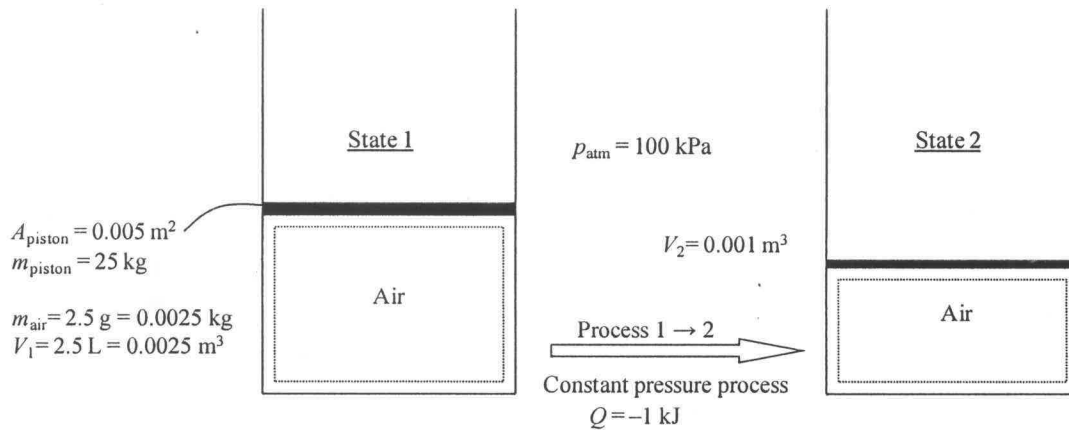


## PROBLEM 2.68

**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:**

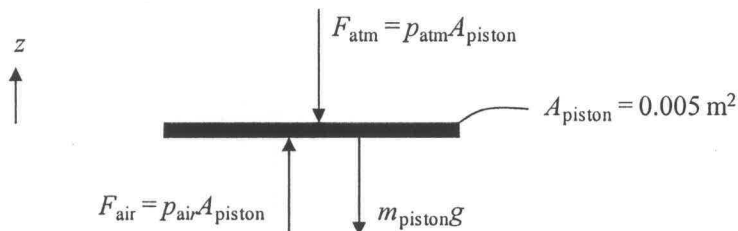


**Engineering Model:**

- (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  $\sum F_z = 0$ , determine  $p_{\text{air}}$  which is the pressure exerted by the air at each state of the process



## PROBLEM 2.68 (Continued)

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

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

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

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

$$\Delta KE + \Delta PE + \Delta U = Q - W$$

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

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

