Syllabus for MEE 725 (Advanced Engg Dynamics):

Books (optional): *Classical Mechanics*, by H. Goldstein; *Mechanics and Symmetry (2003, Springer)* by Marsden and Ratiu; *Nonholonomic Mechanics and Control (2003, Springer),* by A. M. Bloch et al.; *Geometric Control of Mechanical Systems (2004, Springer),* by F. Bullo and A. Lewis.
Prerequisites: none stated in the SU catalog (realistically, undergraduate dynamics or equivalent expected)
Course content on Blackboard: Blackboard@SU

Course Contents and Teaching Philosophy

This course will be research-oriented, and it will be taught accordingly. The topics MAY NOT be followed in the sequence listed in the catalog description. Introduction to generalized coordinates and generalized forces will begin with introduction to the concept of a configuration manifold of a mechanical system. Some necessary concepts from modern (differential) geometry, like coordinate charts and vector fields, will be introduced. Variational mechanics formulations leading to the Euler-Lagrange equations and Hamilton's equations will be covered, with particular examples from mechanics, like linear mechanical systems and continuum mechanics. Particular stress will be laid on mechanical systems in the framework of geometric mechanics, with an introduction to the configuration manifold, velocity phase space (tangent bundle) and momentum phase space (cotangent bundle) of mechanical systems. The Euler-Poincaré and Lie-Poisson equations for rigid body rotational and translational motion will be introduced in this framework. If time permits, the dynamics of multi-body systems as connections of rigid bodies, will be introduced. Reading and written assignments on topics covered in class will be given. A mid-term exam (take home) will be given during the middle of the semester. A final term paper on dynamics analysis of a nonlinear mechanical system of the individual's choice is required for final grade. This individual term paper has to be presented in front of the class during the last week of classes.

Schedule

Week 1: Newton's laws and equations of motion of a particle, equations of the classical two-body problem, introduction to configuration space of mechanical systems (week of Jan 16)
Week 2: Configuration manifold, coordinate charts and generalized coordinates, introduction to variational mechanics, **reading assignment 1**
Weeks 3-4: Variational mechanics, generalized forces, principle of least action, the Lagrange-d'Alembert principle, Euler-Lagrange equations, Hamilton's equations for conservative systems, **written assignment 1**
Week 5: Linear mechanical systems, the (dynamic) Euler-Bernoulli beam equation, introduction to geometric mechanics (week of Feb 16)
Week 6: Velocity phase space as tangent bundle of configuration manifold, kinetic energy understood as a metric on the configuration manifold, Christoffel symbols, the

Euler-Lagrange equation expressed in terms of coordinates on the tangent bundle, **reading assignment 2**
Week 7: Euler-Lagrange equation in the presence of conservative and non-conservative generalized forces, momentum phase space as cotangent bundle of configuration manifold, Hamilton's equations in terms of coordinates on the cotangent bundle
Week 8: Hamilton's equations in the presence of conservative and non-conservative forces; **Midterm Exam** (take-home, given Tuesday, March 6; due Thursday, March 8)
Week 9: **Spring Break** (March 11-18)
Week 10: Introduction to the Lie group of rigid body rotations, rigid body rotational kinematics, generalized coordinate and unit quaternion representations of rigid body attitude, **reading assignment 3**
Weeks 11-12: Comparisons between different coordinate representations and the group representation of attitude, Euler's equation for rotational motion derived in the framework of geometric mechanics, conservation of spatial angular momentum in the absence of torques, Euler's equation for rotational motion in the presence of torques, **written assignment 2**
Week 13: Euler's equation represented on the cotangent bundle of the Lie group of rigid body rotations, introduction to the Lie group of rigid body rotational and translational motions (week of April 12)
Week 14: The Euler-Poincaré equation on the Lie group of rigid body motions, without and with external forces and torques, Euler's equation for rotational motion as a special case of the Euler-Poincaré equation, **reading assignment 4**
Week 15: The Lie-Poisson equation on the Lie group of rigid body motions, without and with external forces and torques, introduction to multi-body systems (if time permits)
Final Project Presentations: May 3 and/or May 4.

Additional Reference Material

The material covered in class will not be drawn from any single book; however, material covered in the lectures will be self-contained and adequate to handle the exam, reading and written assignments, and project in the course. Besides the books listed, other textbooks on advanced dynamics may be useful as references.