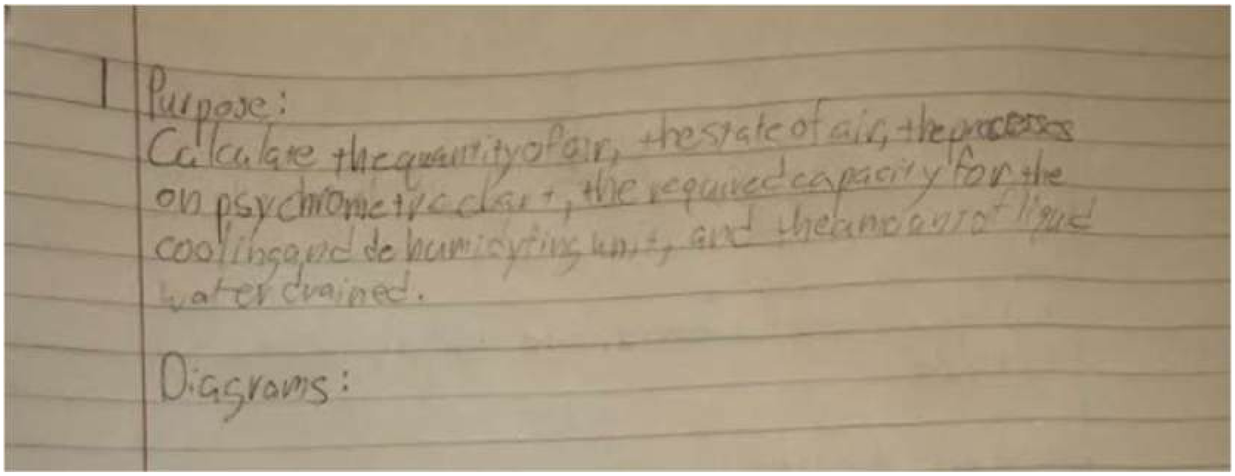
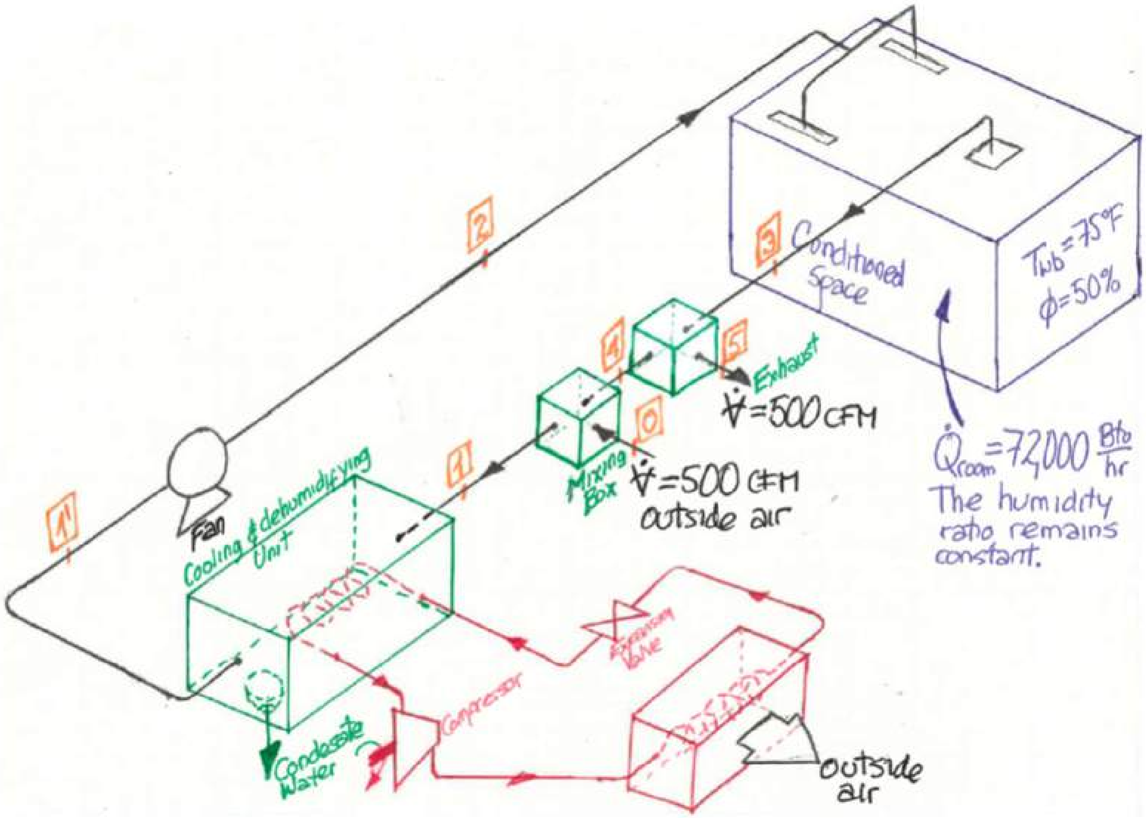


1 Purpose:
Calculate the quantity of air, the state of air, the processes on psychrometric chart, the required capacity for the cooling and dehumidifying unit, and the amount of liquid water drained.

Diagrams:



Sources.
Cengal, Boles, and Kanoglu Thermodynamics and Engineering Approach 9th Edition

Design Considerations:
two seperate set of numbers, one inside and one outside

Data and Variables
inside:
drybulb - 75°F
relative humidity - 50%
Total heat gain - 72000 Btu/hr

outside:
dry bulb - 90°F
relative humidity - 60%
airflow rate - 500 cfm

Procedure and Calculations:
I will firs focus on part A of the problem then work my way down through the problem.

