**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 a power cycle or a refrigeration cycle.

**Schematic & Given Data:**

![Diagram](image)

- $W_{12} = 16.5 \text{ kJ}$
- $W_{cycle} = -8.3 \text{ kJ}$

**Energy 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 $V_i$, note that

$$W_{12} = \int_{V_i}^{V_f} p \, dV = -P \left[ V_f - V_i \right] \Rightarrow V_i = V_f + \frac{W_{12}}{-P}$$

or

$$V_i = 0.028 \text{ m}^3 + \frac{16.5 \text{ kJ}}{140 \text{ kPa}} \left| \frac{\text{kJ}}{10^3 \text{ Nm}^2} \right| = 0.103 \text{ m}^3 \quad \Rightarrow \quad V_i$$

(b) To find $W_{12}$, write $W_{cycle} = W_{12} + W_{23}$. Since the only work in the cycle occurs due to 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

$$W_{12} = W_{cycle} - W_{23} - W_{12}$$

$$= -8.3 \text{ kJ} - 16.5 \text{ kJ} = -24.8 \text{ kJ} \quad \Rightarrow \quad W_{12}$$

A power cycle is one for which $W_{cycle} > 0$. Here, we have $W_{cycle} = -24.8 \text{ kJ}$. Thus, the cycle cannot be a power cycle, but it can be a refrigeration (compression) cycle.

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

$$\Rightarrow \quad Q_{12} = \Delta U + W_{12}$$

$$\frac{V_2}{V_1} \frac{U_2}{U_1}$$

$$\Rightarrow \quad Q_{12} = -18.5 \text{ kJ}$$