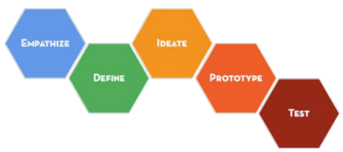
Lecture 1

Engineering Design Def'n:
An ability to develop solutions for complex, open-ended engineering problems and to create systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

Following the design process: DESIGN THINKING → demonstrate the basic steps of design and help improve the odds of creating "good" designs:



You need to develop many skills if you are to become a good engineering designer:
Problem solving; technical skills; soft skills; creativity/arts/media; teamwork; communication; entrepreneurship; etc.

What is Hydroponics? A: the process of growing plants and different sorts of produce in nutrient filled water, instead of using soil

Benefits of Hydroponics:
- **Water Savings**: Studies estimate that plants grown using hydroponics saves 70-90% versus the amount of water used by traditional soil-based methods
- **Space efficient**: Faster growth rate and greater yields. Possible vertical growth
- **Organic:** Eliminates unwanted organisms (weeds, insects and pests) from harming your crops without chemicals
- **Controlled environment:** growth can occur year-round and, in any environment, as it does not depend on weather or soil conditions

Lecture 2

Suggested Solution Steps:
- 1st understand the problem. -what is required?
- Identify potential concepts and pick a sol'n -is it feasible?
- Develop and refine the solution -what are the key characteristics? -what good will this sol'n be?
- Complete the solution -how much will it cost?

NEEDS IDENTIFICATION *
*using reading

Understand the problem:
- what is the real need? – to provide an adequate supply if portable (drinking) water to each household
- how much water is required each year per household?

Water Demand:
- Requirement: what is the annual water demand? –(calculations) 34, 560 L/yr
- Must supply: 2, 880 L/ mth or 34, 560 L/yr

Is this "reasonable" → always do a "sanity check" on your results
→ always check results with previous experience or literature – "sanity check"

CONCEPTUAL DESIGN*

Design Criteria:
- First, determine criteria you can use to judge the quality of the solution
- In this case: Ability to supply water when needed; cost; ease of obtaining materials; ease of construction; ability to provide clean (drinking) water

Solution – Rainwater harvesting

Is this feasible? "ability to supply water when needed"
Check feasibility – Rainwater Harvesting → is it feasible? -How much water can be collected in the worst year?

Rainfall by year – historical rainfall data: 1985 – driest year on record [835 mm of rain]
Rainfall collected – (calculations) available water: 37, 575 L → greater than demand so it feasible
Proposed concept is acceptable.

PRELIMINARY DESIGN*

Configuration
- What is the general configuration?
- What are the key components in terms of design? -what do we have control over? – what affects reliability of the system?

Develop a Detailed Sol'n: the key component is the reservoir or storage tank

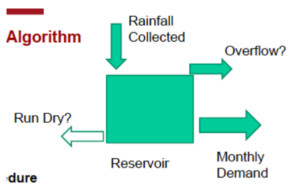
Reservoir Size? Estimate a reasonable reservoir size based on the monthly precipitation in the worst year

Initial design:
• How big should the reservoir be? – plot available water (runoff) per month for worst year

Preliminary Design:
• How big should the reservoir be? -Monthly = 2, 880 L - 3 month approx. = 9000 L (first estimate)

How Do We Improve the Estimate?
• Refine the sol'n by performing analytical simulations – try different reservoir sizes to determine the relability
• Reliability = % months with adequate water

Simulation Algorithm:
Simulation Procedure
• Starting Balance
• Balance = Previous Balance – Monthly Demand + Rainfall Collected
• Check if dry (no negative balance!)
• Check if Overflow
• Repeat for 20 years (240 months)



Simulation Results
Choose a suitable tank size to maximize reliability while minimizing cost

DETAILED DESIGN*

How much will it cost? Select material based on lowest cost
Ferrocement – 10, 000 L tank – 660$
Is this cost feasible?
Calculations: A storage tank costs about 27, 500 Rupees, versus an estimated annual income of 4, 800 Rupees!

