Tut 1 Solution(3-8-2016)

Q.1. Discussed in Class

Q.2 Discussed in Class

Q.3

**SOLUTION** Properties and phase descriptions of water are to be determined at various states.

***Analysis*** (*a*) The quality is given to be $x = 0.6$, which implies that 60 percent of the mass is in the vapor phase and the remaining 40 percent is in the liquid phase. Therefore, we have saturated liquid–vapor mixture at a pressure of 200 kPa. Then the temperature must be the saturation temperature at the given pressure:

$$T = T_{\text{sat @ 200 kPa}} = \mathbf{120.21°C} \qquad \text{(Table A-5)}$$

At 200 kPa, we also read from Table A–5 that $u_f$ = 504.50 kJ/kg and $u_{fg}$ = 2024.6 kJ/kg. Then the average internal energy of the mixture is

$$\begin{aligned} u &= u_f + xu_{fg} \\ &= 504.50 \text{ kJ/kg} + (0.6)(2024.6 \text{ kJ/kg}) \\ &= \mathbf{1719.26 \text{ kJ/kg}} \end{aligned}$$

(*b*) This time the temperature and the internal energy are given, but we do not know which table to use to determine the missing properties because we have no clue as to whether we have saturated mixture, compressed liquid, or superheated vapor. To determine the region we are in, we first go to the saturation table (Table A–4) and determine the $u_f$ and $u_g$ values at the given temperature. At 125°C, we read $u_f$ = 524.83 kJ/kg and $u_g$ = 2534.3 kJ/kg. Next we compare the given $u$ value to these $u_f$ and $u_g$ values, keeping in mind that

$$\begin{array}{lll} \text{if} & u < u_f & \text{we have } \textit{compressed liquid} \\ \text{if} & u_f \le u \le u_g & \text{we have } \textit{saturated mixture} \\ \text{if} & u > u_g & \text{we have } \textit{superheated vapor} \end{array}$$

In our case the given $u$ value is 1600, which falls between the $u_f$ and $u_g$ values at 125°C. Therefore, we have saturated liquid–vapor mixture. Then the pressure must be the saturation pressure at the given temperature:

$$P = P_{\text{sat @ 125°C}} = \mathbf{232.23 \text{ kPa}} \qquad \text{(Table A–4)}$$

The quality is determined from

$$x = \frac{u - u_f}{u_{fg}} = \frac{1600 - 524.83}{2009.5} = \mathbf{0.535}$$

The criteria above for determining whether we have compressed liquid, saturated mixture, or superheated vapor can also be used when enthalpy $h$ or specific volume $v$ is given instead of internal energy $u$, or when pressure is given instead of temperature.

(*c*) This is similar to case (*b*), except pressure is given instead of temperature. Following the argument given above, we read the $u_f$ and $u_g$ values at the specified pressure. At 1 MPa, we have $u_f$ = 761.39 kJ/kg and $u_g$ = 2582.8 kJ/kg. The specified $u$ value is 2950 kJ/kg, which is greater than the $u_g$ value at 1 MPa. Therefore, we have superheated vapor, and the temperature at this state is determined from the superheated vapor table by interpolation to be

$$T = \mathbf{395.2°C} \qquad \text{(Table A–6)}$$

We would leave the quality column blank in this case since quality has no meaning for a superheated vapor.

(*d*) In this case the temperature and pressure are given, but again we cannot tell which table to use to determine the missing properties because we do not know whether we have saturated mixture, compressed liquid, or superheated vapor. To determine the region we are in, we go to the saturation table (Table A–5) and determine the saturation temperature value at the given pressure. At 500 kPa, we have $T_{sat}$ = 151.83°C. We then compare the given $T$ value to this $T_{sat}$ value, keeping in mind that

if $T < T_{\text{sat @ given } P}$ we have *compressed liquid*

if $T = T_{\text{sat @ given } P}$ we have *saturated mixture*

if $T > T_{\text{sat @ given } P}$ we have *superheated vapor*

In our case, the given $T$ value is 75°C, which is less than the $T_{sat}$ value at the specified pressure. Therefore, we have compressed liquid (Fig. 3–41), and normally we would determine the internal energy value from the compressed liquid table. But in this case the given pressure is much lower than the lowest pressure value in the compressed liquid table (which is 5 MPa), and therefore we are justified to treat the compressed liquid as saturated liquid at the given temperature (*not* pressure):

$$u \cong u_{f\,@\,75°C} = \mathbf{313.99\ kJ/kg} \qquad \text{(Table A–4)}$$

We would leave the quality column blank in this case since quality has no meaning in the compressed liquid region.

