CHEM ENG 4E03/6E03
Modern Methods for Process Control

Course outline, Fall 2026

Administrative details

Mode of instruction

- Instruction is primarily based on in-person lectures, including in-class discussions and workshop-style exercises. Lectures will also have automatic echo360 recordings that will expire after 2 weeks.
- Office hours will be held as video chats in Microsoft Teams.
- Masking is encouraged, and lectures may switch to Microsoft Teams in an emergency.
- All critical communication about deadlines etc. will be posted as "announcements" in Avenue to Learn. Please check the course's Avenue page daily for announcements.

Instructor

Dr. Kamil A. Khan (he/him); (kamilkhan@mcmaster.ca)

Office: JHE 202
Teams ID: khank11

Lecture times, TAs, and office hours

Included in a syllabus addendum in Avenue.

Description

This course aims to address the design and analysis of discrete–time control laws that are predominantly model-based and suitable for implementation on digital computers, and to provide a broad foundation for further independent or graduate study in process control.

After completing this course, the student should be able to:

- Develop useful linear control models (in continuous time or discrete time, and from first principles or from empirical data) to describe the behaviour of real-world process systems.
- Characterize the open-loop response behaviour of multiple-input multiple-output (MIMO) linear time-invariant control systems, and design appropriate controllers.
- Understand and simulate differential-algebraic equation (DAE) models that are prevalent in real-world chemical engineering.
- Gain a comprehensive understanding of model-predictive control (MPC): the most common control strategy in the chemical process industry for handling systems that are MIMO and/or physically constrained, and for handling planned changes in set point.
- Understand how modern control methods are tailored toward the particular strengths and capabilities of computers.
- Implement relevant algorithms and methods in MATLAB.
- Understand and discuss the theoretical justifications underlying covered techniques; these will typically involve aspects of linear algebra.

This course is associated with the following indicators of the Canadian Engineering Accrediation Board (CEAB):

- 1.1: Competence in mathematics
- 1.2: Competence in natural sciences
- 2.1: Identifies and states reasonable assupmtions and suitable engineering fundamentals, before proposing a solution path to a problem
- 2.2: Proposes problem solutions supported by substantiated reasoning, recognizing the limitations of the solutions
- 4.2: Explores a breadth of potential solutions, considering their benefits and tradeoffs as they relate to the project requirements
- 4.3: Develops models/prototypes, tests, evaluates, and iterates as appropriate
- 5.1: Evaluates engineering tools, identifies their limitations, and selects, adapts, or extends them appropriately
- 5.2: Successfully uses engineering tools

Prerequisites

The only formal prerequisite for this class is CHEMENG 3P04 (Process Control). The world of process control beyond 3P04 is heavily rooted in mathematics, and this class will involve linear algebra and vector calculus.

Course assessment

Final grade breakdown

	% of final grade
Assignments	20
Midterm exam #1	20
Term project	20
In-class tutorials	5
Final exam	35

- If any MSAF is approved, then that work's weight will be transferred to the final exam.
- Final course grades may be adjusted at the discretion of the instructor.

Tests and exam

- There will be a midterm test and a final exam; time and date TBD.
- A "McMaster standard calculator" may be used in each test/exam.
- The test/exam are "closed book", with a formula sheet attached (and maintained on Avenue). In addition, one double-sided sheet of prepared notes is permitted in the midterm, and two double-sided sheets are permitted in the final exam.
- The final exam tests cumulative knowledge.

Assignments

There will be 4 or 5 assignments given throughout the semester. Your lowest-scoring assignment (*after* any MSAFs have been considered) will not count toward your final grade. Several assignment problems will involve coding in MATLAB.

Assignments must be prepared a certain way, and submitted through Avenue. Please refer to the Assignment Policy (posted in Avenue) for details regarding submission, grading, and collaboration. Late assignment submissions will receive the following penalties:

- -20 percentage points if they are one day late,
- -50 percentage points if they are two days late,
- and they will not be accepted or graded after that.

Course project

A course project will be assigned after the midterm recess, with a written report and short oral presentation due in the last week of classes. The project is to be carried out in groups of 3 or 4, and will have both a research component and an implementation component.

A list of topic suggestions will be provided, and grading rubrics will be posted for the report and presentation. The instructor and/or TAs will check in on the progress of each group. Each student will submit a confidential project contribution assessment form.

If the project makes use of any external references/sources, then those must be cited correctly in the report, in any reasonable citation style.

In-class tutorials

Some in-class work will be collected and graded as tutorials, due at the end of the relevant lecture (except for an excused absence). Any good-faith attempt at a lecture's tutorial will be awarded full points for that tutorial; the "tutorial" grade is essentially a participation grade.

