First Name  Solution  Last Name

CIRCLE YOUR LECTURE BELOW:

<table>
<thead>
<tr>
<th>Time</th>
<th>7:30 am</th>
<th>8:30 am</th>
<th>10:30 am</th>
<th>11:30 am</th>
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<tbody>
<tr>
<td>Joglekar</td>
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<td>Gore</td>
<td>Abraham</td>
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<thead>
<tr>
<th>Time</th>
<th>1:30 pm</th>
<th>3:30 pm</th>
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<tbody>
<tr>
<td>Naik</td>
<td>Naik</td>
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ME 200 Exam 1
September 19, 2013
8:00 p.m. to 9:00 p.m.

INSTRUCTIONS

1. This is a **closed book and closed notes examination**. You are provided with an equation sheet and all the needed property tables.
2. Do not hesitate to ask the instructor if you do not understand a problem statement.
3. Start each problem on the same page as the problem statement. Write on only one side of the page. Materials on the back side of the page will not be graded. There are blank pages following problems 2 and 3 for your work.
4. Put only one problem on a page. Another problem on the same page will not be graded.
5. Show your system and list relevant assumptions and basic equations for problem 2.
6. If you give multiple solutions, you will receive only a partial credit although one of the solutions might be correct. Delete the solution you do not want graded.
7. For your own benefit, please write clearly and legibly. Maximum credit for each problem is indicated below.
8. After you have completed the exam, at your seat **put your papers in order**. This may mean that you have to remove the staple and re-staple. **Do not turn in loose pages**.
9. Once time is called you will have three minutes to turn in your exam. Points will be subtracted for exams turned in after these three minutes.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible</th>
<th>Score</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td></td>
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</table>
Problem 1 (25 points) Answer the following questions. For Problem 1 only, assumptions need not be stated. No credit will be given for (a) and (b) without correct justification even if the answer is correct.

(a) A heated steel ball of certain mass is initially held at an elevation above the ground. The ball is released and begins to cool and accelerate as it falls. What happens to the total energy of the ball? Justify your answer with an equation. (5 points)

(i) Increases (ii) Decreases (iii) Remains Same (iv) Insufficient Information

\[ E = U + KE + PE \]

Mechanical energy (KE plus PE) remains constant; internal energy (U) decreases because of decreasing temperature

(b) A substance is initially at its critical point inside a rigid tank. What is the phase of the substance after it is cooled? Justify your answer with a diagram. (10 points)

(i) Superheated Vapor (ii) Compressed Liquid (iii) Saturated Liquid-Vapor Mixture (iv) Insufficient Information

![Diagram showing phase change from superheated vapor to saturated liquid-vapor mixture]
Problem 1 (continued)

(c) Heat is transferred to air inside a piston-cylinder device initially at $P_1$ and $V_1$. The air is finally at $P_2 > P_1$ and $V_2 = 2V_1$. Friction is negligible.

Show the expansion process on P-V diagram. (10 points)
**Problem 2 (30 points)** Air is contained in a frictionless piston-cylinder device initially at a pressure of 4 bar and occupies volume of 1 m$^3$ (State 1). Heat is added to air such that the final volume of air inside the cylinder is 2 m$^3$ (State 2). During heat addition $PV = $ constant for air inside the cylinder. Atmospheric pressure air of 1 bar acts on the piston from the outside.

If necessary, use: $\int \frac{dV}{V} = \ln V$

(a) Calculate the work (kJ) for air inside the cylinder during the process.
(b) Calculate the work (kJ) for atmospheric air during the process.
(c) Find the net work (kJ) during the process.
(d) Is the net work done on the system or by the system? Explain.

Identify your system, list assumptions, and start with basic equations.

**Assumptions**
- Neglect friction
- Quasi-equilibrium expansion process

**Basic Equation(s)**

$$ W_b = \int PdV $$

**Solution**

(a) Boundary work during the expansion process for air inside the cylinder:

$$ W_{12} = \int_{1}^{2} PdV = \text{constant} \int_{1}^{2} \frac{dV}{V} = P_1V_1 \ln \left(\frac{V_2}{V_1}\right) = (4 \times 100) \text{ kPa} \times 1 \text{ m}^3 \times \ln \left(\frac{2 \text{ m}^3}{1 \text{ m}^3}\right) $$

$$ W_{12} = +277.26 \text{ kJ} $$

Since $W > 0$ work is done by the air inside the cylinder
Problem 2 (continued)

(b) Since atmospheric pressure is constant, the boundary work for atmospheric air:
\[ W_{\text{atm}} = \int P_dV = P_{\text{atm}} (V_2 - V_1) = (1 \times 100) \text{ kPa} \times (1 - 2) \text{ m}^3 \]
\[ W_{\text{atm}} = -100 \text{ kJ} \] Since \( W < 0 \) work is done on the atmospheric air.

