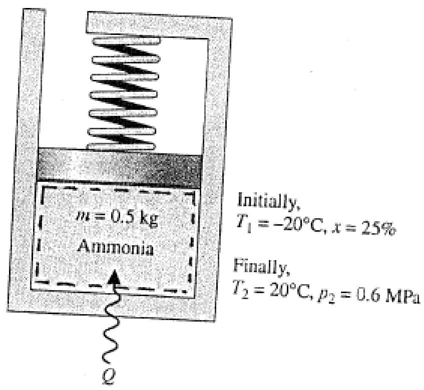
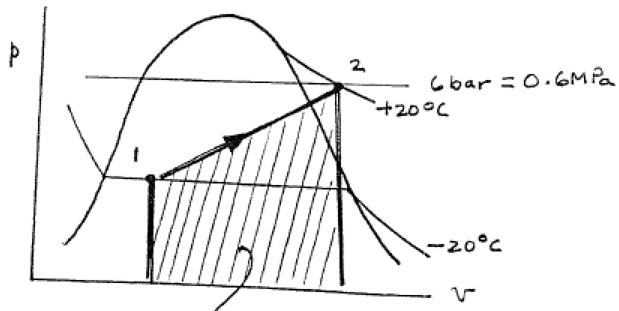
PROBLEM 3.84

KNOWN: Ammonia contained in a piston-cylinder assembly undergoes a process during which it is heated.

FIND: For the process, find Q and W.

SCHEMATIC & GIVEN DATA:





$W_{12} = m\left(\frac{P_1+P_2}{2}\right)(v_2 - v_1)$

ENGINEERING MODEL:

1. The ammonia is the system.
2. Volume change is the only work mode. As shown by the p-v diagram, pressure varies linearly with volume.
3. There are no significant kinetic and potential energy effects.

ANALYSIS: Since volume change is the only work mode, $W_{12} = \int_1^2 p\,dV$, or $W_{12} = m\int_{v_1}^{v_2} p\,dv$. This can be evaluated geometrically as, $W_{12} = m\,P_{ave}(v_2 - v_1)$.

Thus, ($P_1 = P_{sat}(T_1) = 1.9019$ bar)

$$W_{12} = m\left[\frac{P_1+P_2}{2}\right](v_2 - v_1) = 0.5\,kg\left[\frac{1.9019+6}{2}\right]bar\left|\frac{10^5 N/m^2}{1\ bar}\right|(0.22155 - 0.157)\frac{m^3}{kg}\left|\frac{1\,kJ}{10^3 N\cdot m}\right|$$
$$= 12.75\,kJ$$ ◄ W_{12}

Using x at the initial state, $v_1 = v_f + x(v_g - v_f) = \frac{1.5038}{10^3} + 0.25\left(0.6233 - \frac{1.5038}{10^3}\right) = 0.157\,\frac{m^3}{kg}$ (Data from Table A-13)

Then, from Table A-15, $v_2 = 0.22155\ m^3/kg$.

Writing an energy balance,

$$\Delta U + \Delta KE^{\,0} + \Delta PE^{\,0} = Q_{12} - W_{12} \Rightarrow Q_{12} = m(u_2 - u_1) + W_{12}$$

Using Table A-13 data, $u_1 = u_f + x(u_g - u_f) = 88.4 + 0.25(1299.23 - 88.40) = 391.11$ kJ/kg.

From Table A-15, $u_2 = 1347.62$ kJ/kg. Thus,

$$Q_{12} = 0.5\,kg\,(1347.62 - 391.11)\frac{kJ}{kg} + 12.75\,kJ$$
$$= 491.01\,kJ$$ ◄ Q_{12}