1

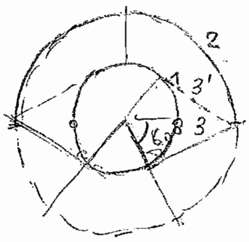
3A6 EXAMPLE SHEET – 2 CRIBS

(a) $F_{11} = 0$ $\qquad F_{11} + F_{12} = 1$

$F_{12} = 1$ $\qquad F_{21} = F_{12} \dfrac{A_1}{A_2} = \dfrac{2R}{3/4\, 2\pi R} = 0.424$

(b) $A_2 = 2A_1$ $\qquad \underline{F_{11} = 0}$

$D_2 = 2 D_1$



$\dfrac{R}{2R} = \cos\theta \qquad \theta = 60^\circ$

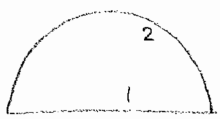
$\underset{0}{\cancel{F_{11}}} + F_{12} + F_{13} = 1$

$\underset{0}{\cancel{F_{11}}} + \underbrace{F_{13} + F_{13'}}_{SYM} = 1$

$2F_{13} = 1 \longrightarrow F_{13} = \frac{1}{2}$

$\therefore F_{12} = 1 - F_{13} = \underline{0.5}\,; \quad F_{21} = F_{12}\, A_1/A_2 = \frac{1}{2} \dfrac{4\pi R^2}{\frac{1}{2} 4\pi (2R)^2} = \underline{0.25}$

(c)



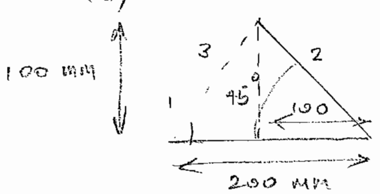
$F_{11} = 0$

$\underset{0}{\cancel{F_{11}}} + F_{12} = 1 \longrightarrow F_{12} = 1$

$F_{21} = F_{12}\, A_1/A_2 = 1 \;\; 2R/\pi R = 0.636$

$F_{22} = 1 - F_{21} = 0.363$

(d)



$\underbrace{F_{11} + F_{12} + F_{13}}_{2F_{12}} = 1$ (SYMMETRY)

$F_{11} = 0$

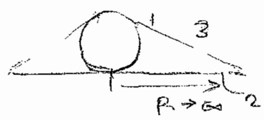
$F_{12} = F_{13} = 0.5$

$A_2 = 100\sqrt{2}\ mm^2$ $\qquad F_{21} = F_{12} \dfrac{A_1}{A_2} = 0.5 \dfrac{200}{100\sqrt{2}} = 0.707$

$F_{22} = 0$

$F_{23} = 1 - F_{22} - F_{23} = 0.292$

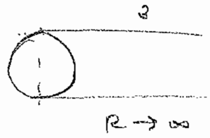
(e)



$F_{11} = 0$ $\qquad \overset{0}{\cancel{F_{11}}} + F_{12} + F_{13} = 1$

$F_{22} = 0$

$$F_{21} = F_{12}\,\frac{A_1}{A_2} = 0 \quad @\ R \to \infty$$

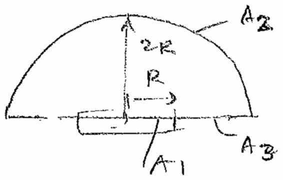


@ $R \to \infty$ $\quad \underbrace{F_{13} + F_{12}} = 1$

By symmetry $\quad 2F_{12} = 1$

$$F_{12} = 0.5$$

(f)

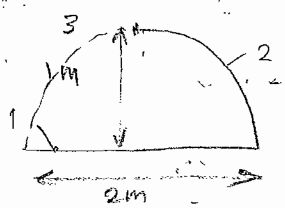


$$\underset{0}{\cancel{F_{11}}} + F_{12} + \underset{0}{\cancel{F_{13}}} = 1 \qquad F_{21} = F_{12}\,\frac{A_1}{A_2} = 1 \cdot \frac{\pi R^2}{\frac{1}{2}4\pi(2R)^2} = 0.125$$

$$\underset{0}{\cancel{F_{31}}} + F_{32} + \underset{0}{\cancel{F_{33}}} = 1 \qquad F_{32} = 1$$

$$F_{23} = F_{32}\,\frac{A_3}{A_2} = 1 \cdot \frac{\overbrace{\pi\left((2R)^2 - R^2\right)}^{3}}{\frac{1}{2}4\pi(2R)^2} = \frac{3}{8}$$

(g)

