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Georgia Institute of Technology

ME 3322A: Thermodynamics: Fall 2014
Homework Set # 3
Due Date: Sept 11, 2014

	Problem # in Textbook		Answer
	6^{th} Ed.	**7^{th} Ed.**	
1	3.12	3.12	b) 2.93 ft^3/lb_m; c) 0.06109 m^3/kg
2	3.15	3.15	14.9%, 3.533 lb/ft^3
3	3.22	3.21	149 kPa; 104.35 m^3
4	3.33	3.32	x_2=0.662 F
5	3.42	3.41	b) 849 kJ/kg; d) h=269.7 Btu/lb ; e) h=5299.15 kJ/kg
6	3.47	3.46	407.6 kJ/kg

PROBLEM 3.12

(a) Water. $v = 0.5\ m^3/kg$, $p = 3\ bar$. Find T in °C.

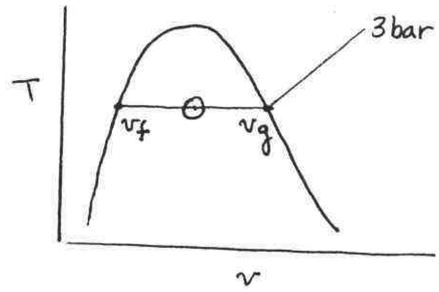


Table A-3, $v_f = 1.0732/10^3\ m^3/kg$, $v_g = 0.6058\ m^3/kg$.
Since $v_f < v < v_g$, the state is in the two-phase, liquid-vapor region — see T-v diagram.
Thus, $T = T_{sat}(3\ bar) = 133.6°C$ ⟵ T

(b) Ammonia. $p = 11\ lbf/in^2$, $T = -20°F$. Find v in ft^3/lb.

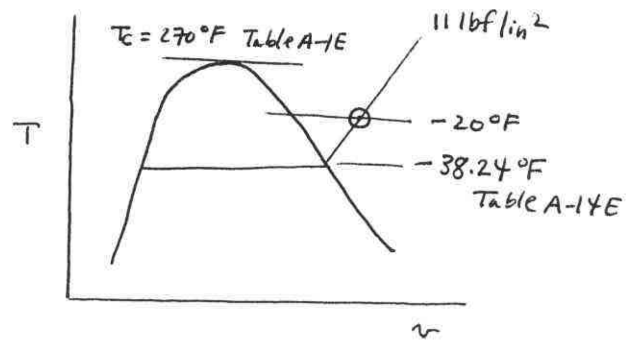


Table A-15E

	10 lbf/in²	12 lbf/in²
−20°F	$v = 27.241\ \frac{ft^3}{lb}$	$v = 22.621\ \frac{ft^3}{lb}$

⟹ at 11 lbf/in²

$v = 24.931\ \frac{ft^3}{lb}$ ⟵ v

(c) Propane. $p = 1\ MPa$, $T = 85°C$. Find v in m^3/kg.

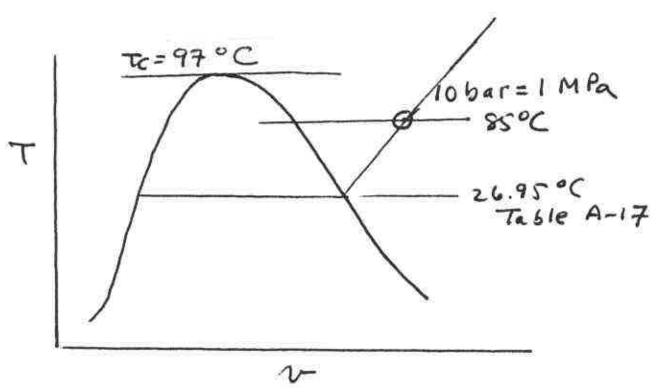


Table A-18 at 10 bar:

