ME 451
Kinematics and Dynamics of Machine Systems
Fall 2011

Time: 11:00 – 12:15 PM Tu & Th
Room: 1152ME
Instructor: Dan Negrut
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Phone: 608 890 0914
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Course Page: learnuw.wisc.edu (for grades), and www.sbel.wisc.edu/Courses/ME451/2011/index.htm
Graders: Toby Heyn (heyn@wisc.edu)
Office Hours: Monday, 2 – 3:30 PM
Wednesday, 2 – 3:30 PM
Other times by appointment (please call or email to arrange)

Text: The books below have been placed on reserve at Wendt library in conjunction with this course[1]. The first book will be the one that comes closest to the material covered in the class. The author provided a pdf of the entire book and gave me permission to distribute it for free.

1. Computer-Aided Kinematics and Dynamics of Mechanical Systems, Volume I: Basic Methods, by Edward J. Haug, Allyn and Bacon, 1989
2. Dynamics of Multibody Systems, by Ahmed A. Shabana, 3rd ed., 2007
3. Scientific Computing, An Introductory Survey, by Michael T. Heath, 2nd ed., 2002

Prerequisites: ME 240 or equivalent, MATLAB programming

Recommended Supplemental Text: *MATLAB & Simulink Student Version Release R2011a*
Available for purchase at bookstore and at www.mathworks.com/academia/student_version/index.html
MATLAB is available through CAE.

Course Objectives: This course reviews and reinforces the student's understanding of Kinematics and the Dynamics of multibody systems with immediate application to the study of mechanisms and machines. All aspects of multi-body kinematics and dynamics are covered making the course good as a Senior elective course or as a graduate level review for the PhD qualifying exam. This course assumes knowledge of elementary vector algebra and the concepts of time and partial derivatives. An elementary Physics course covering Newton's laws or course(s) on Statics and Dynamics will prove very helpful in understanding the material covered in ME451. More precisely, the course reviews these topics and then applies them to more complex problems. The course will place equal emphasis on gaining both an analytical understanding and insight/intuition on the subject. The material presented in the class will emphasize the analytical component of the subject, while the homework, particularly through the MATLAB coding and ADAMS modeling assignments, will encourage you to see beyond equations and abstract constructs. It is also anticipated that this course will significantly improve your MATLAB programming skills and help you learn how to model/simulate/analyze mechanical systems in ADAMS, the most widely used mechanical system simulation software package. Note that this course requires a good deal of MATLAB programming.

[1] See http://madcat.library.wisc.edu/cgi-bin/Pwebrecon.cgi?DB=local&CRSE=%283510%29&INST=%284035%29&CNT=25+records+per+page

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Course Grading

Grades will be based on your performance on written homework, two midterm exams, and one final exam. All homework and exam scores will be maintained on the Learn@UW course website. This will allow you to monitor your performance and also see aggregate scores for the rest of the class, which should give you a continuous idea of your performance. Should you have questions about your score, please contact the instructor. Specific score-related questions about homework and exams must be raised prior to the next class period after receiving the score. If homework that is turned in does not appear to be graded (missing) on the Learn@UW course website please point that out to me within one week after the return of the corresponding set of graded homework.

Percentage participation to the final grade shall be distributed in the following manner:

Homework	=	**40%**
Exam I	=	**15%**
Exam II	=	**15%**
Final Exam	=	**20%**
Final Project	=	**10%**

The PowerPoint notes used in class, handwritten notes, and examples covered in class will be made available on the course web-site at www.sbel.wisc.edu/Courses/ME451/2011/index.htm. Solutions to homework problems will be posted at learnuw.wisc.edu.

Homework & Project: Problems will be assigned regularly during the semester. All assigned homework will be collected at the beginning of class on the date due. No late homework will be accepted. Homework solutions should be *neat and well organized*. All necessary diagrams and calculations must be clearly shown. Homework solutions will be made available. The homework with the lowest score will be dropped when computing the final homework average. There will be one Final Project, which can be an ADAMS project or a MATLAB simulation engine. You will get to choose the topic of the project that you work on after the topic gets ok'ed by the instructor.

Exams: Exams will include short-answer questions and problems, and may include both take-home and in-class portions. In-class portions will be given during the lecture sessions shown on the schedule. Take-home problems, if any, will be more involved and may require the use of computational tools (MATLAB and/or ADAMS). The best way to prepare for exams is to participate in class, learn the fundamental concepts, and redo homework and example problems. The first exam will be given on November 3. The second exam will be given on December 1 (date might change to December 8 due to conference travel). Reviews will be held for each of these two exams, the day before the exam, starting at 7:15 PM in room 1152ME. The ME451 final exam will be a comprehensive exam, scheduled for Saturday, December 17 at 2:45PM.

Disability requests: I must hear from anyone who has a disability that may require some modification of seating, testing or other class requirements so that appropriate arrangements may be made. Please see me after class or during my office hours.

Complaints: If you have a complaint regarding the course and if you are unsatisfied with the response of the instructor, then you should contact the Chair of the Department of Mechanical Engineering. The Chair's office is in 3065 Mechanical Engineering Building, and an appointment to see the Chair can be made by contacting the Department Office at 263-5372.

