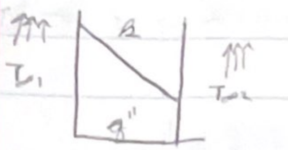
HW #7

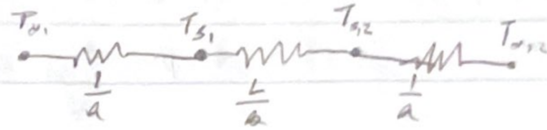
9.1) $L = 75e^{-3}\,m$ $\quad T_{\infty_1} = 200°C$

$k = 2.5\,W/m\cdot K$ $\quad T_{\infty_2} = 100°C$

h_{min} & max h from 1.1 find min & max heat flux for i) free conv in gas ii) free conv in liquids iii) forced conv in gas iv) forced conv in liquid v) conv w/ phase change



use thermal resistance

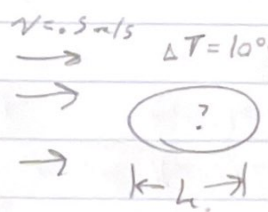


$$q'' = \frac{T_{\infty_1} - T_{\infty_2}}{\frac{1}{h} + \frac{L}{k} + \frac{1}{h}}$$

calculated in python

	h_{min}	h_{max}	q''_{min}	q''_{max}
i)	2	25	97.09	909.09
ii)	50	1,000	1428.57	3125
iii)	25	250	909.09	2631.58
iv)	100	20,000	2000	3322.26
v)	2,500	100,000	3296.75	3331.11

9.3) $V = .5\,m/s$ $\quad \Delta T = 10°C$



$L_c = .5\,m$

Graph Re, Gr, Gr/Re^2 over $10°C \le T_f \le 90°C$

$283.15\,K \le T_f \le 363.15$

only non-fixed quantities are β & ν

$\beta = 1/T_f$ air

$\boxed{\text{assume fluid is air}}$ @ 1 atm

temp.	ν_{air} A-4
250	11.44
300	15.89
350	20.92
400	26.41

$$Gr = \frac{g \Delta T L_c^3}{\nu^2 T_f}$$

$$Re = \frac{V L_c}{\nu}$$

interpolation

$$\frac{T_f - T_1}{T_2 - T_1} = \frac{\nu_f - \nu_1}{\nu_2 - \nu_1}$$

$$\nu_f = \frac{T_f - T_1}{T_2 - T_1} \cdot (\nu_2 - \nu_1) + \nu_1$$

math done in python

HW#7

9.4) $L_c = 0.015m$, $\Delta T = 10°C$ find Ra for... $\nu = \frac{\mu}{\rho}$, $\alpha = \frac{k}{\rho c_p}$

$$Ra = GrPr = \frac{g\beta\Delta T L_c^3}{\nu^2} \cdot \frac{\nu}{\alpha} = \underbrace{g\Delta T L_c^3}_{\text{constant}} \cdot \frac{\beta}{\nu\alpha}$$

need β, ν, α for each fluid

$g\Delta T L_c^3 = (9.81)(10)(0.015)^3 = 3.31e\text{-}4$

Air (1 atm, 400K) Table A.4

$\beta = 1/T_f = 1/400$, $\nu = 26.41e\text{-}6$, $\alpha = 38.3e\text{-}6$

$$Ra = g\Delta T L_c^3 \cdot \frac{1}{(400)(26.41e\text{-}6)(38.3e\text{-}6)} = \boxed{818.31} \text{ air}$$

He (1 atm, 400K) Table A.4

$\beta = 1/T_f = 1/400$, $\nu = 199e\text{-}6$, $\alpha = 295e\text{-}6$

$$Ra = g\Delta T L_c^3 \cdot \frac{1}{(400)(199e\text{-}6)(295e\text{-}6)} = \boxed{14.10} \text{ He}$$

Glycerin (285K) Table A.5

$\beta = \frac{1}{2}(.47+.48)e\text{-}3 = 0.475e\text{-}3$, $\nu = \frac{1}{2}(4200+1460)e\text{-}6 = 2830e\text{-}6$, $\alpha = \frac{1}{2}(.972+.955)e\text{-}7 = 9.635e\text{-}8$

$$Ra = g\Delta T L_c^3 \cdot \frac{\beta}{\nu\alpha} = \boxed{576.76} \text{ Glycerin}$$