	10 bar
80°C	$v = 0.05992\ m^3/kg$
85°C	----
90°C	$v = 0.06226\ m^3/kg$

$\Rightarrow v = 0.06109\ \frac{m^3}{kg}$ ⟵ v

PROBLEM 3.15

(a) Water at 100°C, $m = 4\,kg$, $V = 1\,m^3$

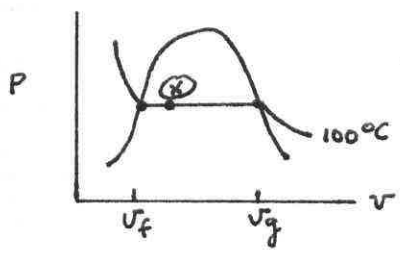
$$v = \frac{V}{m} = \frac{1\,m^3}{4\,kg} = 0.25\,m^3/kg$$

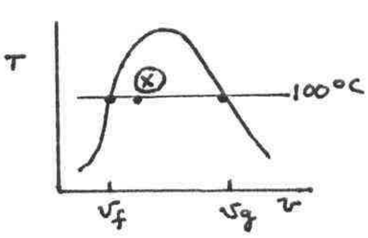
Table A-2 at 100°C: $v_f = 1.0435/10^3\ m^3/kg$, $v_g = 1.673\ m^3/kg$

Since $v_f < v < v_g$, the state is a two-phase, liquid-vapor state.

$$v = v_f + x(v_g - v_f) \Rightarrow x = \frac{v - v_f}{v_g - v_f} = \frac{0.25 - (1.0435/10^3)}{1.673 - (1.0435/10^3)} = 0.149$$

(14.9%)





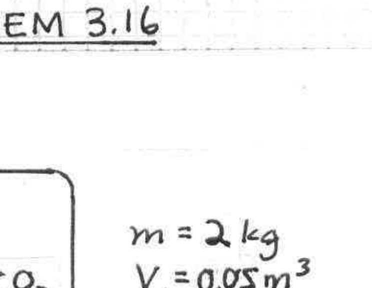
(b) Ammonia at $40\,lbf/in^2$, $u = 308.75$ Btu/lb

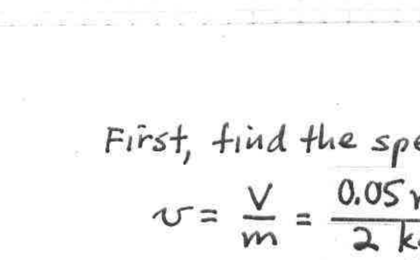
From Table A-14E at $40\,lbf/in^2$, $v_f = 0.0245\ ft^3/lb$, $v_g = 7.041\ ft^3/lb$
$u_f = 54.89$ Btu/lb, $u_g = 562.6$ Btu/lb

Since $u_f < u < u_g$, the state is a two-phase, liquid-vapor state.

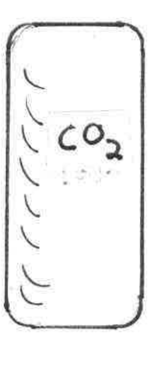
$$u = u_f + x(u_g - u_f) \Rightarrow x = \frac{u - u_f}{u_g - u_f} = \frac{308.75 - 54.89}{562.6 - 54.89} = 0.5$$

Then, $v = v_f + x(v_g - v_f) = 0.0245 + 0.5(7.041 - 0.0245) = 3.533\ \frac{ft^3}{lb}$





PROBLEM 3.16



$m = 2\,kg$
$V = 0.05\,m^3$
$v_f = 0.896 \times 10^{-3}\ \frac{m^3}{kg}$
$v_g = 3.824 \times 10^{-2}\ \frac{m^3}{kg}$