(c) Net work during the expansion process:
\[ W_{\text{net}} = W_{\text{gas}} + W_{\text{atm}} = W_{12} + W_{\text{atm}} = (+277.26 - 100) \text{ kJ} \]
\[ W_{\text{net}} = +177.26 \text{ kJ} \] +3 (for net work equation)

(d) Since \( W_{\text{net}} > 0 \Rightarrow \text{the net work is done by the system on the surroundings} \] +2
Problem 3 (45 points) Vapor power generation plants typically use water as the working fluid. In a certain power plant, steam enters the turbine at 50 bar and 500°C (State 1). Steam exits at 0.06 bar and contains 10% liquid by mass in a saturated mixture (State 2). After condensation, water leaves as saturated liquid at 0.06 bar (State 3). Water is pumped to boiler pressure and exits at 50 bar and 40°C (State 4).

(a) Complete the following table with eight missing entries. Clearly show work for determination of phase (saturated liquid, saturated vapor, saturated liquid vapor mixture (SLVM), compressed/sub-cooled liquid (CL), superheated vapor (SHV)) for states 1 and 4. Show any necessary calculations with basic equations for missing property values.

<table>
<thead>
<tr>
<th>State</th>
<th>Pressure (bar)</th>
<th>Temperature (°C)</th>
<th>Specific Volume (m³/kg)</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.06</td>
<td></td>
<td></td>
<td>SLVM</td>
</tr>
<tr>
<td>3</td>
<td>0.06</td>
<td></td>
<td></td>
<td>Sat. Liquid</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) Locate all four states of water on T-v diagram on the next page. Label states, show property values, and indicate appropriate lines of constant pressure. Note that the T-v diagram need not be to scale; however, the relative locations of all four states must be correct.
Problem 3 (continued)

(b)

\[ T_1 = 500^\circ C \]
\[ T_2 = T_3 = 36.16^\circ C \]
\[ T_4 = 40^\circ C \]
\[ v_3 = 0.0010064 \]
\[ v_1 = 0.07154 \]
\[ v_2 = 21.3652 \]

Solution

(a) State 1: \( P_1 = 50 \text{ bar} \) and \( T_1 = 500^\circ C \)

Table A-3: \( T_{\text{sat}}(P_1) = 264^\circ C \) \( \Rightarrow \) \( T_1 > T_{\text{sat}}(P_1) \) \( \Rightarrow \) \text{superheated vapor (SHV)}

Table A-4: \( v(40 \text{ bar}, 500^\circ C) = 0.08643 \text{ m}^3/\text{kg} \) and \( v(60 \text{ bar}, 500^\circ C) = 0.05665 \text{ m}^3/\text{kg} \)

Interpolating:

\[ \frac{v_1 - 0.08643}{0.05665 - 0.08643} = \frac{50 - 40}{60 - 40} \Rightarrow v_1 = 0.07154 \text{ m}^3/\text{kg} \]

State 2: \( P_2 = 0.06 \text{ bar} \) and quality \( x_2 = 1 - 0.1 = 0.9 \)

Table A-3: Since SLVM, \( T_2 = T_{\text{sat}}(P_2) \) \( \Rightarrow \) \( T_2 = 36.16^\circ C \)
Problem 3 (continued)

\[ v_2 = v_f(P_2) + x_2 v_{fg}(P_2) = v_f(P_2) + x_2 \left[ v_g(P_2) - v_f(P_2) \right] \]

Table A-3: \( v_f(P_2) = 1.0064 \times 10^{-3} \text{ m}^3/\text{kg} \) and \( v_g(P_2) = 23.739 \text{ m}^3/\text{kg} \) \( \Rightarrow v_2 = 21.3652 \frac{\text{m}^3}{\text{kg}} \)

State 3: \( P_3 = 0.06 \text{ bar} \), saturated liquid

Table A-3: Since saturated liquid, \( T_3 = T_{sat}(P_3) \) \( \Rightarrow T_3 = 36.16 \degree C \)

\[ v_3 = v_f(P_3) \Rightarrow v_3 = 1.0064 \times 10^{-3} \frac{\text{m}^3}{\text{kg}} \]

State 4: \( P_4 = 50 \text{ bar} \) and \( T_4 = 40 \degree C \)

Table A-3: \( T_{sat}(P_4) = 264 \degree C \) \( \Rightarrow T_4 < T_{sat}(P_4) \) \( \Rightarrow \text{sub-cooled (compressed) liquid (CL)} \)

Table A-5: \( v_4 = v(50 \text{ bar}, 40 \degree C) \) \( \Rightarrow v_4 = 1.0056 \times 10^{-3} \frac{\text{m}^3}{\text{kg}} \)