ME 312

Analysis and Synthesis of Mechanisms

Fall 2024

Course Information

Time:	Monday 3:40 pm – 5:30 pm and Thursday 1:40 pm – 2:30 pm
Location:	FENS G029 and FENS L056
Recitation	Thursday 2:40 pm – 4:30 pm FENS L056
Credit:	3 credit hours

Instructor

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Resources

Web Site:	Available through SUCourse+. Please check regularly for announcements and updates.
Recommended Reading:	Rao, *Dynamics of Particles and Rigid Bodies: A Systematic Approach*, Cambridge University Press, Reissue Edition, 2011.
Reference Books:	Kane and Levinson, *Dynamics: Theory and Applications*, `https://ecommons.cornell.edu/bitstream/1813/638/10/Dynamics-Theory_opt.pdf`, 1985. Norton, *Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines*, Third Edition, McGraw-Hill Higher Education, 2003. Wilson and Sadler, *Kinematics and Dynamics of Machinery*, Third Edition in SI Units, Prentice Hall, 2003.

Prerequisites

Students are expected to have a working knowledge of differential equations and linear systems. Familiarity with statics, kinematic and dynamics is expected. Programming skills, especially familiarity with Matlab, is a plus.

Purpose

This course is designed to equip students with fundamental theories and methodologies that are used in kinematic analysis, dynamic analysis, and synthesis of mechanisms commonly encountered in machine design. Students will learn analytical and computational techniques for displacement, velocity, and acceleration analyses of mechanisms, as well as methods for force analysis using static and dynamic approaches. Kinematics (and time permitting dynamics) of gear trains, screw mechanisms, and belt/chain drive mechanisms will be discussed. Students will be introduced to the mechanism design process. Synthesis of mechanisms for the generation of a prescribed path and motion will be covered. Throughout the course, vector-based approaches will be emphasized. Analytical and computational methods for mechanism synthesis will also be exercised.

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Course Objectives

The goal of this course is to introduce juniors and seniors to basic methods in the synthesis, kinematic, and dynamic analysis of mechanisms commonly encountered in machine design. By the end of the course, each student should be able to do the following:

1. Demonstrate an understanding of fundamental concepts in mechanisms (linkages, cams, gears, etc.).

2. Identify basic types of mechanisms, joints, and motion.

3. Determine degree of freedom (mobility) of mechanisms and equivalent linkages.

4. Perform position, velocity, and acceleration analyses of rigid body systems using analytical and computational methods.

5. Perform force analysis of linkages using static (and dynamic) methods.

6. Describe the mechanism design process.

7. Synthesize mechanisms for prescribed path and motion generation using analytical and computational methods.

8. Analyze (and design) gear trains, cam-followers, belt and chain drives, and screw mechanisms.

Homework Sets

Homework sets will be assigned regularly and posted on the course website.

Exams

There will be one midterm exam and one final exam. Since the course continually builds upon previous material, all exams will be comprehensive. All exams are closed book and closed notes. A cheat sheet containing relevant formulas is provided.

Take-Home Exam/Project

Students will be assigned a take-home exam, also called a term project.

Lecture

The lecture format will be loose. There may be a short break during the two hour lecture period. Extra lectures and problem solving sessions may be scheduled when necessary. Class participation and cooperation among students are highly encouraged. Student feedback will be collected throughout the semester and adaptation will be undertaken accordingly.

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Grading Policy

Your course grade is determined from the total points you receive from attendance, homework, midterm, take-home exam, and the final exam. Borderline grades are determined by class participation.

Homework sets must be submitted to SUCourse+ by the deadline. **No late problem sets will be accepted.** (Extensions may be granted for special circumstances and only when requested **at least one day in advance**.)

You are responsible for all information given in class verbally and/or in writing. Any information about the course on the web may be replaced by the information announced in the class.

Cooperative efforts at understanding the material and the assignments of the course are encouraged. You may also use the assignments of the previous years as exercised. However, you may only submit work that **you** have completed **individually**. For example, you may communicate verbally about methods for solving the assigned problems, but sharing of written work is not permitted. Copying solutions from the assignments of the previous years is also **strictly forbidden**. Submitting any work that is not the result of a student's own effort (including AI generated solutions) is considered cheating and will result in **disciplinary action**.

Homework:	20%
Midterm Exam:	25%
Take-home Exam/Project:	22%
Final Exam:	30%
Attendance:	3%
	100%

Other Notes

Any student with a disability requiring accommodation in this course is encouraged to contact the instructor during the first two weeks of the semester.

Additional Reading

- Myszka, *Machines and Mechanisms: Applied Kinematic Analysis*, Second Edition, Prentice-Hall, 2002.

- Hartenberg, *Kinematic Synthesis of Linkages*, 1964. Available online at:
  http://kinematic.library.cornell.edu:8190/toc_hartenberg1.html

- Mallik, Ghosh, and Dittrich, *Kinematic Analysis and Synthesis of Mechanisms*,CRC, 1994.

- Eckhardt, *Kinematic Design of Machines and Mechanisms*, McGraw-Hill Professional, 1998.

- Lopez-Gomez, *Spatial Mechanisms: Analysis and Synthesis*, Narosa, 2001.

- Uicker, Pennock, and Shigley, *Theory of Machines and Mechanisms*, Third Edition, Oxford University Press, 2003.

Tentative Schedule and Topics

Week 1 – 4	*Fundamentals* Vector Algebra Reference Frames and Rotations in Space Angular Velocity Vector Calculus Nomenclature on Machines and Mechanisms Kinematic Diagrams and Kinematic Inversion Degrees of Freedom/Mobility and Grashoff Criteria
Weeks 5 and 6	*Displacement and Velocity Analyses* Displacement Analysis: Analytical Methods Displacement Analysis: Computational Methods Velocity Analysis: Analytical Methods Kinematic Analysis of Gear Mechanisms
Week 7	*Acceleration Analysis* Acceleration Analysis: Analytical Methods Coriolis Acceleration Equivalent Linkages
Weeks 8 and 9	*Force Analysis* Static Force Analysis of Mechanisms Mass Moment of Inertia, Center of Gravity Inertia Forces and Torques in Linkages Dynamic Force Analysis
Weeks 10 and 11	*3D Dynamics* Free Body Diagrams Newton-Euler Equations of Motion Dynamic Simulation of Mechanisms
Weeks 12 – 14	*Kinematic Synthesis* Mechanism Design Process Type Synthesis Number Synthesis Dimensional Synthesis Synthesis for Function Generation Synthesis for Prescribed Path and Motion Generation