Instrumentation and Process Control

University of Colorado – Department of Chemical Engineering
CHEN 4570 – Spring 2000

Instructor: Christine Hrenya
Office: 130 ECCH
Office phone: 492-7689

E-mail: hrenya@colorado.edu
Office Hours: Thursday 4-6 PM

TA's: Charlie Nuttelman (charles.nuttelman@colorado.edu) and Sherri Paulson (sherri.paulson@colorado.edu) will be responsible for grading weekly assignments, supervising laboratory periods, and grading lab reports. The TA's will *not* be holding office hours. If there are questions on course material, please contact Christine Hrenya via e-mail, office hours, or individual appointment. You can also stop by the office without an appointment, but I may have to postpone if that time is inconvenient.

Text: Seborg, D. E., T. F. Edgar, and D. A. Mellichamp, Process Dynamics and Control, Wiley, New York, 1989.

Supp.: Workshop Packet for CHEN 4570, available in CU bookstore

Email: A course e-mail list has been established, and all students are required to subscribe. To do so, send an e-mail message to listproc@lists.colorado.edu with the following contents in the body of the message:

subscribe chen-4570 full-name-of-student

Ftp: Lecture notes, homework solutions, and exam solutions will be posted on the course ftp site at ftp.colorado.edu, under the directory:

/ftp/cuboulder/courses/chen4570

Prereq: Introduction to Linear Algebra and Differential Equations (APPM 2360)

Background

The concepts and implementations of instrumentation and control pervade all chemical processes. In fact, they go well beyond chemical processes to manufacturing, research laboratories, anywhere measurements must be made and systems regulated. Instrumentation and control are essential to the operation of all modern processes.

Although many measurement principles and feedback control have been practiced for 2500 years or so, their scientific understanding has been built in the 20th Century. This understanding is an important element of your education, and the ability to put this understanding into practice is an important professional skill for the chemical engineer.

This course transforms mathematics and theory into practice. The idealisms of theory confront the realisms of actual systems. It is an interesting and compromising juxtaposition and is at the heart of what engineering is all about.

Course Content

The first segment of the course introduces the mathematics and modeling of the dynamic behavior of processes. Most control deals with regulation of the time-varying changes in processes; so dynamic behavior must be understood first. The mathematics underlying this segment is applied ordinary differential equations. Students' knowledge of ODE's is usually rusty, if existent; therefore, a review is indicated.

Control is then introduced, not in an abstract way, rather through the implements that are used in industry. This introduction is followed by a mathematical analysis of feedback control systems that provides the keys to designing these systems.

An important and traditional aspect of control systems is frequency response, characterizing the dynamic behavior of systems by how they respond to sinusoidal inputs of varying frequency. Although frequency response is already part of the background of electrical engineering students by the time they get to a course in control, that is not the case for chemical engineers. This topic is introduced and followed by the topics of feedforward, cascade and advanced control techniques. The focus with the latter is on methods that have found wide application in industry.

Topic	No. of Meetings
Introduction, Modeling, and Math Background	7
Process Dynamics	9
Controllers and Instrumentation	5
Feedback Control System Design	7
Frequency Response	9
Feedforward, Cascade & Time-delay Control	3
Logic, Sequence & PLC's	3
Course Evaluation	1
	44

Learning Goals

To learn the fundamentals of measurement for most process variables and how these measured quantities are transformed and transmitted. To learn the concepts of process control, including principles of feedback, stability, and feedforward. To apply these concepts to the design of instrumentation and control systems for typical chemical processes. To gain practice in the installation and adjustment of instrumentation and control systems, including analog and digital types.

Learning Activities

"Active" Lectures – meet every Monday, Wednesday and Friday at 10:00 – 10:50 in ITLL 1B50

- Classes will typically begin with 10-15 minutes of lecture. Lecture notes will be posted to the course ftp site by 12:00 AM on the day of class, and should be printed and brought to class by each student. Lectures will followed by in-class group exercises, during which the instructor will be available for help and guidance. This mode of instruction requires student participation and places a premium on class attendance and prompt arrival.

