Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page. Tables and charts that you may need are provided at the end.

Note: From questions 2, 3, 4 and 5, the best three will count, i.e., I will correct all of these four questions and count the best three results towards your total

Name: ____________________

UT EID: ____________________

Question 1: Multiple Choice Questions . . . . 10 points

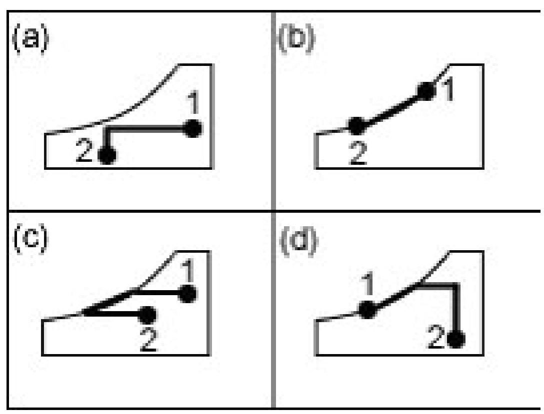
2 (a) At the condenser, the refrigerant changes

- ◯ from high pressure vapor to high pressure liquid
- ◯ from high pressure vapor to low pressure liquid
- ◯ from high pressure liquid to high pressure vapor
- ◯ from high pressure vapor to low pressure vapor

4 (b) A refrigerator has a coefficient of performance of 1.6. How much work must be supplied to this refrigerator for it to reject 1000 kJ of heat?

- ◯ 385 kJ
- ◯ 625 kJ
- ◯ 836 kJ
- ◯ 1000 kJ

2 (c) Humid air is cooled, dehumidified and reheated during an isobaric process. Which one of the psychometric charts below correctly depicts these processes?



- ◯ (a)
- ◯ (b)
- ◯ (c)
- ◯ (d)

2 (d) The ratio of the mass of vapor to the total mass of the moist air mixture is called

- ◯ vapor ratio
- ◯ vapor content
- ◯ index
- ◯ quality

3.12 R-22

State	t(°C)	P(MPa)	h(kJ/kg)	s(kJ/kg K)
1	35	1.5	87.72	
2		0.5	87.72	
3	5	1.5	50.48	
4		0.2	50.48	
5	-20	0.2	243.1	0.985
6		0.5	266.5	0.985
7	5	0.5	254	
8		0.5	264	
9		1.5	294	

Energy balance on intercooler to obtain mass ratios

$$\dot{m}_3 h_1 + \dot{m}_7 h_2 = \dot{m}_3 h_3 + \dot{m}_7 h_7$$

$$\dot{m}_3 (h_1 - h_3) = \dot{m}_7 (h_7 - h_2)$$

$$\frac{\dot{m}_3}{\dot{m}_7} = \frac{h_7 - h_2}{h_1 - h_3} = \frac{254 - 87.72}{87.72 - 50.48} = 4.47$$

Mixing of streams 6 and 7 to determine h_8

$$\dot{m}_3 + \dot{m}_7 = \dot{m}_1, \quad 4.47\,\dot{m}_7 + \dot{m}_7 = 5.47\,\dot{m}_7 = \dot{m}_1, \quad \frac{\dot{m}_1}{\dot{m}_7} = 5.47$$

$$\dot{m}_3 h_6 + \dot{m}_7 h_7 = \dot{m}_1 h_8$$

$$h_8 = \frac{\dot{m}_3}{\dot{m}_1} h_6 + \frac{\dot{m}_7}{\dot{m}_1} h_7 = \frac{h_6}{\dot{m}_1/\dot{m}_3} + \frac{h_7}{\dot{m}_1/\dot{m}_7}$$

$$h_8 = \frac{h_6}{(1 + \dot{m}_7/\dot{m}_3)} + \frac{h_7}{\dot{m}_1/\dot{m}_7} = \frac{266.5}{(1 + 1/4.47)} + \frac{254}{5.47} = 264 \frac{\text{Btu}}{\text{lbm}}$$

Locate state 9 at 1.5 MPa, $s_9 = s_8$

Prob. 3.12 cont'd.

$$C.O.P. = \frac{\dot{Q}_{4-5}}{\dot{W}_{5-6} + \dot{W}_{8-9}} = \frac{\cancel{\dot{m}_3}\,(h_5 - h_4)}{\cancel{\dot{m}_3}\,(h_6 - h_5) + \frac{\dot{m}_1}{\dot{m}_3}(h_9 - h_8)}$$

$$C.O.P. = \frac{243.1 - 50.48}{(266.5 - 243.1) + 1.22\,(294 - 264)}$$

$$C.O.P. = 3.21$$

Problem 8.28 Use Chart C-8E

a.) Connect states 4 & 5

Use Eqns 8.3, 8.4 or 8.9 to locate state 6 on the mixing line.

