Reading Questions

ChE 436

PPC, Ch. 1

Competencies - What are the 2 level-three competencies listed for the Process Control class? (These are also on the ChE 436 web page).

1.1 Many of the products from chemical plants are intermediate ingredients or feedstocks for use in down stream processes. What impact might process control have on these intermediate products and how might this impact affect the design and operation of down stream processes?

1.2 Why do think that we refer to the structure of a basic control system as a control loop? What is "open loop" or "manual" mode? What is "closed loop" or "automatic" mode?

1.3 Please study carefully the relationship between Fig. 1.3 and Fig. 1.4. In what ways are these diagrams different? In what ways are they the same? Given Fig. 1.3, you should be able to draw Fig. 1.4.

1.4 Considering the system shown in Fig. 1.3, let’s imagine a situation where my kids left the door open again and the house is too cold.

a) Which is greater, the set point or the temperature in the house?

b) Did the set point change when the door was left open?

c) What is the sign (positive or negative) of the controller error?

d) Add the label "Door Left Open" to the appropriate location on Fig. 1.4 (please draw the diagram).

1.5 Describe the relationship between Fig. 1.4 and Fig. 1.5 (one sentence should suffice).

PDC, Ch. 1

1.1. What are the two kinds of control strategies introduced in this chapter?

1.2. For each of the strategies listed in (1) above, provide at least one advantage and one disadvantage.

1.3. If you were forced to chose only one of these strategies, which would you chose and why?

1.4. What is the purpose of a block diagram?

1.5. What is the difference between an analog controller and a digital controller?

1.6. In this class we will discuss the behavior and design of analog controllers. However, computers (inherently digital) are frequently used for control. Under what conditions might it be appropriate to use relations developed for analog controllers (continuous input/output) to design digital systems? Do you expect these conditions to exist in practical chemical processes?

PPC, Ch. 2

2.1. In the text the author stated that "the dynamic behavior of the Gravity Drained Tanks changes as operating level changes." What do you think that this statement means? Please explain.

2.2. A mathematical model of a jacketed reactor is presented on p. 2-4 of the text. Please identify the physical meaning of each of the terms in each of the equations. What does it mean to have multiple steady states

PPC, Ch. 3

The purpose of this chapter is to demonstrate the use of a simple model to represent the dynamic behavior of systems of interest to chemical engineers. In this context, the word "model" means an expression that is a function of time and has adjustable parameters so that we can fit it to the data. You have probably all fit data points to a line. A line is a time of model which has two parameters, the slope and intercept. Unfortunately, the dynamic behavior (behavior as a function of time) of most chemical systems does not fit a line. Instead, the data are fit to a first order plus dead time (FOPDT) model which has the following form (for t > qp):

$$K_p\left[1-\exp\left(\frac{t-\theta_p}{\tau_p}\right)\right]$$

1. What are the three parameters used in a FOPDT model?

2. The step test and pulse test are "open loop" tests. What does that mean?

3. What is the process gain a measure of? Why do you think that it is called the steady-state process gain?

4. Suppose that you turn the knob on your water heater 1/4 turn and the temperature of the water increases by 25 degrees F. What is the steady-state gain for this process? What units, if any, does the gain have? Does the gain provide any information on how quickly the new temperature is reached?

5. What is the process time constant a measure of? Which is greater, the time constant for a fast process or the time constant for a slow process? Why?

6. What is the purpose of the apparent dead time? Do you expect dead time to be important in chemical processes? Why or why not?

7. Why model dynamic behavior?

PPC, Ch. 4

1. Name an advantage and disadvantage of on/off control.

PPC, Ch. 5

1. Carefully examine Fig. 5.1 and answer the following questions with respect to the figure:

a. Does the behavior shown in the diagram correspond to the open-loop or closed-loop response? (Justify your answer).
b. The lower curve on the diagram is the controller output. Examination of the graph shows three large spikes. What causes these spikes and why are they important?
c. Describe "offset" as shown in the diagram (what is it?).
2. Consider the P-Only Control Law shown in equation 5.1:
a. What does UBIAS represent?
b. Let's assume that the design level of operation is a value of 50 for the controlled variable. In addition, the controller gain is 2, and a controller output (U(t)) of 20 is required to achieve a value of 50 for the controlled variable under design conditions. What is the value of UBIAS which corresponds to these conditions? What is the set point?
c. Assume that UBIAS is 10, Kc is 0.5, and the design level of operation yields a value of 24 for the controlled variable. Further assume that changes in the market require a change in the set point of this loop from 24 to 28. If UBIAS remains at 10, please show that a P-only controller with this bias cannot reach the new setpoint (i.e., the error cannot be zero at a setpoint of 28). What might be done to bring the error to zero at the new setpoint?

