1. Tubular module

C3

Derive

①

filter

$$\Delta P(x) = \Delta P_i \cosh(mx) - \beta \sinh(mx)$$

$$m = \sqrt{\frac{16 \mu L_p}{R^3}} \; ; \quad \beta = \frac{8 \mu u_i}{m R^2}$$

Q_p = Permeat flow rate

$$= \int_0^L v_w * 2\pi R \, dx$$

$$= 2\pi R L_p \int_0^L \Delta P(x) \, dx$$

$$= 2\pi R L_p \int_0^L [\Delta P_i \cosh(mx) - \beta \sinh(mx)] \, dx$$

$$= 2\pi R L_p \left[\Delta P_i \frac{\sinh(mL)}{m} - \frac{\beta}{m} (\cosh mL - 1) \right]$$

$$= \frac{2\pi R L_p \Delta P_i}{m} \left[\sinh(mL) - \frac{\beta}{\Delta P_i} \{\cosh(mL) - 1\} \right]$$

Recovery, $f = \frac{Q_p}{Q_i}$

$$= \frac{2\pi R L_p \Delta P_i}{m Q_i} \left[\sinh(mL) - \frac{\beta}{\Delta P_i} \{\cosh(mL) - 1\} \right]$$

$$= \frac{2\pi R L_p \Delta P_i}{m Q_i} \left[\sinh(mL) - \frac{\beta}{\Delta P_i} \{\cosh(mL) - 1\} \right]$$

$R = 0.05$ m; $\Delta P = 4.14 \times 10^5$ Pa; $L_p = 2 \times 10^{-11}$ m/Pa.s

$$Q_{in} = 40 \text{ L/h} = \frac{40 \times 10^{-3}}{3600} \text{ m}^3/\text{s} = 1.11 \times 10^{-5} \text{ m}^3/\text{s}$$

$$m = \sqrt{\frac{16 \mu L_p}{R^3}} = \sqrt{\frac{16 \times 10^{-3} \times 2 \times 10^{-11}}{0.05^3}} = 5.1 \times 10^{-5} \text{ m}^{-1}$$

$$\beta = \frac{8 \mu u_i}{m R^2}$$

$$u_i = \frac{Q_i}{\pi R^2} = \frac{1.11 \times 10^{-5}}{\pi (.05)^2} \text{ m/s}$$

$$= 1.41 \times 10^{-3} \text{ m/s}$$

$$\beta = \frac{8 \times 10^{-3} \times 1.41 \times 10^{-3}}{5.1 \times 10^{-5} \times .05^2} = 88.47$$

(2)

$$\frac{2\pi R L_p \Delta P_i}{m \delta_i} = \frac{2\pi \times 0.05 \times 2\times10^{-11} \times 4.14\times10^{5}}{5.1\times10^{-5} \times 1.11\times10^{-5}}$$

$$= 4.6\times10^{3}$$

$$f = 4.6\times10^{3}\left[\sinh(mL) - \frac{\cancel{88.47}}{4.14\times10^{5}}\{\cosh(mL)-1\}\right]$$

$$0.6 = 4.6\times10^{3}\left[\sinh(mL) - 2.14\times10^{-4}\{\cosh(mL)-1\}\right]$$

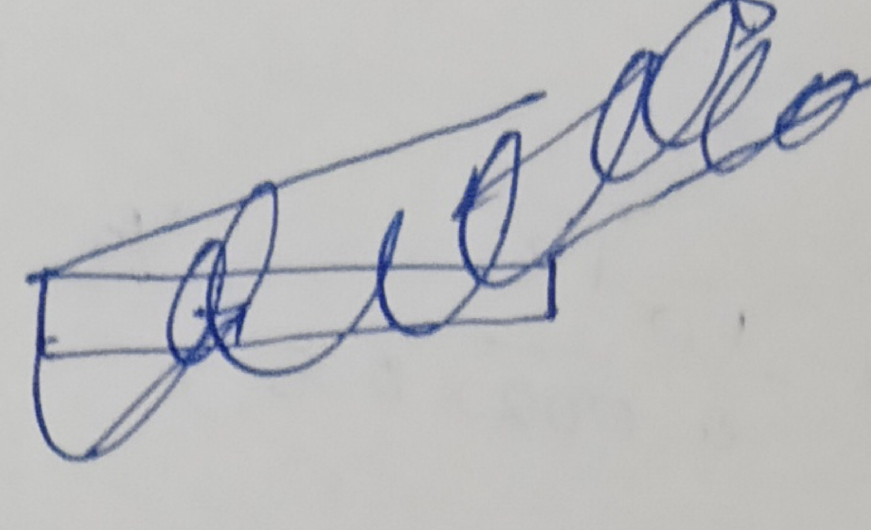
$$1.3\times10^{-4} = \sinh\left[5.1\times10^{-5} L\right] - 2.14\times10^{-4}\{\cosh(mL)-1$$

