HW 2 **Chapter 2:**

#8
a) $q''_x = 14.0\ kW/m^2$
b) $q''_x = -4.0\ kW/m^2$
c) $T = 110^o C$
d) $T = 60^o C$
e) $q''_x = -10.0\ kW/m^2$, $T_1 = -20^o C$

#23
a) $\dot{q} = 2.0e5\ W/m^3$
b) $q''_x(L) = 10.0\ kW/m^2$

#26
a) $\dot{q} = 1.0e6\ W/m^3$
b) $a = 120^\circ\ C$
$b = 1.0 \times 10^4$ K/m
$c = -1.0 \times 10^5$ K/m^2

HW 3 **Chapter 3:**

#5 $q'' = 14.1\ W/m^2$

#9 $k_B = 1.53\ W/mK$

#15 $R_{tot} = 0.1854\ K/W$

#39 $q' = 7.7\ W/m$

#46

$$\frac{q'_o}{q'_i} = \frac{(T_h - T_{\infty,o})}{(T_h - T_{\infty,i})} \times \frac{(h_i 2\pi r_1)^{-1} + \frac{\ln(r_2/r_1)}{2\pi k_B}}{(h_o 2\pi r_3)^{-1} + \frac{\ln(r_3/r_2)}{2\pi k_A}}$$

#58

#73
a) $k_B = 15.3\ W/m\,K$
b)

#81

$$T(x) = -\frac{\dot{q}_o}{k}\left[\frac{x^2}{2} - \frac{x^3}{6L}\right] + \frac{\dot{q}_o L}{2k} x + T_o.$$

#92 $T_0 = 192^o C$

HW 4 **Chapter 3:** #125

$q_{conv} = 0.374\ W$

$q = 1.037e5\ W$

#134 a)

$$R_f = \frac{\theta_b}{16 q_f} = \frac{\cosh mL + (h_o / mk)\sinh mL}{16\left(h_o P k A_{c,f}\right)^{1/2}\left[\sinh mL + (h_o / mk)\cosh mL\right]}$$

b) $q_f = 2.703\ W$

#144 a) $q_f = 12.8\ W$

b) $q' = 2.91\ kW/m$

HW 5 **Chapter 4:** #10 q’=q/L=84 W/m

#12 $T_1 = 25°C + 50\ W/(5\ W/m\cdot K \times 0.143 m) = 94.9°C$.

HW 6 **Chapter 4:** #32a

#40 $$-T_0 + \frac{1}{4}T_1 + \frac{k_A}{2(k_A + k_B)}T_2 + \frac{1}{4}T_3 + \frac{k_B}{2(k_A + k_B)}T_4 = 0$$

#51a $T_0 = 162.5\ ^oC$

HW 7 **Chapter 5:** #5 $t = 1122\ s = 0.312h$

#18 $t = 8.31s.$

#22

#23 $L = 2.52\ m$

$E_i - E_f = 0.022\ J$

HW 8 **Chapter 5:** #39a 33,800 s

#49a $t = 1.72\,(0.015m)^2 \times 400\ kg/m^3 \times 1600\ J/kg \cdot K / 1.7W/m \cdot K = 145s$.

#59 t=42 s

Note that the one-term approximation is accurate, since Fo > 0.2.

#76 k=0.45W/mK with $\alpha = 4.30 \times 10^{-7}\ m^2/s$

#93

#106 $T(0, 180s) = T_0 = 275\ C$

$T(45mm, 180s) = T_3 = 312\ C$

HW 9 **Chapter 6:** #1 $h = \frac{-k_f E}{D - T_\infty}$

#19 q = 2066 W

#21 $\frac{\overline{h}_x}{h_x} = 1.11$

HW 10 **Chapter 7:** #2

$$\delta = 5L\,Re_L^{-1/2} = 5(1\,m)(1161)^{-1/2} = 0.147\,m$$

$$\delta_t = \delta\,Pr^{-1/3} = 0.147\,m(1081)^{-1/3} = 0.0143\,m$$

$$h_L = \frac{k}{L}0.332\,Re_L^{1/2}\,Pr^{1/3} = \frac{0.140\,W/m\cdot K}{1\,m}0.332(1161)^{1/2}(1081)^{1/3} = 16.25\,W/m^2\cdot K$$

$$\tau_{s,L} = 0.0842\,kg/m\cdot s^2 = 0.0842\,N/m^2$$

c) $q' = -5200\frac{W}{m}$

#11

We begin by calculating the Reynolds numbers for the two different surface temperatures:

$$Re_{L1} = \frac{u_\infty L}{\nu_1} = \frac{5\text{ m/s} \times 2\text{ m}}{1.669 \times 10^{-5}\text{ m}^2/\text{s}} = 5.99 \times 10^5$$

$$Re_{L2} = \frac{u_\infty L}{\nu_2} = \frac{5\text{ m/s} \times 2\text{ m}}{1.82 \times 10^{-5}\text{ m}^2/\text{s}} = 5.49 \times 10^5$$

