ChemBE 409 Learning Objectives for Final Exam Fall 2010

Students should be able to….

Introduction to Process Control

1. Justify the study of process control.[CB]
2. Define and use process control terms (controlled variable, state variable, feedforward, etc.).[CB]
3. Explain steps of developing a control strategy.[CB]
4. Create a block diagram of a control process.

Mathematical Modeling Basics

5. Explain the differences between various types of models (deterministic, continuous, etc.).[CB]
6. Recognize limitations of models.[CB]
7. Create a steady-state or dynamic model for a chemical process system.
8. Derive population model equations for cells, molecules, or organisms.
9. Describe the approach of pharmacokinetic modeling.[CB]
10. Derive dynamic equations for compartment-based models of living organisms.
11. Evaluate the degrees of freedom of a system.
12. Formulate a state-space model in matrix form.
13. Write a Matlab program to integrate a dynamic model (*e.g.* using ode45) .[S]

Linearization

14. Express a system in terms of deviation variables via a Taylor expansion.
15. Recognize non-linear terms in a system of ODEs and handle them (*e.g.*, linearize them) appropriately when necessary.

Laplace Transforms

16. Derive the Laplace transform of a function.
17. Take the Laplace transform and inverse transform of various functions.
18. Solve an inverse transform by first doing a partial fraction expansion.
19. Use the Initial and Final Value Theorems to deduce properties of functions from their Laplace transforms.
20. Solve differential equations using Laplace transforms.

Transfer Functions

21. Derive the TF for a chemical or biological process.
22. Find the steady-state behavior of a process response from the TF.
23. Add or multiply TFs as appropriate for complex processes.

First and Second Order Processes

24. Use standard process inputs and derive and/or apply the responses of first and second order and integrating processes.
25. Identify qualitative behavior of second-order systems from the denominator polynomial.
26. Solve problems involving gain, time constants, period, phase lag, overshoot, decay, and/or settling time.

Poles, Zeros, Time Delay

27. Identify poles and zeros of a transfer function.[CB]
28. Infer qualitative behavior of a function from its poles.
29. Identify numerator dynamics and analyze initial, long-term, and intermediate-time complex dynamic responses including inverse response and overshoot.
30. Solve problems with time delay, employing Padé expansions when necessary.

Matlab

31. Manipulate vectors and matrices; plot data.[S]
32. Write functions.[S]
33. Write short programs using loops, conditionals, nested function calls, vectors and matrices to solve numerical problems.[S]
34. Solve systems of ODEs numerically.[S]

Empirical Models

35. Describe theoretical and empirical modeling.[CB]
36. Use process data to develop an empirical model of a process.

Introduction to Biomolecular Control

37. Describe the Central Dogma of Biology and identify steps where control can be achieved.[CB]
38. Describe the *lac* operon as a model biomolecular control system, using standard biochemical terms properly (operator, inducer, repressor, promoter, gene, constitutive, induced).[CB]

Feedback Controllers and Instrumentation

39. Describe the characteristics of P, PI, PD and PID controllers and the qualitative effects of manipulating controller gain, integral time and derivative time.[CB]
40. Describe/identify common measurement devices and final control elements.[CB]
41. Derive characteristics of P, PI, PD and PID controllers through analysis of closed-loop transfer function and/or stability considerations.

Closed-Loop Transfer Functions

42. Derive closed loop transfer functions for arbitrary block diagram configurations.
43. Derive controller settings based on closed-loop response criteria.
44. Solve problems relating to initial and final behavior of closed-loop systems.
45. Solve for the dynamic response of a closed-loop system.

Stability

46. Define stability. [CB]
47. Identify stable and unstable functions as well as oscillatory functions.
48. Sketch the location of poles and/or zeros in the complex plane and sketch the accompanying time-domain responses.
49. Analyze stability using a Routh array or direct substitution.
50. Sketch or interpret a root locus diagram.

Controller Design and Tuning

51. List criteria for controller design.[CB]
52. Design a controller transfer function using direct synthesis.

53. Calculate controller parameters using Cohen-Coon rules, Tyreus-Luyben, Ziegler-Nichols, or other standard methods.

Lab Skills

54. Execute experiments using a computer control system.
55. Work efficiently in teams.
56. Present work in written reports.

Frequency Response Fundamentals and Controller Design

57. Derive expressions for the amplitude ratio and phase shift for arbitrary TFs.
58. Create Bode and Nyquist plots.[S]
59. Sketch or interpret Bode and Nyquist plots for polynomial TFs and those with time delay.
60. Analyze the stability of a system from a Bode plot or Nyquist plot. [CB]
61. Calculate the gain and phase margins of a feedback system, or choose controller parameters to achieve particular gain and phase margins.

Biological Circuits and Systems Biology

62. Estimate the probability of observing simple motifs in a random network.
63. Write model equations & plot the dynamic behavior of small motifs in a biomolecular network using logic function assumptions.
64. Describe and sketch autoregulation and feed-forward loops in gene transcription / protein systems.
65. Identify the functions carried out by small motifs of biomolecules and the advantages these motifs provide over unregulated gene expression.
66. Create topological generalizations of motifs.
67. Simulate complex dynamic models for biomolecular systems with many components.[S]

Introduction to Nonlinear Dynamics

68. Analytically solve for a trajectory given initial conditions and a linear system.
69. Sketch a phase portrait for a linear system or for some nonlinear systems.
70. Identify attractors, repellors, centers, and saddles from the eigenvalues of a system near a fixed point. [CB]
71. Identify or define limit cycles and describe qualitative features of chaotic trajectories.[CB]
72. Integrate a nonlinear system using a numerical tool.[S]

Assumed basic engineering knowledge: Derivatives and integrals, basic differential equations, balance equations, thermodynamics and equilibrium relationships, transport equations & constitutive laws, chemical kinetics, unit operations, biomacromolecules and cell biology.

Reading: Bequette Chapters 1-7. Berg/Tymoczko/Stryer Chapter 31. Alon Chapters 1-5. Abraham/Shaw 6, 7.1, 8.3, 9. Articles by Jain, Keasling, Lorenz.

CB indicates likely "closed-book" material. In fact, any qualitative, conceptual, or terminology questions are fair for the closed-book portion of an exam.

S indicates tasks that require software and a computer and therefore would be inappropriate for an "unplugged" exam. However, conceptual questions regarding the numerical solution of problems may be addressed on an exam.