



MECH 410Q/540G: Numerical Trajectory Optimization

University of British Columbia

Department of Mechanical Engineering

Course Instructor: Dr. Dominic Liao-McPherson

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Office location: KAIS 3105

Office hours: TBD

Contact Information

- In general, technical questions should be posted on Piazza (so that everyone can see and benefit from the answer). I will try to answer questions within 2 - 3 (working) days.
- Students with questions that cannot be posted to the forum, (e.g., those involving personal or private information) should email the instructor directly.
- When contacting the instructor or teaching assistant, please include the course code in your subject heading [MECH410Q/540G], and include your name and student number in all communications.

Course Requirements/Prerequisites: MECH 359 or MECH 358 (or equivalent)

Class Meeting Time and Location: Mo/We 8:30am – 10:00am, MacLeod 3002

UBC's Point Grey Campus is located on the traditional, ancestral, and unceded territory of the xwməθkwəyəm (Musqueam) people.

Course Structure

- In-person lectures
- Homework Assignments (4x)
- Midterm exam
- Final exam

Learning Outcomes or Objectives:

This is an introductory course in numerical optimization. *The main goal of the course is to teach students how to solve engineering problems using optimization techniques.* The course focuses mostly on trajectory optimization problems arising in mechanical and aerospace engineering but the material is applicable much more broadly, e.g., to problems in design or structural optimization.

At the end of the course, students will be able to:

1. Translate engineering objectives into optimization problems



2. Classify different types of optimization problems and
 - a. derive optimality conditions for each class
 - b. understand what features leads to well vs. ill posed problems
 - c. understand how different features impact “solvability”
3. Solve simple optimization problems by hand
4. Analyze common optimization algorithms from a theoretical perspective
5. Implement optimization algorithms in software
6. Deploy standard software and algorithms to solve complex problems

Course Schedule and Topics

Week	Topics
1	Introduction, a taxonomy of optimization problems, and examples of engineering applications.
2-3	Review of calculus and linear algebra
3-4	Optimality conditions for finite dimensional problems
5	Discrete-time optimal control problems
6-8	Algorithms and software for finite dimensional problems
9-10	Continuous-time optimal control problems: The calculus of variations and Pontryagin’s maximum principle
11	Linear-quadratic optimal control problems
12-13	Transcription and collocation

Learning Activities

- **Attend lectures:** Students are expected to attend the in-person lectures whenever possible, and to ask questions whenever they have any in and outside of class.
- **Use Software:** Students should use MATLAB and the MATLAB optimization toolbox to complete homework and projects

Learning Materials

Required Textbooks: None. Optional textbooks:

- Wright, Stephen, and Jorge Nocedal. "Numerical optimization." *Springer Science* 35.67-68 (1999): 7. **(Available online at the UBC library)**
- Vinter, Richard B., and R. B. Vinter. *Optimal control*. Vol. 2. No. 1. Boston: Birkhäuser, 2010. **(Available online at the UBC library)**
- Beletskii, Vladimir Vasil'evich, and Arturo Locatelli. *Optimal Control: An Introduction*. Springer Science & Business Media, 2001.

All materials (lecture slides, homework assignments etc.) will be 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>)

Assessment, Evaluation, and Grading

- Homework assignments 30%,
- Midterm 35%,
- Final 35%

Students are required to take the final exam.

Homework assignments: Assignments will be given periodically. Unless otherwise noted, assignments must be submitted as *paper hard copies* and will be collected at the beginning of class.

- The instructor and TA will not help students solve the homework assignments.
- Assignments are to be done **individually**. Copying another student's assignment or usage of generative tools (e.g., ChatGPT etc.) is **NOT allowed** and constitutes academic misconduct¹. Potential penalties include failing the course and code submissions will be checked for plagiarism².

Late hand-in policy: A 25% penalty will be levied on late assignments received by the beginning of the next class. After this they will be assessed a mark of 0.

Exam policies: Closed-book. One-page double-sided letter-size hand-written cheat sheet is allowed. Calculators are not allowed.

Undergraduate students must achieve a weighted average of at least 50% on the midterm and final to pass the course as per MECH department policy³.

¹ 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>.

² In this course, you will be using Turnitin, which is a tool to help review your written work. When creating an account in the tool, you will be asked to provide personally identifying information. Please know you are not required to consent to sharing this personal information with the tool, if you are uncomfortable doing so. If you choose not to provide consent, you may create an account using a nickname and a non-identifying email address, then let your instructor know what alias you are using in the tool.

³ In undergraduate MECH courses where at least 50% of the final grade is assigned to examinations, students may only pass the course if they achieve a weighted average examination grade of at least 50%. The "examination grade" includes scores from the final examination, midterms, and other tests done individually in a classroom setting. In the event of a student receiving an "examination grade" of less than 50%, the "examination grade" total will be entered as their final grade for the course.



Policies and Resources to Support Student Success

To request for an academic concession, please complete online reporting of in-term concessions ('self-declaration' for short-term illnesses without need for a medical note) as soon as you can, and then discuss it with the instructor. Concessions will not be granted without completing the form.

<https://academicervices.engineering.ubc.ca/form-request-for-academic-concession-in-term-work/>

- **For missed lectures:** You don't need to complete the online form. Please read the notes, discuss with your colleagues, and consider attending office hours.
- **For missed homework assignments:** Depending on the length of the academic concession, the instructor will decide how to handle the missed homework assignments (e.g., a deadline extension based on the discussion, or moving the weight of a missed assignment to other combination of assignments).
- **For missed midterm:** The weight will be transferred to the final.
- **For missed final exam:** We will follow the UBC Senate Policy on Academic Concession.

Respectful Environment

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), located in CEME 2205, where there are staff who can provide support and refer students to the appropriate resources.

Discussion Boards: Profanity or derogatory terms are strictly forbidden. Please be polite and professional

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.