

Course Outline

1. COURSE INFORMATION

Session Offered	Winter 2024	
Course Name	Advanced Control Theory	
Course Code	PROCTECH 4CT3	
Date(s) and Time(s) of lectures	Lectures: Virtual Classroom Mo 2:30PM – 3:20PM Th 11:30AM - 1:20PM Labs: Classroom We 9:30AM - 10:20AM We 1:30PM - 2:20PM	
Program Name	Automation Engineering Technology	
Calendar Description	This course covers process characteristics, methods of analysis, controller design, adaptive control, loop tuning, process control improvement examples with emphasis on plant control and tutorial exercises using MATLAB.	
Instructor(s)	Ahmed AbouArkoub (C01, L01, L02)	E-Mail: arkouba@mcmaster.ca Office Hours & Location: by appointment

2. COURSE SPECIFICS

Course Description	This course covers concepts and principles used to analyze dynamical chemical processes, and to develop automatic control strategies to operate them safely and economically. Linearization and state space modelling for single and multivariable systems are covered. PID controller design and tuning methods are explained. Advanced single loop control methods, including cascade control, feedforward control, selective/override control, gain scheduling, are covered. Multivariable systems and loop pairing techniques are studied. Multivariable control methods and Model predictive control techniques are developed and simulated. MatLab, Simulink and the Control Toolbox will be used to analyze process control systems such as Level, Flow, Pressure, and Temperature control in steam drum, surge drum, and CSTR systems.		
Instruction Type	Code	Type	Hours per term
	C	Classroom instruction	39
	L	Laboratory, workshop or fieldwork	12
	T	Tutorial	
	DE	Distance education	
	Total Hours		51
Resources	ISBN	Textbook Title & Edition	Author & Publisher
	ISBN: 9781119285915 (Primary)	Process Dynamics and Control, 4E	Seborg, Edgar, Mellichamp, Doyle III Wiley
	ISBN: 9780071163576 (Secondary)	Process Control, 2E	Thomas Marlin
	Other Supplies	Source	
	Matlab, Control Tool Box & Simulink	www.mathworks.com Available for free for all McMaster Students	
Prerequisite(s)	PROCTECH 3CE3, 3CT3		

Corequisite(s)		
Antirequisite(s)		
Course Specific Policies	<p>Students will write 5 quizzes, where the best 4 out of 5 will be counted toward their final mark.</p> <p>Students will have one week after a lab experiment to submit their lab reports. The lab reports must be submitted within the first 15 minutes of the start of the subsequent lab session. The lab report may be submitted late at a penalty of 10% per day up to a maximum of 70% off, or seven days late. If a report is submitted after the seven day late period, the report will receive a mark of zero. One lab report will be submitted per group. Students that miss a lab will require an official exemption, i.e. MSAF, to avoid receiving a mark of zero. Otherwise, the lab may be omitted from the final lab mark, or a makeup lab session may be held if possible. Lab attendance is mandatory to receive marks for the lab reports.</p>	
Departmental Policies	<p>Students must maintain a GPA of 3.5/12 to continue in the program.</p> <p>In order to achieve the required learning objectives, on average, B.Tech. students can expect to do at least 3 hours of “out-of-class” work for every scheduled hour in class. “Out-of-class” work includes reading, research, assignments and preparation for tests and examinations.</p> <p>Where group work is indicated in the course outline, such collaborative work is mandatory.</p> <p>The use of cell phones, iPods, laptops and other personal electronic devices are prohibited from the classroom during the class time, unless the instructor makes an explicit exception.</p> <p>Announcements made in class or placed on Avenue are considered to have been communicated to all students including those individuals that are not in class.</p> <p>Instructor has the right to submit work to software to identify plagiarism.</p>	
3. SUB TOPIC(S)		
Week 1&2 08-01-2024	Introduction to Process Control Instrumentation. Process Models and Dynamic Behaviours.	Ch 1
Week 3 22-01-2024	Theoretical Models of Chemical Processes: General Modeling Principles, Material and Energy Balances, Dynamic Models of Processes	Ch 2
Week 4 29-01-2024	Theoretical Models of Chemical Processes General Modeling Principles, Material and Energy Balances, Dynamic Models of Processes	Ch 2
Week 5 05-02-2024	Linearization of nonlinear models	Ch 4.3
Week 6 12-02-2024	Dynamic Response Characteristics Processes with time delays, State-space and transfer function matrix models, Multiple-input multiple-output (MIMO) processes	Ch 6
Week 7	Dynamic Response Characteristics	Ch 6

