Name: Joseph Specht

Quiz 8 (Total: 30 points)

Due back on Wed. 5 April in the Quiz 8 folder on Canvas

- *Follow the problem-solving strategy that you learnt in class. You will be penalized if you do not.*
- *Save your entire assignment as <u>one</u> PDF document and upload it in the appropriate assignment folder on Canvas.*
- *Assignments will only be graded if the honor code statement, below, is completed and signed.*

Honor Code Statement

ME 200, Quiz 8

Being a student of high standards, I pledge to embody the principles of *academic integrity*.

This ME 200 quiz is my own work. I did not seek (or get) outside help or collaboration with any of the questions and their solutions. I also did not offer my solutions to any other student.

I understand that this quiz is "open book" and "open notes" which means that I was permitted to use my prescribed textbook and lecture notes when addressing any of the questions. I have properly cited any other resources, with full cognizance of the regulations pertaining to plagiarism, copyright infringement, academic cheating, etc., as stipulated in the Student Code.

I acknowledge that academic violations will be dealt with according to the UIUC Student Code, Article 1, Part 4.

ME 200 Student's signature: Joseph Specht

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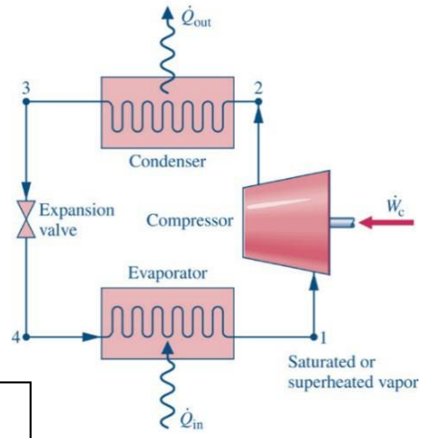
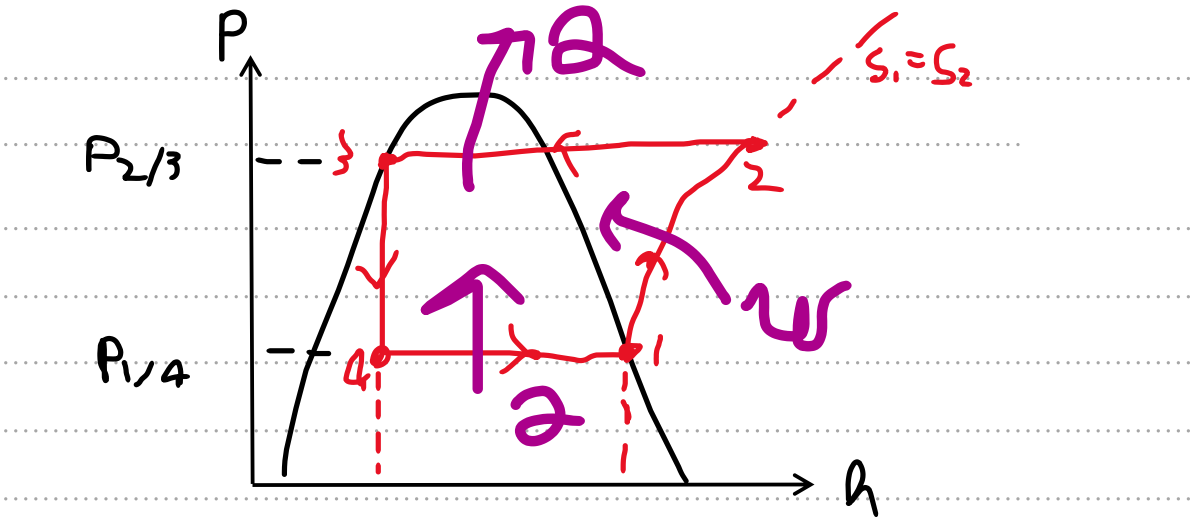
Date: 4/2/23

Consider an air-conditioning system that operates on an ideal vapor-compression cycle. The system uses R-134a as refrigerant. The refrigerant enters the compressor as a saturated vapor at 5ºC and leaves the condenser as a saturated liquid at 55ºC. The mass flowrate of the refrigerant is 0.7 kg/s.



1. Draw the cycle on a *p-h* diagram and indicate all state points. Clearly show the processes where heat and work transfer take place. Also indicate all known temperatures and pressures. *(2)*

T_1 = 5 *C (sat vapor)
T_3 = 55 *C (sat liquid)



2. Complete this table *after* you have performed all calculations in Questions 3 – 5. (No credit will be given for completing the table. Non-completion of the table will however result in 5 points being deducted from your quiz total.)

Process	Specific heat, *q* (kJ/kg)	Specific work, *w* (kJ/kg)	Change in specific enthalpy, $h_{exit} - h_{inlet}$ (kJ/kg)
1 – 2	0	-30.7455	29.8675
2 - 3	-151.548	0	-151.548
3 - 4	0	0	0
4 - 1	120.8025	0	120.8025
Σ:	-30.7455	-30.7455	0

3. Calculate the specific enthalpies and specific entropies at state points 1, 2, 3 and 4. <u>Show ALL interpolations</u>! *(16)*

We know that @ state point 1, we have a saturated refrigerant 134a that is a saturated vapor, so go to table A-10 and interpolate to find the enthalpy and entropy

$$\frac{h_1 - h_{g@T=4°C}}{5°C - 4°C} = \frac{h_{g@T=8°C} - h_{g@T=4°C}}{8°C - 4°C}$$

$$\frac{h_1 - 249.53}{5 - 4} = \frac{251.80 - 249.53}{8 - 4}$$

$$h_1 = 250.0975 \frac{kJ}{kg}$$

Now we must repeat the same process to find the entropy!

$$\frac{s_1 - s_{g@T=4°C}}{5°C - 4°C} = \frac{s_{g@T=8°C} - s_{g@T=4°C}}{8°C - 4°C}$$

$$\frac{s_1 - .9169}{5 - 4} = \frac{.9150 - .9169}{8 - 4}$$

$$s_1 = .916425 \frac{kJ}{kg * K}$$

Before we calculate the values at state point 2, we need to know the pressure at this state, but we are in luck as the pressure at state point 3 and 2 are the same and we know information about state point 3.

@ State point 3, we have a saturated liquid at T=55*C, so using table A-10, we can find all these values

$$\frac{p_3 - p_{sat@55°C}}{55°C - 52°C} = \frac{p_{sat@56°C} - p_{sat@55°C}}{56°C - 52°C}$$

$$\frac{p_3 - 13.851}{55°C - 52°C} = \frac{15.278 - 13.851}{56°C - 52°C}$$

$$p_3 = p_2 = 14.92125\ bar$$

After solving state point 3, we can find the enthalpy and entropy at state point 2. We know that state points 1 and 2 have the same entropy and we know state point 2 will be superheated as you do work on a saturated vapor that experiences adiabatic compression. We also know the pressure is equal to p_3.

$$\frac{h_3 - h_{f@p=14bar}}{14.92125bar - 14bar} = \frac{h_{f@p=16bar} - h_{f@p=14bar}}{16bar - 14bar}$$

$$\frac{h_3 - 125.26}{14.92125 - 14} = \frac{134.02 - 125.26}{16 - 14}$$

$$h_3 = 129.295\frac{kJ}{kg}$$

If we do the same interpolation process for the entropy, we get…

$$\frac{s_3 - s_{f@p=14bar}}{14.92125bar - 14bar} = \frac{s_{f@p=16bar} - s_{f@p=14bar}}{16 - 14}$$

$$\frac{s_3 - .4453}{14.92125 - 14} = \frac{.4714 - .4453}{16 - 14}$$

$$s_3 = .4573\frac{kJ}{kg * K}$$

Now that we have solved for state point 3, we can realize s_1 = s_2 and use table A-12 to solve for h_2.

