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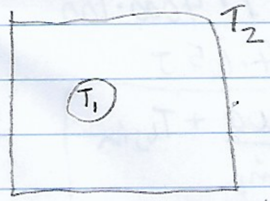
Mech 346 A1

1. - sunlight through a window heating a room (radiation)
   - heating element for boiling water in a kettle (convection)
   - air conditioner (heat exchanger that extracts heat from air and pushes the heat outside, producing cool air for inside)
   - My laptop overheating during class and the case being very hot (conduction)
   - My ice cream melting when I leave it in a bowl (convection as it is exposed to warm air in the room)

2.



$T_1 = 33°C = 306K$ $\quad \epsilon_1 = \epsilon_2 = 1$

$T_2 = 21°C = 294K$ $\quad h_c = 2.5\ W/m^2K$

(i) Linearized: $h_r = 4\epsilon_1 \sigma T_M^3$
$= 4 \cdot (5.67 \cdot 10^{-8}) \cdot (300^3)$

$h_r = 6.1$

$\dot{Q}_{rad} = A_1 h_r (T_1 - T_2)$

$\boxed{\dot{Q}^{lin}_{rad} = 73.2 \cdot A_1}$

(i) Non-linearized: $\dot{Q}_{rad} = A_1 \cdot \epsilon_1 \cdot \sigma \,(T_1^4 - T_2^4)$
$= A_1 \cdot (5.67 \cdot 10^{-8})(1.29 \cdot 10^9)$

$\boxed{\dot{Q}^{nonlin}_{rad} = A_1 \cdot 73.5}$

(ii) $\dot{Q}_{conv} = (T_1 - T_2) \cdot h_c \cdot A_1$

$\boxed{\dot{Q}_{conv} = 30 \cdot A_1}$

Fraction due to convection $\rightarrow f_{conv} = \dfrac{\dot{Q}_{conv}}{\dot{Q}_{conv} + \dot{Q}_{rad}}$

for linearized: $f^{lin}_{conv} = \dfrac{30 A_1}{(30+73.2)A_1} = \boxed{0.29 = f^{lin}_{conv}}$

non-linearized: $f^{nonlin}_{conv} = \dfrac{30 A_1}{(30+73.5)A_1} = \boxed{0.28 = f^{nonlin}_{conv}}$

Note: $f_{rad} = 1 - f_{conv}$ in both cases

3. stream a fixed, unspecified $\dot{m}_b$

$c_a = 4\ \text{KJ/KgK}$ $\quad \dot{m}_a = 1\ \text{Kg/s}$ $\quad T_{a,in} = 400K$ $\quad T_{b,in} = 300K$

$c_b = 2\ \text{KJ/KgK}$ $\quad \dot{m}_b = ?$ $\quad T_{a,out} = 300K$ $\quad T_{b,out} = ?$

a) $\Delta T_a = 100K \rightarrow \Delta E = \dot{m}_a c_a \Delta T_a$

$\Delta E = 4 \cdot 10^5\ J$

$\Delta E = \dot{m}_b c_b \Delta T_b \rightarrow T_{bo} - T_{bi} = \dfrac{\Delta E}{\dot{m}_b \cdot c_b} \rightarrow \boxed{T_{bo} = \dfrac{200}{\dot{m}_b} + T_{bi}}$

b) $\Delta S = \Delta S_a + \Delta S_b = \boxed{\dot{m}_a c_a \ln\left(\dfrac{T_{ao}}{T_{ai}}\right) + \dot{m}_b c_b \ln\left(\dfrac{T_{bo}}{T_{bi}}\right) = \dot{S}}$

$\boxed{\dot{S} = 2\dot{m}_b \ln\left(\dfrac{\frac{200}{\dot{m}_b} + 300}{300}\right) - 1.15}$

c) Plot attached

d) $\boxed{\text{Reversible if } \dot{S} = 0}$ by plotting $\dot{S}(\dot{m}_b)$ on $m_b = [0, 5]$ and using fzero($\dot{S}$, 2) function in matlab, root is found numerically to be 1.99.

