MODEL EXAMINATION SOLUTION	**YEAR OF STUDY: ME XXXX**	
EXAM TITLE: Engineering Thermodynamics II	**Practice Exam**	
SECTION:	**QUESTION NO: 1**	**AUTHOR INITIALS: BP**

MARKS

Solution:

State 1: given: P_1 = 2000 kPa, T_1 = 300°C, V_1 = 0.1 m^3

Superheated Steam: v_1 = 0.12547 m_3/kg, u_1 = 2772.56 kJ/kg

Mass: m = V_1 / v_1 = 0.1 m^3 / 0.12547 m^3/kg = 0.797 kg

Process 1-2: heat is removed at constant volume until the piston is at the onset of movement.

State 2: P_2 = 500 kPa because piston is at onset of movement (given). Thus, pressure is equal to that of the air supply (i.e. same as the force on the piston)

V_2 = V_1 (piston has not yet moved) & v_2 = v_1 because the mass has not changed;

$v_2 = v_1$ = 0.12547 m^3/kg

(a) At 500 kPa $v_{f@500kPa} < v_2 < V_{g@500kPa}$.

- Thus **state 2 is a saturated liquid vapor mixture** (4 pts)
- Find quality at state 2 and the internal energy at state 2.
  - $x_2 = (v_2 - v_{f@500kPa}) / v_{fg@500kPa}$ = (0.12547-0.001093)/0.3738 → x_2 = 0.333
  - $u_2 = u_{f@500kPa} + x_2 * u_{fg@500kPa}$ = 639.66 + 0.333*1921.57 → u_2 = 1279.54 kJ/kg
  - $T_2 = T_{sat@500kPa}$ = 151.86°C

Process 2-3: Piston is moving and force acting on piston is equivalent to $P_{air} * A_{piston}$. Area of piston is constant, so the force is constant for process 2-3

(b) P_3 = 500 kPa (4 pts)

(c) To find boundary work, we need to find the variables at state 3

- State 3: T_3 = 100°C, P_3 = 500 kPa → compressed liquid
- v_3 = 0.001043 m^3/kg; u_3 = 418.80 kJ/kg
- Final volume: $V_3 = v_3 * m$ = 0.001043m^3/kg * 0.797 kg; V_3 = 0.000831 m^3
- $W_{boundary} = \int PdV$ → constant P → $W_{boundary} = P(V_3 - V_2)$ (2 pts)
- $W_{boundary}$ = 500 kPa * (0.000831 – 0.1)m^3; **$W_{boundary}$ = - 49.6 kJ = W_{32}** (2 pts)
- Work is into the system. W_{IN} = 49.6 kJ

(d) Apply first law of thermodynamics to find the total heat transfer

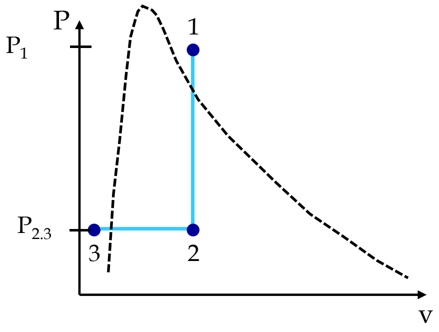
- Process 1-2: $m(u_2 - u_1) = Q_{21}$; $Q_{21} = 0.797kg(1279.54 - 2772.56)\frac{kJ}{kg}$ =-1189.94 kJ
- Q_{21} = -1189.94 kJ or 1189.94 kJ out of the system (1-2pts)
- Process 2-3: $m(u_3 - u_2) = Q_{32} - W_{32}$; $(W_{32} = W_{boundary})$
- $Q_{32} = m(u_3 - u_2) + W_{32} = 0.797kg(418.8 - 1279.54)\frac{kJ}{kg} + (-49.6kJ) = -735.6kJ$
- Q_{32} = -735.6 kJ or 735.6 kJ out of the system (1-2pts)
- **$Q_{total} = Q_{21} + Q_{32}$ = (-1189.94 + -735.6 kJ) = -1925.55 kJ** (1pts)

(e) State 1 → superheated vapor, State 2 → saturated mixture (x_2 = 0.333), State 3 → compressed liquid

Process 1-2: decrease in pressure at constant volume

Process 2-3: decrease in volume at constant pressure

(2 pts for states, 2 points for processes (i.e. correct paths))



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