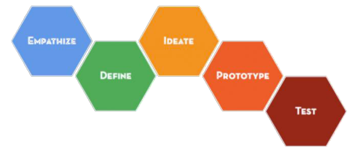
Social Issues: Power structures, daily rituals of the villagers, who will have ownership over the water, how women and men relate, community's previous experience with Non-gov'tal organizations
Cultural Issues: Local acceptance/familiarity of the technology, taste of the water, distance/time required to extract water, manpower required to extract water, religious/spiritual beliefs, are people displaced during the building process?

Lessons Learned:
• First, understand the problem
• Establish feasibility
– Physical, technical, economic
– Check your results at each step of the process
• Establish topology and size components
• Perform appropriate analyses
• Refine solution using successive approximation
– Increasingly complex analyses, properly verified
• Keep in mind other factors
– Cost, manufacturability, environmental, cultural, …

Lecture 3

What is Design Thinking?
An approach to solving design problems by understanding user needs and developing the design tools required to solve those problems.

Design thinking Process



Think back to the gift giving exercise.

EMPATHIZE
Step 1: Interview Your Partner
Step 2: Dig Deeper
DEFINE
Step 3: Capture Findings
Step 4: Define the Problem Statement
IDEATE
Step 5: Sketch
Step 6: Share your solutions and get feedback
Step 7: Iterate based on feedback
PROTOTYPE
Step 8: Build Your Solution
TEST
Step 9: Share your solution and get feedback

Lecture 4

What is Customer Needs Identification?
Customer Needs Identification is the process of determining what and how a user interacts with a product. User needs are non-technical, and they reflect the users' perception of the product, NOT the actual design specifications. Although they are frequently closely related.

Are they Customers or Users?
• A user is a person who uses the product
• Customer is the person who pays for the product
• They are sometimes the same **BUT** are often different

Goals of Customer Needs Identification
• Focuses the product development process on the actual needs of the customer
• Helps to both identify the more obvious explicit needs, but also the less obvious latent needs

How Do We Identify Customer Needs?
• Gather raw data from customers
• Interpret the data in terms of customer needs
• Organize the needs
• Establish relative importance of needs
• Reflect on the results

Before you Start…
• Determine **who** the customers are
• Determine **what** information should be gathered from the customers
• Determine **how** that information should be gathered

1- How Do You Gather Raw Data?
• **Observation**: Seeing someone struggle with a problem is an easy way to get an understanding of the issue
– Passive: watch a user in their natural environment
– Active: work side-by-side with the user and gain and understanding of their problems from their perspective
• **Interviews**: One-on-one meetings with potential users. They frequently take place in the user's environment
• **Focus groups:** Focus groups are like expanded interviews. They involve about 8 to 12 customers. The group is lead in a discussion by an interviewer

In the case of the EWC case?
• Go to India, live in the village for few days/weeks if possible
• Observe the villagers when they do their daily chores
• Interview the villagers (more than one)
• See if you can get a group together and form a focus group (town hall meeting?)

How Do You Prepare for a Successful Interview?
• Prepare an interview script, but don't be afraid to deviate if appropriate
• Ideally, interviews should be done with all "customers"
• Suppress preconceived hypothesis about the needs
• Have the user demonstrate the product and/or typical related tasks
• Be alert for surprises and the expression of needs you hadn't considered. Pursue surprising answers with follow-up questions
• Watch for non-verbal information

Lead Users
Users-that are experiencing needs that are ahead of the targeted market(s). Often, they help develop product or service prototypes to satisfy their leading-edge needs which may become commercially attractive to firms
• The three types of lead users are:
1. lead users of the target application and market
2. lead users of similar applications in advanced "analog" markets
3. lead users with respect to important attributes of problems faced by users in the target market

Who Are the Lead Users in the EWB Case?
• First, you will need to identify a specific problem. The problem could be: "cost of water storage devices"
• Then, you could identify:
– Villagers who have solved their water problem
– Other villages in India who have dealt with the issue
– Someone who has developed cheap containers for storing something completely different than water

