Homework Answers
CM3110 Transport I
Morrison

HW 1

1. Problem J: 25mol%
2. Text 4.13: $1.04 \times 10^6\ dynes/cm^2$
3. Problem C: $1.3 \times 10^5 Pa$
4. Text 1.10: $7.8\ m/s$
5. Stretch: Text 1.19: 1.4 l/min
6. Problem A: $1.1\ gpm$
7. Problem J: 1900 kW
8. Text 1.26: $p_2 = p_1 + \rho g(h_1 - h_2)$
9. Text 1.41: $-Usin\theta$
10. Text 1.44: $\begin{pmatrix} 12 \\ 12 \\ 0 \end{pmatrix}_{r\theta z} = (12 \quad 12 \quad 0)_{r\theta z}$
11. Text 1.45: $(cos\theta + 4)|_{1,0,0} = 5$
12. B:
    a. 5
    b. $\begin{pmatrix} 5 \\ 1 \\ 8 \end{pmatrix}_{xyz}$
    c. 3
    d. $\frac{5}{3}$
13. Stretch: Text 1.48: $\begin{pmatrix} 4\cos\theta - sin\theta \\ -4sin\theta - cos\theta \\ 1 \end{pmatrix}_{r\theta z}$
14. Stretch: Text 1.58: ask Dr. Morrison or TA
15. Problem D: $Q = \frac{\pi R^4 \Delta P}{8\mu L}$
16. Text 2.21: $Q = 13.6\ l/min,\ Re = 4200$, turbulent
17. Problem F: $1.30\ atm$
18. Text 1.36: $v_2 = \sqrt{2\alpha(gh + (P - P_{atm}/\rho)}$
19. Text 3.11: Stretch: $y(7.0) = 63.4$ according to the model; but the model doesn't fit that well at that particular point.
20. Problem H: $4\pi R^2$
21. Text 4.14: 720 Pa
22. Text 4.20: Stretch: $p_{bot} = p_{atm} + \rho gh$
23. Stretch: Text 1.8: $v = 3.17\ ft/s$, $8.1\ ft$ head loss
24. Problem E1: $28kW$
25. Stretch: Problem E2: $2.4\ kW$

HW 2

1. Text 2.2: For a shear rate of $1.0\ s^{-1}$, the two fluids would generate the following stresses: $3.06 \times 10^{-4} Pa$ for acetone and 8.94×10^{-4} for water.
2. Text 2.6: $20s^{-1}$; note that the answer would be $-20s^{-1}$ in some coordinate systems
3. Text 2.10: Stretch: $2\mu_1 = \mu_2$
4. Text 3.14: Stretch: $\pi R^2 \rho U$
5. Text 3.16: mass flow $= \frac{\rho U}{\sqrt{2}} bc$, momentum flow = $\frac{\rho U^2 bc}{\sqrt{2}} \hat{e}_x$
6. Text 3.22: Stretch: $A/2$
7. Text 3.24: $< v > = \frac{H^2 \Delta p}{3\mu L} + \frac{V}{2}$; $y_{at\ max} = \frac{\mu L V}{2H\Delta p}$
8. Text 3.31: $\underline{g} = \begin{pmatrix} 0 \\ g \sin\delta \\ g\cos\delta \end{pmatrix}_{xyz}$; in flow direction: $g\cos\delta$
9. Text 6.2: See text
10. Problem B: see text or instructor
11. Text 6.21: 0.0027 m^3/s
12. Text 6.30: $r = R, v_z = 0; r = 0, \frac{dv_z}{dr} = 0$
13. Text 6.33: Stretch. Fluid 1: $y = 0, v_x = 0; y = h_1, v_x^{fluid1} = v_x^{fluid2}; y = h_1, \tau_{yx}^{fluid1} = \tau_{yx}^{fluid2}$; Fluid 2: $y = h_1 + h_2, v_x = V$
14. Text 6.39: $v_x = \left(\frac{P_L - P_0}{2L\mu} + \rho g \frac{sin\psi}{2\mu}\right)(y^2 - By)$; $Q = \frac{\left(\frac{P_0 - P_L}{2L\mu} - \rho g \frac{sin\psi}{2\mu}\right) W B^3}{6}$; $\underline{F} = WL \begin{pmatrix} -\frac{B}{2}\left(\frac{(P_L - P_0)}{L} + \rho g\ sin\psi\right) \\ \frac{P_L + P_0}{2} \\ 0 \end{pmatrix}_{xyz}$
15. Text 6.43: $\frac{v_z}{V} = \frac{\ln\left(\frac{r}{R}\right)}{ln\kappa}$; $Q = \frac{V\pi R^2}{2ln\kappa}(\kappa^2 - 1) - \kappa^2 R^2 \pi V$; $\underline{F} = \begin{pmatrix} 0 \\ 0 \\ \frac{2\pi\mu V L}{ln\kappa} \end{pmatrix}_{xyz}$
16. Text 7.6: see text
17. Text 7.40: Stretch. Text 7.40: $v_z = \left(\frac{\bar{\rho}\bar{\beta}(T_2 - T_1) g b^2}{12\mu}\right)\left(\frac{y^3}{b^3} - \frac{y}{b}\right)$
18. Problem A: a) $\underline{\mathcal{T}} = R\Phi_0 \hat{e}_z$, b) $\underline{\mathcal{T}} = -4\pi L\mu b \hat{e}_z$

