CIRCLE YOUR LECTURE BELOW

<table>
<thead>
<tr>
<th>Div. 1 – 7:30 am</th>
<th>Div. 2 – 8:30 am</th>
<th>Div. 3 – 10:30 am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naik</td>
<td>Mongia</td>
<td>Frankel</td>
</tr>
<tr>
<td>Div. 4 – 1:30 pm</td>
<td>Div. 5 – 3:30 pm</td>
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<tr>
<td>Lopez</td>
<td>Pourpoint</td>
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</tbody>
</table>

EXAM 1

INSTRUCTIONS

- This is a closed book and closed notes exam. Answer as many questions as you can in the allotted time. Do not hesitate to ask questions if you do not understand a problem statement. For your own benefit, please write clearly and legibly. Maximum credit for each problem is indicated below. To receive full credit for a problem, you must follow instructions, show all work, and write the answers in the appropriate boxes.

- For Problems 1 and 2, significant credit will be given if you start with the basic equation(s), list all assumption(s), and illustrate the method by which you propose to solve the problem correctly. Some parts of Problem 3 will be given no partial credit.

- Do not write on the back of any page. Material on the back of a page may not be graded. If additional pages are needed, ask for additional pages. Insert the extra pages in their proper order and staple them to the exam.

- The use of PDAs, Blackberry-type devices, cell phones, laptop computers, or any other sources of communication (wireless or otherwise) are strictly prohibited during examinations. Doing so is cheating. If you bring a cell phone or other communication devices to the examination, they must be turned off prior to the start of the exam, placed in your backpack, and the backpack stored below your seat, and only picked up as you leave the examination room for the final time. They are not to be turned on again until after you have exited the examination room. Otherwise it will be considered a form of cheating and treated as such.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Problem 1: (30 points)

Given:
A gas in piston-cylinder device undergoes a thermodynamic cycle consisting of the following three processes.
Process 1-2: Compression with no change in internal energy \( U_2 = U_1 \)
Process 2-3: Constant volume cooling to \( P_3 = 1.4 \text{ bar} \) and \( V_3 = 0.028 \text{ m}^3 \)
Process 3-1: Constant pressure expansion in which \( W_{31} = +10.5 \text{ kJ} \)

For the complete cycle, \( W_{\text{cycle}} = -8.3 \text{ kJ} \) and there are no changes in kinetic and potential energy.

Find:
(a) What is the volume (m\(^3\)) at state 1? Write any necessary assumptions, equations, and show your solution in the spaces provided. (6 points)

(b) Calculate the work (kJ) and heat transfer (kJ) for process 1-2. Write any necessary assumptions, equations, and show your solution in the spaces provided. (11 points)

(c) Is this a power cycle or a refrigeration cycle? You must provide an appropriate justification to receive credit. (5 points)
Name: Naik                         Sameer                        Thermo No: 0000
                        (Last)                          (First)

Assumptions: (2 points)
- Negligible leakage in the piston-cylinder device i.e. closed system
- Quasi-equilibrium processes

Basic Equations: (6 points)

\[ W_b = \int PdV \]

\[ Q - W = \Delta E = \Delta U + \Delta PE + \Delta PE \Rightarrow Q - W = \Delta U \]

Solution:
(a) Work during constant pressure expansion from state 3 to state 1:

\[ W_{31} = \int_3^1 PdV = P_3 (V_1 - V_3) \Rightarrow +10.5 \text{ kJ} = (1.4 \times 100) \text{ kPa} \times (V_1 - 0.028) \text{ m}^3 \]

Volume at state 1: \[ V_1 = 0.103 \text{ m}^3 \]

(b) Considering energy balance for process from state 1 to state 2:

\[ Q_{12} - W_{12} = \Delta U_{12} = U_2 - U_1 = 0 \Rightarrow Q_{12} = W_{12} \]

Work during the complete cycle: \[ W_{cycle} = W_{12} + P_2 \Delta V_2 + W_{31} \text{ since } W_{23} = \int_2^3 PdV = 0 \]

\[ \Rightarrow -8.3 \text{ kJ} = W_{12} + 10.5 \text{ kJ} \Rightarrow W_{12} = \textcolor{red}{-18.8 \text{ kJ}} \text{; negative sign indicates work done on the system during the compression process} \]

\[ \Rightarrow Q_{12} = \textcolor{red}{-18.8 \text{ kJ}} \text{; negative sign indicates heat transfer from the system to surroundings} \]

(c) Net work from the cycle is negative \( W_{cycle} < 0 \) (anti-clockwise on P-V diagram) \( \Rightarrow \) the given cycle is a \textbf{refrigeration cycle}
Problem 2: (30 points)

Given:
A rigid vessel with volume 10 L initially contains a mixture of liquid water and vapor at temperature of 100°C with 12.3% quality (state 1). The vessel is slowly heated until its temperature increases to 150°C (state 2).