$$\frac{h_2 - h_{@p=14,T=60}}{14.92125bar - 14bar} = \frac{h_{@p=16,T=60} - h_{@p=14,T=60}}{16bar - 14bar}$$

$$\frac{h_2 - 283.10}{14.92125 - 14} = \frac{278.20 - 283.10}{16 - 14}$$

$$h_2 = 280.843\frac{kJ}{kg * K}$$

Since we know h_3 = h_4, the only information we need to find is s_4, so we go to table A-10 as state point 4 lies in the saturated mixture region. We know p_1 = p_4, so we must find p_1 first.

$$\frac{p_1 - p_{sat@T=4}}{5°C - 4°C} = \frac{p_{sat@T=8} - p_{sat@T=4}}{8°C - 4°C}$$

$$\frac{p_1 - 3.3765}{5-4} = \frac{3.8756 - 3.3765}{8-4}$$

$$p_1 = p_4 = 3.5013\ bar$$

Now that have these two properties, we can find the value of s_4 from table A-10. But first, we must find the vapor quality.

$$h_4 = h_{f@p4} + x * h_{fg@p4}$$

$$\frac{h_{f@p4} - 55.35}{3.5013 - 3.3765} = \frac{60.73 - 55.35}{3.8756 - 3.3765}$$

$$h_{f@p4} = 56.70$$

$$\frac{h_{fg@p4} - 194.19}{3.5013 - 3.3765} = \frac{191.07 - 194.19}{3.8756 - 3.3765}$$

$$h_{fg@p4} = 193.401$$

Since we know h_4, h_f@p4, and h_fg@p4, we can find x

$$x = \frac{h_4 - h_{f@p4}}{h_{fg@p4}} = .3754$$

If we have this value, we can then interpolate from A-10 to find s_4

$$s_4 = s_{4f} + x * s_{4fg}$$

First, we need to find the values of s_f and s_fg, so

$$\frac{s_{4f} - .2162}{3.5013 - 3.3765} = \frac{.2354 - .2162}{3.8756 - 3.3765}$$

$$s_{4f} = .221$$

Now, we have to find s_g to find s_fg

$$\frac{s_{4g} - .9169}{3.5013 - 3.3765} = \frac{.9150 - .9169}{3.8756 - 3.3765}$$

$$s_{4g} = .916425$$

This means s_fg is…

$$s_{fg} = s_g - s_f = .6954$$

With all the entropies we need, we can find the final value of s_4

$$s_4 = s_{4f} + x * s_{4fg} = .482$$

State point	H [kJ/kg]	S [kJ/(kg*K)]
1	250.0975	.916425
2	280.843	.916425
3	129.295	.4573
4	129.295	.482

Now that we have all these values, we just need to calculate the work and heat transfer with the first law

$$(q_{in} - q_{out}) - (w_{in} - w_{out}) = h_2 - h_1$$

For 1-2, we know this is adiabatic and gives no work, so

$$w_{in} = h_1 - h_2 = 30.7455$$

For 2-3, we know this is an isobaric process, so work is zero and this process ejects heat, so q_out = 0

$$q_{out} = h_3 - h_2 = -151.548$$

For process 3-4, we know it is a valve that does no work or add any heat, so everything is 0.

For process 4-1, we know this is an isobaric process, so work is 0 and this raises the enthalpy, so q_out=0

$$q_{in} = h_1 - h_4 = 120.8025$$

4. Calculate the specific work required at the compressor. *(3)*

For 1-2, we know this is adiabatic and gives no work, so

$$w_{in} = h_1 - h_2 = 30.7455$$

5. Calculate heat transfer rate (in kW) in the condenser. *(3)*

For 2-3, we know this is an isobaric process, so work is zero and this process ejects heat, so q_out = 0

$$q_{out} = h_3 - h_2 = -151.548$$

6. Calculate heat transfer rate (in kW) in the evaporator. *(3)*

For process 4-1, we know this is an isobaric process, so work is 0 and this raises the enthalpy, so q_out=0

$$q_{in} = h_1 - h_4 = 120.$$

7. Calculate the coefficient of performance of the cycle. *(3)*

$$COP = \frac{q_{out}}{w_{in}} = 4.929, \text{ which seems high}$$