CHBE 470: Process Dynamics and Control
Fall 2022

I. General Course Information

Your prior CHBE coursework has primarily focused on steady-state processes. However, in practice, processes usually are not steady state. For example, the temperature in your home or in a building is constantly fluctuating and depends on the temperature outdoors, the operation of the cooling system, and how many people are in the room. A continuous stirred reactor can experience fluctuations in the inlet flowrate of a chemical, which will produce fluctuations in the reaction rate, the concentration of product at the outlet, and potentially the reactor temperature. A control mechanism may be needed to reduce the magnitude of fluctuations and ensure safe operation.

There are many examples of chemical disasters caused by faulty or improperly applied control systems. In 2010, an explosion in the Deepwater oil rig in the Gulf of Mexico caused the largest marine oil spill in history. This explosion was caused, in part, by a faulty blowout preventer. We are still dealing with the consequences of this oil spill. In 2011, a tsunami and earthquake hit Japan, resulting in multiple nuclear meltdowns, explosions, and the contamination of the environment with radioactive material. The most severe nuclear incident in history the meltdown and explosion of the Chernobyl nuclear reactor in 1986. The entire city of Pripyat was evacuated and remains evacuated to this day due to severe radioactive contamination. The Chernobyl incident was recently documented in the HBO series Chernobyl, which described the failure in process control that led to the accident. The final trial scene of this series describes the failure in operation and process control that produced the disaster: https://www.youtube.com/watch?v=DDBkMIwb9Mk (full scene in a sequence of 3 videos).

Other examples of process control are all around us and important to our day-to-day lives. Our bodies and brains work hard to maintain homeostasis – that means there are sophisticated control mechanisms to control your body temperature, control appetite, when you feel sleepy, and how you feel emotionally. Drugs (caffeine, nicotine, cocaine, opioids, etc.) will both impact how you feel but also elicit a control response by your body and brain that counteracts the effect of the drug. Your body does this as a survival mechanism, but this response (with continued usage of the drug) can lead to significant withdrawal symptoms and/or dependency. Things we do every day without thinking (opening a door, walking up/down stairs, putting food in our mouths) involve sophisticated control mechanisms. If you don't believe me, take a look at these videos of Robots falling down: https://www.youtube.com/watch?v=g0TaYhjpOfo – it is very hard to build a robot that does the simple things we do every day because of the sophisticated control mechanisms our bodies are equipped with. Control can also involve large populations, such as controlling the spread of a disease, conservation efforts to support endangered species or remove invasive species. These are complex control problems because there are a large number of variables, and it can be difficult to correlate an output or result with a specific input.

Understanding the basics about process control and operation is critical to the safety and the proper operation of many engineering processes. This course will build on previous CHBE coursework and will emphasize process dynamics, which describes the responses of systems out of steady-state, and process control, which involves the implementation of automated control strategies for ensuring effective and safe operation of processes.

Class Time: 10:00 – 10:50 AM on Mondays, Wednesdays, and Fridays. The course will be taught face-to-face. Lecture notes will be shared and posted in Canvas.

Class Location: Keck 101. When necessary, we will meet via Zoom at the following link: https://riceuniversity.zoom.us/j/94045086932?pwd=ZU91S0RFQTUvRTZSNm1CV00ydzA5dz09

II. Teaching Staff

Prof. Rafael Verduzco, Office located in Keck Hall room 212. Phone: x 6492. Email: rafaelv@rice.edu. Prof. Verduzco will hold office hours immediately after class and by appointment.

Prof. Verduzco is a graduate from Rice (BS Chemical Engineering 2001) and the California Institute of Technology (PhD Chemical Engineering 2007). Prof. Verduzco has previously taught Thermodynamics, Heat and Mass Transfer, Polymer Chemistry, and specialty courses for both undergraduates and graduates. This is his second time teaching Process Control. Prof. Verduzco leads a laboratory focused on polymer science with a broad range of applications in energy, health, and remediation. More information about his research activities are available at polymers.rice.edu.

The best way to reach Prof. Verduzco is through email – he may respond very quickly (sometimes within seconds) and will almost always respond the same day. Prof. Verduzco has also created a Slack channel for discussing content related to the class. I will provide additional information about homework and exams through Slack, and I strongly recommend everyone join so you have the most up-do-date information. Here is the link to join: https://join.slack.com/t/ricechbe470/shared_invite/zt-1c6nvcykm-rXWFeeoSXOasqoxRfvEUKg

Yuge Feng (yf23@rice.edu) and Zhenyang Jia (zj12@rice.edu) are the TAs for the course. They will hold two TA sessions per week. One will be held on Wednesday at 6PM and the second on Thursday at 4PM, both in Keck Hall room 105.

