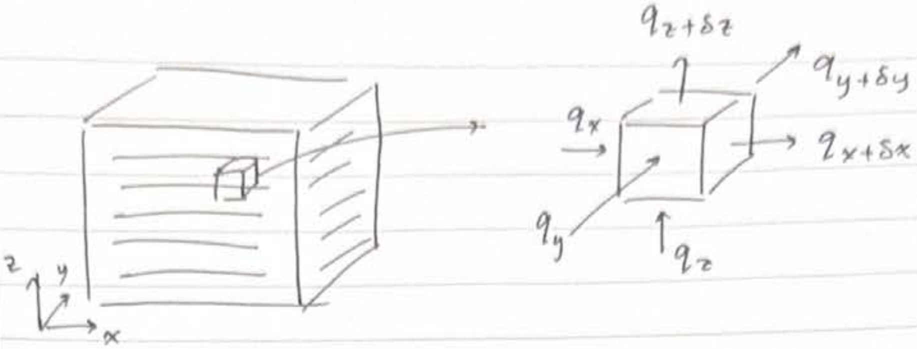
a)



$$\rho \delta V c \frac{\partial T}{\partial t} = \left(q_x - q_{x+\delta x}\right)\delta y \delta z + \left(q_y - q_{y+\delta y}\right)\delta x \delta z + \left(q_z - q_{z+\delta z}\right)\delta x \delta y$$

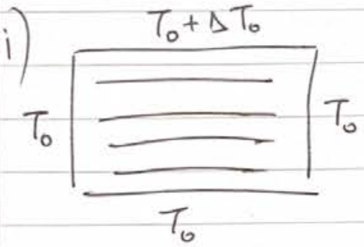
$$\Rightarrow \rho \delta x \delta y \delta z \, c \frac{\partial T}{\partial t} = -\frac{\partial q_x}{\partial x}\delta x \delta y \delta z - \frac{\partial q_y}{\partial y}\delta x \delta y \delta z - \frac{\partial q_z}{\partial z}\delta x \delta y \delta z$$

$$\Rightarrow \rho c \frac{\partial T}{\partial t} = \lambda_{\parallel}\frac{\partial^2 T}{\partial x^2} + \lambda_{\parallel}\frac{\partial^2 T}{\partial y^2} + \lambda_{\perp}\frac{\partial^2 T}{\partial z^2}$$

$$\Rightarrow \boxed{\frac{\partial T}{\partial t} = \alpha_{\parallel}\frac{\partial^2 T}{\partial x^2} + \alpha_{\parallel}\frac{\partial^2 T}{\partial y^2} + \alpha_{\perp}\frac{\partial^2 T}{\partial z^2}}$$

$$\alpha_x = \frac{\lambda_{\parallel}}{\rho c} \; ; \quad \alpha_y = \frac{\lambda_{\parallel}}{\rho c} \; ; \quad \alpha_z = \frac{\lambda_{\perp}}{\rho c}$$

b) i)



No variation in y or t:
The governing equation is

$$\alpha_{\parallel}\frac{\partial^2 T}{\partial x^2} + \alpha_{\perp}\frac{\partial^2 T}{\partial z^2} = 0$$

Introduce a reduced temperature $\Theta = \dfrac{T - T_0}{\Delta T}$

Boundary conditions:
$$\left.\begin{aligned} &\Theta(x=0, z) = 0 \\ &\Theta(x=W, z) = 0 \\ &\Theta(x, z=0) = 0 \end{aligned}\right\} \text{homogeneous}$$
$$\Theta(x, z=H) = 1$$

Governing equation $\alpha_{\parallel}\dfrac{\partial^2 \Theta}{\partial x^2} + \alpha_{\perp}\dfrac{\partial^2 \Theta}{\partial z^2} = 0$

Separation of variables: $\Theta(x,z) = X(x)\,Z(z)$

$$\frac{\partial^2\Theta}{\partial x^2} = X''Z \; ; \quad \frac{\partial^2\Theta}{\partial z^2} = XZ''$$

hence $\alpha_{\parallel} X''Z + \alpha_{\perp} XZ'' = 0$

$$\Rightarrow \frac{X''}{X} = -\frac{\alpha_{\perp}}{\alpha_{\parallel}}\frac{Z''}{Z} = -\beta^2$$

negative, because we expect sinusoidal variation in x, given the boundary conditions.