First, find the specific volume

$$v = \frac{V}{m} = \frac{0.05\,m^3}{2\,kg} = 0.025\,m^3/kg$$

Now, the quality is

$$x = \frac{v - v_f}{v_g - v_f} = \frac{0.025 - 0.896 \times 10^{-3}}{3.824 \times 10^{-2} - 0.896 \times 10^{-3}}$$

$$= 0.645\ (64.5\%)$$

PROBLEM 3.22

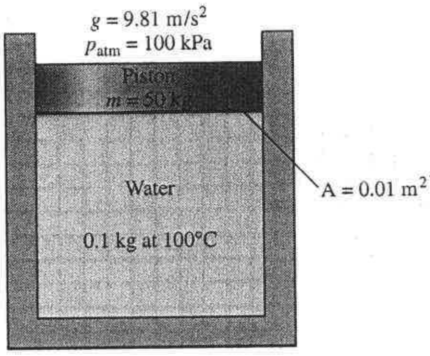
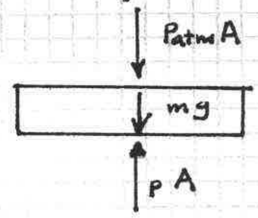


Fig. P3.22

Since the piston moves smoothly in the cylinder, the force of the pressure acting on the bottom of the piston balances the force of the atmosphere acting on the top of the piston and the piston weight:

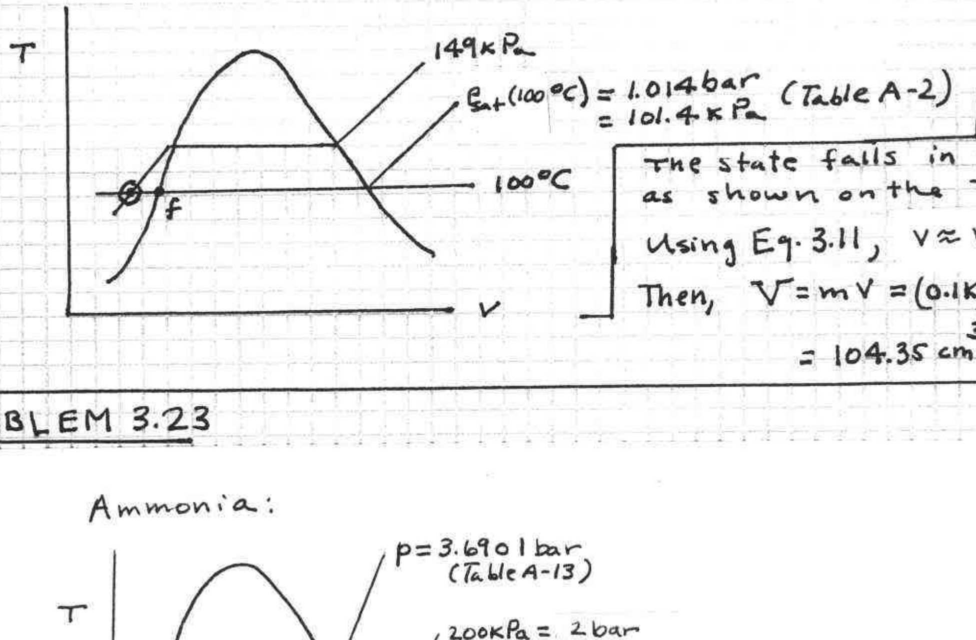


$$\Rightarrow \quad pA = p_{atm}A + mg \quad \Rightarrow \quad p = p_{atm} + mg/A$$

$$= 100\,kPa + (50\,kg)(9.81\,\tfrac{m}{s^2})\left(\frac{1}{0.01\,m^2}\right)\left|\frac{1\,N}{1\,kg\cdot m/s^2}\right|\left|\frac{1\,kPa}{10^3\,N/m^2}\right|$$

$$= 149\,kPa \longleftarrow$$

At $T = 100\,°C$ and $p = 149$ kPa, fix the state:



The state falls in the liquid region, as shown on the T-v sketch.