2- Interpreting the Data
Suggestions and constraints for expressing the data:
– Write the needs in terms of what the product has to do, not how it might do it
– Express the needs as specifically as the raw data implies
– Use positive phrasing
– Express the needs as an attribute of the product
– Avoid the words must and should

3- Organize the Needs
• **Print** each need statement on a card or Post-It note
• **Eliminate** redundant statements
• **Group** the statements according to the similarity of needs they express
• **Choose** a label for each group
• **Consider** "super groups" of 2-5 groups
• **Review and edit** the organized needs statements

4- Establish Relative Importance
• Two basic approaches:
– Consensus of the team
– Further customer surveys
• A numerical ranking process is a common tool. For example:
  5 – Satisfying the need is critical
  4 – Satisfying the need is highly desirable
  3 – Satisfying the need would be nice, but is not necessary
  2 – Satisfying the need is not important
  1 – Satisfying the need is undesirable

5- Reflect on the Process
• Consider the statements that have been gathered and study their interpretations
• Try to evaluate how the process was executed:
– Have all types of customers been interviewed?
– Do any customers require follow-up interviews?
– Are any of the needs surprising?
• Look for ways to improve or refine the Customer Needs Identification process:
– Would more interviews help? Less?
– How about focus groups?
– Could the process have been done faster?
• Remember, as of now there are no product specifications! This entire process is about identifying needs, not designing solutions. That comes later.

***SKI HILL EXAMPLE (see slides)**

What is the Problem Definition?
A problem definition is a claim of one or two sentences in length that outlines the problem that will be addressed by the design process based on the customer needs.

What does it Include?
A good problem statement should answer these questions:
  1. What is the problem? This should explain what needs are being addressed
  2. Who has the problem or who is the client/customer/end-user? This should explain who needs the solution and who will decide if the problem has been solved (solved really well)
• Additionally, the statement can also include the following:
  3. What form can the solution be? What is the scope and limitations (e.g. in time, money, resources, technologies) that can be used to solve the problem

Be Careful!
• The primary purpose of a problem statement is to focus the attention of the problem-solving team
• However, if the focus of the problem is too narrow or the scope of the solution too limited, the creativity and innovativeness of the solution can be stifled

Lecture 5 (Lecture 6 due to a swap).

What are Design Criteria?
• A precise description of what the product has to be based on interpreted needs, also called:
  - "Requirements"
  - "Characteristics"
• Functional Requirements: Are design criteria that affect the solutions "function" (if measurable, then also a metric)
• Non-Functional Requirements: Are design criteria that do not affect the "function" of the solution
• Constraints: Set of important considerations that must be taken into account in your design

What is a Metric?
• Metrics are a list of measurable attributes you want your solution to have (i.e., weight, size, speed, impact resistance, etc.)
• Metrics have readily identifiable units of measure
• Metrics can be used to measure solution performance
• Metrics are obtained from:
- Functional design criteria ("Musts" i.e., mandatory and "Wants" i.e., would be nice)
- Benchmarking (what is the competition doing?)

Engineering Design Specifications
• Target Specifications are numerical values based on defined metrics that are desired of potential solutions
• Create a list of Design Criteria based on interpreted customer needs
• Do product Benchmarking
- Look at other products that satisfy some/all needs
- Gather data about those products
• Set Target Specifications
- Set values considered to be ideal
- Set values considered to be acceptable

Translate Needs into Design Criteria

Benchmarking
• Two kinds of benchmarking data:
- Benchmarking competitive products in terms of customers' perceptions
- Benchmarking competitive products in terms of technical performance
• To create a competitively superior product, the team must know what the competition can do
• There are opportunities to learn specific design approaches by observing competitors' products

See slides for exercise using the case study.

Setting Target Specifications

• From the list of design criteria and based on benchmarking, set target specifications by defining ideal and acceptable values

• Examples (ideal "perfect world" values or range of values): Exactly X; A list of discrete values; The "sweet spot" in a range of values

• Examples (marginally-acceptable "on the edge" values): At least X, At most X, Between X and Y, No worse than…

Summary

• Once the problem has been identified, the next stop is to develop a set of design criteria

• Those design criteria are based on the customer needs, as well as benchmarking the competition

• The design criteria should include functional and non-functional requirements, as well as constraints

• If functional requirements can be represented using units of measure, then they are metrics

Lecture 6 – Client Meeting..

