A copper block of volume 1 L is heat treated at 500°C and now cooled in a 200-L oil bath initially at 20°C, shown in Fig. P5.60. Assuming no heat transfer with the surroundings, what is the final temperature?

Solution:

C.V. Copper block and the oil bath.

\[ m_{\text{met}} = V\rho = 0.001 \times 8300 = 8.3\text{kg}, \quad m_{\text{oil}} = V\rho = 0.2 \times 910 = 182\text{kg} \]

\[ m_{\text{met}}(u_2 - u_1)_{\text{met}} + m_{\text{oil}}(u_2 - u_1)_{\text{oil}} = Q_2 - W_2 = 0 \]

Solid and liquid:

\[ \Delta u \cong C_v \Delta T \]

\[ m_{\text{met}}C_v(T_2 - T_{1,\text{met}}) + m_{\text{oil}}C_v(T_2 - T_{1,\text{oil}}) = 0 \]

\[ 8.3 \times 0.42(T_2 - 500) + 182 \times 1.8(T_2 - 20) = 0 \]

\[ 331.09T_2 - 1743 - 6552 = 0 \]

\[ \Rightarrow T_2 = 25^\circ\text{C} \]

A cylinder with a piston restrained by a linear spring contains 2 kg of carbon dioxide at 500 kPa, 400°C. It is cooled to 40°C, at which point the pressure is 300 kPa. Calculate the heat transfer for the process.

Solution:

Linear spring gives

\[ W_2 = \int PdV = \frac{1}{2}(P_1 + P_2)(V_2 - V_1) \]

\[ Q_2 = m(u_2 - u_1) + W_2 \]

Equation of state: PV = mRT

State 1: \[ V_1 = mRT_1/P_1 = 2 \times 0.18892 \times 673.15/500 = 0.5087 \text{m}^3 \]

State 2: \[ V_2 = mRT_2/P_2 = 2 \times 0.18892 \times 313.15/300 = 0.3944 \text{m}^3 \]

\[ W_2 = \frac{1}{2}(500 + 300)(0.3944 - 0.5087) = -45.72 \text{kJ} \]

From Figure 5.11: \[ C_p(T_{\text{avg}}) = 45/44 = 1.023 \Rightarrow C_v = 0.83 = C_p - R \]

For comparison the value from Table A.5 at 300 K is \[ C_v = 0.653 \text{kJ/kg K} \]

\[ Q_2 = mc_v(T_2 - T_1) + W_2 = 2 \times 0.83(40 - 400) - 45.72 = -643.3 \text{kJ} \]
A piston/cylinder arrangement, shown in Fig. P5.73, contains 10 g of air at 250 kPa, 300°C. The 75-kg piston has a diameter of 0.1 m and initially pushes against the stops. The atmosphere is at 100 kPa and 20°C. The cylinder now cools to 20°C as heat is transferred to the ambient. Calculate the heat transfer.

Determine if piston will drop. So a force balance to float the piston gives:

\[
P_{\text{float}} = P_0 + \frac{mg}{A} = 100 + \frac{75 \times 9.80665}{\pi \times 0.1^2 \times 0.25 \times 1000} = 193.6 \text{ kPa}
\]

If air is cooled to \( T_2 \) at constant volume

\[
P_2 = P_1 T_2/ T_1 = 250 \times 293.15/573.15 = 127.9 \text{ kPa} < P_{\text{float}}
\]

State 2: \( T_2 \), \( P_2 = P_{\text{float}} \)

State 1: \( V_1 = mRT_1/P_1 = 0.010 \times 0.287 \times 573.15 / 250 = 0.00658 \text{ m}^3 \)

Ideal gas \( \Rightarrow V_2 = \frac{V_1 T_2 P_1}{P_2 T_1} = \frac{0.00658 \times 293.15 \times 250}{193.65 \times 573.15} = 0.00434 \text{ m}^3 \)

\[\int P \, dV = P_{\text{float}}(V_2 - V_1) = 193.65(0.00434 - 0.00658) = -0.434 \text{ kJ} \]

\[1Q_2 = m(u_2 - u_1) + _1W_2 = mC_v(T_2 - T_1) + _1W_2 \]
\[= 0.1 \times 0.717 \times (20 - 300) - 0.434 = -2.44 \text{ kJ} \]

A piston/cylinder has 1 kg propane gas at 700 kPa, 40°C. The piston cross-sectional area is 0.5 m², and the total external force restraining the piston is directly proportional to the cylinder volume squared. Heat is transferred to the propane until its temperature reaches 700°C. Determine the final pressure inside the cylinder, the work done by the propane, and the heat transfer during the process.

Process: \( P = P_{\text{ext}} = CV^2 \Rightarrow PV^{-2} = \text{const.} \text{, } n = -2 \)

Ideal gas: \( PV = mRT \), and process yields

\[
P_2 = P_1(T_2/T_1)^{n-1} = 700 \left(\frac{700+273.15}{40+273.15}\right)^{\frac{2}{3}} = 1490.7 \text{ kPa}
\]

\[1W_2 = \int P \, dV = \frac{P_2 V_2 - P_1 V_1}{1 - n} = \frac{mR(T_2 - T_1)}{1 - n} \]
\[= \frac{1 \times 0.18855 \times (700 - 40)}{1 - (-2)} = 41.48 \text{ kJ} \]

\[1Q_2 = m(u_2 - u_1) + _1W_2 = mC_v(T_2 - T_1) + _1W_2 \]
\[= 1 \times 1.490 \times (700 - 40) + 41.48 = 1024.9 \text{ kJ} \]