

**ME 40**  
**Thermodynamics**  
**Spring 2009**

**Quiz #3**

**March 16, 2009**

**Name:** \_\_\_\_\_

**SID:** \_\_\_\_\_

Instructions:

Read each question carefully. Take into consideration the point values for each question. **Write your name and SID on each page.** You have roughly 45 minutes.

One double-sided reference sheet is permitted.

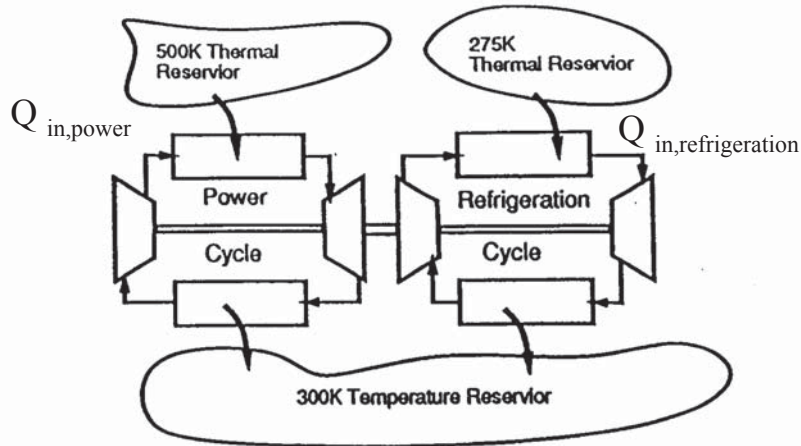
Good luck!

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### Question 1: [10 points]

Consider a device consisting of two cycles as sketched below. The heat engine cycle (the power cycle) operates between two thermal reservoirs at 500 K and 300 K respectively. The refrigeration cycle interacts with reservoirs at 300 K and 275 K respectively. The power from the heat engine cycle is used entirely to run the refrigeration cycle. Both cycles are assumed to be ideal Carnot cycles. Determine the ratio of heat inputs into these two cycles,  $Q_{in,refrigeration}/Q_{in,power}$



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### Question 2: [5 points]

An ideal gas initially at 300 K and 500 kPa (State 1) passes through an *adiabtic* throttling device. The pressure of this ideal gas drops to 100 kPa (State 2). Determine 1) the change of entropy per unit mass of this ideal gas (2 points), and 2) the minimum work required to reverse the throttling process from State 2 to State 1 (3 points). The gas constant of this ideal gas is  $R=0.3$  kJ/kg-K.

### Question 3: [5 points]

An inventor claims that a new refrigeration compressor has been designed to receive saturated R-134a vapor at  $-20^{\circ}\text{C}$  (entropy of this vapor is  $s_g=0.9456$  kJ/kg-K) and delivers superheated vapor at 0.7 MPa,  $30^{\circ}\text{C}$  (entropy  $s_{\text{super}}=0.9313$  kJ/Kg-K). The compression process has a net heat *loss* of 5kJ/kg to the surroundings at 300 K. Perform a steady-flow analysis to determine if the compression process violates the second law?

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### Question 4: [10 points]

Steam at 6 MPa and 500°C enters a two-stage *adiabatic* turbine at a rate of 10 kg/s. Ten percent of the steam (mass flow rate =1 kg/s) is extracted at the end of the first stage at a pressure of 200 kPa. The remainder (mass flow rate =9 kg/s) is further expanded in the second stage and leaves turbine at 20 kPa. Determine the **maximum possible** power output of this turbine (sum of 1<sup>st</sup> and 2<sup>nd</sup> stages). Note: properties of steam at 6 MPa and 500°C:  $v=0.05667$  m<sup>3</sup>/kg,  $u=3083.1$  kJ/kg,  $h=3423.1$  kJ/kg,  $s=6.8826$  kJ/kg-K.

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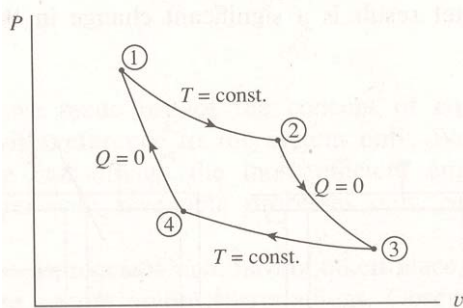
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### Question 5: [10 points]

A Carnot engine operating on **air** accepts 50 kJ/kg of heat from a high temperature reservoir at  $T_H$  and rejects 20 kJ/kg to a low temperature reservoir at  $T_L$  as sketched below. The pressure after isothermal expansion is 200 kPa (State 2) and the specific volume at State 3 is  $10 \text{ m}^3/\text{kg}$ .

- 1) Determine the temperature ratio of high temperature and low temperature reservoirs,  $T_H/T_L$  [2 points].
- 2) Determine the pressure at State 3. [5 points]
- 3) Determine  $T_H$  and  $T_L$ . [3 points]

Note: isentropic (adiabatic & reversible) compression and expansion processes satisfy the relationship  $Pv^k = \text{constant}$ . For air,  $k=1.4$ , and  $R_{\text{air}} = 0.287 \text{ kJ/kg}\cdot\text{K}$  and we will assume ideal gas law for air:  $Pv=R_{\text{air}} T$ .



P-v diagram for Carnot engine

1→2: Isothermal expansion

2→3: Adiabatic & reversible expansion

3→4: Isothermal compression

4→1: Adiabatic & reversible compression