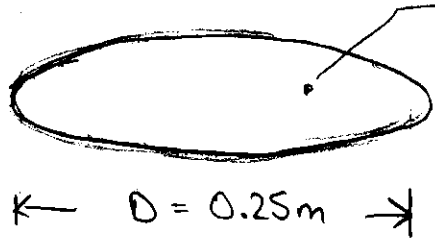
Problem 9.40 Circular Grill

$A_s = \frac{\pi D^2}{4}$

$A_s = 0.0491\ m^2$



$T_s = 130°C$

$\varepsilon = 0.9$

$T_\infty = T_{surr} = 24°C$

$T_{surr} = 297\ K$

* assume lower surface is insulated

$$q = q_{rad} + q_{conv} = \varepsilon \sigma A_s \left[T_s^4 - T_{surr}^4\right] + h A_s \left[T_s - T_\infty\right]$$

Free Convection (Upper Surface of Heated Plate)

$T_{film} = 350K$

$\beta = 1/350K$

$\nu = 20.92 \times 10^{-6}\ m^2/s$

$\alpha = 29.9 \times 10^{-6}\ m^2/s$

$k_f = 0.030\ W/mK$

$L = \frac{A_s}{P} = \frac{D}{4} = 0.0625\ m$

$Ra_L = \frac{g\beta (T_s - T_\infty)}{\nu\alpha} L^3$

$Ra_L = 1.16 \times 10^6$

$\overline{Nu}_L = 0.54\ Ra_L^{1/4} = 17.72$

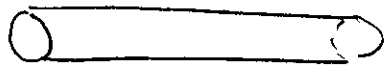
$\overline{Nu}_L = \frac{hL}{k_f} \Rightarrow h = 8.5\ W/m^2K$

$q_{rad} = \varepsilon \sigma A_s \left[403^4 - 297^4\right] = 46.6\ W$

$q_{conv} = h A_s \left[130 - 24\right] = 44.2\ W$

$$\boxed{q = 90.8\ W}$$

Problem 9.61 Horizontal Electrical Cable



$D = 25\ mm$

$q' = 30\ W/m$

$T_\infty = 27°C = 300K$

$$q' = \pi D h \left[T_s - T_\infty\right]$$

assume $h \cong 8\ W/m^2K \Rightarrow T_s = 75°C = 348K$

Intial Guess $T_s \cong 350K \Rightarrow T_{film} = 325K$

$$Ra_D = \frac{g\beta(T_s - T_\infty)D^3}{\nu\alpha}$$

$\nu = 18.4 \times 10^{-6}\ m^2/s$

$\alpha = 26.2 \times 10^{-6}\ m^2/s$

$K_f = 0.028\ W/mK$

$\beta = \frac{1}{325K}$ Air (Ideal Gas)

$Ra_D = 48900$

$$\overline{Nu}_D = \left\{0.60 + \frac{0.387\, Ra_D^{1/6}}{\left(1 + \left(\frac{0.559}{P_r}\right)^{9/16}\right)^{8/27}}\right\}^2$$

$P_r = 0.702$

$$\overline{Nu}_D = 6.46 = \frac{\bar{h} \cdot D}{K_f} \Rightarrow h = 7.2\ W/m^2K$$

$$q' = \pi D h \left[T_s - T_\infty\right]$$

$q' = 30\ W/m$

$D = 0.025\ m$

$\Downarrow$

$T_s = 80\ °C$

* Intial Guess was close, but we could iterate for a better answer

Problem 10.5 Nucleate Pool Boiling

Platinum Plated
$D = 10mm$
$\Delta T_{excess} = 10°C$

Eq. 10.5

$$q_s'' = \mu_l h_{fg} \left[\frac{g(\rho_l - \rho_v)}{\sigma} \right]^{1/2} \left(\frac{C_{p,L} \Delta T_e}{C_{s,f} h_{fg} Pr_L^n} \right)^3$$

water – platinum (Table 10.1)

