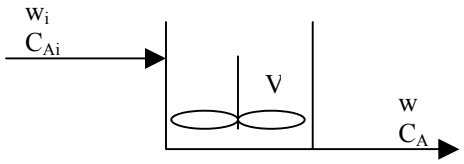
ChEE 413
Spring 2005
Homework Handout 4

1) Problem 1 - Number 4-12 from Edition 1
A stirred tank reactor is operated with a feed mixture containing reactant A at a mass concentration C_{Ai}. The feed flow rate is w_i, as shown below in the drawing:



Under certain conditions, the system operates according to the model:

$$\frac{d(\rho V)}{dt} = w_i - w$$

$$\frac{d(pVC_A)}{dt} = w_i C_{Ai} - wC_A - \rho VkC_A$$

Derive transfer functions of the outlet concentration C_A with respect to
a) C_{Ai}
b) w_i (assuming that w remains equal to w_i)

2) Problem 5.3 from Edition 1 - The transfer function:

$$G(s) = \frac{Y(s)}{X(s)} = \frac{10}{s+1}$$

and represents the model of a process written in deviation variable form. Derive an expression for the response y(t) to the input, x(t) = 1+ t for an initial value y(0) = 2 corresponding to a value of x(0) = 1.

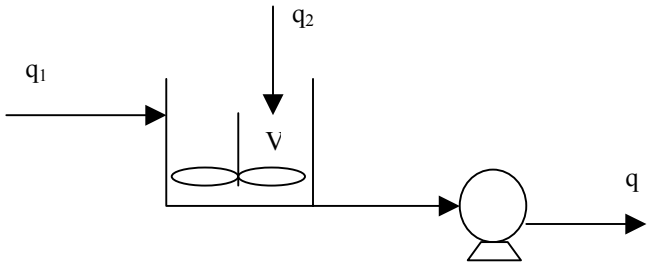
3) Problem 5.5 from Edition 1 - A thermocouple has the following characteristics when it is immersed in a stirred tank:

Mass of thermocouple = 1 g
Heat capacity of thermocouple = 0.25 cal/g ^oC
Heat transfer coefficient = 20 cal/ cm^2 h ^oC (for the thermocouple and bath)
Surface area of thermocouple = 3 cm^2

a) Derive a transfer function model for the thermocouple relating the change in its indicated output T to the change in the temperature of its surroundings, T_s, assuming uniform temperature (no gradients in the thermocouple bead), no condution in the leads, constant physical properties, and that the millivolt-level output is converted directly to a ^oC reading by a very fast meter.
b) If the thermocouple is initially out of the bath and at room temperature (23 ^oC), what is the maximum temperature that it will register if it is suddenly plunged into the bath (80 ^oC) and held there for 20 sec.?

4) Problem 5.6 from Edition 1 - A bare thermocouple, when suddenly moved from a temperature of 82 oF into a stream of hot air at a constant termperature of 105 ^oF, reads 93 oF after 1 sec. If the same thermocouple is used to record the temperature of the same hot airstream when the temperature is falling at a constant rate of 2 ^oF per second, what ill be the error in the thermocouple reading at the end of 10 sec? You may assume that the thermocouple has first-order dynamics with gain equal to one.

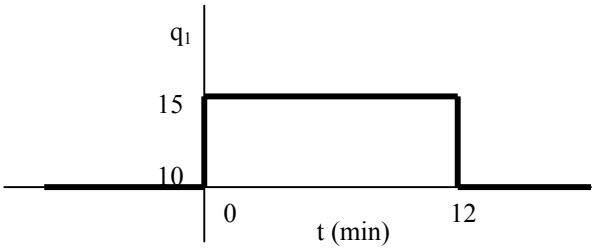
5) Problem 5.8 from Edition 1 - A liquid storage system is shown here:



where h is the height of the fluid in the tank. The normal operating conditions are:

$$\bar{q}_1 = 10\frac{ft^3}{\min},\ \bar{q}_2 = 5\frac{ft^3}{\min},\ and\ \bar{h} = 4ft$$

The tank is 6 ft in diameter and the density of each stream is 60 lb/ft^3. Suppose that a pulse change in q_1 occurs as shown in the following:



a) what is the transfer function relating H' to Q_i'?
b) derive an expression for h(t) for this input change.
c) what is the new steady-state value of liquid level, $\bar{h}_2$
d) we will not do d even though it might be in the answer key here.