$$X'' + \beta^2 X = 0$$

$$\Rightarrow X = \sum_n a_n \sin\beta_n x + a_n' \cos\beta_n x$$

at $x=0$, $X=0$: $a_n' = 0$

at $x=W$, $X=0$: $\sin\beta_n W = 0 \Rightarrow \beta_n = \frac{n\pi}{W}$, $n \in \mathbb{N}$

$$Z'' - \frac{\alpha_{\perp}}{\alpha_{\parallel}}\beta^2 Z = 0 \qquad \text{let } \gamma^2 = \frac{\alpha_{\perp}}{\alpha_{\parallel}}\beta^2$$

$$\Rightarrow Z = \sum_n c_n \sinh\gamma_n z + c_n' \cosh\gamma_n z$$

at $z=0$, $Z=0$: $c_n' = 0$

Combining the constants a_n & c_n:

$$\boxed{\Theta = \sum_n b_n \sin\left(\frac{n\pi x}{W}\right)\sinh\left(\sqrt{\frac{\alpha_{\perp}}{\alpha_{\parallel}}}\,\frac{n\pi z}{W}\right), \quad n \in \mathbb{N}}$$

ii) at $z=H$, $\Theta = 1$ for all x:

$$1 = \sum_n b_n \sin\frac{n\pi x}{W}\sinh\sqrt{\frac{\alpha_{\perp}}{\alpha_{\parallel}}}\,\frac{n\pi H}{W}$$

To find b_n, we multiply both sides by $\sin\frac{m\pi x}{W}$, $m \in \mathbb{N}$ and integrate from 0 to W:

$$\int_0^W 1 \cdot \sin\frac{m\pi x}{W}\,dx = \int_0^W \sum_n b_n \sin\frac{m\pi x}{W} \sin\frac{n\pi x}{W} \sinh\sqrt{\frac{\alpha_\perp}{\alpha_\parallel}}\frac{n\pi H}{W}\,dx$$

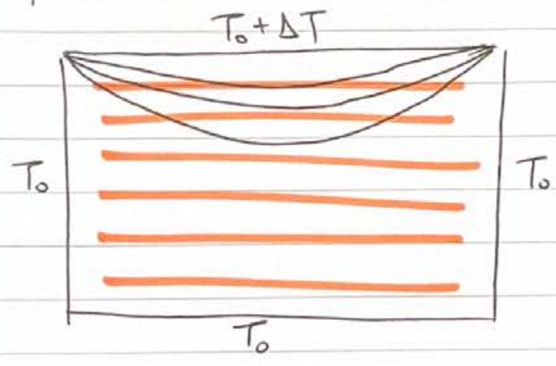
$$\Rightarrow -\frac{W}{m\pi}\left[\cos\frac{m\pi x}{W}\right]_0^W = \sum_n b_n \sinh\sqrt{\frac{\alpha_\perp}{\alpha_\parallel}}\frac{n\pi H}{W} \underbrace{\int_0^W \sin\frac{m\pi x}{W}\sin\frac{n\pi x}{W}\,dx}_{\substack{=0 \text{ if } m\neq n \\ =\frac{W}{2} \text{ if } m=n}}$$

$$\frac{W}{m\pi}(1-\cos m\pi) = \frac{W}{2} b_m \sinh\sqrt{\frac{\alpha_\perp}{\alpha_\parallel}}\frac{m\pi H}{W}$$

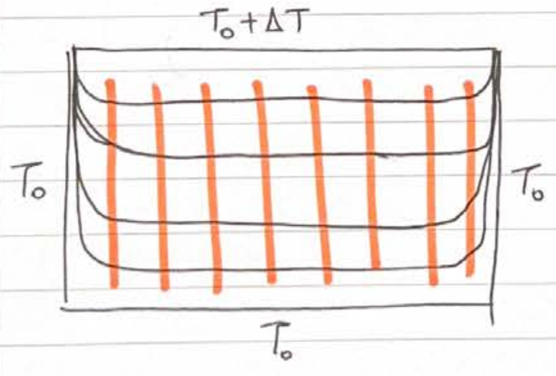
$$\Rightarrow b_m = \frac{2\left[1-(-1)^m\right]}{m\pi \sinh\sqrt{\frac{\alpha_\perp}{\alpha_\parallel}}\frac{m\pi H}{W}}$$

$$\therefore \boxed{\Theta(x,z) = \frac{T(x,z)-T_0}{\Delta T} = \sum_n \frac{2\left[1-(-1)^n\right]}{n\pi \sinh\left(\sqrt{\frac{\alpha_\perp}{\alpha_\parallel}}\frac{m\pi H}{W}\right)} \sin\left(\frac{m\pi x}{W}\right) \sinh\left(\sqrt{\frac{\alpha_\perp}{\alpha_\parallel}}\frac{n\pi z}{W}\right)}$$

c)



d)



Facile conduction in the -z direction. Vertically stacked graphene sheets (above) act as poor conductors, while horizontally stacked sheets (left) conduct heat in the z-direction well.

