

**COMMONWEALTH GRADUATE ENGINEERING PROGRAM
DISTANCE LEARNING COURSE PLANNING SHEET
UNIVERSITY OF VIRGINIA**

Course: **MAE 625- MULTIBODY MECHANICAL SYSTEMS**
Semester: **SPRING-2008**
Instructor: **P. N. SHETH**
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Textbook(s): (Student to purchase)

- (1) Uicker, J. J., and P. N. Sheth, 2007, Matrix Methods for Design Analysis of Multibody Systems, Manuscript of a Textbook which will be made available to the students through the University of Virginia Bookstore beginning in early January, 2008, at a nominal cost.

Additional supplementary materials including (i) relevant Journal articles, and (ii) MATLAB code for general purpose functions in Multibody Applications will be available for downloading from the Course website.

Reference(s): Limit 4

Although a number of textbooks on Multibody Mechanical Systems are available that provide complementary material to the material presented in this course, no specific References on Library Reserve are required for this course. Some material, such as Journal articles which reinforce the course material will be distributed in the class or placed on the website. Students are expected to have a general familiarity with MATLAB programming and the students may wish to develop this familiarity by independently reviewing any of the available references on MATLAB.

Computer Needs: Students will need to write simple programs for course problems. These programs may be most conveniently written in MATLAB. Students will also be provided with some pre-written MATLAB functions and code for further use in their homework problems. The rich libraries of functions for numerical, graphical, and symbolic computations in MATLAB make it a convenient and expeditious tool for the students to learn in its own right.

Computer Capability: **Standard WINDOWS based PC running MATLAB**

Software required: **MATLAB**

Provided? It is requested that the sites make the arrangement to install MATLAB on their computers. Students may also wish to purchase a Student Version of MATLAB for their own PCs.

MAE 625
MULTIBODY MECHANICAL SYSTEMS

CATALOG DESCRIPTION

Analytical and computational treatment for modeling and simulation of 3-Dimensional multibody mechanical systems. Provide a systematic and consistent basis for analyzing the interactions between motion constraints, kinematics, static, dynamic, and control behavior of multibody mechanical systems. Applications to machinery, vehicle systems, robotic devices and mobile robots, biomechanical models for gait analysis and human motions, and motion control. Matrix modeling procedures with symbolic and numerical computational tools will be utilized for demonstrating the methods developed in this course. Focus on the current research and computational tools and examine a broad spectrum of physical systems where multibody behavior is fundamental to their design and control.

COURSE DESCRIPTION

Multibody mechanical systems have a pervasive presence in real or virtual mechanisms, linkages, machinery, robotic and other automated machines and vehicles, on and off road vehicles, appliances, aerospace systems, biomechanical models of musculo-skeletal systems including gait and athletic activity models, rehabilitation aids and assistive devices, models of occupant dynamics in vehicular crash or other events, deployable/morphing structures including tensegrity systems and kinetic structures, and many other devices and systems. Powerful and general-purpose analytical and computational tools have evolved for analyzing the spatial motions, forces, and dynamics of these systems. Control and dynamic aspects for the design of real-time controllers for these systems are evolving into a unified analytical treatment. The matrix modeling procedures and the associated symbolic/numerical computational schemes provide a generic platform for analyzing these systems. This course focuses on the analytical methods that are fundamental to the modeling and analysis of these systems. The power of general-purpose higher level languages such as MATLAB provides significant opportunities for applying these analytical foundations to complex systems. The students may optionally utilize a programming language such as C, FORTRAN, or VISUAL BASIC to complete some homework problems, although the pre-packaged code will be provided in MATLAB scripts in m files.

Commercial CAE tools such as ADAMS, DADS, IMP, MADYMO, VISUAL NASTRAN and others have some variants of these methods embedded in software. The relationship of the fundamental analytical formulations presented in this course and the commercial software packages will be reviewed.

PREREQUISITES

Engineering, Mathematics, or a Science degree; familiarity with linear algebra and dynamics typically covered in an undergraduate engineering or physics curriculum, and an interest in computational problem solutions.