26-02-2024	Review of first order, second order, system with inverse dynamics	
Week 8 04-03-2024	Review of PID Control Basic Control Modes, Integrator wind-up, digital implementation, Closed Loop Analysis	Ch 8, 11
Week 9 11-03-2024	PID Controller Design and Tuning Closed-Loop Oscillation-Based Tuning, Tuning Rules for FOPDT Processes, Direct Synthesis, IMC.	Ch 12
Week 10 18-03-2024	Enhanced Single-Loop Control Strategies Cascade Control, Time-Delay Compensation	Ch 16
Week 11 25-01-2024	Enhanced Single-Loop Control Strategies Selective Control/Override Systems, Split-Range Control, Gain Scheduling	Ch 16
Week 12 01-04-2024	Multivariable Control Analysis of Multivariable Control Systems, Design of Multivariable Control Systems	Ch 20
Week 13 & 14 08-04-2024	Final Exam Review & Project-Case Studies	
<p>Midterm Recess: Monday, February 19 to Sunday, February 25 Classes end: Wednesday, April 10 Final Examination Period: Friday, April 12 to Thursday, April 25 All examinations MUST be written during the scheduled examination period.</p>		
List of experiments		
Lab 1 10-01-2024	Matlab Review	
Lab 2 17-01-2024	Simulink Review	
Lab 3 24-01-2024	Using Simulink to simulate nonlinear dynamical systems	
Lab 4 31-01-2024	Isothermal Chemical Reactor Simulation	
Lab 5 07-02-2024	PID Controller tuning for an Isothermal Chemical Reactor	
Lab 6 14-02-2024	Ziegler-Nichols PID Tuning	
Lab 7 28-02-2024	Lab Review	
Lab 8 06-03-2024	Lab Test	
Lab 9 13-03-2024	Project	
Lab 10 20-03-2024	Project	
Lab 11 27-03-2024	Project	

Lab 12 03-03-2024	Open lab
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Note that this structure represents a plan and is subject to adjustment term by term. The instructor and the University reserve the right to modify elements of the course during the term. The University may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes.

4. ASSESSMENT OF LEARNING *including dates*	Weight
Quizzes	10%
Class Participation	5%
Class Project (week Mar 13 th , 2024)	10%
Lab-Reports	10%
Lab test (week Mar 6 th , 2024)	5%
Mid-term Test(s) (week Mar 4 th , 2024)	25%
Final examination (cumulative knowledge, 12-04-2024)	35%
TOTAL	100%

Percentage grades will be converted to letter grades and grade points per the University calendar.

5. LEARNING OUTCOMES
1. Develop fundamental models in process control systems engineering.
2. Study the steady state solution and linearization to form state space models
3. Explain model based control for improved control performance, based on internal model control (IMC), and convert internal model control to a classical feedback (PID) controller.
4. Understand the widely used cascade, feed-forward and ratio control loop strategies to improve control loop performance, either due to poor tuning or change in process due to nonlinearity.
5. Determine the basic strategies for design and implementation of multivariable controllers, perform matrix transfer function block diagram and understand the order of multiplications.
6. Understand the control and optimization hierarchy – that important operation and decisions at different corporate levels are made on different timescales.
7. Develop an appreciation for some of the complexities of plant-wide control, and understand the control strategies associated with equipment/unit operations that are part of a typical chemical process plant.

6. COURSE OUTLINE – APPROVED ADVISORY STATEMENTS

ANTI-DISCRIMINATION

The Faculty of Engineering is concerned with ensuring an environment that is free of all discrimination. If there is a problem, individuals are reminded that they should contact the Department Chair, the Sexual Harassment Officer or the Human Rights Consultant, as soon as possible.

http://www.mcmaster.ca/policy/General/HR/Discrimination_Harassment_Sexual_Harassment-Prevention&Response.pdf

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. It is your responsibility to understand what constitutes academic dishonesty.

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: “Grade of F assigned for academic dishonesty”), and/or

suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at <https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/>

The following illustrates only three forms of academic dishonesty: The following illustrates only three forms of academic dishonesty:

- plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
- improper collaboration in group work.
- copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

ONLINE PROCTORING

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

COMMUNICATIONS

It is the student's responsibility to:

- Maintain current contact information with the University, including address, phone numbers, and emergency contact information.
- Use the University provided e-mail address or maintain a valid forwarding e-mail address.
- Regularly check the official University communications channels. Official University communications are considered received if sent by postal mail, by fax, or by e-mail to the student's designated primary e-mail account via their @mcmaster.ca alias.
- Accept that forwarded e-mails may be lost and that e-mail is considered received if sent via the student's @mcmaster.ca alias.
- Check the McMaster/Avenue email and course websites on a regular basis during the term.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the “Code”). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, whether in person or online.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students’ access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University’s Academic Accommodation of Students with Disabilities policy.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar “Requests for Relief for Missed Academic Term Work”.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office normally within 10 working days of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests. <http://www.mcmaster.ca/policy/Students-AcademicStudies/Studentcode.pdf>

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, including lectures by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.