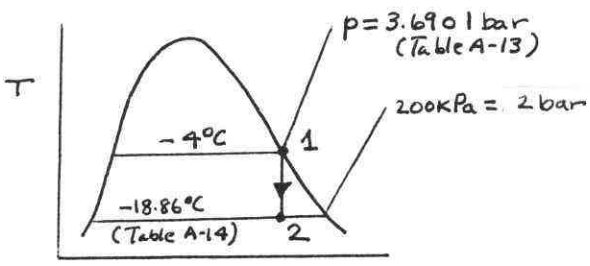
Using Eq. 3.11, $v \approx v_f(100°C) = 1.0435 \times 10^{-3}\ m^3/kg$

Then, $V = mv = (0.1\,kg)\left(\frac{1.0435}{10^3}\right)\frac{m^3}{kg}\left|\frac{10^2\,cm}{1\,m}\right|^3$

$$= 104.35\ cm^3 \longleftarrow$$

PROBLEM 3.23

Ammonia:



v

As shown by the T-v diagram, state 2 is in the two-phase liquid-vapor region at 2 bar. Table A-14 gives $T_2 = -18.86°C \longleftarrow T_2$

Then, with $v_1 = 0.334\ m^3/kg$ from Table A-13 and $v_2 = v_1$,

$$x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{0.334 - (1.5071/10^3)}{0.5946 - (1.5071/10^3)} = 0.561\ (56.1\%) \longleftarrow x_2$$

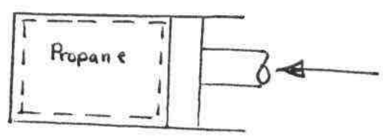
where v_f and v_g are from Table A-14 at 2 bar.

PROBLEM 3.33

KNOWN: Propane in a piston-cylinder assembly undergoes a constant-pressure process for which data are provided.

FIND: Determine specified data at the final state.

SCHEMATIC & GIVEN DATA:



$m = 7\,lb$
$p_1 = 200\,lbf/in^2$
$T_1 = 200\,°F$
$W = -88.84\,Btu$

ENGR. MODEL:

1. The given mass of propane is the closed system.
2. Volume change is the only work mode.
3. The process occurs at constant pressure.

ANALYSIS: Two properties are required to fix the final state. One of these is the pressure: $p_2 = 200\,lbf/in^2$. The other is the specific volume found from the given value for work:

Since volume change is the only work mode and pressure remains constant,

$$W = \int_1^2 p\,dV = mp(v_2 - v_1)$$

Solving for v_2

$$v_2 = \frac{W}{mp} + v_1$$

From Table A-18E, $v_1 = 0.7025\,ft^3/lb$. Thus

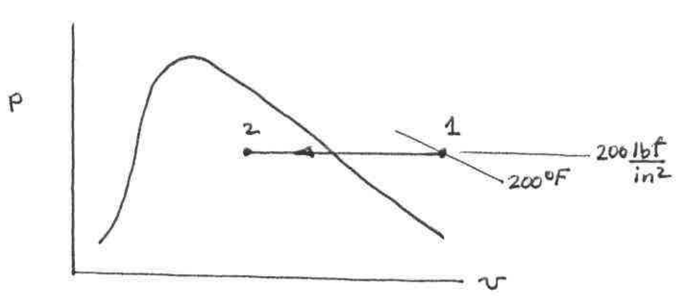
$$v_2 = \frac{(-88.84\,Btu)}{(7\,lb)(200\,\frac{lbf}{in^2})}\left|\frac{778\,ft\cdot lbf}{1\,Btu}\right|\left|\frac{1\,ft^2}{144\,in^2}\right| + 0.7025\,\frac{ft^3}{lb}$$

$$= -0.3428\,\frac{ft^3}{lb} + 0.7025\,\frac{ft^3}{lb} = 0.3597\,\frac{ft^3}{lb}$$