Lecture 7

Reminder: High Flying Teams

• Diversity:

- Personalities, culture, education, and experience
- Different ways of thinking, strengths, knowledge and skills
- Reduces the likelihood of weaknesses

• Organization, punctuality and quality of work:

- Creates a positive environment
- Personal success comes from trust in your dream

• Active and on-going communication

• Respect, support and an open mind

• Enthusiasm

Team Conflict

• Healthy and constructive can help promote success and innovation

• Teams with diverse viewpoints, experiences, skills and opinions, will usually be more successful than teams with similar individuals

• However, team members must be open to these differences

But What Happens When It Doesn't Work So Well?

• A conflict resolution process is required

• The human experience of conflict typically involves:

- Our emotions, perceptions, and actions

• Negative experiences must be replaced with positive experiences

• Teams can do this using a three-step process

Step 1: Prepare for Resolution

• Acknowledge the conflict

- Cannot be managed and resolved otherwise
- Tendency is to ignore (which makes the situation worst)

• Discuss the impact it has on team dynamics and performance

• Agree to a cooperative process

- Everyone involved must agree
- Opinions and pride must be temporarily set aside

• Agree to communicate

- People involved must talk about the issue
- Active listening is essential!

Step 2: Understand the Situation

• Clarify positions
- Get through the emotions and reveal the true issue
- Everyone's position must be identified and articulated

• List facts, assumptions and beliefs underlying each position

• Analyze in smaller groups (separate alliances)
- Which facts and assumptions are true? Need more info?
- Helps gain a better understanding and may reveal new ideas
- Remain open and listen, rather than criticize and judge

• Convene back as a team

Step 3: Reach an Agreement

• The team must decide what decision or course of action to take

• Understanding the facts and assumptions makes reaching an agreement easier

• If further analysis and evaluation is required, create a plan:
- Agree on what needs to be done
- By when
- By whom

• Make sure the team is committed to work with the outcome of the analysis or evaluation

5 Conflict Management Styles

Each can be beneficial in different situations

Matching Conflict Styles to Situations

• **Time pressure**: if there was never time pressure, integration (collaboration) might always be the best approach to use

• **Issue importance**: extent to which the conflict involves important priorities, principles or values

• **Relationship importance:** how important is it that you maintain a close, mutually supportive relationship with your team members

• **Relative power**: how much power you have compared to other team members

There Is No One Right Answer…

• But there are better styles to achieve positive conflict outcomes depending on the specific situation and circumstances

• As long as everyone is happy enough and no one is willing to actively resist, then the conflict can be considered resolved

• Following the three-step process and being aware of the different conflict management styles which can be used in different situations will help

Lecture 8

Concept Generation

• This is the creative phase of the design process
-Many ideas and concepts are generated

• It is a divergent phase where many possibilities are considered without judgment

• For a typical design project:
- At least three conceptual design alternatives should be generated
- These concepts should be well documented using sketches and descriptions

• There is no formula or set of rules to generate ideas! Rather, a set of practical strategies to:
- Help designers enhance their inherent creativity
- Facilitate the generation of new ideas

Freehand Sketching

• Ideation – Integral to the design process
- Generation of design concepts to solve the design problem

• Usually, freehand sketching is used to explore, study and communicate these design concepts

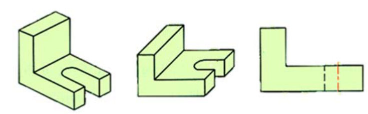
• The "BEST" design engineers can immediately communicate an idea via a freehand sketch

• Simple: all you need is a paper and pencil. Don't use templates and compasses. They will slow you down!

