INTRODUCTION TO PROCESS CONTROL WINTER 2024

CHE 341

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CLASS SCHEDULE

Section	Location	Time	Instructor(s)
CHE 341 001 *[LEC]*	E6 2024	Wednesdays 1:30 p.m. - 2:20 p.m. Mondays 1:30 p.m. - 3:20 p.m.	Joshua Pulsipher joshua.pulsipher@uwaterloo.ca
CHE 341 101 *[TUT]*		Wednesdays 2:30 p.m. - 3:20 p.m.	
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INSTRUCTOR & TA (TEACHING ASSISTANT) INFORMATION

Course Instructor

Joshua Pulsipher

Email: pulsipher@uwaterloo.ca

Office: E6-5008

Office hours: Fridays at 11:00 am - 12:00 pm in E6-5008

Teaching Assistant

Shayesteh Dolatabadi

Email: shayesteh.dolatabadi@uwaterloo.ca

Office: E6-3114

Office hours: Fridays at 1:30 - 2:20 pm in E6-4002

COURSE DESCRIPTION

> *Calendar Description for CHE 341*
>
> Laplace transform techniques. Proportional-integral-derivative control. Frequency response methods. Stability analysis. Controller tuning. Process control simulation and computer control systems. Process identification. [Offered: F, W]
>
> Prereq: Level at least 3B Chemical Engineering or Environmental Engineering

LEARNING OUTCOMES

By the end of this course students should be able to:

Understand the concepts of process control and its relation to industrial processes. [1c, 1d]
Develop basic process dynamic models from fundamental chemical engineering processing units. [2a, 2b]
Differentiate between the different process dynamics expected from chemical engineering processes. [1a]
Understand the concept of feedback in process control and the basic equipment/devices needed to perform basic feedback control for chemical engineering processes. [2a, 2c, 3c, 5a, 8b]
Design and tune basic feedback controllers (i.e. P, PI, PID) and understand the advantages and limitations of each controller. [1d, 2a, 2b, 3b, 4a, 4b, 5a, 5b, 5c, 6a, 6b, 7a, 7b]
Understand the basic concepts of advanced process control systems (e.g. cascade control, feed forward). [1d, 3b, 9a]
Develop the ability to use computer software to help describe and design control systems. [2b, 4c, 5a, 5b, 5c, 7c]
Comprehend the concept of process stability and predict the closed-loop behavior of simple control loops. [1a, 1d, 2c, 5c]
Understand (qualitatively) the role of valves and sensors in process control. [1c]
Model single-input-single-output (linear) dynamic systems in different representations (e.g., time-domain, Laplace domain, state-space) and describe the relative advantages/limitations of each. [1a, 1c, 2b]

The graduate attributes set by the Canadian Engineering Accreditation Board (CEAB) that map to these outcomes (e.g., 1a, 2b) are provided at https://uwaterloo.ca/chemical-engineering/sites/default/files/uploads/documents/ga-and-pi-updated.pdf (https://uwaterloo.ca/chemical-engineering/sites/default/files/uploads/documents/ga-and-pi-updated.pdf)

TENTATIVE COURSE SCHEDULE

This course is comprised of 3 core instructional modules that each conclude with a test. The remainder of the semester will be used for projects and advanced lecture topics. A tentative schedule is provided below which may be adjusted as necessary. A more detailed up-to-date schedule will be provided via Learn.

Module 1: Dynamic Modeling

Date	Label	Topic
8-Jan	Lectures 1-2	Course introduction; transient balances
10-Jan	Tutorial 1; Lecture 3	Python review; simulating dynamic models
15-Jan	Lectures 4-5	Linearizing balance equations; FOPDT models
17-Jan	Lecture 6; Tutorial 2	Parameter regression; test review
22-Jan	Test 1	Test on Module 1