$\Rightarrow$ $\boxed{\text{Reversible if } \dot{m}_b = 1.99\ \text{Kg/s}}$

e) $\dot{S} < 0$ violates 2nd law of thermo;

$$\dot{S} = \begin{cases} > 0, & \dot{m}_b > 1.99 \\ = 0, & \dot{m}_b = 1.99 \\ < 0, & \dot{m}_b < 1.99 \end{cases} \rightarrow \boxed{\dot{m}_b < 1.99\ \text{Kg/s violates 2nd law of thermo}}$$

f) $T_{bo} = \dfrac{200}{\dot{m}_b} + T_{bi}$, $\dot{m}_b = 1.99\ \text{Kg/s} \rightarrow \boxed{T_{bo} = 400K}$

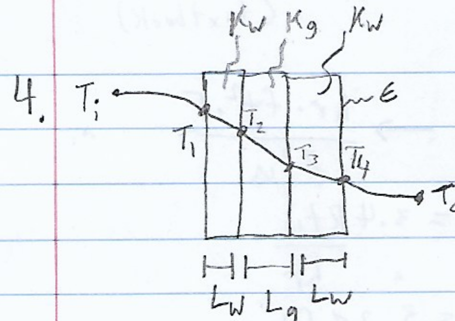
for reversible process

g) Reversible $\rightarrow \dot{S} = 0 \rightarrow \dfrac{\Delta Q_b}{T_{avg,a}} = \dfrac{\Delta Q_b}{T_{avg,b}} \rightarrow \Delta Q_b = \Delta Q_a$

since $T_{avg,a} = T_{avg,b}$ for reversible design.

This won't work in a parallel design since T_{bo} can't be larger than T_{ai}, so no heat will flow from hot to cold.

4.

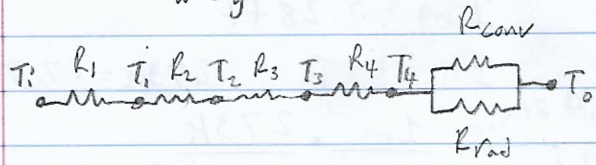


$L_w = 0.03m \quad L_g = 0.06m$

$T_i = 20C = 293K \quad h_{c,i} = 3\frac{W}{m^2K} \quad K_w = 0.17\frac{W}{m\cdot K}$

$T_o = -3C = 270K \quad h_{c,o} = 6\frac{W}{m^2K} \quad K_g = 0.043\frac{W}{m\cdot K}$

$\epsilon = 0.9$



$R_1 = \frac{1}{h_{c,i}A} \quad R_2 = R_4 = \frac{L_w}{K_w A}$

$R_3 = \frac{L_g}{K_g A} \quad R_{conv} = \frac{1}{h_{c,o}A}$

$R_{rad} = h_r A \quad T_m = \frac{T_4 - T_o}{2} \approx T_o$ since we don't know T_4 but the difference should be small.

$\boxed{h_r = 4\epsilon_i \sigma T_m^3}$

$$\dot{Q} = UA(T_i - T_o) \qquad \frac{1}{UA} = \Sigma R_{th} = \frac{1}{A}\left[\frac{1}{h_{c,i}} + \frac{2L_w}{K_w} + \frac{L_g}{K_g} + \frac{1}{h_{c,o}+h_r}\right]$$

eff R of parallel conv & rad $\Big\}$ $R_5 = \left[\frac{1}{R_{conv}} + \frac{1}{R_{rad}}\right] = \frac{1}{(h_{c,o}+h_r)A}$

$$\Rightarrow \boxed{\dot{Q} = A\cdot(T_i - T_o)\cdot\left[\frac{1}{h_{c,i}} + \frac{2L_w}{K_w} + \frac{L_g}{K_g} + \frac{1}{h_{c,o}+h_r}\right]^{-1}}$$

$\dot{Q} = A \cdot 10.2$

Flux: $\frac{\dot{Q}}{A} = 10.2\ \frac{W}{m^2}$

$\times 0.5778 \quad \frac{W}{mK} \rightarrow \frac{Btu}{hr \cdot ft \cdot F}$

(textbook)

5. $K_{fiberglass} = 0.035 \ W/m \cdot K$ $\quad \frac{W}{mK} \rightarrow \frac{hr \cdot ft^2 \cdot F}{Btu}$

$K_{white pine} = 0.12 \ W/mK$ @ 273 K $\quad 1 W = 3.4 \frac{Btu}{hr}$

$1 m = 3.28 ft$

$1 K = 1.8°F \quad 273 K = 67.73°F$

i) $K_f = 0.035 \frac{W}{m \cdot K} \cdot \frac{3.4 \ Btu/hr}{1 W} \cdot \frac{1 m}{3.28 ft} \cdot \frac{273 k}{67.73°F}$

$K_f = 0.035 \cdot 4.18 \frac{Btu}{hr \cdot ft \cdot F} \rightarrow \boxed{K_f = 0.15 \frac{Btu}{hr \cdot ft \cdot F}}$

$R = \frac{L}{K}$, $L = 0.1 m = 0.328 ft$

$R = \frac{0.328}{0.15} \frac{hr \cdot ft^2 \cdot F}{Btu} \rightarrow \boxed{R = 2.2 \frac{hr \cdot ft^2 \cdot F}{Btu}}$