• Although quick, sketches are planned

• Visualize the sketch
- Size of paper & scale
- Orientation of the object
- Minimum detail to communicate the idea

• Type of sketch (listed in the order of image)
- Isometric
- Oblique
- Orthographic

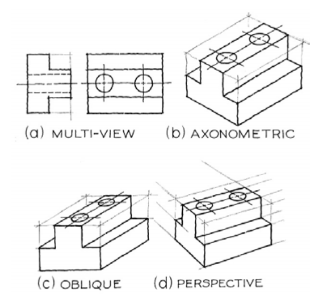


Types of Sketches

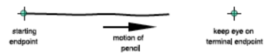
• Multi-View (orthographic)
- Advantage: true faces
-Disadvantage: hard to visualize

• Isometric (a type of axonometric drawing) & Perspective
- Advantage: easy to visualize the object
- Disadvantage: no true face

• Oblique
- Advantage: one true face
- Disadvantage: not "photorealistic"

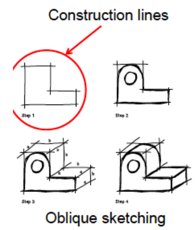


Freehand Sketching
• Fundamental rule of sketching: maintain proportions
• Hint: use standard techniques to draw lines and arcs
• Lines
– Locate a start “dot”
– Locate an end “dot”

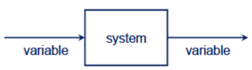


– Put pencil on start dot, keep eyes on end dot and smoothly move pencil toward the end dot (always pull, never push)
• Circles (arcs)
– Draw light horizontal and vertical lines that intersect at the center
– Lightly mark the radius on the lines
– Connect the radius marks with arcs to complete the circle (adapt the natural radius of your wrist and hand)

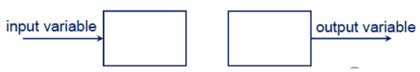
Construction Lines
• Light and thin lines (barely visible)
• Serve as paths for final straight lines
• Intersection of construction lines specify the length of the final lines
• Points marked by the intersection of construction lines serve as guides for sketching of arcs and circles
• Guide the proportions of the sketch



Block Diagrams
System components (software code, electrical systems, etc.) can be represented by “blocks” in block diagrams:

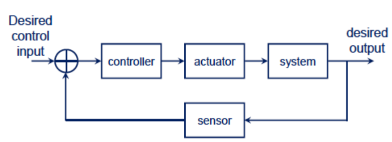


• Many systems are hierarchical (i.e. composed of multiple subsystems)
• Systems must have at least one input variable and at least one output variable



The objectives of a block diagram are:
• To provide an understanding of signal flows in the system (i.e. inputs and outputs of subsystems)
• To enable modelling of complex systems from simple building blocks
• To allow us to generate the overall system transfer function (i.e. how do we get from the input to the output)

General Feedback Control System
• This is a general model and can vary significantly depending on the control system



Generating Ideas – Brainstorming Process
1. Define and agree on the objective
2. Brainstorm ideas and suggestions having agreed on a time limit
3. Categorize/condense/combine/refine
4. Analyze and assess effects or results
5. Prioritize/rank options as appropriate
6. Agree on actions and timescale
7. Control and monitor follow-up

How to Brainstorm Ideas and Suggestions
• Cross stimulation
– Provocation is supplied by the ideas of others, amplifying the number of ideas that will be generated
• Suspended judgment
– No attempt is made at evaluating ideas during brain storming sessions. Avoid remarks such as:
• “that would not work because…”
• “It is well known that…”
• Formality of setting
– The more formal the session, the higher the chance of success
– Having defined roles also helps

Format for Group Brainstorming
• Time: 20 minutes
• The Chairman’s job is to:
– Guide the session without controlling it
– Ensure that only one person speaks at a time
– Stop people who evaluate or criticize the ideas of others
– Define the central problem and keep pulling people back to it
– End the session when time runs out or when people get bored
– Organize the listing and evaluation of ideas
• The Note-taker’s job is to record all the ideas during the session into a permanent list

Example using case study see slides…

Lecture 9

What is a Project?
Project (dictionary definition*): Specific plan or design ("scheme") or a Planned undertaking
• Project (our definition): A series of tasks complex enough to require planning and then also monitoring, once task execution starts
– We define "project management" as the process of doing the planning and monitoring of the tasks for a project (this may or may not be done by the person actually executing those tasks)
• Many projects have significant time constraints
– "time management" is most often used to describe techniques for personal/individual organization, especially when tasks need to be completed which have time constraints

