**DEN 432**

**S 24**

**Week 4 Exam Notes**

**1/9/24**

**1. Introduction to the Mechanical Design Process**

Key Questions

1. What is the stage-gate design process?

2. What are the phases?

3. What are the gates?

4. What are the stages of the Product Life Cycle?

5. What is the design process?

6. What are the phases of product design?

7. What makes design hard?

8. What is the design process paradox?

9. What are the Hanover Principles.

* The design process is the organization and management of people and the information they develop in the evolution of a product.
* The success of the design process can be measured in the cost of the design effort, the cost of the final product, the quality of the final product, and the time needed to develop the product.
* Cost is committed in the design process, so it is important to pay attention to early phases.
* Cross-functional engineering integrates all the stakeholders from the beginning of the design process and emphasizes both the design of the product and concern for all processes-the design process, the manufacturing process, the assembly process, and the distribution process.
* All products have a life cycle beginning with establishing a need and ending with retirement.
* The mechanical design process is a problem-solving process that transforms an ill-defined problem into a final product. Design problem have more than one satisfactory solution.
* In problem solving there are seven actions to be taken: establish need, plan, understand, evaluate, decide, and communicate.
* As knowledge is gained design freedom is diminished.
* The design process includes project definition, product definition, conceptual design, and product development.
* Design for sustainability is the necessary component of every design process.

**2. Understanding Mechanical Design**

Key Questions

1. Why is it that design costs so little yet have such a big impact on product cost?

2. What can you learn from reversed engineering?

3. Who determines product quality? Should six-sigma always be the key objective?

4. Is the lowest cost always the design requirement? Should it be?

5. Is the quickest time to market always the key objective? Should it be?

6. What is the fuzzy-front end process?

7. What are the challenges associated with the concept of “Crossing the Chasm”?

* A product can be divided into functionally oriented elements. These are made-up of mechanical assemblies, electronic circuits, and computer programs. Mechanical assemblies are built of various components.
* The important form and function aspects of mechanical devices are called features.
* Function and behavior tell what a device does; form describes how it is accomplished.
* Function relates desired behavior.
* One component may play a role in many functions, and a single function may require many different components.
* There are many different types of mechanical design problems: selection, configuration, parametric, original, redesign, routine, and mature.
* Mechanical objects can be described semantically, graphically, analytically, or physically.
* The design process is a continuous constraining of the potential product designs until one product finally evolves. This constraining of the design space is made through repeated comparison with the design requirements.
* Mechanical design is the refinement from abstract representation to a final physical artifact.
* The most valuable information is the decisions that are communicated to others.
* Product decomposition (reversed) engineering is a useful way to understand the structure and the architecture of a product.

**3. Designers and Design Teams**

Key Questions

1. What are the key cognitive characteristics of designers?

2. Can creativity be learned?

3. Are people rational?

4. Who makes better decisions: a team or an individual?

5. Who should lead a design team?

6. Is a process design a problem-design process?

7. Who was Dr. Edward deBono? What is the meaning of concept of lateral thinking?

8. What is the purpose of cross-functional integration?

9. When would you implement each of these team structures: light, medium, heavy, or stealth?

* The human mind uses the long-term memory, the short- term memory, and a controller in the internal environment in problem solving.
* Knowledge can be considered composed of chunks of information that are general, domain-specific, or procedural in content.
* The short-term memory is a small and fast processor. Its properties determine how we solve problems. We use the external environment to augment the size of the short-term memory.
* The long-term memory is the permanent storage facility in the brain. IT is slow to remember, it is fast to recall, and it never gets full.
* Creative designers are people of average intelligence, they are visualizers, hard workers, constructive nonconformists with knowledge about the problem domain. Creativity takes hard work and van be aided by a good environment, practice, and design procedures.
* Because of the size and complexity of most products, design work is usually accomplished by teams rather than individuals.
* Working in teams requires attention to every team member’s problem-solving style-introvert or extrovert, fact or possibility oriented, objective or subjective, decisive or flexible.

