Overall Course Schedule:

Live Sessions:	Mondays and Fridays	2:30 – 3:50 pm EST	via Teams
Make-Up Days:	Tue. Aug. 3 & Thu. Aug. 5	2:30 – 3:50 pm EST	via Teams
Term Holidays:	May 24 (Victoria Day), July 1 & 2 (Canada Day + 1), and August 2 (Civic Holiday)		
Deliverables:	All course deliverables must be submitted by 9 pm EST on the given date.		

Course Instructor	Lab Instructor	Teaching Assistant
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Course Description:
This course introduces students to the field of robotics, with a focus on the mechanics and control of serial manipulators (i.e., robot arms). In the first half of the course, you will learn how to model a robot's kinematics. Building on this, you will learn how to generate trajectories and formulate a robot's dynamic equations, then use them to control a robot. This course also includes a hands-on lab, which requires the application of all these topics to both a simulated and physical robot, and a course-long project.

Course Overview:
The following topics (from the calendar entry) will be covered in this course, using the format that best suits the material. The order listed here does not necessarily reflect the presentation order.

Homogeneous transformations	Dynamics
Kinematics and inverse kinematics	Path planning
Denavit-Hartenberg convention	Nonlinear control
Jacobians and velocity transformations	Compliance and force control

Course Objectives:
By the end of this course, our goal is that for any given serial manipulator you will be able to:

- Derive and compute the robot's kinematics (forward, velocity, and inverse)
- Formulate the robot's equations of motion (forward and inverse dynamics)
- Design and generate trajectories of motion (in both joint and task space)
- Develop and implement various controllers (in both joint and task space)

Textbook:
"Modern Robotics: Mechanics, Planning, and Control" by Professors Kevin Lynch and Frank Park.

Throughout the term, you and your peers will be expected to review and collaboratively annotate videos about and content from this book using the Perusall platform (accessed via LEARN). On Perusall, you can ask questions, provide answers, upvote existing questions and answers, and provide direct feedback on what topics and exercises you would like to have explained further by the teaching team in live sessions.

If you are interested in taking your knowledge of robotics further, there are more videos, software, and other additional resources available on the textbook's website at http://modernrobotics.org.

Class Discussion Forum:
This term we will be using Piazza for class discussion and Q&A. The platform is well suited and designed to get you help fast and efficiently, from your classmates and the teaching team. Instead of emailing us, we strongly encourage you to post your questions on Piazza to get faster (and often better) answers.

A link to the Piazza page for this course can be found on LEARN under General Resources.

Evaluation:
The course evaluation includes marks for engagement, assignments, lab deliverables, and a project:

Engagement	10%	Based on your participation on the Piazza & Perusall platforms.
Assignments	20%	Best 4 (out of 6) assignments are each worth 5% of final grade.
Lab Deliverables	30%	Includes 2% based on your group-evaluated lab contributions.
Course Project	40%	Marks are distributed proportionally across the project sections.

Engagement:
Throughout this course there will be many chances to demonstrate your engagement with the content: It is expected that you will check the Piazza page for answers to any general questions you might have, ask any questions you have that have not already been posted, and take part in answering your peers' questions as part of your engagement with the content of the course. You are expected to do the same on Perusall (ask and answer questions, upvote questions and answers, etc.) for the videos and readings.

Assignments:
The assignments will help you evaluate your understanding of the core concepts by applying them. Each assignment includes a set of questions related to recent topics introduced in the videos and readings on Perusall. There are 6 assignments throughout the term, each covering 1-2 chapters (as listed below).

To enable deeper engagement with the concepts, you will evaluate your peers' work (and vice versa) using the Kritik platform. Since the evaluation phase will start after submission, assignments may not be submitted late. However, only your best 4 (of 6) assignment marks will be included in your final grade.

Assignments open on the first day where the associated content is being covered, and each assignment must be submitted to Kritik by the Assignment Due date (as shown in the course schedule and summarized below). After submitting your assignment, you will have until the Evaluation Due date to anonymously evaluate and critique several of your peers' submissions. Finally, you will then have until the Feedback Due date to provide feedback on the evaluations and critiques you received on your work.

Preliminary Assignment Schedule (Any updates will be announced in a live session and posted on LEARN):

	Assignment Opens	**Assignment Due**	**Peer Evaluation Due**	**Feedback Due**
Chapter 2	May 10	May 19	May 26	May 27
Chapter 3	May 17	June 2	June 9	June 10
Chapters 4 & 5	May 31	June 16	June 23	June 24
Chapters 6 & 9	June 14	June 30	July 7	July 8
Chapter 8	June 28	July 14	July 21	July 22
Chapter 11	July 12	July 28	August 4	August 5

Labs:
The labs allow you to apply core concepts from the course on a real robot. There is one introductory lab, 3 course-based labs (in groups), and a peer evaluation, which must all be completed to pass the course.

Each lab consists of the following three components (each with their own associated Due date):

- **Part A:** This is where you will apply the concepts you have learned in the course to the given lab task(s) and iteratively create, test, and revise software to achieve the task(s) using a simulated robot. Once it can achieve the given task(s), you will submit your tested software (and any other Part A deliverables as outlined in the lab manual) to LEARN by the Part A Due date for that lab.
- **Part B:** In the order they were submitted (i.e., a first-in, first out queue), you will receive initial feedback on your Part A deliverables. This will include video of your software running on the physical robot and copies of any logged outputs produced during its operation. You may then (if desired) revise and resubmit your files to LEARN by the Part B Due date with no grading penalty.
- **Report:** The report must include all the required elements from Parts A and B, as outlined in the lab manual, as well as responses to the report-specific prompts that are included at the end of each lab manual. The report must be submitted to LEARN by the Report Due date to be marked.

