Name: Joseph Specht

Quiz 7 (Total: 30 points)

Due back on Wed. 29 March 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 one 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 7

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.

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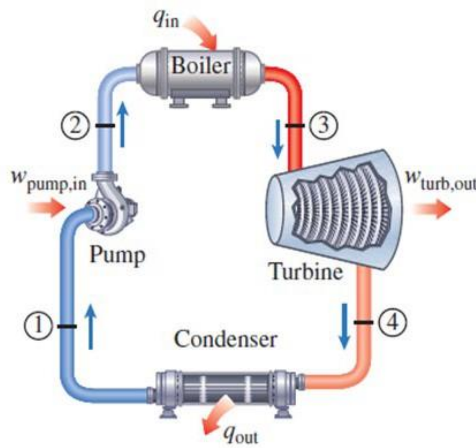
Date: 3/29/23

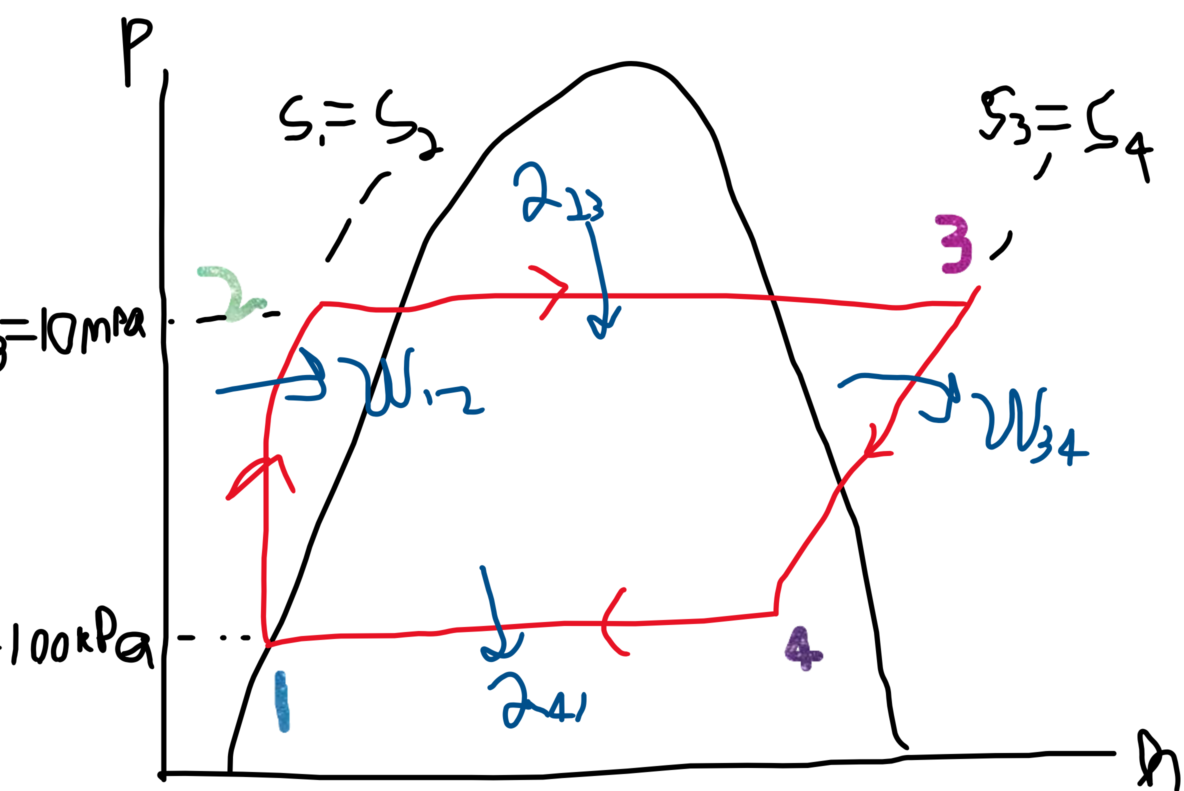
1. Calculate the thermal efficiency of an ideal steam power plant operating on the Rankine cycle. Steam enters the turbine at 10 MPa and 400ºC. The pressure in the condenser is maintained at 100 kPa, because the thermal energy is used for heating nearby buildings. Assume that the water state at the inlet of the feedwater pump is saturated.
   Write down and solve the energy equation for each of the four processes; <u>show all your calculations</u>. You must also complete the table below after you have done all your calculations. Of course, <u>you must illustrate the cycle on a *p-h* diagram</u>. *(30 points)*



