ME 24-221
Thermodynamics I

Solution to Assignment No: 5
Due Date: 13 October 2000
Fall 2000
Instructor: J.Murthy

5.60 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.

$m_{met} = V\rho = 0.001 x 8300 = 8.3 kg, \quad m_{oil} = V\rho = 0.2 x 910 = 182 kg$

$m_{met}(u_2 - u_1)_{met} + m_{oil}(u_2 - u_1)_{oil} = {}_1Q_2 - {}_1W_2 = 0$

solid and liquid: $\Delta u \cong C_V \Delta T$

$m_{met}C_{Vmet}(T_2 - T_{1,met}) + m_{oil}C_{Voil}(T_2 - T_{1,oil}) = 0$

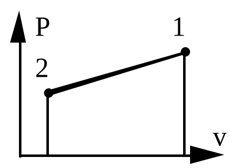
$8.3 x 0.42(T_2 - 500) + 182 x 1.8 (T_2 - 20) = 0$

$331.09 T_2 – 1743 – 6552 = 0$

$\Rightarrow T_2 =$ **25 °C**

5.65 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

$${}_1W_2 = \int P dV = \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$$

$${}_1Q_2 = m(u_2 - u_1) + {}_1W_2$$

Equation of state: $PV = mRT$

State 1: $V_1 = mRT_1/P_1 = 2 x 0.18892 x 673.15 /500 = 0.5087 m^3$

State 2: $V_2 = mRT_2/P_2 = 2 x 0.18892 x 313.15 /300 = 0.3944 m^3$

$${}_1W_2 = \frac{1}{2}(500 + 300)(0.3944 - 0.5087) = -45.72 kJ$$

From Figure 5.11: $C_p(T_{avg}) = 45/44 = 1.023 \Rightarrow C_V = 0.83 = C_p - R$

For comparison the value from Table A.5 at 300 K is $C_V = 0.653$ kJ/kg K

${}_1Q_2 = mC_V(T_2 - T_1) + {}_1W_2 = 2 x 0.83(40 - 400) - 45.72 =$ **-643.3 kJ**

5.73 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:

$$P_{float} = P_0 + \frac{m_p g}{A} = 100 + \frac{75 \text{ x } 9.80665}{\pi \text{ x } 0.1^2 \text{ x } 0.25 \text{ x } 1000} = 193.6 \text{ kPa}$$

If air is cooled to T_2 at constant volume

$P_2 = P_1T_2/T_1 = 250 \text{ x } 293.15/573.15 = 127.9 \text{ kPa} < P_{float}$

State 2: T_2, $P_2 = P_{float}$

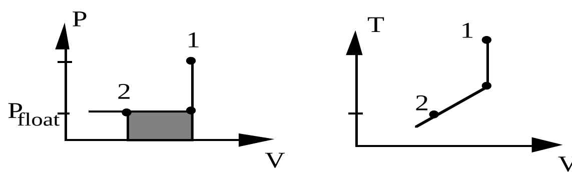
State 1: $V_1 = mRT_1/ P_1 = 0.010 \text{ x } 0.287 \text{ x } 573.15 / 250 = 0.00658 \text{ m}^3$

$$\text{Ideal gas} \Rightarrow V_2 = \frac{V_1T_2P_1}{P_2T_1} = \frac{0.00658 \text{ x } 293.15 \text{ x } 250}{193.65 \text{ x } 573.15} = 0.00434 \text{ m}^3$$

${}_1W_2 = \int P\, dV = P_{float}(V_2 - V_1) = 193.65(0.00434 – 0.00658) = -0.434 \text{ kJ}$

${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 \cong mC_V(T_2 - T_1) + {}_1W_2$

$= 0.1 \text{ x } 0.717 \text{ x } (20 - 300) - 0.434 =$ **-2.44 kJ**



5.84 A piston/cylinder has 1 kg propane gas at 700 kPa, 40°C. The piston cross-sectional area is 0.5 m^2, 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: $P = P_{ext} = CV^2 \Rightarrow PV^{-2} = \text{const}, \ n = -2$

Ideal gas: PV = mRT, and process yields

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

$${}_1W_2 = \int_1^2 PdV = \frac{P_2V_2 - P_1V_1}{1 - n} = \frac{mR(T_2 - T_1)}{1 - n}$$

$$= \frac{1\times 0.18855\times(700-40)}{1-(-2)} = \mathbf{41.48 \text{ kJ}}$$

${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = mC_V(T_2 - T_1) + {}_1W_2$

$= 1 \text{ x } 1.490 \text{ x } (700 - 40) + 41.48 =$ **1024.9 kJ**