4-23 A piston-cylinder device contains nitrogen gas at a specified state. The boundary work is to be determined for the isothermal expansion of nitrogen.

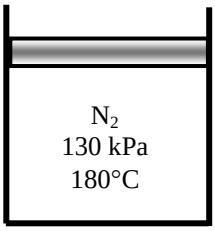
Properties The properties of nitrogen are R = 0.2968 kJ/kg.K , k = 1.4 (Table A-2a).

Analysis We first determine initial and final volumes from ideal gas relation, and find the boundary work using the relation for isothermal expansion of an ideal gas

$$V_1 = \frac{mRT}{P_1} = \frac{(0.25\,\text{kg})(0.2968\,\text{kJ/kg.K})(180+273\,\text{K})}{(130\,\text{kPa})} = 0.2586\,\text{m}^3$$

$$V_2 = \frac{mRT}{P_2} = \frac{(0.25\,\text{kg})(0.2968\,\text{kJ/kg.K})(180+273\,\text{K})}{80\,\text{kPa}} = 0.4202\,\text{m}^3$$

$$W_b = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right) = (130\,\text{kPa})(0.2586\,\text{m}^3)\ln\left(\frac{0.4202\,\text{m}^3}{0.2586\,\text{m}^3}\right) = \mathbf{16.3\,kJ}$$



4-24 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.

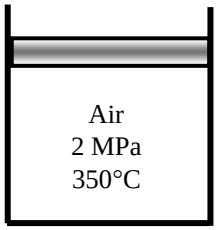
Properties The properties of air are R = 0.287 kJ/kg.K , k = 1.4 (Table A-2a).

Analysis For the isothermal expansion process:

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

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

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



For the polytropic compression process:

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

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

For the constant pressure compression process:

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

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

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