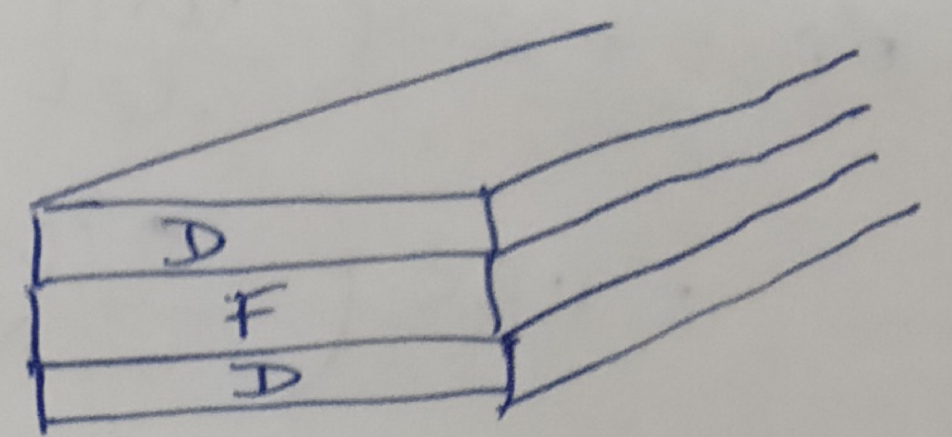
$$\Downarrow$$

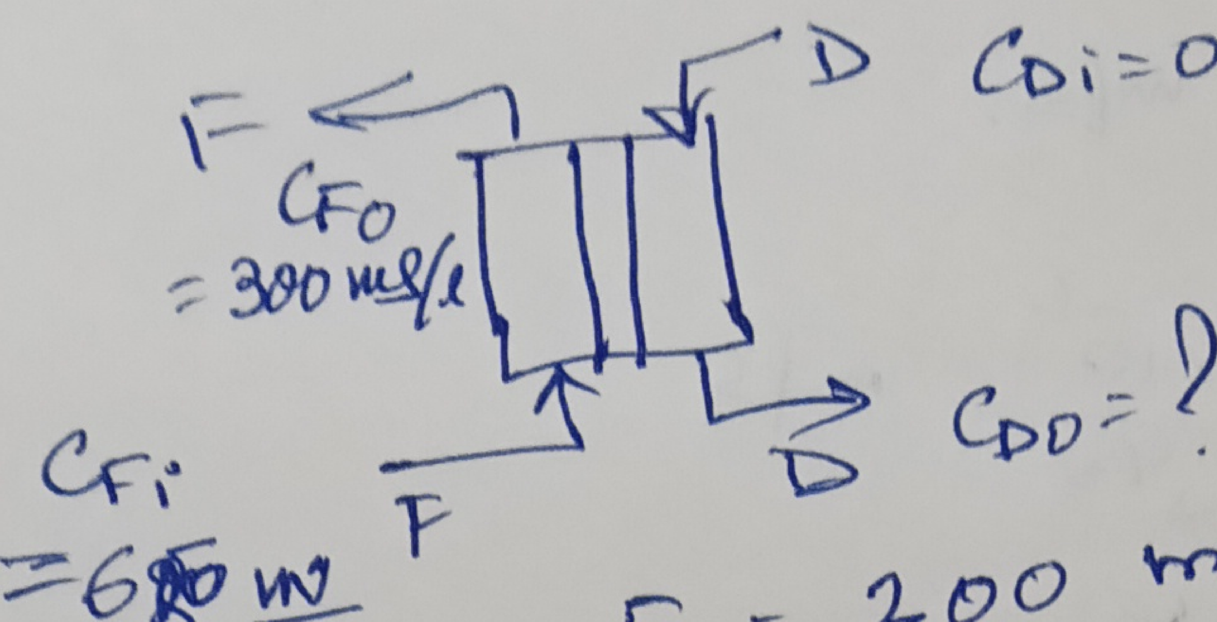
Trial & error

$$\boxed{L = 2.56\,m}$$

2.







