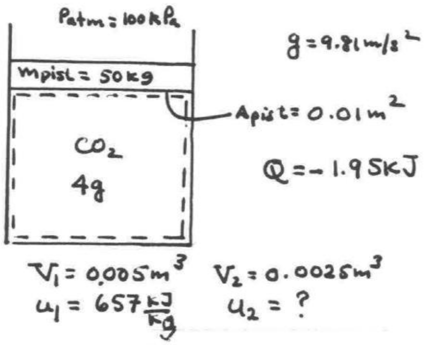
PROBLEM 2.72

KNOWN: Data are provided for CO_2 gas contained in a piston-cylinder assembly.

FIND: For the CO_2 determine the pressure and the final specific internal energy.

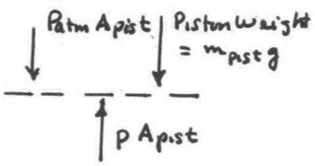
SCHEMATIC & GIVEN DATA:



ENGR. MODEL:

1. The CO_2 is the closed system.
2. The moving boundary is the only work mode.
3. As cooling occurs slowly there is no acceleration of the piston. The value of g remains constant.
4. Friction between the piston and cylinder can be ignored.
5. For the CO_2, $\Delta KE = 0$ and ΔPE can be ignored.

ANALYSIS: (a) Since there is no friction and the piston is not accelerated, the force exerted by the CO_2 in the cylinder on the bottom of the piston is equal to the weight of the piston plus the force exerted by the atmosphere on the top of the piston:



$$\Rightarrow \quad p\,A_{pist} = P_{atm} A_{pist} + m_{pist}\, g$$

$$p = P_{atm} + \frac{m_{pist}\, g}{A_{pist}}$$

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

$$= 149.1\,\text{kPa}\left|\frac{1\,\text{bar}}{10^2\,\text{kPa}}\right| = 1.491\,\text{bar} \longleftarrow p$$

(b) The work can be evaluated using Eq. 2.17. Since the pressure remains constant

$$W = \int_1^2 p\,dV = p[V_2 - V_1] = 1.491\,\text{bar}\left|\frac{10^5\,\text{N/m}^2}{1\,\text{bar}}\right|\left[0.0025 - 0.005\right]\text{m}^3\left|\frac{1\,\text{kJ}}{10^3\,\text{N}\cdot\text{m}}\right|$$

$$= -0.373\,\text{kJ}$$

An energy balance for the CO_2 reads,

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

$$\Delta U = -1.95\,\text{kJ} - (-0.373\,\text{kJ}) = -1.577\,\text{kJ}$$

Then, with $\Delta U = m(u_2 - u_1)$,

$$u_2 = \frac{\Delta U}{m} + u_1$$

$$= \frac{-1.577\,\text{kJ}}{(4/1000)\,\text{kg}} + 657\,\text{kJ/kg}$$

$$= 262.8\,\frac{\text{kJ}}{\text{kg}} \longleftarrow u_2$$