55°F is an assumption for air supply temp this is usually given at 100% relative humidity

a
$Q = \dot{m} \cdot c_p \cdot \Delta T$
$Q = \rho \cdot V \cdot c_p \cdot \Delta T$
$Q = 0.0765 \cdot V \cdot 0.24 \cdot 60 \cdot \Delta T$
$72000 = 0.0765 \cdot V \cdot 0.24 \cdot 60 \cdot (75 - 55)$
$V = 3267.97$ cfm

b
State 1: outside
dry bulb - 90°F
relative humidity - 60%

State 2: air supply
dry bulb - 55°F ← from part A assumption
relative humidity - 100%

State 3: inside
dry bulb - 75°F
relative humidity - 50%

State 4: air return
dry bulb - 75°F ← no change from 3
relative humidity - 50%

State 5: mixed air
dry bulb - 77.30
relative humidity -

$$T_5 = \frac{(500 \cdot 90) + (2767.97 \cdot 75)}{3267.97} = 77.30°F$$ ← [illegible]

C state 1

$\omega - P_{sat}(90°F) = 0.699$

$P_v = 0.6 \cdot 0.699 = 0.4194$

$\omega_1 = 0.622 \cdot \frac{P_v}{P_{atm} - P_v} = 0.622 \cdot \frac{0.4194}{14696 - 0.4194}$

$\omega_1 = 0.0183$ lb/lb

state 2:

$\omega - P_{sat}(55°F) = 0.214$

$P_v = 1 \cdot 0.214 = 0.214$

$\omega_2 = 0.622 \cdot \frac{0.214}{14.696 - 0.214} = 0.00919$ lb/lb

state 3:

$\omega - P_{sat}(75°F) = 0.430$

$P_v = 0.5 \cdot 0.430 = 0.215$

$\omega_3 = 0.622 \cdot \frac{0.215}{14.696 - 0.215} = 0.00923$ lb/lb

state 4:

$\omega - P_{sat}(75°F) = 0.430$

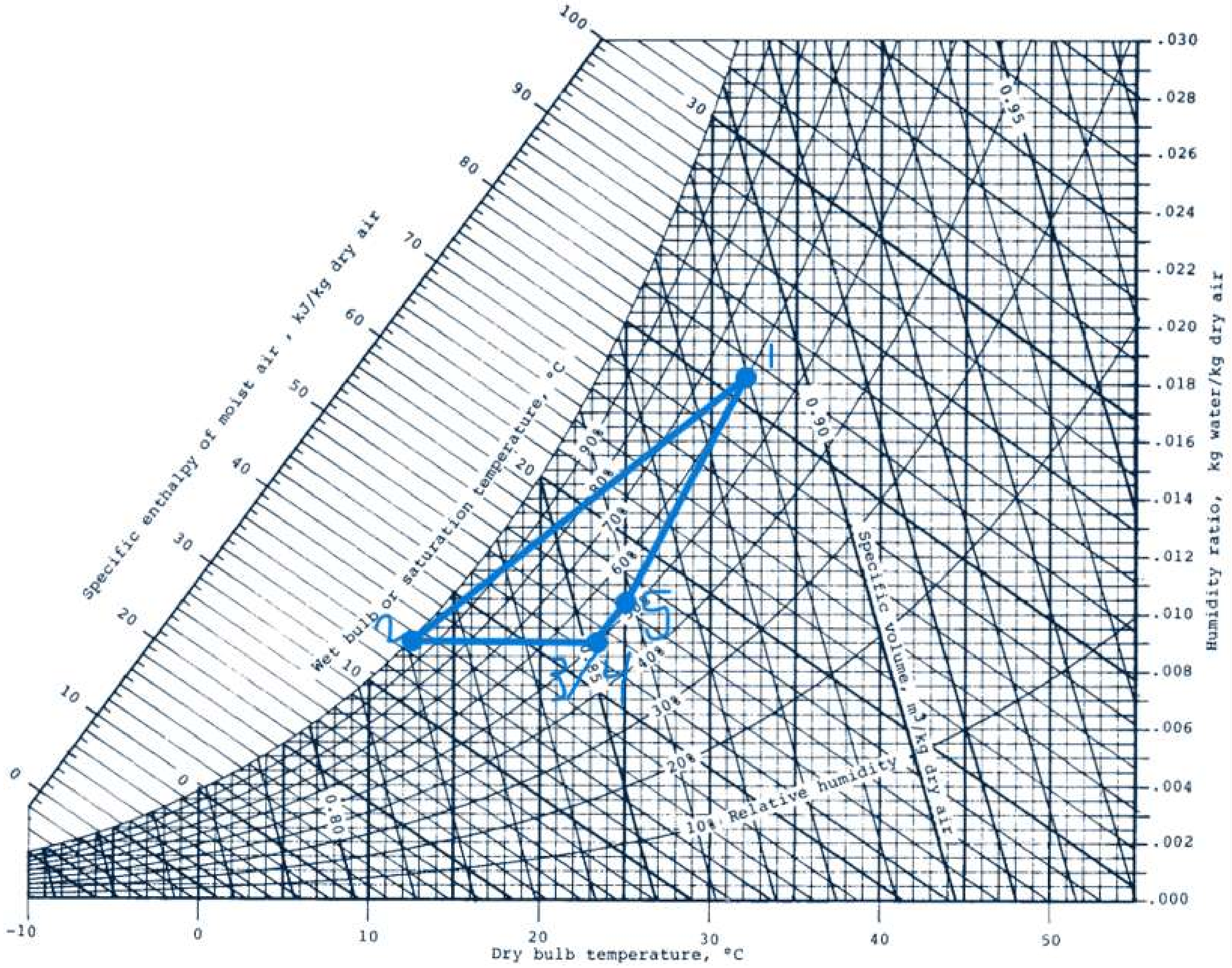
$P_v = 0.5 \cdot 0.430 = 0.215$

$\omega_4 = 0.622 \cdot \frac{0.215}{14.696 - 0.215} = 0.00923$ lb/lb

state 5:

