MECH/EECS 567 / ROB 510: Robot Kinematics and Dynamics

Winter 2025

Course Information

- **Class Meetings:** Tuesday / Thursday, 10:30 a.m. – 11:50 a.m.
- **Dates:** Starts: January 9, 2025 Ends: April 22, 2025
- **Location:** 2505 GGBL (*recorded*)

Instructional Team

Instructor

- **Robert D. Gregg, Ph.D.**
- **Office:** 2260 FRB
- **Email:** rdgregg@umich.edu
- **Office Hours:** Tuesday/Thursday 11:50 a.m. – 12:30 p.m., or by appointment

Graduate Student Instructor 1

- **Albert Lee**
- **Office:** 2104 FRB
- **Email:** albjlee@umich.edu
- **Office Hours:** Tuesday 1:30 p.m. – 2:30 p.m. at 2320 FRB; Thursday 2:00 p.m. – 3:00 p.m. at FRB 2141 (*Remote option available*)

Graduate Student Instructor 2

- **Jose Montes Perez**
- **Office:** 2104 FRB
- **Email:** jmontp@umich.edu
- **Office Hours:** Wednesday 11:00 a.m. – 12:00 p.m.; Friday 2:00 p.m. – 3:00 p.m. at FRB 2141 (*Remote option available*)

Exams

- **Midterm:** Friday, March 14 (take-home)
- **Final:** Wednesday, April 30 (take-home)

Prerequisites / Co-requisites

An introduction to linear systems at the level of *EECS 560 / AERO 550 / ME 564* or *ROB 501* is highly recommended. An undergraduate controls class is recommended. Knowledge of linear algebra and differential equations is required.

Course Description

MECH/EECS 567 / ROB 510 — Robot Kinematics and Dynamics (3 credits). Geometry, kinematics, differential kinematics, dynamics, and control of robot manipulators. The mathematical tools required to describe spatial motion of a rigid body will be presented in full.

Student Learning Outcomes

Upon successful completion of this course, students will:

1. have a basic understanding of the kinematics of robot manipulators and mobile robots.
2. understand the dynamics of Lagrangian mechanical systems and be able to compute the dynamic equations of motion of any robot manipulator.
3. have a basic understanding of nonlinear control methods such as feedback linearization, passivity-based, robust, and adaptive control, and be able to analyze the stability and tracking performance of closed-loop systems using Lyapunov theory.
4. be able to model, design, and simulate nonlinear controllers for manipulators and mobile robots.

Required Textbooks and Materials

- (MLS) R. Murray, Z. Li, and S. Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC Press, Boca Raton, FL, 1994. *Free digital copy on Canvas.*
- (SHV) Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, 2nd ed., John Wiley & Sons, Inc., New York, NY, 2020. Online UM library access: https://search.lib.umich.edu/catalog/record/99187338256706381

Required Software

- **MathWorks MATLAB:** https://teamdynamix.umich.edu/TDClient/76/Portal/KB/ArticleDet?ID=5448
- **Wolfram Mathematica:** https://its.umich.edu/computing/computers-software/software-services/software-information/mathematica
  Tutorials: http://www.wolfram.com/broadcast/screencasts/handsonstart/

Online Resources

We will be using Piazza for class discussion. Rather than emailing questions to the teaching staff, please post your questions on Piazza (except when related to grades). Check existing threads first; contribute to answers when you can.

Topical Outline

Screw Theory for Kinematics (MLS)

- Rotation Matrices and Homogeneous Transformations
- Exponential Coordinates for Rigid Motion
- Twists and Wrenches
- Forward Kinematics (D–H and Product of Exponentials)
- Inverse Kinematics
- The Manipulator Jacobian

Dynamics (MLS/SHV)

- The Euler–Lagrange Equations
- The Dynamics of Example Manipulators
- Properties of Manipulator Dynamic Equations

Multivariable Nonlinear Control (SHV)

- Lyapunov Stability and the Invariance Principle
- PD Control
- Inverse Dynamics
- Adaptive Control
- Passivity-Based Control
- Force Control
- Impedance Control

Exams and Grading

There will be homework assignments involving worked problems and computer simulations, a midterm exam, and a final exam. Grades will be determined as follows:

- **Homework:** 15%
- **Midterm Exam:** 40%
- **Final Exam:** 45%

Active participants on Piazza whose answers get endorsed by instructors will receive extra credit to bump borderline course grades.

Homework Scoring (each problem)

- **3 points:** Perfect or nearly so (minor numerical mistakes that don't affect reasoning are acceptable).
- **2 points:** Several minor errors or one major error, but demonstrates solid understanding.
- **1 point:** Attempt made, but reasoning is wrong or incomplete, or the solution is unreadable.
- **0 points:** Not attempted.

Homework is submitted via Gradescope (scans or high-quality photos). **No late HW** accepted; lowest HW score is dropped. Each set is normalized to 100%. For grading concerns, consult the GSI first; the instructor will get involved afterwards if needed.

Other Course Policies

Make-up Exams: No make-up exams. With an excused absence (doctor's note, job-related travel, holy day, etc.; provide documentation), the weight shifts to the remaining exam.

Late Work: Not acceptable.

Honor Code: Submitting online solutions as your own constitutes dishonest conduct and a violation of the College of Engineering Honor Code; cases will be referred to the Honor Council.

Class Attendance: You are responsible for taking notes. Lecture notes will not be provided. If absent, watch the recording.

Classroom Citizenship: Maintain professionalism. Avoid side conversations; refrain from bringing distracting/smelly foods. Electronic devices should be off during class except for note-taking or in-class exercises.

Accessibility & Inclusion

Disability Statement: The University of Michigan provides equal opportunity for participation in all programs, services, and activities. For accommodations, contact the Services for Students with Disabilities (SSD) Office, G664 Haven Hall, 734-763-3000. Once eligibility is determined, you will receive a VISA form; please present it at the beginning of the term or at least two weeks before a needed accommodation.

Inclusion Statement: The course welcomes and values diversity across all identities and backgrounds. All members are expected to contribute to a respectful, welcoming, and inclusive environment. Suggestions to improve inclusivity are encouraged and appreciated.

These descriptions and timelines are subject to change at the discretion of the Professor.