ally high value), and the yield factor $Y_{X/S}$ = 0.5 g biomass/g substrate consumed. If normal operation is with a sterile feed containing 10 g/l glucose at a rate of 100 l/h:

a. What is the specific biomass production rate (g/l-h) at steady state?

b. If recycle is used with a recycle stream of 10 l/h and a recycle biomass concentration five times as large as that in the reactor exit, what would be the new specific biomass production rate?

c. Explain any difference between the values found in parts a and b.

9.2. In a two-stage chemostat system, the volumes of the first and second reactors are $V_1 = 500$ l and $V_2 = 300$ l, respectively. The first reactor is used for biomass production and the second is for a secondary metabolite formation. The feed flow rate to the first reactor is $F = 100$ l/h, and the glucose concentration in the feed is $S = 5.0$ g/l. Use the following constants for the cells.

$$\mu_m = 0.3\ \text{h}^{-1}, \qquad K_S = 0.1\ \text{g/l}, \qquad Y_{X/S} = 0.4\ \frac{\text{g dw cells}}{\text{g glucose}}$$

a. Determine cell and glucose concentrations in the effluent of the first stage.

b. Assume that growth is negligible in the second stage and the specific rate of product formation is $q_P = 0.02$ g P/g cell h, and $Y_{P/S} = 0.6$ g P/g S. Determine the product and substrate concentrations in the effluent of the second reactor.

9.3. Consider the following batch growth data:

Time h	X g/l	P g/l	dX/dt g/l-h	dP/dt g/l-h
0	0.3	<0.01	—	—
3	1.0	<0.01	0.30	—
6	2.3	<0.01	0.55	—
8	4.0	0.010	1.0	0.005
9	5.1	0.025	1.3	0.010
10	6.5	0.060	1.4	0.045
10.5	7.0	—	1.4	—
11	7.4	0.10	0.60	0.059
12	7.7	0.17	0.20	0.072
13	7.8	0.26	0.02	0.105
14	—	0.36	—	0.130
15	8.0	0.47	~0	0.087
16	8.0	0.54	~0	0.042
17	—	0.58	—	0.021
18	—	0.60	—	0.005

You have available three tanks of different volumes: 900, 600, and 300 l. Given a flow rate of 100 l/h, what configuration of tanks would maximize product formation?

9.4. Penicillin is produced by *P. chrysogenum* in a fed-batch culture with the intermittent addition of glucose solution to the culture medium. The initial culture volume at quasi-steady state is $V_0 = 500$ l, and glucose-containing nutrient solution is added with a flow rate of $F = 50$ l/h. Glucose concentration in the feed solution and initial cell concentration are $S_0 = 300$ g/l and $X_0 = 20$ g/l, respectively. The kinetic and yield coefficients of the organism are $\mu_m = 0.2\ \text{h}^{-1}$, $K_S = 0.5$ g/l, and $Y_{X/S} = 0.3$ g dw/g glucose.