

**06-720    Advanced Process Systems Engineering    Spring, 2011**  
**Homework 10                      Due: 4/25/11**

1. Consider the batch reactor system in Example 8.3 in the book. Formulate this problem using 3 point Radau collocation and variable finite elements.
  - (a) Solve this problem without the control bound and compare with the solution in the book.
  - (b) Solve the problem with  $u(t) \leq 2$ . Compare the state profiles with a profile determined by a DAE solver. How many finite elements are needed to achieve a solution with less than  $10^{-4}$  error in the states?
2. Write the KKT conditions for (10.19). Using Gauss-Legendre collocation, apply the quadrature formulation and extend the derivation in Section 10.4 to deal with algebraic variables and decision variables  $p$ .
3. Consider the singular catalyst mixing problem in Example 8.9.
  - (a) Apply 3 point Gauss collocation and solve with piecewise constant controls for increasing values of  $N$ .
  - (b) Apply 3 point Radau collocation and solve with piecewise constant controls for increasing values of  $N$ . Compare this solution with Gauss collocation.
  - (c) Apply 3 point Radau collocation and solve with control coefficients at each collocation point for increasing values of  $N$ . Compare this solution to the ones with piecewise controls.