

Course Outline (F2023)

ELE719: Fundamentals of Robotics

Instructor(s)	Dr. Y. C. Chen [Coordinator] Office: ENG458 Phone: (416) 979-5000 x 556090 Email: yaochen@torontomu.ca Office Hours: Refer to D2L
Calendar Description	This course provides a comprehensive treatment on the fundamentals of robotic manipulators and mobile robots. Topics include: homogeneous transformations, the Denavit-Hartenberg representation of linkages, solution of the forward kinematics problem. Closed-form and numerical solutions of the inverse kinematics problem. Differential kinematics and motion, Jacobian matrix, singularities. Kinematic and dynamic model of mobile robots. Path planning, trajectory planning and motion control for mobile robots.
Prerequisites	ELE 639 or MEC 709
Antirequisites	None
Corerequisites	None
Compulsory Text(s):	1. ELE719 Laboratory Manual, F2023 Edition, Y.C. Chen. Available through D2L.
Reference Text(s):	1. Robotics: Modelling, Planning and Control, B. Siciliano, et al., Springer-Verlag, 2009. Also available online through TMU Library.
Learning Objectives (Indicators)	At the end of this course, the successful student will be able to: <ul style="list-style-type: none"> 1. Develop both kinematics models for mobile robots and robotics manipulators, develop dynamics models for mobile robots. (1b) 2. Interconnect electrical and control engineering concepts to solve control problem for mobile robots. (1c) 3. Probabilistic localization for mobile robots. (2a) 4. Design motion controllers for mobile robots. (4b) <p>NOTE: Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board (CEAB).</p>
Course Organization	3.0 hours of lecture per week for 13 weeks 2.0 hours of lab per week for 12 weeks 0.0 hours of tutorial per week for 12 weeks
Teaching Assistants	For Sections 012, 042, 052: Somayeh Barzegar, sbarzegar@ryerson.ca For Sections 022, 032: Sara Salamat, sara.salamat@ryerson.ca

Course Evaluation	Theory
	Mid-Term Exam 25 %
	Final Exam (Theory Part) 40 %
	Laboratory
	Lab Experiments 25 %
	Final Exam (Lab Part) 10 %
	TOTAL: 100 %
	<p>Note: In order for a student to pass a course, a minimum overall course mark of 50% must be obtained. In addition, for courses that have both "Theory and Laboratory" components, the student must pass the Laboratory and Theory portions separately by achieving a minimum of 50% in the combined Laboratory components and 50% in the combined Theory components. Please refer to the "Course Evaluation" section above for details on the Theory and Laboratory components (if applicable).</p>
Examinations	Mid-Term exam will be announced on D2L. Final exam will be held during exam period.
Other Evaluation Information	None
Other Information	Lecture and laboratory schedules are tentative and subject to change. Consult D2L for updates. Laboratory work requires the use of a Linux virtual machine that runs on Windows OS. See the Laboratory Manual on hardware and software requirements.

Course Content

Week	Hours	Chapters / Section	Topic, description
1	1	1.1-1.4	Introduction: Automation and robots, robot classification, applications, robot specifications.
1-3	6	2.1-2.5 2.7	Rigid Motion and Homogeneous Transformation: Rotation, composite rotation, translation, composite translation, homogeneous transform.

3-5	6		Wheeled Mobile Robots: Inverse and forward kinematics models, dynamic model.
5-7	6		Motion Control for Mobile Robots: Localization, trajectory tracking and obstacle avoidance.
7-9	6	2.8-2.10	Forward Kinematics and the Denavit-Hartenberg Representation for Robotic Manipulators: Coordinate frames, kinematic chains, link and joint parameters, the Denavit-Hartenberg (DH) representation, the arm equation. Joint Space and Operational Space.
9-11	6	2.12	Inverse Kinematics for Robotic Manipulators: Solving the arm equation, general properties of solutions, kinematic decoupling, inverse position and inverse orientation problems.
11-13	6	3.1-3.3 3.6	Differential Kinematics and Differential Motion for Robotic Manipulators: Linear and angular velocities the manipulator, geometric Jacobian, singularities, differential motion transform.