$\omega - \omega_5 = \frac{\omega_1 V_1 + V_4 \cdot \omega_4}{V_{total}} = \frac{0.0183 \cdot 500 + 0.00923 \cdot 2767.97}{3267.97}$

$\omega_5 = 0.0106$ lb/lb


Specific enthalpy of moist air, kJ/kg dry air
0
10
20
30
40
50
60
70
80
90
100
Wet bulb or saturation temperature, °C
0
10
20
30
90%
80%
70%
60%
50%
40%
30%
20%
10% Relative humidity
0.80
0.90
0.95
Specific volume, m³/kg dry air
Humidity ratio, kg water/kg dry air
.030
.028
.026
.024
.022
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
.000
Dry bulb temperature, °C
-10
0
10
20
30
40
50
1
2
3/4
5

d

$V_{total} = 3267.47$ cfm

$V_{outdoor} = 500$ cfm

outdoor fraction $= \frac{500}{3267.47} = 0.153$

return fraction $= 0.847$

$h_1 = 34.07$ $h_4 = 20.42$ $h_2 = 15.49$

$h_{mix} = 0.153 \cdot h_1 + 0.847 \cdot h_4 = 0.153 \cdot 34.07 + 0.847 \cdot 20.42$

$h_{mix} = 22.51$ Btu/lb

$Q_c = \dot{m} \cdot (h_{mix} - h_2)$

$Q_c = \rho \cdot V_{total} \cdot (h_{mix} - h_2)$

$Q_c = 0.0765 \cdot 3267.97 \cdot (22.51 - 15.49)$

$Q_c = 1755.00$ lb/min → 105300 Btu/hr

e

$\Delta\omega = \omega_{mix} - \omega_2$

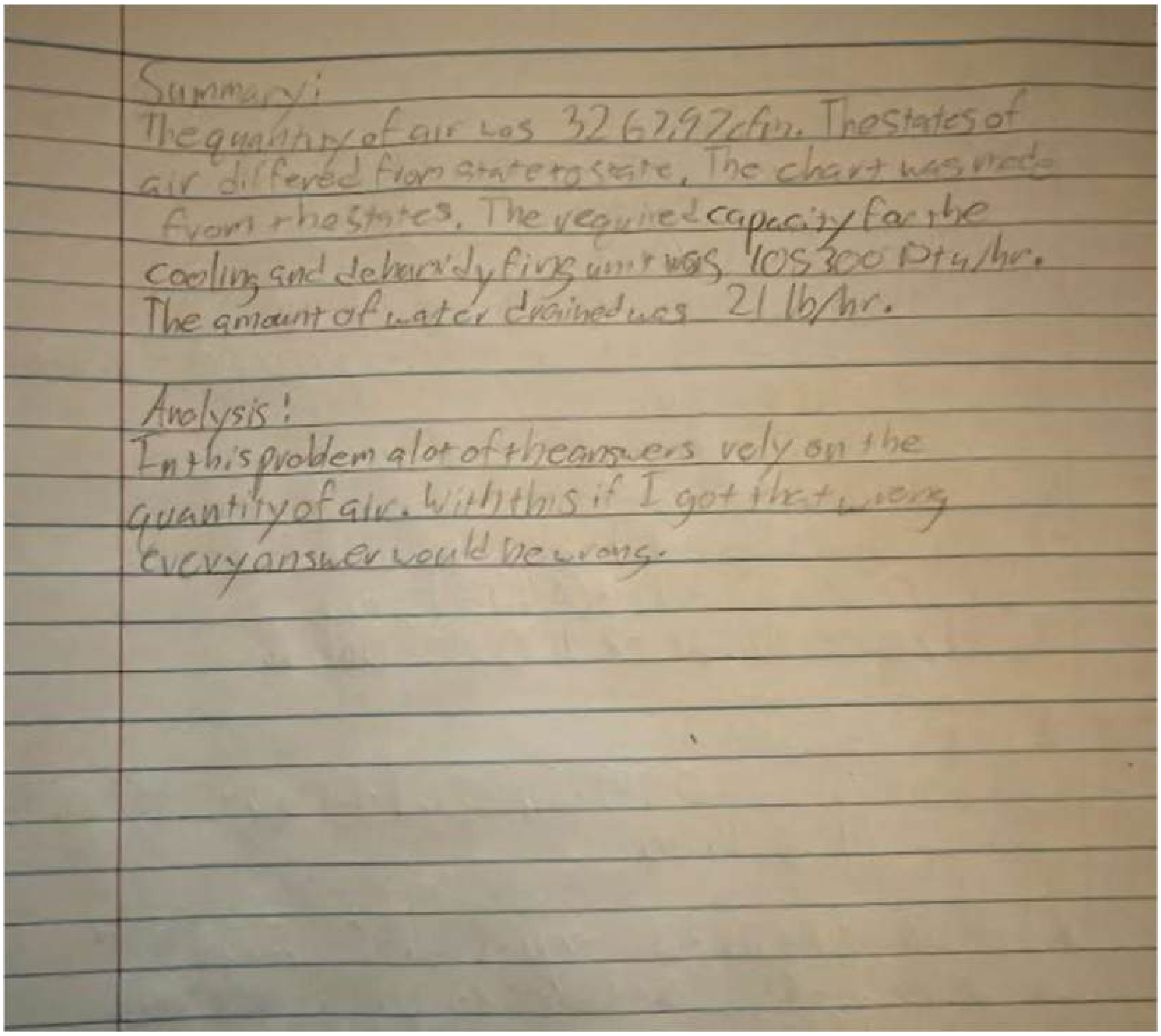
$\omega_{mix} = 0.153 \cdot \omega_1 + 0.847 \cdot \omega_4 = 0.153 \cdot 0.0183 + 0.847 \cdot 0.00923$

