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MAE91 Summer 2004 – Quiz 2 Dr. H. Susan Zhou

Closed book and notes - 35 minutes

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1. Draw a T-v diagram for water at different pressure. Define critical point, saturated-liquid line, saturated-vapor line on the diagram. Give definition of saturated liquid, saturated vapor, compressed liquid, superheated vapor and quality.



Saturated liquid: a liquid whose temp. is such that it is starting to evaporate. (its molecules have sufficient K.E. to escope and being saturated vopor: a vapor whose temp is the same as that it is not reaching compressed liquid: a liquid under a certain pressure so that it is not reaching saturation temp. superheated vopor: when all the liquid has saturated and temp > saturation temp. quality: ratio of volume of vapor to total volume. Muss of vapor/ total has 2. The figure shows a frictionless piston-cylinder device where a linear spring acts on the piston. Initially, the cylinder contains water at temperature T_1 and quality x_1 . The initial volume of the water is V_1 . If the piston rests at the stops, the enclosed volume is $V_{stop}=2V_1$. If the piston rests at the bottom of the cylinder, the force on the linear spring is zero. Heat is transferred to the cylinder until the water temperature increases to T_2 with quality $x_2 < 1$.

GIVEN: the values of V_1 , T_1 , x_1 and T_2 .

- **REQUIRED:**
- a) Plot the process for the two cases of "piston resting at the stops at the final state" and "piston not resting" on two separate P-v diagrams.
- b) Write the steps to find out the mass of the water in the cylinder.



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Quiz #2 Solutions

Problem 1

1. Problem Statement:

Draw a T-v diagram for water at different pressure. Define critical point, saturated-liquid line, saturated-vapor line on the diagram. Give definition of saturated liquid, saturated vapor, compressed liquid, superheated vapor and quality.



2. Assumptions and Givens:

$P_1 < P_2 < P_3$

Critical Point: A point at which the saturated liquid and the saturated vapor states are the same.

Saturated-Liquid: A substance where the quality is 0 or exists as a liquid at the saturation temperature and pressure. It is *just* beginning to go into a mixed gas/liquid state.

Saturated-Vapor: A substance where the quality is 1 or exists as a vapor at the saturation temperature and pressure. It is *just* beginning to go into a pure gas state.

Compressed Liquid: A substance where the phase is completely water and the pressure is greater than the saturation pressure for a given temperature.

Superheated Vapor: A substance where the phase is completely vapor and the temperature is greater than the saturation temperature.

Quality: It is the ratio of the mass of vapor to the total mass. This only has meaning for saturated states. (States inside the curve)

- 3. Fundamental Laws:
- 4. Steps:
- 5. Numerical Substitution:

Problem 2

1. Problem Statement:

The figure shows a frictionless piston-cylinder device where a linear spring acts on the piston. Initially, the cylinder contains water at temperature T_1 and quality x_1 . The initial volume of the water is V_1 . If the piston rests at the stops, the enclosed volume is $V_{stop}=2V_1$. If the piston rests at the bottom of the cylinder, the force on the linear spring is zero. Heat is transferred to the cylinder until the water temperature increases to T_2 with quality $x_2 < 1$.

GIVEN: the values of V_1 , T_1 , x_1 and T_2 .

REQUIRED:

- a) Plot the process for the two cases of "piston **resting** at the stops at the final state" and "piston **not resting**" on **two separate P-v** diagrams.
- b) Write the steps to find out the mass of the water in the cylinder.





2. Assumptions and Givens:

- The mass of the water is constant in the system.
- Initial state is a saturated state because it has a defined quality.
- Both of the final cases are also in a saturated state because the quality $x_2 < 1$
- There are two cases in this problem.
 - The first case the temperature increases and the piston comes to rest at the stops.
 - The second case the temperature increases but the piston does not reach the stops
- The cylinder is of constant area so a change in volume has a direct relation with the change in the height of the piston.

3. Fundamental Laws:

$$v = \frac{V}{m}$$

$$v = v_f + xv_{fl}$$

$$x = m_{vap} / m$$

$$F_{spring} = -kx$$

$$V = Ah$$

4. Steps:

a)

Plot of process with piston RESTING at stops at the final state.



During this process the pressure varies linearly with volume, since with a constant area, a change in volume corresponds to a change in height. As the height increases the spring is depressed and the force of the spring increases linearly. Once the piston reaches the stops the volume can no longer be increases, but the pressure and temperature can still be increased. Remember that in this plot both pressure and temperature is changing.

Plot of process with piston NOT RESTING at stops at the final state.



During this process the pressure varies linearly with volume, since with a constant area, a change in volume corresponds to a change in height. As the height increases the spring is depressed and the force of the spring increases linearly. Remember that in this plot both pressure and temperature is changing.

b)

We are initially given enough information to determine the initial state. Knowing the initial state we can find the mass of water.

 T_1, x_1 Using these values and table B.1.1 find v_f, v_g, v_{fg}

$$v_1 = v_f + x v_{fg}$$

$$\therefore m = \frac{V_1}{v_1}$$

Since the mass remains constant, once we find the mass in the first state, we always know the mass of the system.

5. Numerical Substitution: