AME 453: ENGINEERING DYNAMICS

Fall 2011

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Course Description: This course focuses on *classical dynamics*, that is, the study of motion of interacting bodies. The topics to be covered range from the motion of a single particle to systems of particles and rigid bodies with particular emphasis on rotations in three-dimensional space.

Pre-requisites: Dynamics AME 301 and basic knowledge of ordinary differential equations.

List of topics: The following is a tentative outline of the topics to be covered.

1. **Newtonian Dynamics of a single particle** (∼2 weeks)
   - Inertial frames. Kinematics of a particle. Cartesian and curvilinear coordinates systems.
   - Integrable and non-integrable constraints. Constraint forces.
   - Balance laws. Work and power.
   - Conservative forces. Energy conservation. Momentum conservation.
   - Motion in rotating frames. Foucault pendulum.
2. **Introduction to dynamical systems techniques** (∼2 weeks)
   - Phase space of 1 degree of freedom (d.o.f.) linear systems.
   - Phase portrait for conservative and dissipative 1 d.o.f. linear systems.
   - Equilibrium points. Stability of equilibrium points.
   - Phase portrait of non-linear 1 d.o.f. systems. Linear and nonlinear stability.
3. **Newtonian Dynamics of systems of particles** (∼1.5 weeks)
   - Internal forces. Balance laws.
   - Central forces. 2-body and 3-body problems.
4. **Lagrangian Mechanics** (∼2.5 weeks)
   - Lagrange's equations of motion.
   - Generalized coordinates. Generalized momenta. Generalized forces.
   - Conserved quantities. Ignorable coordinates and symmetries. Noether theorem.
   - Small oscillations of multi-degree of freedom systems. Stability of equilibria of multi-degree of freedom systems
5. **Rigid Body Motion** (∼4-5 weeks)
   - Rotation matrices, Euler and Rodrigues representations of rotation matrices
   - Kinematics of a rigid body: angular velocity and acceleration, corotational basis
   - Moment of Inertia matrix. Angular momentum. Rotational Kinetic Energy
   - Eulers equations of motion and their stability. Poinsot Construction.

These ideas will be illustrated through examples such as the motion of planar, spherical and double pendula, particles on rotating surfaces, rolling and sliding disks and spheres, heavy tops, gyroscopes, etc.

References: I will mostly follow the book on Mechanics by Laudau L.D. and Lifshitz E.M. I'll provide you with my set of notes. It is also useful to consult web resources and the following classic texts (some cover more material than we do in this class so don't be alarmed):

- Your textbook for AME 301
- Hand L. & Finch J., Analytical Mechanics
- Goldstein H., Poole C. & Safko J., Classical Mechanics
- Ginsberg, J.H., Advanced Engineering Dynamics
- Arnold, V.I., Mathematical methods of classical mechanics
- Lecture notes of Prof. David Tong of the University of Cambridge: `http://www.damtp.cam.ac.uk/user/tong/dynamics.html`
- Lecture notes of Prof. Masahiro Morii of Harvard University: `http://www.hepl.harvard.edu/~morii/phys151/lectures/`

Homework assignments: There will be weekly homework sets assigned every Wednesday and due the following Wednesday. The purpose of the problem assignments is to help you understand the material and communicate your knowledge in writing. It is not necessary that you type your solution but write it in a neat and legible way.

Class projects: In addition to the weekly homework sets, I would like to assign one to two "open-ended" projects that require you to model, simulate, and analyze a system of particles or rigid bodies using the techniques we developed in class. The projects will be chosen as the semester progresses and will involve that you work together in teams. A 1-2 pages (double spaced, 12pt font, 1 inch margins) description of your results should be submitted for each project. Your main findings and computer animations will be discussed and shown in class.

Office hours: TBA

Grading: Grades will be based on the following categories:

Categories	Weight
Homework assignments	25%
Projects	15%
Class Participation	10%
Mid-term Exam	20%
Final Exam	30%