ME 200 Fall 2012
Exam 3

LAST NAME: 

FIRST NAME: 

PUID: _ THERMO NO: 

Circle your section:
Gore  Frankel  Sojka  Kim  Clark
7:30AM  10:30AM  1:30PM  3:30PM  4:30PM

Instructions: This is a closed book/note exam. You may use a calculator. You must start from the most basic form of the equations and simplify accordingly to receive full credit. Show all your work! Keep your eyes on your own paper. If you are caught cheating you will get a zero for the exam and your name will be turned over to the Dean of Students.

Score:

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>TOTAL POSSIBLE</th>
<th>YOUR SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>20</td>
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<tr>
<td>2</td>
<td>37</td>
<td>20</td>
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<td>3</td>
<td>35</td>
<td>19</td>
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<tr>
<td>TOTAL</td>
<td>100</td>
<td>49</td>
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</tbody>
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Regrade: Problem 1 needs 10 more points
Just added up points incorrectly
1. Answer the following questions showing all work including a sketch of the device.

(a) An inventor claims to have developed a refrigeration cycle that removes heat from the closed region at \(-12^\circ C\) and transfers it to the surroundings at \(25^\circ C\) while maintaining a coefficient of performance of 6.5. Is this claim reasonable? Why? [7 points]

\[
\text{COP}_{\text{act}} = \frac{T_H}{T_H - T_c} = \frac{12 + 273}{25 + 273} = 2.61K
\]

\[
\text{COP}_{\text{act}} < \text{COP}_{\text{rev}}
\]

so yes it is possible

(b) A Carnot heat engine receives heat from a reservoir at \(900^\circ C\) at a rate of 800 kJ/min and rejects waste heat to the ambient air at \(27^\circ C\). The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at \(-5^\circ C\) and transfers it to the same ambient air at \(27^\circ C\). Determine (i) the maximum rate of heat removal from the refrigerated space in kJ/min and (ii) the total rate of heat rejection to the ambient air in kJ/min. [7 points]

(i) \(\text{Carnot = reversible}
\)

\[
5581.841\text{ kJ/min}
\]

(ii) \(\eta = 1 - \frac{Q_c}{Q_H}
\)

\[
Q_H = 6248.330\text{ kJ/min}
\]

\[
Q_c = \frac{W}{\eta}
\]

\[
Q_{\text{out}} = \frac{W}{\eta} - \frac{W_{\text{net},\text{out}}}{\eta}
\]

\[
\eta \cdot Q_{\text{in}} = W_{\text{net},\text{out}}
\]

\[
W_{\text{out},\text{engine}} = 595.396\text{ kJ/min}
\]
(c) Answer the following true or false. Explain.

(i) The change of entropy of a closed system is the same for every process between two specified states. [7 points].

true because entropy is independent of the path taken and relies only on the end points.

(ii) The entropy of a fixed amount of an ideal gas increases in every isothermal compression (volume reduction). [7 points].

false because the process line would cause the volume reduction, not compressing resulting in a decrease of S.
2. An inventor filed for a patent for a device called an injector (see figure below). According to the inventor’s claims, the device is adiabatic and operates under steady state conditions. It uses steam at 3.5 bar and 240 °C (state 1) to “pump” liquid water at 1 bar and 20 °C (state 2). The claimed mass ratio is \( m_2/m_1 = 4.15 \). The two streams mix and exit the device as a single stream at 5 bar.

\[ m_2 = 4.15m_1 \]

(a) Find the state of the exiting stream, assuming that the device can actually operate as claimed. Be sure to clearly identify your system on the sketch. [27 points]

(b) The patent clerk took one glance at the claim and pronounced that it is impossible to mix two streams, both at low pressures, and come up with a stream at a much higher pressure, without resorting to external work input. Being a cautious and experienced bureaucrat, however, the patent clerk decided to hire you as a consultant before rejecting the patent. What would be your advice? [10 points]

\[ \Delta h = \sum m_i (h_i - h_{out}) \]

\[ m_1 h_1 + m_2 h_2 = m_3 h_3 \]

\[ h_3 = 892.317 \text{kJ/kg} \]

\[ x \@ h_3 = 0 \]

\[ 892.317 = 640.23 + x(2748.7 - 640.23) \]

\[ x = 0.120 \] so state is \( h \)

That it is possible ble of the \( p-h \) diagram

\[ \Delta \text{gen} = ? \]
Use this as extra space.
Use this as extra space.
3. A rigid tank contains an ideal gas at 40°C that is being stirred by a paddle wheel. The paddle wheel does 200 kJ of work on the ideal gas. It is observed that the temperature of the ideal gas remains constant during this process as a result of heat transfer between the system and the surroundings at 25°C. Determine (a) the entropy change of the ideal gas [20 points] and (b) the total entropy generation for the system plus the surroundings [10 points], (c) is the increase of entropy principle satisfied during this process? [5 points].

System = Ideal gas inside tank

\[ W = -200 \text{ kJ} \]
\[ Q = -200 \]

\[ \Delta S = \frac{Q}{T} + \sigma_{gen} \]
\[ \frac{200}{298} = 1.565 \]
\[ \Delta S = 2.2 \times 10^4 \text{ kJ/kg.K} \]

\[ D_{sys} = D_{sur} - \frac{Q}{W} \ln \frac{P_1}{T_1} = 0 \]

b) \[ \sigma_{sys} + \sigma_{sur} =? \]
\[ 1.565 + 1.49 \rightarrow 3.065 \text{ kJ/kg.K} \]
\[ \frac{313}{200} + \frac{298}{200} = \]

\[ \sigma_{sys} + \sigma_{sur} = \frac{313}{200} + \frac{298}{200} = 3.065 \text{ kJ/kg.K} \]

c) Satisfied because entropy increases
Use this as extra space.