



# ENGG\*4460 Robotic Systems

01

Fall 2021

Section(s): C01

School of Engineering

Credit Weight: 0.50

Version 1.00 - September 08, 2021

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## 1 Course Details

### 1.1 Calendar Description

This course covers robot technology fundamentals, mathematical representation of kinematics, planning and execution of robot trajectories, introduction to robot languages, programming of robotic systems, different application domains for robots (e.g. assembly, manufacturing, medical, services, etc.), and robot sensors. The goal of this course is to provide students with a comprehensive background, approaches and skills to apply robotics technology to real world engineering applications and problems.

**Pre-Requisites:** ENGG\*1500, ENGG\*2400

### 1.2 Course Description

This course covers robot technology fundamentals, mathematical representation of kinematics, planning and execution of robot trajectories, introduction to robot languages, programming of robotic systems, different application domains for robots (e.g. assembly, manufacturing, medical, services, etc.), and robot sensors. The goal of this course is to provide students with a comprehensive background, approaches and skills to apply robotics technology to real world engineering applications and problems.

### 1.3 Timetable

Lectures:

Tuesday 04:00PM - 05:20PM AD-S, Room Virtual (check courselink for the link)

Thursday 04:00PM - 05:20PM AD-S, Room Virtual (check courselink for the link)

Laboratory:

Wednesday 11:30AM - 01:20PM RICH 2504

Wednesday 08:30AM - 10:20AM RICH 2504

Tuesday 01:30PM - 03:20PM RICH 2504

Thursday 10:00AM - 11:50AM RICH 2504  
 Friday 09:30AM - 11:20AM RICH 2504  
 Friday 12:30PM - 02:20PM RICH 2504

Tutorials:

Monday 07:00PM - 07:50PM AD-S Room Virtual (check courselink for the link)  
 Monday 06:00PM - 06:50PM AD-S Room Virtual (check courselink for the link)  
 Wednesday 07:00PM - 07:50PM AD-S Room Virtual (check courselink for the link)  
 Wednesday 06:00PM - 06:50PM AD-S Room Virtual (check courselink for the link)  
 Thursday 07:00PM - 7:50PM AD-S Room Virtual (check courselink for the link)

## 1.4 Final Exam

Friday Dec. 10, 2021 11:30AM - 01:30PM

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# 2 Instructional Support

## 2.1 Instructional Support Team

**Instructor:** Medhat Moussa Ph.D., P.Eng.  
**Email:** mmoussa@uoguelph.ca  
**Telephone:** +1-519-824-4120 x53425  
**Office:** THRN 1343  
**Office Hours:** TBA on Courselink or by appointment

**Lab Co-ordinator:** Kevin Dong  
**Email:** kdong@uoguelph.ca  
**Telephone:** +1-519-824-4120 x56455  
**Office:** RICH 2506

## 2.2 Teaching Assistants

**Teaching Assistant (GTA):** Evan Tollenaar  
**Email:** etollena@uoguelph.ca  
**Office Hours:** TBA on Courselink

**Teaching Assistant (GTA):** Alessandro Giuliano  
**Email:** agiulian@uoguelph.ca  
**Office Hours:** TBA on Courselink

**Teaching Assistant (GTA):** Andrew Newton  
**Email:** anewto03@uoguelph.ca  
**Office Hours:** TBA

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## 3 Learning Resources

### 3.1 Required Resources

**Course Website (Website)**

<https://courselink.uoguelph.ca>

Course material, news, announcements, and grades will be regularly posted to the ENGG\*4460 Courselink site. You are responsible for checking the site regularly.

**Webcam (Equipment)**

Assessments may be administered using the Respondus invigilation system which requires students to have a webcam.

**Introduction to Robotics Mechanics and Control (Textbook)**

J. J. Craig, 4th Edition, Pearson Prentice Hall, 2017.

### 3.2 Recommended Resources

**Robot Modeling and Control (Textbook)**

M. Spong, S. Hutchinson, and M. Vidyasagar, Wiley, 2006.

**Additional Materials (Other)**

Additional materials and articles will be posted on the website or during the lab

### 3.3 Additional Resources

**Lecture Information (Notes)**

Selected lecture notes will be posted on the course website.

