Summer (1st Session) 2012

AME503: Advanced (Topics in) Mechanical Design
(a.k.a.: Innovative Design Thinking for New Product Developments)

COURSE SYLLABUS

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Course Section: 28880R (on-campus); 29054D (off-campus)

Course Unit: 3 Units

Prerequisite: A graduate student standing in engineering is required.
(or with a special approval by the Instructor)
This is a degree required course for MSPDE (Master of Science in
Product Development Engineering) http://wisdom.usc.edu/mspde

Class Dates and Hours: May 16, 2012 Wednesday - June 26, 2012 Monday
Mondays and Wednesdays, 5:10pm to 8:20pm

Class Location: Room: RTH-115 (Ronald Tutor Hall)

Office Hours: 4:00pm to 5:00pm, on Mondays and Wednesdays (5/16 to 6/26)
• Face-to-face meetings held in 430H, OHE/USC
• Phone meetings via 213-740-9616
• Skype (lu2137409616) and/or WebEx conference meeting
  (Email appointments/confirmations are required for all meetings)

Teaching Assistant: Mr. TBD (TA Office Hours: from TBD pm to TBD pm; on TBD days)
Office: TBD; Email: tbd@usc.edu; phone: 213-740-tbd
Background, Objective, and Goals:

As the competitions for more function, higher quality, lower costs, swift delivery and life-cycle accountability of products and systems intensify rapidly, the industry has reached a strategic inflection point (SIP) where nothing short of fundamental changes will do. To succeed on today’s highly-competitive global technology market, the company must totally revamp the traditional product development processes and systems thinking so that designers can creatively “do-the-right-thing” first, and then effectively “do-the-thing-right”. The overall objective of this graduate-level course is to introduce an “innovative design thinking” (IDT) framework and method which can systematically guide rational and optimal engineering decisions through the functional design (i.e., choose functional requirements based on customer needs), conceptual design (i.e., create design parameters based on functional requirements), and technical design (i.e., determine variable values based on design parameters) phases. The fundamental decision principles, logic foundations, relevant design theories and applicable innovation methods which collectively constitute this innovative design thinking framework will be explained in this course. Real-world examples (and some counter-examples) of using innovative design thinking in various product industries will be included to help the students’ understandings of the basic concepts.

The objective of this course will prepare the students with the necessary foundations and skills to become an innovative design thinker who is able to choose design targets rationally and solve design problems optimally. In a typical undergraduate engineering design curriculum, main focuses are placed on using physics-based engineering knowledge to perform technical analyses to support the evaluations of mechanical components design. Some advanced-level undergraduate courses (such as AME410) briefly discuss design theories and methodologies, with emphases on specific design procedures. These analysis-based design approaches, which are mostly “bottom-up” in nature, and procedural-oriented design processes, which are without deep theoretical understandings, are not sufficient for students to deal with the real-world design tasks when they join the industrial workforce, nor to comprehend the state-of-the-art of engineering design research when they enter the graduate school.

As the first graduate-level engineering design course at the AME department and a program required course of the Master of Science in Product Development Engineering (MSPDE) degree, this course - Advanced Mechanical Design (or more appropriately called: Advanced Topics in Mechanical Systems Design, or Innovative Design Thinking for New Product Developments) bridges the gaps between students’ undergraduate education in engineering components design (i.e., bottom-up and analysis-based) with graduate-level advanced issues in engineering systems design (i.e., top-down, synthesis-based). Following a synthesis-based innovative design thinking framework, the students will learn how to rationally identify break-through design opportunities from market intelligences and then carry out innovative conceptual designs during a new product development process. Equipped with knowledge from AME503, the students should have sufficient backgrounds to utilize proven design theories, methods and techniques developed from recent design researches to enhance their abilities to perform advanced engineering design of technical products, processes, and systems. In short, AME503 is
a transition from the undergraduate-level bottom-up analysis-based components design to the graduate-level top-down synthesis-based systems design.

