10.37 first midterm
March 23, 2007
3 problems total

Problem 1. (40 points total)

The following liquid-phase hydration reaction occurs in a 10,000 L CSTR:

$$A \xrightarrow{+H_2O} B$$

With a first-order rate constant of 2.5 x 10^{-3} min^{-1}.

a) (20 points) What is the steady-state fractional conversion of A if the feed rate is 0.3 L/sec and the feed concentration $C_{A,o}$ = 0.12 mol/L?

b) (10 points) If the feed rate suddenly drops to 70% of its original value and is maintained there, what is the fractional conversion of A after 60 minutes, and what is the new steady state fractional conversion?

c) (10 points) What is the ratio of the steady-state productivity (moles/time) of B for case b) relative to case a)?

Problem 2. (30 points)

A 600 L tank reactor gives 75% conversion for a first order irreversible reaction. However, the paddle turbine motor is underpowered and so the tank is not well stirred. In fact, a pulse-tracer experiment to determine the residence time indicates that approximately 400 L of the tank may be considered as a dead volume that does not interact appreciably with the input or output streams. If you replace the stirrer with one sufficiently strong to obtain complete mixing throughout the reactor volume, what conversion will be obtained?

Problem 3. (30 points)

In a biorefinery, a steady-state PFR operating at 600 K is used to convert cellulose oligomers $C_nH_{2n}O_n$ suspended in water into "syngas" (a mixture of CO and H_2 that can be easily converted into many different fuels or chemicals):

$C_{24}H_{48}O_{24}(g) \rightarrow 24\ CO(g) + 24\ H_2(g)$

The cellulose oligomers are introduced as a 20 wt% slurry in liquid water; 60 grams of the slurry are introduced every second. At this high temperature, it is a good approximation to assume all the species in the reactor are in the gas phase. The reaction rate law has been measured at 600 K under these conditions to be:

$r = k\ [C_nH_{2n}O_n(g)] / \{1 + a\ [CO(g)]\}$

where $k = 0.01\ s^{-1}$ and a = 10 liter/mole

The pressure in the reactor is 20 atm. There is no significant pressure drop in the reactor. The cross-sectional area inside the reactor is 10 cm^2, and the reactor is 3 m long.

Write the differential equation(s) that would have to be solved to predict the moles/second of H_2 coming out of the reactor. Write the equation(s) in the standard ODE format:

$$dY/dz = f(Y)$$

where Y(z) are the unknown(s) you want to compute, and there are no other unknowns on the right hand side of the equation(s). Please do not attempt to solve the equation(s).