Are you Organized?
1. One set of people tend to be organized and methodical in how they work
– They might find this lecture "interesting, but obvious"
2. Another set of people are more "chaotic"
– They might find this lecture "useless" or view organizational effort as a "waste of time" or as "unnecessary overhead"
– Your work will improve, if you make the effort to build organizational habits into your daily routine. It is worth it! It is. Really.
3. A third set of people might switch between these two behaviour types
– Hopefully, this lecture will help you stay more in category 1

Personal Time Management
• Being organized takes effort
– People have different inherent (or learned!) skill levels!
– Your work quality and quantity will be greater, if you are 'organized'
• Being organized takes time
– While it may seem like no work is being done, the important work will get done first, if you are organized!
• Have a "To Do" list (ideally just one) that lists all of the things that you need to do
– This might be a piece of paper or a file on a computer or phone
– You cross things off the list when they are done or add new items
• Use an agenda or a planner to write down what you have to do (from your "To Do" list) when it must be finished and also an indication of each task's priority/importance

Multi-tasking Wastes Time
• Multi-tasking: Multiple tasks are done in parallel by a single person, who switches between them
– This is how a single-core computer processor works too!
– Switching between jobs incurs context switching overhead (where intermediate results are recorded, ready for next time, when the job is resumed)
• Context-switching wastes time on a computer and wastes time when people do it too
– Multi-tasking gives the illusion that more work is being done! Actually, less work is being done!
– People (and computers!) are more efficient (i.e. they actually get more done in a specific time period) when they do one job at a time

Context-Switching Overhead
• Reduce work 'inbox' count by reducing: the number of different email accounts, the number of social networking applications you scan, the number of devices you check, the number of physical piles of work you make
• Clear your desk and reduce distractions: Throw away material and only keep things, only if you are planning to look at them again
– Clear all unnecessary objects from your desk!
– Work in front of a blank wall
• Focus on one thing at a time
– Having a 'To Do' list helps with this, since this helps avoid wasting time thinking about 'other' things (i.e. brain multi-tasking!)

Working in Teams – Time Management
• Designing or working in a team environment is different from designing or working by yourself
• We have already learned:
– Diverse teams often generate better conceptual designs
– Design teams may have challenges with conflict management
• Time management is important for individuals, but it is even more important when working in a team
– This is because of the dependencies that can exist when tasks are being done by different people
– To see this, we will do a simple word exercise task

Exercise see slides

Tasks and Milestones
• Task: Activity with a duration and an owner (prime) who is responsible for making sure that the task is completed "on time"
• Milestone: A significant event (with a duration of zero) with a date when the deliverable is required/available

Task Duration Estimation
• Time taken for a task depends on a person's
– Level of expertise
– Existing level of work (i.e. how busy they already are!)
– How motivated or interested they are in their assigned task (really good engineers can get something done, whether or not they are interested, but even they will work harder on tasks of interest to them
– Dependencies (on other people or tasks or on specific resources or raw material)
• Estimates for a task will be more accurate, if:
– The task has been done before under similar conditions
– The previous duration is remembered properly (Record such data!)
– The things that went well or badly are also remembered from the previous execution time (or times!)

Task Duration Estimation Problems
• Most people under-estimate the time that is required to complete a task, because they ignore the variability inherent with the duration of any real-world task and assume that everything will go well
– This results in a "best case" schedule
– Competitive industries usually can't tolerate "worst-case" schedules, either, so something in the middle is required

• We should estimate an average value for task duration which is right between one where “it won’t be quicker than this” and one where “it won’t be longer than this” (i.e. “it could be longer, or it could be shorter”)
– This will correspond better to reality, where some parts of a task go more quickly than expected, but others don’t

Planning poker exercise…

Task Assignment Strategies (Task Ownership)
• Tasks may be assigned in different ways, and the choice of who is given a task may be affected by:
– The expertise of the individuals available
– The availability/readiness of the individuals to do more work
– The interests of the individuals
– Dependencies on specific resources or facilities or dependencies on other assigned tasks
• If possible, dependent tasks should be assigned to the same person to minimize or eliminate task dependencies and context switching overhead
– May require tasks to be re-defined into smaller, more manageable sub-tasks