Module 2: Controller Design

Date	Label	Topic
24-Jan	Lectures 7-8	Control design; P-only controllers
29-Jan	Lecture 9; Tutorial 3	PI controllers; level control case study
31-Jan	Lecture 10; Tutorial 4	PID controllers; nonlinear system control case study
5-Feb	Lectures 11-12	Valve design; disturbances
7-Feb	Lecture 13; Tutorial 5	Sensors; test review
12-Feb	Test 2	Test on Module 2

Temperature Control Lab

Date	Label	Topic
14-Feb	Lectures 14-15	TCLab introduction; temperature control

Module 3: Dynamic System Analysis

Date	Label	Topic
26-Feb	Lectures 16-17	Laplace transforms; transfer functions
28-Feb	Lecture 18; Tutorial 6	Stability analysis; transfer function examples
4-Mar	Lectures 19-20	SOPDT models; SOPDT parameter estimation
6-Mar	Lecture 21; Tutorial 7	State-space models; simulating higher-order systems
11-Mar	Lectures 22-23	Cascade control; feedforward control
13-Mar	Tutorials 8-9	Case studies; test review
18-Mar	Test 3	Test on Module 3

Course Project and Advanced Control Topics

Date	Label	Topic
21-Mar	Lecture 24; Tutorial 10	Control project introduction; introduction to Julia
25-Mar	Lectures 25-26	Introduction to optimization; constrained optimization
27-Mar	Lecture 27; Tutorial 11	Model predictive control; control project help session
1-Apr	Lecture 28; Tutorial 12	Introduction to machine learning; final exam review
3-Apr	--	Project presentations

Important Note: The lecture/tutorial on March 21st is on a Thursday instead of a Wednesday and will take place from 3:30 to 5:30 pm in E6-2024 (i.e., we are swapping lecture periods with ChE 331). Class on April 3rd will begin at 12:30 pm instead of 1:30 pm to have enough time for presentations.

Deliverable Scheduling

Deliverables will be scheduled via Learn and included in the up-to-date schedule. A short post-lecture review quiz will typically be due at 11:59 pm on the same day as the corresponding lecture/tutorial. Assignments will typically be due on Mondays at 1:30 pm. Tests will be taken in-person in the regular classroom with a 60 min time-limit unless otherwise notified. A comprehensive final examination will be taken in-person at time and place determined by the university.

TEXTS / MATERIALS

Title / Name	Notes / Comments	Required
TCLab Temperature Control Lab	https://www.amazon.com/TCLab-Temperature-Control-Lab/dp/B07GMFWMRY	Yes

The TCLab will be used for most assignments and will be needed to complete the temperature control lab. Multiple students are allowed to share a single TCLab. A limited number of TCLabs will be available for check out from Prof. Pulsipher for those that are unable to purchase their own unit; however, these will only be available on a first-come-first-serve basis. Students are highly encouraged to purchase their own unit.

Students are also strongly encouraged to bring a laptop to class to participate in exercises/tutorials that frequently involve computer programming.

STUDENT ASSESSMENT

Component	Value
Assignments and Quizzes	10%
Temperature Control Lab Written Report	10%
Tests 1-3	35%
Project Written and Oral Report	20%
Final Exam	25%

- You must pass the final exam with at least 50% to pass this class. If your final exam score is <50%, then it will replace your overall score grade.
- Attendance to lectures and tutorials is mandatory. Please email the instructor if cannot make due to extenuating circumstances.
- All assignments and reports will be submitted electronically via Learn.
- Late submissions for any deliverable will not be accepted. If you cannot submit due to extenuating circumstances (as outlined below by administrative policy and university policy), then the weight for that deliverable (e.g., assignment, test) will be distributed over the remaining deliverables in the same category. If there are no remaining deliverables the weight will be moved to the final exam.
- For quizzes, the lowest two scores will be dropped and each quiz can be attempted twice.

ASSIGNMENT SCREENING

No assignment screening will be used in this course.

ADMINISTRATIVE POLICY

GENERATIVE AI

Generative artificial intelligence (GenAI) trained using large language models (LLM) or other methods to produce text, images, music, or code, like Chat GPT, DALL-E, or GitHub CoPilot, may be used in this course with proper documentation, citation, and acknowledgement. Permitted uses of and expectations for using GenAI will discussed in class and outlined on assignment instructions.