By Eqn 8.9: $\dot{m}_{a,6} t_6 = \dot{m}_{a,4} t_4 + \dot{m}_{a,5} t_5$

$\dot{m}_{a,5} = \dot{m}_{a,2} = 6000$ lbma/hr

$\dot{m}_{a,4} = 4000$ lbma/hr

$\therefore$ $t_6 = 0.4(72) + 0.6(35) = 49.8°F$

Read $\phi_6 \cong 40\%$

b.) State 7 is located along the constant W-line starting at state 6 and ending at 80°F

Use Eqn 8.11 or 8.12 to find ${}_6\dot{Q}_7$

By Eqn 8.12: ${}_6\dot{Q}_7 = \dot{m}_{a,6}(c_{pa} + c_{pw} W_6)(t_7 - t_6)$

$${}_6\dot{Q}_7 = 10{,}000\,[0.24 + (0.444)(0.003)](80 - 49.8) = 72{,}900\ \frac{\text{Btu}}{\text{hr}}$$

c.) Process line from state 7 to state 8 is constant t^* and state 8 is saturated (Given condition)

From the chart: $t^*_7 = t^*_8 = 54°F$ and $t_8 = 54°F$.

d.) $\dot{m}_w = \dot{m}_{a,6}(W_8 - W_7) = 10{,}000 \frac{\text{lbma}}{\text{hr}}(0.0088 - 0.003)\frac{\text{lbm}_w}{\text{lbma}}$

$\dot{m}_w = 58$ lbmw/hr

e.) State 1 is on a constant W-line from state 8.

By Eqn 8.28: $(\dot{Q}_s)_{\text{Zone A}} = \dot{m}_{a,1}\bar{c}_p(t_1 - t_2)$

$32{,}000 = 6000(0.245)(t_1 - 68)$

$t_1 = 89.8°F$, Read $\phi_1 \cong 30\%$

f.) Locate State 3 using SHR = 0.7 from state 4 and at the intersection of constant W from state 8.