Lab 1 will be completed individually to familiarize you with the simulation software. Please let us know if you have any issues/challenges with getting access to the required software or with the submission process for the labs, as the first lab will also serve as a test of the submission process for the term.

In Labs 2-4, you will work in self-assigned groups of three students. Groups of two may be permitted at the discretion of the lab instructor. We reserve the right to separate groups and reassign their members if anyone is neglecting their duties and/or if we believe a group is not working well together. At the end of the term, you will evaluate each group member's contributions to the labs (including your own).

All deliverables must be submitted to their assigned Dropbox on LEARN by the associated Due date (as shown in the course schedule and summarized below). Every student is responsible for making sure their files (in Lab 1) or their group's files (in Labs 2-4) are successfully uploaded in the desired format(s). Detailed information about the labs (and any changes to this outline) will be provided on LEARN.

Late Submissions:
Late Part A files may be submitted up until the Part B Due date with no grading penalty. However, initial feedback will not be provided on these late submissions and no submissions will be accepted after the Part B Due date. If desired, you may submit incomplete Part A files by the Part A due date to receive partial feedback, then submit your complete set of files by the Part B Due date with no grading penalty.

Late reports will not be accepted without prior approval, given only under extenuating circumstances.

Preliminary Lab Schedule (Any updates will be announced in a live session and posted on LEARN):

	Lab Opens	Part A Due	Part B Due	Report Due	% of Final Grade
Lab 1	May 10	May 18	May 25	June 1	5%
Lab 2	May 31	June 8	June 15	June 22	7%
Lab 3	June 21	June 29	July 6	July 13	9%
Lab 4	July 12	July 20	July 27	August 3*	7%

*NOTE: The group evaluation process will only be open August 4 & 5 (after the Lab 4 Report Due date).

Course Project:
The project this term is to design, model, and control a robot to hit a ping pong ball with a paddle given only the ball's initial velocity. It consists of 6 sections: an introductory section and 5 course-based sections. You must individually complete every section to pass the course. Each section includes both code deliverables, which can be unit tested in MATLAB Grader, and a report, as a MATLAB Live Script.

The project sections are organized as follows (each building on the results of the previous section):

- **Introduction**: Getting familiar with the MATLAB Grader environment and MATLAB Live Scripts.
- **Task**: Applying Chapters 2 + 3 to determine how the ball will be moving, where it will pass through a given workspace, and where the paddle needs to be placed to intercept the ball.
- **Design**: Applying Chapters 4 + 5 to design a serial manipulator capable of moving the paddle as needed, in terms of its position and velocity, to intercept the motion of the ball.
- **Validation**: Applying Chapters 6 + 9 to determine how to actuate the joints of the robot to move the paddle where it needs to be, including generating a trajectory to be followed.
- **Dynamics**: Applying Chapter 8 to generate the equations of motion for your robot once suitable masses and inertias are defined, including both the forward and inverse dynamics.
- **Controls**: Applying Chapter 11 to develop controllers for your robot in both joint and task space and then test them in simulation to verify their performance.

Section reports (with code) must be submitted to their associated Dropbox on LEARN by the Report Due date (as shown in the course schedule and summarized below). In submission order, you will receive initial feedback and may (if desired) revise and resubmit your report by the Grading Starts date. Each student is responsible for making sure their files are successfully uploaded in the required format(s). Detailed information about the project (and any changes to this outline) will be posted on LEARN.

Late Submissions:
Late reports may be submitted up until the Grading Starts date with no grading penalty. However, initial feedback will not be provided on these late submissions and no submissions will be accepted after the date Grading Starts. If desired, you may submit an incomplete report by the Report Due date to receive partial feedback, then submit a complete report by the Grading Starts date with no grading penalty.

Preliminary Project Schedule (Any updates will be announced in a live session and posted on LEARN):

	Section Opens	Report Due	Grading Starts	% of Final Grade
Introduction	May 10	May 21	May 31	2%
Task	May 17	June 7	June 14	7%
Design	May 31	June 21	June 28	7%
Validation	June 14	July 5	July 12	7%
Dynamics	July 28	July 19	July 26	7%
Controls	July 12	August 9*	August 16*	10%

*NOTE: For the final project section (Controls), the Report Due and Grading Starts dates take place during the final exam period for the term. Please make sure to manage your time accordingly.

Intellectual Property

This course uses the intellectual property (IP) of the teaching team and/or the University of Waterloo to enhance your educational experience. This includes course content (e.g., lectures, handouts, slides, and copies thereof), assessment materials (e.g., problem and solution sets), and work protected by copyright (used with the permission of the copyright owner). Sharing this material (with peers or externally) either during or after the course without the IP owner's permission is a violation of their IP rights. For this reason, it is necessary to ask the teaching team and/or the University of Waterloo for permission before uploading and sharing their IP online (e.g., to an online repository or your peers). For more details, read Policy 73 – Intellectual Property Rights and the official Relationships with External Organizations page.

Academic Integrity

In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check the Office of Academic Integrity for more information.]

Grievance

A student who believes that a decision affecting some aspect of his/her/their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline

A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for his/her/their actions. [Check the Office of Academic Integrity for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.

Appeals

A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she/they has/have a ground for an appeal should refer to Policy 72, Student Appeals.

Note for Students with Disabilities

AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.