Spring 2024

AME409: Senior Design Project

Department of Aerospace & Mechanical Engineering

University of Southern California

COURSE SYLLABUS

Instructor: Dr. Yan Jin

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Course Section:	28807D
Course Unit:	4 Units
Prerequisite:	Senior Standing
Class Hours:	Wednesdays 3:30 p.m. – 7:20 p.m.
Class Location:	GFS-118
Office Hours:	Wednesdays 11:00 a.m. – 12:30 p.m. or by appointment
Teaching Assistant:	TBD

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Course Description

In this senior design course, we embark on a journey into the development of innovative vehicles and alternative energy systems, all within the backdrop of escalating energy costs and the growing call for environmentally responsible engineering practices. Aspiring designers, equipped with advanced technical skills, will explore the engineering of integrating and optimizing various subsystems, all working harmoniously to create a highly efficient whole. They will grapple with fundamental relationships for crucial parameters such as weight, strength, power, and performance, which are often more abstract and less precisely defined compared to the concepts learned in other engineering classes. Rather than the reductionist approaches seen in specialized fields, this course champions an integrative, holistic method for conceiving complete systems.

The course is structured around a combination of lectures that cover the core elements of modern technology and interactive workshops. In these workshops, students collaborate in small groups to craft initial designs for their chosen vehicle system. To conclude their journey, students are tasked with delivering a complete design report and a formal presentation to the class, sharing their insights and discoveries from the design process.

Course Objectives

This class sets forth the following objectives for students:

- Embrace and apply an iterative, integrative, and holistic design process.
- Innovatively solve complex design challenges.
- Grasp the fundamental relationships governing vehicle weight, power, strength, and performance.
- Cultivate effective teamwork skills and collaborate seamlessly as team members.
- Clearly define requirements or a mission statement, and craft a design that aligns with these specifications.
- Explore diverse approaches to mitigate or eliminate vehicle emissions.
- Analyze power requirements and devise power systems that cater to both power and emission requirements.
- Calculate energy demands and specify the key components of the vehicle.

- Master vehicle steering dynamics and engineer a steering mechanism that meets performance expectations.
- Comprehend vehicle rolling dynamics and design a suspension system that aligns with performance goals.
- Recognize the significance of ergonomics in engineering design and address ergonomic considerations within the design project.

Prerequisite

Senior standing.

Course Structure

This course encompasses five key components, including an introduction to engineering design, analysis and design of vehicle power systems, energy system design, automotive steering and suspension design, and the art of packaging design and ergonomics. To enhance the effectiveness and efficiency of the learning process, we've structured the course into the following modules.

Module 1: Introduction to Engineering Design

The primary objective of this module is to provide a foundational understanding of essential concepts and methodologies in engineering design, encompassing form, function, behavior, and the design processes. Topics covered in this module include:

- Definition and scope of engineering design
- Engineering design processes
- Different phases of engineering design

Module 2: Vehicle Power System Analysis and Preliminary Design

Within the realm of vehicle design, the power system plays a pivotal role. This module commences with the identification of customer needs and progresses to explore power requirements and the formulation of innovative solutions. Topics covered in this module include:

- Automotive design process
- Customer identification and style design
- Automotive aerodynamics and power required estimate
- Hybrid power systems & electric power systems

- Power available curve and power system design

Module 3: Energy System Analysis and Preliminary Design

Ensuring an adequate operational range for a vehicle necessitates a reliable source of energy. Building upon the foundations laid in power system design, this module delves into a comprehensive examination of diverse driving scenarios and explores strategies for supplying energy to the vehicle system. Topics covered in this module include:

- Driving mission scenario analysis
- Energy required estimate
- Energy system design and layout
- Ways to improve energy efficiency through alternative powertrains

Module 4: Automotive Steering and Suspension Dynamics and Design

Complementing the considerations of power and energy systems discussed previously, this module acquaints students with fundamental concepts and analytical techniques related to automotive steering and suspension dynamics. It further delves into the methodology for defining key parameters of steering and suspension systems. Topics covered in this module include:

- Introduction of beam theory
- Automotive chassis systems
- Steering system dynamics and design
- Suspension system dynamics and design

Module 5: Packaging Design and Ergonomics

The art of packaging design is pivotal, as it directly impacts the comfort and experience of the driver and passengers inside the vehicle. This module explores the intricate world of packaging design and offers valuable insights into seat layout and sightline design to enhance user comfort and satisfaction. Topics covered in this module include:

- Introduction to packing design and ergonomic issues
- Driver and passenger seats design
- Estimate of visual sightlines of the driver
- Weight schedule and vehicle cost estimate

Course Work

This course entails a weekly commitment of four hours, wherein 1 to 2 hours are dedicated to lectures, and the remaining time is devoted to hands-on workshop sessions where students collaborate in groups. The course curriculum strikes a balance between two crucial facets: a focused study on general methods of engineering design and problem-solving, nurturing innovation, and fostering creativity, and the practical development of a preliminary design for an innovative vehicle.

Lectures:

Lectures are scheduled for 1 to 2 hours each week. During these sessions, the instructor will comprehensively cover the foundations of engineering design and the fundamentals of automotive engineering and vehicle design, aligning with the course structure outlined earlier. Active participation of all students in these lectures is imperative and highly encouraged.

