ME460: Kinematic Analysis and Synthesis

Fall 2013: Monday, Wednesday, and Friday 9:30-10:20am, MEB103

Instructor: Dr. Katherine Steele **Office:** MEB323 **Office Hours:** M/W 10:30am–12:00pm
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TA: Sam Wallen **Office Hours:** T/R 2:30 – 4:30pm in MEB236
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Website: Lectures, homeworks, and announcements on Canvas
Text: Kinematic, Dynamics, and Design of Machinery (2^{nd} Edition)
K.J. Waldron and G.L. Kinzel, John Wiley and Sons, Inc., 2004
Required materials: ruler, compass, protractor, drafting triangle, graph paper

Course Description:

This course will introduce students to the concepts of kinematics, kinematic analysis (including position, velocity, and acceleration), and linkage design (for two and three position motion, path and function generation). Students will learn to use both graphical and computer techniques for analysis and synthesis of kinematic systems. *Prerequisites:* mechanical engineering senior, courses in statics and dynamics, or permission of instructor.

Course Objective:

At the end of this course the student should be able to:

1. Model real mechanisms for mobility, position, velocity, and acceleration
   - -Given a realistic drawing or photograph of a linkage, determine the kinematic structure.
   - -Given a schematic model of a linkage, calculate the mobility of the mechanism.
   - -Given a scaled drawing of a planar linkage with revolute and prismatic joints, calculate the position, velocity, and acceleration of any point on the linkage.
   - -Given a scaled drawing of a planar linkage with lower and higher pairs, calculate the position and velocity of any point on the linkage.
2. Design linkages for rigid-body guidance, rocker amplitude, path generation, and function generation
   - -Given a schematic drawing of three positions of a rigid body, design both a four-bar linkage and a slider crank mechanism that will guide the body through the three positions.
   - -Given a time ratio and rocker angle, design a four-bar linkage to operate as a crank-rocker.
   - -Given access to coupler curve plots, design a six-link mechanism for a prescribed motion of the output link as a function of the motion of the input crank.
   - -Given an arbitrary function, design a four-bar or slider crank linkage that will approximate it.
3. Analyze and design cam/follower mechanisms
   - -Given the follower displacement as a function of the cam rotation, design a cam mechanism for either translating or oscillation followers.
   - -Given the locations of dwells in the displacement function, design a follower displacement profile for specified values of the derivatives.ss
4. Use both graphical and analytical approaches to mechanism analysis
   - -Given a scaled drawing of a planar mechanism with revolute and prismatic joints, construct vector polygons representing the position, velocity, and acceleration of any point in the linkage.
   - -Given a scaled drawing of a planar linkage with lower and higher pairs, construct vector polygons representing the position and velocity of any point in the linkage.
   - -Given a dimensioned, schematic drawing of a planar linkage, draw a vector loop and analyze the mechanism for position, velocity, and acceleration using vector component equations.
   - -Given a scaled drawing of a planar linkage, locate the instant centers of velocity and use them to find the velocity of any point in the mechanism.

Grading & Structure:

20% Homework

Homework will be assigned on a weekly basis. **Homework is due by the beginning of the class period indicated on the schedule**. Homework will not be accepted late except under extreme circumstances at the discretion of the instructor. Students are encouraged to work together on homework assignments; however, every student must individually submit homework consisting of his/her own work. Submitting homework that is copied in any portion from another source, including another student's work, constitutes academic misconduct. All assigned problems will be graded as 0, 1, or 2 depending on the completeness and correction of the solution. Your lowest homework grade will be dropped if you turn in all assignments by the end of the quarter. Regrade requests must be submitted to the instructor within 2 business days from when the homework is returned and be accompanied by a paragraph description of why the request is being submitted and highlight supporting evidence.

