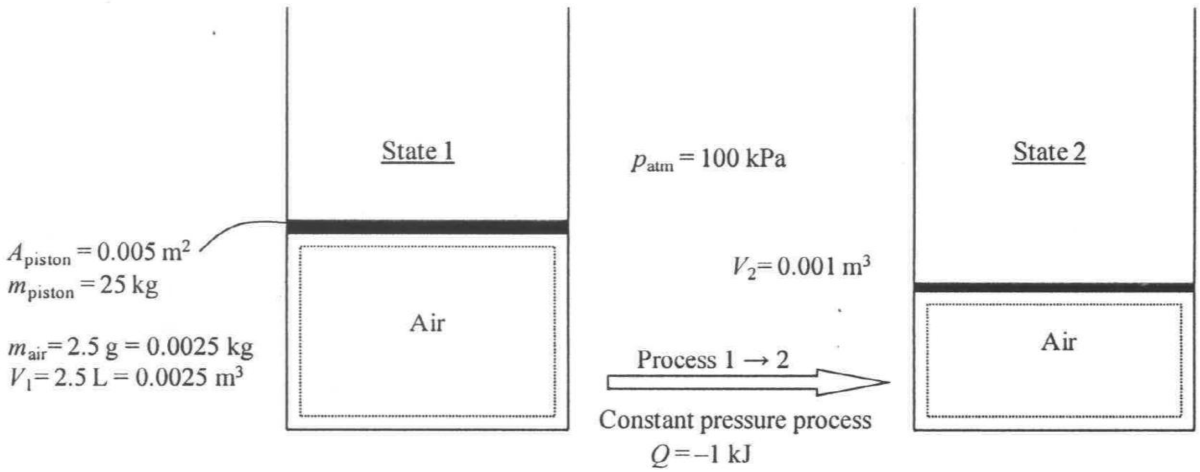
PROBLEM 2.71

Known: Vertical piston-cylinder assembly contains air of known mass. The initial and final volumes of air, and the heat transfer are specified.

Find: Determine the change in specific internal energy of the air, in kJ/kg.

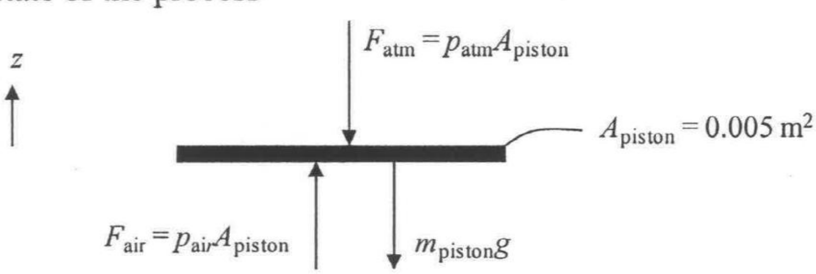
Schematic and Given Data:



Engineering Model:
(1) The air within the piston-cylinder assembly is the closed system.
(2) Kinetic and potential energy effects are negligible for the air.
(3) There is no friction between the piston and the cylinder wall.
(4) The process occurs slowly with no acceleration of the piston.
(5) The acceleration of gravity is constant.

Analysis:

Using a FBD with $\Sigma F_z = 0$, determine p_{air} which is the pressure exerted by the air at each state of the process



PROBLEM 2.71 (Continued)

$$p_{\text{air}} A_{\text{piston}} = p_{\text{atm}} A_{\text{piston}} + m_{\text{piston}} g$$

$$p_{\text{air}} = p_{\text{atm}} + \frac{m_{\text{piston}} g}{A_{\text{piston}}} = 100\text{kPa} + \frac{(25\text{kg})\left(9.8\frac{\text{m}}{\text{s}^2}\right)}{0.005\text{m}^2}\left|\frac{1\text{N}}{\frac{\text{kg}\cdot\text{m}}{\text{s}^2}}\right|\left|\frac{1\text{kPa}}{10^3\frac{\text{N}}{\text{m}^2}}\right|$$

$$p_{\text{air}} = (100+49)\text{kPa} = 149\,\text{kPa}$$

Thus the pressure of the air remains constant.

To evaluate W, in kJ, begin with Eq. 2.17, noting that the pressure is constant, and integrate

$$W = \int_{V_1}^{V_2} p\,dV = p\int_{V_1}^{V_2} dV = p(V_2 - V_1) = 149\text{kPa}(0.001 - 0.0025)\text{m}^3\left|\frac{1000\frac{\text{N}}{\text{m}^2}}{1\text{kPa}}\right|\left|\frac{1\text{kJ}}{1000\text{N}\cdot\text{m}}\right| = -0.2235\,\text{kJ}$$

Determine the change in specific internal energy, in kJ/kg, using the closed system energy balance

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

$$\Delta U = Q - W = -1\,\text{kJ} - (-0.2235\,\text{kJ}) = -0.7765\,\text{kJ}$$

$$\Delta U = m(u_2 - u_1) \quad \text{or} \quad (u_2 - u_1) = \frac{\Delta U}{m} = \frac{-0.7765\,\text{kJ}}{0.0025\,\text{kg}} = -310.6\frac{\text{kJ}}{\text{kg}} \longleftarrow$$