24-441 Engineering Design II: Conceptualization and Realization
Spring 2016

Class	M&W 2:30 - 4:20 PM DH 2122, F 1:30 – 3:30 PM SH 214 HH-B134 (Prototyping), Machine Shop (Machining)
Instructor	Levent Burak Kara (lkara@cmu.edu) Scaife Hall 411
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Text Books

Required: George E. Dieter, Linda C. Schmidt., *Engineering Design*, 5th Edition (or later), McGraw-Hill. 4th Edition is also fine, but you will have to crosscheck the reading assignments.

Recommended:

- Ullman, D., *The Mechanical Engineering Design Process*, 3rd Edition, McGraw-Hill
- Kevin Otto & Kristin Wood, *Product Design*, Pearson
- Niku, S., *Creative Design of Products and Systems,* Wiley
- Ulrich, K. and S. Eppinger, *Product Design and Development*, 3rd edition, McGraw-Hill,
- Shigley, J. C. Mischke and R. Budynas, *Mechanical Engineering Design*, 7th Edition, McGraw-Hill, 2004
- Cagan and Vogel, *Creating Breakthrough Products*, Financial Times Prentice Hall, 2002
- Haik and Shahin, Engineering Design Process

Resources

The **machine shop** on the Hammerschlag C-level is available to students who have taken the safety course. ***All students are required to pass the course***. The shop contains basic machines, hand tools, a 5-axis CNC machine, 3D printing machines, and some storage. Some materials and components are available for use.

The **tool room** in Hammerschlag B-134 is available to students on a pre-arranged basis and under supervision of the TA. The room is locked and may not be used without a TA present. Students are responsible for cleaning and returning all tools to their proper places after using the room. The room also contains shelving for project storage.

Website

http://blackboard.andrew.cmu.edu

All team and student submissions should be of reasonable size (each file less than 5-10MB each). Tips on reducing file sizes:

- On PPT or Keynote, reduce file size by reducing image size/resolution.
- Use suitably compressed video files (common file formats requested).

Course Objectives:

In this course, students will gain hands-on, practical experience applying engineering principles, theories, thought processes, and problem solving skills to the design and prototyping of a physical product. Students will develop skills for working in teams, working with ***open-ended problems***, identifying needs and opportunities, and making appropriate engineering assumptions. Students are expected to research the topic area, identify opportunities and design criteria, generate creative concepts, synthesize detailed design of a concept, analyze the design and a number of criteria to make improvements and prototype and communicate the final solution.

While most courses in the mechanical engineering curriculum focus on a structured transfer of theoretical knowledge in analysis of mechanical phenomena, this course aims to provide students with a chance to build complimentary knowledge in application and synthesis. Topics covered will include:

- Product development and design process
- Stakeholder research
- Product dissection
- Requirements setting, problem ID.
- Project planning
- Value opportunity analysis (VOA)
- Quality function deployment (QFD) and House of Quality (HoQ)
- Concept generation techniques
- Design selection matrices (Pugh Charts)
- Prototyping
- Functional decomposition
- Failure mode and effects analysis (FMEA)
- Design for manufacturability, assembly, and Environment (DFMAE)
- Life cycle analysis (LCA)
- Economic analysis
- CAD and engineering drawings
- Optimization
- Intellectual property, professionalism, and ethics

Learning Outcomes:

Academic:

- Learn formal product **design process**
- Gain experience in identifying, defining and solving an ***open-ended*** design problem
- Learn how to transform the results of **market and user study** into **engineering requirements**
- Learn and execute **key design steps** including opportunity identification, concept generation and selection, optimization, prototyping, engineering analysis, detailed design and product deployment

- Transform creative ideas into reality and present the result through careful **implementation**, **analysis**, **evaluation**, and **communication**
- Understand and measure the **environmental impacts** of design decisions
- Apply one or more **fundamental engineering principles** to the solution of the design problem
- Learn how to create and communicate **design documentation** in a clear, complete, and professional way

Professional and Social:

- Learn how to work effectively in a team setting
- Learn how to plan, implement, and assess a time-bound professional assignment
- Learn how to manage and resolve conflict of opinions and behavioral differences
- Learn how to plan and manage time
- Gain experience in oral and written communication through in-class presentations and written design reports
- Develop an understanding of personal accountability and reliability in group settings

Who can take this class?