Water (310K) Table A.6

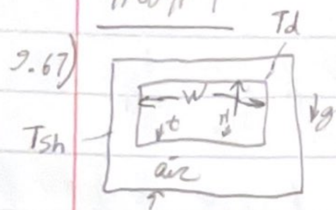
$\beta = 361.9e\text{-}6$ $\nu = \mu_f v_f = (695e\text{-}6)(1.007e\text{-}3) = 7.0e\text{-}7$

$\alpha = k_f v_f / c_{pf} = (628e\text{-}3)(1.007e\text{-}3)/(4.178e\text{-}3) = 1.51e\text{-}7$

$$Ra = g\Delta T L_c^3 \cdot \frac{\beta}{\nu\alpha} = \boxed{1.13e6} \; H_2O$$

HW#7

9.67)



$T_d = 40°C$, $T_{sh} = 20°C$, $g = 9.81\ m/s^2$

$W = .8m$, $H = .3m$, $t = 0.06m$

find q'/L

A.4 (for air) say $T_{air} = \frac{1}{2}(40+20)°C = 303\,K \approx \underline{300\,K} = T_{air}$

$\beta = 1/303$, $\nu = 15.89e{-6}$, $\alpha = 22.5e{-6}$, $k = 26.3e{-3}$, $Pr = 0.707$

need $Ra = \frac{g\beta\Delta T\, t^3}{\nu\alpha} = \frac{(9.81)(\frac{1}{303})(20)(0.06)^3}{(16.19e{-6})(22.5e{-6})} = 3.84e5$

use 9.50 for

$$Nu = 0.22\left(\frac{Pr}{0.2+Pr}Ra\right)^{0.28}\left(\frac{\overset{H+2t}{H}}{t}\right)^{-1/4} = 0.22\left(\frac{0.707}{0.2+0.707}3.85e5\right)^{0.28}\left(\frac{.30+.12}{.06}\right)^{-1/4} = 4.62$$

$\Rightarrow h_{vert} = \frac{Nu\,k}{t} = \frac{4.62 \times 26.5e{-3}}{0.06} = 2.041\ W/m^2K$

for top & bot, heating is different. Bot has no convection as heated from top

bot: $Nu = 1 \Rightarrow h_{bot} = k/t = 26.3e{-3}/0.06 = 0.438\ W/m^2K$

top: $Ra > Ra_{crit}$ ∴ Eq. 9.49; $Nu = 0.069\,Ra^{1/3}Pr^{0.074} = 4.89$

$h_{top} = Nu\,k/t = (4.89)(26.3e{-3})/(0.06) = 2.14\ W/m^2\cdot K$

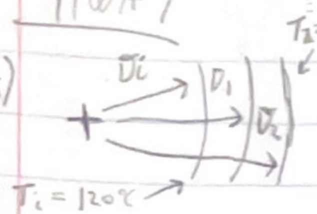
$q' = [2h_{vert}(H+2t) + (h_{bot}+h_{top})(W)]\Delta T$

$= [2(2.041)(.42) + (0.438+2.14)(.8)]\,20$

$$\boxed{q'_{conv} = 75.54\ W/m}$$

HW#7

9.74)



$D_i = 100e{-3}\,m$, $D_1 = 120e{-3}\,m$, $D_2 = 140e{-3}\,m$

$L = 10e{-3}\,m$

A-4) $T = \frac{1}{2}(T_i + T_o) = \frac{1}{2}(120+35)°C = 350K$, $\nu = 20.92e{-6}\,m^2/s$

$k = 0.03\,W/m\cdot K$, $Pr = 0.7$, $\alpha = 29.9$, $\beta = 1/350$

$q' = \frac{T_i - T_2}{R_1 + R_2} = \frac{T_i - T_1}{R_1}$ Eq 9.58) $\frac{q}{L} = q' = \frac{2\pi k_{eff}\Delta T}{\ln(r_o/r_i)}$ Eq 9.59) $k_{eff} = 0.386k\left(\frac{Pr}{0.861+Pr}\right)^{1/4} Ra_c^{1/4}$

Eq 9.60) $L_c = \frac{2[\ln(r_o/r_i)]^{4/3}}{(r_i^{-3/5} + r_o^{-3/5})^{5/3}}$ w/ $Ra = g\beta\Delta T L_c^3/\alpha\nu$

& $R_1 = \frac{\ln(D_o/D_i)}{2\pi k_{eff}}$ $T_1 = T_i - q' R_1$

solve using iterative python

=> a) $q' = 44.9$ W/m < $q'_{ideal} = 100$ W/m

b) $q' = 47.3$ W/m, expect to ↑