a. Determine the culture volume at $t = 10$ h.

b. Determine the concentration of glucose at $t = 10$ h at quasi-steady state.

c. Determine the concentration and total amount of cells at quasi-steady state when $t = 10$ h.

d. If $q_P = 0.05$ g product/g cells h and $P_0 = 0.1$ g/l, determine the product concentration in the vessel at $t = 10$ h.

9.5 The bioconversion of glucose to ethanol is carried out in a packed-bed, immobilized-cell bioreactor containing yeast cells entrapped in Ca-alginate beads. The rate-limiting substrate is glucose, and its concentration in the feed bulk liquid phase is $S_{0i} = 5$g/l. The nutrient flow rate is $F = 2$ l/min. The particle size of Ca-alginate beads is $D_P = 0.5$ cm. The rate constants for this conversion are

$$r_m = 100 \text{ mg } S/\text{cm}^3 \cdot \text{h}$$

$$K_S = 10 \text{ mg } S/\text{cm}^3$$

for the following rate expression:

$$r_s = \frac{r_m S}{K_S + S}$$

The surface area of the alginate beads per unit volume of the reactor is $a = 25$ cm^2/cm^3, and the cross-sectional area of the bed is $A = 100$ cm^2. Assuming a first-order reaction-kinetics (e.g., relatively low substrate concentrations), determine the required bed height for 80% conversion of glucose to ethanol at the exit stream. *Hint:* To calculate the effectiveness factor, we can use the following equations:

$$\eta = \frac{1}{\phi}\left[\frac{1}{\tanh 3\phi} - \frac{1}{3\phi}\right]$$

where

$$\phi = \frac{V_P}{A_P}\sqrt{\frac{k_1}{D_S}}$$

and

$$k_1 = \frac{r_m}{K_S}, \qquad D_S = 10^{-6} \text{ cm}^2/\text{s}$$

9.6. A fluidized-bed, immobilized-cell bioreactor is used for the conversion of glucose to ethanol by *Z. mobilis* cells immobilized in κ-carrageenan gel beads. The dimensions of the bed are 10 cm (diameter) by 200 cm. Since the reactor is fed from the bottom of the column and because of CO_2 gas evolution, substrate and cell concentrations decrease with the height of the column. The average cell concentration at the bottom of the column is $X_0 = 45$ g/l, and the average cell concentration decreases with the column height according to the following equation:

$$X = X_0(1 - 0.005Z)$$

where Z is the column height (cm). The specific rate of substrate consumption is $q_S = 2$ g S/g cells · h. The feed flow rate and glucose concentration in the feed are 5 l/h and 160 g glucose/l, respectively.

a. Determine the substrate (glucose) concentration in the effluent.

b. Determine the ethanol concentration in the effluent and ethanol productivity (g/l · h) if $Y_{P/S} = 0.48$ g ethanol/g glucose.