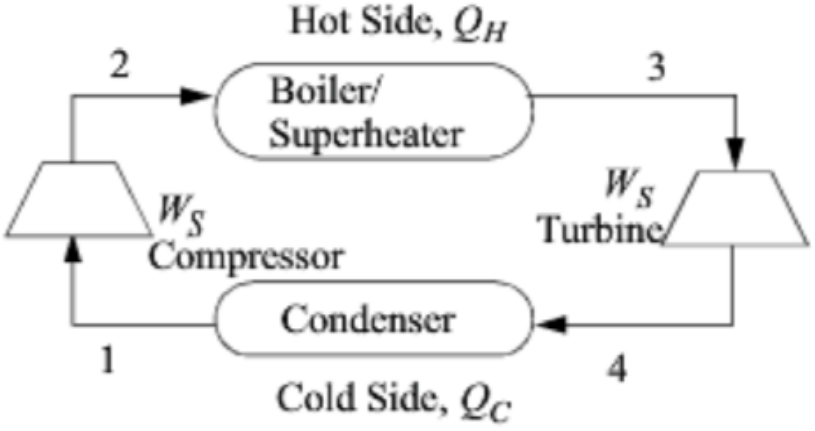
Chemical Engineering Thermodynamics
Quiz 1
January 14, 2021

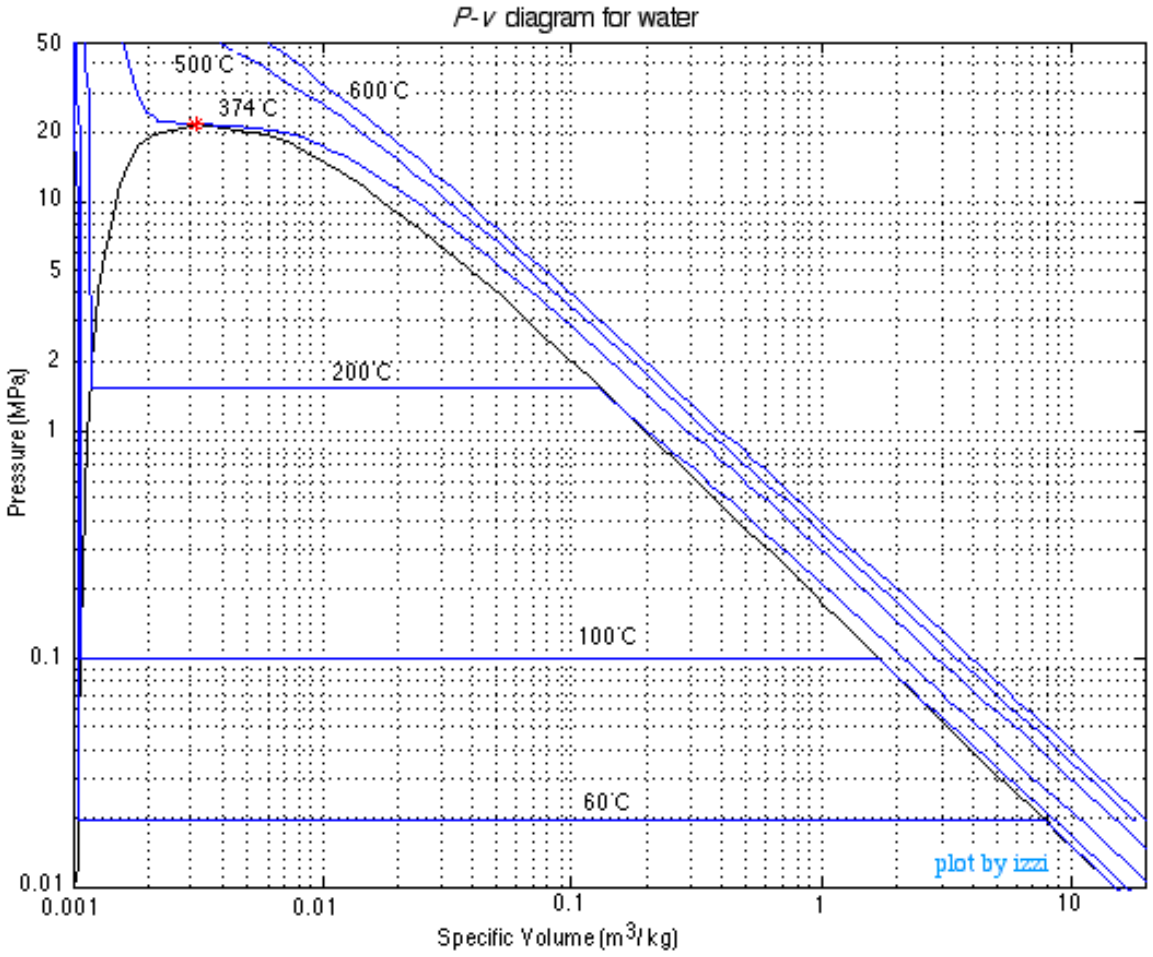
Turn in the completed Excel sheet and the PV plot

Consider a simplified steam turbine/condenser/compressor/boiler/superheater for production of electricity shown in the schematic. Using the steam table at the back of the book, ***fill in the Excel table*** and use it to ***answer the questions***.