$\omega_{mix} = 0.0106$ lb/lb

water drained $= \dot{m} \cdot \Delta\omega \rightarrow \rho \cdot V_{total} \cdot (\omega_{mix} - \omega_2)$

water drained $= 0.0765 \cdot 3267.47 \cdot (0.0106 - 0.00919)$

water drained $= 0.35$ lb/min → 21.0 lb/hr

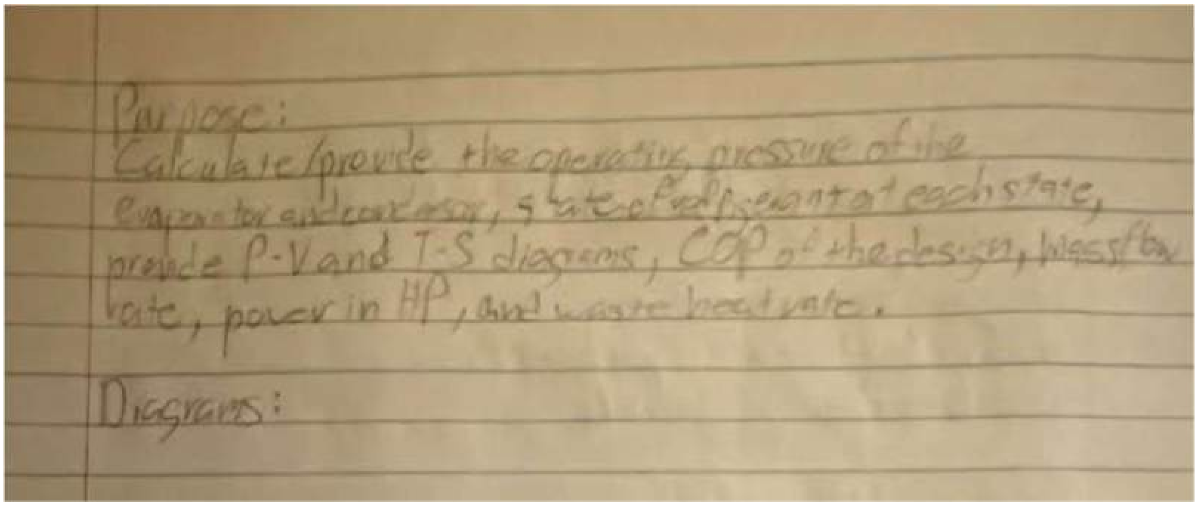


Summary:

The quantity of air was 3267.97 cfm. The states of air differed from state to state. The chart was made from the states. The required capacity for the cooling and dehumidifying unit was 105300 Btu/hr. The amount of water drained was 21 lb/hr.

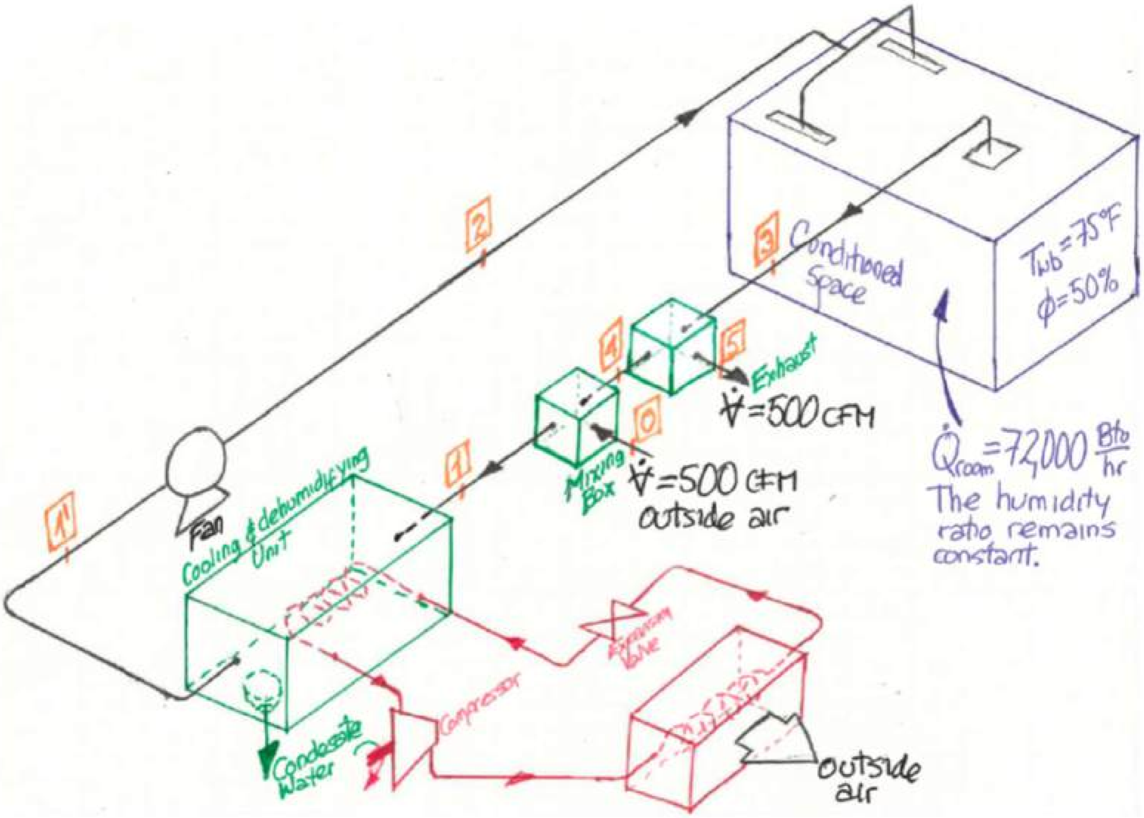
Analysis:

