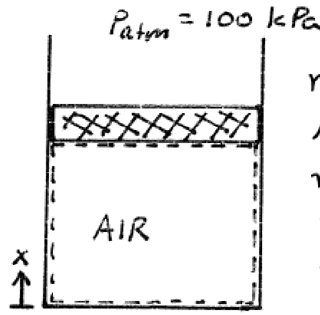
PROBLEM 2.68

KNOWN: A known quantity of air undergoes a process in a vertical piston-cylinder assembly. The initial and final volumes are given, and the change in specific internal energy is specified.

FIND: Determine the heat transfer.

SCHEMATIC & GIVEN DATA:



m_{pist} = 50 kg

A_{pist} = 0.01 m^2

m_{air} = 5 g = 0.005 kg

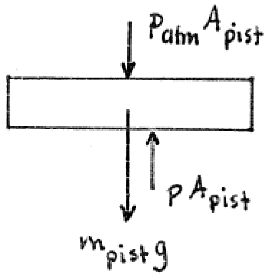
V_1 = 5 L = 0.005 m^3

V_2 = 0.002 m^3

Δu = −260 kJ/kg

ENGR. MODEL: (1) The air is a 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, g = 9.81 m/s².

ANALYSIS: For the piston, $\Sigma F_x = 0$. Thus, if p is the pressure exerted by the air at each state of the process, we get



$$pA_{pist} = p_{atm}A_{pist} + m_{pist}g$$

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

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

$$= 149.05\text{ kPa}$$

To find the work for the process, use Eq. 2.17. Noting that the pressure is constant

$$W = \int_{V_1}^{V_2} p\,dV = p(V_2 - V_1)$$

$$= (149.05\text{ kPa})(0.002 - 0.005)\text{m}^3 \left|\frac{10^3\text{ N/m}^2}{1\text{ kPa}}\right|\left|\frac{1\text{ kJ}}{10^3\text{ N}\cdot\text{m}}\right|$$

$$= -0.447\text{ kJ}$$

Now, the energy balance reduces to $\Delta KE^{\,0} + \Delta PE^{\,0} + \Delta U = Q - W$. Thus, with $\Delta U = m_{air}\Delta u$

$$Q = m_{air}\Delta u + W = (0.005\text{ kg})\left(-260\frac{\text{kJ}}{\text{kg}}\right) + (-0.447\text{ kJ})$$

$$Q = -1.747\text{ kJ}$$ ← Q