Homework Answers
CM3110 Transport I
Morrison

HW 1

1. Problem J: 25mol%
2. Text 4.13: $1.04 \times 10^6$ dynes/cm²
3. Problem C: $1.3 \times 10^5$Pa
4. Text 1.10: $7.8 \text{ m/s}$
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: $\begin{pmatrix} 12 \\ 0 \end{pmatrix}_{r\theta z} = (12 \\ 12 \\ 0)_{r\theta z}$
11. Text 1.45: $(\cos\theta + 4)|_{1,0,0} = 5$
12. B:
   a. 5
   b. $\begin{pmatrix} 5 \\ 8 \end{pmatrix}_{xyz}$
   c. 3
   d. $\frac{5}{3}$
13. Stretch: Text 1.48: $\begin{pmatrix} 4 \cos \theta - \sin \theta \\ -4 \sin \theta - \cos \theta \end{pmatrix}_{r\theta z}$
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: $Q = 13.6 \text{ l/min}, Re = 4200$, 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: $4\pi R^2$
22. Text 4.20: Stretch: $p_{bot} = p_{atm} + \rho gh$
23. Stretch: Text 1.8: $v = 3.17 \text{ ft/s}, 8.1 \text{ ft head loss}$
24. Problem E1: 28$kW$
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 \[8.94 \times 10^{-4}\] for water.
2. Text 2.6: 20\(s^{-1}\); note that the answer would be \(-20\) 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 = \(\frac{\rho U^2 b c}{\sqrt{2}} \hat{e}_x\)
6. Text 3.22: Stretch: \(A/2\)
7. Text 3.24: \(<v> = \frac{H^2 \Delta p}{3 \mu L} + V/2\) at max \(= \frac{\mu V}{2H \Delta p}\)
8. Text 3.31: \(g = \begin{pmatrix} g \sin \delta \\ g \cos \delta \end{pmatrix}_{xyz}\); in flow direction: \(g \cos \delta\)
10. Problem B: see text or instructor.
11. Text 6.21: 0.0027 m\(^3\)/s
12. Text 6.30: \(r = R, v_z = 0; r = 0, \frac{dv_z}{dt} = 0\)
13. Text 6.33: Stretch. Fluid 1: \(y = 0, v_x = 0; y = h_1, v_x^{\text{fluid1}} = v_x^{\text{fluid2}}; y = h_1, \tau_y^{\text{fluid1}} = \tau_y^{\text{fluid2}}\); Fluid 2: \(y = h_1 + h_2, v_x = V\)
14. Text 6.39: \(v_x = \left(\frac{P_L - P_0}{2L \mu} + \rho g \frac{\sin \psi}{2 \mu}\right) (y^2 - By); Q = \frac{(P_g - P_L) - \rho g \sin \psi}{2 \mu} W B^3; F = WL \left(\frac{B}{2} \left(\frac{P_L - P_0}{L} + \frac{\rho g \sin \psi}{2 \mu}\right)\right)_{xyz}\)
15. Text 6.43: \(\frac{v_x}{V} = \frac{\ln(\frac{r}{R})}{\ln k}; Q = \frac{Vs \pi R^2}{2 \ln k} (\kappa^2 - 1) - \kappa^2 R^2 \pi V; F = \begin{pmatrix} 0 \\ \frac{2sp \mu VL}{\ln k^2} \end{pmatrix}_{xyz}\)
16. Text 7.6: see text.
17. Text 7.40: Stretch. Text 7.40: \(v_z = \left(\frac{P_L (T_2 - T_1) g b^2}{12 \mu}\right) \left(\frac{V^3}{b^3} - \frac{V}{b}\right)\)
18. Problem A: a) \(T = R \Phi_0 \hat{e}_z\), b) \(T = -4\pi L \mu b \hat{e}_z\)

11 February 2021 2
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: $F_{drag} = 16 N$
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 $R_1 = 0.545 in$, $R_2 = 0.834 in$, $\rho = 997.08 kg/m^3$, $P_1 = 30 psi$; $Q = 50 gpm$, the answer is $R = 262 N \hat{e}_x + 141 \hat{e}_y = 59 lbf \ \hat{e}_x + 32 lbf \ \hat{e}_y$ (use the MEB to estimate $\Delta p$).
22. Text 8.20: Stretch: see above and for $R_1 = 0.545 in$, $R_2 = 0.834 in$, $\rho = 997.08 kg/m^3$, $P_1 = 30 psi$; For $Q = 50 gpm$, the answer is $R = -6 N \hat{e}_x + 234 N \hat{e}_y = -1 lbf \ \hat{e}_x + 53 lbf \ \hat{e}_y$ (use the MEB to estimate $\Delta p$).
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 $R = \left( \frac{-\rho A_1 (v)^2 + \frac{\rho A_2 (v)^2}{2} + \frac{P_1 A_1}{2} - P_1 A_1}{\sqrt{\rho A_2 (v)^2} - \frac{\rho A_2 \sigma^2}{2} + M_C g - \frac{P_1 A_2 \sigma^2}{2}} \right)_{xyz}$