Only students in Senior standing are allowed to enroll in this class.

Meetings:

Each team will meet with the instructor and TAs on a weekly basis. Teams are expected to come prepared to each meeting detailing the work that has been done, questions or difficulties, and what next tasks are planned. **Teams are expected prepare short point presentations (5-page slide)** and bring physical artifacts relevant to their projects to demonstrate their work and receive feedback.

Attendance, Quizzes, Class Work:

Attendance to lectures, team meetings, machine shop meetings and in-class presentations is strongly encouraged. Attendance will be taken during most of the team and machine shop meetings, and will contribute to your final grade.

Several quizzes and class work problems may be administered throughout the semester. Activities will be individual or team-based assignments. **No make-up quizzes or class work will be administered.** The quizzes will typically include questions from your reading assignment and questions specific to your projects. All work will be administered in class. You are welcome to use your textbook and computer during quizzes. Such activities will be announced in advance. Sometimes attendance will count toward a quiz grade.

Grading:

The central goal of this course is to expose students to common design process and analysis tools and give students a guided experience in synthesis and application of analysis to a realistic open-ended problem. As such, grading will be a function of **quality of work, effort, participation, accountability, demonstration, and communication**. Design groups will consist of at most five students. All team

members must be able to justify and articulate their contribution to the project. If your instructor and/or TA feel that your contribution to your group is questionable, then the instructor may administer an oral examination covering questions regarding your project and course material. In such situation, your course grade will be determined directly by the outcome of this exam. Grade distribution is as follows:

Myers Briggs test	0% *(Mandatory)*
Project Proposals v1, v2	0% *(Mandatory)*
Presentation 1	1% *(Attendance is graded only)*
Presentation 2	5% *(1% Attendance, 4% presentation assessment)*
Report 1	10%
Report 2	12.5%
Prototype I and write-up	10%
Prototype II and write-up	12.5%
Final Report	20%
Final Prototype + Design Performance	15%
Quizzes/Classwork, Attendance	5%
Individual student assessment	5%
Submission of peer evaluation	3% *(1% per submission)*
Faculty Course Evaluation	1%
Total	**100%**

Grading Scale:

A
Superior performance. All requirements are met in a timely and thoughtful manner. Creativity and rigor are demonstrated. All communications are clear, with no flaws. Diligence and intellectual effort clearly demonstrated. Solution is exciting and meaningful.

B
Acceptable performance. All requirements are met in a complete and timely manner. All communications are clear with no flaws. However, the work lacks excitement and sufficient justification to indicate potential success. Or, the student did not demonstrate sufficient contribution to project at a superior level.

C
Below average performance. While the requirements may have been met, there is one or more flaws such as technical feasibility and quality; clarity, breadth and depth of solution or process; insufficient assumptions; insufficient phase results; overall completeness. Or, the student did not demonstrate sufficient contribution to project at an acceptable level.

D
Performance well below average. The work is not representative of a Carnegie Mellon Senior Mechanical Engineering student. Inadequate planning, work distribution, and a lack of motivation and commitment will likely result in such outcome.

R
Very poor performance: Student clearly lacked sufficient participation in course, team and/or project to justify graduation and passing course.

Prototyping Budget:

A budget of up to **$750** will be reimbursed to each team for prototyping costs and expenses outside those offered by the machine shop. Valid receipts for each purchase are needed to process reimbursement. Guidelines for submitting your receipts are provided on Blackboard→Course Info.

Purchases: https://www.cmu.edu/me/department/course-purchasing/index.html

Reimbursements: https://www.cmu.edu/me/department/expense-reimbursement/index.html

Students are welcome to use their own funds if they wish to build a more expensive prototype; however, prototype expectations are based on the allocated budget. Carnegie Mellon cannot reimburse tax. If a single item to be purchased is **over $100**, the students may ask Chris to purchase it for them to avoid being charged for tax.

Teamwork and Peer Review:

All team members must have a strong understanding of the process, decisions, and the state of knowledge of the project. On certain days, team members may be selected at random to present the team's recent progress. All team members are responsible for making sure each member is up to date and involved.