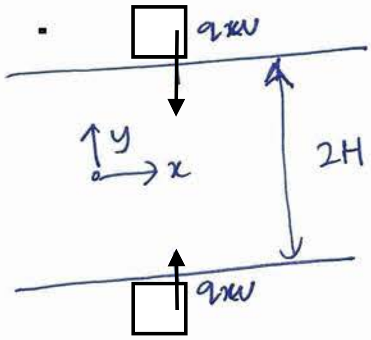
$$\frac{\alpha_\parallel}{\alpha_\perp} = \frac{\lambda_\parallel}{\lambda_\perp} = \frac{2000}{5} = \underline{\underline{400}}.$$

Q2 (a) N.S equation. Fully developed flow, steady state

$$\mu \frac{\partial^2 u_x}{\partial y^2} = \frac{dp}{dx}$$

τ constant

u - velocity along channel



BC1 $\left.\frac{\partial u_x}{\partial y}\right|_{y=0} = 0.$

BC2 $u_x(y = \pm H) = 0$

$$u_x = \frac{dp}{dx}\frac{1}{2\mu}y^2 + C_1 y + C_2$$

Using BC#1 $C_1 = 0$

using BC#2

$$0 = \frac{dp}{dx}\frac{1}{2\mu}H^2 + C_2$$

$$C_2 = \frac{dp}{dx}\frac{1}{2\mu}H^2$$

$$\boxed{u_x = -\frac{1}{2\mu}\frac{dp}{dx}(H^2 - y^2)}$$

(b)
$$U_b = \frac{1}{2H}\int_{-H}^{H} u_x(y)\,dy$$

$$= -\frac{1}{2\mu}\frac{dp}{dx}\frac{1}{2H}\int_{-H}^{H}(H^2 - y^2)\,dy$$

$$= -\frac{1}{2\mu}\frac{dp}{dx}\frac{1}{2H}\frac{4H^3}{3}$$

$$= -\frac{H^2}{3\mu}\frac{dp}{dx}$$

(c) $\rho C_p \left(\cancel{\frac{\partial T}{\partial t}} + U_x \frac{\partial T}{\partial x} \right) = \lambda \frac{\partial^2 T}{\partial y^2}$

0
steady state

$$U_x \frac{\partial T}{\partial x} = \alpha \frac{\partial^2 T}{\partial y^2}$$

$$U_x = -\frac{1}{2\mu} \frac{dp}{dx} (H^2 - y^2)$$

$$= -\frac{H^2}{2\mu} \frac{dp}{dx} \left(1 - \left(\frac{y}{H}\right)^2\right)$$

$$= \frac{3}{2} U_b \left(1 - \left(\frac{y}{H}\right)^2\right)$$

$$\frac{3}{2} U_b \left(1 - \left(\frac{y}{H}\right)^2\right) \frac{\partial T}{\partial x} = \alpha \frac{\partial^2 T}{\partial y^2}$$

(d) $G = \frac{dT}{\partial x} = \text{constant}$

$$\frac{3}{2} U_b G \left(1 - \left(\frac{y}{H}\right)^2\right) = \alpha \frac{\partial^2 T}{\partial y^2}$$

$$\alpha \frac{\partial T}{\partial y} = \frac{3}{2} U_b G \left(y - \frac{y^3}{3H^2}\right) + C_1$$

BC1 Symmetric $\left.\frac{\partial T}{\partial y}\right|_{y=0} = 0$

$$\therefore C_1 = 0$$

$$\alpha T = \frac{3}{2} U_b G \left(\frac{y^2}{2} - \frac{y^4}{12H^2}\right) + C_2$$

BC2 $y=0$ $T = T_0$

$$T = \frac{3}{2}\frac{U_bG}{\alpha}\left(\frac{y^2}{2}-\frac{y^4}{12H^2}\right)+T_0$$

Let's express the T to include q_w

$$-\lambda \frac{\partial T}{\partial y}\bigg|_{y=H} = \dot{q}_w$$

$$-\lambda \frac{\rho c_p}{\lambda}\frac{3}{2}U_bG\left(H-\frac{H^3}{3H^2}\right) = \dot{q}_w$$

$$\dot{q}_w = -U_bG\rho c_p H$$

$$U_bG = -\frac{\dot{q}_w}{\rho c_p H}$$

$$\therefore T = -\frac{3}{2}\frac{\dot{q}_w}{H\lambda}\left(\frac{y^2}{2}-\frac{y^4}{12H^2}\right)+T_0$$

$$T(y=H) = -\frac{3}{2}\frac{\dot{q}_w}{H\lambda}\left(\frac{H^2}{2}-\frac{H^2}{12}\right)+T_0$$

$$= -\frac{\cancel{3}}{2}\frac{\dot{q}_w}{H\lambda}\left(H^2\frac{5}{\cancel{12}_{4}}\right)+T_0$$