27. Stretch. Text 9.24: For gravity in the $-\hat{e}_x$ direction ($g = -g \hat{e}_x$) and flow in to each unit in the $\hat{e}_z$ direction, the $x$-component of the force on the fluid ($R$, 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 $R_z = -\pi R^2 (P_1 + P_2) - 2 \rho \pi R^2 (v)^2 / \beta$ 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 $\Pi(x,y,z)$. 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:

$$R = \left( \frac{\rho A_2 (v)^2 + P_2 A_2}{\rho A_1 (v)^2 + P_1 A_1 + M_C g} \right)_{xyz}$$

11 February 2021
HW 4

1. See assignment. Answers: 170 \( \frac{W}{m^2} \); overestimate
2. Problem H: Answer: 8.9 kW/m²
3. See assignment: Answer: 12 W/m²K
4. See assignment. Answers: \( T = \left( \frac{\pi R}{4} \right) (R^2 - r^2) + \frac{S_\pi R}{2n} + T_b, \frac{q_r}{A} \bigg|_{r=R} = \frac{S_\pi R}{2} \)
5. Stretch Geankoplis 4.2-4, modified, see assignment. Answer: \( \frac{q}{A} = \frac{a(T_1-T_2)+\frac{b}{2}(T_1^2-T_2^2)+\frac{c}{3}(T_1^3-T_2^3)}{H} \)
6. Stretch. See assignment. Answer: see TA or instructor.
7. Geankoplis 4.1-1: 40 W/m²
8. See assignment. Answer: -430 W/m²
9. See assignment. Solution: see TA or instructor.
10. See assignment. Solution: see TA or instructor.
11. See assignment. Answer: a) 1100 W/m²; b) 92 W/m²
12. See assignment. Answer: 37.5°C
13. Stretch See assignment. a) -900 to (-17,000) W/m² (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/m² b) higher magnitude of flux
15. Problem J. Answer: 7.0 \( \times 10^2 \) W/m²
16. Problem L. Answer: \( h_{comp} = 56 \frac{W}{m^2K} \), \( h_{rad} = 7.1 \frac{W}{m^2K} \), \( \frac{q}{A} = 5600W/m² \) (no radiation); \( \frac{q}{A} = 6300W/m² \) (with radiation)
17. Stretch Problem N (stretch). \( h_{tm} = 5300 \frac{W}{m^2K} \), \( T = 21°C \)
18. See assignment. No answer provided (summary of data correlations). See lecture notes for an example.
19. Geankoplis 4.5-6: 84 lb_m/h
1. Geankoplis 4.7-1: \( h = 5.4 \text{ W/m}^2 \), \( q = 92 \text{ W/m} \) (not using the simplified equation); \( q = 85\text{ W/m} \) (simplified equation)
2. Geankoplis 4.7-3: \( Q = 45 \text{ W} \)
3. Geankoplis 4.5-4: \( T_1^0 = 299.5^\circ \text{C}, A = 97 \text{m}^2 \) (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: \( T_1^0 = 299.5^\circ \text{C}, A = 97 \text{m}^2 \)
How does the 1-2 shell-and-tube compare to the double pipe?
5. Stretch See assignment. Answers: a) 26 kW, b) \( \Delta T_{lm} = 63^\circ \text{C} \); c) \( U_o = 500 \text{ W/m}^2 \text{K} \)
6. See assignment. Answer: 180kW.
7. Geankoplis 4.10-3: 160W
9. Geankoplis 4.11-1: a) 14,000 W/m\(^2\), b) 4500 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) \( h_i = 6900 \frac{W}{m^2K} \), \( h_o = 2200 \text{ W/m}^2 \text{K} \), \( U_o = 1400 \text{ W/m}^2 \text{K} \) b) with water-side fouling \( U_o = 1100 \text{ W/m}^2 \text{K} \), with orange-juice side fouling, \( U_o = 900 \text{ W/m}^2 \text{K} \), with fouling on both sides, \( U_o = 800 \text{ W/m}^2 \text{K} \)
13. Problem M. Answer: c; yes, radiation is important; \( h_{total} = 62 \frac{W}{m^2K} \), \( q = 6300 \text{ W/m}^2 \)
14. Problem K. Answer: \( h = 7.0 \frac{W}{m^2K} \), \( q = 130 \text{ W} \) (natural convection only)