STUDENT POPULATION

This is a 3 credit, graduate level course. The following types of students may benefit from this course.

- Graduate students in Mechanical and Aerospace Engineering with interest in dynamics and control, robotics, spacecraft and other aerospace vehicles and deployable systems, machinery systems, on and off road vehicle systems, and occupant dynamics and injury models in accident scenarios.
- Biomechanical students interested in computer models of musculo-skeletal systems, gait analysis, or athletic activity models.
- Electrical engineering students interested in robotics and automation.
- Computer Science students interested in animation and visualization of dynamic systems.
- Students from the School of Architecture interested in kinetic structures.

SYLLABUS

- (1) Overview of Multibody systems and their kinematics, static, dynamic, and control behavior. Planar and spatial systems.**
- (2) Topological models and network analysis of mechanical networks. Definition of constraints, holonomic and nonholonomic constraints, open loop tree structures, unrooted (free flying) mechanical systems; links, joints, springs, dampers, forces, and torques in the analytical framework.**
- (3) Symbolic modeling of multibody systems with Denavit-Hartenberg (D-H) and extended S-U notations; (4x4) matrix transformations for modeling links and joints; curves and surfaces in contact; applications to geared systems and mobile robots.**
- (4) Modeling of 3D motions; Euler parameters.**
- (5) Modeling of system constraints. Jacobian matrix of a multibody system. Computational analysis of the Jacobian matrix rank and singular value decomposition. Identification of degrees of freedom and generalized coordinates of multibody systems from numerical analysis of Jacobian matrix. Singularities in multibody systems. Serial and parallel robots; Stewart platforms. Vehicle suspensions.**
- (6) Forward and inverse kinematic analysis of 3D multibody systems. Position configurations, velocities, and accelerations.**
- (7) Static equilibrium configurations of multibody systems.**
- (8) Nonlinear dynamic models of multibody systems. Numerical integration solutions. Linearized solutions for vibratory behavior and frequency response. Static and dynamic forces/moments through constraints. Forward and inverse dynamic analysis of multibody systems. Control of these systems.**

INSTRUCTOR

Dr. Pradip N. Sheth is an Associate Professor of Mechanical Engineering at the University of Virginia. At the University of Virginia, Dr. Sheth has taught graduate courses on Manufacturing Systems, Manufacturing Automation Technologies, Manufacturing Processes and Materials, Mechanical Design, and Dynamics/Control of Multibody Systems. At the undergraduate level, Dr. Sheth teaches courses on Engineering Design, Dynamics, Control Systems engineering, and Mechatronics. Dr. Sheth's research at the University of Virginia focuses on control of motions as applied to flexible automation of products and manufacturing tools, multibody mechanical systems for machinery, robots, biomechanical devices, and vehicles. Current research in these areas include (i) the development of a smart walker for the elderly, and a smart ankle brace for children with cerebral palsy, (ii) the development of tools for rotating machinery dynamics and control, and (iii) optimization of multibody systems, including applications of Mechatronics.

Prior to joining the University of Virginia in December 1985, Dr. Sheth worked in industry for about 14 years. Dr. Sheth's industrial experience includes work at Allis-Chalmers Corporation and Ford Motor Company in design and manufacturing with emphasis on CAD/CAM/CAE techniques and automation.

Dr. Sheth received his M.S. and Ph.D. in Mechanical Engineering from the University of Wisconsin-Madison. Dr. Sheth is co-developer with Dr. John Uicker of the University of Wisconsin-Madison of a widely used Computer Aided Engineering software tool called IMP for multibody systems including mechanisms and linkages. He holds a patent on a vibration absorber device for vertical pumps. Another patent on an integrated system for maintenance and inspection of highway high-mast light poles has been licensed by the University of Virginia Patent Foundation to a company in Ohio for product development and marketing the technology. A patent on an intelligent walker for the elderly has been licensed by another company for further development of a marketable product in the eldercare market.