1. You pour 0.5 L of boiling water into a 5 L glass jar. After a few seconds – during which the steam rising from the liquid has displaced all of the air in the jar – you tightly cap the jar and place the jar in the refrigerator. At this moment the system can be assumed to be a saturated mix, with 1/10 of the total volume in the liquid phase. The system cools to 5°C. Calculate how much heat was transferred to the system.

2. A rigid container of volume 0.1 m$^3$ contains 5 kg of water at 20°C. The maximum allowable pressure of the container is set at 5 MPa. The system is now connected to a heat source, which transfers heat at a rate of 500 W to the container. How long will the container survive?

3. A system contains 2 kg water at 500°C and 500 kPa. Heat is now transferred from the water in a constant pressure process. At the end of process 3000 kJ of heat has been removed from the water. Find the initial and final volumes of the system.

4. Air is contained in a piston–cylinder apparatus. Initial conditions are $V_1 = 0.05$ m$^3$, $P_1 = 120$ kPa, and $T_1 = 300$ K. Heat is now added to the gas, and the air expands in a constant pressure process. At the end of the process the volume has doubled. Determine the final temperature and the heat transfer to the air. Use the air tables in the back of the book to solve this problem.

5. Air is contained in an insulated piston–cylinder apparatus. Initial conditions are $V_1 = 0.1$ m$^3$, $P_1 = 120$ kPa, and $T_1 = 300$ K. The air is now slowly compressed, and the volume at the final state is half the initial volume. Assuming the specific heat of the air is constant with $C_P = 1.005$ kJ/kg K, calculate the final temperature of the gas and the work done to the gas.

To work this problem, start with the first law for the adiabatic (no heat transfer) process; this will be the case because the cylinder is insulated:

$$u_2 - u_1 = -\frac{W_{1\rightarrow 2}}{m} = -w_{1\rightarrow 2} = -\int_1^2 P \, dv$$

or, on a differential basis,

$$du = -P \, dv$$

If this does not make sense, integrate the second equation from states 1 to 2, and you will get the first equation. Now use the relations for an ideal gas:

$$P = \frac{RT}{v} \quad \text{and} \quad du = C_v \, dT$$

Replace this into the previous equations, separate the variables, and integrate from state 1 to 2. Using the properties of logarithms, you should get

$$\frac{T_2}{T_1} = \left( \frac{v_1}{v_2} \right)^{R/C_v}$$

This will allow you to get the final temperature, and the first law will give the work.

If you use $R = C_P - C_v$, and combine the previous equation with the ideal gas law to eliminate $T$, you will find

$$\frac{P_2}{P_1} = \left( \frac{v_1}{v_2} \right)^{C_P/C_v}$$

i.e., this is a polytropic process with exponent $n = C_P/C_v$. The ratio of specific heats $C_P/C_V$, which is given the symbol $k$ and $\approx 1.4$ for air, will be an important property when dealing with ideal gas properties. Also note that

$$\frac{R}{C_v} = \frac{C_P - C_v}{C_v} = k - 1$$

6. A rigid, insulated tank is internally divided into two subvolumes, A and B, each of equal volume. Side A contains 1 kg of an ideal gas at 100°C and 1 MPa pressure, while side B contains a vacuum. The partition is now suddenly removed, and the gas in A undergoes a free expansion to fill the entire tank. Find the final temperature of the gas. Note that a free expansion involves zero work.

7. Repeat the problem, except now take side A to initially contain 1 kg of saturated water vapor at 1 MPa initial pressure. Use the H2O code to solve this problem. Does the water behave like an ideal gas?