HW 3

1. Problem A: $330\ Pa$
2. Problem B: $4.5\ m/s$
3. Text 9.12: negligible
4. Text 9.8: $0.02\ m$ of heat loss
5. Problem E: $3.0\ psi$
6. Text 7.21: see text
7. Text 7.33: $2.2\ ml/s$
8. Problem G: $2.5 \times 10^4 \frac{Pa}{m}$
9. Text 8.3: see text
10. Text 2.13: $F_{drag} = 16N$
11. Text 2.14: $u_1 = 46u_2$
12. Text 2.30: see text
13. Text 2.31: Stretch: search internet or instructor
14. Problem F: Ergun equation; see instructor
15. Problem G: $3.2 \times 10^{-4} m/s$
16. Text 8.47 127 mph
17. Text 8.49 belly-to-earth, $C_D \approx 0.34$; head first, $C_D \approx 0.83$
18. Text 8.6: see Figure 8.8
19. Text 8.11: $Re = 36$; not creeping flow.
20. Text 8.12: $Re = 0.0023$; is creeping flow (creeping flow=Stokes flow)
21. Text 8.19: Stretch: Text 8.19: see above and for $R_1 = 0.545in$, $R_2 = 0.834in$, $\rho = 997.08kg/m^3$, $P_1 = 30psi$; $Q = 50gpm$, the answer is $\underline{R} = 262\ N\ \hat{e}_x + 141\ \hat{e}_y = 59\ lb_f\ \hat{e}_x + 32\ lb_f\ \hat{e}_y$ (use the MEB to estimate Δp).
22. Text 8.20: Stretch: see above and for $R_1 = 0.545in$, $R_2 = 0.834in$, $\rho = 997.08kg/m^3$, $P_1 = 30psi$; For $Q = 50gpm$, the answer is $\underline{R} = -6\ N\ \hat{e}_x + 234\ N\ \hat{e}_y = -1\ lb_f\ \hat{e}_x + 53\ lb_f\ \hat{e}_y$ (use the MEB to estimate Δp).
23. Text 8.33: see Chapter 8
24. Text 8.46: see Chapter 8 and Figure 8.54
25. Text 9.4: see instructor
26. Text 9.20 The answer is an equation $\underline{R} = \begin{pmatrix} -\rho A_1 \langle v \rangle_1^2 + \frac{\rho A_2 \langle v \rangle_2^2}{2} + \frac{P_2 A_2}{2} - P_1 A_1 \\ \frac{\sqrt{3}\rho A_2 \langle v \rangle_2^2}{2} + M_{CV} g + \frac{P_2 A_2 \sqrt{3}}{2} \\ 0 \end{pmatrix}_{xyz}$
27. Stretch. Text 9.24: For gravity in the $-\hat{e}_x$ direction $\left(\underline{g} = -g\hat{e}_x\right)$ and flow in to each unit in the $\hat{e}_z$ direction, the x-component of the force on the fluid ($\underline{R}$, which is opposite in sign to the force on the walls) is the same in both cases (due only to gravity); the z-component (R_z) is different, being $R_z = (P_2 - P_1)\pi R^2$ for the straight tube and $R_z = -\pi R^2 (P_1 + P_2) - 2\rho\pi R^2 \langle v \rangle^2 / \beta$ for the U-tube.
28. Text 9.4: It's the same, but the two methods are not both equally easy. For one you need the whole stress field $\underline{\underline{\Pi}}(x, y, x)$. That's sometimes impossible to get. With the macroscopic momentum balance, you can get macroscopic forces (of that's all you're looking for).
29. Text 9.19: The answer is an equation:

$$\underline{R} = \begin{pmatrix} \rho A_2 \langle v \rangle_2^2 + P_2\ A_2 \\ \rho A_1 \langle v \rangle_1^2 + P_1 A_1 + M_{CV} g \\ 0 \end{pmatrix}_{xyz}$$

