ChBE 4400 Process Dynamics and Control (required course)

Credit: 3-1-4

Instructor: F. Joseph Schork (lecture)
Clifford Henderson (laboratory)

Textbook: *Process Dynamics and Control*, Seborg, Edgar, Mellichamp and Doyle, 3rd Edition, Wiley, 2011
ChBE 4400 Laboratory Manual to be downloaded from the web

Catalog Description: Dynamics of chemical processes and their control. Techniques of conventional process control as well as digital control. Laboratory experiments to illustrate these concepts.

Prerequisites: Thermodynamics II (ChBE 3130), minimum grade of "C" and
Transport Phenomena II (ChBE 3210), minimum grade "C"

Objectives: This course introduces two basic concepts: (1) Process dynamics and various forms of mathematical models to express them, including differential equations, Laplace transfer functions, and frequency response plots, and (2) Analyze, design and tune feedback / feedforward controllers in the context of various control strategies used to control chemical and biological processes. The design and analysis are mostly for linear systems and connection to nonlinear systems is made by introducing the concept of linearization around a chosen operating point. Students perform computer-simulation- based design projects as well as laboratory experiments to relate the learned mathematical concepts to real world processes and also to learn team-based problem solving.

Learning Outcomes: By the end of this course, a student should be able to:

1. Understand and discuss the importance of process control in process operation and the role of process control engineers (Student Outcomes: f, g, i)

2. Understand and design the modem hardware and instrumentation needed to implement process control. (Student Outcomes: b, c, 1)

3. Develop mathematical models of chemical and biological processes by writing unsteady-state mass and energy balances. (Student Outcomes: a)

4. Recognize and fit various simple empirical models that are used for designing controllers. (Student Outcomes: a, b)

5. Analyze linear dynamical systems using matrix algebra and Laplace transforms (Student Outcomes: a)

6. Design and tune feedback controllers on real systems as well as simulated systems. (Student Outcomes: b, c, d)

7. Analyze stability and performance of feedback loops using Laplace and frequency domain techniques. (Student Outcomes: a)

Topical Outline

1. Introduction
    a. Introduction to process dynamics
    b. Introduction to process control
2. Control Loop Hardware
    a. Sensors, transmitters, and control valves
    b. Distributed control systems
    c. Smart instrumentation and field bus
3. Dynamic Modeling and Simulation
    a. Lumped and distributed parameter systems
    b. Numerical solution of nonlinear AEs and ODEs.
4. Laplace Transform Based Analysis
    a. Linearization of nonlinear ODEs
    b. Laplace transform and transfer function
5. Models for Control
    a. 1^{st} order, 2^{nd} order, and higher order systems
    b. Generalization (“Making friends with transfer functions)
6. Frequency Response Analysis
    a. Frequency response and Bode diagram
    c. Sketching Bode diagram for general transfer functions
7. Analysis of feedback systems
    a. Laplace domain analysis (characteristic equation)
    b. Frequency domain analysis (Bode stability criterion)
8. PID Control
    a. Reaction curve based PID controller tuning
    b. Continuous cycling based PID controller tuning
9. Control Strategies
    a. Feedforward control, cascade control, and ratio control
    b. Anti-windup and bumpless transfer
10. Multivariable Control
    a. Interactions in multi-loop control
    b. Relative Gain Array (RGA), interaction measure, and loop pairing
    c. Control strategies and Optimization based Model Predictive Control
11. Statistical Process Control
    a. Complementary role of SPC with respect to APC

Prepared by: F. Joseph Schork, February 12, 2014