PPC, Ch. 6

1. What is the purpose of the Design Tools software?

2. What advantage(s) does Design Tools have over graphical fitting?

3. What is the difference between pulse testing and step testing? Name an advantage of each. Which do you think is preferred in practice? Why?

4. Qualitatively, what is the difference between the response of a linear system and a nonlinear system to step tests performed at different levels? What challenges do nonlinear systems present?

PPC, Ch. 7

1. What is the main point of this chapter?

2. This chapter describes the FOPDT model as a linear model. Clearly, the response is not linear with time. In what way is the model linear?

3. What is the difference between a self-regulating and non-self-regulating process? Qualitatively, sketch the response of each to a step change in input.

PPC, Ch. 8

1. Consider the response of the integral mode to a step change in setpoint. Is it possible for the integral term in the control law to have a finite value when the error is equal to zero? Why or why not?

2. The principal advantage of integral control is that it eliminates offset. How does the integral term eliminate offset?

3. Figure 8.9 is referred to as a tuning map. Why? How might such a map be used?

4. The text states that reset windup occurs when the final control element becomes saturated (reaches a physical limit).

a) What causes the final control element to become saturated?
b) The final control element in a chemical process is typically a valve. What happens when a valve becomes saturated? How does this affect the ability of the valve to influence the process?

PPC, Ch. 9

1. Why might oscillations occur in control systems? (In other words, how might the control system interact with the process to cause oscillations in the controlled variable?)

2. This chapter lists criteria for good controller performance. These criteria, however, correspond to an oscillatory response such as that shown in Fig. 8.1. Why is such a response considered desirable?

3. If the controller were tuned so that the response did not oscillate, how would you expect trise of the non-oscillatory response to compare to trise of the oscillatory response (longer, shorter or equal)? Why?

PPC, Ch. 10

1. The text discusses the derivative term on the error (E) and on the measured variable (Y(t)). Which of these is preferred and why? If your only purpose was disturbance rejection (no set point changes), then which would be preferred and why?

2. The text stated that the derivative term works to decrease oscillations. Does this term work in the same direction or opposite direction as the proportional and integral terms? Support your answer.

3. How does noise impact the derivative mode of the controller? Why?

PDC, pp. 282-307

This section of the text presents correlations for PID controllers based on a FOPDT model. Note that the section talks about a process transfer function. This is a concept which we have not yet discussed. However, the transfer function of a FOPDT model contains the process gain, time constant, and dead time as follows:

$$G(s) = \frac{K_p e^{-\theta_p s}}{\tau_p s + 1}$$

1. How were the Cohen-Coon relationships developed? What criteria were used?

2. Qualitatively describe the approach used to get parameters from the integral-error based methods.

3. ITAE parameters can be found in PDC Table 12.3 and in the Appendix of PPC. Compare the presentation of the parameters from each of these sources. Is the presentation the same? Is the presentation equivalent? Which source is easier to use? Why?

PDC, Ch. 9

1. Summarize in your own words the purpose of this chapter and how it fits into the big picture. In your opinion, which aspects of the chapter are most important?

2. What is a transducer? Give two examples.

3. Please write down the standard ranges used for instrumentation signals. You will be expected to know these ranges (for use on a closed-book exam, etc.).

4. Why are pneumatic instruments "intrinsically safe?"

5. Several types of sensors are listed in the text. Which of these, if any, have you been exposed to and/or used?

6. Draw a block to represent the sensor/transmitter described on p.204-205 (you should have an empty rectangle on your paper). Label the input (T in oC) and the output (4-20 mA signal). What is the relationship between the input and the output?

7. Pneumatic valves are either air-to-open (AO) or air-to-close (AC). What is the basis for deciding which of these is most appropriate? Give an example where you think air-to-open would be preferred.

8. What three types of valve characteristics were mentioned in the chapter?

9. Draw a simple physical system which corresponds to the qualitative information shown in Fig. 9.11. Briefly explain the concepts illustrated in this figure. (Note: this is important)

PDC 2.1-2.4

1. These sections discuss the development of a model. What is meant by the word model?

2. Does the type of model discussed in these sections include spatial resolution of variables (changes with respect to location)? Justify your response.

3. In several of your previous classes you have performed balances on control volumes. How do those balances relate to the balances described in your reading? What assumptions are made concerning the control volume?

4. Section 2.4 describes a degree of freedom analysis. How does this analysis compare with that which you have performed in previous chemical engineering courses?

5. Study Examples 2.1 and 2.2. Eugene claims that the definition of the inputs is completely arbitrary. Do you agree? Why or why not?

6. How do models relate to feedback control? Which elements of the block diagram are we considering in these sections?

PDC 4.3

1. This section treats the linearization of non-linear models. Please address the following:

a) What is a nonlinear model as used in this section?
b) Why linearize the model?
c) Linearization is typically performed around a certain point. What is the natural choice for that point in a chemical process that we are trying to control?
d) What are deviation variables?
e) When and where have you used a Taylor series previous to this class?

