

Western University
Faculty of Engineering
Department of Electrical and Computer Engineering

MSE 4401A: Robotic Manipulators

Course Outline 2023-24

Description: This course presents an overview of robotic manipulators and the theory behind modelling, planning and control of serial manipulators. It includes topics in robot kinematics and dynamics, differential kinematics, path and trajectory planning, dynamics and control.

Academic Calendar Copy: Introduces the basic principles and techniques involved in modeling, simulating and controlling rigid-link manipulators. Forward and inverse kinematics. Manipulator dynamics. Control of robot manipulators.

Contact Hours: 3 lecture hours, 3 laboratory hours/week, 0.5 course.

Prerequisites: MSE 3302A/B

Pre- or Corequisite(s): MSE 3381A/B or MME 3381A/B.

Restricted to students enrolled in the Mechatronic Systems Engineering program.

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

CEAB Academic Units: Engineering Science 100%

Textbook: M.W. Spong, S. Hutchinson, and M. Vidyasagar, Robot Modeling and Control, Second Edition, New York: John Wiley and Sons, 2020.

Required Software: MATLAB and Simulink, including the Robotics Toolbox.

General Learning Objectives (CEAB Graduate Attributes)

Knowledge Base	A	Use of Engineering Tools	A	Impact on Society and the Environment	
Problem Analysis	A	Individual and Team Work	A	Ethics and Equity	
Investigation		Communication Skills	D	Economics and Project Management	
Design		Professionalism		Life-Long Learning	

Notation. I – The instructor will introduce the topic at the level required. It is not necessary for the student to have seen the material before. **D** – There may be a reminder or review, but the student is expected to have seen and been tested on the material before taking the course. **A** – It is expected that the student can apply the knowledge without prompting (e.g. no review).

Course Topics and Specific Learning Outcomes	CEAB Graduate Attributes Indicators
<p>1. Introduction to Robotics and Rigid Motions</p> <p>At the end of this section, students will be able to:</p> <ol style="list-style-type: none">Define and describe robotic manipulators as well as the different types and their characteristics.Define the relative position and orientation of serial links using homogeneous transformation matricesDemonstrate ability to define an engineering problem at an advanced level to be solved using serial link manipulators.	<p>KB-4, PA-1</p> <p>Project Step #1</p>
<p>2. Forward and Inverse Kinematics</p> <p>At the end of this section, students will be able to:</p> <ol style="list-style-type: none">Compute the forward kinematics of serial manipulators.Compute the inverse kinematics of serial manipulators using the algebraic and geometric approaches.Demonstrate ability to formulate a strategy to solve an engineering problem at an advanced level using robot kinematics.	<p>KB-4, PA-2</p> <p>Project Step #2: Parts 1 and 2</p>

<p>3. Velocity Kinematics: The Jacobian</p> <p>At the end of this section, students will be able to:</p> <ol style="list-style-type: none"> Calculate the Jacobian Matrix of serial manipulators using various approaches. Identify the location of kinematic singularities. Use the Jacobian matrix, to calculate velocities, and forces/torques, and to characterize manipulability. Demonstrate ability to formulate a strategy to solve an engineering problem and reach substantiated conclusions at an advanced level using robot kinematics. 	<p>KB-4, PA-2, PA-3</p> <p>Project Step #2: Part 3</p>
<p>4. Path and Trajectory Planning</p> <p>At the end of this section, students will be able to:</p> <ol style="list-style-type: none"> Apply different methods for creating a smooth path in joint space. Implement algorithms to achieve adequate robot navigation in the presence of obstacles. Demonstrate ability to define an engineering problem, formulate a strategy to implement path planning optimization algorithms, and reach substantiated conclusions at an advanced level. 	<p>KB-4, PA-1, PA-2, PA-3</p> <p>Project Step #3</p>
<p>5. Dynamics and Control</p> <p>At the end of this section, students will be able to:</p> <ol style="list-style-type: none"> Formulate the equations of motion of serial manipulators. Implement different types of control systems and identify the best way to control a robot. Demonstrate ability to formulate a strategy to solve a robotics control problem and reach substantiated conclusions at an advanced level. <p>Laboratory Reports, Project Reports</p>	<p>KB-4, PA-2, PA-3</p> <p>Project Step #4</p> <p>CS-3, ITW-3, ET-2</p>

Evaluation

Course Component	Weight
Laboratories	30%
Project	20%
Midterm Test	20%
Final Examination	30%

Laboratory: Students will attend a 3-hour laboratory session each week. Three laboratory reports will be completed throughout the term, each one corresponding to three weeks of lab work, and worth 10% of the final grade. Lab reports are to be handed in online and are due 1 week after the third laboratory session for each lab, or on the last day of classes, whichever is earlier.