Read $t_3 \cong 94.5°F$, By Eqn 8.12

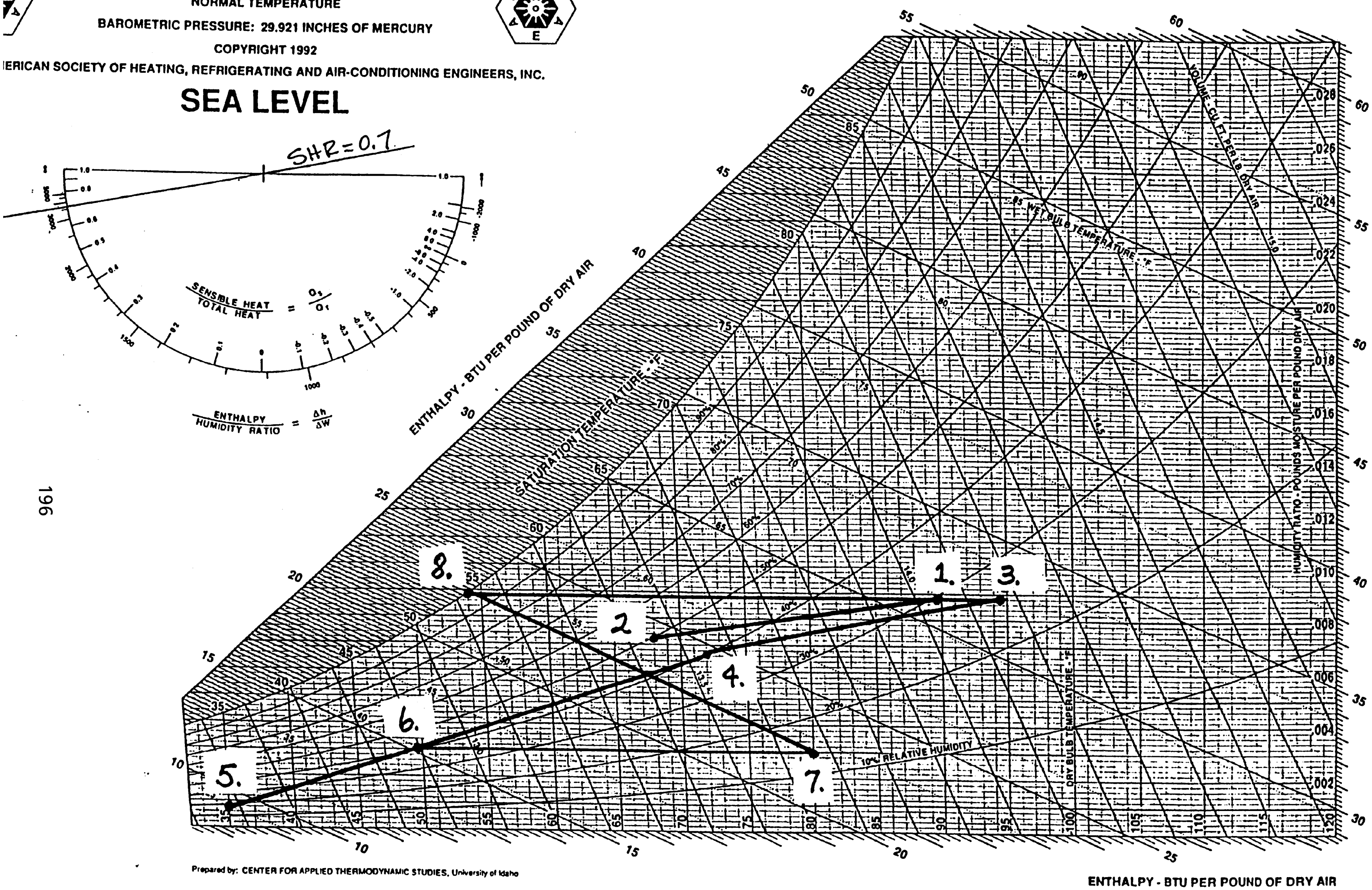
$${}_8\dot{Q}_3 = 4{,}000\,[0.24 + (0.444)(0.0088)](94.5 - 54) = 39{,}500\ \frac{\text{Btu}}{\text{hr}}$$

ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE

BAROMETRIC PRESSURE: 29.921 INCHES OF MERCURY

SEA LEVEL



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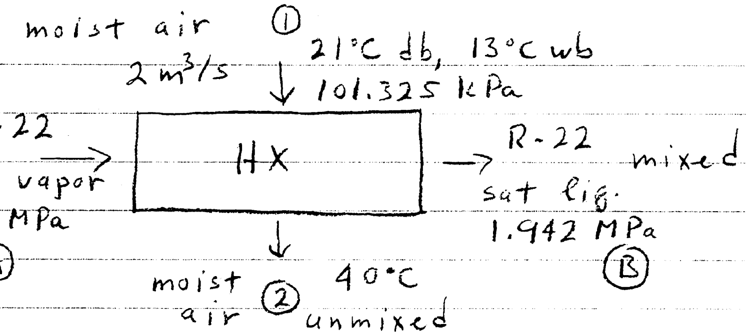
Problem 8.28

11.4



a) Mass flow rate of R-22
from an energy balance on the HX

$$\dot{m}_{R-22}\,(h_A - h_B) = \dot{m}_a\, c_p\,(t_2 - t_1)$$

$$\dot{m}_{R-22} = \frac{\dot{m}_a\, c_p\,(t_2 - t_1)}{h_A - h_B}$$

$$\dot{m}_a = \dot{V}_1 / v_1\,,\quad v_1 = 0.841\ m^3/kg_a \text{ (Chart C-8SI)}$$

$$= 2\ \frac{m^3}{s} \Big/ 0.841\ m^3/kg_a = 2.38\ kg_a/s$$

By Eq. (7.23), Table 7.3 and Chart C-8SI,

$$c_{pa} = 1.00\ \frac{kJ}{kg_a\,°C} + \left(0.006\ \frac{kg_w}{kg_a}\right)\left(1.86\ \frac{kJ}{kg_w\,°C}\right) = 1.011\ \frac{kJ}{kg_a\,°C}$$

