MECH 425: Analytical Methods in Dynamics and Vibrations
Spring 2021

Instructor: Subhrajit Bhattacharya (sub216)

Course Information and Policies:

Lectures and Meetings:
Video Lectures: Posted on course-site before Zoom meetings.
Zoom meetings: Mon & Wed, 12:10pm - 1:25pm

Texts / Reading Materials:
The class lectures and the notes that you take from the lectures will constitute the primary reading and reference materials for this course. We will follow a specific order for the topics, will approach certain topics in specific ways, and will use Matlab/Mathematica for solving problems – many of which can be best (and possibly solely) understood by following the class lectures closely.

The following books (any edition should be fine) will however serve as reference texts for this class:
1. "Analytical Dynamics" by Haim Baruh, WCB/McGraw-Hill.
2. "Advanced Engineering Dynamics" by J.H. Ginsberg, Cambridge University Press.
3. "Classical Mechanics" by Herbert Goldstein, Charles P. Poole Jr., John L. Safko, Pearson.

Out of the above, #1 (book by Baruh) is the preferred reference for problems/applications. However, if you are unable to get a copy of that book, #2 (book by Ginsberg) is a reasonable alternative. #3 (book by Goldstein) is an excellent reference text with in-depth discussions on many of the topics that we will cover in this class.

Software and Programming Languages:
In this course we'll use MATLAB (alternatively, Octave) and Mathematica. Both are available for your use through Lehigh University's LTS: https://software.lehigh.edu/install/ . While I will run a few simple in-class tutorials on these software, if you have never used either of these before, it is expected that you'll self-teach yourself the basics of these tools.

Grading Policy:
- There will be weekly homeworks assigned, which you will not need to turn in and on which you'll not be graded. It is however important that you practice the problems assigned in the homeworks in order to properly learn the class material and be able to do well in the projects and the exams (many of the project/exam problems will be based on the homework problems).
- There will be a **mini-project assigned every two to three weeks**, which you'll need to turn in through course-site. The projects will contain one or two problems that you will have about two weeks to work on. The projects will be worth **40%** of the total course credit.
- There will be one **midterm exam**, which will be worth **25%** of the total course credit.

- The **final exam** will be worth **25%** of total course credit.
- The remaining 10% of the total course credit will be on class participation.

IMPORTANT: All submissions that you make to the instructor for grading (projects or take-home exams) should be your own individual work. It will be a violation of the university's academic integrity vignettes and the course policy to collaborate on or discuss solutions to such assignments with your classmates. You are however allowed to discuss the weekly homeworks (for which no submission is necessary) with your classmates.

Academic Integrity:
Students are expected to be familiar with all the academic integrity principles of Lehigh University. Please visit the Academic Integrity Resources page for details: https://citl.lehigh.edu/academic-integrity-resources

Accommodations:

- Reasonable accommodation will be provided for students observing religious holidays, as outlined in the university's religious holiday policy: http://chaplain.lehigh.edu/node/6 . Please inform the instructor of your absence during religious holiday as early as possible in the semester.
- Students with documented disability requiring accommodation during exams should contact *Support Services (301 Williams Hall: 610-758-4152)*, as well as inform the instructor in advance. This should be done as early as possible in the semester.

Principles of Our Equitable Community:
In accordance with Lehigh University's Principles of Diversity and Inclusion, everyone in this course is encouraged to foster an environment that is welcoming and collaborative, both inside and outside the class.

Catalog Description for MECH 425 (Analytical Methods in Dynamics and Vibrations)

Topics to be covered include coordinate systems, conservation laws, equilibrium and stability, systems of particles, variable-mass systems, transport equation; basic concepts from variational calculus; generalized coordinates, holonomic & nonholonomic constraints, generalized forces, D'Alembert's principle, Hamilton's principle, Lagrange's equations, generalized momenta; 3D rigid-body motion, inertia tensors, Euler angles, axis-angle representation, Hamilton's and Lagrange's equations for rigid bodies; oscillations, free and forced response of linear systems, linearization of nonlinear systems, discrete eigenvalue problem; chaotic systems, perturbation theory; additional topics if time permits: configuration spaces, forward and inverse kinematics, Jacobian, singularities, position control, nonholonomic systems.

Learning Objectives

1. Students will learn about different coordinate systems (Cartesian, cylindrical, spherical), representation of vectors using those, and transformation between those.
2. Students will be able to identify generalized coordinates, constraints (holonomic and non-holonomic) and degrees of freedom of a system.
3. Students will learn the conceptual underpinnings of conservation laws and learn to use those in solving engineering problems.
4. Students will learn to write linearized equations of motion for systems that can undergo undamped, damped and forced vibration, write general solution for such systems, and use MATLAB to numerically integrate linear and nonlinear multi-d.o.f. systems.
5. Students will learn to perform modal analysis and study impulse response of multi-d.o.f. systems.
6. Students will learn various conservation principles (linear/angular momentum, energy) and the conditions under which they hold.
7. Students will learn to solve problems involving equilibrium and stability analysis.
8. The students will learn the foundational principles of variational calculus.
9. The derivations of Lagrange's equations and Hamilton's principle will be presented.
10. Students will learn to use symbolic manipulation software (Mathematica) to derive the equations of motion of a large and complex system from the expression of its Lagrangian.
11. Students will learn to represent configurations of spatial rigid bodies and rotations of such rigid bodies (Euler angles).
12. Students will learn how to compute velocities and acceleration of points on rigid bodies and use them to solve kinematics problems involving multiple rigid bodies.
13. Dynamics of rigid bodies, including moment equations will be covered, which will be used to solve problems.
14. Work-energy principle for rigid bodies will be used to solve problems.
15. The students will learn to use Analytical mechanics (Lagrange's equations) for studying the motion of rigid bodies.
16. Students will be introduced to chaotic systems and use Matlab to simulate and analyze such systems.
17. Students will learn about forward/inverse kinematics of robotic manipulators, Jacobian, and simple proportional control of such manipulators.