The specific learning goals of this course include:

1) Understand the innovative design thinking framework, which consists of “do-the-right-thing” rationally and “do-the-thing-right” optimally.
2) Clarify the notions of social and brute realities, the concepts of rationality and optimality, and their different roles in the functional design, conceptual design and technical design phases of product/system developments.
3) Learn the basics of empirical innovation principles, the Axiomatic Design theory, and the TRIZ (Inventive problem-solving method) and how they can be used in a complementary manner to support innovative design thinking.
4) Practice those empirical principles of understanding true customer needs (basic and functional features) and stimulating future customer wants (i.e., excitement features).
5) Practice the Axiomatic Design process and basic design axioms to generate and compare initial design concepts through direct synthesis reasoning (vs. iterative analyses).
6) Practice the usage of TRIZ methods to improve initial design concepts by formulating and resolving various systems and technical contradictions.
7) Put all the innovative design thinking principles and practices together in a big picture of complex engineered systems to highlight the key takeaways of the course.

Scope and Lecture Modules:

This course is composed of the following ten lecture modules:

1. Innovative Design Thinking (IDT) for New Product Development
   - What is innovation?
   - What is design and design thinking?
   - Rationality with social reality and optimality with brute reality in IDT
   - How to apply IDT to develop new products with breakthrough innovation?
2. A Reasoning Structure of IDT (CN --> FR --> DP --> PV)
   - Achieving abstraction via functional thinking in IDT
   - Applying a reasoning structure to abstraction to support IDT
   - The customer (CN), functional (FR), physical (DP) and process (PV) domains in IDT
   - The three design phases from CN, to FR, to DP, to PV
3. The Logic Foundation to Support Systematic Reasoning in IDT
   - The basics of making logic propositions; synthesis reasoning
   - The analytic proposition that leads to part-of (or specified-by) dependencies
• The synthetic proposition that leads to means-of (or realized-by) dependencies
• The abstraction and instantiation operations in IDT
• How to abstract a concept with logic propositions?
• How to instantiate a concept with logic propositions?
• The 2-D zigzagging reasoning process with synthetic and analytic propositions

4. IDT Functional Design (CN --> FR)
• What is functional design and why it is important?
• Discovering hidden market demands (the Kano Customer Satisfaction Model)
• The five steps of functional design
• Using QFD to document customer voices
• The complete, minimal and independent criteria of functional requirements

5. IDT Conceptual Design (FR --> DP) - Step 1: seeding the initial concepts
• What is conceptual design and why it is important?
• What is a design concept (i.e., means to satisfy a functional requirement)?
• Functional requirements vs. design constraints (the constrained-by operations)
• Seeding, categorizing, and ranking multiple design concepts
• A spotlight metaphor for seeding initial design concepts
• Working examples of seeding initial design concepts

6. IDT Conceptual Design (FR --> DP) - Step 2: managing functional dependencies
• Functional vs. physical dependencies
• Systems complexity and functional dependency
• The Independence Axiom of design (i.e., independent FR-DP as the ideal design)
• Categorizing uncoupled, decoupled and coupled design concepts
• Working examples of uncoupled, decoupled and coupled design concepts

7. IDT Conceptual Design (FR --> DP) - Step 3: rank-ordering and choosing design concepts
• Why do we need to rank-order design concepts?
• From implemental uncertainty to information content of design concepts
• Target value, design range, mean value and system range of FR-DP
• The Information Axiom of design (i.e., lowest risk FR-DP as the ideal design)
• The information Axioms, robust design, and six sigma of design concepts
• Working examples of rank-ordering and choosing design concepts

8. IDT Concept Improvement (DP <-- FR) - Modeling dependencies as contradictions
• Two kinds of concept improvement scenarios (coupled FR-DP or more FRs)
• Using an inventive problem solving method (TRIZ) to improve design concepts
• Technical system, design resource, ideal design, design contradiction
• Laws of evolution of technical systems toward the ideality
• The TRIZ problem solving framework (abstraction and instantiation)
• Working examples of TRIZ inventive problem solving

9. IDT Concept Improvement (DP <-- FR) - Step 4: Resolving system contradictions
• Using basic parameters to translate to a standard TRIZ problem
• What are TRIZ invention principles?
• What is a system (or technical) contradiction?
• Converting a "coupled-FR" design concept to a TRIZ system contradiction
• Using TRIZ solution matrix to find standard solutions for system contradictions
• Resolving system contradictions can reduce the coupling of design concepts
• Working examples of resolving system contradictions

