# University Of California, Berkeley
# Department of Mechanical Engineering

## ME 236U – Control and dynamics of unmanned aerial vehicles (3 units)

***Syllabus***

### DESCRIPTION

This course is a room share with ME136, and teaches students the dynamic analysis and control of unmanned aerial vehicles (UAVs). The course covers modeling and dynamics of aerial vehicles, common control strategies, sensing and estimation. A laboratory sequence allows students to apply knowledge on a real quadcopter system, by programming a microcontroller to control a UAV.

### COURSE PREREQUISITES

Introductory control (ME132 or similar), Dynamics (ME104 or similar).

Taken concurrently: a graduate controls class (ME232 or similar).

### TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

To be made available online.

### COURSE OBJECTIVES

Introduce the students to analysis, modeling, and control of unmanned aerial vehicles. Lectures will cover:

- Principle forces acting on a UAV, including aerodynamics of propellers
- The kinematics and dynamics of rotations, and 3D modeling of vehicle dynamics
- Typical sensors, and their modeling
- Typical control strategies, and their pitfalls
- Programming a microcontroller

During the laboratory sessions, students will apply these skills to create a model-based controller for a UAV.

### DESIRED COURSE OUTCOMES

At the end of the course, students are able to:

- reason about the dominant effects acting on a UAV
- explain and derive dynamic relationships governing UAV flight
- explain different sensors available on a UAV

- As part of a team:
  - design a nested controller for a quadcopter UAV
  - implement a controller in C++, compile & flash code to a microcontroller

**TOPICS COVERED**

- Principle forces acting on a UAV, including aerodynamics of propellers
- The kinematics and dynamics of rotations, and 3D modeling of vehicle dynamics
- Typical sensors, and their modeling
- Typical control strategies, and their pitfalls
- Programming a microcontroller

**CLASS/LABORATORY SCHEDULE**

Three hours of lecture per week, and three hours of laboratory every second week.

**CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT**

Students become comfortable working with an advanced robotics system, and related computer tools. Students can reason about practical considerations relating to constrained systems such as UAVs.

**COMPARISON TO ME136**

Compared to the room-share offering ME136, students taking this course will have additional homework problems in the graded homework sets. The problems for the graduate students will have a deeper theoretical component, and students will be expected to be able to prove statements about dynamics. Graduate student teams will also be assigned a topical research paper which they must present to the class: the students are expected to present the material through the lens of the course, and place the research in a greater context, especially to a broad audience (including the undergraduates attending the class). The exam questions for the ME236U students will be different than those for the ME136, especially requiring a deeper ability to derive results from first principles, and prove fundamental statements.

**ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES**

graded laboratory reports, including homework problems [30%]
midterm exam [30%]
final exam [40%]

**SAMPLE OF WEEKLY AGENDA**

1. Introduction to UAVs
2. Introduction to programming the system I
3. Aerodynamics of a thin aerofoil, propeller dynamics
4. Modeling of 3D rigid bodies
5. 3D Kinematics
6. 3D Dynamics (Newton-Euler equations), inertial sensors

7. Introduction to estimation
8. Dynamics of UAVs
9. Control and stabilization: computing an equilibrium, linearization
10. Nested control loops, separation principle
11. Trajectory generation and tracking
12. Rotation formalisms: rotation matrix, quaternions
13. Dynamics of unforced rotations
14. Comparison of different vehicle designs: helicopter / fixed-wings

**PERSON(S) WHO PREPARED THIS DESCRIPTION**
Mark Mueller, 2018-10-19

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**ABBREVIATED TRANSCRIPT TITLE (19 SPACES MAXIMUM):** CTN & DYN UNMND VEH **TIE CODE:** LECS
**GRADING:** Letter

**SEMESTER OFFERED:** Fall
**COURSES THAT WILL RESTRICT CREDIT:** None
**INSTRUCTORS:** Mueller
**DURATION OF COURSE:** 15 Weeks

**EST. TOTAL NUMBER OF REQUIRED HRS OF STUDENT WORK PER WEEK:** Varies
**IS COURSE REPEATABLE FOR CREDIT?** No
**CROSSLIST:** None