



**MECH 468: Modern Control Engineering  
MECH 509: Controls  
2020W2**

**University of British Columbia**

**Department of Mechanical Engineering**

**Course Instructor: Dr. Ryoze Nagamune**

Contact Information:

**Email:** [nagamune@mech.ubc.ca](mailto:nagamune@mech.ubc.ca)

**Office hours:** TuTh 5-6pm, or by appointment for online meeting on Zoom in Canvas

**Teaching Assistants:** Yue Niu ([niuyueubc@gmail.com](mailto:niuyueubc@gmail.com)) (only for marking assignments)

**Course Requirements/Prerequisites:** One of MECH 366, MECH 466.

**Class Meeting Time and Location:** MWF 1-1:50pm (PST) on Zoom in Canvas

**Course Structure**

- Live lectures on Canvas/Zoom, with lecture slides posted on Canvas, Mondays, Wednesdays & Fridays 1-1:50pm.
  - o Lectures will be recorded and posted on Canvas after the lectures.
- Five homework assignments.
- Midterm on February 24 (Wednesday), at 1-1:50pm. Final exam in April.
- Project for MECH 509 students.

**Learning Outcomes or Objectives:**

This course is an introductory course on linear control systems based on the state-space models. The main goal of the course is to provide students with basic tools in modeling, analysis and design for control and estimation. The analysis in this course includes stability, controllability, observability, realization and minimality of the state-space model, while the design methods are divided into pole placement for state feedback and observer design, and optimal methods such as linear quadratic regulator, Kalman filter and linear quadratic Gaussian control. Students will also learn how to apply the theory to engineering problems with MATLAB. The course will cover both continuous-time and discrete-time systems, as well as both time-invariant and time-varying systems. Simple examples from mechanical and electrical engineering will be used to show the applicability of the theory.



This course will give the basic knowledge for advanced control courses, such as nonlinear control, robust control, optimal control, adaptive control, digital control, sampled-data control, hybrid control, and system identification.

### Course Schedule and Topics

Week	Topics	HW
1-2	Introduction, state space model, linearization, discretization	HW1
3	BIBO stability, internal stability, Lyapunov theorem	
4-5	Controllability, observability, Kalman decomposition	HW2
6-7	Realization, minimal realization, <b>Midterm exam</b>	HW3
8-9	State feedback control, observer, observer-based control	HW4
10-11	Linear quadratic regulator, Kalman filter	HW5
12-13	Project presentation	

### Learning Activities

**Attendance to lectures on Mondays, Wednesdays and Fridays at 1-1:50pm.**

- Students are encouraged to attend the lectures if possible, or to listen to the recorded lectures.

### Project for MECH 509 students

Each MECH 509 student is required to formulate a realistic control problem (preferably related to his/her own research, or otherwise we can help), to do analysis and design for the problem using the course material, to analyze the designed controller in simulation (and in implementation if possible), to give a seminar, and to submit a report. The project should show the usefulness and/or the limitation of linear control systems theory.

### Learning Materials

Required Textbooks: None. Optional textbooks are:

- Linear Systems Theory (2nd Edition) Princeton University Press, 2018, Joao Hespanha
- Linear System Theory and Design (4th Edition) Oxford University Press, 2012, Chi-Tsong Chen
- Linear State-Space Control Systems Wiley, 2007, Robert L. Williams II and Douglas A. Lawrence
- A Linear Systems Primer Birkhauser, Boston, 2007, Panos J. Antsaklis and Anthony N. Michel
- Control System Design: An Introduction to State-Space Methods Dover Pub., 2005, Bernard Friedland
- Modern Control Theory Prentice Hall, 1991, William L. Brogan
- Optimal State Estimation John Wiley & Sons, 2006, Dan Simon
- Optimal Filtering Dover Publications, 2005, Brian D. O. Anderson and John B. Moore
- Optimal Control and Estimation Dover Publications, 1994, Robert F. Stengel



All materials (lecture slides, homework assignments etc.) are posted on Canvas.

Computer with MATLAB installed. (MATLAB is available for free for UBC students.)

<https://it.ubc.ca/services/desktop-print-services/software-licensing/matlab#getMATLAB>)

Computer with a webcam (for exam invigilation on Zoom or Proctorio) and ability to scan or photograph documents (for uploading assignments and exams on Canvas)

## **Assessment, Evaluation, and Grading**

### ***Grading scheme:***

MECH468 (3 credits): Homework 20%, Midterm 30%, Final 50%

MECH509 (4 credits): Homework 20%, Midterm 30%, Final 30%, Project 20%

***Homework assignment:*** Assignments will be given periodically. Your answers should be scanned and uploaded on Canvas by the due date/time. Assignments are to be done **individually**. **Copying another student's assignment is not allowed.** Possible penalties for plagiarism include a mark of zero for all assignments.

