Bachelor of Technology Partnership

Course Outline

1. COURSE INFORMATION

Session Offered	Winter 2017	
Course Name	Control Theory II	
Course Code	PROC TECH 4CT3	
Date(s) and Time(s) of lectures	Tuesday 2:30-3:30pm (Jan4th to April 6th) Thursday 3:30 to 5:30pm (Jan4th to April 6th)	
Program Name	Process :Automation 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	E-Mail: arkouba@mcmaster.ca Office Hours & Location: Wed. 10:30 to 11:30

2. COURSE SPECIFICS

Course Description

Instruction Type

Code	Type	Hours per term
C	Classroom instruction	36
L	Laboratory, workshop or fieldwork	8
T	Tutorial	8
DE	Distance education	
	Total Hours	52

Resources

ISBN	Textbook Title & Edition	Author & Publisher
0-13-353640-8	Process Control: Modeling, Design and Simulation	B. Wayne Bequette.

Other Supplies	Source
Matlab, Control Tool Box & Simulink Programs	www.mathworks.com

Prerequisite(s)	PROCTECH 3CE3, 3CT3
Corequisite(s)	
Antirequisite(s)	
Course Specific Policies	
Departmental Policies	Students must maintain a GPA of 3.5/12 to continue in the program. 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. Where group work is indicated in the course outline, such collaborative work is mandatory. 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. 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.

	Instructor has the right to submit work to software to identify plagiarism.	
3. SUB TOPIC(S)		
Week 1	**Introduction.** Instrumentation. Process Models and Dynamic Behaviours.	Student Exercises. (Ch#1)
Week 2	**Fundamental Models-Part I.** Background. Process Balance Equations. Material Balances. Constitutive Relationships. Material and Energy Balances. Form of Linear Dynamic Models.	Models and Deviation Variables. (Ch#2) Student Exercises. Module 5.1-5.4. Isothermal Chemical Reactor.
Week 3	**Fundamental Models-Part II.** Background. Process Balance Equations. Material Balances. Constitutive Relationships. Material and Energy Balances. Form of Dynamic Models.	(Ch#2) Module 8. CSTR.
Week 4	**Fundamental Models,** Linear and non Linear Models and Deviation Variables. **Empirical Models.** Introduction. First-Order + Dead Time. Integrator + Dead Time. Discrete-Time Autoregressive Models. Parameter Estimation. Discrete Step and Impulse Response Models. (Ch#4). PID Controller Algorithms. Routh Stability Criterion. Effect of Tuning Parameters. Response to Disturbances. (Ch#5)	(Ch#4) & (Ch#5)
Week 5	**Dynamic Behaviour.** Background. Linear State Space Models. Review First-Order Behaviour. Integrating System. Second-Order Behaviour. Lead-Lag Behaviour. Poles and Zeros. Processes with Dead Time. Converting State Space Models to Transfer Functions. (Ch#3) **PID Controller Tuning.** Introduction. Closed-Loop Oscillation-Based Tuning. Tuning Rules for First-Order + Dead Time Processes. Direct Synthesis. (Ch#6)	(Ch#3) & (Ch#6)
Week 6	**Internal Model Control.** Introduction to Model-Based Control. Practical Open-Loop Controller Design. Generalization of the Open- Loop Control Design Procedure. Model Uncertainty and Disturbances. Development of the IMC Structure. IMC Background. The IMC Structure. The IMC Design Procedure. Effect of Model Uncertainty and Disturbances. Improved Disturbance Rejection Design. Manipulated Variable Saturation. (Ch#8)	(Ch#8) Module 5.5. Isothermal Chemical Reactor.
Mid-term Recess: Monday, February 20 to Sunday, February 26, 2017		
Week 7	**Project-Part I,**	
Week 7 and 8	**The IMC-Based PID Procedure.** Background. The Equivalent Feedback Form to IMC. IMC-Based Feedback Design for Delay-Free Processes. IMC-Based Feedback Design for Processes with Time Delay. Summary of IMC-Based PID Controller Design for Stable Processes. IMC-Based PID Controller Design for Unstable Processes.	(Ch#9)

Week 8	**Cascade and Feed-Forward Control.** **Ratio, Selective, and Split-Range Control.** . Background. Introduction to Cascade Control. Cascade-Control Analysis. Cascade-Control Design. Cascade IMC. Feed-Forward Control. Feed-Forward Controller Design (Ch#10). Anti-reset Windup. Auto-tuning Techniques. Nonlinear PID Control. Controller Parameter (Gain) Scheduling.	(Ch#10-12)
Week 9	**Control-Loop Interaction.** **Multivariable Control.** Introduction. Motivation. The General Pairing Problem. The Relative Gain Array. Properties and Application of the RGA. Return to the Motivating Example. RGA and Sensitivity. Using the RGA to Determine Variable Pairings. MATLAB RGA Function File. (Ch#13) Background. Zeros and Performance Limitations. Scaling Considerations. Directional Sensitivity and Operability. Block-Diagram Analysis. Decoupling. IMC. MATLAB tzero, svd, and LTI Functions. (Ch#14)	(Ch#13 & 14)
Week 10	**Project-Part II**	
Week 10 and 11	**Plant-wide Control.** Background. Steady-State and Dynamic Effects of Recycle. Unit Operations Not Previously Covered. The Control and Optimization Hierarchy. Further Plant-wide Control Examples. (Ch#15)	(Ch#15)
Week 12	**Model Predictive Control.** Motivation. Optimization Problem. Dynamic Matrix Control. Constraints and Multivariable Systems. Other MPC Methods. MATLAB. (Ch#16) Student Exercises. Appendix 16.1: Derivation of the Step Response Formulation.	(Ch#16) Module 16.
Week 13	**Digital Control.** Quantitative methods for analyzing and designing discrete control system. Analysis of discrete systems, sampling data, stability, study state errors, transient response on the z-plane, Implementing a digital compensator.	Instructor Notes, Module 16. Digital Control.