Laboratory(L)/Tutorials(T)/Activity(A) Schedule

Week	L/T/A	Description
2-3	Lab 1	Introductory Python Programming
4	Tutorial 1	Tutorial
5,7	Lab 2	Inverse Kinematics and Simple motions (No lab or tutorial in Week 6)

8-9	Lab 3	Forward Kinematics and Kinematics Control
10	Tutorial 2	Tutorial
11-12	Lab 4	Obstacle Avoidance Control
13	Tutorial 3	Tutorial

University Policies

Students are reminded that they are required to adhere to all relevant university policies found in their online course shell in D2L and/or on [the Senate website](#)

Important Resources Available at Toronto Metropolitan University

- [The Library](#) provides research [workshops](#) and individual assistance. If the University is open, there is a Research Help desk on the second floor of the library, or students can use the [Library's virtual research help service](#) to speak with a librarian.
- [Student Life and Learning Support](#) offers group-based and individual help with writing, math, study skills, and transition support, as well as [resources and checklists to support students as online learners](#).
- You can submit an [Academic Consideration Request](#) when an extenuating circumstance has occurred that has significantly impacted your ability to fulfill an academic requirement. You may always visit the [Senate website](#) and select the blue radio button on the top right hand side entitled: Academic Consideration Request (ACR) to submit this request.

For Extenuating Circumstances, Policy 167: Academic Consideration allows for a once per semester ACR request without supporting documentation if the absence is less than 3 days in duration and is not for a final exam/final assessment. Absences more than 3 days in duration and those that involve a final exam/final assessment, require documentation. Students must notify their instructor once a request for academic consideration is submitted. See Senate [Policy 167: Academic Consideration](#).

- If taking a remote course, familiarize yourself with the tools you will need to use for remote learning. The [Remote Learning Guide](#) for students includes guides to completing quizzes or exams in D2L Brightspace, with or without [Respondus LockDown Browser and Monitor, using D2L Brightspace](#), joining online meetings or lectures, and collaborating with the Google Suite.
- Information on Copyright for [Faculty](#) and [students](#).

Accessibility

- Similar to an [accessibility statement](#), use this section to describe your commitment to making this course accessible to students with disabilities. Improving the accessibility of your course helps minimize the need for accommodation.
- Outline any technologies used in this course and any known accessibility features or barriers (if applicable).
- Describe how a student should contact you if they discover an accessibility barrier with any course materials or technologies.

Academic Accommodation Support

Academic Accommodation Support (AAS) is the university's disability services office. AAS works directly with incoming and returning students looking for help with their academic accommodations. AAS works with any student who requires academic accommodation regardless of program or course load.

- Learn more about [Academic Accommodation Support](#).
- Learn [how to register with AAS](#).

Academic Accommodations (for students with disabilities) and Academic Consideration (for students faced with extenuating circumstances that can include short-term health issues) are governed by two different university policies. Learn more about [Academic Accommodations versus Academic Consideration and how to access each](#).

Wellbeing Support

At Toronto Metropolitan University, we recognize that things can come up throughout the term that may interfere with a student's ability to succeed in their coursework. These circumstances are outside of one's control and can have a serious impact on physical and mental well-being. Seeking help can be a challenge, especially in those times of crisis.

If you are experiencing a mental health crisis, please call 911 and go to the nearest hospital emergency room. You can also access these outside resources at anytime:

- **Distress Line:** 24/7 line for if you are in crisis, feeling suicidal or in need of emotional support (phone: 416-408-4357)
- **Good2Talk:** 24/7-hour line for postsecondary students (phone: 1-866-925-5454)
- **Keep.meSAFE:** 24/7 access to confidential support through counsellors via [My SSP app](#) or 1-844-451-9700

If non-crisis support is needed, you can access these campus resources:

- **Centre for Student Development and Counselling:** 416-979-5195 or email csdc@torontomu.ca
- **Consent Comes First - Office of Sexual Violence Support and Education:** 416-919-5000 ext 3596 or email osvse@torontomu.ca
- **Medical Centre:** call (416) 979-5070 to book an appointment

We encourage all Toronto Metropolitan University community members to access available resources to ensure support is reachable. You can find more resources available through the [Toronto Metropolitan University Mental Health and Wellbeing](#) website.