Study in Startup Dynamics of a Continuous Stirred Tank Reactor (CSTR)

**Design Application (only if specifically assigned)**

For a first order reaction \( A \rightarrow B \), the design equation for the CSTR is:

\[
C_{A,\text{out}} = \frac{C_{A,\text{in}}}{1 + \frac{kV}{Q}}
\]

where \( C_{A,\text{out}} \) is the concentration of the reactant *leaving* the reactor and \( C_{A,\text{in}} \) is the concentration of reactant *entering* the reactor. These concentrations have units of moles/gal. The quantity \( Q \) is the volumetric flow rate of liquid (gal/hr) entering and leaving the reactor and \( k \) is the first order rate constant in hr\(^{-1}\). The volume of the reactor (in gal) is represented by \( V \). We are interested in a particular reaction involved in the manufacture of nylon. The first order rate constant is 0.9/hr and we wish to process 12 gal/hr of liquid. At the end of the process we want the concentration of \( A \) to be 1/10,000 of its starting value (i.e. \( C_{A,\text{in}} / C_{A,\text{out}} = 10,000 \)). The question is whether to do this with a single reactor or to chain reactors in series where the outlet from one reactor is the inlet to the next.

The cost function for a reactor is expressed by:

\[
\text{Cost (\$)} = 12,000 \ V^{0.4}
\]

where \( V \) is the volume of the reactor in gal. Assume that any reactors placed in a series would all have the same volume. Please determine the following:

(a) The optimum number of reactors in the reaction train
(b) The volume of each reactor
(c) The total cost