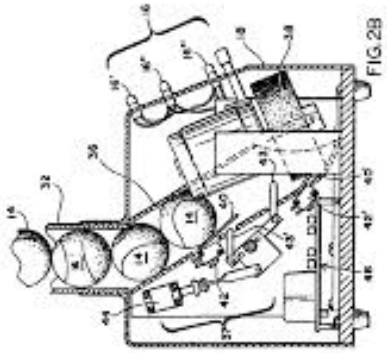


FIG.2B