**4. The Design Process**

Key Questions

1. What are the phases of the mechanical process design?

2. What is needed for a successful design review?

3. Having a standard design process necessary?

4. Should quality be designed-in or tested out of a product?

5. What is a product definition phase?

6. What is a project definition phase?

7. What is a conceptual design phase?

8. What is a product development phase?

9. What is the product support phase?

* There are specific design process techniques to support the planning, specification development, conceptual design, and product design phases of the design cycle.
* The techniques help to design effort in its earliest stages, where the major decisions are made. Additionally, the techniques encourage communication, force documentation, and encourage data gathering to support creativity.
* Communication is an integral part of the design process.
* The design process consists of a series of decisions.
* The design process focuses effort on early stages, when the major decisions are made, and quality benchmarks are defined.
* The project definition phase of the design process includes activities to discover, choose, and plan design projects.
* The conceptual design phase of the design process focuses on concept generation, evaluation, and decision making.
* The product development phase of the design process includes activities that help refine a concept into a product.
* The product support phase includes activities that occur after the product is in production and includes its support, changes, and retirement.

**5. Project Definition**

Key Questions

1. Does one type of plan fit all design projects?

2.What is a difference between a waterfall and a spiral plan?

3.How can a plan be developed when the future is so uncertain?

4.What are the sources of new concept ideas?

5. What does it mean for product to be mature?

6. What is a decision tree approach to project planning?

7. What is a Gantt chart?

8. What is a PERT chart?

* Planning is an important engineering activity
* Progressive companies have a generic product development process that serves as a basis for planning each product development activity.
* Design projects commonly fall into one of four types: variation of an existing product. Improvement of an existing product, development of a new product for low volume production, and development of new products for high volume production.
* Design teams may have representatives from many different disciplines, and they may be organized in one of five different structures.
* The use of prototypes and models is important to consider during planning.
* There are five planning steps: identify the task, state their objectives, estimate the resources needed, develop a sequence, and estimate costs.
* Design projects originate from market pull, technology push, or product design
* Choosing which projects to undertake is critical to the efficient use of resources.
* The goal is to design a plan to meet the needs of the project.
* There are six basic decision-making activities: clarify the issue, generate alternatives, develop criteria, identify criteria importance, evaluate the value of the alternatives, and decide what to do next.

**6. Product Definition**

Key Questions

1. How can you identify the “customers” for a product?

2. Why is it so important to understand the voice of the customer and work to translate this into engineering specifications?

3. How can you best benchmark the competition to understand design and business opportunities?

4. How can you justify taking time at the beginning of a project to do specification development instead of developing concepts immediately?

* Understanding the design problem is best accomplished through a technique called quality function deployment (QFD). This method transforms consumers requirements into targets for measurable engineering requirements.
* Important information to be developed at the beginning of the problem includes consumers’ requirements, competition benchmarks, and engineering specifications complete with measurable benchmarks.
* Time spent completing the QFD is more than recovered later in the design process.
* There are many customers for most design problems.
* All design problems are poorly defined
* Your decisions, good or bad, affect everyone downstream.

**8. Concept Evaluation and Selection**

Key Questions

1. How can rough conceptual ideas be evaluated without refining them?

2.What is technology readiness?

3. What is the decision matrix?

4. How can I manage risk?

5. How can I make robust decisions?

* The feasibility of a concept is based on the design engineer’s knowledge. Often it is necessary to augment this knowledge with the development of a simple models.
* For the technology to be used in a product, it must be ready. Six measures of technology readiness can be applied.
* Product safety implies concern for injury to humans and for damage to the device itself, other equipment, or the environment.
* Safety can be designed into a product , added on, or warned against. The first of these is best.
* A mishap assessment is easy to accomplish and gives good guidance.
* The decision-matrix method provides means of comparing and evaluating concepts. The comparison is between each concept and a datum relative to the customers’ requirements. The matrix gives insight into strong and weak areas of concepts. The decision-matrix method can be used for subsystems of the original problem.
* An advanced decision matrix method leads to robust decisions by including the effects of uncertainty in the decision-making process.
* Belief maps are simple yet powerful way to evaluate alternatives and work to gain team consensus.

**9. Product Generation**

Key Questions

1. What are the steps to turn an abstract concept into a quality product?

2. What is a BOM?

3. In what order should we consider constraints, configuration, connections, and component during the design of parts and assemblies?