Laboratory – meet Monday or Wednesday at 2:00 – 4:50 in ITLL HP Plaza or in the ChE Undergraduate Laboratory (ECCH 1B70)

- Fourteen laboratory meetings are scheduled over the course of the semester, and attendance is mandatory:

  Rotation 1: 1/24 – 2/16 *theme*: *basic instrumentation and software* (assigned groups)

  4 labs: ⇨ build and test a simple op-amp circuit
  ⇨ LabVIEW 1: tutorial & signal I/O
  ⇨ Control Station tutorial and process characterization
  ⇨ thermocouple and thermistor calibration

  Rotation 2: 2/21 – 3/22 *theme: dynamic testing* (reassigned groups)

  5 labs: ⇨ build and test an op-amp instrumentation amplifier
  ⇨ LabVIEW 2: data acquisition, display & storage
  ⇨ Control Station: dynamic testing and controller tuning
  ⇨ dynamic testing of heat exchanger or valve apparatus
  ⇨ pulse testing of chemical reactor, CSTR and PFR

  Rotation 3: 4/2 – 5/3 *theme: controller tuning* (student-selected groups)

  5 labs: ⇨ CSTR temperature control or PFR temperature control
  ⇨ evaporator flow control or valve-position control
  ⇨ Control Station: cascade control
  ⇨ LabVIEW 3: heat exchanger temperature or fluids unit level
  ⇨ build and test voltage-to-current converter
- Each student will hand in his/her own bound laboratory notebook at the end of each laboratory period for grading. On the first page of the laboratory notebook, please indicate your name and laboratory session (Monday or Wednesday), and keep an index of the title/date/pages for each completed laboratory.

Homework

- Weekly assignments will be generally assigned/due on Friday, and are due at the beginning of class. Late homeworks will not be accepted since the solutions will be posted on the course ftp site the day which the homeworks are due.
- Students are encouraged to work in groups of up-to-3 individuals and hand in only one assignment per group, with the responsibility for individual learning residing with the group. Students may not claim credit for work they have not contributed to in a significant way -- this would be an ethical violation (see below). Group work means just that -- students must work together on all the problems of the assignment and not assign different problems to separate group members, only collecting the different efforts at the end.
- If it is believed that a homework set has been graded unfairly, please resubmit within one week to TA for re-grade of entire assignment.

Exams

- The exams will be given during a 2-hour period outside of the scheduled class time. All exams will be composed of two sections. The first section will be closed-book, and should take roughly 1/4 of the total exam time. The second portion of the exam will be open-everything (i.e., notes, homework, text, workshops,…)
- The exams will have problems similar to those on the homework assignments; therefore, students who have mastered the course material through the homework assignments will probably do quite well on the exams, and students who shortchange the homeworks with also come up short on the exams. The final exam will be comprehensive, covering the entire course material.
- No make-up exams will be given. If there is an extreme emergency, contact me *before* exam date for permission to be excused. If excused, the final exam grade will be used in place of the missed exam. If the final exam is excused, the grade on the previous exams will be averaged and used in

place of the final exam. If more than one exam is missed, an incomplete/fail will be given for the course.

- Exam solutions will be posted on the course ftp site after the exams are returned.
- If it is believed that an exam has been graded unfairly, please resubmit to instructor within one week for re-grade of entire exam.
- Important Dates:

Exam 1:	Thursday, Feb. 24	(7-9:00 PM, ECCR 200)
Exam 2:	Thursday, Apr. 6	(7-9:00 PM, ECCR 200)
Final Exam:	Wednesday, May 10	(10:30 AM – 1:00 PM, ITLL 1B50)

Grading

Final course grades will *not* be curved. Instead, the grade will be determined based on the distribution and scale shown below, with plus and minus grades assigned for scores near the cutoffs:

Homework	20%	A	85-100
Workshops	10%	B	75-85
Exam 1	15%	C	65-75
Exam 2	15%	D	55-65
Final Exam	20%	F	0-55
Laboratory	20%		

Deadlines and Late Work

As a general rule, late work is not accepted. Assignments are due at the beginning of class, and are late if handed in close to the end of class or thereafter. Workshop exercises are due at the end of the class period. Exceptions are made in the case of illness, only if proper documentation of the illness is provided. Arrangements should be made in advance in the case of trips out of town. Work will normally be due in advance of such trips. Labs cannot, generally, be made up.

Quality and Presentation of Written Work

Written work in this course must satisfy a quality standard. If it does not, it will be returned to the student ungraded and a zero grade will be recorded. Presentation must be neat and organized. Problem solutions involving derivations and calculations must include explanatory comments between steps and results must be set off clearly. Homework assignment solutions must be on engineering paper if hand-written or on white paper if typed or computer-printed. Multiple pages must be stapled in the upper left corner. Take the time to make your work presentable!

Academic Ethics

If a student violates academic ethics in this course, the consequences will be an automatic F in the course, a letter of reprimand placed in the student's College file, and referral of the matter to the Committee on Undergraduate Academic Affairs for possible further action. The basic rule is that a student may not present as their own the work of another student nor allow their own work to be presented as the work of another student. In group work, all members are required to participate in the assignment.