Recommendations for how to cite generative AI in student work at the University of Waterloo may be found through the Library: https://subjectguides.uwaterloo.ca/chatgpt_generative_ai (https://subjectguides.uwaterloo.ca/chatgpt_generative_ai) . Please be aware that generative AI is known to falsify references to other work and may fabricate facts and inaccurately express ideas. GenAI generates content based on the input of other human authors and may therefore contain inaccuracies or reflect biases.

In addition, you should be aware that the legal/copyright status of generative AI inputs and outputs is unclear. Exercise caution when using large portions of content from AI sources, especially images. More information is available from the Copyright Advisory Committee: https://uwaterloo.ca/copyright-at-waterloo/teaching/generative-artificial-intelligence (https://uwaterloo.ca/copyright-at-waterloo/teaching/generative-artificial-intelligence)

You are accountable for the content and accuracy of all work you submit in this class, including any supported by generative AI.

Faculty of Engineering Guiding Practices.

Territorial Acknowledgement. The University of Waterloo acknowledges that much of our work takes place on the traditional territory of the Neutral, Anishinaabeg and Haudenosaunee peoples. Our main campus is situated on the Haldimand Tract, the land granted to the Six Nations that includes six miles on each side of the Grand River. Our active work toward reconciliation takes place across our campuses through research, learning, teaching, and community building, and is centralized within the Office of Indigenous Relations (https://uwaterloo.ca/indigenous) .

Inclusive Teaching-Learning Spaces: The University of Waterloo values the diverse and intersectional identities of its students, faculty, and staff. The University regards equity and diversity as an integral part of academic excellence and is committed to accessibility for all. We consider our classrooms, online learning, and community spaces to be places where we all will be treated with respect, dignity, and consideration. We welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. We are all expected to contribute to a respectful, welcoming, and inclusive teaching- learning environment. Any member of the campus community who has experienced discrimination at the University is encouraged to seek guidance from the Office of Equity, Diversity, Inclusion & Anti-racism (EDI-R) (https://uwaterloo.ca/equity-diversity-inclusion-anti-racism/) via email at equity@uwaterloo.ca (mailto:equity@uwaterloo.ca) . Sexual Violence Prevention & Response Office (SVPRO) (https://uwaterloo.ca/sexual-violence-prevention-response-office) , supports students at UWaterloo who have experienced, or have been impacted by, sexual violence and gender-based violence. This includes those who experienced harm, those who are supporting others who experienced harm. SVPRO can be contacted at svpro@uwaterloo.ca (mailto:svpro@uwaterloo.ca)

Religious & Spiritual Observances: The University of Waterloo has a duty to accommodate religious and spiritual observances under the Ontario Human Rights Code. Please inform the instructor at the beginning of term if special accommodation needs to be made for religious observances that are not otherwise accounted for in the scheduling of classes and assignments. Consult with your instructor(s) within two weeks of the announcement of the due date for which accommodation is being sought.

Respectful Communication and Pronouns. Communications with Instructor(s) and TAs should be through recommended channels for the course (e.g., email, LEARN, Piazza, Teams, etc.) Please use your UW email address. Include an academic signature with your full name, program, student ID. We encourage you to include your pronouns to facilitate respectful communication (e.g., he/him; she/her; they/them). You can update your chosen/preferred name at WatIAM. (https://idm.uwaterloo.ca/watiam/) You can update your pronouns in Quest (https://uwaterloo.ca/quest/help/students/how-do-i/view-or-update-my-personal-information) .

Mental Health and Wellbeing Resources. If you are facing challenges impacting one or more courses, contact your academic advisor, Associate Chair Undergraduate, or the Director of your academic program. Mental health is a serious issue for everyone and can affect your ability to do your best work. We encourage you to seek out mental health and wellbeing support when needed. The Faculty of Engineering Wellness (https://uwaterloo.ca/engineering-wellness-program/) Program (https://uwaterloo.ca/engineering-wellness-program/) has programming and resources for undergraduate students. For counselling (individual or group) reach out to Campus Wellness and Counselling Services. (https://uwaterloo.ca/campus-wellness/counselling-services) Counselling Services is an inclusive, non-judgmental, and confidential space for anyone to seek support. They offer confidential counselling for a variety of areas including anxiety, stress management, depression, grief, substance use, sexuality, relationship issues, and much more.

