ChE 140 Midterm 1
October 5, 2011

Problem 1 (20 points) ____________

Problem 2 (25 points) ____________

Problem 3 (30 points) ____________

Problem 4 (25 points) ____________

Total Score (Out of 100 points) ____________

Problem 1 (20 points):

Find the shape of the trough X=f(Y) with length L (figure shows half of the trough) that would cause the liquid water level y to decrease linearly with time ($dY = \beta\ dt$, β is a constant). The water drains at a rate (dV/dt) given by $\alpha Y^{1/2}$ (α is a constant) when the water level is Y.

Problem 2 (25 points):

The flow chart above describes the separation of A from a mixture of A and B. The system is at steady state, and there is no reaction. The following information is known (and has also been labeled on the flow chart above):

The overall feed stream (stream 1) contains A and B, and is 30wt% A.
Separator #1 separates some of the A in stream 2 into stream 3 (no B goes into stream 3; both A and B go into stream 4), and operates optimally with a separator feed stream (stream 2) containing 29wt% A.
Separator #2 is designed for a separator feed stream (stream 6) having a flow rate of 175kg/hr, and is 50% efficient at separating component A into stream 7, meaning 50% of the A in stream 6 is separated into stream 7 (and no B goes into stream 7).
Stream 8 contains 15wt% A.

Do a degree of freedom analysis on each unit (including separators, mixers, and splitter) as well as the overall system. (10 points)
Develop a strategy and solve for the following flowrates: m_1, m_5, and m_9. Make sure to clearly indicate what you are doing in each step! (15 points)

Problem 3 (30 points):

Ammonia is made at 200. bar and 327°C by the following reaction:

$N_2\ (g) + 3\ H_2\ (g) \rightleftharpoons 2\ NH_3\ (g)$ $\qquad\qquad$ $K = 3.36x10^{-4}$

Nitrogen and hydrogen are fed to the reactor (stream 2) in stoichiometric proportion.

What is the equilibrium per pass conversion? (15 points)
What is the molar flow rate of stream 4? (15 points)

Problem 4 (25 points):

(Distillation and Reaction in a CSTR) The cracking of liquid dodecane (A, $C_{12}H_{26}$) to one mole of gaseous butane (B, C_4H_{10}) and two moles of gaseous butene (C, C_4H_8) is carried out in a steady-state CSTR held at 300 K and 1 bar total pressure. The products are removed as a gaseous stream and are not soluble in the liquid, causing the liquid volumetric flow rate to be smaller at the outlet than at the inlet. Pure A has negligible vapor pressure, enters at 5 liters/h, and the unconverted A exits as a liquid stream. The volume of liquid within the reactor is 1 liter and is kept constant by a level controller. The rate of formation of A is

r_A (moles A/(liter liquid)-h) = $- k C_A$

where k is 1 h^{-1} at 300 K. The density of pure A is 0.6 g/cm^3 and the molecular weights are M_A=170 g/mol, M_B=58 g/mol, and M_C=56 g/mol.

Calculate the following:

the fractional conversion of A (f_A) (15 points)

the molar rate of butane (B) leaving the reactor (5 points)

at 350 K, the rate constants is twice that at 300 K, what is the inlet volumetric flow rate of pure A required to give the same conversion as in part (i) (5 points)