Homework-4 Solutions

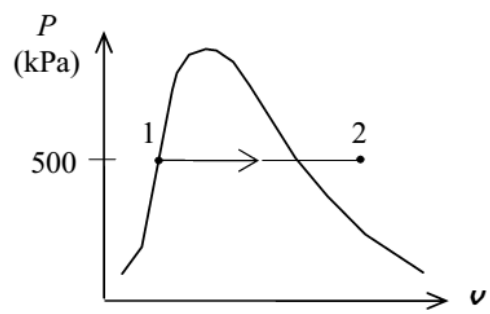
Q 4-11

Assumptions The process is quasi-equilibrium.

Properties Noting that the pressure remains constant during this process, the specific volumes at the initial and the final states are (Table A-11 through A-13)

$$\left.\begin{array}{l} P_1 = 500 \text{ kPa} \\ \text{Sat. liquid} \end{array}\right\} v_1 = v_{f\,@\,500\text{ kPa}} = 0.0008059 \text{ m}^3/\text{kg}$$

$$\left.\begin{array}{l} P_2 = 500 \text{ kPa} \\ T_2 = 70°\text{C} \end{array}\right\} v_2 = 0.052427 \text{ m}^3/\text{kg}$$



Analysis The boundary work is determined from its definition to be

$$m = \frac{V_1}{v_1} = \frac{0.05 \text{ m}^3}{0.0008059 \text{ m}^3/\text{kg}} = 62.04 \text{ kg}$$

and

$$W_{b,\text{out}} = \int_1^2 P\,dV = P(V_2 - V_1) = mP(v_2 - v_1)$$

$$= (62.04 \text{ kg})(500 \text{ kPa})(0.052427 - 0.0008059)\text{m}^3/\text{kg}\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)$$

$$= \mathbf{1600\ kJ}$$

Q 4-21

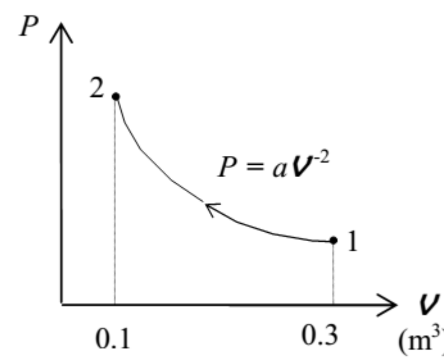
Assumptions The process is quasi-equilibrium.

Analysis The boundary work done during this process is determined from

$$W_{b,\text{out}} = \int_1^2 P\,dV = \int_1^2 \left(\frac{a}{V^2}\right) dV = -a\left(\frac{1}{V_2} - \frac{1}{V_1}\right)$$

$$= -(8 \text{ kPa}\cdot\text{m}^6)\left(\frac{1}{0.1 \text{ m}^3} - \frac{1}{0.3 \text{ m}^3}\right)\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)$$

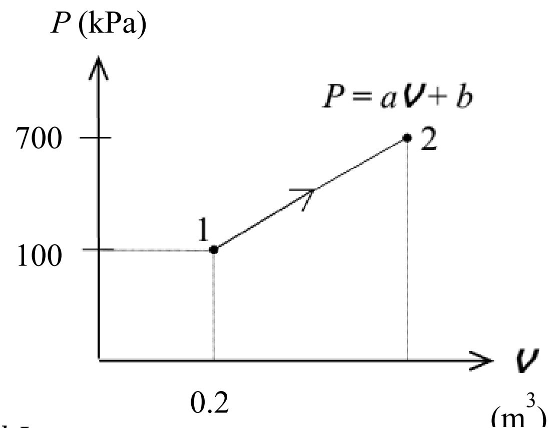
$$= \mathbf{-53.3\ \ kJ}$$



Discussion The negative sign indicates that work is done on the system (work input).

Q 4-22

Analysis (*a*) The pressure of the gas changes linearly with volume, and thus the process curve on a P-V diagram will be a straight line. The boundary work during this process is simply the area under the process curve, which is a trapezoidal. Thus,



At state 1: $P_1=aV_1+b$

100 kPa = (1220 kPa/m^3) (0.2 m^3) +b

b = -144 kPa

At state 2: $P_2=aV_2+b$

700 kPa = (1220 kPa/m^3) V_2 + (-144 kPa)

V_2= 0.692 m^3

W_{out} = Area = $\frac{(P_1+P_2)}{2}(V_2-V_1) = \left(\frac{100+700}{2}\right)(0.692-0.2)\,kJ$

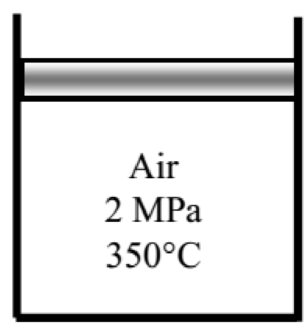
W_{out} = **196.8 kJ**

Discussion The positive sign indicates that work is done by the system (work output).

Q 4-24

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

Analysis For the isothermal expansion process:



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

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

$$W_{b,1-2} = P_1V_1\ln\left(\frac{V_2}{V_1}\right) = (2000\text{ kPa})(0.01341\text{ m}^3)\ln\left(\frac{0.05364\text{ m}^3}{0.01341\text{ m}^3}\right) = \mathbf{37.18\text{ kJ}}$$

For the polytropic compression process:

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

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

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

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