Workshop:

Our workshop sessions, spanning 2 to 3 hours each week and following the lectures, provide a dedicated space for students to engage in their weekly assignments. Students will assemble into groups of 4-6 individuals, fostering collaboration and collective problem-solving during these sessions. In the initial half of the semester, students will tackle individual assignments and work on individual midterm reports, leveraging the power of group discussions for support and insight. Following the spring break, the focus shifts to group work, with students collaborating to complete group assignments and deliver the final project report and presentation as a unified team.

Work Assignment:

Throughout the semester, students will be given weekly work assignments. Each assignment will encompass 2-5 analysis and/or design tasks, strategically crafted to aid students in (1) assimilating the knowledge gleaned from lectures and (2) advancing in the design process of their selected vehicle.

Midterm Report:

Beginning in the third week, students will embark on their individual vehicle design journey, centered around the theme of a hybrid PZEV (Partial Zero Emissions Vehicle) for the Los Angeles basin, featuring alternative low-emission power systems to enhance range. Just prior to the spring break, students will submit their Midterm Report, titled "Performance and Energy System Report," which serves as a comprehensive documentation of their individual vehicle design. This report should encompass a detailed description of style

design, power, and energy system design for a specific vehicle with an advanced and hybrid powertrain. Evaluation will focus on the report's thoroughness, accuracy, and the innovative merits of the vehicle design presented.

Team Project:

In the post-spring break phase, teams comprising 4 to 6 members will start to work together, each team directed towards crafting a design tailored to their chosen specifications. The design topic aligns with the individual vehicle design theme. The team project commences immediately after the spring break with an initial systems analysis. Subsequently, following reviews, revisions, and approvals, the teams will advance to complete the Preliminary Design of their designated vehicle. This culminates in the production of a formal engineering report titled "Final Project Report," encompassing the comprehensive journey from identifying customers in Module 2 to detailing weight schedules and cost estimates in Module 5.

Course Materials

Course materials will be provided online on the course blackboard.

Grading Requirements

Student performance will be assessed based on the following grading scheme:

Work Assignment: 35%

A total of thirteen (13) homework assignments will contribute to 35% of the final grade. Each work assignment encompasses 2-5 analysis and/or design tasks, and students are strongly encouraged to tackle these assignments during workshop sessions.

Midterm Report: 35%

The Midterm Report is a formal engineering design document detailing each student's individual design project. It is due on the Friday preceding the spring break week. Evaluation will focus on the report's thoroughness, accuracy, and the innovative merits of the vehicle design presented.

Team project: 30%

It's important to note that 30% of your semester grade is contingent on the outcomes of your term design project, which is a collaborative effort within your team. The project work completed by the team will initially receive a collective team grade. This team grade is then adjusted for each student based on the student’s contribution to the teamwork assessed by the instructor with the information of confidential peer evaluations conducted by all team members at the end of the semester.

Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. SCampus, the Student Guidebook, (www.usc.edu/scampus or http://scampus.usc.edu) contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A. Academic integrity will be strongly enforced.

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Section 11, Behavior Violating University Standards https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriatesanctions/. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the Office of Equity and Diversity http://equity.usc.edu/ or to the Department of Public Safety http://capsnet.usc.edu/department/department-publicsafety/online-forms/contact-us. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report or can initiate the report on behalf of another person. *The Relationship and Sexual Violence Prevention & Services* https://studenthealth.usc.edu/rsvp/ provides 24/7 confidential support, and the sexual assault resource center webpage https://sarc.usc.edu/reporting-options/ describes reporting options and other resources.

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 the instructor 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. Website and contact information for DSP: http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD), (213) 740-8216 (FAX), ability@usc.edu.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, *USC Emergency Information* http://emergency.usc.edu/ will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology..

Course Schedule

WK	Date	Lecture	Workshop	Work Due
1	1/10	• Course Introduction	WA#1: Explore Automobiles	.
2	1/17	• Automotive Design Process & 3-V Drawing	WA#2: 3-V Drawing	Exploration Report
3	1/24	• Powertrain Systems and Hybrid Vehicles	WA#3: Hybrid Power-train Configuration	3-V Drawing
4	1/31	• Power Required	WA#4: Power Required Curve	Hybrid Powertrain Configuration
5	2/7	• Maximum Power & Power Split	WA#5: Power Split	Power Required Curve
6	2/14	• Transmission Design & Power Available	WA#6: Power Available Curve	Power Split
7	2/21	• Energy Required & Mission Design	WA#7: Energy Required	Power Available Curve
8	2/28	• Energy System Layout • More on Motors	WA#8: Energy System Layout	Energy Required
9	3/6	• Energy System Recap • More on Batteries	Q & A's	Energy System Study Report (Fri)
10	3/13	Spring Break: No class		
11	3/20	• Auto Chassis & Project Planning	WA#9: Project Planning	
12	3/27	• Steering Dynamics	WA#10: Ackerman Angle	Project plan
13	4/3	• Steering Geometry Design	WA#11: Steering Geometry Design	Ackerman Angle
14	4/10	• Suspension Geometry Design	WA#12: Suspension Geometry Design	Steering Geometry Design
15	4/17	• Ergonomics & Weight Schedule	WA#13: Ergo Design	Suspension Design
16	4/24	Project Briefing		
17	5/3	Final design report (PDF file) due 11:59pm		