Resources and Risk Contingency Plans
• Finally, once a basic project schedule has been created, it is necessary to analyze the feasibility and accuracy of the schedule
– Note any significant resources that are required (besides people) such as prototyping material or tools that need to be purchased
– May be necessary to order material in advance, if there are significant purchasing or shipping delays associated with items
• Create a RISK list and what happens if those risks prove to be real and a “poor outcome” results
– Quantify the severity of each poor outcome
– Quantify the likelihood of each poor outcome
– Derive mitigating or contingency plans and then related activities to handle poor outcomes that are deemed to be both severe and likely

Summary – Project Planning and Time Management
• Time management takes time but improves work quality and quantity
- Have a “To Do” list and use an agenda (showing prioritized deliverables and the dates that they are required)
- Avoid multi-tasking and the resulting context switching overhead that comes with it
• Projects with any complexity need to be planned
– List all the tasks, durations and their dependencies and assign ‘owners’ for each task to produce a schedule (e.g. a Gantt chart)
– Use tools like Planning Poker to estimate task durations in groups
– Perform a risk analysis and create contingency plans, for any risks that are both significant and reasonably likely

Lecture 10

Engineering Design Analysis
Engineering analysis involves the application of principles and scientific analytical processes to study the properties and state of a system, apparatus or mechanism.
Engineering analysis is done in stages:
1. Separate the system being analyzed into the constituent modules or operational subcomponents
2. Analyze or examine each operational subcomponent
3. Recombine these analyzed subcomponents using basic principles of physics and the laws of nature

Importance of Engineering Analysis
• Engineering analysis is one of the fundamental pillars of our profession
• This analysis is what allows us to guarantee our work
• A good analysis allows us to predict the results of our design and prevent possible system failures

The Engineering Analysis Process
1. Based on the preliminary concepts selected, determine a list of initial components and materials that best meet the target specifications
2. Use the values of the properties of these components and materials to calculate as accurately as possible the specific values of the design based on defined metrics
3. Compare to the target specifications and change your choice of components and materials as necessary
4. Repeat steps 2 and 3 until you are satisfied

How is it done?
• Engineering Analysis uses mathematical calculations, models, simulations and experimental prototyping to ensure that each subsystem meets design specifications
• Don’t forget to use the knowledge that you already have!
• In engineering, always try to use the simplest method first to arrive at a satisfactory result
• If you are missing tools or information, realize this fact (not always easy) and then go and find what you need!
• Don’t be shy about checking or verifying your work with others... Nobody is perfect!

Warning!
• Do not make random choices for components & materials!
Advice:
– Check compatibility between selected components and materials
– Check availability of selected components and materials
• Check if the components and materials you choose are commonly used (otherwise they may be expensive)
• That said, do not be afraid to use new materials and new components if these can be justified (for innovation?) or are necessary to get the job done!

Design Analysis → Skill hill case study

1. List of components and materials
• Start with the preliminary concepts chosen and the target specifications:
– Create a list of components and materials needed for the design concepts
– Make sure that the components and materials can meet the list of metric and non-metric specifications (based on your knowledge and experience)
– If choices conflict with each other, a compromise is required
• In case of compromise, use the design criteria priorities to help choose the most important specifications

2. Calculation based on properties
• Research to find the properties of the components and materials:
– Create a table of properties that will be useful
– Refer to the sources for these properties (in case you need more information)
• Calculate the specification values for your design concepts to allow comparison with the target specifications
– Assume reasonable values if the concept is still not sufficiently well-developed
– Overestimate assumed values, when possible, to provide for a margin of error

3. Compare with target specifications
• Compare the values that you have calculated with the target specifications
• If the calculated values are not within the target specifications, modify your choice of components and materials
4. Repeat steps 2 and 3 as required

Limitations of Analysis
• While you might be able to calculate it, this does not mean it will work ...