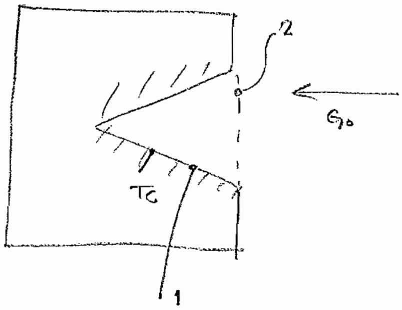


$$\underset{0}{\cancel{F_{11}}} + \underbrace{F_{12} + F_{13}}_{2F_{12}} = 1 \qquad (\text{SYM})$$

$$F_{12} = 0.5$$

$$\therefore F_{21} = F_{12}\,\frac{A_1}{A_2} = \frac{1}{2}\,\frac{2}{\frac{1}{4}\pi(2)} = 0.637$$

12



$\epsilon_1 = 1$

IF THE SURFACE IS INSULATED:

$$q_1 = A_1 \epsilon_1 E_{b1} - A_1 G_1 = A_1 \epsilon_1 E_{b1} - A_1 \left(\underbrace{(1-\epsilon_1) F_{11} E_{b1}}_{0} + G_0 F_{21} + E_{bsur} F_{21} \right) = 0$$

<u>VIEW FACTOR</u>

$$G_0 = \frac{E_{b1} - E_{bsur} F_{21}}{F_{21}}$$

$$F_{21} + \cancel{F_{22}}^{0} = 1$$

$$F_{21} = 1$$

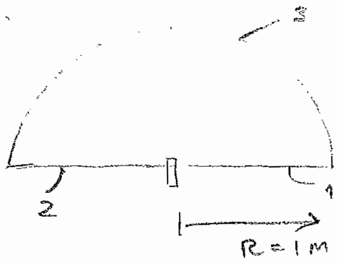
$$G_0 = \frac{\sigma (T_1^4 - T_{sur}^4)}{1}$$

$$G_0 = 5.67 \times 10^{-8} \frac{W}{m^2 K^4} \left[(298.15 + 10.1)^4 - 298.15^4 \right]$$

$$\boxed{G_0 = 63.8 \; W/m^2}$$

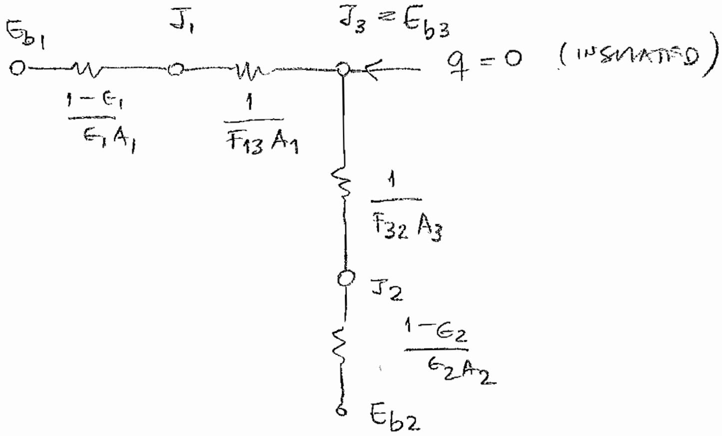
13)

3



EQUIVALENT CIRCUIT

(a)



$$q_1 = \frac{E_{b1} - E_{b2}}{\frac{1-\epsilon_1}{\epsilon_1 A_1} + \frac{1}{F_{13} A_1} + \frac{1}{F_{32} A_3} + \frac{1-\epsilon_2}{\epsilon_2 A_2}}$$

$$F_{13} = F_{23}$$

$$\underset{0}{\cancel{F_{11}}} + \underset{0}{\cancel{F_{12}}} + F_{13} = 1 \qquad F_{13} = 1$$

$$F_{32} = F_{23} \frac{A_2}{A_3} = \frac{A_2}{A_3} \qquad \text{AND} \qquad A_1 = A_2 = R \cdot 1 = 1\,\mathrm{m}^2/\mathrm{m}$$

$$q_1 = A_1 \frac{(E_{b1} - E_{b2})}{\frac{1-\epsilon_1}{\epsilon_1} + 1 + 1 + \frac{1-\epsilon_2}{\epsilon_2}}$$

$$q_1 = \frac{1\,\mathrm{m}^2}{\mathrm{m}} \frac{(5.670 \times 10^{-8}\,\mathrm{W/m^2 K^4})((1600\,\mathrm{K})^4 - (500\,\mathrm{K})^4)}{\frac{1-0.85}{0.85} + 1 + 1 + \frac{1-\cancel{1}}{\cancel{1}}} = 169.1\,\frac{\mathrm{kW}}{\mathrm{m}}$$

