Chemical Engineering 436

Exam 2

Open Book, Closed Notes

2 Hour Time Limit

John D. Hedengren
Professor

Name ____

Start Time: ______________________

End Time: ______________________

Total Time: ______________________

The exam consists of 4 problems. There should be sufficient room to work the problems on the exam itself. However, you may use additional pages if necessary.

Most of the points will be rewarded for the form of the equations. If you are pressed for time, do not plug in the numbers for the final equations.

Please circle your answers!!!

Please check to make sure that you have answered all of the parts to each problem.

1. (15 points) By inspection determine which of the following process models can be approximated reasonably accurately by a first-order-plus-time-delay (FOPTD) model. For each acceptable case, calculate the approximate K_P, τ_P, and θ_P.

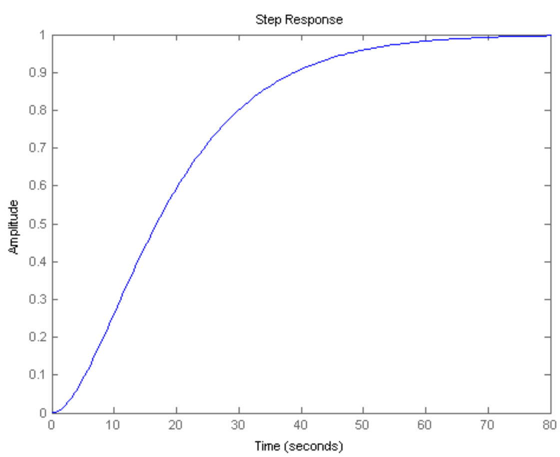
$a)\quad \dfrac{K}{(10s+1)(10s+1)}$

$b)\quad \dfrac{K}{(10s+1)(8s+1)(s+1)}$

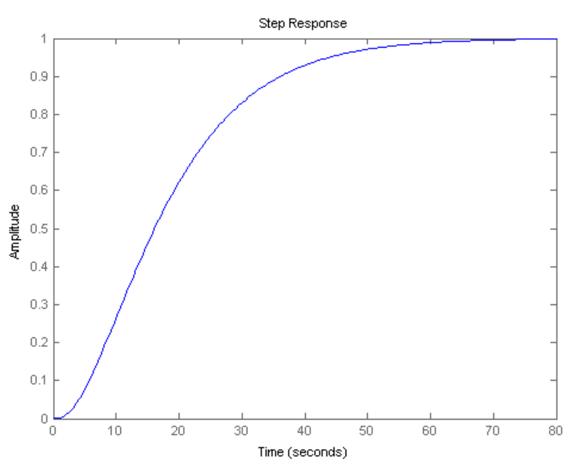
$c)\quad \dfrac{K}{(10s+1)(s+0.5)^5}$

$d)\quad \dfrac{K(20s+1)}{(10s+1)(s+1)}$

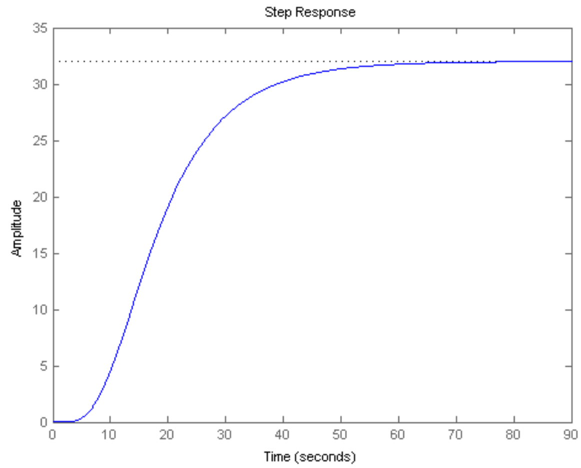
$e)\quad \dfrac{K}{10s^2+11s+1}$



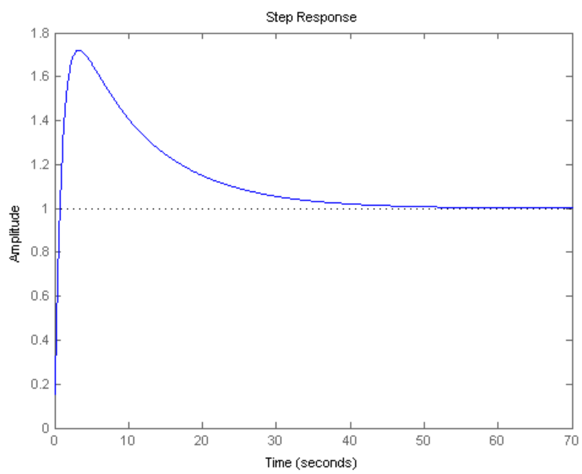
a)



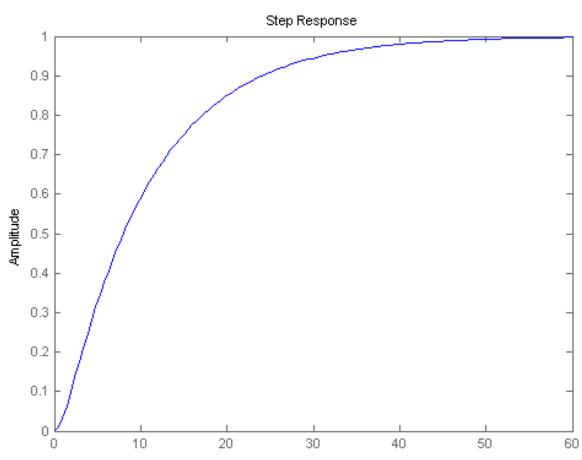
b)


Step Response
Amplitude
Time (seconds)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90

c)


Step Response
Amplitude
Time (seconds)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
10
20
30
40
50
60
70

d)


Step Response
Amplitude
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60

e)

2. (25 points) The temperature deviation of a reactor is described by the following transfer function relating the temperature deviation to the inlet reactant concentration in deviation variables:

$$\frac{T'(s)}{C_i'(s)} = \frac{12}{8s^2 + 4s + 2}$$

(a) Find values for the process time constant, the gain, and the damping coefficient.

(b) If the temperature can never increase by more than 20 above the steady-state value (including any overshoot), what is the largest step change in the inlet reactant concentration deviation that the system will allow? Assume $T'(t=0)=0$. Don't forget to adjust for the gain.

3. (20 pts) For a system where the transfer function is:

$$\frac{Y'(s)}{X'(s)} = \frac{2}{3s+1}$$

and the input function is

$$X'(s) = \frac{2}{s(0.5s+1)} - \frac{e^{-5s}}{s^2} + \frac{e^{-7s}}{s^2}$$

(a) Please sketch the shape of the input function X'(s) in the time domain.

(b) Please derive the expression for y'(t).

4. (40 points) The isothermal stirred tank reactor shown below has the following reaction rate ($A+B\rightarrow C$):

$$-r_A = k_1 C_A C_B - k_2 C_B$$

You may assume that V, q_1, q_2, and q_{out} are constant.

(a) Derive the dynamic mole balance equations for A and B.

(b) Linearize the equations.

(c) Put the equations in deviation variables.

(d) Put the equations into Laplace coordinates.

(e) Using the mole balance for B, solve for $C_B'(s)$.

(f) Substitute the expression from (e) for $C_B'(s)$ into the appropriate place in the mole balance for A. (Simplify by using variables such as a, b, d,, etc., for constant terms).

(g) Get the following transfer function: $C_A'(s)/C_{Ai}'(s)$.

(h) What is the order of this transfer function?