Summarize and check your results here: η_th = 31.42%

	Q [kJ/kg]	*W [kJ/kg]*	*Δh [kJ/kg]*
1 – 2	0	-10.38	$h_2 - h_1 =$ 427.84 - 417.46 = 10.38
2 – 3	2668.66	0	$h_3 - h_2 =$ 3096.5 - 427.84 = 2668.66
3 – 4	0	848.80	$h_4 - h_3 =$ 2247.70 – 3096.5 = -848.80
4 – 1	-1830.24	0	$h_1 - h_4 =$ 417.46 – 2247.70 = -1830.24
	q_{net} = **838.42**	w_{net} = **-838.42**	Δh_{cycle} = **0**

<u>Diagram:</u>



1-2: Isentropic Compression (Pump)

We know for this process, the heat transfer, and the work in is 0, so the first law of thermodynamics is…

$$q_{net} - w_{net} = \Delta h$$

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

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

We also know state 1 is a saturated liquid and it is water, so use (A-3) and find value at p_1 = 100 kPa, so

$$h_1 = h_{f@p=1bar} = 417.46\frac{kJ}{kg}$$

We also need to know s_1, so we use the same table to get this value

$$s_1 = 1.3026\frac{kJ}{kg*K}$$

Now, we know the pressure of the second is p_2 = 10 MPa, and when work is done, we know that state 2 can only be in the subcooled region, so use (A-5)

Need to interpolate because s_1 = s_2 is not an exact value,

$$\frac{1.3026\frac{kJ}{kg*K} - 1.2992\frac{kJ}{kg*K}}{1.7292\frac{kJ}{kg*K} - 1.2992\frac{kJ}{kg*K}} = \frac{h2 - 426.50\frac{kJ}{kg}}{595.42\frac{kJ}{kg} - 426.50\frac{kJ}{kg}}$$

Solving the above problem gives

$$h_2 = 427.84\ \frac{kJ}{kg}$$

Now, we must find out the work done,

$$w_{in} = h_2 - h_1 = (427.84 - 417.46)\frac{kJ}{kg} = 10.38\frac{kJ}{kg}$$

2-3: Isobaric Heat Injection (Boiler)

Since this is a constant pressure heat injection, we know q_out and w_net are both 0, so the first law is

$$q_{net} - w_{net} = \Delta h$$

$$q_{in} = h_3 - h_2$$

We know the pressure at 3 is the same as state 2, which is 10 MPa. We also know T_3 = 400 *C. Using this information, we can see from the superheated vapor table (A-3) T_3 > T_sat, so we are superheated.

$$h_3 = 3096.5 \frac{kJ}{kg}$$

$$s_3 = 6.2120 \frac{kJ}{kg * K}$$

Now all that's left is finding q, so

$$q_{in} = h_3 - h_4 = (3096.5 - 427.84)\frac{kJ}{kg} = 2668.66\frac{kJ}{kg}$$

3-4: Isentropic Expansion (Turbine)

Since this is a turbine, it is isentropic and there is no work in, so the first law is

$$w_{out} = h_3 - h_4$$

We know that state point 4 is going to be inside the saturation curve because at p = 100 kPa, we see that s_f < s_3 = s_4 < s_g, so we know that this is a saturated solution, and we need to solve for the quality.

$$s_4 = s_f + x\left(s_g - s_f\right)$$

$$x = \frac{s_4 - s_f}{s_g - s_f} = \frac{6.2120 - 1.3026}{7.3594 - 1.3026} = .8106$$

Now that we have x, we can find h_4 with the following equation

$$h_4 = h_f + x\left(h_{fg}\right) = 417.46 + .8106(2258) = 2247.70\,\frac{kJ}{kg}$$

Now that we have the enthalpies, we can find the work out from the following equation

$$w_{out} = h_3 - h_4 = (3096.5 - 2247.70)\,\frac{kJ}{kg} = 848.80\,\frac{kJ}{kg}$$

4-1: Isobaric Heat Rejection (Condenser)

We already know the values of h at each point, so we can just apply the first law of an isobaric process

$$q_{net} - w_{net} = \Delta h$$

$$q_{out} = h_4 - h_1 = (2247.70 - 417.46)\frac{kJ}{kg} = 1830.24\frac{kJ}{kg}$$

Thermal Efficiency:

The thermal efficiency is found from the following equation

$$\eta_h = \frac{w_{net}}{q_{in}} = \frac{w_{out} - w_{in}}{q_{in}} = \frac{848.8 - 10.38}{2668.66} = 31.41\%$$