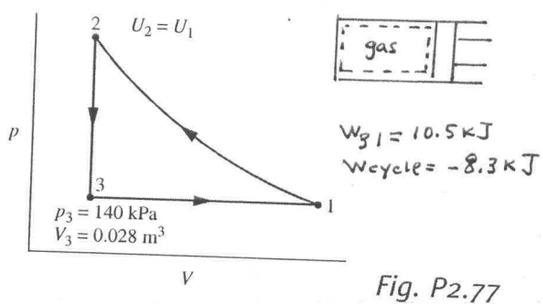
PROBLEM 2.77

KNOWN: A gas within a piston-cylinder assembly undergoes a thermodynamic cycle consisting of three processes in series.

FIND: Determine V_1, W_{12}, and Q_{12}. Determine if the cycle can be power cycle or a refrigeration cycle.

SCHEMATIC & GIVEN DATA:



$W_{31} = 10.5$ kJ

$W_{cycle} = -8.3$ kJ

Fig. P2.77

ENGR. MODEL:

1. The gas is the closed system.
2. Volume change is the only work mode.
3. For each process, $\Delta KE = \Delta PE = 0$.

ANALYSIS:

(a) To find V_1, note that

$$W_{31} = \int_3^1 p\,dV = p\,[V_1 - V_3] \Rightarrow V_1 = V_3 + \frac{W_{31}}{p}$$

(p = 140 kPa)

or

$$V_1 = 0.028\,m^3 + \frac{10.5\,kJ}{140\,kPa}\left|\frac{10^3\,N\cdot m}{1\,kJ}\right|\left|\frac{1\,kPa}{10^3\,N/m^2}\right| = 0.103\,m^3 \quad \leftarrow V_1$$

(b) To find W_{12}, write $W_{cycle} = W_{12} + W_{23} + W_{31}$. Since the only work mode is volume change, the work is given by Eq. 2.17. Since the piston does not move in process 2-3 (volume is constant), $W_{23} = 0$. Thus

$$W_{12} = W_{cycle} - \cancel{W_{23}}^{\,0} - W_{31}$$

$$= -8.3\,kJ - 10.5\,kJ = -18.8\,kJ \quad \leftarrow W_{12}$$

A power cycle is one for which $W_{cycle} > 0$. Here, we have $W_{cycle} = -8.3$ kJ. So, the cycle cannot be a power cycle, but it can be a refrigeration (or heat pump) cycle. ← cycle type

To find Q_{12}, write an energy balance: $\Delta U + \cancel{\Delta KE} + \cancel{\Delta PE} = Q_{12} - W_{12}$

$$\Rightarrow Q_{12} = \underbrace{\cancel{\Delta U}^{\,0}}_{U_2 = U_1} + W_{12}$$

$$\Rightarrow Q_{12} = -18.8\,kJ \quad \leftarrow Q_{12}$$