HW 4

1. See assignment. Answers: $170\,\frac{W}{m^2}$; overestimate
2. Problem H: Answer: $8.9\ kW/m^2$
3. See assignment: Answer: $12\ W/m^2K$
4. See assignment. Answers: $T = \left(\frac{S_e}{4k}\right)(R^2 - r^2) + \frac{S_eR}{2h} + T_b, \left.\frac{q_r}{A}\right|_{r=R} = \frac{S_eR}{2}$
5. Stretch Geankoplis 4.2-4, modified, see assignment. Answer: $\frac{q}{A} = \frac{a(T_1-T_2)+\frac{b}{2}(T_1^2-T_2^2)+\frac{c}{4}(T_1^4-T_2^4)}{H}$
6. Stretch. See assignment. Answer: see TA or instructor.
7. Geankoplis 4.1-1: $40\ W/m^2$
8. See assignment. Answer: $-430\ W/m^2$
9. See assignment. Solution: see TA or instructor.
10. See assignment. Solution: see TA or instructor.
11. See assignment. Answer: a) $1100\ W/m^2$; b) $92\ W/m^2$
12. See assignment. Answer: 37.5^oC
13. Stretch See assignment. a) -900 to $(-17{,}000)\ W/m^2$ (1 sig fig) b)$0.0028\ m/W$ c) $0.0058 - 0.012\ m/W$ d) $0.022 - 0.69\ m/W$, 2) e) oil side heat transfer coefficient dominates.
14. See assignment. Answers: a) $-16{,}000\ W/m^2$ b) higher magnitude of flux
15. Problem J. Answer: $7.0 \times 10^2\ W/m^2$
16. Problem L. Answer: $h_{conv} = 56\,\frac{W}{m^2K}, h_{rad} = 7.1\,\frac{W}{m^2K}, \frac{q}{A} = 5600W/m^2$ (no radiation); $\frac{q}{A} = 6300W/m^2$ (with radiation)
17. Stretch Problem N (stretch). $h_{lm} = 5300\,\frac{W}{m^2K}, T = 21^oC$
18. See assignment. No answer provided (summary of data correlations). See lecture notes for an example.
19. Geankoplis 4.5-6: $84\ \mathrm{lb_m/h}$

HW 5

1. Geankoplis 4.7-1: $\mathrm{h} = 5.4\ \mathrm{W/m^2}$, $\mathrm{q} = 92\ \mathrm{W/m}$ (not using the simplified equation); $\mathrm{q} = 85\mathrm{W/m}$ (simplified equation)
2. Geankoplis 4.7-3: $\mathrm{Q} = 45\mathrm{W}$
3. Geankoplis 4.5-4: $\mathrm{T}_1' = 299.5^{\mathrm{o}}\mathrm{C}$, $\mathrm{A} = 97\mathrm{m}^2$ (assume double-pipe heat exchanger; note Geankoplis' use of an improbable number of sig figs)
4. Geankoplis 4.5-4, except with 1-2 shell-and-tube heat exchanger: $\mathrm{T}_1' = 299.5^{\mathrm{o}}\mathrm{C}$, $\mathrm{A} = 97\mathrm{m}^2$. How does the 1-2 shell-and-tube compare to the double pipe?
5. Stretch See assignment. Answers: a) $26\ kW$, b) $\Delta T_{lm} = 63^o C$; c) $U_o = 500\ W/m^2K$
6. See assignment. Answer: 180kW.
7. Geankoplis 4.10-3: $160\mathrm{W}$
8. See assignment. Answer: $260\mathrm{W}$. Neither radiation nor natural convection dominates.
9. Geankoplis 4.11-1: a)$14{,}000\ \mathrm{W/m^2}$, b) $4500\ \mathrm{W/m^2}$, c) one more
10. Geankoplis 4.7-8: We need to calculate radiation and natural convection contributions to the total. Answers: radiation 5.5kW; natural convection 1.3 kW; total 6.8 kW.
11. See assignment. Answer: Only heat exchanger C will work.
12. See assignment. Answers: a)$h_i = 6900\frac{W}{m^2K}, h_0 = 2200\ W/m^2K, U_o = 1400\ W/m^2K$ b) with water-side fouling $U_o = 1100\ W/m^2K$, with orange-juice side fouling, $U_o = 900\ W/m^2K$, with fouling on both sides, $U_o = 800\ W/m^2K$
13. Problem M. Answer: c; yes, radiation is important; $h_{total} = 62\frac{W}{m^2K}; \frac{q}{A} = 6300W/m^2$
14. Problem K. Answer: $h = 7.0\frac{W}{m^2K}, q = 130\ W$ (natural convection only)