Find:
(a) Complete the following table for water. Write any necessary assumptions, equations, and show your solution in the spaces provided. (11 points)

<table>
<thead>
<tr>
<th>State</th>
<th>Temperature (°C)</th>
<th>Specific Volume (m³/kg)</th>
<th>Specific Internal Energy (kJ/kg)</th>
<th>Phase</th>
<th>Quality (%) (If Applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0.2067</td>
<td>675.71</td>
<td>SLVM</td>
<td>12.3%</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>0.2067</td>
<td>1643.79</td>
<td>SLVM</td>
<td>52.5%</td>
</tr>
</tbody>
</table>

(b) Show the process from state 1 to state 2 on the P-v diagram in relation to the vapor dome. You must label the states, show pressure and specific volume values, and indicate appropriate lines of constant of temperature. (8 points)

(c) Determine the heat transfer (kJ) required during the heating process. Write any necessary assumptions, equations, and show your solution in the spaces provided. (4 points)

(c) Heat transfer required during the heating process = +46.86 kJ
Assumptions: (2 points)
- Rigid tank is closed system
- \( \Delta KE = 0, \Delta PE = 0 \)
- No work interactions for the system

Basic Equations: (5 points)
\[
y = y_f + x \left( y_g - y_f \right)
\]
\[
m = \frac{V}{v}
\]
\[
Q - W = \Delta U + \Delta KE + \Delta PE \Rightarrow Q_{12} = U_2 - U_1 = m(u_2 - u_1)
\]

Solution:
(a) State 1: \( T_1 = 100^\circ C, x_1 = 0.123 \)

Using Table A-2:
\[
v_1 = v_f + x_1 \left( v_g - v_f \right) = 0.0010435 \, \text{m}^3/\text{kg} + 0.123 \times (1.673 - 0.0010435) \, \text{m}^3/\text{kg}
\]
\[
\Rightarrow v_1 = 0.2067 \, \text{m}^3/\text{kg}
\]

Similarly, \( u_1 = u_f + x_1 \left( u_g - u_f \right) = 418.94 \, \text{kJ/kg} + 0.123 \times (2506.5 - 418.94) \, \text{kJ/kg} \Rightarrow u_1 = 675.71 \, \text{kJ/kg} \)

State 2: \( v_2 = v_1 \) (rigid tank \( \Rightarrow \) total volume and total mass constant i.e. specific volume same)

Using Table A-2: \( v_f \) at \( 150^\circ C < v_2 = 0.2067 \, \text{m}^3/\text{kg} < v_g \) at \( 150^\circ C \Rightarrow \text{SLVM} \)

Quality at state 2:
\[
x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{0.2067 - 0.0010905}{0.3928 - 0.0010905} \Rightarrow x_2 = 0.525
\]

\[
u_2 = u_f + x_2 \left( u_g - u_f \right) = 631.68 \, \text{kJ/kg} + 0.525 \times (2559.5 - 631.68) \, \text{kJ/kg} \Rightarrow u_2 = 1643.79 \, \text{kJ/kg}
\]

(b) See the P-v diagram above.

(c) Considering energy balance, the heat transfer during the heating process is: \( Q_{12} = m(u_2 - u_1) \)

Mass inside the rigid tank:
\[
m = \frac{V}{v_1} = \frac{10/1000 \, \text{m}^3}{0.2067 \, \text{m}^3/\text{kg}} = 0.0484 \, \text{kg}
\]

\[
i.e. \, Q_{12} = 0.0484 \, \text{kg} \times (1643.79 - 675.71) \, \text{kJ/kg} \Rightarrow i.e. \, Q_{12} = +46.86 \, \text{kJ} \; \text{positive sign indicates heat transfer into the system}
\]
Problem 3: (40 points)

Write your answers in the boxes provided for each question. Only the answers written in the boxes will be graded. For Problem 3 only, you do not have to list assumptions; however, you must show work (basic equations and calculations to support your answers) to receive full credit. There is no partial credit for 3(a), 3(d), and 3(e).