From Table A-17E at $200\,lbf/in^2$, we see $v_f < v_2 < v_g$. Thus state 2 is a two-phase liquid-vapor state. Calculating quality

$$x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{0.3597 - 0.03432}{0.5261 - 0.03432}$$

$$= 0.662 \quad (66.2\%)$$

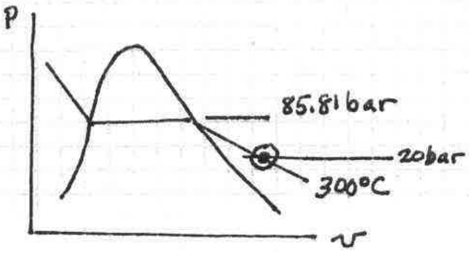


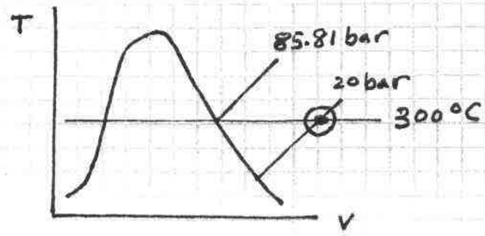
PROBLEM 3.42 Water is the substance.

(a) $p = 2\ \text{MPa}$, $T = 300°C$, Find u, in kJ/kg.

Table A-4:

$\underline{u = 2772.15\ \frac{kJ}{kg}}$

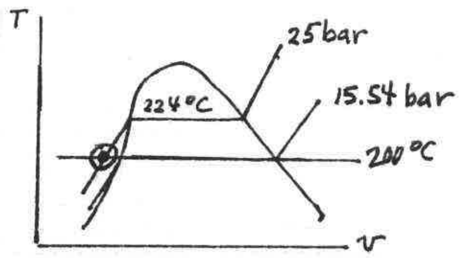


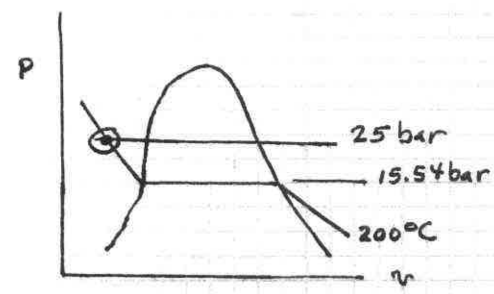


(b) $p = 2.5\ \text{MPa}$, $T = 200°C$, Find u, in kJ/kg.

Table A-5:

$\underline{u = 849.9\ \frac{kJ}{kg}}$





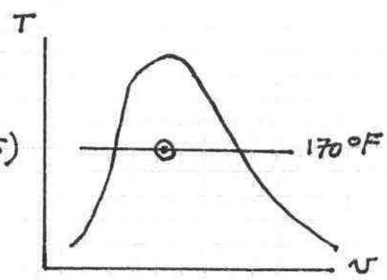
(c) $T = 170°F$, $x = 50\%$, find u, in Btu/lb.

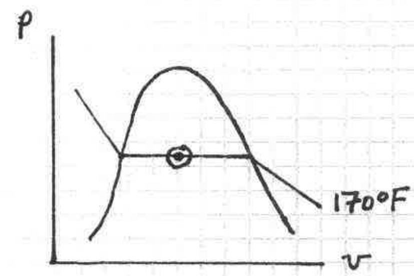
Table A-2E:

$u_x = u_f + x(u_g - u_f)$

$= 137.95 + 0.5(1065.4 - 137.95)$

$= \underline{601.68}\ \frac{Btu}{lb}$



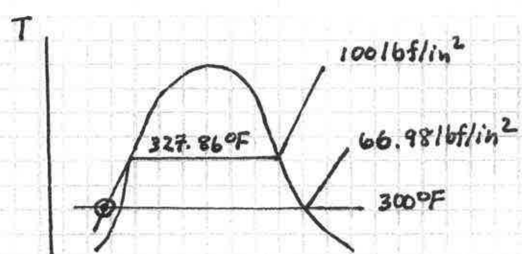


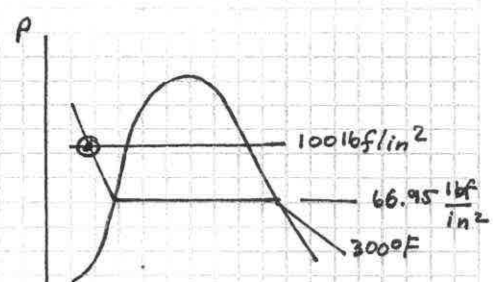
(d) $p = 100\ \text{lbf/in}^2$, $T = 300°F$, find h, in Btu/lb