Students who miss the lab without a legitimate reason will receive a zero for the corresponding laboratory report. Students who miss a lab with academic consideration are required to contact the course instructor for further instructions. Failure to do so will result in a zero mark for that lab. A minimum mark of 50% in the total lab grade is required to pass the course.

Project: The course project will be completed in 4 steps, each one worth 5% of the final grade. Reports are to be submitted online. The deadlines for the four steps of the project will be announced on the course website. Project reports are expected to be completed individually. A minimum mark of 50% in the total project grade is required to pass the course.

Midterm Test: The midterm test will take place in October, during the regularly scheduled lecture hours. The midterm test will cover the material discussed in class up to that point. Duration: 1 hour 50 minutes. Closed book exam. Necessary equations are provided. No programmable calculators are allowed.

Final Examination: The final exam will be scheduled during the regular Fall term examination period in April. Duration: 3 hours. Closed book exam. Necessary equations are provided. No programmable calculators are allowed. To obtain a passing grade in the course, a mark of 50% or more must be achieved on the final examination. A final examination mark < 50% will result in a final course grade of 48% or less. (Check <https://studentservices.uwo.ca/secure/Exams/>)

Late Submission Policy: All lab reports and the project report are due by 11:59 PM on the specified due date. Late submissions will be penalized 10%. Submissions that are more than 3 days late will not be accepted.

Use of English: In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

Attendance: Any student who, in the opinion of the instructor, is absent too frequently from class, laboratory, or tutorial periods will be reported to the Dean (after due warning has been given). On the recommendation of the department, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

Absence Due to Illness or Other Circumstances: Students should immediately consult with the instructor or department Chair if they have any problems that could affect their performance in the course. Where appropriate, the problems should be documented (see the attached "Instructions for Students Unable to Write Tests or Examinations or Submit Assignments as Scheduled"). The student should seek advice from the instructor or department Chair regarding how best to deal with the problem. Failure to notify the instructor or department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

For more information concerning medical accommodations, see the relevant section of the Academic Handbook:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf

For more information concerning accommodations for religious holidays, see the relevant section of the Academic Handbook:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

Academic Consideration for work worth less than 10% of the overall grade in the course: A student seeking academic consideration for any work worth less than 10% of the total course grade must contact the Dean's office and, if applicable, submit the relevant medical documentation to that office.

Missed Midterm Examinations: If a student misses a midterm examination, the exam will not be rescheduled. The student must follow the Instructions for Students Unable to Write Tests and provide documentation to their department within 24 hours of the missed test. The department will decide whether to allow the reweighting of the test, where reweighting means the marks normally allotted for the midterm will be added to the final exam. If no reasonable justification for missing the test can be found, then the student will receive a mark of zero for the test.

If a student is going to miss the midterm examination for religious reasons, they must inform the instructor in writing within 48 hours of the announcement of the exam date or they will be required to write the exam.

Course Delivery with Respect to the COVID-19 Pandemic: Although the intent is for this course to be delivered in-person, the changing COVID-19 landscape may necessitate some or all of the course to be delivered online, either synchronously (i.e., at the times indicated in the timetable) or asynchronously (e.g., posted on OWL for students to view at their convenience). The grading scheme will not change. Any assessments affected will be conducted online as determined by the course instructor.

When deemed necessary, tests and examinations in this course will be conducted using a remote proctoring service. By taking this course, you are consenting to the use of this software and acknowledge that you will be required to provide personal information (including some biometric data) and the session will be recorded. Completion of this course will require you to have a reliable internet connection and a device that meets the technical requirements for this service. More information about this remote proctoring service, including technical requirements, is available on Western's Remote Proctoring website at: <https://remoteproctoring.uwo.ca>.

Cheating and Plagiarism: Students must write their essays and assignments in their own words. Whenever students take an idea or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. University policy states that cheating, including plagiarism, is a scholastic offence. The commission of a scholastic offence is attended by academic penalties, which might include expulsion from the program. If you are caught cheating, there will be no second warning.

All required papers may be subject to submission for textual similarity review to commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted will be included as source documents on the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between the University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, in the relevant section of the Academic Handbook:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Use of Electronic Devices: Students may use laptops, tablet computers, or smart phones only to access the course OWL site during lectures and tutorials. Use of nonprogrammable calculators only is permitted during tests and examinations. No other electronic devices may be used at any time during lectures, tutorials, or examinations.

Policy on Repeating All Components of a Course: Students who are required to repeat an Engineering course must repeat all components of the course. No special permissions will be granted enabling a student to retain laboratory, assignment, or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted by the student for grading in subsequent years.

Internet and Electronic Mail: Students are responsible for regularly checking their Western e-mail and the course web site (<https://owl.uwo.ca/portal/>) and making themselves aware of any information that is posted about the course.