$F = 200$ ml/min

$D = 600$ ml/min

$$200(650 - 300) = 600(C_{Do} - 0)$$

$$\Rightarrow 350 = 3 C_{Do}$$

$$\Rightarrow \boxed{C_{Do} = 116.67 \text{ mg/l}}$$

Let, N no. feed channels are there

Flow rate in 1 channel $= \frac{200}{N}$ ml/min

$$= \frac{200}{N} * \frac{10^{-6}}{60} \; m^3/s$$

$$= \frac{3.33 \times 10^{-6}}{N} \; m^3/s$$

C.S. of Feed channel

$$= W * H = 0.1 \times 10^{-3} \; m^2 = 10^{-4} \; m^2$$

u_o = vel. in 1 channel (Feed)

$$= \frac{3.33 \times 10^{-6}}{N} * \frac{1}{10^{-4}} \; m/s$$

$$= \frac{0.033}{N} \; m/s.$$

$$d_e = 4 * h = 2H = 0.002 \, m$$

$$Sh = 1.85 \left(Re\, Sc \frac{d_e}{L}\right)^{1/3}$$

$$K_f \frac{d_e}{D} = 1.85 \left(\frac{u_o d_e}{\nu} \cdot \frac{\nu}{D} \cdot \frac{d_e}{L}\right)^{1/3} = 1.85 \left(\frac{u_o d_e^2}{DL}\right)^{1/3}$$

$$K_f = 1.85 \left(\frac{u_o D^2}{d_e L}\right)^{1/3}$$

$$\cancel{K_f = 1.85\left(\frac{u_0 d_e^2}{D L}\right)^{1/3}}$$

$$K_f = 1.85\left(\frac{u_0 D^2}{d_e L}\right)^{1/3}$$

$$= 1.85\left(\frac{0.033}{N} * \frac{10^{-18}}{0.002 \times 0.5}\right)^{1/3} \quad m/s$$

$$= \frac{5.9 \times 10^{-6}}{N^{1/3}}, \quad m/s.$$

$$K_D = 1.5 K_f = \frac{8.85 \times 10^{-6}}{N^{1/3}}, \quad m/s$$

$$\frac{1}{K_0} = \frac{1}{K_f} + \frac{1}{K_D} + \frac{t}{D_m}$$

$$= \frac{1}{K_f} + \frac{1}{1.5 K_f} + \frac{t}{D_m}$$

$$= \frac{1.67}{K_f} + \frac{t}{D_m}$$

$$= \frac{1.67 \times N^{1/3}}{5.9 \times 10^{-6}} + \frac{40 \times 10^{-6}}{8 \times 10^{-11}}$$

$$= 0.28 \times 10^{6} N^{1/3} + 5 \times 10^{5}$$

$$= 2.8 \times 10^{5} N^{1/3} + 5 \times 10^{5}$$

$$K_0 = \frac{1}{5 \times 10^5 + 2.8 \times 10^5 N^{1/3}}, \quad m/s$$

$$= \frac{10^{-5}}{5 + 2.8 \times N^{1/3}}, \quad m/s.$$

$$A_m = (2LW) * N = 2 \times 0.5 \times 0.1 N, \ m^2$$

$$= 0.1 N, \ m^2$$

$$(\Delta C)_{LMTD} = \frac{(650 - 116.67) - (300 - 0)}{\ln \frac{650 - 116.67}{300}}$$

$$= \cancel{\frac{233.33}{0.5754}} = 405.54 \ mg/l.$$

$$= 405.54 \times \frac{10^{-6}}{10^{-3}} \ \frac{kg}{m^3}$$

$$= 405.54 \times 10^{-3} \ kg/m^3$$

$\dot{m}$ = mass transferred

$= K_o A_m (\Delta C)_{LMTD}$

$$= \frac{10^{-5}}{5+2.8N^{1/3}} * 0.1N * 405.54\times10^{-3}$$

$$= \frac{4.05\times10^{-7}N}{5+2.8N^{1/3}}, \text{ kg/s.}$$

$$\dot{m} = 200\ \frac{ml}{min} * (650-300)\ mg/l$$

$$= \frac{200\times10^{-6}}{60}\ \frac{m^3}{s} * 350\times\frac{10^{-6}}{10^{-3}}\ kg/m^3$$

$$= 11.67\times10^{-7}\ kg/s.$$

$$\therefore \frac{4.05\times10^{-7}N}{5+2.8N^{1/3}} = 11.67\times10^{-7}$$

$$\Rightarrow 0.35N = 5 + 2.8N^{1/3}$$

N	100	50	48	46	44	42
LHS	35	17.5	16.8	16.1	15.4	14.7
RHS	18	15.32	15.17	15.03	14.9	14.73

$$\boxed{N = 42}$$ Ans.