By Table A.3SI, $h_A = 262.43\ kJ/kg$, $h_B = 107.85\ kJ/kg$
(50°C sat)

$$\dot{m}_{R-22} = \frac{2.38\ kg_a/s\,(1.011\ kJ/kg_a\,°C)(40-21)\,°C}{(262.43 - 107.85)\ kJ/kg}$$

$$\dot{m}_{R-22} = 0.296\ kg/s$$

11.4 Cont'd

b) As the refrigerant remains isothermal, $C_r = 0$

By Eq. 11.25, $NTU = -\ln(1-\varepsilon)$

$$\varepsilon = \frac{t_2 - t_1}{t_A - t_1} = \frac{40-21}{50-21} = 0.655$$

$$NTU = -\ln(1-0.655) = 1.064$$

c) $NTU = U_o A_o / C_{min}$ or $U_o A_o = NTU\,(C_{min})$

$$C_{min} = C_{air} = \dot{m}_a c_p = 2.38 \frac{kg_a}{s}\left(1.011\ kJ/kg_a\,°C\right) = 2.41 \frac{kW}{°C}$$

$$U_o A_o = 1.064\left(2.41 \frac{kW}{°C}\right) = 2.56 \frac{kW}{°C}$$

d) As the refrigerant is isothermal, $F \equiv 1$

e) $$\Delta t_m = \Delta t_{m,cf} = \frac{t_2 - t_1}{\ln\left(\dfrac{t_B - t_1}{t_A - t_2}\right)} = \frac{(40-21)\,°C}{\ln\left(\dfrac{50-21}{50-40}\right)} = 17.8\,°C$$

f) $\dot{Q} = \dot{m}_a c_p (t_2 - t_1)$ (or $\dot{m}_{R-22}(h_A - h_B)$)

$$= C_{air}(t_2 - t_1)$$

$$= 2.41 \frac{kW}{°C}(40-21)\,°C = 45.8\ kW$$

18.25

Duct sizing

By Fig. 18.18b, to the nearest duct diameter shown on the figure:

1-2, 3000 L/s, 630 mm, $\vec{V}$ = 9.6 m/s, $\Delta P/L$ = 1.5 Pa/m
3-6, 1000 L/s, 400 mm, $\vec{V}$ = 8.0 m/s, $\Delta P/L$ = 1.8 Pa/m
7-10, 2000 L/s, 500 mm, $\vec{V}$ = 10.1 m/s, $\Delta P/L$ = 2.1 Pa/m

Pressure Drop Calculations

1-2

$\Delta P = 20\,m\,(1.5\ Pa/m) = 30\ Pa$

2-3

By Table 18.8

$A_s/A_c = (400/630)^2 = 0.40$

$\dot{V}_s/\dot{V}_c = (1000\ L/s)/(3000\ L/s) = 0.33$

$C_s = 0.14$, $P_v = (9.6/1.29)^2 = 55.4\ Pa$

$\Delta P = 0.14\,(55.4\ Pa) = 7.8\ Pa$

3-4 + 5-6

$\Delta P = (5+30)m\,(1.8\ Pa/m) = 63\ Pa$

4-5

By Table 18.7, $C_o = 0.07$, $P_v = (8.0/1.29)^2 = 38.5\ Pa$

$\Delta P = 0.07\,(38.5\ Pa) = 2.7\ Pa$

2-7

By Table 18.8

$A_b/A_c = (500/630)^2 = 0.63$

$\dot{V}_b/\dot{V}_c = 2000/3000 = 0.67$

$C_b = 0.60$

$\Delta P = 0.60\,(55.4\ Pa) = 33.2\ Pa$

18.25 Cont'd.

7-8 + 9-10

$\Delta P = (15+25)m\,(2.1\ Pa/m) = 84\ Pa$

8-9

By Table 18.7

$C_o = 0.06, \quad P_v = (10.1/1.29)^2 = 61.3\ Pa$

$\Delta P = 0.06\,(61.3\ Pa) = 3.7\ Pa$

Total Pressure Drop 1-6

$\Delta P_{1-6} = 1\text{-}2,\ 2\text{-}3,\ 3\text{-}4,\ 4\text{-}5,\ 5\text{-}6 + \Delta P_{diffuser}$

$= 30 + 7.8 + 63 + 2.7 + 12 = 115.5\ Pa$

$\Delta P_{1-10} = 1\text{-}2,\ 2\text{-}7,\ 7\text{-}8,\ 8\text{-}9,\ 9\text{-}10 + \Delta P_{diffuser}$

$= 30 + 33.2 + 84 + 61.3 + 12 = 220.5\ Pa$

The total pressure available at location 1 must be at least 220.5 Pa higher than ambient to overcome the duct losses. The branch from 3 to 6 may require resizing or a balancing damper to balance the system.