Accessibility: Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 519-661-2111 ext. 82147 for any specific question regarding an accommodation.

Support Services: Office of the Registrar, <http://www.registrar.uwo.ca/>
Student Development Centre, <http://www.sdc.uwo.ca/>
Engineering Undergraduate Services, <http://www.eng.uwo.ca/undergraduate/>
USC Student Support Services, <http://westernusc.ca/services/>

Students who are in emotional/mental distress should refer to Mental Health @ Western, http://www.health.uwo.ca/mental_health/, for a complete list of options about how to obtain help.

STATEMENT ON GENDER-BASED AND SEXUAL VIOLENCE

Western [is committed to reducing incidents of gender-based and sexual violence](#) and providing compassionate support to anyone who has gone through these traumatic events. If you have experienced gender-based or sexual violence (either recently or in the past), you will find information about support services for survivors, including emergency contacts, [here](#). To connect with a case manager or set up an appointment, please contact support@uwo.ca.

INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED

If, on medical or compassionate grounds, you are unable to write term tests or final examinations or complete course work by the due date, you should follow the instructions listed below. You should understand that academic relief will not be granted automatically on request. You must demonstrate to your department (or the Undergraduate Services Office) that there are compelling medical or compassionate grounds that can be documented before academic relief will be considered. Different regulations apply to term tests, final examinations and late assignments. Please read the instructions carefully.

A. GENERAL REGULATIONS & PROCEDURES

1. All first-year students will report to the Undergraduate Services Office by submitting the [Academic Consideration Request Form](#), for all instances.
2. If you are an upper year student and you are missing a test/assignment/lab or examination you will report the absence by submitting [Academic Consideration Request Form](#). Absences worth LESS THAN 10% of your mark, will be processed by your department office. If your course work is worth 10% OR MORE of your final grade, your request will be processed by the Undergraduate Services Office.
3. Check the course outline to see if the instructor has a policy for missed tests, examinations, late assignments or attendance.
4. Documentation must be provided as soon as possible. If no one is available in your department office or the Undergraduate Services Office, leave a message clearly stating your name & student number and reason for your call. The department telephone numbers are given at the end of these instructions.
5. If you decide to write a test or an examination you should be prepared to accept the mark you earn. Rewriting tests or examinations or having the value of a test or examination reweighted on a retroactive basis is not permitted.

B. TERM/MIDTERM TESTS

1. If you are in first year and you are unable to write a midterm/term test, contact the Undergraduate Services Office, SEB 2097 PRIOR to the scheduled date of the test.
2. If you are an upper year student and you are unable to write a midterm/term test, inform your instructor PRIOR to the scheduled date of the test and request relief through the [Academic Consideration Request Form](#). If the instructor is not available, leave a message for him/her at the department office. If the test is worth LESS THAN 10% of your mark, your request for relief will be processed by your department office. If the test is worth MORE THAN 10% of your final grade your request for relief will be processed by the Undergraduate Services Office.

3. Be prepared to attach supporting documentation to the Department Chair and/or the Undergraduate Services Office through the online form (see next page for information on documentation).
4. Discuss with the instructor if and when the test can be rescheduled. The approval of the Chair or the Undergraduate Services Office is required when rescheduling midterm/term tests.

C. FINAL EXAMINATIONS

1. If you are unable to write a final examination, contact the Undergraduate Services Office PRIOR TO THE SCHEDULED EXAMINATION TIME to report your absence using the [Academic Consideration Request Form](#) and request permission to write a Special Final Examination. If no one is available in the Undergraduate Services Office, leave a message clearly stating your name & student number.
2. Be prepared to provide the Undergraduate Services Office with supporting documentation (see next page for information on documentation) the next day, or as soon as possible (in cases where students are hospitalized). The following circumstances are not considered grounds for missing a final examination or requesting special examinations: common cold, headache, sleeping in, misreading timetable and travel arrangements.
3. In order to receive permission to write a Special Examination, you must obtain the approval of the Chair of the Department **and** the Associate Dean and in order to apply you must submit an "[Application for a Special Exam](#)" form. The Undergraduate Services Office will then notify the course instructor(s) and reschedule the examination on your behalf.

PLEASE NOTE: It is the student's responsibility to check the date, time and location of the Special Examination.