Classes end: Thursday, April 6, 2017
Final examination period: Tuesday, April 11 to Thursday, April 27, 2016
All examinations MUST be written during the scheduled examination period.

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**
Assignments	10
Mid-term test1	20
Mid-term test2	20
Labs and Project	20
Final examination (tests cumulative knowledge)	30
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, focusing on the dynamic behaviours of linear systems.
3) Develop empirical models, including continuous and discrete transfer function models.
4) 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.
5) 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.
6) Determine the basic strategies for design and implementation of multivariable controllers, perform matrix transfer function block diagram and understand the order of multiplications.
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.
8) Understand the control and optimization hierarchy – that important operation and decisions at different corporate levels are made on different timescales.
9) Develop interactive digital control systems and study the effect of discretization on the control system dynamic performance.

6. POLICIES

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 required to exhibit honestly and use ethical behaviour in all aspects if the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity.

Academic dishonesty is to knowingly act of 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.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various kinds of academic dishonesty please refer to the Academic Integrity Policy, located at: http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf .

The following illustrates only three forms of academic dishonesty:

1. Plagiarism. E.g. the submission of work that is not own or for which other credit has been obtained
2. Improper collaboration in group work
3. Copying or using unauthorized aids in tests and examinations.

Requests for Relief for Missed Academic Term Work (Assignments, Mid-Terms, etc.)

The McMaster Student Absence Form is an on-line self-reporting tool for **Undergraduate Students** to report absences for:

1) Relief for missed academic work worth less than 25% of the final grade resulting from medical or personal situations lasting up to three calendar days:

- Students may submit a maximum of one academic work missed request per term. It is the responsibility of the student to follow up with instructors immediately (within the 3 day period that is specified in the MSAF) regarding the nature of the accommodation. All work due in that time period however can be covered by one MSAF.

2) MSAF cannot be used to meet religious obligation or celebration of an important religious holiday, for that has already been completed or attempted or to apply for relief for any final examination or its equivalent.

3) For medical or personal situations lasting more than three calendar days, and/or for missed academic work worth 25% or more of the final grade, and/or for any request for relief in a term where the MSAF has not been used previously in that term:

- Students must visit their Associate Dean's Office (Faculty Office) and provide supporting documentation.

E-Learning Policy

Consistent with the Bachelor of Technology's policy to utilize e-learning as a complement to traditional classroom instruction, students are expected to obtain appropriate passwords and accounts to access Avenue To Learn for this course. Materials will be posted by class for student download. It is expected that students will avail themselves of these materials prior to class. Students should be aware that, when they access the electronic components of this course, private information such as first and last names, user names for the McMaster e-mail account, and program affiliation may become apparent to all other students in the course. The available information is dependent on the technology used. Continuation in this course will be deemed consent to this disclosure. If you have any questions or concerns about this disclosure please discuss this with the course instructor. Avenue can be accessed via http://avenue.mcmaster.ca.

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.

Turnitin (Optional)

This course will be using a web-based service (Turnitin.com) to reveal plagiarism. Students submit their assignment/work electronically to Turnitin.com where it is checked against the internet, published works and Turnitin's database for similar or identical work. If Turnitin finds similar or identical work that has not been properly cited, a report is sent to the instructor showing the student's work and the original source. The instructor reviews what Turnitin has found and then determines if he/she thinks there is a problem with the work. Students who do not wish to submit their work to Turnitin.com must still submit a copy to the instructor. No penalty will be assigned to a student who does not submit work to Turnitin.com. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, etc.). To see the Turnitin.com Policy, please go to http://www.mcmaster.ca/academicintegrity/turnitin/students/

Protection of Privacy Act (FIPPA)

The Freedom of Information and Protection of Privacy Act (FIPPA) applies to universities. Instructors should take care to protect student names, student numbers, grades and all other personal information at all times. For example, the submission and return of assignments and posting of grades must be done in a manner that ensures confidentiality.

http://www.mcmaster.ca/univsec/fippa/fippa.cfm

Academic Accommodation of Students with Disabilities Policy

Students who require academic accommodation must contact Student Accessibility Services (SAS) to make arrangements with a Program Coordinator. Academic accommodations must be arranged for each term of study. Student Accessibility Services can be contacted by phone 905-525-9140 ext. 28652 or e-mail sas@mcmaster.ca. For further information consult McMaster's policy for Academic Accommodation of Students with Disabilities
http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicAccommodation-StudentsWithDisabilities.pdf

Students must forward a copy of the SAS accommodation to the instructor of each course and to the Program Administrator of the B.Tech. Program immediately upon receipt. If a student with a disability chooses NOT to take advantage of a SAS accommodation and chooses to sit for a regular exam, a petition for relief may not be filed after the examination is complete. http://sas.mcmaster.ca

Student Code of Conduct

The Student Code of Conduct (SCC) exists to promote the safety and security of all the students in the McMaster community and to encourage respect for others, their property and the laws of the land. McMaster University is a community which values mutual respect for the rights, responsibilities, dignity and well-being of others. The purpose of the Student Code of Conduct is to outline accepted standards of behavior that are harmonious with the goals and the well-being of the University community, and to define the procedures to be followed when students fail to meet the accepted standards of behavior. All students have the responsibility to familiarize themselves with the University regulations and the conduct expected of them while studying at McMaster University.
http://studentconduct.mcmaster.ca/student_code_of_conduct.html