**Lab Information (Other)**

The handouts for labs and tutorials will be given during the lab sections.

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## 4 Learning Outcomes

The course objective is to provide students a solid theoretical base for further studies in Robotics. The course will follow a traditional format for robot modeling and analysis starting with Kinematics and moving to trajectory and control.

### 4.1 Course Learning Outcomes

By the end of this course, you should be able to:

1. Achieve broad knowledge of current state of robotics technology and the interdisciplinary nature of robotics design and operation.
2. Describe various components of a robotics system from both a hardware and software perspective.
3. Operate safely a robotics arm using different coordinate frames.

4. Program a robotics arm to perform various operations.
5. know the robotics design process from forward kinematics to dynamics and control
6. Develop forward and inverse kinematics relations for simple and complex robots.
7. Analyze and formulate the effect of differential motions and forces using the Jacobian techniques.
8. Compute a trajectory plan of a robot arm given specific end-effector goals
9. Develop a complete dynamic equation of motion for all joints of a simplified manipulator using either the Lagrangian or Newton-Euler approaches.

## 4.2 Engineers Canada - Graduate Attributes (2018)

Successfully completing this course will contribute to the following:

| #   | Outcome                                                                           | Learning Outcome    |
|-----|-----------------------------------------------------------------------------------|---------------------|
| 1   | Knowledge Base                                                                    | 1, 2, 3, 5, 6, 7, 9 |
| 1.2 | Recall, describe and apply fundamental principles and concepts in natural science | 9                   |
| 1.3 | Recall, describe and apply fundamental engineering principles and concepts        | 9                   |
| 1.4 | Recall, describe and apply program-specific engineering principles and concepts   | 1, 2, 3, 5, 6, 7, 9 |
| 2   | Problem Analysis                                                                  | 6, 7, 8, 9          |
| 2.1 | Formulate a problem statement in engineering and non-engineering terminology      | 6, 7, 8             |
| 2.2 | Identify, organize and justify appropriate information, including assumptions     | 6, 7, 8             |
| 2.3 | Construct a conceptual framework and select an appropriate solution approach      | 6, 7, 9             |
| 2.4 | Execute an engineering solution                                                   | 9                   |
| 4   | Design                                                                            | 5                   |
| 4.1 | Describe design process used to develop design solution                           | 5                   |
| 5   | Use of Engineering Tools                                                          | 3, 4                |
| 5.1 | Select appropriate engineering tools from various alternatives                    | 3, 4                |
| 5.2 | Demonstrate proficiency in the application of selected engineering tools          | 3, 4                |

| #    | Outcome                                                                                                           | Learning Outcome |
|------|-------------------------------------------------------------------------------------------------------------------|------------------|
| 5.3  | Recognize limitations of selected engineering tools                                                               | 3, 4             |
| 9    | Impact of Engineering on Society and the Environment                                                              | 1                |
| 9.3  | Anticipate the positive and negative impacts of introducing innovative technologies to solve engineering problems | 1                |
| 12   | Life Long Learning                                                                                                | 1                |
| 12.1 | Identify personal career goals and opportunities for professional development                                     | 1                |

### 4.3 Relationships with other Courses & Labs

Previous Courses:

- ENGG\*1500: Solving systems of linear equations, matrix algebra, complex numbers

Follow-on Courses:

- The School is not offering any undergraduate advanced robotics course. Yet this course is part of the mechatronics stream for both Mechanical and ES&C students and as such other courses in mechatronics are complimentary to this course.