$q_1 = 1950W$

$q_2 = 3440W$

#15 a) $q = 17.6W$

b) $q = 143.6W$

#17 29 ^oC

HW 11 **Chapter 7:**

#42

$$F_D = 1.1(0.025\ \text{m})\ 1.048\ \text{kg/m}^3\ (15\ \text{m/s})^2 / 2 = 3.24\ \text{N/m}.$$

$$q' = \bar{h}(\pi D)\ (T_s - T_\infty) = 88\ \text{W/m}^2\cdot\text{K}(\pi \times 0.025\ \text{m})\ (100-25)^\circ\text{C} = 520\ \text{W/m}.$$

#47ab

$$\bar{h} = \left(\overline{Nu}_D k/D\right) = (16.7 \times 0.0282\ \text{W/m}\cdot\text{K}/0.002\ \text{m}) = 235\ \text{W/m}^2\cdot\text{K}$$

$$q_f = M\frac{\sinh mL + (\bar{h}/mk)\cosh mL}{\cosh mL + (\bar{h}/mk)\sinh mL} = 0.868\ \text{W}.$$

#70

Condition	Re_D	$\overline{Nu}_D$	$\bar{h}_D$ ($W/m^2\cdot K$)	T_s (°C)
(w) water	7.465×10^4	499	3491	18.8
(a) air	1.72×10^4	67.5	20.1	672

#79

$$T_g = 610\ \text{K} = 337^\circ\text{C}.$$

HW 12 **Chapter 8:**

#3

Cast iron $\Delta p = 0.402$ bar $P = 1.97$ kW

#4

$$P = \Delta p \cdot \dot{V} = \Delta p \cdot \frac{\dot{m}}{\rho} = 5.38 \times 10^6\ \text{N/m}^2\ \frac{24\ \text{kg/s}}{884\ \text{kg/m}^3} = 1.459 \times 10^5\ \text{N}\cdot\text{m/s} = 146\ \text{kW}.$$

#6

Liquid	T (k)	$\dot{m}$ (kg/s)	$x_{fd,h}$ (m)	$x_{fd,t}$ (m)
Water	300	0.0063	0.464	2.72
Water	400	0.0059	1.72	2.30
Engine Oil	300	0.0056	7.27×10^{-4}	4.65
Engine Oil	400	0.0052	37.7×10^{-3}	5.74

#14

From Newton's law of cooling, Eq. 8.27,

$$T_s(x) = (q_s''/h) + T_m(x)$$

$$T_s(x) = \frac{q_{s,m}''}{h}\sin\frac{\pi x}{L} + T_{m,i} + \frac{LDq_{s,m}''}{\dot{m}\,c_p}(1 - \cos \pi x/L).$$

#16a

ANALYSIS: (a) With constant heat flux, from Eq. 8.38,

$$q = q_s''(\pi DL) = 1000\ \text{W/m}^2(\pi \times 0.05\ \text{m} \times 3\ \text{m}) = 471\ \text{W}.$$

From the overall energy balance, Eq. 8.34,

$$T_{m,o} = T_{m,i} + \frac{q}{\dot{m}c_p} = 20^\circ\text{C} + \frac{471\ \text{W}}{0.005\ \text{kg/s} \times 1008\ \text{J/kg}\cdot\text{K}} = 113.5^\circ\text{C}$$

From the convection rate equation, it follows that

$$T_{s,i} = T_{m,i} + \frac{q_s''}{h} = 20^\circ\text{C} + \frac{1000\ \text{W/m}^2}{25\ \text{W/m}^2\cdot\text{K}} = 60^\circ\text{C}$$

$$T_{s,o} = T_{m,o} + q_s''/h = 113.5^\circ\text{C} + 40^\circ\text{C} = 153.5^\circ\text{C}$$

HW 13 **Chapter 8:**

#23a

For L = 5 m, $\bar{h} = 5.64(3.66+17.51) = 119\ \mathrm{W/m^2\cdot K}$, hence

$$T_{m,o} = 100^\circ C - (75^\circ C)\exp\left(-\frac{\pi \times 0.025\,m \times 5\,m \times 119\ W/m^2\cdot K}{0.5\,kg/s \times 2035\ J/kg\cdot K}\right) = 28.4^\circ C$$

For L = 100 m, $\bar{h} = 5.64(3.66+3.38) = 40\ \mathrm{W/m^2\cdot K}$, $T_{m,o} = 44.9°C$.

