4.38

A piston cylinder contains 1 kg of liquid water at 20°C and 300 kPa, as shown in Fig. P4.38. There is a linear spring mounted on the piston such that when the water is heated the pressure reaches 3 MPa with a volume of 0.1 m^3.

a) Find the final temperature

b) Plot the process in a P-v diagram.

c) Find the work in the process.

Solution:

Take CV as the water. This is a constant mass:

$$m_2 = m_1 = m \;;$$

State 1: Compressed liquid, take saturated liquid at same temperature.

B.1.1: $v_1 = v_f(20) = 0.001002 \text{ m}^3/\text{kg}$,

State 2: $v_2 = V_2/m = 0.1/1 = 0.1 \text{ m}^3/\text{kg}$ and $P = 3000$ kPa from B.1.3

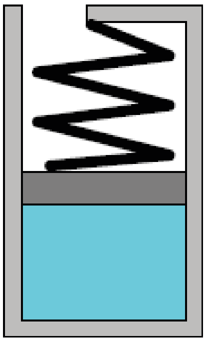
=> Superheated vapor close to T = 400°C

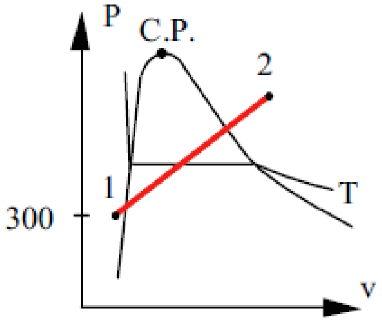
Interpolate: $T_2 = \mathbf{404^{o}C}$

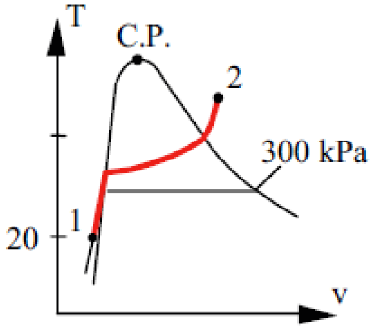
Work is done while piston moves at linearly varying pressure, so we get:

$$_1W_2 = \int P\, dV = \text{area} = P_{avg}\,(V_2 - V_1) = \frac{1}{2}\,(P_1 + P_2)(V_2 - V_1)$$

$$= 0.5\,(300 + 3000)(0.1 - 0.001) = \mathbf{163.35\ kJ}$$







4.72

10 kg of water in a piston cylinder arrangement exists as saturated liquid/vapor at 100 kPa, with a quality of 50%. It is now heated so the volume triples. The mass of the piston is such that a cylinder pressure of 200 kPa will float it, see Fig. P4.72.

a) Find the final temperature and volume of the water.

b) Find the work given out by the water.

Solution:

Take CV as the water $m_2 = m_1 = m;$

Process: $v = \text{constant}$ until $P = P_{\text{lift}}$ then P is constant.

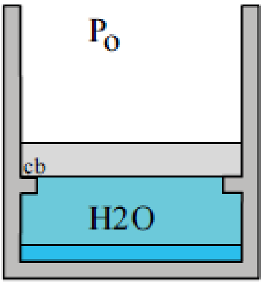
State 1: $v_1 = v_f + x\, v_{fg} = 0.001043 + 0.5 \times 1.69296 = 0.8475 \text{ m}^3/\text{kg}$

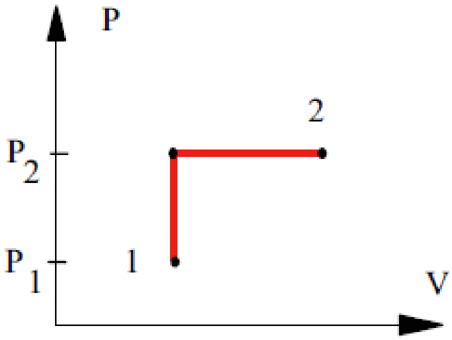
State 2: $v_2,\ P_2 \le P_{\text{lift}} \;\Rightarrow\; v_2 = 3 \times 0.8475 = 2.5425 \text{ m}^3/\text{kg};$

$\mathbf{T_2 = 829°C}\ ;\ \ V_2 = m\, v_2 = \mathbf{25.425\ m^3}$

$${}_1W_2 = \int P\, dV = P_{\text{lift}} \times (V_2 - V_1)$$

$$= 200 \text{ kPa} \times 10 \text{ kg} \times (2.5425 - 0.8475) \text{ m}^3/\text{kg} = \mathbf{3390\ kJ}$$





4.124

A cylinder fitted with a piston contains propane gas at 100 kPa, 300 K with a volume of 0.2 m^3. The gas is now slowly compressed according to the relation $PV^{1.1}$ = constant to a final temperature of 340 K. Justify the use of the ideal gas model. Find the final pressure and the work done during the process.

Solution:

The process equation and T determines state 2. Use ideal gas law to say

$$P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}} = 100 \left(\frac{340}{300}\right)^{\frac{1.1}{0.1}} = \mathbf{396\ kPa}$$

$$V_2 = V_1 \left(\frac{P_1}{P_2}\right)^{1/n} = 0.2 \left(\frac{100}{396}\right)^{1/1.1} = 0.0572\ m^3$$

For propane Table A.2: $T_c = 370$ K, $P_c = 4260$ kPa, Figure D.1 gives Z.

$T_{r1} = 0.81$, $P_{r1} = 0.023$ => $Z_1 = 0.98$

$T_{r2} = 0.92$, $P_{r2} = 0.093$ => $Z_2 = 0.95$

Ideal gas model **OK** for both states, minor corrections could be used. The work is integrated to give Eq.4.4

$$_1W_2 = \int P\, dV = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{(396 \times 0.0572) - (100 \times 0.2)}{1 - 1.1}\ \text{kPa m}^3$$

$$= \mathbf{-26.7\ kJ}$$