(b)

$$q_1 = \frac{E_{b1} - J_3}{\frac{1-\epsilon_1}{\epsilon_1 A_1} + \frac{1}{F_{13} A_1}} = \frac{J_3 - E_{b2}}{\frac{1}{F_{32} A_3} + \underset{0}{\cancel{\frac{1-\epsilon_2}{\epsilon_2 A_2}}}} \Longrightarrow J_3 = q_1 \left[\frac{1}{F_{32} A_3}\right] + E_{b2}$$

$$J_3 = \frac{q_1}{A_2} + E_{b2} = \frac{169{,}101\ W/m}{1\ m^2/m} + \underbrace{(5.67\times10^{-8})W/m^2K^4(500\ k)^4}_{3544\ W/m^2}$$

$$= 172{,}645\ W/m^2$$

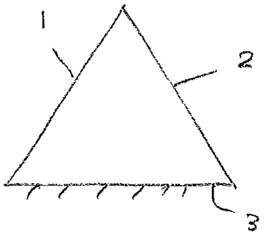
$$T_3 = \left(\frac{E_{b3}}{\sigma}\right)^{1/4} = \left(\frac{J_3}{\sigma}\right)^{1/4} = \left(\frac{172645\ W/m^2}{5.67\times10^{-8}\ W/m^2K^4}\right) = \underline{\underline{1320\ k}}$$

NOTES;

- NOTE THAT ϵ_3 DOES NOT SHOW UP, SINCE 3 IS A RERADIATING SURFACE WHERE $q_3 = J_3 - G_3 = \epsilon_3 E_{b3} + (1-\epsilon_3)G_3 - G_3 = 0$

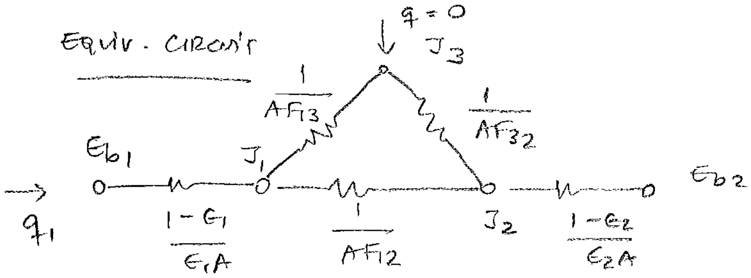
$$\underline{E_{b3} = G_3}$$

(4)



$A_1 = A_2 = A_3 = A = 1\,m^2/m$

EQUIV. CIRCUIT



BY SYMMETRY: $F_{12} = F_{13} = F_{32}$

$\cancel{F_{11}}_{\,0} + F_{12} + F_{13} = 1 \qquad F_{12} = F_{13} = F_{32} = 1/2 = F$

(a) $$q_1 = \frac{E_{b1} - E_{b2}}{\dfrac{1-\epsilon_1}{\epsilon_1 A} + \underbrace{\dfrac{1}{\dfrac{1}{1/AF} + \dfrac{1}{\frac{1}{AF} + \frac{1}{AF}}}}_{\frac{2}{3}\frac{1}{AF}} + \dfrac{1-\epsilon_2}{\epsilon_2 A}}$$

$$q_1 = \frac{(5.67\times10^{-8})(1\,m^2/m)\left((1000K)^4 - (700K)^4\right)}{\dfrac{1-0.33}{0.33} + \dfrac{2}{3}\dfrac{1}{1/2} + \dfrac{1-0.5}{0.5}} = \underline{9873\ W/m^2}$$

(b) $$q_{13} = \frac{J_1 - J_3}{1/AF} = \frac{J_3 - J_2}{1/AF}$$

$$J_3 = \frac{J_1 + J_2}{2}$$

$$J_1 = E_{b1} - \frac{q_1}{A}\frac{(1-\epsilon_1)}{\epsilon_1} \quad ; \quad J_2 = E_{b2} + \frac{q_1}{A}\frac{(1-\epsilon_2)}{\epsilon_2 A}$$

$$J_3 = \frac{1}{2}\left\{(E_{b1} + E_{b2}) + \frac{q_1}{A}\left[\frac{(1-\epsilon_2)}{\epsilon_2} - \frac{1-\epsilon_1}{\epsilon_1}\right]\right\}$$

$$= \frac{1}{2}\left[\left(5.67\times10^{-8}\frac{W}{m^2K^4}\right)\left[(1000K)^4 + (700K)^4\right] + \left(9873\frac{W}{m^2}\right)\left[\frac{1-0.5}{0.5} + \frac{1-0.33}{0.33}\right]\right]$$

