PROBLEM 2.59

KNOWN: A gas contained in a piston-cylinder assembly undergoes a constant-pressure expansion while being slowly heated. State data are provided.

FIND: For the gas, evaluate work and heat transfer. For the piston, evaluate work and change in potential energy.

SCHEMATIC & GIVEN DATA:

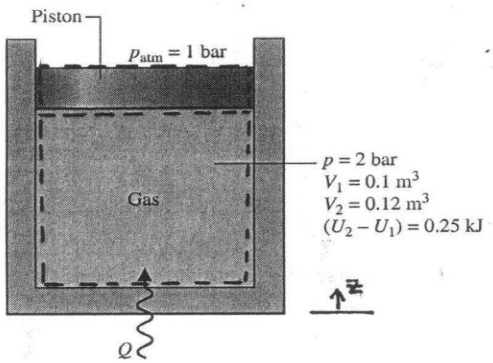


Fig. P2.56

ENGINEERING MODEL:

1. As shown in the schematic, two closed systems are considered: the gas and the piston.
2. The gas undergoes a constant-pressure process.
3. For the gas there is no change in potential energy (see Example 2.3) and no overall change in kinetic energy.
4. For the piston, there is no heat transfer. Also, there is no change in internal energy, no overall change in kinetic energy, and no friction.

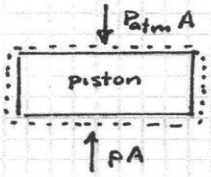
ANALYSIS: (a) Taking the gas as the system, the work is obtained from Eq. 2.17:

$$W = \int_1^2 p\,dV = p[V_2 - V_1] = \left(2\times10^5 \frac{N}{m^2}\right)(0.12 - 0.1)\,m^3 \left|\frac{1\,kJ}{10^3\,N\cdot m}\right| = 4\,kJ$$

Reducing an energy balance, $\Delta U + \Delta KE + \Delta PE = Q - W \Rightarrow Q = W + \Delta U$

$$\Rightarrow Q = 4\,kJ + 0.25\,kJ = 4.25\,kJ$$

(b) Taking the piston as the system, an energy transfer by work occurs on the bottom surface from the gas. At the top surface the piston does work on the atmosphere:



$$W_{piston} = \int F\,dz = (p_{atm}A - pA)\Delta z = (p_{atm} - p)(A\Delta z)$$

$$= (p_{atm} - p)\Delta V \quad (\Delta V \text{ of gas})$$

$$= (1 - 2)\left(10^5 \frac{N}{m^2}\right)(0.12 - 0.1)\,m^3 \left|\frac{1\,kJ}{10^3\,N\cdot m}\right|$$

$$= -2\,kJ$$

An energy balance for the piston reduces as follows:

$$[\Delta U + \Delta KE + \Delta PE]_{piston} = Q_{piston} - W_{piston}$$

$$\Rightarrow \Delta PE]_{piston} = -W_{piston}$$

$$= +2\,kJ \quad (1)$$

1. Overall energy "balance sheet" in terms of magnitudes:

Input: $Q = 4.25\,kJ$

Disposition of the energy input:

⊙ Stored as ΔU in the gas:	0.25 kJ
⊙ Stored as ΔPE in the piston:	2.00 kJ
⊙ Transfer by work to the atmosphere	2.00 kJ
	4.25 kJ