## 5 Teaching and Learning Activities

### 5.1 Lecture

#### Week 1

**Topics:** Course introduction and outline  
Fundamentals of Robotics

**Learning Outcome:** 1, 2

#### Week 2

**Topics:** Spatial Description and Transformations  
**Learning Outcome:** 5

|                          |                                                          |
|--------------------------|----------------------------------------------------------|
| <b>Week 3</b>            |                                                          |
| <b>Topics:</b>           | Forward Manipulator Kinematics                           |
| <b>Learning Outcome:</b> | 5, 6                                                     |
| <b>Week 4</b>            |                                                          |
| <b>Topics:</b>           | Forward Kinematics<br>Introduction to Inverse Kinematics |
| <b>Learning Outcome:</b> | 5, 6                                                     |
| <b>Week 5</b>            |                                                          |
| <b>Topics:</b>           | Inverse Manipulator Kinematics                           |
| <b>Learning Outcome:</b> | 5, 6                                                     |
| <b>Week 6</b>            |                                                          |
| <b>Topics:</b>           | Inverse Manipulator Kinematics                           |
| <b>Learning Outcome:</b> | 5, 6                                                     |
| <b>Week 7</b>            |                                                          |
| <b>Topics:</b>           | Jacobians: Velocities and Static Forces                  |
| <b>Learning Outcome:</b> | 7                                                        |
| <b>Week 8</b>            |                                                          |
| <b>Topics:</b>           | Trajectory Planning<br>Mid-term                          |
| <b>Learning Outcome:</b> | 8                                                        |
| <b>Week 9</b>            |                                                          |
| <b>Topics:</b>           | Manipulator Dynamics                                     |
| <b>Learning Outcome:</b> | 9                                                        |
| <b>Week 10</b>           |                                                          |
| <b>Topics:</b>           | Manipulator Dynamics                                     |
| <b>Learning Outcome:</b> | 9                                                        |
| <b>Week 11</b>           |                                                          |
| <b>Topics:</b>           | Manipulator Dynamics                                     |
| <b>Learning Outcome:</b> | 9                                                        |
| <b>Week 12</b>           |                                                          |
| <b>Topics:</b>           | Advanced topics                                          |

**Learning Outcome:** 1

## 5.2 Seminar

**Topics:** Tutorials will run twice a week in two hours sessions where the teaching assistant will solve practice problems with students. Students can enroll in either tutorial sessions. The following is an example of one section.

| Week  | Topic                                    |
|-------|------------------------------------------|
| 1     | No Tutorial                              |
| 2-3   | Tutorial 1 and 2                         |
| 4     | Tutorial 3                               |
| 5     | Tutorial 4                               |
| 6     | Tutorial 5                               |
| 7     | No Tutorials- preparing for mid-term     |
| 8     | Tutorial 6                               |
| 9     | Tutorial 7                               |
| 10-11 | Tutorial 8                               |
| 12    | No Tutorials - preparing for final exam. |

**Learning Outcome:** 5, 6, 7, 8

## 5.3 Lab

**Topics:** The following lab schedule and topics are tentative and may change in content, due dates, and format. Labs are arranged in rotations. Every 3 weeks the students in each section will study a different robotics cell rotating between the three cells in the lab. The following is an example of one section.

| Week | Topic                   |
|------|-------------------------|
| 1    | Safety Lab              |
| 2-4  | Lab rotation 1          |
| 5    | Holiday and study break |
| 6-8  | Lab rotation 2          |
| 9-11 | Lab rotation 3          |

**Learning Outcome:** 2, 3, 4

## 5.4 Other Important Dates

Thursday, September 9, 2021 - First day of class

Monday, October 11, 2021 - Holiday -- **No Classes Scheduled** -- Classes rescheduled to Friday, December 3

Tuesday, October 12, 2021 - Fall Study Break Day -- **No Classes Scheduled** -- classes rescheduled to Thursday, December 2

Monday, December 6, 2021: Final Examination commences

You can also refer to the undergraduate calendar for the semester's scheduled dates.