Materials & fees

- No textbooks are required for this class; lecture slides will be posted to Avenue as `.pdf` files (typically a couple of days before the relevant lectures), and slides annotated in-class will be posted afterwards (typically the day after a lecture).
- The following texts may nevertheless be helpful:
  - Bequette, B.W., Process Control. *Modeling, Design and Simulation*, Prentice-Hall, 2003.
  - Brosilow, C. and B. Joseph, *Techniques of Model-Based Control*, Prentice-Hall, 2002.
  - Lee, J.H., Kaisare, N.S., and García, C.E., *Model Predictive Control: Fundamentals and Practice*, Wiley, 2026.
  - Maciejowski, J.M., *Predictive Control with Constraints*, Prentice Hall, 2002.
  - Marlin, T.E., *Process Control: Designing Processes and Control Systems for Dynamic Performance*, 2nd Edn., 2000. Tom Marlin has made this book freely available at http://pc-textbook.mcmaster.ca.
  - Ogunnaike, B. and H. Ray, *Process Dynamics, Modeling, and Control*, Oxford University Press, London, 1994
  - Seborg, D., T. Edgar, and D. Mellichamp, *Process Dynamics and Control*, Wiley, New York, 1989 (and later editions)
  - and any introductory books on linear algebra or vector calculus.
- It is recommended (but not required) to use a personal laptop computer for the programming assignments in this course, and to bring it to each lecture. The cluster computers in JHE may also be used for assignments and the project.
- The midterm/final exams will require a McMaster standard scientific calculator.

Provisional course outline

[Approximate numbers of lectures in square brackets]

0. Introduction [1]
1. Linearity [2]
2. Dynamic models [3]
    - Components of dynamic models
    - Continuous–time representations
    - Linearization
    - Discrete–time representations
    - Continuous-to-discrete translation
3. Frequency domain analysis [4]
    - Laplace transforms and transfer functions
    - z–transforms and pulse transfer functions
    - Open-loop stability and dynamic response
4. Model identification [5]
    - Components of optimization problems
    - Quadratic functions of many variables
    - Least-squares formulation for model identification
    - Handling deadtime
    - Input test signal and data pre-processing
5. Feedback control for continuous– and discrete–time models [8]
    - Closed-loop transfer functions
    - Closed-loop stability and internal stability
    - Controller design by direct synthesis
6. More about dynamic models [4]
    - Manipulating ODE models
    - Differential-algebraic equations (DAEs)
7. Model Predictive Control (MPC) [9]
    - Formulation
    - Implementation
    - Closed–loop properties

Approved advisory statements

An excerpt from McMaster's Undergraduate Course Management Policy is attached as the final three pages of this document. The remainder of that policy applies as well.

Additional statements

AI policy

Students are not permitted to use generative AI in this course, except when explicitly permitted in writing by the instructor. In alignment with McMaster's academic integrity policy, it "shall be an offence knowingly to ... submit academic work for assessment that was purchased or acquired from another source". This includes work created by generative AI tools. Also stated in the policy is the following: "Contract Cheating is the act of "outsourcing of student work to third parties" (Lancaster & Clarke, 2016, p. 639) with or without payment." Using Generative AI tools is a form of contract cheating. Charges of academic dishonesty will be brought forward to the Office of Academic Integrity.

At certain points in the course it may make sense to modify the schedule. The instructor may modify elements of the course and will notify students accordingly (in class, and as an announcement in the course's Avenue page).

The P.R.O.C.E.S.S.

As some of you may already be aware, the department of Chemical Engineering has a storied history of education. In addition to teaching and learning, the department is proud of our graduates not only for their academic success, but their more intrinsic traits that make them respected members of the engineering community.

Recently, several high-ranking graduates from the McMaster Chemical Engineering Program employed in various industries were interviewed to ask what traits they look for when hiring for engineering positions. Using this information, the department would like to present to you the *PROCESS*: a code of conduct that we hope will guide our students throughout this program and their careers to come.

- Professionalism
- Responsibility
- Ownership
- Curiosity
- Empathy
- Selflessness
- Service

It is up to YOU to interpret these traits and apply them to your time at McMaster and your career as you see fit. These traits will not be assessed for grades but will be strongly encouraged throughout your time at McMaster. We hope that you identify with these character traits and what they mean to you, and that you *trust the process*.

COURSE OUTLINE – APPROVED ADVISORY STATEMENTS

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:

- 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. Avenue to Learn, 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, 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.

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 mailto:sas@mcmaster.cato 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

In the event of an absence for medical or other reasons, students should review and follow the *Policy on Requests for Relief for Missed Academic Term Work*.[3]

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.

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.

[3] Updated to the *Policy on Requests for Relief for Missed Academic Term Work* effective May 1, 2021

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, Avenue to Learn and/or McMaster email.