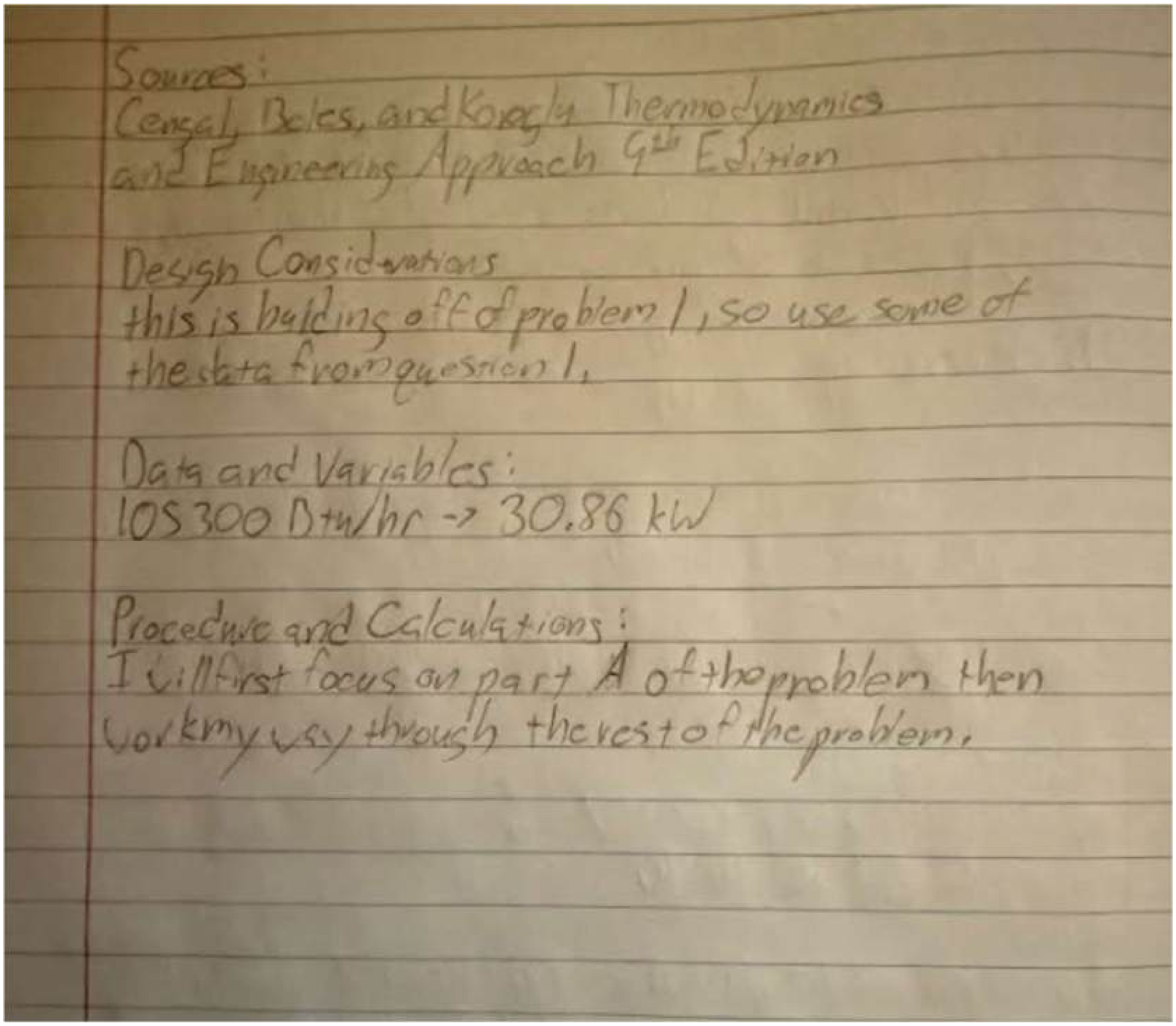
In this problem alot of the answers rely on the quantity of air. With this if I got that wrong every answer would be wrong.



Purpose:
Calculate/provide the operating pressure of the evaporator and condensor, state of refrigerant at each state, provide P-V and T-S diagrams, COP of the design, mass flow rate, power in HP, and waste heat rate.