Some teams may experience an imbalance in team member contributions, effort, or reliability. The course instructors are available to provide advice and resolve team inequity and conflict. However, students should view this time as a learning experience: Such situations occur regularly in industry as well. Such challenges are opportunities to develop strategies and to identify the best way to address such issues in the future. In addition, one common question asked at job interviews is: *"Describe a time when you experienced difficulties working in a team or experienced a team failure. What did you do about it?"* This is a good chance to build a strong answer to this question.

Several mechanisms will be used for peer review:

- Between teams: Each team will receive feedback from other teams in peer review sessions and/or presentations schedules prior to the date of each report. These sessions will sharpen communication skills, help catch oversights and simple mistakes, and identify possible new ideas or areas for improvement in order to strengthen the project.
- Within teams: Every student is required to turn in peer evaluations with each report for each member of their team (including themselves) **three times** during the semester. These reports are primarily to help the instructors identify difficulties and miscommunications, and they will also be used for grading.

If a student does not contribute to his or her team as evidenced in the peer evaluations, the course instructor may assess the student individually and reserves the right to grade the student based solely on this assessment.

Final Project Exhibition:

We will have a final design exhibition at the end of the semester (see schedule). Faculty, local industry members, and campus and community members will be invited to see student projects. Teams will have tables and poster easels for displaying and communicating their design solutions. All students must attend the exhibition.

Design Notebooks (Optional):

Each student is encouraged to maintain a bound design notebook used exclusively for this class for ideas, sketches, notes, and thoughts. Entries should be dated in order to record the process and provide a support mechanism for a legal (patent) standpoint to protect intellectual property. It will also help teams to compile their reports and explain their process and to write a provisional patent application draft.

Late Policy:

Late assignments will not be accepted.

Design Project Guidelines

Project Overview:

- **Moderate Scope and Complexity:** Each team is welcome to choose a project they like. However, the projects must be appropriately challenging and relevant to be commensurate with your four years of mechanical engineering training. The system should involve a sufficient level of complexity (number of parts, number of functions, geometric constraints etc.) to provide challenges in studying the product and to leave open opportunities for making design improvements. Some students may choose to study a family of products that share components as a way to introduce design complexity.

- **Mechanical System:** The product must involve multiple mechanical components that interact.

- **Moving Parts:** The product must involve moving parts.

- **Portability:** Teams will need to store the product and bring it to campus as needed.

- **Safety:** You will be disassembling and working with the product during the class, so products with compressed gas, explosive or hazardous materials, or other significant safety issues should be avoided.

Final Design Exposition

- Create a poster outlining the study of your product and your proposal for product changes and new product concept
- Bring CAD models fully defining the design and all of its components, including suggested materials and manufacturing processes for each. Clearly identify the advantages of the new design with respect to the old design and justify your recommendation for whether your suggested changes or new design should be implemented
- Bring your final prototype demonstrating your design and how it will function.
- Include final analyses of mechanical aspects of the design as well as analyses such as DFMA, FMEA, DFE etc.
- If appropriate, include a sketch of a provisional patent describing the invention, and identifying novelties that can be taken to patent lawyers for review.

Policy on Video/Audio recording or photographing

No student may record, photograph, or tape any classroom activity without the express written consent of Prof. Kara. If a student believes that he/she is disabled and needs to record or tape classroom activities, the student should contact the Office of Disability Resources to request an appropriate accommodation. In the event that such an accommodation has been arranged, the material may not be further copied, distributed, published, or otherwise used for any other purpose without the express written consent of Prof. Kara. Failure to adhere to this requirement could result in sanctions from Carnegie Mellon.