$$= -\frac{\dot{q}_w}{\lambda}\frac{5}{8}H + T_0$$

Given that $T_b = T_0 - \frac{\dot{q}_w H}{\lambda}\frac{39}{280}$

Heat transfer coefficient

$$h = \frac{\dot{q}_w}{|T_{wall} - T_b|}$$

$$h = \frac{\dot{q}_w}{|T(y=H) - T_b|}$$

$$h = \frac{\dot{q}_w}{0.486\ \dot{q}_w H/\lambda} = \frac{\lambda}{0.486 H}$$

$$Nu = \frac{hD}{\lambda} = \frac{h(2H)}{\lambda}$$

$$= \frac{2}{0.486}$$

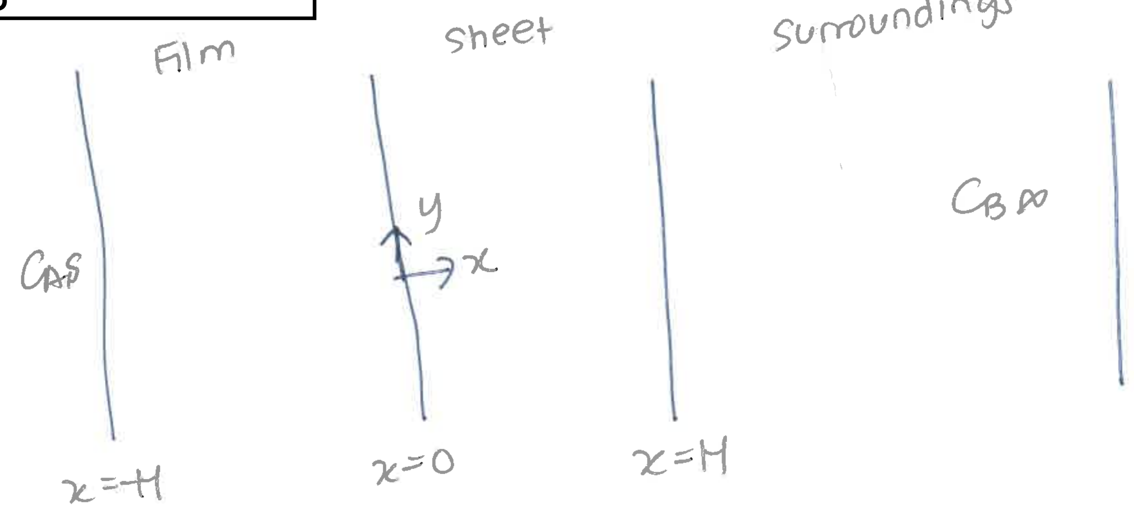
$$= 4.16$$

(f) Higher Nu number near the entrance.

Only a thin layer of fluid near the wall is heated

$(T_{wall} - T_b) \sim$ small , so Nu $\uparrow$

Q3



(a) Species A in Film only

$$D\frac{\partial^2 C_A}{\partial x^2} = 0$$

Species B in sheet only

$$D_B\frac{\partial^2 C_B}{\partial x^2} = 0$$

1-D problem

Boundary conditions

(1) $C_A(x=-H) = C_{AS}$

(2) At the film and sheet interface $x=0$

$$+D_A\frac{\partial C_A}{\partial x}\bigg|_{x=0} = -kC_A(x=0)$$

(3) $$-D_B\frac{\partial C_B}{\partial x}\bigg|_{x=0} = kC_A(x=0)$$

(4) Sheet to surrounding for B

$$-D_B\frac{\partial C_B}{\partial x}\bigg|_{x=H} = h_m\left(C_B(x=H) - C_{B\infty}\right)$$

Step1 Solve $C_A(x)$

$$C_A(x) = C_1 x + C_2 \qquad \left.\begin{matrix} C_1 \\ C_2 \end{matrix}\right\} \text{constants}$$

$\underline{BC1}$ $\quad C_A(x=-H) = C_{AS}$

$$C_{AS} = -HC_1 + C_2$$

$\underline{BC2}$ $\quad -D_A \left.\frac{\partial C_A}{\partial x}\right|_{x=0} = k\, C_A(x=0)$

$$-D_A C_1 = +kC_2$$

$$C_1 = \frac{-k}{D_A} C_2$$

$$C_{AS} = \frac{Hk}{D_A} C_2 + C_2$$

$$C_2 = \frac{C_{AS}}{1 + \frac{Hk}{D_A}} \qquad \therefore C_1 = \frac{-kC_{AS}}{D_A + Hk}$$

$$\boxed{C_A = \frac{C_{AS}(D_A - kx)}{D_A + Hk}} \; //$$

Solve for $C_B(x)$

$$C_B(x) = C_3 x + C_4 \qquad \left.\begin{matrix} C_3 \\ C_4 \end{matrix}\right\} \text{constants}$$

