# SYLLABUS

03 September 2019

## COURSE DESCRIPTION.

The design of artifacts is addressed from a multidisciplinary perspective that includes engineering, art, psychology, marketing, and economics. Using a decision-making framework, emphasis is placed on understanding basic quantitative methods employed by the different disciplines for making design decisions, and on the interdisciplinary interactions throughout the design development process, Students work in teams to apply the methods on a design project from concept generation to prototyping and design verification. The course is open to all seniors and graduate students (3 or 4 credits).

ME seniors must register for ME455 either to satisfy the ME450 capstone requirement (4 credits) or as an elective (3 credits). All graduates (ME, DESCI, other) must register for DESCI 501 as an elective (3 credits).

## LEARNING OBJECTIVES

- Gain a complete baseline design experience in developing an artifact from the articulation of the social and business needs to an engineered prototype and an associated business plan for realizing the product.
- Learn how to support design decisions through analysis, and to integrate analytical disciplinary knowledge from technical engineering fields with that from physical and cognitive ergonomics, aesthetics, economics, marketing, and business.
- Learn the limits of analysis and how to manage the incompleteness of information, emotionally and practically.
- Learn how to use physical and virtual prototypes to facilitate design thinking and to support design decision making.

## PREREQUISITES

Familiarity with undergraduate math requirements typical in science and engineering programs is expected. ME seniors must satify all ME450 prerequisites and other constraints. Non-ME students must have senior or graduate standing and should consult the instructor to confirm they have a suitable background for the course.

## COURSEWORK

Students work in teams on a design project proposed by the team. Project work includes:

- Definition of design problem. Understanidng of design context Contexts: User, Business, Social, Ecological, Regulatory, Personal Values
- Concept generation. Early prototyping for concept exploration.
- Embodiment design. Development of mathematical models for design decisions from engineering, economic, and marketing, and business perspectives. These will include use of engineering analysis tools and software, Excel-based economic analysis, and conjoint analysis.
- Conduct of scientific surveys to support user preference modeling.

- Functional, physical and virual prototype construction to demonstrate functionality of embodiment design.
- Manufacturing, materials, environmental impact, lifecycle, and financial analysis.
- Value proposition and business plan

In-class quizzes and optional (extra-credit) homeowrk will be assigned to augment the project work. Grading is based on class participation, project team work, individual project work, and quizz/homework. More details are discussed in class.

The amount of work is similar to that required in ME 450. Prototyping work is done earlier in the semester to allow time for redesign.

The class meets TuTh 1:30-3:30 pm in 165 Chrysler for regular lectures. Additional work in shops/labs is expected.

All students must be certified to use the ME shops.

DETAILED TOPICS
The following topics correspond to Modules on the Canvas course site. Some modules will require self-study based on student interest and project relevance.

**1 Designing in the Designed World**

1.1 The Designed World
Personal Values • Team, Business and Social Values • Customer, Subject, User or Fellow Human? • Analysis and Synthesis, Qualitative and Quantitative Thinking • Design Thinking • Design Science

1.2 The Design Process
Design as a Process • Intuitive Process Models • Formal Process Models • Process Models Values and Pitfalls

1.3 The Design Project
Organized Chaos • Checklists • Timelines

1.4 The Design Team
Individuals and Teams • Team Roles • Leadership • Team Decision Making

1.5 Prototyping
Sketching • Alpha, Beta Prototypes • Virtual Prototypes

1.6 Analytical Design: Decision Making
The Decision-Making Paradigm • Optimal Design • Mathematical Optimization • Multicriteria Models • Configuration Design vs. Proportional Design • Hierarchies and Decomposition

**2 Defining the Design Problem**

2.1 Solving the right problem
The Why Cascade • Product, Service, Systems • Design Contexts

2.2 Gathering Information: Checklists
Needs, Wants, and Desires • Context Information Checklists

2.3 Scenarios, Personas, and Storyboards
Personal • Scenarios • Storyboards
2.4 Surveys and Survey Design
2.5 Qualitative Analysis
Methods • Data Format • Analysis: Coding, Validation
2.6 Design Problem Mapping
Attributes • Characteristics • Objectives • Requirements • Measuring Success
2.7 Design Contexts
User Context • Business Context • Social Context • Ecosystem Context • Regulatory Context
2.8 Checking Your Values
Professional Ethics • Codes of Values • Sharing Values