Diagrams:



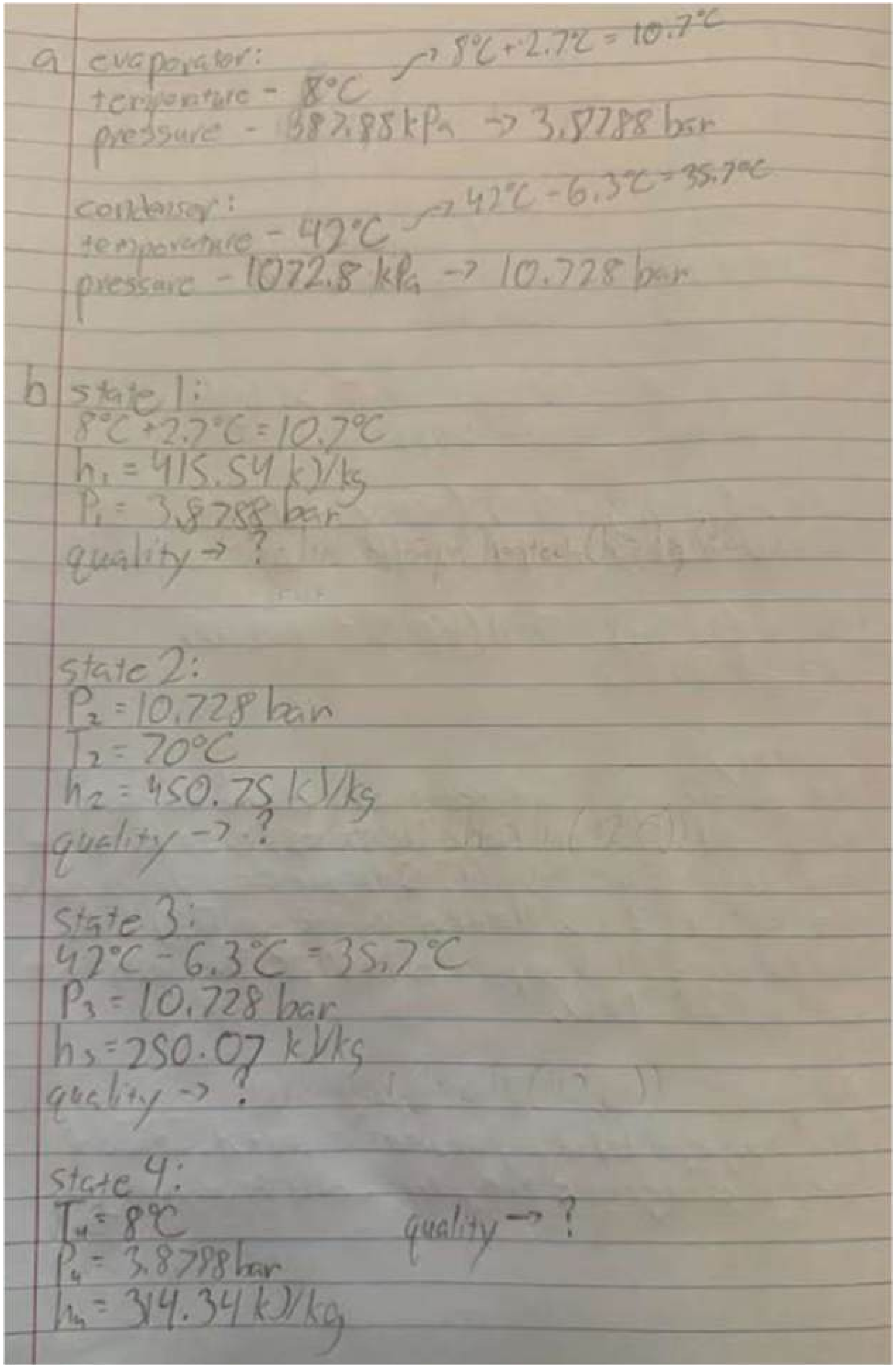


Sources:
Cengal, Boles, and Koragly Thermodynamics
and Engineering Approach 9th Edition

Design Considerations
this is bulding off of problem 1, so use some of
the data from question 1,

Data and Variables:
105300 Btu/hr -> 30.86 kW

Procedure and Calculations:
I will first focus on part A of the problem then
work my way through the rest of the problem.



a evaporator:
temperature - 8°C → $8°C + 2.7°C = 10.7°C$
pressure - 387.88 kPa → 3.8788 bar

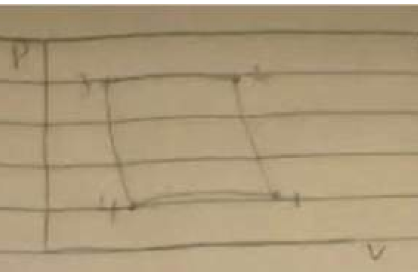
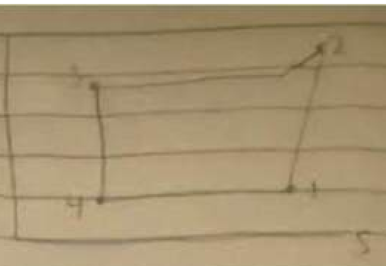
condenser:
temperature - 42°C → $42°C - 6.3°C = 35.7°C$
pressure - 1072.8 kPa → 10.728 bar

b state 1:
$8°C + 2.7°C = 10.7°C$
$h_1 = 415.54$ kJ/kg
$P_1 = 3.8788$ bar
quality → ?

state 2:
$P_2 = 10.728$ bar
$T_2 = 70°C$
$h_2 = 450.75$ kJ/kg
quality → ?

state 3:
$42°C - 6.3°C = 35.7°C$
$P_3 = 10.728$ bar
$h_3 = 250.07$ kJ/kg
quality → ?

state 4:
$T_4 = 8°C$
$P_4 = 3.8788$ bar
$h_4 = 314.34$ kJ/kg
quality → ?

c



d $COP = \frac{Q}{W} = \frac{30.86\ kW}{10.42\ kW} = 2.83$

e $\dot{m} = \frac{Q}{h_1 - h_4} = \frac{30.86}{415.54 - 314.34} = 0.31\ kg/s$

f $W = \dot{m}(h_2 - h_1) = 0.31(450.75 - 415.54)$
$W = 10.42\ kW \rightarrow 14.64\ HP$

