CHL 261 Instrumentation and Process Control

Major Part I: December 1, 2006

15 marks **Open Book, Open Notes** **1 hour**

(There are 8 questions in this test, printed on both sides of this sheet. Please provide short, to-the-point answers.)

1. Gases A and B are fed continuously to a tank with a volume of 30 ft^3. The normal tank conditions are 40 psia and 80 F, and the normal flow rates are $F_A = 40$ ad $F_B = 10$ cfm measured at the tank conditions. If the flow of B is suddenly increased to 12 cfm, when does the concentration of B reach 90% of the new steady state value?

   (2 marks)

2. The approximate transfer function for a controller is:

$$G_c = \frac{K_c(\tau_D s + 1 + 1/\tau_R s)}{(\tau_D' s + 1 + 1/\tau_R s)}$$

   Plot the Bodě Plot as a function of τ_D/τ_D'. *(2 marks)*

3. Is it possible to constitute an underdamped second order system from two non-interacting first order systems in series? Justify/prove your answer. *(2 marks)*

4. Why does the point (-1,0) hold so much significance in the Nyquist Stability Criterion. Provide a precise answer. *(1 mark)*

5. A student has Laplace transformed an ordinary differential equation and obtained the following transform:

$$Y(s) = \frac{4}{s^4 + 3s^3 + 4s^2 + 6s + 4}$$

   The following facts are known:

   (i) The original ODE had all zero initial conditions.

   (ii) Its only input was sin ωt where the radian frequency was $\omega = \sqrt{2}$.

   What can you say about the original ODE (in other words, determine the original ODE to the maximum extent possible)? Is your result unique? Why/why not? *(2 marks)*

6. The dynamic behavior of a packed bed reactor can be approximated by the transfer function model:

$$\frac{T'(s)}{T_i'(s)} = \frac{3(2-s)}{(10s+1)(5s+1)}$$

where T_i is the inlet temperature, T is the outlet temperature (^{O}C) and the time constants are in hours. The inlet temperature varies in a cyclic fashion due to changes in ambient temperature from day to night.

As an approximation, assume that T_i' varies sinusoidally with a period of 24 hours and amplitude of 12^{O}C. What is the maximum variation in outlet temperature T?

(2 marks)

7. What is a process interlock and at what level (layer) does it appear vis-à-vis a process control system? Would to set the accuracy level of measurements that drive the interlocks at a higher level (higher accuracy) or lower when compared to the instrumentation in the process control system? *(2 marks)*

8. What do you mean by <u>perfect control</u> and why is it theoretically impossible to achieve with feedback control? How can feed-forward control remedy that situation? Explain the idea briefly by taking a process example <u>not discussed in class in this context</u>?

(2 marks)

CHL 261 Instrumentation and Process Control

Major Part 2: December 1, 2006

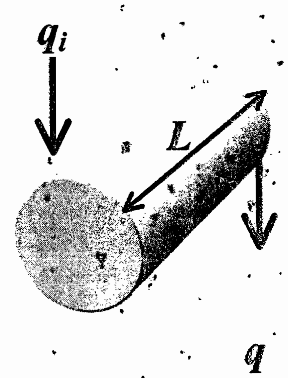
15 marks **Open Book, Open Notes** **1 hour**

(There are 3 questions in this test, printed on both sides of this sheet.)

1. A horizontal cylindrical tank as shown in the Figure is used to slow the propagation of liquid flow surges in a processing line. The Figure shows an end view of the tank: liquid enters from the top (curved surface) through a pipe (not shown), amd exits from the bottom (curved surface) from near the opposite face. w is the width of the liquid surface, and h is the height of the liquid surface, both of which vary with time in an unsteady state.

   Develop a model for the height of liquid h in the tank at any time with the inlet and outlet volumetric flow rates as model inputs. Linearize the model assuming that the process is initially in steady state, and the density ρ is a constant.

   (6 marks)



2. Evaluate the stability of the closed loop system with:

$$G_p(s) = \frac{4e^{-s}}{5s+1},\ G_v(s) = 2,\ G_m(s) = 0.25,\ G_c(s) = K_c$$

   (a) Plot the Bode plot for this system.
   (b) Find the critical frequency, gain and phase margins and ultimate period from these plots. What settings for a PID controller would you recommend using the Ziegler-Nichols rules?
   (c) If a Nyquist plot were to be made with 1.5 times the ultimate gain of the above process, would the plot encircle (-1,0)?

   (5 marks)

3. A process is desribed by the transfer function:

$$G(s)=\frac{K}{(\tau s+1)(s+1)}$$

Using the Routh test, find the range of controller settings that yield <u>stable</u> closed-loop systems for:

(a) A proportional-only controller.
(b) A proportional-integral controller.
(c) What can you say about the effect of adding the integral mode on the stability of the controlled system; that is, does it tend to stabilize or destabilize the system relative to proportional-only controller? Justify your answer.

(4 marks)