Table A6-E

ii) $K_{cork} = 0.27 \frac{Btu \cdot in}{h \cdot ft^2 \cdot F}$ from Table A6-E

$R = \frac{L}{K} \rightarrow L = R \cdot K \ \frac{hr \cdot ft^2 \cdot F}{Btu} \cdot \frac{Btu \cdot in}{hr \cdot ft^2 \cdot F}$

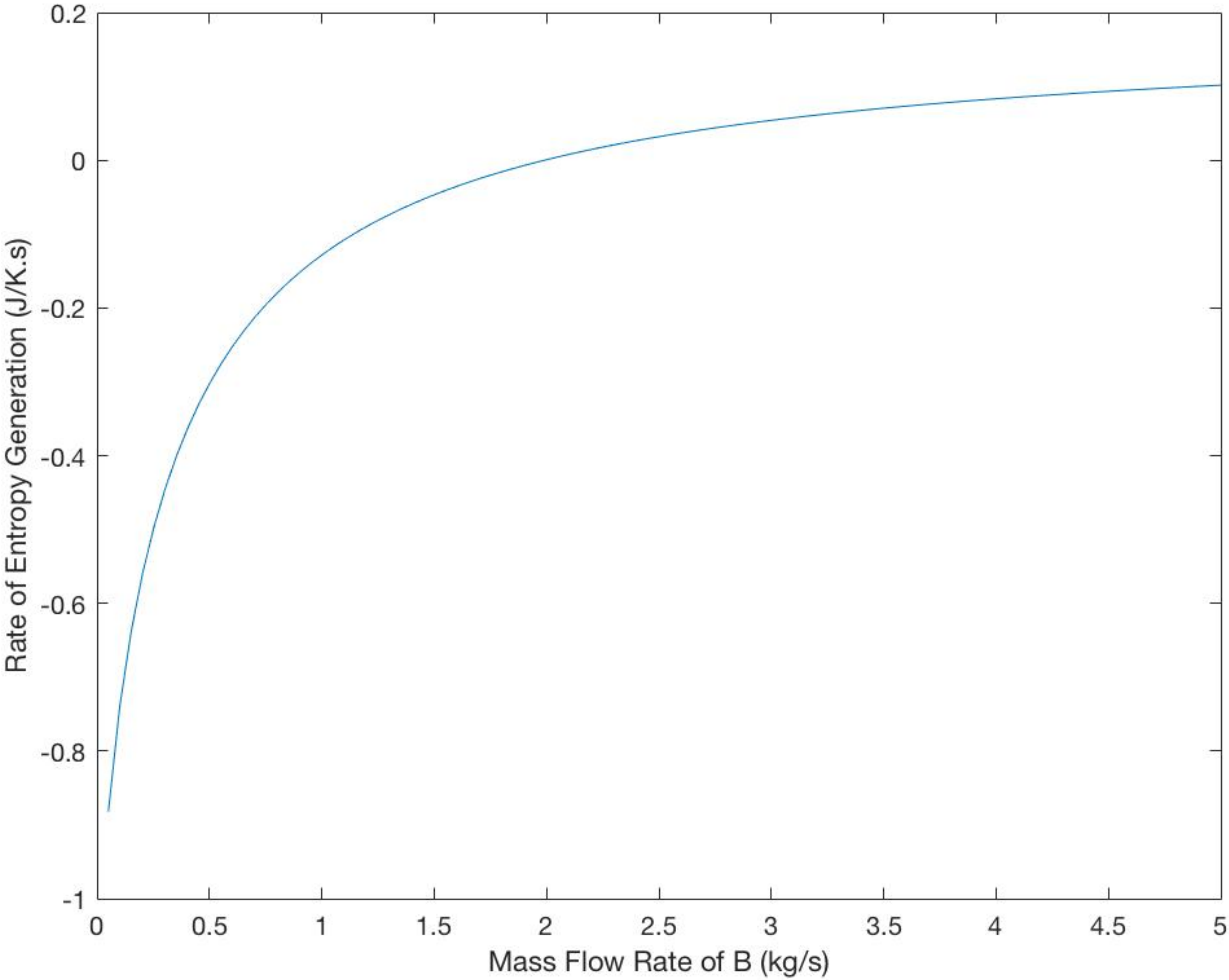
$L = 18 \cdot 0.27 \ in$

$\boxed{L = 4.86 \ in}$

iii) $K_{wp} = 0.064 \frac{Btu}{hr \cdot ft \cdot R}$ from Table A-8E

$L = 2 cm = 0.0656 ft$

$\Rightarrow R = \frac{L}{K_{wp}} = \frac{0.0656}{0.064} = 1.025 R = \boxed{1.025 \frac{hr \cdot ft^2 \cdot F}{Btu}}$


0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Rate of Entropy Generation (J/K.s)
Mass Flow Rate of B (kg/s)