(a) Mass of 100 kg weighs more on earth \((g = 9.81 \text{ m/s}^2)\) as compared to Jupiter \((g = 25 \text{ m/s}^2)\). Indicate true or false by circling one answer. (2 points)

\[
W = mg \\
g_{\text{earth}} < g_{\text{Jupiter}} \Rightarrow W_{\text{earth}} < W_{\text{Jupiter}}
\]

\begin{tabular}{|c|c|}
\hline
\(\text{a)}\) True & \(\text{False}\) \\
\hline
\end{tabular}

(b) On a winter day, temperature \((T_1)\) in Anchorage, Alaska is \(-40^{\circ}\text{C}\). On that same day, temperature \((T_2)\) in Sydney, Australia is \(90^{\circ}\text{F}\). What is the temperature difference \((K)\) between Sydney and Anchorage on this winter day? You must show work to receive credit. (6 points)

\[
T_1 = -40 + 273.15 = 233.15 \text{ K} \\
T_2 = 90^{\circ}\text{F} + 459.67 = 549.67 \text{ ^\circ}\text{C} \\
= \frac{549.67}{1.8} = 305.38 \text{ K}
\]

\[
T_2 - T_1 = 72.23 \text{ K}
\]

(c) Complete the following table for energy interactions of a closed system. You must show work to receive credit. (12 points)

<table>
<thead>
<tr>
<th>Process</th>
<th>(\Delta U) (kJ)</th>
<th>(\Delta KE) (kJ)</th>
<th>(\Delta PE) (kJ)</th>
<th>(\Delta E) (kJ)</th>
<th>(Q) (kJ)</th>
<th>(W) (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>950</td>
<td>50</td>
<td>0</td>
<td>1000</td>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>-500</td>
<td>0</td>
<td>50</td>
<td>-450</td>
<td>0</td>
<td>450</td>
</tr>
<tr>
<td>C</td>
<td>-650</td>
<td>50</td>
<td>0</td>
<td>-600</td>
<td>-500</td>
<td>100</td>
</tr>
</tbody>
</table>

Process A:

\[
\Delta E = \Delta U + \Delta KE + \Delta PE = 950 + 50 + 0 = 1000 \text{ kJ}
\]

Applying the first law of thermodynamics: \(Q - W = \Delta E \Rightarrow W = 1000 - 1000 = 0 \text{ kJ}\)

Process B:

\[
\Delta E = \Delta U + \Delta KE + \Delta PE \Rightarrow -450 = \Delta U + 0 + 50 \Rightarrow \Delta U = -500 \text{ kJ}
\]

Applying the first law of thermodynamics: \(Q - W = \Delta E \Rightarrow Q = 450 + (-450) = 0 \text{ kJ}\)

Process C:

\[
\Delta E = \Delta U + \Delta KE + \Delta PE \Rightarrow -600 = -650 + \Delta KE + 0 \Rightarrow \Delta KE = 50 \text{ kJ}
\]

Applying the first law of thermodynamics: \(Q - W = \Delta E \Rightarrow Q = 100 + (-600) = -500 \text{ kJ}\)
(d) Identify by circling one of the answers the state of water at pressure 5 bar and temperature 200°C. (4 points)

\[ P = 5 \text{ bar}; \ T_{\text{sat}} = 159.9{}^\circ C \text{ (Table A-3)} \Rightarrow T = 200{}^\circ C > T_{\text{sat}} \Rightarrow \text{SHV} \]

saturated liquid  saturated vapor  superheated vapor  compressed liquid

(e) What is the specific volume of water at pressure 5 bar and temperature 200°C? (4 points)

Using Table A-4 for \( P = 5 \text{ bar}, \ T = 200{}^\circ C \)

(e) Specific volume

\[ = 0.4249 \text{ m}^3/\text{kg} \]

(f) Show the state of water at 5 bar and 200°C on the \( P-v \) and \( T-v \) diagrams. You must clearly label the state and indicate appropriate lines of constant pressure and temperature. (12 points)