**3 Creating Designs**

3.1 Concept Generation, Prior Art and Patents
Prior Art • Intellectual Property • Patentability • Patent Search
3.2 Creativity, Blockbusting, Ideation
Creativity and Design • Stimulators and Blocks • Perceptual Blocks • Emotional Blocks • Cultural Blocks • Organizational and Situational Blocks • Expressive Blocks • Brainstorming • Morphological Analysis • Synectics
3.3 Design Heuristics
Cognitive Heuristics • Designing with Heuristics
3.4 Function Analysis and Decomposition
Primary and Secondary Functions • Function Structure and Decomposition • Multifunctional Components, Efficiency and Reliability
3.5 Reverse Design
Reverse Analysis • Benchmarking • Finding Gaps
3.6 Quick prototyping
Visual Thinking • Sketching • Digital Prototyping
3.7 Surveys and Conjoint Analysis
3.8 Adaptive Smart Design
3.9 Computational Design
3.10 Concept Selection and Embodiment Design
Mapping Functions to Objects • Concept Demonstration • Path to Realization
3.11 Construction of Alpha Prototype: Concept Demonstration

**4 Designing for Humans**

4.1 Designing for the Human Body and Mind
4.2 Eliciting Preferences
Revealed Preferences • Stated Preferences • Individual and Aggregate Preferences
4.3 Crowdsourcing, Big Data and Collaborative Design
Interactive Design • Crowdsourcing • Big Data • Collaborative Design
4.4 The Physical Human
Ergonomics and Human Factors • Anthropometry: Human Variability
4.5 Cognitive Ergonomics
Cognition • Human-Computer Interaction • Neuroergonomics • Interaction Design

4.6 Emotional and Aesthetic Design
Emotional Processing • Objects as Symbols • Pleasure • Proportionality • Craftsmanship
4.7 Kansei Analysis
4.8 Universal Design
Design for All • Universal Design Principles • Design Standards
4.9 The Human in the System
Unintended Use • Maintenance and Service

**5 Embodiment**
5.1 Embodiment and Detailed Design
Product Realization • Forms and Layouts • Manufacturing and Materials • Evaluation
5.2 Functionality
Analysis and Simulation • Virtual Prototypes • Physical Prototypes
5.3 Analytical Design: Optimization
Mathematical Models • Model Analysis • Optimization Algorithms
5.4 Materials and Manufacturing
Bill of materials • Custom vs. off-the-self parts • Parts and assembly • Production
5.5 Ecological Impact
Quantitative Assessment • Eco-audits • Life Cycle Analysis • Sustainability as an Objective
5.6 Design Failure Modes and Effects Analysis
5.7 Beta Prototype: Functionality Validation

**6 Modeling the Producers**
6.1 From Design to Product
6.2 The Nature of Cost
Cost vs. Benefit • Fixed and Variable Cost • Investment Cost • Cost Modeling • Bill of Materials
6.3 Demand: Classic Microeconomic Model
Linear Demand • Price Sensitivity and Elasticity • Design Sensitivity and Elasticity
6.4 Integration of Design in the Enterprise
Profit as an Objective • Functionality as Constraints • Enterprise Optimization
6.5 Demand: Marketing Models
Conjoint Analysis • Design Part Worths • Heterogeneity
6.6 Producers' Optimization: Refinements
Using Marketing Models for Demand • Market Equilibrium • Government Regulations and Policies
6.7 Non-homogeneous Preference, Market Segmentation, Product Families
Estimate Partworths • Sawtooth Market Simulator

**7 Making Value**
7.1 From Product to Value
Making Value • For Profit or Not
7.2 Investment Economics

Cost Benefit Analysis • Net Present Value Method• Annual Cost Method • Rate of Return Method • Break-Even Point Method• Taxes and Depreciation

7.3 Elements of a Business Plan
Business Opportunity • Product Description • Market Analysis • Capital and Human Resources

7.4 Financial Data
Capital, Labor Equipment and Supply • Investment Analysis • Profit and Loss Statement

7.5 Financial Data: Pro Forma Cash Flow Analysis

**8 Reflection and Practice**

8.1 Prototypes
- 8.1.1 Sketching
  Storyboard • Concept Sketches • Technical Drawings
- 8.1.2 Design Concept: Alpha Prototype
- 8.1.3 Design Functionality: Beta Prototype
- 8.1.4 Embodiment: Beta+ Prototype

8.2 Reports
- 8.2.1 Design Problem Definition
- 8.2.2 Design Concept
- 8.2.3 Design Embodiment
- 8.2.4 Design Technical Report
- 8.2.5 Business Plan
- 8.2.6 Design Journal

8.3 Presentations
- 8.3.1 Design Problem Definition
- 8.3.2 Design Concept
- 8.3.3 Design Embodiment
- 8.3.4 Design Technical Report
- 8.3.5 Business Plan

8.4 Designing in the Designed World: The Team Perspective

8.5 Design Process Model Revisited: The Team Perspective