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		Date	Topics	Reading (Dieter Schmidt)	Student Due Dates	From Teaching Staff
Problem ID	**W1**	**11-Jan** **13-Jan** **15-Jan**	Lecture, Intro, Project ID Lecture, Design Process, Lecture, Machine Shop Tour + Problem defn/requirements Quiz 1	(Ch1,Ch2) (Ch1,Ch2) (Ch3,Ch5)	 Lock teams. MBP test.	Project proposal form v1, MBP test.
	W2	**18-Jan** **20-Jan** **22-Jan**	*No class – MLK day* Team meetings- A [Proposal meetings] Team meetings- B [Proposal meetings]		Project proposal v1	Project proposal form v2
	W3	**25-Jan** **27-Jan** **29-Jan**	Team meetings- A [Proposal meetings] Team meetings- B [Proposal meetings] (Kara@MechE Sem.)		Project proposal v2	Project proposal form v2, Q1 ret. Pres.1 guidelines & review criteria.
Concept Generation & Evaluation & VMM	**W4**	**1- Feb** **3- Feb** **5- Feb**	Lecture, Concept Gener&Eval, Functional representation Team meetings- A Team meetings- B	(Ch6,Ch7)		Report 1 guidelines.
	W5	**8- Feb** **10- Feb** **12- Feb**	Lecture, Prototyping + Arduino presentation Presentation 1 – A groups: Problem ID. Presentation 1 – B groups: Problem ID.	(Ch8)	Peer eval.-1. Presentation 1 Presentation 1	 Q2 ret.
	W6	**15- Feb** **17- Feb** **19- Feb**	Dr. Seth Orsborn Guest Lecture on Design Team meetings- A: Team feedback + next steps Team meetings- B: Team feedback + next steps			Q3 ret. Prsnt. 1 feedback. Invite Red Team.
Physical Prototyping & Evaluation	**W7**	**22- Feb** **24- Feb** **26- Feb**	Lecture, Optimization Machine Shop Machine Shop	(Ch15)	 Report 1 (Sunday Feb 28)	PT1 guidelines. Q4 ret. Invite Red Team. Report 1 feedback.
	W8	**29- Feb** **2- Mar** **4- Mar**	Machine Shop Machine Shop – PT1 Review [Red Team] *No class – Spring break*		PT1 rev. PT-1 write-up.	Q5 ret. Pres.2 guidelines/review criteria.
	W9	**7- Mar** **9- Mar** **11- Mar**	*No class – Spring break* *No class – Spring break* *No class – Spring break*			
Analysis & Detail Engineering	**W10**	**14- Mar** **16- Mar** **18- Mar**	Lecture, Engineering Analysis, Embodiment and Detail design Team meetings- A Team meetings- B	(Ch8,Ch9)	 Peer eval.-2. due	Week 11 prep. PT 1 feedback.
	W11	**21- Mar** **23- Mar** **25- Mar**	Lecture, FMEA Present. 2 – A groups: Concept Gen + VMM + PT1 + Engr. Analysis Present. 2 – B groups: Concept Gen + VMM + PT1 + Engr. Analysis	(Ch14)	 Presentation 2 Presentation 2	Report 2 guidelines.
Manufacturing & Evaluation	**W12**	**28- Mar** **30- Mar** **1- Apr**	Lecture, QFD + HoQ Team meetings- A / Machine Shop Team meetings- B / Machine Shop	(Ch3)		Presen. 2 feedback. PT2 guidelines & review criteria.
	W13	**4- Apr** **6- Apr** **8- Apr**	Lecture, DFMA + Tolerancing + Quiz9 Machine Shop Machine Shop	(Ch13)		 Invite Red Team. Report 2 feedback.
	W14	**11- Apr** **13- Apr** **15- Apr**	Machine Shop HH B134 – PT2 Review [Red Team] *No class: Spring Carnival*		PT2 rev. PT-2 write-up, Report 2 due	
	W15	**18- Apr** **20- Apr** **22- Apr**	Lecture, Material Selection + Cost Analysis + Quiz10 Life Cycle Analysis + Quiz11 Machine Shop	(Ch12,Ch16,Ch17)		Final report guidelines. PT 2 feedback.
	W16	**25- Apr** **27- Apr** **29- Apr**	Lecture, Ethics, Intellectual Property, Conclusions Machine Shop Machine Shop	(Ch18,Ch5)	 Final posters due electronically	
	Fin1	**2- May** **4- May** **6- May**	**Final Design Expo. UC, Rangos 1&2 10:00AM – 2:00PM**		 Peer eval.-3 Final Report	

*VMM: Virtual Mock Model. This is a detailed soft (CAD) model demonstrating:

(1) Major functional parts,

(2) Their assembly,

(3) Kinematics/Dynamics of the design.

All assignment deadlines are due 11:59pm of the indicated date.

Reimbursement forms can be found under BB > Course Info