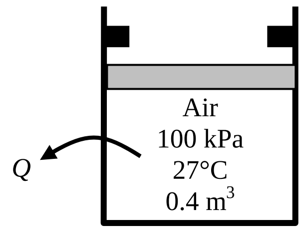
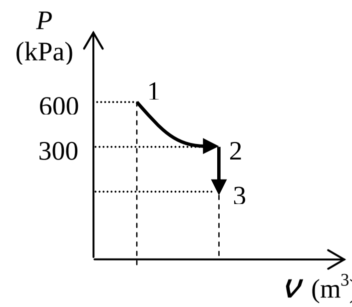
4-82 Air at a specified state contained in a piston-cylinder device undergoes an isothermal and constant volume process until a final temperature. The process is to be sketched on the *P*-*V* diagram and the amount of heat transfer is to be determined.

Assumptions **1** Air is an ideal gas since it is at a high temperature relative to its critical temperature of 304.2 K. **2** The kinetic and potential energy changes are negligible, $\Delta \text{ke} \cong \Delta \text{pe} \cong 0$.

Properties The properties of air are R = 0.287 kJ/kg·K and c_v = 0.718 kJ/kg·K (Table A-2*a*).

Analysis (a) The processes 1-2 (isothermal) and 2-3 (constant-volume) are sketched on the P-*V* diagram as shown.





(b) We take air as the system. This is a *closed system* since no mass crosses the boundaries of the system. The energy balance for this system fort he process 1-3 can be expressed as

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$-W_{b,\text{out},1-2} + Q_{\text{in}} = \Delta U = mc_v(T_3 - T_1)$$

The mass of the air is

$$m = \frac{P_1 V_1}{RT_1} = \frac{(600\ \text{kPa})(0.8\ \text{m}^3)}{(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(1200\ \text{K})} = 1.394\ \text{kg}$$

The work during process 1-2 is determined from boundary work relation for an isothermal process to be

$$W_{b,out,1-2} = mRT_1 \ln\frac{V_2}{V_1} = mRT_1 \ln\frac{P_1}{P_2}$$

$$= (1.394\ \text{kg})(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(1200\ \text{K})\ln\frac{600\ \text{kPa}}{300\ \text{kPa}}$$

$$= 332.8\ \text{kJ}$$

since $\dfrac{V_2}{V_1} = \dfrac{P_1}{P_2}$ for an isothermal process.

Substituting these values into energy balance equation,

$$Q_{\text{in}} = W_{b,\text{out},1\text{-}2} + mc_v(T_3 - T_1)$$

$$= 332.8\ \text{kJ} + (1.394\ \text{kg})(0.718\ \text{kJ/kg}\cdot\text{K})(300 - 1200)\text{K}$$

$$= \mathbf{-568\ kJ}$$

Thus,

$$Q_{\text{out}} = \mathbf{568\ kJ}$$