Intellectual Property. Be aware that this course contains the intellectual property of their instructor, TA, and/or the University of Waterloo. Intellectual property includes items such as:

- Lecture content, spoken and written (and any audio/video recording thereof).
- Lecture handouts, presentations, and other materials prepared for the course (e.g., PowerPoint slides).
- Questions or solution sets from various types of assessments (e.g., assignments, quizzes, tests, final exams); and
- Work protected by copyright (e.g., any work authored by the instructor or TA or used by the instructor or TA with permission of the copyright owner).

Course materials and the intellectual property contained therein are used to enhance a student's educational experience. However, sharing this intellectual property without the intellectual property owner's permission is a violation of intellectual property rights. For this reason, it is necessary to ask the

instructor, TA and/or the University of Waterloo for permission before uploading and sharing the intellectual property of others online (e.g., to an online repository).

Permission from an instructor, TA or the University is also necessary before sharing the intellectual property of others from completed courses with students taking the same/similar courses in subsequent terms/years. In many cases, instructors might be happy to allow distribution of certain materials. However, doing so without expressed permission is considered a violation of intellectual property rights and academic integrity.

Please alert the instructor if you become aware of intellectual property belonging to others (past or present) circulating, either through the student body or online.

Continuity Plan - Fair Contingencies for Unforeseen Circumstances (e.g., resurgence of Covid). In the event of emergencies or highly unusual circumstances, the instructor will collaborate with the Department/Faculty to find reasonable and fair solutions that respect rights and workloads of students, staff, and faculty. This may include modifying content delivery, course topics and/or assessments and/or weight and/or deadlines with due and fair notice to students. Substantial changes after the first week of classes require the approval of the Associate Dean, Undergraduate Studies.

Declaring absences (undergraduate students and/or courses only): Regardless of the process used to declare an absence, students are responsible for reaching out to their instructors as soon as possible. The course instructor will determine how missed course components are accommodated. Self-declared absences (for COVID-19 and short-term absences up to 2 days) must be submitted through Quest (https://uwaterloo.ca/quest/help/students/how-do-i/self-declare-absence-undergraduate-students) . Absences requiring documentation (e.g., Verification of Illness Form, bereavement, etc.) are to be uploaded by completing the form on the VIF System (https://vif.uwaterloo.ca/) . The UW

Verification of Illness form (https://uwaterloo.ca/campus-wellness/health-services/student-medical-clinic/verification-illness-services) , completed by a health professional, is the only acceptable documentation for an absence due to illness. Do not send documentation to your advisor, course instructor, teaching assistant, or lab coordinator. Submission through the VIF System, once approved, will notify your instructors of your absence.

Rescheduling Co-op Interviews: Follow the co-op process for rescheduling co-op interviews (https://uwaterloo.ca/co-operative-education/find-your-co-op-job/find-job-waterlooworks/interview/interview-conflicts) for conflicts to graded assignments (e.g., midterms, tests, and final exams). Attendance at co-operative work-term employment interviews is not considered to be a valid reason to miss a test.

UNIVERSITY POLICY

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 (https://uwaterloo.ca/academic-integrity/) for more information.]

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4 (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70) . 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 their actions. [Check the Office of Academic Integrity (https://uwaterloo.ca/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 (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) . For typical penalties, check Guidelines for the Assessment of Penalties (https://uwaterloo.ca/secretariat/guidelines/guidelines-assessment-penalties) .

Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70) (other than a petition) or Policy 71, Student Discipline (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72, Student Appeals (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-72) .

Note for students with disabilities: AccessAbility Services (https://uwaterloo.ca/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.

Turnitin.com: Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit alternate assignment.