$\underline{BC}$

$$-D_B \left.\frac{\partial C_B}{\partial x}\right|_{x=H} = h_m(C_B(x=H) - C_{B\infty})$$

$$-D_B C_3 = h_m (C_3 H + C_4 - C_{B\infty})$$

$$C_4 = C_{B\infty} - C_3 \left(\frac{D_B}{h_m} + H \right)$$

Next BC For B

$$-D_B \left. \frac{\partial C_B}{\partial x} \right|_{x=0} = k\, C_A(x=0)$$

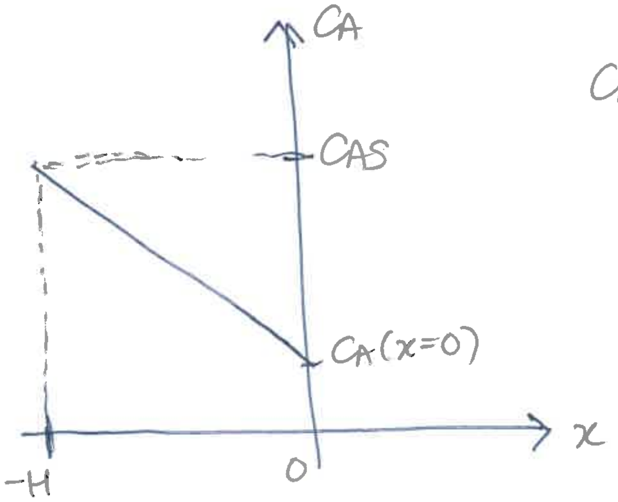
$$-D_B\, C_3 = k \frac{C_{AS} D_A}{D_A + Hk}$$

$$C_3 = -\frac{k}{D_B} \frac{C_{AS} D_A}{D_A + Hk}$$

$$\therefore C_4 = C_{B\infty} + \frac{C_{AS} D_A}{D_A + Hk} \left(\frac{k}{D_B} \right) \left(\frac{D_B}{h_m} + H \right)$$

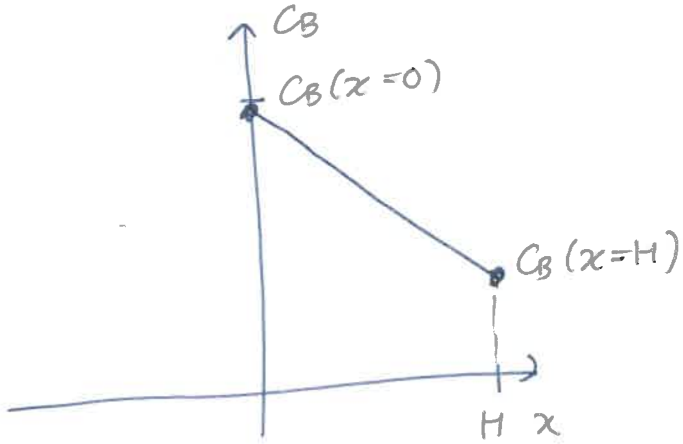
$$C_B(x) = -\frac{k}{D_B} \frac{C_{AS} D_A}{D_A + Hk}\, x + C_{B\infty} + \frac{C_{AS} D_A}{D_A + Hk} \left(\frac{k}{D_B} \right) \left(\frac{D_B}{h_m} + H \right)$$

sketch



$$C_A(x=0) = \frac{C_{AS} D_A}{D_A + Hk}$$

Sketch C_B



diff by this term.

$$C_B(x=0) = C_{B\infty} + \frac{C_{AS} D_A}{D_A + Hk}\left(\frac{k}{D_B}\right)\left(\frac{D_B}{h_m} + H\right)$$

$$C_B(x=H) = C_{B\infty} + \frac{C_{AS} D_A}{D_A + Hk}\left(\frac{k}{D_B}\right)\left(\frac{D_B}{h_m}\right)$$

(c) $$J_A = -D_A \frac{\partial C_A}{\partial x}$$

$$= \frac{C_{A0} k D_A}{D_A + kH} = \frac{C_{A0}}{1/k + H/D_A}$$

(d) we want the flux from the interface to the surrounding.

$$J_B = \frac{C_B(x=0) - C_{B\infty}}{\underbrace{\frac{H}{D_B}}_{\text{diffusive}} + \underbrace{\frac{1}{h_m}}_{\text{convective mass transfer}}}$$

$\leftarrow$ denominator is the total mass transfer resistance eq.

$$J_B = \frac{\frac{C_{AS} D_A}{D_A + Hk}\left(\frac{k}{D_B}\right)\left(\frac{D_B}{h_m} + H\right)}{\left(\frac{H}{D_B} + \frac{1}{h_m}\right)}$$

$$= \frac{C_{AS} D_A}{D_A + Hk} k \frac{\cancel{\left(\frac{1}{h_m} + \frac{H}{D_B}\right)}}{\cancel{\left(\frac{1}{h_m} + \frac{H}{D_B}\right)}}$$

$$J_B = \frac{C_{AS} D_A}{D_A + Hk} k$$

(e) As $k \to 0$, $C_A \to C_{A0}$ throughout the film

system becomes rate-limited.