10. IDT Concept Improvement (DP <-- FR) - Step 5: Resolving physical contradictions
• What is a physical contradiction?
• Principles of separation in time, space, system, condition, etc.
• Converting a "coupled-DP" design concept to a TRIZ physical contradiction
• Using separation principles to find standard solutions for physical contradictions
• Converting a system (or technical) contradiction to a physical contradiction
• Working examples of resolving physical contradictions

Learning Components:

There are three inter-related learning components in this graduate course:

• Classroom Lectures

Weekly lectures on Tuesday evenings will focus on discussions of advanced subjects in engineering design and product development as listed in the Course Background, Objective and Scope section above. Specific lecture topics can be found in the Course Schedule section of this syllabus. The instructor will develop his own lecture notes in the form of PowerPoint slides, drawn from research papers and reference books. No textbook is required for this course. Additional reading assignments from relevant research papers will be given whenever appropriate. Students are expected to read these assignments as a “preview” for the lectures.

Off-campus (DEN) students are encouraged to watch the live web castings of classroom lectures whenever possible through the DEN webcast systems. Live lectures are always recorded for later reviews by all students. Off-campus students are encouraged to phone in for questions/discussions during the live lecture period, and, if equipped with a desktop web camera, choose to participate in the question/answer with two-way live video via the WebEx system. For technical questions regarding remote lecture/question participations, off-campus students should consult with DEN technical staff directly.
• Paper Studies

Studying the state-of-the-art research papers in the relevant technical fields is an important means of learning in a graduate-level course. Two (2) technical papers, selected from the wide areas of new product development process and/or design theory and methodology, will be assigned to the class. Students are required to study these papers and write summary reports, showing their understanding of the content and its relevance to the course subjects. Students are encouraged to reference those design theories, processes and technologies discussed in classroom lectures. Specific paper handouts and due dates can be found in the Course Schedule of this syllabus. A specific Discussion Board will be created on the course website for each assigned paper study. In addition to paper study reports, all students are encouraged to post their inputs, opinions and suggestions of the paper onto this Discussion Board before and after the due date of the written reports.

Office Hours:

Standard office hours with the Instructor are from 4:00pm to 5:00pm, on Tuesdays. Although on-campus students can come to OHE 430H for face-to-face meetings, all students and teams, whenever possible, are encouraged to experiment with the Skype/WebEx systems with live audio/video supports for office hour meetings. Group meetings using Skype/WebEX with the Instructor during office hours are also possible in the same manner. All meetings must have prior appointments and confirmations via emails.

Reading Materials:

Due to the broad scope and diverse subjects that will be discussed in this graduate-level course, no single book can adequately cover them all. Therefore, no required textbook or case study handbook is assigned. Instead, the following reference books are recommended, and periodic handouts, copied from these references, will be given in the class.

Recommended Reference Books (items 1 and 2 in bold-face are the key references):

1. “Axiomatic Design – Advances and Applications”, by Nam P. Suh, the Oxford University Press.
4. “Complexity: Theory and Applications”, Nam P. Suh, Oxford University Press, USA

The instructor may recommend additional reading materials and website reference resources during the semester whenever appropriately.

**Course Website:**

Students’ learning of this course is supplemented by a specially designed course website on the DEN instruction system (https://www.uscden.net/webapps/login/). All registered students have access to this website (AME503_20122). The course website structure and contents are implemented to support the specific organization of the course instruction as described in this syllabus. All students should browse around the entire site to familiarize themselves with various areas and functions of this course website.

