PROBLEM 3.37

KNOWN: Refrigerant 134 contained in a piston-cylinder assembly is slowly heated. Data is provided at the initial and final states.

FIND: Determine the work, in kJ/kg.

SCHEMATIC & GIVEN DATA:

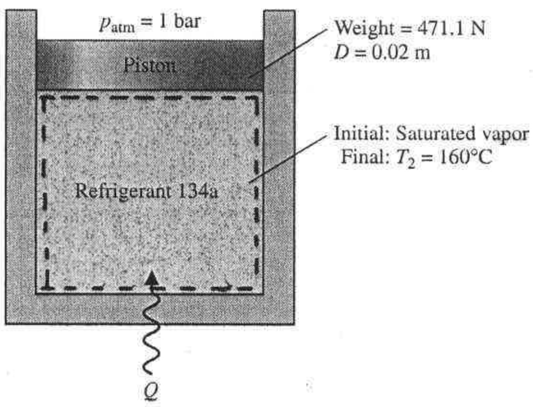
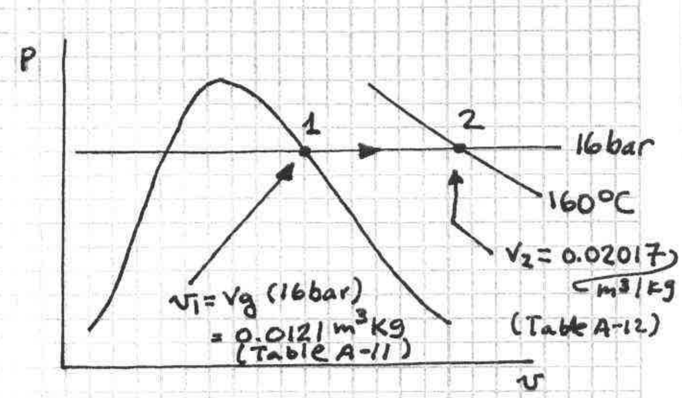


Fig. P3.37



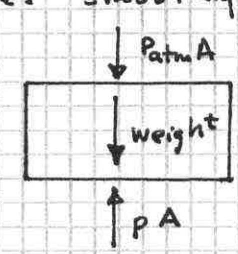
ENGINEERING MODEL:

1. The Refrigerant 134a is the closed system.
2. During the process the refrigerant is slowly heated and the piston moves smoothly in the cylinder.
3. Volume change is the only work mode.

ANALYSIS

With assumptions 2 and 3 the work can be evaluated from Eq. 2.17, expressed as $W/m = \int_1^2 p\,dv$. To apply this requires that states 1 and 2 be fixed and pressure-volume relation be determined.

Using a force balance for the piston, we conclude the pressure of the refrigerant remains constant during the process: Since the piston moves smoothly in the cylinder, the only forces are those shown:



$$\Sigma F = 0 \Rightarrow pA = p_{atm}A + \text{Weight}$$

$$\therefore\ p = p_{atm} + \frac{\text{Weight}}{A}$$

$$= 1\text{ bar} + \left(\frac{471.1\text{ N}}{3.14\times10^{-4}\text{ m}^2}\right)\left|\frac{1\text{ bar}}{10^5\text{ N/m}^2}\right|$$

$$= 16\text{ bar}.$$

$$A = \frac{\pi D^2}{4} = \frac{\pi(0.02\text{ m})^2}{4} = 3.14\times10^{-4}\text{ m}^2$$

The process is sketched on the accompanying p-v diagram. Since pressure is constant, we get

$$\frac{W}{m} = p(v_2 - v_1)$$

$$= (16\text{ bar})\left|\frac{10^5\text{ N/m}^2}{1\text{ bar}}\right|(0.02017 - 0.0121)\frac{\text{m}^3}{\text{kg}}\left|\frac{1\text{ kJ}}{10^3\text{ N}\cdot\text{m}}\right| = 12.9\ \frac{\text{kJ}}{\text{kg}} \longleftarrow$$