ME 200 Spring 2007  
Exam 2  
Tuesday March 6

- You may use only your own book, your own notes (this includes course instructor notes you have written on) and any quizzes you were given in class.
- You may not use any additional material, such as another persons notes, other books, technical papers, solution manuals, old exams, anyone else’s homework, etc.
- You must turn off all communications devices before starting this exam, place them under your seat out of sight, and leave them off until you exit the examination room.
- You must place all materials, other than your calculator, pencil, eraser, book/notes, and this exam under your seat and not move them until you leave the exam hall for the last time this evening. Recall that this includes any communications devices.
- You must interpolate when necessary. You will not obtain full credit if you choose “the closest answer.”
- You must follow the problem solution format to obtain full credit.

Name:______________________  Thermo No:________

CIRCLE YOUR DIVISION

<table>
<thead>
<tr>
<th>Division</th>
<th>Professor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Div. 1 (830)</td>
<td>Prof. Sojka</td>
</tr>
<tr>
<td>Div. 2 (1030)</td>
<td>Prof. Abraham</td>
</tr>
<tr>
<td>Div. 3 (1230)</td>
<td>Dr. Tree</td>
</tr>
<tr>
<td>Div. 4 (230)</td>
<td>Dr. Son</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (34 pts)</td>
<td></td>
</tr>
<tr>
<td>2 (46 pts)</td>
<td></td>
</tr>
<tr>
<td>3 (20 pts)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>
1. (Part a is worth 12 pts, part b is worth 4 pts, and part c is worth 18 pts) A new house is to be heated using a Carnot heat pump. The work required to operate the heat pump is supplied by a Carnot heat engine. A schematic of the combined heat pump-heat engine system is shown at right. Although the heat pump and heat engine are both ideal devices, only 50% of the work produced by the engine is received by the heat pump.

a. Determine the magnitude of the work produced by the heat engine. Report your answer in kJ.

b. Determine the magnitude of the work received by the heat pump. Report your answer in kJ.

c. Determine the total amount of heat transferred to the house, by adding the heat transferred from the heat engine to the heat transferred from the heat pump to the house. Report your answer in kJ.

\[
Q_{He} = \frac{T_H}{T_e} = \frac{540}{30} = 18 \text{ kJ}
\]

\[
W_e = Q_{He} - Q_{Ce} = 1800 \text{ kJ}
\]

\[
W_p = 0.5 \cdot W_e = 900 \text{ kJ}
\]

\[
Q_{Hp} = \frac{T_H}{T_c} = \frac{25 + 273}{5 + 273} = 1.07
\]

\[
W_p = Q_{Hp} - Q_{Cp} = 1.07 Q_{Cp} - Q_{Cp} = 0.072 Q_{Cp}
\]

\[
Q_{Cp} = \frac{3250 \text{ kJ}}{0.072} = 46,200 \text{ kJ}
\]

\[
Q_{Hp} = 495 \text{ kJ}
\]

\[
Q_{House} = Q_{Ce} + Q_{Hp} = 153400 \text{ kJ}
\]
2. (Part a is worth 18 pts, part b is worth 14 pts, and part c is worth 14 pts) 225 kg/min of liquid water enters a heat exchanger at 120°C and exits at 40°C. The water is cooled by passing air through the heat exchanger at an inlet volume flow rate of 1000 m³/min. The air enters at 1 bar and 25°C and exits at 1 bar. The heat exchanger is not insulated, and transfer heat to the surroundings at a rate of 50 kW. The specific heats at constant pressure for water and air are 4.18 kJ/kg-K and 1.005 kJ/kg-K, respectively.

Determine
a. the mass flow rate of air, in kg/min.
b. the change in enthalpy of the water, in kJ/kg.
c. the outlet temperature of the air, in °C.

\[
\dot{Q} - \dot{W} = \sum m_i (h_{in} + h_f) - \sum m_i (h_{in} + h_f) \\
\dot{Q} = \dot{m}_{water} \Delta h_{water} + \dot{m}_{air} \Delta h_{air} = -50 \text{ kW} \\
\dot{m}_{water} = 10^3 \text{ kg/min} \times \frac{225 \text{ kg}}{\text{3600 sec}} = 170 \text{ kg/min} \\
\Delta h_{water} = C_{p_{water}} \Delta T_{water} = 4.18 \text{ kJ/kg-K} \times (40 - 120) \text{ K} = 334 \text{ kJ/kg} \\
\dot{Q} = -50 \text{ kW} = -334 \text{ kJ/kg} - 170 \text{ kg/min} \times \frac{1000 \text{ m}^3}{\text{min}} \times \frac{25 \text{°C}}{60 \text{ sec}} \Delta T_{air} \\
\Delta T_{air} = 61.2 \text{°C} \\
T_{out} \text{ air} = 86.2 \text{°C}
\]
3. (20 pts) Air exiting a gas turbine engine passes through a nozzle. The nozzle inlet conditions are 2000 F, 200 psi, 10 ft/s. The area is 1.5 ft². The nozzle exit conditions are 15 psi, 1000 ft/s and 1200 F.

Is this nozzle adiabatic? If not, report the value of the heat transfer (in Btu/sec) and indicate whether energy flows into, or out of, the nozzle.

\[
\dot{Q} - \dot{W} = \dot{\Sigma} \frac{\Delta h}{\text{in}} (h + u^2/2 + gz) - \dot{\Sigma} \frac{\Delta h}{\text{out}} (h + u^2/2 + gz)
\]

\[
\dot{Q} = \dot{m}(\Delta h + \Delta ke) \Rightarrow \dot{Q} = (\Delta h + \Delta ke)
\]

\[
\dot{q} = \frac{-202 \text{ Btu/lbm}}{\text{since } \dot{Q} \neq 0} \text{ is not adiabatic since heat transfer is out of system}
\]