

5-25 A piston-cylinder device contains air gas at a specified state. The air undergoes a cycle with three processes. The boundary work for each process and the net work of the cycle are to be determined.

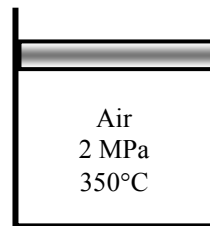
Properties The properties of air are $R = 0.287 \text{ kJ/kg}\cdot\text{K}$, $k = 1.4$ (Table A-2a).

Analysis For the isothermal expansion process:

$$V_1 = \frac{mRT}{P_1} = \frac{(0.15 \text{ kg})(0.287 \text{ kJ/kg}\cdot\text{K})(350 + 273 \text{ K})}{(2000 \text{ kPa})} = 0.01341 \text{ m}^3$$

$$V_2 = \frac{mRT}{P_2} = \frac{(0.15 \text{ kg})(0.287 \text{ kJ/kg}\cdot\text{K})(350 + 273 \text{ K})}{(500 \text{ kPa})} = 0.05364 \text{ m}^3$$

$$W_{b,1-2} = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right) = (2000 \text{ kPa})(0.01341 \text{ m}^3) \ln\left(\frac{0.05364 \text{ m}^3}{0.01341 \text{ m}^3}\right) = \mathbf{37.18 \text{ kJ}}$$



For the polytropic compression process:

$$P_2 V_2^n = P_3 V_3^n \longrightarrow (500 \text{ kPa})(0.05364 \text{ m}^3)^{1.2} = (2000 \text{ kPa}) V_3^{1.2} \longrightarrow V_3 = 0.01690 \text{ m}^3$$

$$W_{b,2-3} = \frac{P_3 V_3 - P_2 V_2}{1 - n} = \frac{(2000 \text{ kPa})(0.01690 \text{ m}^3) - (500 \text{ kPa})(0.05364 \text{ m}^3)}{1 - 1.2} = \mathbf{-34.86 \text{ kJ}}$$

For the constant pressure compression process:

$$W_{b,3-1} = P_3 (V_1 - V_3) = (2000 \text{ kPa})(0.01341 - 0.01690) \text{ m}^3 = \mathbf{-6.97 \text{ kJ}}$$

The net work for the cycle is the sum of the works for each process

$$W_{\text{net}} = W_{b,1-2} + W_{b,2-3} + W_{b,3-1} = 37.18 + (-34.86) + (-6.97) = \mathbf{-4.65 \text{ kJ}}$$