- Announcements -- important announcements of this course (check it frequently)
- Course Information -- syllabus; information about instructor; how to use this website
- Lecture Webcasting -- video files of each lecture
- Lecture Slides -- PowerPoint slides of lecture notes
- Paper Studies -- information about your paper studies
- Design Projects -- information about your team design projects
- Additional Readings -- interesting articles that are related to the course subjects
- Resource Links -- external links to websites that have relevant information to the course
- Communication -- all communication tools, including emails and roster
- Discussion Board -- share your thoughts with the class (NOTE: this is part of your grade)
- Tools -- Digital Drop-box and other useful functions to manage your course work

**Course Grading:**

Students will be graded according to the following grading scheme:

- 50% -- Two paper study reports (25% each)
- 40% -- Final examination (open-book)
- 10% -- Participations in Course Discussion Board

**Grading Components:**

- Paper Study Reports (50%)
Two (2) relevant research papers will be assigned for detail readings and comments. For each assigned paper, students will be asked to write a study report up to 5 pages in length, 12 pt, type, typewritten, double-spaced, with maximum 1” margins.

Students are expected to use and reference as much as possible the materials discussed in classroom lectures in developing these paper study reports. Please avoid repeating the content of the paper. Reports are due at the beginning of the class (see the Course Schedule below). Students can turn in paper study reports one week late for 50% of the credit. No credit will be given afterwards.

**Final Examination (40%)**

Final exam is open-book, limited to the materials that have been discussed in classroom lectures, design team projects, and/or paper studies. Questions are open-ended, but are made brief and point specific as much as possible. They often require only short answers that show your comprehension of concepts, definitions, approaches, and tools covered.

**Discussion Board Participation (10%)**

A Discussion Board thread will be created after each lecture on the DEN course website. Students are asked to participating in this discussion board frequently to share their opinions and thoughts on any subjects relate to the course lectures.

**Course Schedule:**

A tentative course schedule with specific lecture topics and paper study assignments are included below. The Instructor reserves the right to modify this schedule according to the lecture progresses and class needs.

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Lecture: Mondays and Wednesdays (5:10pm–8:20pm)</th>
<th>Paper Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 5/16</td>
<td>Wed</td>
<td>Course Overview, Innovative Design Thinking (IDT) for New Product Development</td>
<td>Paper Study 1 Assign</td>
</tr>
<tr>
<td>2 5/21</td>
<td>Mon</td>
<td>A Reasoning Structure of IDT (CN --&gt; FR --&gt; DP --&gt; PV)</td>
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</tr>
<tr>
<td>3 5/23</td>
<td>Wed</td>
<td>The Logic Foundation to Support Systematic Reasoning in IDT</td>
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<tr>
<td>4 5/28</td>
<td>Mon</td>
<td>Memorial Day (University Holiday - no class)</td>
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<tr>
<td>5 5/30</td>
<td>Wed</td>
<td>IDT Functional Design (CN --&gt; FR)</td>
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</tr>
<tr>
<td>6 6/4</td>
<td>Mon</td>
<td>IDT Conceptual Design (FR --&gt; DP) - Step 1: seeding the initial concepts</td>
<td>Paper Study 1 Due</td>
</tr>
<tr>
<td>7 6/6</td>
<td>Wed</td>
<td>IDT Conceptual Design (FR --&gt; DP) - Step 2: managing functional dependencies</td>
<td>Paper Study 2 Assign</td>
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<tr>
<td>8 6/11</td>
<td>Mon</td>
<td>IDT Conceptual Design (FR --&gt; DP) - Step 3: rank-ordering and choosing concepts</td>
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<tr>
<td>9 6/13</td>
<td>Wed</td>
<td>IDT Concept Improvement (DP ↔ FR) - Modeling dependencies as contradictions</td>
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<td>10 6/18</td>
<td>Mon</td>
<td>IDT Concept Improvement (DP ↔ FR) - Step 4: Resolving system contradictions</td>
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<tr>
<td>11 6/20</td>
<td>Wed</td>
<td>IDT Concept Improvement (DP ↔ FR) - Step 5: Resolving physical contradictions</td>
<td></td>
</tr>
<tr>
<td>12 6/25</td>
<td>Mon</td>
<td>Final Examination (open books and notes)</td>
<td>Paper Study 2 Due</td>
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**Academic Integrity:**

"The Viterbi School of Engineering adheres to the University's policies and procedures governing academic integrity as described in SCampus. Students are expected to be aware of and to observe the academic integrity standards described in SCampus, and to expect those standards to be enforced in this course."

**Students with Disabilities:**

Any Student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m. - 5:00 p.m., Monday through Friday. The phone number for DSP is (213)740-0776.