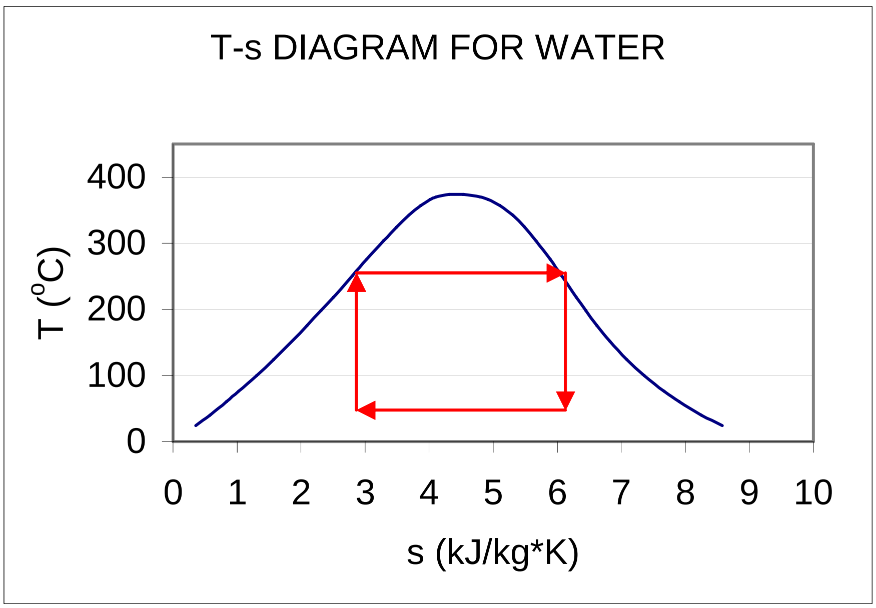
AREN 2110: Thermodynamics
Review Problems
Fall 2005

SOLUTIONS

1. A Carnot heat engine cycle with steam/water as the working fluid and a net power output of 1 MW consists of four processes:

1 $\rightarrow$ 2: reversible isothermal expansion from saturated liquid to saturated vapor at 250 ^{o}C.
2 $\rightarrow$ 3: reversible adiabatic expansion
3 $\rightarrow$ 4: reversible isothermal compression at 10 kPa
4 $\rightarrow$ 1: reversible adiabatic compression

a) Draw the process on the T-s diagram below, show arrows for process direction, and complete the table of properties for each state:



	1	2	3	4
T (^{o}C)	**250**	**250**	**45.81**	**45.81**
s (kJ/kg-K)	**2.7927**	**6.0730**	**6.0730**	**2.7927**

b) Calculate the efficiency of the cycle

$$\eta = 0.39$$

c) What is the moisture content of the steam at state 3?

(1-x) = 0.28 or 28%

d) What is the mass flow rate of steam?

$$\dot{m} = 1.5 \text{ kg/s}$$

e) Calculated the rejected heat (kW).

$$\dot{Q}_{rejected} = -1{,}574.3 \text{ kw}$$

f) Calculate the entropy transferred to/from the surroundings during process 1 → 2.

Transferred entropy (1→2) = 4.92 kw/K

g) Calculate the entropy transferred to/from the surroundings during process 3 → 4.

Transferred entropy (3→4) = - 4.92 kw/K

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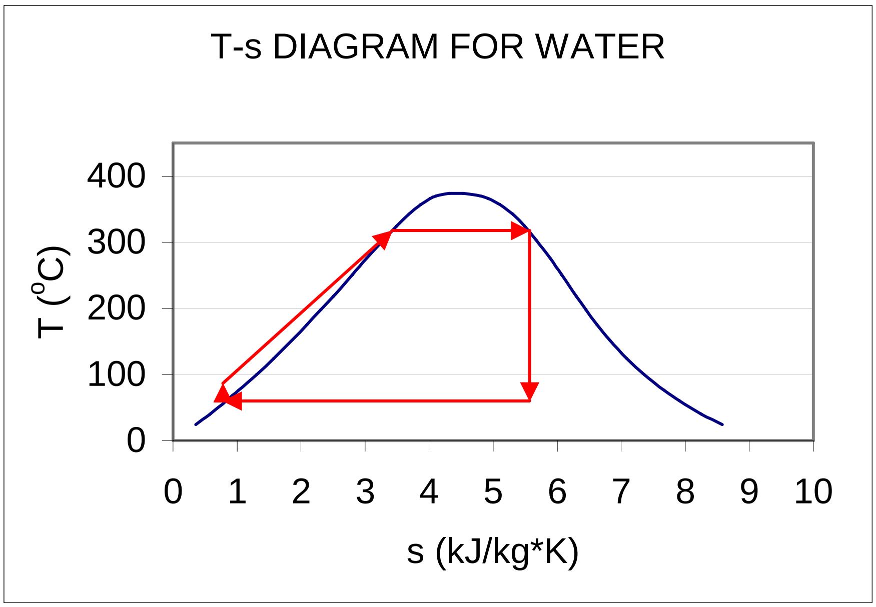
2. A Rankine power generation cycle is operated with a boiler pressure of 10 MPa with heat from a coal-fired furnace at 350 ^oC. Heat is rejected from a condenser pressure of 25 kPa into a river with average water temperature of 20 ^oC. The mass flow rate of steam is 25 kg/s. Water is saturated liquid at the pump inlet, and saturated vapor at the turbine inlet.

a) Draw the process on the T-s diagram below.



b) Calculate the cycle efficiency.

η = 0.35

c) Calculate the net power output from the plant (MW).

$$\dot{W}_{net} = \mathbf{21.2\ Mw}$$

d) Calculate the entropy generated in the surroundings by the cycle.

$$\dot{S}_{gen} = \mathbf{38.2\ kw/K}$$

3. A heat pump operating on a vapor-compression-refrigeration cycle removes heat from groundwater with an average temperature of 15 ^oC, by pumping R-134a refrigerant through wells at a pressure of 0.14 MPa. Heat is rejected from the condenser with pressure equal 1.2 MPa into a house with the indoor air temperature maintained at 22 ^oC. The house loses heat at the rate of 50,000 kJ/hr. The refrigerant is saturated vapor at the compressor inlet and saturated liquid at the condenser outlet.

a) Calculate the temperature of the R-134a at the compressor outlet.

$$T_2 = 54.4\ ^oC$$

b) Calculate the coefficient of performance for the heat pump

$$COP_{HP} = 3.7$$

c) Calculate the required mass flow rate of refrigerant

$\dot{m}$ **= 0.084 kg/s**

d) Calculate the entropy generated in the surroundings during the isenthalpic throttling process in kW/K.

$\dot{S}_{gen}$ **= 0.0036 kw/K**

e) Calculate the entropy generated in the surroundings during the heat rejection process in kW/K.

$\dot{S}_{gen}$ **= 0.0038 kw/K**