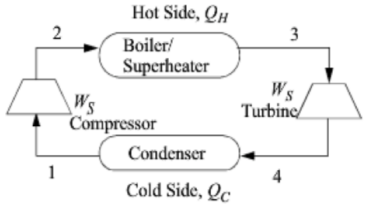
The compressor uses 15 kW and has 100% efficiency.
The flow rate is 1200 kg/h for all streams.
Water Molecular Weight 18.0 g/mol
1 m^3 = 10^6 cm^3
Watt = J/s

a) Determine the shaft work, W_s, for the turbine **in kW** (which is kJ/s). *Under an adiabatic assumption (no heat loss) at 100% efficiency the shaft work equals the difference in enthalpy, H, between the exiting and entering streams.*
b) Calculate the combined heat needed for the boiler and superheater (boiler converts from liquid to vapor and superheater further heats the steam) **in kW** (which is kJ/s). (*This is the difference in enthalpy (H) between the streams.*)
c) Take the ratio of the shaft work recovered from the steam turbine minus that used in the compressor; to the heat needed for the boiler to get an idea of how efficient this system is with a turbine at 100% efficiency. Why is this efficiency less than 100%?
d) The maximum possible efficiency for a heat engine (Carnot cycle) can be shown to be $(T_H - T_C)/T_H$. Compare this best possible efficiency to your efficiency. (Carefully choose the units of temperature.)
e) On the log-log *P* vs *V* plot given below show the points 1, 2, 3 and 4. Drawlines connecting the points on this plot to show the cycle. P times V is energy, what energy is represented by the area within the lines you have drawn?

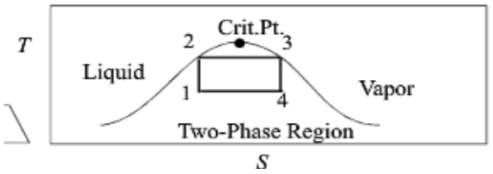



P-v diagram for water
500°C
600°C
374°C
200°C
100°C
60°C
plot by izzi
Pressure (MPa)
Specific Volume (m3/kg)
50
20
10
5
2
1
0.1
0.01
0.001
0.01
0.1
1
10

Stream	*P* (Mpa)	*T* (°C)	State	*q*	*H* (kJ/kg)	*H* L (kJ/kg)	*H* V (kJ/kg)	*V* (m3/kg)	*V* L (m3/kg)	*V* V (m3/kg)	S (kJ/kgK)	SL (kJ/kgK)	SV (kJ/kgK)	iso entropic
1	0.121	105	Liquid/Vapor	0.313	1140	440	2680	0.445	0.00105	1.42	3.22	1.36	7.3	
2	3.98	250	Saturated Liquid	0	1090			0.00125			2.79			
3	3.98	250	Saturated Vapor	1	2800			0.0501			6.07			
4	0.121	105	Saturated Vapor	1	2680			1.42			7.3			q=.648

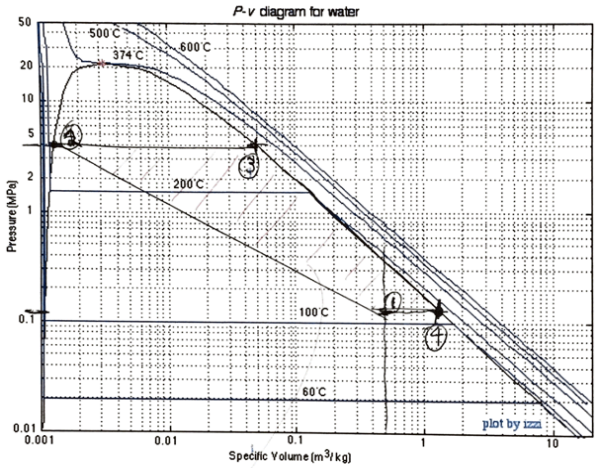


		S kJ/kgK
	3-2	3.28
	4-3	1.23
	1-4	-4.08
	2-1	-0.43
	net	0



H, kW		H, kJ/kg			
570	3-2	1710	**B/SH (b)**		
-40	4-3	-120	**Ws (a)**	**eff**	
-513	1-4	-1540		0.044	This system **(c)**
15	2-1	45	Compressor	0.277	Ideal Carnot **(d)**
	net	95			

(e)



Area is the work done in a cycle.
Work per kg for the system