PDC 3.1-3.4

Note: You may skip the section on complex factors (p. 56-59) as we will be covering this next time.

1. What is the purpose of Laplace transforms?

2. Summarize the content of Sections 3.1-3.4 in outline form.

3. What is the principal purpose of Section 3.1 and how might this information be used?

4. What is the difference between the Step Function and Constant Function described on p. 44?

5. Summarize the procedure used to solve differential equations with Laplace transforms. Which step is most difficult and why?

6. What is partial fraction expansion and why is it useful?

7. What are repeated factors (an example will suffice) and why do they present additional difficulties?

8. What is the purpose of the Real Translation Theorem? How does this theorem relate to process characteristics that we have already examined?

PDC 3.5 (and p. 56-59 on complex factors)

1. Where does the criterion for complex factors given on p. 56 come from (derive it if you can)?

2. On p. 57 it states that the appearance of complex roots implies oscillatory behavior. What does this mean? What does it imply about the time domain? How does it relate back to the differential equation?

3. Two different methods of handling complex roots are treated on p. 57-59. Summarize (list steps) each of them and explain how they are different. Which do you prefer?

4. Section 3.5 provides an example that begins with a process model, illustrates the use of Laplace transforms to solve the model, and finally provides a solution in the time domain. How was the input represented in this problem? Assuming that the reactor model were available in Control Station, what controller setting would you use to simulate the problem described in this section? Why?

PDC 4.1-4.2

1. Eq. 4-7 is a restatement of Eq. 4-5 where certain quantities have been grouped as a time constant and gain.

a. Verify the units on the time constant. From a physical standpoint, does the grouping in Eq. 4-5 which represents the time constant make sense?
b. The term Q' is multiplied by a gain, K. What does this gain represent physically? What are the units on the gain? What are the units on the term KQ'?
c. Why isn't Ti multiplied by a gain?
d. How do the gain and time constant in Eq. 4-7 compare with those we have discussed to this point in the class?
e. In general, how would you rearrange the typical ODE in order to get the time constant and gain?
2. Please describe (in your own words) what you think a transfer function is.

3. What does the use of a transfer function imply about the initial conditions, and how does this relate to the use of deviation variables?

4. The text states (p. 79) that transfer functions are independent of the initial condition and the nature of the input. Why is this important?

5. How does the steady-state gain defined in Eq. 4-32 compare to Kp? Why does setting s equal to zero in the Laplace domain yield the S.S. gain?

6. Imagine a situation where you have one output variable and two input variables. How many transfer functions would be required to relate the inputs to the output?

7. Fig. 4.1 illustrates the additive property of transfer functions. Redraw the figure for the specific situation described on p. 77 (label the inputs, put in the transfer functions, show the addition).

PDC 5.1-5.2

This chapter (Chapter 5) examines the dynamic behavior of systems (still without control). To do this, it first considers several types of process inputs, X(s) (a deviation variable), and the form of those inputs in the Laplace domain. These inputs are then multiplied by the transfer function to get Y(s). Finally, Y(s) is inverted into the time domain to get y(t).

1. What types of inputs are considered (please list them)?

2. How does the response of a first-order system to a step change in input (5-18 & Fig. 5.4) compare to the first-order plus deadtime response we examined earlier in the semester?

3. Briefly explain the procedure used to get T' in Example 5.1. How is T' related to the final temperature?

4. Eq. 5-26 provides the time domain response to a sinusoidal input. What does the response look like as t gets infinitely large?

PDC 5.3-5.4

1. What is the difference between an underdamped and overdamped system?

2. Demonstrate that the system is overdamped when z >1 (use the quadratic formula).

3. How does the response of a second order system to a step change in input (open loop) compare to the response of the closed-loop control systems we examined earlier with Control Station?

4. Examine the response of a second order system to a sinusoidal input (Eq. 5-60). Is this the complete response?
Please explain.

5. Examine Fig. 5.12 and try to determine what it is trying to display (no need to write anything here).

PDC 6.1-6.4

Note: Realizing that you have a lab due and that the reading is longer than usual, I will attempt to cut it down somewhat. I am not doing this because it is ideal, rather to help promote survival.

Edited reading assignment
Section 6.1: p.130-132, p.136-137 (through Example 6.3)
Section 6.2: p.138-139, p.141 (Example 6.6 is also useful if you have the time)
Section 6.3: Skip- the whole point is that we can approximate higher order behavior by FOPDT (you already know this)
Section 6.4: Read the whole section (interacting produces higher order behavior)

1. What are zeros and poles and how are they related to behavior in the time domain?

2. An inverse response can be caused by two first-order processes acting in parallel. How is this possible? What must be true?