***Late hand-in policy:*** Late hand-in of assignments or project reports will be given a mark of zero.

### ***Exam policies:***

- Open-book. Calculators are not allowed.
- Alternative exams can be arranged **ONLY** for medical reasons and with doctor's notes. For other reasons, discuss your case with the instructor before the exam dates.
- Your exams are invigilated on Zoom or Proctorio. Please make sure that you have a computer with a webcam.

Students pass this course based on their final course mark. A weighted average examination grade of at least 50% is **not** required. (The "examination grade" includes scores from the midterm final examinations to be done individually.)

## **Recording of Synchronous Video Lectures**

Live (synchronous) lectures will be recorded for use by students enrolled in this course, but these recordings will not be used beyond the current section of the course. Please be aware that student participation, such as when asking questions in class, will be captured as part of these recordings.

The following information is captured during recordings:

- Audio
- Any content shared or active speaker video. If both are shared during the session, only the content shared is recorded.



- Captions entered during the live session or added later by a moderator. Only one caption track is available. If your session had more than one caption track, only the first available one is captured.
- Chat messages in the Everyone channel. Private messages and chat messages in breakout groups are not recorded.

### **Academic Integrity**

In this course you will be asked to agree to an academic integrity statement as part of testing or other assessment activities. As a student in a professional program, doing your part to adhere to course rules and upholding the academic integrity of your educational experience is in your best interest. Every effort will be made to ensure that assessment is fair for all students in the course. You can do your part by following the rules set out by your course instructors, and seeking assistance or clarification if you have any questions.

### **Academic Misconduct**

Academic honesty is a fundamental requirement of your studies. It is your obligation to inform yourself of the applicable standards. More information is available at <http://calendar.ubc.ca/vancouver/index.cfm?tree=3,54,111,0>.

### **Policies and Resources to Support Student Success**

UBC provides resources to support student learning and to maintain healthy lifestyles but recognizes that sometimes crises arise and so there are additional resources to access including those for survivors of sexual violence. UBC values respect for the person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious and cultural observances. UBC values academic honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions. Details of the policies and how to access support are available at <https://senate.ubc.ca/policies-resources-support-student-success>. Mechanical Engineering also has a Student Services Office ([students@mech.ubc.ca](mailto:students@mech.ubc.ca)), located in CEME 2205, where there are staff who can provide support and refer students to the appropriate resources.

### **Inclusive Environment**

The Department of Mechanical Engineering is committed to providing an inclusive learning experience, and affirms the UBC Statement on Respectful Environment (<https://www.hr.ubc.ca/respectful-environment/files/UBC-Statement-on-Respectful-Environment-2014.pdf>). You are encouraged to contact your instructor should situations arise that are not consistent with this expectation. You are also invited to advise the instructor if you wish to be addressed by or referred to with particular pronouns.

### **Laboratory Safety**

UBC Mechanical Engineering considers safety first, and continuously, in its labs, research, and other activities. Students are expected to engage in safety discussions; to ask questions to ensure they understand safety information; to comply with policies and rules; to maintain a safe workspace; and to report all accidents,



incidents, and near misses immediately to their supervisor and to <https://cairs.ubc.ca>. Students should work with their supervisors to ensure they understand (1) the risks associated with their work and (2) how those risks are controlled.

### **Statement regarding online learning for international students**

*During this pandemic, the shift to online learning has greatly altered teaching and studying at UBC, including changes to health and safety considerations. Keep in mind that some UBC courses might cover topics that are censored or considered illegal by non-Canadian governments. This may include, but is not limited to, human rights, representative government, defamation, obscenity, gender or sexuality, and historical or current geopolitical controversies. If you are a student living abroad, you will be subject to the laws of your local jurisdiction, and your local authorities might limit your access to course material or take punitive action against you. UBC is strongly committed to academic freedom, but has no control over foreign authorities (please visit <http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,33,86,0> for an articulation of the values of the University conveyed in the Senate Statement on Academic Freedom). Thus, we recognize that students will have legitimate reason to exercise caution in studying certain subjects. If you have concerns regarding your personal situation, consider postponing taking a course with manifest risks, until you are back on campus or reach out to your academic advisor to find substitute courses. For further information and support, please visit: <http://academic.ubc.ca/support-resources/freedom-expression>*