ME354

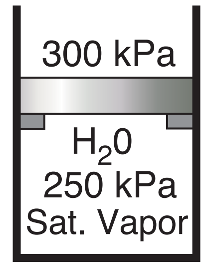
Thermodynamics 2

Quiz #1 - T02:

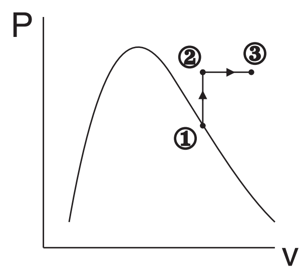
Name: ______________________

ID #: ______________________

Problem: A piston-cylinder device initially contains $0.8\ m^3$ of saturated water vapor at $250\ kPa$. At this state, the piston is resting on a set of stops, and the mass of the piston is such that a pressure of $300\ kPa$ is required to move it. Heat is now slowly transferred to the steam until the volume doubles. Show the process on a $P - v$ diagram with respect to saturation lines and determine (a) the final temperature, (b) the work done during this process, and (c) the total heat transfer.



Since the volume changes as the piston lifts off the stops, the two step process would look as follows on a P-v diagram:



2 marks

Part a

We need to apply a 1st law energy balance to the system to determine the temperature.

$$E_{initial} + Q_{in} - W_{out} = E_{final} \longrightarrow \text{since } \underbrace{KE = PE = 0}_{\text{assumption \#1}} \longrightarrow \Delta U = m(u_3 - u_1) = Q_{in} - W_{out}$$

1 mark

From Table A-5 for saturated vapour at $250\ kPa$

$$v_1 = v_g = 0.71873\ m^3/kg$$

$$u_1 = u_g = 2536.8\ kJ/kg$$

The mass of the vapour can be determined as

$$m = \frac{V_1}{v_1} = \frac{0.8\ m^3}{0.71873\ m^3/kg} = 1.113\ kg$$

1 mark

We know that at the final state the volume doubles, therefore the specific volume at this state is

$$v_{final} = v_3 = \frac{V_3}{m} = \frac{2 \times 0.8\ m^2}{1.113\ kg} = 1.436\ m^3/kg$$

1 mark

From the superheated tables (Table A-6) at $P_3 = 300\ kPa$ and $v_3 = 1.4375\ m^3/kg$, we can interpolate to find

$$T_3 = 662.2\ ^\circ C \Leftarrow$$

1 mark

$$u_3 = 3412.3\ kJ/kg$$

Part b

The work done during the process need only be calculated between states 2 and 3, since there is no change in volume between 1 and 2.

$$W_{out} = \int_2^3 P dV = P(V_3 - V_2) = (300\ kPa)(1.6 - 0.8)\ m^3 \left(\frac{1\ kJ}{1\ kPa \cdot m^3}\right) = 240\ kJ \Leftarrow$$

2 marks

Part c

The heat transfer can be determined from our 1st law balance

$$\begin{aligned} Q_{in} &= m(u_3 - u_1) + W_{out} \\ &= (1.113\ kg)(3412.3 - 2536.8)\ kJ/kg + 240\ kJ/kg \\ &= 1214\ kJ/kg \Leftarrow \end{aligned}$$

2 marks