$$C_A(x=0) \to C_{A0}$$

$C_B \to C_{B0}$ since no reaction at the interface

As $k \to \infty$, system becomes diffusion limited for A

$$C_A(x=0) \to 0$$

Max. possible flux at the interface

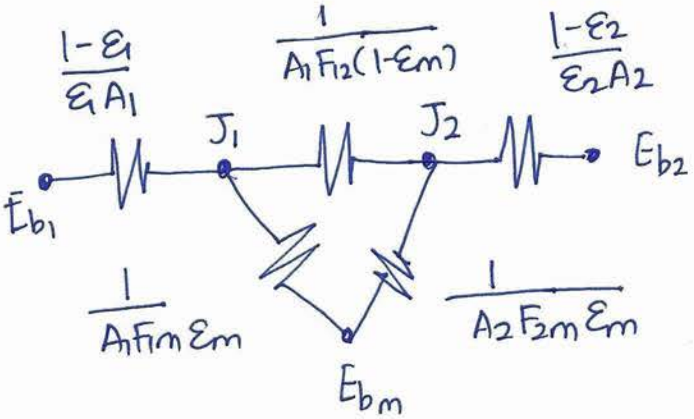
$$J_{A,max} = \frac{D_A C_{A0}}{H}$$

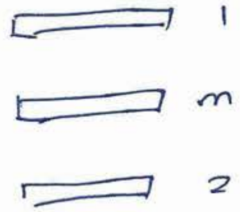
Flux of B will match flux of A.

Diffusion of B will also limit the system.

Q4

(a)





$\varepsilon_1 = 0.4$

$\varepsilon_m = 0.7 \qquad \tau_m = 0.3$

$\varepsilon_2 = 0.6$

(b) Since all plates are long and are in an insulation enclosure, view factors for all are unity.

$F_{12} = 1.0$

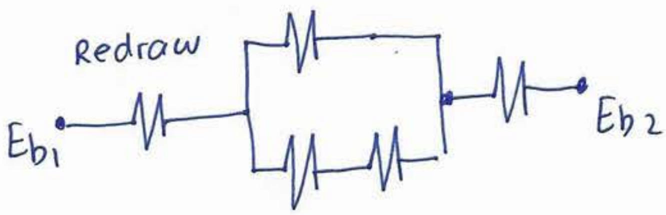
$F_{1m} = 1.0$

$F_{2m} = 1.0$

Also $A_1 = A_2 = A = 0.25\ m^2$

(c) Total effective radiation resistance between the top and bottom plate

Redraw



$$\frac{1}{R_{parallel}} = \frac{1}{\frac{1}{A_1(1-\varepsilon_m)}} + \frac{1}{\frac{2}{A_1\varepsilon_m}} \qquad A_1 = A_2 = A$$

$$= A\left(1 - \frac{\varepsilon_m}{2}\right)$$

$$R_{parallel} = \frac{1}{A\left(1-\frac{\varepsilon_m}{2}\right)} = \frac{1}{0.25(1-0.35)} = 6.154\ m^{-2}$$

$$\text{Total } R = \frac{1-\varepsilon_1}{\varepsilon_1 A} + 6.154 + \frac{1-\varepsilon_2}{\varepsilon_2 A}$$

$$= \frac{0.6}{0.4(0.25)} + 6.154 + \frac{0.4}{0.6(0.25)}$$

$$= 14.82 \text{ m}^{-2}$$

d) $E_{b1} = \sigma T_1^4 = 117573 \text{ W/m}^2$

$E_{b2} = \sigma T_2^4 = 3543.75 \text{ W/m}^2$

Looking at the circuit

$$\frac{J_1 - E_{bm}}{1/A\varepsilon_m} + \frac{J_2 - E_{bm}}{1/A\varepsilon_m} = 0$$

$$1/A\varepsilon_m = \frac{1}{0.25(0.7)} = 5.7143$$

$$\boxed{E_{bm} = \frac{J_1 + J_2}{2}}$$

Node J_1

$$\frac{E_{b1} - J_1}{\frac{1-\varepsilon_1}{\varepsilon_1 A}} = \frac{J_1 - E_{bm}}{\frac{1}{A_1 \varepsilon_m}} + \frac{J_1 - J_2}{\frac{1}{A(1-\varepsilon_m)}}$$

$$\frac{E_{b1} - J_1}{6} = \frac{J_1 - \left(\frac{J_1 + J_2}{2}\right)}{5.7143} + \frac{J_1 - J_2}{13.333}$$