III. Textbook and Resources

This course will utilize the textbook by Thomas Marlin: T. Marlin, *Process Control: Designing Processes and Control Systems for Dynamic Performance*, 2nd Edition, McGraw-Hill 2000.

This textbook is available **for free** through this website: http://pc-textbook.mcmaster.ca/ Prof. Marlin purchased the rights to the textbook and made it freely available to students and instructors. His website also has a number of additional useful resources.

IV. Course Website

Course content will be posted on Canvas (https://canvas.rice.edu/courses/52295). This site will be used to make announcements and post handouts, homework assignments, lecture notes, and grades. Zoom links for virtual class meetings are also available in Canvas. All students registered for the course should automatically have access to this site. Students that do not have access to the site should contact Prof. Verduzco for access.

V. Class Schedule (Tentative)

Lesson	Topic	Text
	DYNAMIC MODELLING	
1	Control Concepts	Ch. 1
2	Control Objectives and Benefits	Ch. 2
3	Dynamic System Model Formulation	Ch. 3.1 – 3.3
4	Degrees of Freedom and Linearization	Ch. 3.4 – 3.5
5	Laplace Transforms	Ch. 4.1 – 4.2
6	Transfer Function	Ch. 4.3
7	Block Diagrams	Ch. 4.4
8	Qualitative Dynamic Responses	Ch. 5.1 – 5.3
9	Empirical Model Identification	Ch. 6.1 – 6.3
	FEEDBACK CONTROL	
10	Process Control Objectives	Ch. 7
11	PID Controller Modes	Ch. 8
12	PID Controller Tuning	Ch. 9
13	Frequency Response	Ch. 4.5
14	Stability Analysis	Ch. 10.1 – 7, 10.9 (10.8 skim)
15	Digital Control Implementation	Ch. 11

VI. Additional Resources

Prof. Tom Marlin has created a website that contains a number of useful learning resources and supplements to the textbook and lectures: http://pc-education.mcmaster.ca/LearningSupport%20Page.htm

VII. Program Objectives and Student Outcomes

The learning objectives for this course include:

- Understanding the importance and basics of process control
- The ability to formulate and solve models for dynamic processes
- The ability to describe process dynamics using block diagrams
- An understanding of process control objectives
- The ability to design and optimize PID controllers for dynamic process
- An understanding of stability and frequency responses in dynamic systems and process control

The course will also satisfy the following CHBE student outcome and program objective:

SO 7 An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

VIII Grading

Grading will be determined based on your performance in homework assignments and exams. Homework assignments will be due on Fridays by 5PM. A grade scale will be used to determine your final letter grade. Note that the following scale is approximate and may be revised before the end of the semester:

		B+	87	C+	80		
A	93	B	85	C	77	D:	60
A-	90	B-	83	C-	70		

The table shows the minimum score you must obtain to get the corresponding grade. For example, if you finish with 86%, you will receive a B.

Tentative date for midterm exam: October 17.

IX. Honor Code Policy

Homework in this course is a valuable tool for helping you learn and retain the information taught in the course. You are encouraged to work together on the homework, but copying is not allowed. Each student will be responsible for turning in a copy of his or her own work. Any suspicion of honor code violations for homework, quizzes, or exams will be reported to the Rice Honor Council. Information about the Rice Honor System can be found at http://honor.rice.edu/

X. Accommodations

Any student with a documented disability seeking academic adjustments or accommodations is requested to speak with me during the first two weeks of class. Students with disabilities are also encouraged to contact disability support services (https://dss.rice.edu/) in the Allen Center, room 111.

XI. Responsible Employee Notification

Rice University cares about your wellbeing and safety. Rice encourages any student who has experienced an incident of harassment, pregnancy discrimination or gender discrimination or relationship, sexual, or other forms interpersonal violence to seek support from The SAFE Office.

At Rice University, unlawful discrimination in any form, including sexual misconduct, is prohibited under Rice Policy on Harassment and Sexual Harassment (Policy 830) and the Student Code of Conduct. As the instructor and a responsible employee, I am required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to the Title IX Coordinator on campus. Although responsible employees are required to make this notification, it is the student?s choice to pursue a formal complaint. The goal is to make sure that students are aware of the range of options available and have access to the resources when in need. For more information, please visit safe.rice.edu, titleix.rice.edu, or email titleixsupport@rice.edu.