D. LATE ASSIGNMENTS

1. Advise the instructor if you are having problems completing the assignment on time (**prior** to the due date of the assignment).
2. Be prepared to submit the [Academic Consideration Request Form](#) and provide documentation if requested by the instructor (see reverse side for information on documentation).
3. If you are granted an extension, establish a due date. The approval of the Chair of your Department (or the Assistant Dean, First Year Studies, if you are in first year) is not required if assignments will be completed prior to the last day of classes.
4.
 - i) Extensions beyond the end of classes must have the consent of the instructor, the department Chair and the Associate Dean, Undergraduate Studies. Documentation is mandatory.
 - ii) A Recommendation of Incomplete Form must be filled out indicating the work to be completed and the date by which it is due. This form must be signed by the student, the instructor, the department Chair and the Associate Dean, Undergraduate Studies.

E. SHORT ABSENCES

If you miss a class due to a minor illness or other problem, check your course outlines for information regarding attendance requirements and make sure you are not missing a test, laboratory or assignment. Cover any readings and arrange to borrow notes from a classmate.

F. EXTENDED ABSENCES

If you are absent more than one week or if you get too far behind to catch up, you should consider reducing your workload by dropping one or more courses. (Note drop deadlines listed below). You are strongly encouraged to seek advice from your Academic Counsellor in the Undergraduate Services Office.

G. DOCUMENTATION

If you consulted an off-campus doctor or Student Health Services regarding your illness or personal problem, **you must provide the doctor with a Student Medical Certificate** to complete at the time of your visit and then bring it to the Department (or the Undergraduate Services Office). **This note must contain the following information: severity of illness, effect on academic studies and duration of absence. Regular doctor's notes will not be accepted; only the Student Medical Certificate will be accepted.**

In Case of Serious Illness of a Family Member: Provide a Student Medical Certificate to your family member's physician to complete and bring it to the Department (or the Undergraduate Services Office if you are in first year).

In Case of a Death: Obtain a copy of the death certificate or the notice provided by the funeral director's office. You must include your relationship to the deceased and bring it to the Department (or the Undergraduate Services Office if you are in first year).

For Other Extenuating Circumstances: If you are not sure what documentation to provide, ask the Departmental Office (or the Undergraduate Services Office if you are in first year) for direction.

Note: Forged notes and certificates will be dealt with severely. To submit a forged document is a scholastic offence (see below).

H. ACADEMIC CONCERNS

1. You need to know if your instructors have a policy on late penalties, missed tests, etc. This information may be included on the course outlines. If not, ask your instructor(s).
2. **You should also be aware of attendance requirements in some courses. You can be debarred from writing the final examination if your attendance is not satisfactory.**
3. If you are in academic difficulty, check out the minimum requirements for progression in the calendar. If in doubt, see your Academic Counsellor.

Calendar References: Check these regulations in your 2023 Western Academic Calendar available at www.westerncalendar.uwo.ca.

Absences Due to Illness:

https://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_135

Academic Accommodations for Students with Disabilities:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_10

Academic Accommodations for Religious or Holy Days:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_16

Course Withdrawals:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=6&SelectedCalendar=Live&ArchiveID=#Page_75

Examinations:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?PolicyCategoryID=5&command=showCategory&SelectedCalendar=Live&ArchiveID=#Page_78

Scheduling of Term Assignments:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=5&SelectedCalendar=Live&ArchiveID=#SubHeading_78

Scholastic Offences:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_20

Student Medical Certificate:

<https://www.eng.uwo.ca/files/undergraduate/student-medical-certificate.pdf>

Engineering Academic Regulations:

http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=4&SelectedCalendar=Live&ArchiveID=#Page_86

Note: These instructions apply to all students registered in the Faculty of Engineering regardless of whether the courses are offered by the Faculty of Engineering or other faculties in the University.

Add Deadlines:

First term half course (i.e. “A” or “F”)	September 15, 2023
Full courses and full-year half course (i.e. “E”, “Y” or no suffix)	September 15, 2023
Second term half course (i.e. “B” or “G”)	January 16, 2024

Drop Deadlines:

First term half course without penalty (i.e. “A” or “F”)	November 13, 2023
Full courses and full-year half courses without penalty (i.e. “E”, “Y” or no suffix)	November 30, 2023
Second term half or second term full course without penalty (i.e. “B” or “G”)	March 7, 2024

Contact Information:

Undergraduate Services Office: engugrad@uwo.ca	SEB 2097 Phone: 519-661-2130	E-mail:
Chemical & Green Process Engineering: cbeugrad@uwo.ca	TEB 477 Phone: 519-661-2131	E-mail:
Civil Engineering: civil@uwo.ca	SEB 3005 Phone: 519-661-2139	E-mail:
Computer, Electrical, Mechatronics Systems & Software Engineering ceugrad@uwo.ca	TEB 279 Phone: 519-661-3758	E-mail:
Integrated Engineering engceli@uwo.ca	ACEB 2410 Phone: 519-661-6725	E-mail:
Mechanical Engineering: mmeundergraduate@uwo.ca	SEB 3002 Phone: 519-661-4122	E-mail:

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