Chemical Engineering 436
Review for Final

Note: This is a general description of the expectations I have for you at the end of this class. It is not intended to be a detailed listing of all possible exam topics.

Control System Basics

I expect you to be familiar with and understand the basic concepts behind control systems. You should know the difference between feedback and feedforward control and be able to tell me where and how each of these might be used. You should understand the components of a feedback control system as shown on both physical and block diagrams. You should also be familiar with the basic types of hardware used in control systems. Given a physical system, you should be able to recommend an appropriate control system.

Response of Transient Systems

A significant portion of the class was dedicated to understanding the transient behavior of systems that were not under control. You should be able to write simple mathematical models to describe such systems based on fundamental material and energy balances. With such a model, you should be able to determine the transient relationship between input and output variables, and express those relationships in the form of transfer functions. You should have a thorough understanding of what a transfer function is, the assumptions implicit in the use of transfer functions, the relationship between the constants in the transfer function and physical variables in the system, the relationship between the transfer function in the Laplace domain and the behavior in the time domain, etc. You should also be able to use empirical methods to obtain a transfer function to fit a set of transient data. Empirical methods include both graphical methods and numerical fitting techniques. You should understand what an open-loop step test is and why it is used. You should also have a qualitative feel for advantages and disadvantages of step vs. pulse testing. You should have a good understanding of the response of first and second order systems. In addition, you should understand why we typically fit systems to FOPDT. You should also understand the difference between a linear and nonlinear system and how to distinguish between them. You should understand how to use linear analysis techniques to approximate the behavior of nonlinear systems, and the implications of the approximations on controller tuning.

Single Input/Single Output Feedback Control with PID Controllers

It is essential that you understand the behavior of simple feedback loops that incorporate PID controllers. As mentioned above, you should know the structure of the loop and the basic components. You should understand both the qualitative and quantitative response of each of the three modes of the PID controller. You should understand the PID control algorithm in both the time and Laplace domain. You should be able to determine the closed-loop response of a system and whether or not the system is stable. You should also understand how the loop responds to a change in load or setpoint. You should be able to determine information on the time-dependent behavior of a system from the closed-loop transfer function without inverting the transform. You should understand the advantages and disadvantages of each PID controller mode and know when they should be applied in a physical system. You should understand how to perform an open-loop step (or pulse) test on a simple system and how to interpret the results. You should have a qualitative understanding of how the closed-loop response changes as the controller parameters are varied. You should understand the difference between the open-loop and closed-loop time constants and how these time constants relate to the physical system(s). For example, how does a change in the controller gain influence the closed-loop time constant? You should also be able to judge whether the controller is aggressive or conservative.

Application to Practical Systems

The ability to apply the above material to practical systems of interest to chemical engineers is a critical element of the course. Simple systems such as a CSTR and a tank(s) have been used as examples throughout the semester. You should be able to relate the components of such a physical system to a block diagram. You should also be able to determine whether a controller should be direct acting or reverse acting, and implement the proper control parameters into an industrial controller. You should understand what an empirically determined transfer function represents, how it relates to the physical system, and how it relates to the block diagram. The lab was an important part of the application work that we did. The tuning procedures are the same ones that we have been talking about most of the semester. Cascade control can also be grouped under application since no new concepts were introduced. You should be able to judge if system performance will be enhanced by the addition of cascade control. You should also be able to tune cascade loops and describe the closed-loop behavior of cascade systems. You should also be familiar with feedforward control, controller interaction problems and how to attack them, and the general concepts for control of distillation columns

Other Types of Controllers

Under this heading we looked at Feedforward controllers, and mentioned briefly the use of direct synthesis to derive the controller transfer function. We also mentioned IMC controllers and their PID equivalents where applicable. You should be able to derive the controller transfer function for a Feedforward controller and determine if it is physically realizable.

Types of Exam Questions (examples only, not inclusive)

1. Given a physical system, determine a suitable PID control system.

2. Given a description of open-loop or closed-loop behavior, provide an explanation for the 'observed' behavior, and perhaps a solution to 'the problem.'

3. Choice of tuning parameters and/or controller modes.

4. Understanding of basic concepts (Eugene claims that ….. Do you agree?)

5. Application of different control strategies (What would you recommend?).

6. Relationship between math/models and physical situation.

7. Questions which probe your understanding of the language (vocabulary) used in Process Control.

8. Judgments- advantages and disadvantages.

9. Sketch- qualitative response of open- and closed-loop systems.

10. Use of non-PID control strategies (e.g., feedforward)

11. Description of procedures- both experimental and theoretical.

Exam Format

A. Closed Book, Closed Notes, In-Class (~30 minutes)
- Vocabulary
- Concepts
- Definitions
- Transient balance equations
- Forms of basic transfer functions
- Standard block diagram

B. Open Book, Closed Notes, In-Class (~2 ½ hrs)
- Story problems
- Material and/or energy balance(s)
- Linearization and deviation variables
- Laplace form
- Block diagram algebra
- Transfer functions
- Stability analysis
- Performance when a setpoint or disturbance changes
- Initial and final values from transfer functions
- Write input function in Laplace coordinates from graph in time coordinates
- Obtain process response constants (τ_p, K_p, θ_p, and ζ_p) from graphical data
- Stability analysis (Routh, Direct Substitution)
- Get transfer function for each piece of equipment
- Valve equations