PROBLEMS

4.1 Conventional Batch Filtration In a laboratory test of the filtration of a cell culture, the following equation was obtained to describe the filtration:

$$\frac{t}{V/A} = K_1\left(\frac{V}{A}\right) + K_2$$

where $K_1 = 0.18$ min/cm^2 and $K_2 = 0.017$ min/cm.

The cell slurry has a viscosity of 2 cp, and the filter cake solids (dry basis) per volume of filtrate was 13 g/liter. The pressure drop for the filtration was 610 mm Hg (0°C). Determine the specific cake resistance α and the medium resistance R_m. Evaluate the relative significance of the medium resistance after 5 min of filtration.

4.2 Batch Filtration with Change in Pressure In a filtration of suspended cells under full vacuum using a 20 cm Büchner funnel, you collect data for the volume of filtrate as a function of time (see Table P4.2). The concentration of cells was 100 g/liter (mass of dry cake solids per volume of filtrate), and the viscosity of the filtrate was 1.0 cp.

(a) What is the resistance of the filter medium?
(b) What is the specific resistance of the cake layer?
(c) Being disappointed in the amount of time required, you decide to give the vacuum filter a boost by pressurizing the funnel to 1 atm gage pressure. The result is the same. Concerned that you may have done the wrong thing, you then remove the funnel pressure and reduce the vacuum in the flask to 0.5 atm. The result is the same. Determine the dependence of the specific resistance of the cake layer as a function of the pressure drop. Comment on what is happening in the filtration.

TABLE P4.2

Time (min)	Volume filtered (liters)
0	0
20	4
30	5
40	6.5
50	7
60	7.5
70	7.8

(d) What is the most effective change you can make to decrease the time required to filter a given volume?

4.3 Filtration on a Filter with Uniform Cylindrical Pores A depth filter has a membrane resistance of $R_m = 10^{12}$ cm^{-1} and retains all particles greater than 0.4 μm in diameter. Design a filter having uniform straight cylindrical pores with identical performance (including identical flux) to that of this depth filter using a polycarbonate film 200 μm thick.

(a) How many pores per square centimeter must the filter with straight cylindrical pores have?
(b) Is a filter with straight cylindrical pores feasible in this situation?

Hint: Assume that the flow rate Q through each pore can be described by the Hagen–Poiseuille equation for laminar flow

$$Q = \frac{\pi\left(\frac{D}{2}\right)^4 \Delta p}{8\mu L}$$

where D and L are the pore diameter and the length, respectively.

4.4 Scaleup of a Rotary Vacuum Filter A rotary vacuum filter is available with an area of 200 m^2 and vacuum pressure of 75 kPa. Filter leaf tests have been performed on a cell broth with a viscosity of 5 cp. The leaf tests gave a specific cake resistance of 1×10^{11} cm/g and a medium resistance of 1×10^8 cm^{-1}. The cake solids (dry basis) per volume of filtrate was 15 g/liter. It is desired to operate the large filter with a cycle time of 45 s and a cake formation time of 10 s. What is the filtration rate expected for the rotary vacuum filter? How significant is the medium resistance?

4.5 Accumulated Cake Solids and Cake Thickness for a Rotary Vacuum Filter For filtration with a rotary vacuum filter, the following variables are known: filtrate viscosity (μ_0), pressure drop (Δp), specific cake resistance (α), mass of cake solids on a dry basis per volume of filtrate (ρ_c), and rate of drum rotation in revolutions/time (ω).

(a) It is desired to know the mass X of accumulated cake solids on the dry basis per unit area of the filter. For the case of negligible medium resistance, determine X as a function of the foregoing variables and Θ, the angle that the drum has rotated from a given point after entering the broth.