3. What is a transportation lag (give a physical example)? How do we represent such a lag in the Laplace domain?

4. What is the purpose of the Pade approximation? Would you use this approximation for a simple time delay (e-qs) in the numerator? Why or why not?

5. Why do the interacting tanks produce second order behavior? Are oscillations possible?

PDC Ch. 7

1. The first section of this chapter talks about linear and nonlinear regression. The text makes it sound like nonlinear regression is a difficult thing to do. Is that true? Have you done this before? If so, what tool(s) did you use?

2. You have already done the graphical fitting described in this section. What are some of the problems that might occur when fitting data with a FOPDT model?

Don't worry about Section 7.3, since the graphical methods for second order systems are, in my view, obsolete.

PDC Ch. 8 (No reading questions due to exam this week - enjoy!)

PDC Section 10.1
We have now developed the basic relationships (transfer functions) for the process and the

controller. With this section we begin to put the pieces together to form a block diagram where each element of the diagram is represented by a transfer function.

1. Figure 10.2 shows two first-order transfer functions which are added together to get the total response. What do each of these transfer functions represent? How are they related to the process? Why are they added together?

2. At the bottom of p. 226, the book arbitrarily chooses to represent the thermocouple and transmitter by a first-order transfer function. What are we assuming when we do this? What does the time constant tm represent? What does this transfer function reduce to when the dynamics are negligible?

3. The transfer function of the I/P transducer was defined as a constant (KIP). What does this imply?

4. In Fig. 10.7, the same gain (Km) is used to convert the setpoint and for the sensor/transmitter. Does the magnitude of the gain for these two transfer functions have to be the same? Why or why not?

PDC Section 10.2

1. Note the definition of notation provided in this section. This is the notation that we will be using. Please become familiar with it so that you will be able to follow the derivations, etc. presented in class. Some of the notation is intuitive (C=controlled variable, M=manipulated variable, etc.) while other aspects are not (R=setpoint, B=measured value of C). A closed book quiz on the notation may be appropriate? (Focus on understanding the symbols as shown in Fig. 10.8).

2. Qualitatively, what does a closed-loop transfer function represent? What is its physical meaning? How might it be used?

3. What value should the transfer function C/R reach as time goes to infinity? Why?

4. What value should the transfer function C/L reach as time goes to infinity? Why?

PDC Section 10.3

1. On pp. 236-238, the text discusses the closed-loop response of a first-order process which is being controlled by a proportional only controller. The gain of the closed-loop transfer function is defined as K1 = KOL/(1 + KOL).

a. What is the definition of KOL? Is this the same gain that you would measure if you performed an open loop step test?

b. What happens to KOL as the controller gain is increased? What impact does this have on the offset (with P-only control)?

c. Derive equation 10-54 and explain its significance.

2. What does the addition of integral control (p. 241) do to the order of the denominator? What impact might this have on the behavior of the system?

3. What is the final value of the closed-loop transfer function shown in equation 10-71? Does this value make sense? Why or why not?

PDC Ch. 11

1. The definition of stability is that the output response is bounded for all bounded inputs (Bounded Input Bounded Output or BIBO for short). Express this criterion in your own words, and give an example of a bounded input and an unbounded input.

2. Why is the General Stability Criterion only concerned with the characteristic equation? Does it apply to open- or closed-loop systems?

3. There are three different methods discussed in the chapter for determining stability. What are they and what is the main idea behind each of them?

4. Why is the Pade approximation used in example 11.8?

PDC Ch. 12

1. In the Direct Synthesis Method we assume (C/R)d and back-calculate the Gc. What does (C/R)d represent? Qualitatively, what are we doing with this method?

2. The text states that Direct Synthesis will not necessarily yield a controller with a PID structure. What does this mean?

3. What are the advantages of Internal Model Control?

4. Why is the process model factored as per eq. 12-28?

PPC 11.5-11.6

1. The text claims that the primary loop should be tuned with the secondary loop in automatic. Eugene claims that this is a mistake. Is Eugene correct? Please justify your response.

2. What is the manipulated variable for the open loop step test used to tune the primary loop? Eugene claims that the variable should really be expressed in mA. Is Eugene correct? Please justify your response.

3. Explain why cascade control improved the closed loop performance of the jacketed reactor system. Under what conditions would you expect the greatest improvement?

PPC 12.1-12.7

1. In section 12.4 it states that the dead time of the manipulated-to-measured process variable dynamics must be smaller than the dead time of the disturbance-to-measured process variable dynamics. Does this make physical sense? Why or why not?

2. Describe the feedforward strategy in your own words and explain the role of GD and GP.

3. Part of tuning a feedforward controller is to quantify the response of the controlled variable to a disturbance. Eugene claims that this is no problem since we did it for cascade control. Do you agree? Please justify your response.