ME 40 Thermodynamics
Quiz 4

April 10, 2013

Closed Book

Allowed 1 page of your own notes (8.5" x 11", front and back).

3 problems, equal weight

General Advice:

Be clear about what system you are analyzing.

Be clear about your assumptions.

Be careful about units.

Name: ....

Student ID# ....

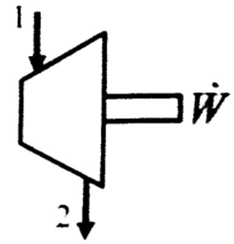
Discussion Section (Circle One)

Monday 1 - 2 pm

Tuesday 4 - 5 pm.

Thursday 1 -2 pm.

Problem 1 (20 points)



A well-insulated turbine takes in air at (T_1, P_1) and has a fixed exit pressure P_2. The turbine efficiency is η_T. Air may be treated as an ideal gas with constant specific heats:

C_p=1.01 kJ/kg K
C_v=0.72 kJ/kg K
R =0.29 kJ/kg K

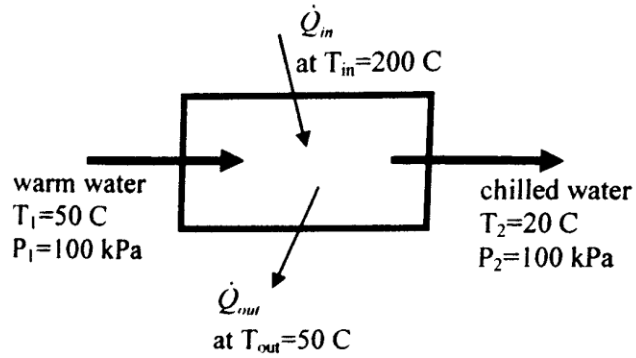
(a) Consider two cases: (i) η_T=100%; (ii) η_T=80%. For both cases complete the table below (provide numerical values including units).

(b) Sketch both cases on T-s and P-v diagrams.

	P_1	T_1	P_2	η_T	T_2	$\dot{W}/\dot{m}$	$\dot{S}_{gen}$ $\dot{m}$
(i)	5 MPa	500 °C	1 MPa	**100%**			
(ii)	5 MPa	500 °C	1 MPa	**80%**			

Problem 2 (30 pts)

A patent application describes a device for chilling water. Only a few key specifications are given. At steady state, the device receives energy by heat transfer ($\dot{Q}_{in}$) at a location on its surface where the temperature is 200 °C, and discharges energy by heat transfer ($\dot{Q}_{out}$) to the surroundings at a different location where the surface temperature is 50 °C. A warm liquid water stream enters at 100 kPa and 50 °C, and a cool liquid stream exits at 100 kPa at 20 °C, with an unknown flowrate $\dot{m}$. The device requires no power source to operate. You may neglect the effects of potential and kinetic energy, and the water can be approximated as incompressible with specific heat 4.2 kJ/kg K. Neither $\dot{Q}_{in}$ or $\dot{Q}_{out}$ is specified.



(a) (25 pts) Derive an expression for the minimum theoretical heat addition $\dot{Q}_{in}$ per unit $\dot{m}$, in terms of given quantities. (Your answer should *not* include $\dot{Q}_{out}$, because $\dot{Q}_{out}$ is unknown.)

(b) (5 pts) Using your result from part (a), calculate the numerical value of $\dot{Q}_{in} / \dot{m}$, in units of kW/(kg/s).

Problem 3 (30 pts)

The well-insulated piston-cylinder apparatus shown below is filled with oxygen vapor. The oxygen is initially held at a pressure P_1 by an external force. The force is slowly reduced and the oxygen smoothly expands until the final state 2 where the pressure is half of the initial pressure. Other initial conditions are given below.

P_1=1 MPa
T_1=300 K
V_1=1 m^3

$P_2=P_1/2=0.5$ MPa
T_2=??
V_2=??

For this problem you may treat oxygen as an ideal gas with constant specific heats:
C_p=0.92 kJ/kg K $\quad$ C_v=0.66 kJ/kg K $\quad$ R =0.26 kJ/kg K

(a) (5 pts) Sketch the process on P-v and T-s diagrams. Label states 1 and 2.

(b) (20 pts) How much work was done by the gas during this process? Obtain a numerical value, in kJ. (Hint: it is easier if you use both the 1st and 2nd laws.)

(c) (5 pts) In a slightly different experiment ("experiment B"), the insulation is removed from the cylinder, and now a heat transfer is used to keep the gas temperature constant throughout the process. The expansion again is gradual and smooth. This experiment B begins from the same State 1 as the first experiment ("experiment A"), and also ends at the same P_2. However now $T_2=T_1$=constant = 300 K. How would the work done by the gas in experiment B compare to the work done in experiment A?

Choose one and justify your answer.

(i) Work is greater in experiment A
(ii) Work is same in both experiments
(iii) Work is greater in experiment B