Problem 1: Fogler, 2-8(d), p. 74

In bioreactors, the growth is generally autocatalytic in that the more cells you have, the greater the growth rate

\[
\text{Cells + nutrients} \xrightarrow{\text{cells}} \text{more cells + product}.
\]

The cell growth rate, \( r_g \), and the rate of nutrient consumption, \( r_s \), are directly proportional to the concentration of cells for a given set of conditions. A Levenspiel plot of \( \frac{1}{r_s} \) as a function of nutrient conversion \( X_s = (C_{S0} - C_S)/C_{S0} \) is given below in Figure P2-8.

![Levenspiel plot for bacteria growth](image)

For a nutrient feed rate of 1 kg/hr with \( C_{S0} = 0.25 \text{ g/dm}^3 \), what chemostat (CSTR) size is necessary to achieve:

\( (d) \) How could you arrange a CSTR and PFR in series to achieve 80% conversion with the minimum total volume? Repeat for two CSTRs in series.
**Problem 2:**  *Fogler, 2-9(c,d), p. 75*

The adiabatic exothermic irreversible gas-phase reaction

\[ 2A + B \rightarrow 2C \]

is to be carried out in a flow reactor for an equimolar feed of A and B. A Levenspiel plot for this reaction is shown in Figure P2-9.

![Levenspiel plot](image)

**Figure P2-9:** Levenspiel plot for Problem 2.

(c) What is the volume of a second CSTR added in series to the first CSTR (from part b, calculated in Problem Set No. 2 last week) necessary to achieve an overall conversion of 80%?

(d) What PFR volume must be added to the first CSTR (from part b, calculated in Problem Set No. 2) to raise the conversion to 80%?
Problem 3:  Fogler, 2-5(c,d), p. 73
You have two CSTRs and two PFRs each with a volume of 1.6 m³. Use Figure 2-2 shown below to calculate the conversion for each of the reactors in the following arrangements:

(c) Two CSTRs in parallel with the feed, $F_{A0}$, divided equally between the two reactors.
(d) Two PFRs in parallel with the feed divided equally between the two reactors.

From page 48 in Fogler:

<table>
<thead>
<tr>
<th>$X$</th>
<th>0.0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-r_A (\frac{\text{mol}}{\text{m}^3 \cdot \text{s}})$</td>
<td>0.45</td>
<td>0.37</td>
<td>0.30</td>
<td>0.195</td>
<td>0.113</td>
<td>0.079</td>
<td>0.05</td>
</tr>
<tr>
<td>$(1/-r_A) (\frac{\text{m}^3 \cdot \text{s}}{\text{mol}})$</td>
<td>2.22</td>
<td>2.70</td>
<td>3.33</td>
<td>5.13</td>
<td>8.85</td>
<td>12.7</td>
<td>20</td>
</tr>
<tr>
<td>$[F_{A0}/-r_A] (\text{m}^3)$</td>
<td>0.89</td>
<td>1.08</td>
<td>1.33</td>
<td>2.05</td>
<td>3.54</td>
<td>5.06</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Plotting $\left(\frac{F_{A0}}{-r_A}\right)$ as a function of the conversion X using the data in Table 2-3, we obtain the plot shown in Figure 2.2.

![Figure 2-2: Levenspiel plot of processed data -2 for Problem 3.](image)
Problem 4:  *Fogler, 2-6(a-b), p. 74*

Read about the chemical reaction engineering description of digestion in a hippopotamus on the CD-ROM accompanying the Fogler text (or on the web).

(a) Write a well constructed paragraph (about five-six sentences) summarizing the main points related to chemical reaction engineering that you learned from the hippo description.

(b) Work problems (1) and (2) below at the end of the hippo discussion:

(1) A hippo is full grown in 4.5 years. A baby hippo follows its mother around and eats one-half of what she eats. However, the rate of digestion in the autocatalytic CSTR stomach, $-r_{AM1}$, is the same as the mother hippo, as is the conversion. Assuming that in the growing stages, the hippo stomach volume is proportional to its age, how old is the baby hippo?

(2) What is the conversion in the intestine (PFR) for the baby hippo discussed in question (1) above, assuming that $V_{\text{max}}$ is one-half that of the mother?