$$\frac{117573 - J_1}{6} = \frac{J_1 - J_2}{11.43} + \frac{J_1 - J_2}{13.333}$$

$$117573 - J_1 = 0.975(J_1 - J_2)$$

$$117573 = 1.975J_1 - 0.975J_2 \quad \cdots \text{①}$$

<u>Node J_2</u>

$$\frac{E_{b2} - J_2}{\frac{1-\varepsilon_2}{\varepsilon_2 A}} = \frac{J_2 - E_{bm}}{\frac{1}{A\varepsilon_m}} + \frac{J_2 - J_1}{\frac{1}{A(1-\varepsilon_m)}}$$

$$\frac{3543.75 - J_2}{2.667} = \frac{J_2 - \left(\frac{J_1+J_2}{2}\right)}{5.7143} + \frac{J_2 - J_1}{13.333}$$

$$3543.75 - J_2 = -0.4333(J_1 - J_2)$$

$$3543.75 = -0.4333J_1 + 1.4333J_2 \quad \cdots \text{②}$$

solve simultaneous Eq$^{t^n}$

$$J_2 = 24060$$

$$J_1 = 71408$$

$$E_{bm} = 47734 \ \text{W/m}^2 = \sigma T_m^4$$

$$T_m^4 = 8.42 \times 10^{11}$$

$$\boxed{T_m \simeq 958 \ \text{K}}$$

(e) $\quad Q_{1\to 2} = ?$

$$R_{total} = 14.82 \ \text{m}^{-2}$$

$$Q_{1\to2} = \frac{E_{b1} - E_{b2}}{R_{tot}}$$

$$= \frac{117573 - 3543.75}{14.82}$$

$$= 7694 \text{ W}$$

(f) Equivalent circuit replaced by a series of R

"No transmissivity resistor in the circuit

Since this is an opaque shield, $Q_{1\to2}$ decreases

$$T = \frac{3}{2}\frac{U_b G}{\alpha}\left(\frac{y^2}{2} - \frac{y^4}{12H^2}\right) + T_0$$

Let's express the T to include q_w

$$-\lambda \left.\frac{\partial T}{\partial y}\right|_{y=H} = \dot{q}_w$$

$$-\lambda \frac{\rho c}{\lambda}\frac{3}{2} U_b G \left(H - \frac{H^3}{3H^2}\right) = \dot{q}_w$$

$$\dot{q}_w = -U_b G \rho c H$$

$$U_b G = -\frac{\dot{q}_w}{\rho c H}$$

$$\therefore T = -\frac{3}{2}\frac{\dot{q}_w}{H\lambda}\left(\frac{y^2}{2} - \frac{y^4}{12H^2}\right) + T_0$$

(e) Bulk mean temp

$$T_m = T_0 - \frac{q_w H}{2\lambda}$$

velocity-weighted average temperature

- allows us to find Nu

$\cancel{T(y=H) = T_m}$

$$T(y=H) = -\frac{3}{2}\frac{\dot{q}_w}{H\lambda}\left(\frac{H^2}{2} - \frac{H^2}{12}\right) + T_0$$

$$= -\frac{\cancel{3}}{2}\frac{\dot{q}_w}{H\lambda}\left(H^2 \frac{5}{\cancel{12}_{4}}\right) + T_0$$