$J_3 = 50\,116\ W/m^2$

$$E_{b3} = J_3 \Longrightarrow T_3 = \left(\frac{E_{b3}}{\sigma}\right)^{1/4} = \left(\frac{50116 \ W/m^2}{5.67\times10 \ W/m^2K^4}\right)^{1/4}$$

$$\underline{T_3 = 970 \ K}$$

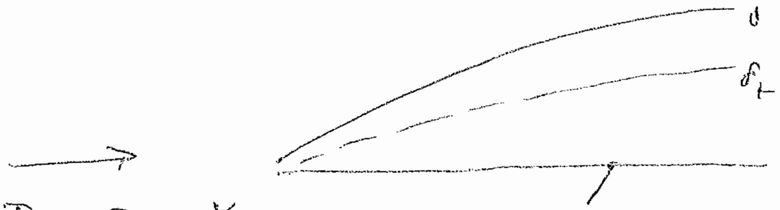
(c) ε_3 DOES NOT AFFECT THE CALCULATION, SINCE

$$q_3 = J_3 - G_3 = \varepsilon_3 E_{b3} + (1-\varepsilon_3) G_3 - G_3 = 0$$

$$E_{b3} = G_3$$

IF THIS CONDITION IS NOT EXACTLY MATCHED, THE RESULTING TEMPERATURE FOR T_3 COULD BE SIGNIFICANTLY DIFFERENT, DUE TO THE T^4 DEPENDENCE OF FLUXES.

5



$T_\infty = 300\,K$

$T_s = 423\,K.$

$U_\infty = 2\,m/sec$

$$\frac{\delta^*}{x} = 1.217\sqrt{\nu/x} \quad ; \quad \frac{\delta_1}{x} = 0.4695\sqrt{\nu/x} = C_f$$

$$\frac{\delta_t}{\delta_1} \approx \begin{cases} Pr^{-1/3} & Pr > 1 \\ Pr^{-1/2} & Pr << 1 \end{cases}$$

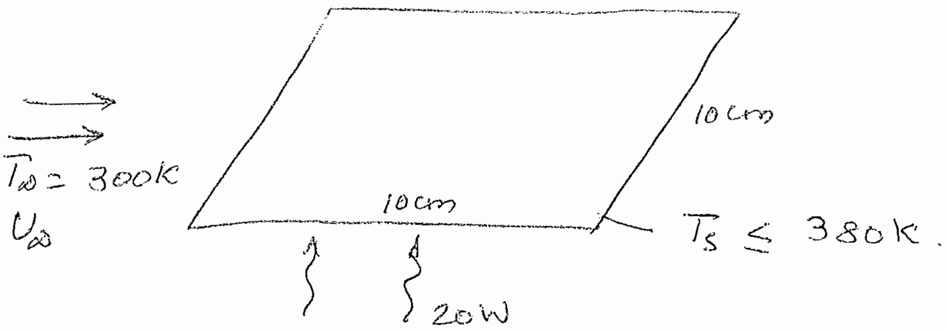
$$\dot{q}_s = k_f \cdot \frac{\Delta T}{\delta_t} = h\,\Delta T$$

$$\Rightarrow h = \frac{q_s}{\Delta T} = \frac{k_f}{\delta_t}.$$

Property	LMA	Air	Water	Engine oil
ρ	6363.2	1.2	997	884
C	365.8	1007	4179	1909
k	39	0.028	0.613	0.145
nu	3.30E-07	1.60E-05	8.57E-07	5.54E-04
alpha	1.6755E-05	2.32E-05	1.47E-07	8.59E-08
Pr	1.97E-02	6.91E-01	5.82E+00	6.45E+03
δ*/x	6.99E-04	4.87E-03	1.13E-03	2.86E-02
δ1/x = Cf	2.70E-04	1.88E-03	4.35E-04	1.11E-02
δt/x	1.92E-03	2.12E-03	2.42E-04	5.94E-04
h = q_dot/ΔT	2.03E+04	1.32E+01	2.54E+03	2.44E+02

x = 1m is used in the above calculation

161



Sol:

Assume the flow to be laminar.

$$\dot{Q} = \bar{h} A (T_s - T_\infty) = \bar{h}(0.01) * 80 \quad W. = 20$$

$$\therefore \bar{h} = 25 \quad W/m^2 K.$$

$$\overline{Nu}_L = 0.664 \, Re_L^{1/2} \, Pr^{1/3} = \frac{\bar{h} L}{k}$$

$$= 0.664 \sqrt{\frac{U_\infty L}{\nu}} \; 0.7^{1/3} * \frac{k_f}{L} = \bar{h} = 25$$

$$\therefore U_\infty = 4.22 \text{ m/sec.}$$

$$\therefore \text{mass flux} = \rho_\infty U_\infty = 5.06 \text{ kg/m}^2\text{-sec. //}$$

$$Re = \frac{4.22 \times 0.1}{1.84 \times 10^{-5}} = 2.29 \times 10^4 < 1 \times 10^5$$

$\Rightarrow$ laminar flow assumption is fine!!