Homework Guidelines:

1. The first page must have your name, due date, and assignment number at the top. It may also include worked problems. No title page is required.
2. Equations must be supplemented with enough text to explain the solution procedure, and symbols used in the equations must be defined. Never include only a numerical calculation without the algebraic form of the equation listed first.
3. **Identify the final answer(s) with a surrounding box.**
4. For any graph or drawing, identify the scales and units used. If any measurements are made from graphs or drawings, the corresponding entities must be shown explicitly. All straight lines must be drawn with a straight edge and all circles with a compass or template.
5. It is the student's responsibility to turn in an assignment that is clear and legible. *Difficulty in following and/or reading the work will result in a reduced grade*. Make good use of "white space" in the assignment.
6. A reduction in the grade will be made for each of the above steps not followed.

20% Final Project & Presentation

This project has essentially one goal: to get you to apply kinematic design principles to the design of a useful object. Your task is to build a small functional prototype that will use at least one four bar linkage and solve a useful task. You will work in teams of 2-3 students. See "Final Project Handout" for complete details.

30% Midterm Exam

30% Final Exam

Both the midterm and final exams will be closed book. You will be allowed one 8.5 inch by 11 inch or smaller piece of paper containing equations written in your own hand on one side of the page. The page of equations must be submitted with your exam. Students who miss an exam due to documented illness or family emergency will take a make-up for full credit as soon as possible after original exam date. Exams missed for other reasons will be allowed to take a make-up at the discretion of the instructor, but the credit received will not exceed 70% of the graded exam score.

Schedule:

Day	Date	Topic	Text Sections	Homework	Project
Introduction to Kinematic Analysis					
Wed	9/25	Introduction	1.1-1.3		
Fri	9/27	Joints and planar linkages	1.4-1.6		
Mon	9/30	Mobility and idle degrees of freedom	1.7-1.8		
Wed	10/2	Inversion and Grashof criterion	1.9-1.10		
Fri	10/4	Motion limits and interference	1.11-1.19	HW 1 Due	Team/Project
Design for Motion and Function Generation					
Mon	10/7	Design for motion generation	6.1-6.2		
Wed	10/9	(continued)	6.3		
Fri	10/11	(continued)	6.3	HW 2 Due	
Mon	10/14	Design for function generation	6.4		
Wed	10/16	Design for rocker amplitude	6.5		
Fri	10/18	Cognate linkages	6.6	HW 3 Due	
Cam Design and Analysis					
Mon	10/21	Cam design and motion programs	8.1-8.4		
Wed	10/23	(continued)	8.5-8.9		
Fri	10/25	Graphical and analytical cam methods	8.10	HW 4 Due	Proposal Due
MIDTERM EXAM					
Mon	10/28	Midterm Review			
Wed	10/30	**Midterm Exam**			
Fri	11/1	Project peer reviews			Peer Review
Graphical Kinematic Analysis					
Mon	11/4	Analytical four-bar analysis	5.1-5.4		
Wed	11/6	Analytical slider-crank analysis	5.5-5.6		
Fri	11/8	Vector loop method of analysis	5.7-5.13	HW 5 Due	
Mon	11/11	**Veteran's Day – No Class**			
Polygon Analysis					
Wed	11/13	Velocity and acceleration polygons	2.1-2.4		
Fri	11/15	Polygon examples and image theorems	2.5-2.9	HW 6 Due	Progress Due
Linkage Theory					
Mon	11/18	General velocity/acceleration equations	3.1-3.4		
Wed	11/20	Spatial applications of general equations	3.5-3.8		
Instant Centers of Velocity					
Fri	11/22	Instant centers	4.1-4.14	HW 7 Due	
Mon	11/25	Static force analysis of mechanisms	13.1-13.10		
Wed	11/27	**Thanksgiving – Open Office Hours**			
Fri	11/29	**Thanksgiving**			
FINAL PROJECTS & EXAM					
Mon	12/2	Project presentations		HW 8 Due	
Wed	12/4	Project presentations			
Fri	12/6	Final Review			Final Project
Wed	**12/11**	**Final Exam – 8:30am–10:20am, MEB103**			