#32a

$$L = \frac{-\dot{m}c_p \ell n(\Delta T_o/\Delta T_i)}{\pi D\bar{h}} = -\frac{2\,kg/s\,(4181\,J/kg\cdot K)\,\ell n(25^\circ C/75^\circ C)}{\pi(0.04\,m)\,6919\,W/m^2\cdot K} = 10.6\,m.$$

#37a

$$\Delta p = 0.0269\frac{1.128\,kg/m^3\,(2.0\,m/s)^2}{2\times 0.15\,m}\times 10\,m = 4.03\,N/m^2$$

where $u_m = \dot{m}/\rho A_c = 0.04\,kg/s \big/ 1.128\,kg/m^3 \times \left(\pi 0.15^2\,m^2/4\right) = 2.0\,m/s$.

#34

a) $L = 8.87m$

b) temperature of the wall at the exit is

$$T_s = \frac{\dot{q}\left(D_o^2 - D_i^2\right)}{4\,h\,D_i} + T_{m,o} = \frac{10^6\ W/m^3\left[(0.04m)^2 - (0.02m)^2\right]}{4\times 1796\ W/m^2\cdot K(0.02m)} + 40^\circ C = 48.4^\circ C$$

and

$$T_{w,max} = -\frac{10^6\ W/m^3}{4\times 15\ W/m\cdot K}\left[(0.02m)^2 - (0.01m)^2\right] + \frac{10^6\ W/m^3\,(0.02m)^2}{2\times 15\ W/m\cdot K}\ell n\frac{0.02}{0.01} + 48.4^\circ C = 52.6^\circ C.$$

#54

a) $T_{m,o} = 37.1°C$

b) $T_{m,o} = 47.4^\circ C$

#55

a) $L = 98.5m$

b) $L = 10.6m$

#61

With condensation occurring when the surface temperature reaches 100°C, the corresponding value of T_m may be determined from the local ($x = x_1$) requirement that $U_i(\pi D_i)\left[T_m(x_1) - T_\infty\right] = h_i(\pi D_i)\left[T_m(x_1) - T_s\right]$. Hence,

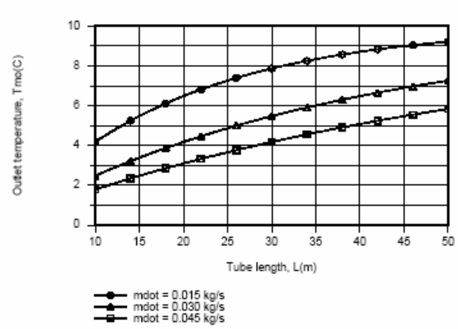
$$T_m(x_1) = \frac{T_\infty - (h_i/U_i)T_s}{1-(h_i/U_i)} = \frac{20-(51.4/3.66)100^\circ C}{1-(51.4/3.66)} = 106^\circ C$$

The distance at which the mean steam temperature is 106°C can then be estimated from Eq. (1), where $P = \pi D_i$ and $U = U_i$,

$$\frac{(20-106)^\circ C}{(20-120)^\circ C} = \exp\left(-\frac{\pi(0.050\,m)3.66\,W/m^2\cdot K(x_1)}{0.0172\,kg/s\times 2080\,J/kg\cdot K}\right)$$

$x_1 = 9.3$ m <

#70



The longer the tube the larger the rate of heat extraction from the soil, and for $\dot{m}$ = 0.030 kg/s, the temperature rise of $\Delta T = (T_{m,o} - T_{m,i}) \approx 7°C$ is well below the maximum possible value of $\Delta T_{max} = 10°C$.

#78

$$q = \dot{m}\,c_p\left(T_{m,o} - T_{m,i}\right) = 0.1\ kg/s \times 1008\ J/kg\cdot K\,(312-285)K = 2724\ W.$$

HW 14 **Chapter 9:** **#2**

Air	727
Helium	12.5
Glycerin	512
Water	$1.01*10^6$

#7 S = 12.6 mm = 0.0126 m (Warning: Ra exceeds critical value)

#10 h=2.94 W/m^2K

#36 q = 468 W

#71 h=9.84 W/m2K

hr=32.1 W/m2K

t=221 s

#90 61 W

#105 m_dot=0.022 kg/s

HW 15 **Chapter 10:** #5 $h = 13,690\ W/m^2 \cdot K.$

#9

Flluid	$q''_{max}\left(MW/m^2\right)$	$q''_{max}/q''_{max,water}$
Mercury	1.34	1.06
Ethanol	0.512	0.41
R-134a	0.281	0.22
Water	1.26	1.00

#14a $T_s = T_{sat} + \Delta T_e = (100 + 18.7)^\circ C = 118.7^\circ C.$

#27 $q_s = 187\ W/m^2 \cdot K\left(\pi \times 0.020m \times 0.200m\right) \times 355K = 835W.$