## 6 Assessments

### 6.1 Assessment Details

#### Quizzes (10%)

(Best two out of the three quizzes will count)

#### Quiz 1 (0%)

**Date:** Tue, Sep 28, 4:00 PM - 4:30 PM

**Learning Outcome:** 5, 5, 6, 6, 7, 7

#### Quiz 2 (0%)

**Date:** Thu, Oct 14, 4:00 PM - 4:30 PM

**Learning Outcome:** 5, 5, 6, 6, 7, 7

#### Quiz 3 (0%)

**Date:** Tue, Nov 16, 4:00 PM - 4:30 PM

**Learning Outcome:** 5, 5, 6, 6, 7, 7

#### Midterm Test (25%)

**Date:** Thu, Oct 28, 4:00 PM - 5:20 PM, TBA

**Learning Outcome:** 1, 2, 5, 6

#### Final Exam (50%)

**Date:** Tue, Dec 15, 8:30 AM - 11:00 AM

**Learning Outcome:** 1, 2, 5, 6, 7, 8

**Labs (15%)**

**Learning Outcome:** 3, 4

**Alternate Lab assessment (15%)**

The current plan for the labs is to be conducted face to face. However, if the University decided as a result of the COVID-19 pandemic to cancel face to face labs, then there will be an alternate assessment of the lab component. This assessment will be a group assessment using the same lab groups. The assessment will not require face to face interaction but will require remote interaction. It will take the form of a term-long small project. Additional details will be provided to class if this situation occurs.

Marks from completed lab assessments will be included in this alternate assessment depending on when the labs are canceled.

## 6.2 Course Grading Policies

**Missed Assessments:** If you are unable to meet an in-course requirement due to medical, psychological, or compassionate reasons, please email the course instructor. See the undergraduate calendar for information on regulations and procedures for Academic Consideration: <http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml>

**Accommodation of Religious Obligations:** If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor. See the undergraduate calendar for information on regulations and procedures for Academic Consideration of Religious Obligations: <http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml>

**Passing grade:** The passing grade in this course is 50%

**Missed tests:** If you miss a test (whether a quiz or midterm) due to grounds for granting academic consideration or religious accommodation, the weight of any missed test will be added to the final exam weight. If you miss a test for reasons that are not grounds for academic consideration, then you will get a zero for that test. There will be no makeup midterm or quizzes.

**Lab Work:** You must attend and complete all laboratories. If you miss a laboratory due to grounds for granting academic consideration or religious accommodation, arrangements must be made with the teaching assistant to complete a makeup lab. If you can't complete a lab due to a COVID 19 restriction, the mark for this lab will be dropped and the lab mark will be based on the completed labs. If you did not complete any lab, the weight of the labs missed will be added to the final exam weight. This is only applicable for COVID 19 related issues where a makeup lab is not possible.

**Late Lab Reports:** Late submissions of lab reports will be subject to the following penalty

policy.

- 25% will be deducted if the report is up to 24 hours late,
  - 50% will be deducted if the report is 24 to 48 hours late,
  - No reports will be accepted after 48 hours of the due date.
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## **7 School of Engineering Statements**

### **7.1 Instructor's Role and Responsibility to Students**

The instructor's role is to develop and deliver course material in ways that facilitate learning for a variety of students. Selected lecture notes will be made available to students on Courselink but these are not intended to be stand-alone course notes. Some written lecture notes will be presented only in class. During lectures, the instructor will expand and explain the content of notes and provide example problems that supplement posted notes. Scheduled classes will be the principal venue to provide information and feedback for tests and labs.

### **7.2 Students' Learning Responsibilities**

Students are expected to take advantage of the learning opportunities provided during lectures and lab sessions. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.

### **7.3 Lab Safety**

Safety is critically important to the School and is the responsibility of all members of the School: faculty, staff and students. As a student in a lab course you are responsible for taking all reasonable safety precautions and following the lab safety rules specific to the lab you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor, GTA or faculty responsible.

## **8 University Statements**

### **8.1 Email Communication**

As per university regulations, all students are required to check their e-mail account regularly: e-mail is the official route of communication between the University and its students.