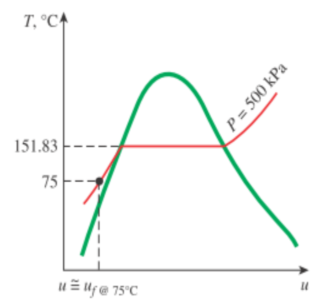



**FIGURE 3–41**

At a given $P$ and $T$, a pure substance will exist as a compressed liquid if $T < T_{sat\,@\,P}$.

(*e*) The quality is given to be $x$ = 0, and thus we have saturated liquid at the specified pressure of 850 kPa. Then the temperature must be the saturation temperature at the given pressure, and the internal energy must have the saturated liquid value:

$$T = T_{\text{sat @ 850 kPa}} = \mathbf{172.94°C}$$

$$u = u_{f\,@\,850\text{ kPa}} = \mathbf{731.00\ kJ/kg} \qquad \text{(Table A–5)}$$

Q.4

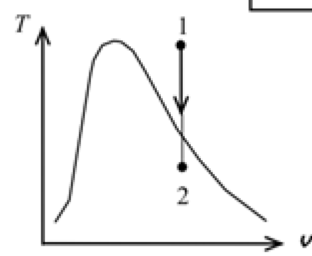
Superheated water vapor cools at constant volume until the temperature drops to 120°C. At the final state, the pressure, the quality, and the enthalpy are to be determined.

***Analysis*** This is a constant volume process ($v = V/m$ = constant), and the initial specific volume is determined to be

$$\left.\begin{array}{l} P_1 = 1.4 \text{ MPa} \\ T_1 = 250^\circ\text{C} \end{array}\right\} v_1 = 0.16356 \text{ m}^3/\text{kg} \qquad \text{(Table A-6)}$$


At 120°C, $v_f = 0.001060 \text{ m}^3/\text{kg}$ and $v_g = 0.89133 \text{ m}^3/\text{kg}$. Thus at the final state, the tank will contain saturated liquid-vapor mixture since $v_f < v < v_g$ , and the final pressure must be the saturation pressure at the final temperature,

$$P = P_{\text{sat@}120^\circ\text{C}} = \mathbf{198.67 \text{ kPa}}$$




(*b*) The quality at the final state is determined from

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{0.16356 - 0.001060}{0.89133 - 0.001060} = \mathbf{0.1825}$$

(*c*) The enthalpy at the final state is determined from

$$h = h_f + x h_{fg} = 503.81 + 0.1825 \times 2202.1 = \mathbf{905.7 \text{ kJ/kg}}$$

Q.5 **SOLUTION** The light bulb of a refrigerator malfunctions and remains on. The increases in the electricity consumption and cost are to be determined.

***Assumptions*** The life of the light bulb is more than 1 year.

***Analysis*** The light bulb consumes 40 W of power when it is on, and thus adds 40 W to the heat load of the refrigerator. Noting that the COP of the refrigerator is 1.3, the power consumed by the refrigerator to remove the heat generated by the light bulb is

$$\dot{W}_{\text{refrig}} = \frac{\dot{Q}_{\text{refrig}}}{\text{COP}_\text{R}} = \frac{40 \text{ W}}{1.3} = 30.8 \text{ W}$$

Therefore, the total additional power consumed by the refrigerator is

$$\dot{W}_{\text{total,additional}} = \dot{W}_{\text{light}} + \dot{W}_{\text{refrig}} = 40 + 30.8 = 70.8 \text{ W}$$

The total number of hours in a year is

$$\text{Annual hours} = (365 \text{ days/yr})(24 \text{ h/day}) = 8760 \text{ h/yr}$$

Assuming the refrigerator is opened 20 times a day for an average of 30 s, the light would normally be on for

$$\text{Normal operating hours} = (20 \text{ times/day})(30 \text{ s/time})(1 \text{ h}/3600 \text{ s})(365 \text{ days/yr})$$
$$= 61 \text{ h/yr}$$

Then the additional hours the light remains on as a result of the malfunction becomes

$$\text{Additional operating hours} = \text{Annual hours} - \text{Normal operating hours}$$
$$= 8760 - 61 = 8699 \text{ h/yr}$$

Therefore, the additional electric power consumption and its cost per year are

$$\text{Additional power consumption} = \dot{W}_{\text{total,additional}} \times (\text{Additional operating hours})$$
$$= (0.0708 \text{ kW})(8699 \text{ h/yr}) = \mathbf{616 \text{ kWh/yr}}$$

and

$$\text{Additional power cost} = (\text{Additional power consumption})(\text{Unit cost})$$
$$= (616 \text{ kWh/yr})(\$0.12/\text{kWh}) = \mathbf{\$73.9/yr}$$

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