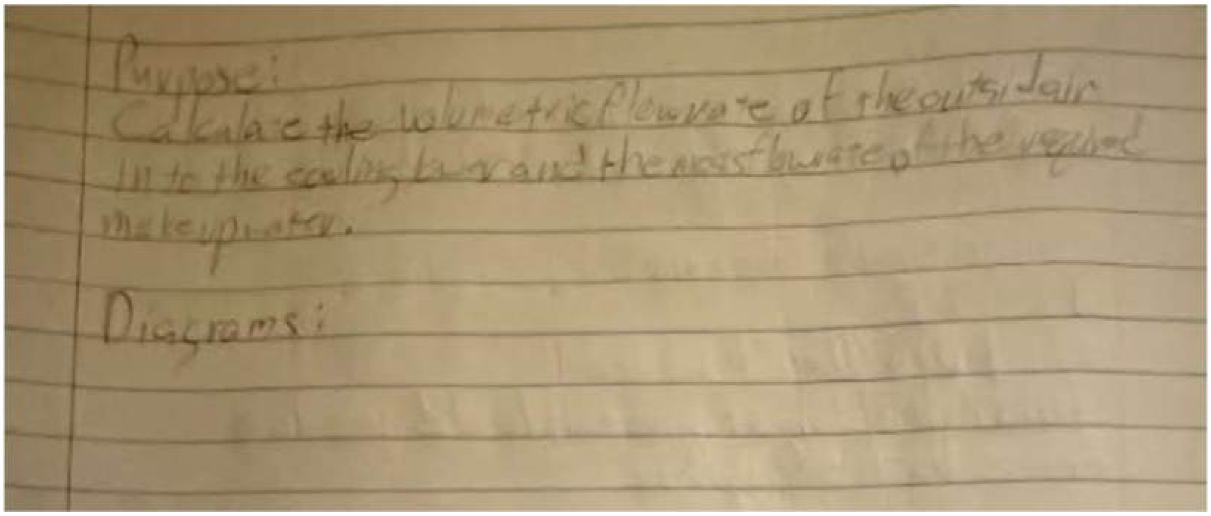
g $Q = \dot{m}(h_2 - h_3) = 0.31(450.75 - 250.07)$
$Q = 62.21\ kW$

Summary:
The operating pressure for the condenser and evaporator are 47°C and 8°C respectively. The states were all different from each other. The P-V and T-S diagrams are shown above. The COP was 2.83. The mass flowrate was 0.31 kg/s. The power required in horse power is 14.64 HP. The waste heat rate is 62.21 kW.

Analysis:
Everything depended on my choice for part A. If I did something wrong there everything would be very wrong. I also did not know how to do the quality.