Table A-2E:
With Eq. 3.14,

$h \sim h_f(T)$

$= \underline{269.7}$ Btu/lb



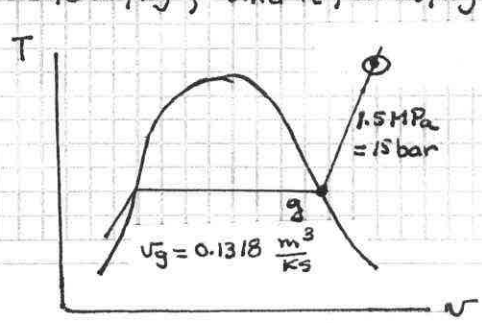


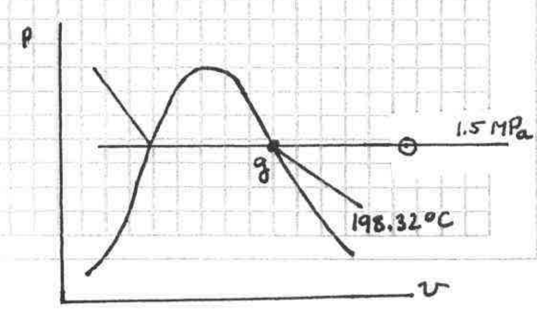
(e) $p = 1.5\ \text{MPa}$, $v = 0.2095\ \text{m}^3/\text{kg}$, find h, in kJ/kg.

Table A-4E:
$v_g = 0.1318\ \text{m}^3/\text{kg}$.

$\Rightarrow v > v_g$

$\underline{h = 3299.15}$ kJ/kg



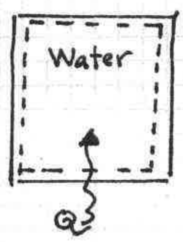


PROBLEM 3.47

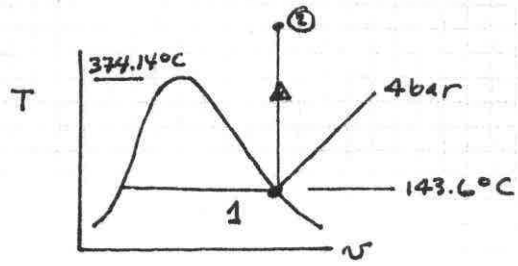
KNOWN: Water contained in a closed, rigid container is heated. State data is provided.

FIND: For the water, determine the heat transfer, in kJ/kg.

SCHEMATIC & GIVEN DATA:



Initial:
Sat. vapor at 4 bar
Final: T = 400°C



ENGINEERING MODEL:

1. The water in the container is the closed system.
2. The only energy transfer is by heat.
3. Kinetic and potential energy effects can be ignored.

ANALYSIS:

Since the total volume and total mass remain constant, the water undergoes a constant-specific volume process, as shown in the T-v diagram.

With 2 and 3, the energy balance reduces as follows:

$$\Delta U + \cancel{\Delta KE} + \cancel{\Delta PE} = Q - \cancel{W}$$

$$\Rightarrow \quad Q = \Delta U$$

$$= m[u_2 - u_1]$$

or

$$\frac{Q}{m} = u_2 - u_1$$

From Table A-3 at 4 bar, $u_1 = u_g = 2553.6$ kJ/kg. Also, $v_1 = v_g = 0.4625$ m³/kg.
Interpolating in Table A-4 with $T = 400°C$ and $v_2 = v_1 = 0.4625$ m³/kg,
$u_2 = 2961.2$ kJ/kg

$$\therefore Q = (2961.2 - 2553.6)\ \text{kJ/kg}$$

$$= +\ 407.6\ \text{kJ/kg}$$

Energy transfer by heat to the water.