University Of California, Berkeley
Department of Mechanical Engineering

ME 271 – Intermediate Dynamics (3 units)

Graduate Course

Syllabus

CATALOG DESCRIPTION

This course introduces and investigates Lagrange's equations of motion for particles and rigid bodies. The subject matter is particularly relevant to applications comprised of interconnected and constrained discrete mechanical components. The material is illustrated with numerous examples. These range from one-dimensional motion of a single particle to three-dimensional motions of rigid bodies and systems of rigid bodies.

COURSE PREREQUISITES

ME 104 or equivalent.

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Recommended texts: Such texts include, but aren't limited to,

1. Intermediate Dynamics for Engineers: A Unified Treatment of Newton-Euler and Lagrangian Approaches, by O. M. O'Reilly, Cambridge University Press, 2008;
2. Analytical Dynamics, by H. Baruh, McGraw-Hill, 1999;
3. Advanced Dynamics, by D. T. Greenwood. Cambridge University Press, 2003; and
4. Tensor Calculus by J.L. Synge and A. Schild, University of Toronto Press, 1949 (Reprinted by Dover Publications, New York, 1978).

Class notes are provided by the instructor. These notes are also supplemented with recent archival journal articles and excerpts from recent publications and the classic literature.

COURSE OBJECTIVES

Introduce students to the notion of exploiting differential geometry to gain insight into the dynamics of a mechanical system. Familiarize the student with classifications and applications of generalized forces and kinematical constraints. Enable the student to establish Lagrange's equations of motion for a single particle, a system of particles and a single rigid body. Establish equivalence of equations of motion using the Lagrange and Newton-Euler approaches. Discuss the developments of analytical mechanics drawing from applications in navigation, vehicle dynamics, toys, gyroscopes, celestial mechanics, satellite dynamics and computer animation.

DESIRED COURSE OUTCOMES

Upon completion of the course, students shall be able to: Establish and use covariant and contravariant basis vectors for an arbitrary curvilinear coordinate system; establish various forms of Lagrange's equations of motion for a discrete mechanical systems; simulate the dynamics of a mechanical system whose equations of motion are described using Lagrange's equations of motion; understand the relationships and equivalence between Lagrange's equations of motion and the Newton-Euler equations of motion; write special-purpose programs within a procedural programming computer environment, such as MATLAB, to simulate the dynamics of systems of particles and rigid bodies; assess the accuracy and realism of a model for a discrete mechanical system.

This course has a companion undergraduate course, ME175, with the same title. Graduate students enrolled in ME271 will be required to complete a semester project.

TOPICS COVERED

1. Curvilinear coordinate systems for a n-dimensional Euclidean space: covariant and contravariant basis vectors and their uses.
2. Integrable and non-integrable constraints in the dynamics of particles and rigid bodies.
3. Parameterizing the rotation of a rigid body using Euler angles, Euler's representation, and Euler-Rodrigues parameters (also known as quaternions).
4. Elements of the kinematics of particles and rigid bodies.
5. Constraint and conservative forces and moments in mechanics.
6. Lagrange's equations of motion for a particle, system of particles and rigid bodies.
7. Elements of the analysis of the dynamics of a mechanical system.
8. Application to mechanical systems: for example, gyroscopes, natural and artificial satellites, spherical robots, navigation, accelerometers, rolling and sliding rigid bodies, and vehicle dynamics.

CLASS/LABORATORY SCHEDULE

Three hours of lecture and one hour of discussion per week.

COURSE SUPPORT

This course needs the normal amount of support: A GSI to conduct office hours, hold the discussion session and assist the graduate students with their semester project. A reader is also needed to grade the homework assignments and provide timely feedback to students.

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

This course contributes primarily to the students' knowledge of engineering topics and does not provide hands-on design experience. However, aspects of design are discussed in connection with the analysis of the dynamics of various devices. Students will be required to present their semester project in a 15 minute oral presentation at the conclusion of the semester.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

[Please provide items and percentage they are worth towards grades. Example:

10%: 10 homework assignments
45%: 2 midterm exams
30%: final exam
15% semester project

SAMPLE OF WEEKLY AGENDA

Week 1	Kinematics of a single particle: curvilinear coordinates
Week 2	Constraints on the motion of a single particle
Week 3	Constraint forces, conservative forces, work-energy considerations
Week 4	Lagrange’s equations of motion for a single particle
Week 5	Applications of Lagrange’s equations of motion for a single particle
Week 6	Kinematics of a systems of particles
Week 7	Applications of Lagrange’s equations of motion for a system of particles
Week 8	Rotations and their representations
Week 9	Applications of Rotations and their representations
Week 10	Kinematics of a rigid body
Week 11	Balance laws for a rigid body and their applications
Week 12	Lagrange’s equations of motion for a rigid body
Week 13	Dynamics of a rigid body: establishing the equations of motion
Week 14	Dynamics of a rigid body: applications and analyses
Week 15	RRR
Week 16	Final Week

ADDITIONAL COMMENTS/CONCERNS

Students will be able to select from a range of semester projects. Same projects will include modeling and simulation of a mechanical system such as a gyroscope or spherical robot and detailed critique and discussion of a paper from the literatures on classical mechanics and engineering dynamics.

PERSON(S) WHO PREPARED THIS DESCRIPTION
Oliver O'Reilly, February 28, 2019

DETAILED WEEKLY SCHEDULE OF TOPICS

The schedule of topics follows the textbook "Intermediate Dynamics for Engineers" Cambridge University Press (2008). An online version of this text is freely available to students.

Week 1	Kinematics of a single particle: curvilinear coordinates
Week 2	Constraints on the motion of a single particle
Week 3	Constraint forces, conservative forces, work-energy considerations
Week 4	Lagrange's equations of motion for a single particle
Week 5	Applications of Lagrange's equations of motion for a single particle
Week 6	Kinematics of a systems of particles
Week 7	Applications of Lagrange's equations of motion for a system of particles
Week 8	Rotations and their representations
Week 9	Applications of Rotations and their representations
Week 10	Kinematics of a rigid body
Week 11	Balance laws for a rigid body and their applications
Week 12	Lagrange's equations of motion for a rigid body
Week 13	Dynamics of a rigid body: establishing the equations of motion
Week 14	Dynamics of a rigid body: applications and analyses
Week 15	RRR
Week 16	Final Week

ABBREVIATED TRANSCRIPT TITLE (19 SPACES MAXIMUM): [INTERMED DYNAMICS]
TIE CODE: [LECS]
GRADING: Letter and/or P/NP
SEMESTER OFFERED: Fall and/or Spring
COURSES THAT WILL RESTRICT CREDIT: ME 175
INSTRUCTORS: O'Reilly, Casey
DURATION OF COURSE: 15 Weeks
EST. TOTAL NUMBER OF REQUIRED HRS OF STUDENT WORK PER WEEK: 9
IS COURSE REPEATABLE FOR CREDIT? No
CROSSLIST: None