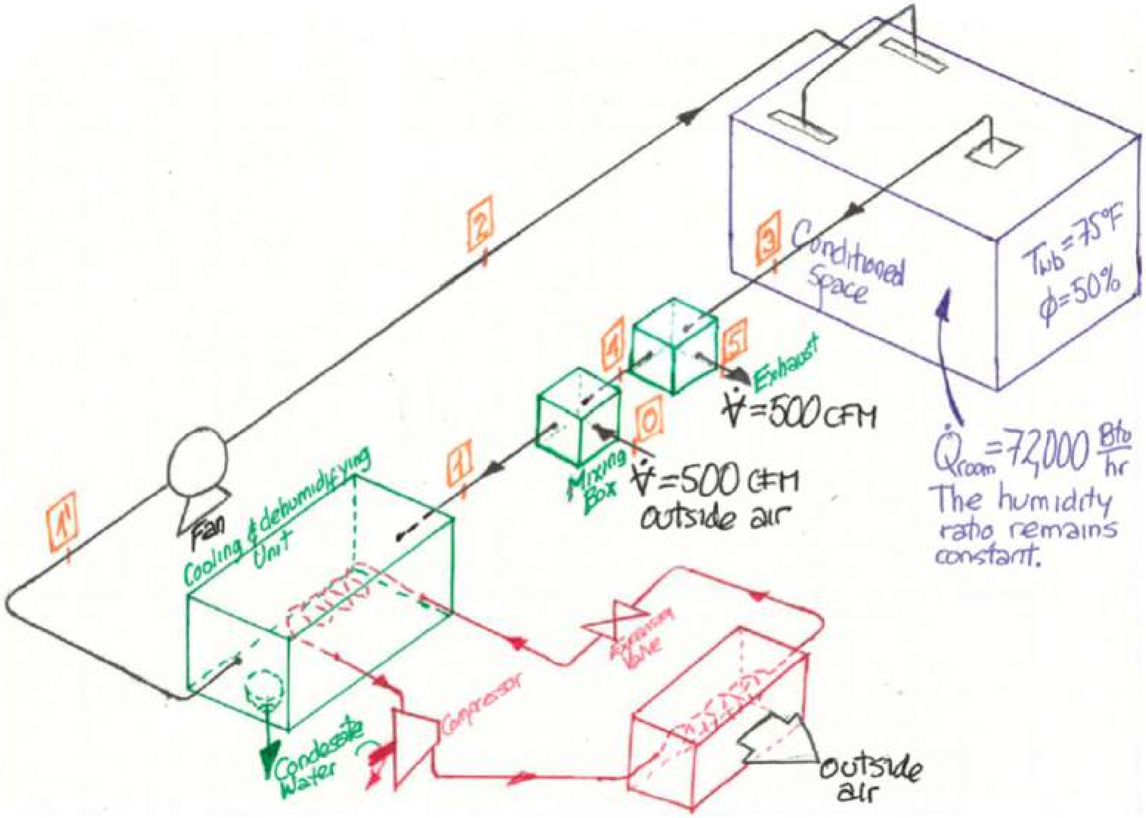
3

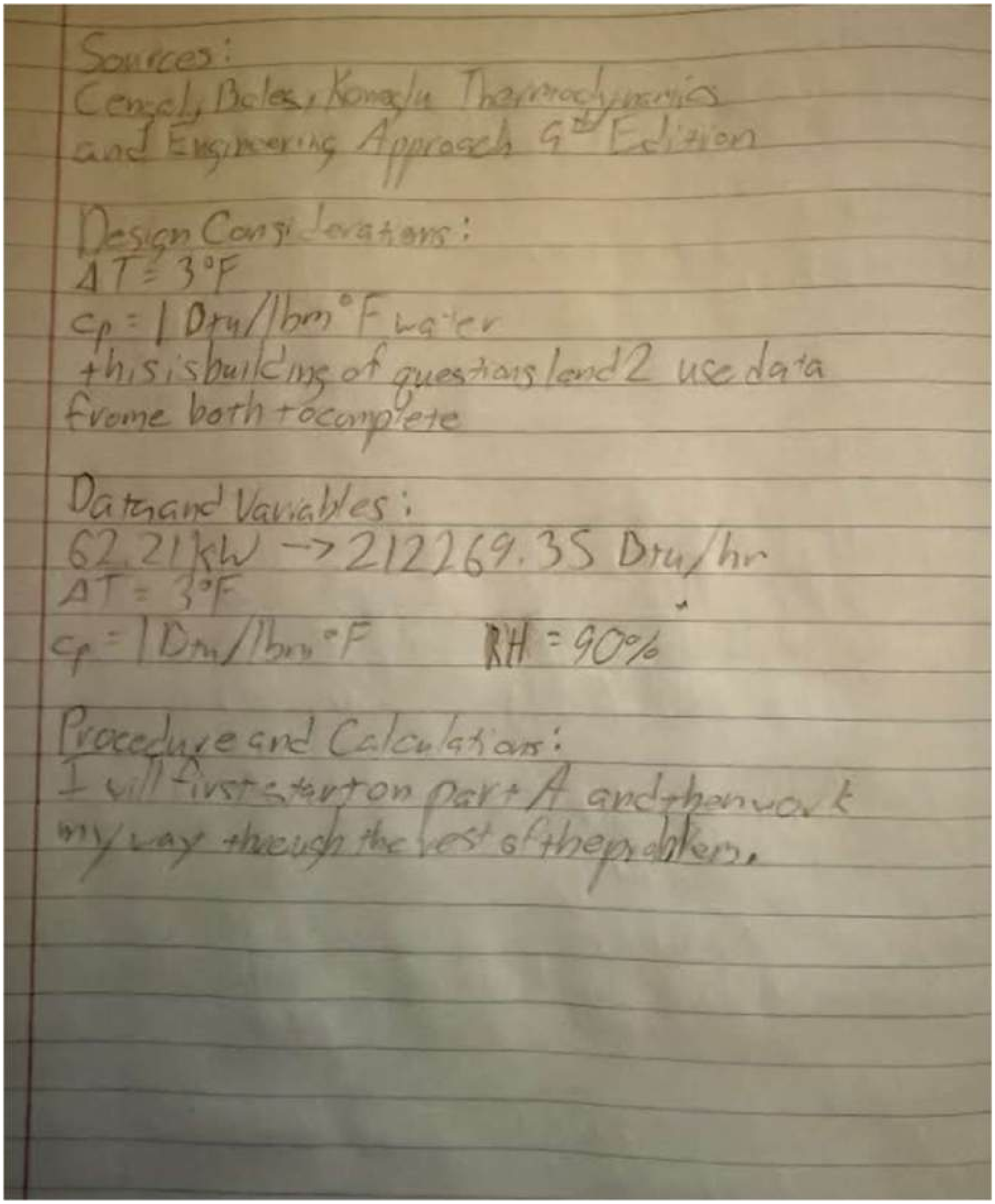
Extra Credit Attempt



Purpose:
Calculate the volumetric flowrate of the outside air
into the cooling tower and the mass flowrate of the required
makeup water.

Diagrams:





Sources:

Cengel, Boles, Kanoglu Thermodynamics
and Engineering Approach 9th Edition

Design Considerations:

$\Delta T = 3°F$

$c_p = 1$ Btu/lbm°F water

this is building of questions 1 and 2 use data
frome both to complete

Data and Variables:

62.21 kW → 212269.35 Btu/hr

$\Delta T = 3°F$

$c_p = 1$ Btu/lbm°F   RH = 90%

Procedure and Calculations:

I will first start on part A and then work
my way through the rest of the problem.

a $Q = \dot{m}_{water} \cdot c_p \cdot \Delta T$

$212269.35 = \dot{m}_{water} \cdot 1 \cdot 3$

$\dot{m}_{water} = 70756.45$

$$V = \frac{\dot{m}}{\rho} = \frac{70756.45}{62.4} = 1133.92\ ft^3/hr$$

b $$\dot{m}_{evapwater} = \frac{Q}{(970 \cdot 0.9)} = \frac{212269.35}{873} =$$

$\dot{m}_{evapwater} = 243.15\ lb/hr$

Summary:

The volumetric flowrate of the outside air is 1133.92 ft^3/hr.
the massflowrate of the required makeup water with 90%
relative humidity is 243.15 lb/hr.

Analysis:

Both of these answers relied on my answer from
number 2 which relied on my answer to number 1.
If I even did one thing wrong my answers would be wrong.