Letter Grades: Final letter grades will be based on the total score accumulated on homework and exams throughout the semester using the following scale:

Score	Grade
≥94	A
87-93	AB
80-86	B
73-79	BC
66-72	C
55-65	D
Below 55	F

ME 451[2]: Kinematics and Dynamics of Machine Systems

Fall 2011

(**SUBJECT TO CHANGE; CHECK CLASS WEBISTE FOR UP-TO-DATE VERSION**)

Date	Topic	Details regarding learning objectives	HW
09/06	Scope of Kinematics and Dynamics Analysis Overview of Existing Methodologies	Understanding the scope of the course. Understanding the goals of the course.	
09/08	Matrix Algebra	Concept of geometric vector Concept of algebraic vector and reference frame Matrices and matrix-vector operations Transformation of coordinates	2.2.5, 2.2.8, 2.2.10 h1_sep08
09/13	Vector Calculus	Review of Concepts of Calculus Vector and matrix differentiation Chain Rule of differentiation	
09/15	Matrix Notation Vector Partial Derivatives Chain Rule of Differentiation		Problem assigned in class, MATLAB, h2_sep15
09/20	MATLAB Tutorial	2261EH Toby Heyn	
09/22	ADAMS Tutorial General Overview	2261EH Justin Madsen	2.4.4, 2.5.1, 2.5.2, 2.5.3 2.5.7, MATLAB, ADAMS3 h3_sep22
09/27	Basic Concepts of Planar Kinematics	Velocity and acceleration of a point fixed in a moving reference frame Absolute vs. Relative Generalized Coordinates Kinematic constraints Degrees of Freedom	
09/29	Absolute Kinematic	Kinematic constraints involving one body:	2.6.1, 3.1.1, 3.1.2,

[2] **Tentative schedule**; changes will occur during the semester. Document will be updated to reflect these changes.

	Constraints	position and angular constraints	3.1.3, MATLAB, ADAMS[3] h4_sep29
10/04	Basic Relative Kinematic Constraints	Kinematic constraints involving pairs of bodies	
10/06	Relative Kinematic Constraints (Cntd.)	Kinematic constraints involving pairs of bodies: distance constraint, revolute joint, translational joint	3.3.2, 3.3.4, 3.3.5, MATLAB, ADAMS3 h5_oct6
10/11	Composite joints Cam-Follower Constraints Point-Curve Constraints	Absolute driving constraints Relative driving constraints	
10/13	Driving Constraints	Excavator example. Implicit Function Theorem	3.4.7, 3.4.8, 3.4.9, ADAMS3, MATLAB h6_oct13
10/18	Position, Velocity, and Acceleration Analysis	Formulating and solving the kinematic problem. Wrecker Boom Example	
10/20	Post-Processing Tutorial. Visualizing the motion of a mechanism	Hammad Mazhar	3.5.1, 3.5.4, 3.5.5, 3.5.6, MATLAB, ADAMS3 h7_oct20
10/25	Elements of the Solution of Kinematic Analysis of Mechanisms	Newton-Raphson method	
10/27	Singular configurations in mechanisms. Dynamics of Planar Systems; The principle of Virtual Work	Variational approach to deriving the equations of motion (EOM) for one planar body	Draft Final Project Proposal Due MATLAB ADAMS3 h8_oct27
11/01	Dynamics of Planar Systems; The principle of Virtual Work	Variational approach to deriving the equations of motion (EOM) for one planar body	
11/03	MIDTERM EXAM 1[4]		Take-home part of Exam 1 assigned
11/08	Equations of Motion for a Planar Body	Equations of Motion for a body with centroidal reference frame Inertia properties for composite bodies Parallel axis theorem	Final Project Proposal Due
11/10	Virtual Work and Generalized Forces Equations of Motion for Systems of Coupled Rigid Bodies	Definition of Virtual Work Computing generalized forces for translational and rotational force elements Understand how to generate the set of constrained equations of motion that govern the time evolution of a mechanical system	
11/15	simEngine2D discussion	Toby Heyn lectures	
11/17	Wrap up Equations of Motion for Systems of Coupled Rigid Bodies Initial Conditions for Dynamics Analysis Computation of Reaction Forces	Introduce the concept of Lagrange Multiplier and Constraint Force	6.1.1 thru 6.1.4, 6.2.1 and MATLAB assignment h09_nov17

[3] Emailed to you.
[4] Review session will be held on Monday, 11/02/2011 at 6:00 PM. Room 1153ME.

11/22	Numerical Integration Methods for First Order IVP	Understand how to solve an Initial Value Problem using Forward and Backward Euler Methods	6.3.3, 6.4.1 and MATLAB assignment h10_nov22
11/24	THANKSGIVING	RECESS	
11/29	Numerical Integration Methods for second order IVPs and DAEs	Learn about Newmark's method for handling second order differential equations. Learn how to solve the index 3 Differential Algebraic Equations (DAEs) of multibody dynamics.	MATLAB assignment h11_nov29
12/01	Numerical Integration Methods for DAEs **MIDTERM EXAM 2**	Learn how to solve the index 3 Differential Algebraic Equations (DAEs) of multibody dynamics. Discuss Quasi-Newton Method **MIDTERM EXAM 2**[5]	Take Home Exam Component Assigned[6] (available online)
12/06	Wrap up Numerical Integration of DAEs. Equilibrium Analysis and Inverse Dynamics Analysis	Understand the numerical formulation of the equilibrium problem. Learn how to compute the set of forces/torques that are required to obtain a prescribed motion of the mechanical system.	
12/08	No lecture	Make-up Lecture was on 12/01	
12/13		Final Project Related	
12/15		Final Project Related	

Final Exam: Saturday, December 17, 2:45 PM. Room: 1255ME

[5] A review will be held at 5 PM in 1152ME. The exam starts at 7:15 PM and runs two hours long.

[6] Due date: December 13, at 11:59 PM