$$= -\frac{q_w}{\lambda}\frac{5}{8}H + T_0$$

$$T_m = T_0 - \frac{q_w H}{\cancel{4}\lambda}\frac{39}{280}$$

Heat transfer coefficient

$$h = \frac{\dot{q}_w}{|T_{wall} - T_m|}$$

$$h = \frac{\dot{q}_w}{|T(y=H) - T_m|}$$

$$h = \frac{\dot{q}_w}{0.486\, \dot{q}_w H/\lambda} = \frac{\lambda}{0.486 H}$$

$$Nu = \frac{hD}{\lambda} = \frac{h(2H)}{\lambda}$$

$$= \frac{2}{0.486}$$

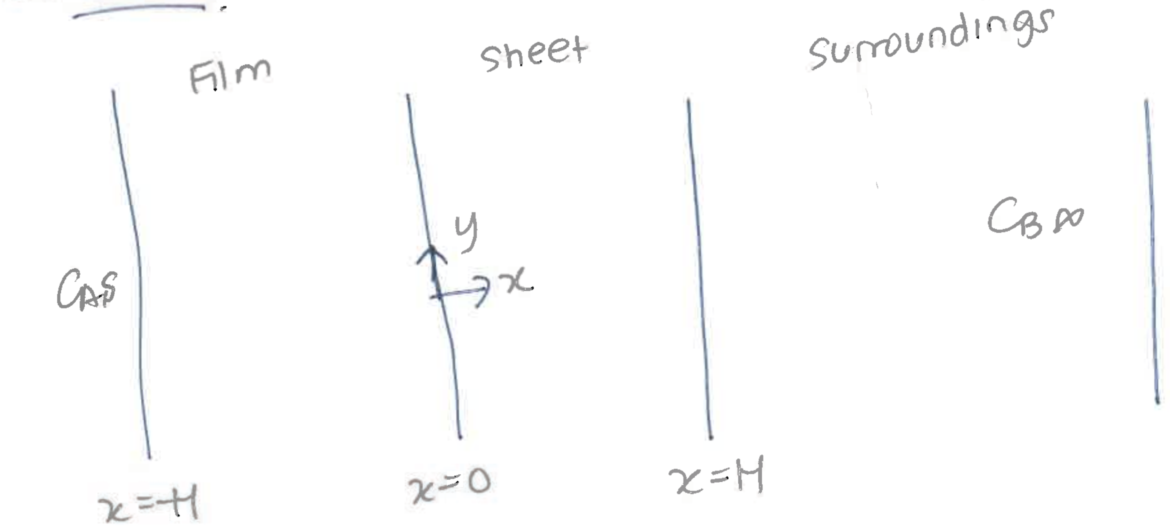
$$= 4.16$$

(f) Higher Nu number near the entrance.

Only a thin layer of fluid near the wall is heated

$(T_{wall} - T_m) \sim$ small , so Nu $\uparrow$

Question 4



(a) Species A in Film only

$$D \frac{\partial^2 C_A}{\partial x^2} = 0$$

Species B in sheet only

$$D_B \frac{\partial^2 C_B}{\partial x^2} = 0$$

1-D problem

Boundary conditions

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(2) At the film and sheet interface $x=0$

$$+D_A \frac{\partial C_A}{\partial x}\Big|_{x=0} = -k C_A(x=0)$$

(3) $$-D_B \frac{\partial C_B}{\partial x}\Big|_{x=0} = k C_A(x=0)$$

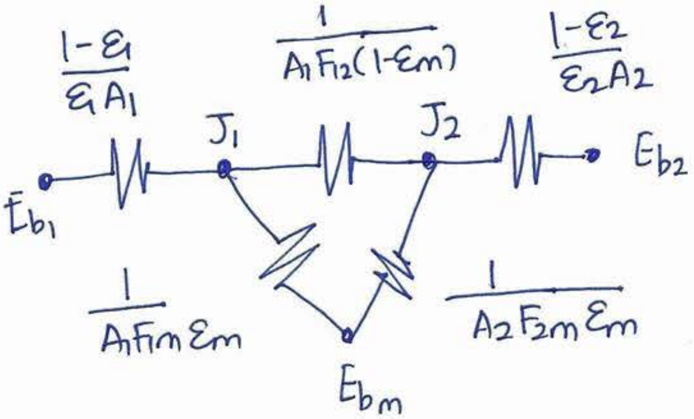
(4) Sheet to surrounding for B

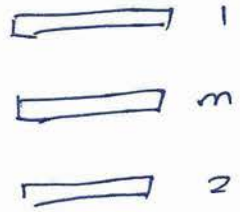
$$-D_B \frac{\partial C_B}{\partial x}\Big|_{x=H} = h_m\left(C_B(x=H) - C_{B\infty}\right)$$

Step 1 Solve $C_A(x)$

Q.2

(a)





$\varepsilon_1 = 0.4$

$\varepsilon_m = 0.7$ $\qquad \tau_m = 0.3$

$\varepsilon_2 = 0.6$

(b) Since all plates are long and are in an insulation enclosure, view factors for all are unity.

$F_{12} = 1.0$

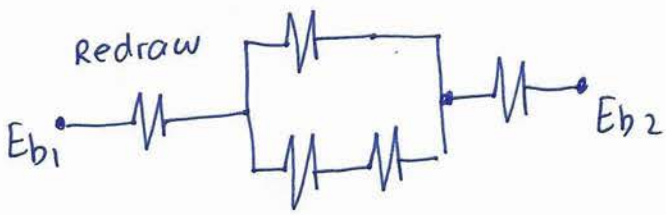
$F_{1m} = 1.0$

$F_{2m} = 1.0$

Also $A_1 = A_2 = A = 0.25\ m^2$

(c) Total effective radiation resistance between the top and bottom plate

Redraw



$$\frac{1}{R_{parallel}} = \frac{1}{\frac{1}{A_1(1-\varepsilon_m)}} + \frac{1}{\frac{2}{A_1 \varepsilon_m}} \qquad A_1 = A_2 = A$$

$$= A\left(1 - \frac{\varepsilon_m}{2}\right)$$

$$R_{parallel} = \frac{1}{A\left(1-\frac{\varepsilon_m}{2}\right)} = \frac{1}{0.25(1-0.35)} = 6.154\ m^{-2}$$