$C_{s,f} = 0.013 \quad n = 1.0$

$T_{sat} = 100°C$

$\mu_l = 279 \times 10^{-6}$ N.s/m^2

$h_{fg} = 2257000$ J/kg

$Pr_l = 1.76$

$\sigma = 58.9 \times 10^{-3}$ N/m

$\rho_l = 1/v_l = 957.8$ kg/m^3

$\rho_v = \frac{1}{v_v} = 0.5956$ kg/m^3

$C_{p,l} = 4217$ J/kgK

$$q_s'' = 137000 \text{ W/m}^2$$

$$q_s'' = h \Delta T_e$$

$$\boxed{h = 13{,}700 \text{ W/m}^2\text{K}}$$

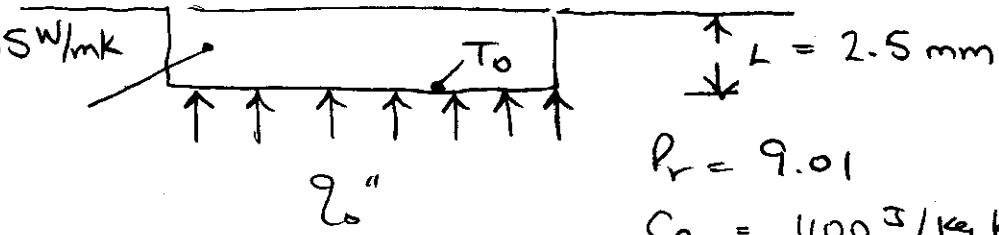
Problem 10.23 Boiling Fluorocarbon Liquid

$T_{sat} = 57\,°C$

$q_o'' = 5 \times 10^4\ W/m^2$

$K_{silicon} = 135\ W/mK$

Silicon Chip



$Pr = 9.01$

$C_{p_l} = 1100\ J/kg\,K$

$h_{fg} = 84400\ J/kg$

$\rho_l = 1619.2\ kg/m^3$

$\rho_v = 13.4\ kg/m^3$

$\sigma = 8.1 \times 10^{-3}\ kg/s^2$

$\mu_l = 440 \times 10^{-6}\ kg/ms$

$C_{sf} = 0.005$

$n = 1.7$

$$q_o'' = \mu_l h_{fg} \left[\frac{g(\rho_l - \rho_v)}{\sigma}\right]^{1/2} \left[\frac{C_{p_l} \Delta T_e}{C_{sf} h_{fg} Pr_L^{\,n}}\right]^3$$

$$\Delta T_e = \frac{C_{sf} h_{fg} Pr_L^{\,n}}{C_{p_L}} \cdot \left[\frac{q_o''}{\mu_l h_{fg} \left[\frac{g(\rho_l - \rho_v)}{\sigma}\right]^{1/2}}\right]^{1/3} \quad (**)$$

$\Delta T_e = 15.92\ °C$

$T_s = 72.9\,°C$

$$R''_{cond} = \frac{L}{K} = 1.852 \times 10^{-5}\ \frac{m^2 K}{W}$$

$$T_o - T_s = R''_{cond} \cdot q''_o = 0.926$$

$$\boxed{T_o = 73.82\ °C}$$

If $q_o'' = 90\%$ of the critical heat flux find T_o

$$q''_{max} = 0.149\, h_{fg} \rho_v \left[\frac{\sigma g (\rho_l - \rho_v)}{\rho_v^2}\right]^{1/4}$$

$q''_{max} = 1.55 \times 10^5 \ W/m^2$

$q''_o = 0.90 \ q''_{max} = 1.39 \times 10^5 \ W/m^2 K$

** using our equation for ΔT_e

$\Delta T_e = 22.3 \ °C$

$T_s = 79.3 \ °C$

$R''_{cond} = 1.85 \times 10^{-5} \ \frac{m^2 K}{W}$

$T_o - T_s = R''_{cond} \cdot q''_o = 2.57$

$\boxed{T_o = 81.9 \ °C}$

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