### **8.2 When You Cannot Meet a Course Requirement**

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons please advise the course instructor (or designated person, such as a

teaching assistant) in writing, with your name, id#, and e-mail contact. The grounds for Academic Consideration are detailed in the Undergraduate and Graduate Calendars.

Undergraduate Calendar - Academic Consideration and Appeals

<https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml>

Graduate Calendar - Grounds for Academic Consideration

<https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml>

Associate Diploma Calendar - Academic Consideration, Appeals and Petitions

<https://www.uoguelph.ca/registrar/calendars/diploma/current/index.shtml>

### 8.3 Drop Date

Students will have until the last day of classes to drop courses without academic penalty. The deadline to drop two-semester courses will be the last day of classes in the second semester. This applies to all students (undergraduate, graduate and diploma) except for Doctor of Veterinary Medicine and Associate Diploma in Veterinary Technology (conventional and alternative delivery) students. The regulations and procedures for course registration are available in their respective Academic Calendars.

Undergraduate Calendar - Dropping Courses

<https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-drop.shtml>

Graduate Calendar - Registration Changes

<https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/genreg-reg-regchg.shtml>

Associate Diploma Calendar - Dropping Courses

<https://www.uoguelph.ca/registrar/calendars/diploma/current/c08/c08-drop.shtml>

### 8.4 Copies of Out-of-class Assignments

Keep paper and/or other reliable back-up copies of all out-of-class assignments: you may be asked to resubmit work at any time.

### 8.5 Accessibility

The University promotes the full participation of students who experience disabilities in their academic programs. To that end, the provision of academic accommodation is a shared responsibility between the University and the student.

When accommodations are needed, the student is required to first register with Student Accessibility Services (SAS). Documentation to substantiate the existence of a disability is required; however, interim accommodations may be possible while that process is underway.

Accommodations are available for both permanent and temporary disabilities. It should be noted that common illnesses such as a cold or the flu do not constitute a disability.

Use of the SAS Exam Centre requires students to book their exams at least 7 days in advance and not later than the 40th Class Day.

For Guelph students, information can be found on the SAS website  
<https://www.uoguelph.ca/sas>

For Ridgetown students, information can be found on the Ridgetown SAS website  
<https://www.ridgetownc.com/services/accessibilityservices.cfm>

## 8.6 Academic Integrity

The University of Guelph is committed to upholding the highest standards of academic integrity, and it is the responsibility of all members of the University community-faculty, staff, and students-to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff, and students have the responsibility of supporting an environment that encourages academic integrity. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

Undergraduate Calendar - Academic Misconduct  
<https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml>

Graduate Calendar - Academic Misconduct  
<https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml>

## 8.7 Recording of Materials

Presentations that are made in relation to course work - including lectures - cannot be recorded or copied without the permission of the presenter, whether the instructor, a student, or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

## 8.8 Resources

The Academic Calendars are the source of information about the University of Guelph's procedures, policies, and regulations that apply to undergraduate, graduate, and diploma programs.

Academic Calendars  
<https://www.uoguelph.ca/academics/calendars>

## 8.9 Disclaimer

Please note that the ongoing COVID-19 pandemic may necessitate a revision of the format of course offerings, changes in classroom protocols, and academic schedules. Any such changes will be announced via CourseLink and/or class email.

This includes on-campus scheduling during the semester, mid-terms and final examination schedules. All University-wide decisions will be posted on the COVID-19 website (<https://news.uoguelph.ca/2019-novel-coronavirus-information/>) and circulated by email.

## 8.10 Illness

Medical notes will not normally be required for singular instances of academic consideration, although students may be required to provide supporting documentation for multiple missed assessments or when involving a large part of a course (e.g.. final exam or major assignment).

## 8.11 Covid-19 Safety Protocols

For information on current safety protocols, follow these links:

- <https://news.uoguelph.ca/return-to-campusess/how-u-of-g-is-preparing-for-your-safe-return/>
- <https://news.uoguelph.ca/return-to-campusess/spaces/#ClassroomSpaces>

Please note, these guidelines may be updated as required in response to evolving University, Public Health or government directives.

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