4. How can force flow help in the design of components?

5. Who should make the parts you design?

* A bill of material in a parts list-an index to the product.
* Products must be developed from concepts through concurrent development of form, material, and production methods. This process is driven by the functional decomposition.
* Form is bound by the geometric constraints and defined by the configuration and connected components.
* The development of most components and assemblies starts at their interfaces, or connections, since for the most part functions occur at the interfaces between components.
* Product development is an iterative loop that requires the development of new concepts, the decomposition of the product into subassemblies and components, the refinement of the product toward a final configuration, and the patching of features to help find a good product design.
* Vendor selection in an important part of the design process.

**10. Product Evaluation for Performance and the**

 **Effects of Variation**

Key Questions

1. What is best to evaluate the product performance, analytical models or physical testing?

2. What is a P-diagram and how does it help identify noise?

3. How are trade-offs made?

4. What are the three types of noises and how do they affect product quality?

5. Why is tolerance stacking important during assembly?

6. How is robust design used to ensure quality?

* Product evaluation should be focused on comparison with engineering requirements and also on the evolution of the function of the project.
* Product should be refined to the degree that their performance can be represented as numerical values in order to be compared with engineering requirements.
* P-diagrams are useful for identifying and representing the input signals, control parameters, noises, and output response.
* Physical and analytical models allow for comparison with the engineering requirements.
* Concerns must be shown for both the accuracy and variation of the model.
* Parameters are stochastic, not deterministic. They are subject to three types of noises: the effects of aging, the environment change, and of manufacturing variation.
* Robust design takes noise into account during the determination of the parameters that represent the product. Robust design implies minimization the variation of the critical parameters.
* Tolerance stacking can be evaluated both by the additive method and by statistical means.
* Both analytical and experimental methods exist for finding the most robust design.

**11. Product Evaluation: Design for Cost, Manufacture,**

 **Assembly, and Other Measures**

Key Questions

1. What is the cost (DFC) and how can cost be estimated?

2. How can a product be easy to manufacture (DFM) and assemble (DFA)?

3. How do failure modes and effects analysis (FMEA), fault tree analysis (FTA), and design for reliability (DFR) help eliminate failures?

4. Can products be designed that are easy to test (DFT) and measure (DFM)?

5. What can a designer do to protect the environment through design for sustainability (DFS)?

* Cost estimation is an important part of the product evaluation process.
* Features should be judged on their value-the cost of the function
* Design for manufacture focuses on the production of components
* Design for assembly is a method for evaluating the ease of assembly of a product. It is most useful for high-volume products that have molded components. Thirteen guidelines are given for this evaluation technique. Also, this best practice leads to design for disassembly, a consideration in sustainability.
* Functional development gives insight into potential failure modes. The identification of these modes can lead to design of more reliable and easier-to maintain products.
* Design for sustainability emphasizes concern for energy, pollution, and resource conservation in processing raw materials for products. It also emphasizes concern for recycling, reuse, or disposal of the product after its useful life is over.

**12. Wrapping up the Design Process and Supporting**

 **the Product**

Key Questions

1. What additional documents are needed to launch a product?

2. What is important in supporting of vendor and customer relationship?

3. How are engineering changes managed?

4. How can you apply for a patent?

5. What does it mean to retire a product?

**Course Context:** **Applied Engineering Definitions**

Applied engineering deals with the application of management along with design and technical skills required for designing new products. Integrating systems, execution of new product designs, improving the current manufacturing processes while managing and directing the physical or technical functions of a firm are also encompassed in this field.

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**Applied Engineering Sub Disciplines**

Applied Engineering has been divided into the following:

* Manufacturing execution systems,
* Supply chain management systems,
* Six sigma,
* Lean enterprises,
* Quality control,
* Motorsports management and technology
* Nano engineering technology

**Definitions**

**Optimization** means finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones.

In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense.

Practice of optimization is restricted by the lack of full information, and the lack of time to evaluate what information is available (see bounded reality for details).

In computer simulation (modeling) of business problems, optimization is achieved usually by using linear programming techniques of operations research.

**Design** means realization of a concept or idea into a configuration, drawing, model, mold, pattern, plan or specification (on which the actual or commercial production of an item is based) and which helps achieve the item's designated objective(s).

**Process** is a sequence of interdependent and linked procedures which, at every stage, consume one or more resources (employee time, energy, machines, and money) to convert inputs (data, material, parts, etc.) into outputs. These outputs then serve as inputs for the next stage until a known goal or end result is reached.