4.9 PROBLEMS

Problem 4.9.1. A 50-kg copper block at 400 K is placed in contact with a 75-kg steel block at 300 K in an insulated environment from other objects as shown in Fig. 4.8. Find (a) the final temperature of the blocks, (b) the change in the internal energy of each block, (c) the change in the entropy of each block, and (d) the total entropy change. (e) Why is the total entropy change not equal to zero even when no heat is exchanged with the environment?

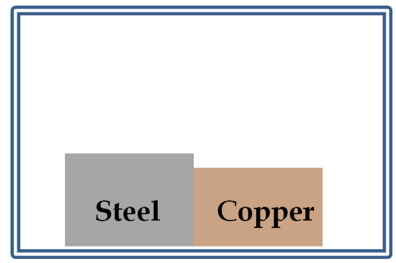

Figure 4.8: Problem 4.9.1.

Problem 4.9.2. An insulated container has two chambers separated by a diathermal wall. At time $t = 0$ there is a 400-g aluminum container with 200 g of water at 350 K in one chamber, and at the same time there is a 200-g copper container with 300 g of water at 297 K in the other chamber. The two chambers are then allowed to come to thermodynamic equilibrium. What is the change in the entropy between the initial and the final states of the full system consisting of everything in the two chambers?

Problem 4.9.3. A monatomic ideal gas (n moles) goes through a cyclic process shown in Fig. 4.9. (a) Find the change in the entropy of the gas in each step and the total entropy change over the entire cycle. (b) Does your answer for the total entropy change over one cycle make sense? Why or why not?

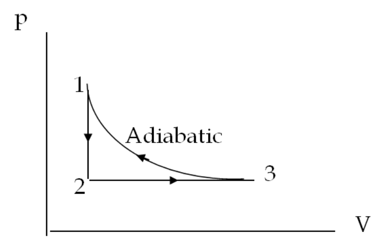

Figure 4.9: Problem 4.9.3.

Problem 4.9.4. Two water baths of mass 1000 kg each are to serve as heat source and heat sink for a Carnot engine. One of the baths is at temperature T_1 and the other at temperature T_2 with $T_1 > T_2$. In each cycle the Carnot engine takes an infinitesimal amount of heat dQ_1 from the higher temperature bath and produces an infinitesimal work dW and rejects the remainder dQ_2 to the lower temperature reservoir. As a result, the temperature of the higher temperature reservoir decreases in time while the temperature of the lower temperature bath increases until the two baths reach the same final temperature T_f at which point the engine stops producing any work. (a) Find T_f in terms of the initial temperatures T_1 and T_2 of the two baths. (b) Evaluate the total work produced. (c) Find the net change in the entropy.

Problem 4.9.5. Two mole of the Nitrogen gas, considered as a diatomic ideal gas with $\gamma = 7/5$ in the temperature range under consideration here, occupies a volume of 10 L in an insulated cylinder at temperature 300 K. The gas is adiabatically and reversibly compressed to a volume of 5 L. The piston of the cylinder is locked in its place and the insulation around the cylinder is removed. The heat-conducting cylinder is then placed in a 300 K heat bath. Heat from the compressed gas leaves the gas, and the temperature of the gas becomes 300 K again. The gas is then slowly expanded at the fixed temperature 300 K until the volume of the gas becomes 10 L, thus making a complete cycle for the gas. For various steps and for the entire cycle calculate the following, (a) the work done by the gas, (b) the heat into or out of the gas, (c) the change in the internal energy of the gas, and (d) the change in the entropy of the gas.

Problem 4.9.6. (a) Draw the Carnot engine cycle in the temperature-entropy plane. (b) What is the interpretation of the area enclosed by the cycle in the TS-plane? Explain.

Problem 4.9.7. Three moles of the Nitrogen gas at 400 K in a container is suddenly expanded to twice its volume. The process is so rapid that no heat is exchanged with the environment but the temperature of the final state upon reaching equilibrium is found to be 300 K. The gas is then compressed isothermally at 300 K back to the initial volume. Find the total change in entropy of the gas. Treat the Nitrogen gas as a diatomic ideal gas with the molar specific heat $C_V = \frac{5}{2}R$.

Problem 4.9.8. A nonconducting cylinder of total volume 2 L closed at both ends is divided into two parts by a diathermal frictionless circular wall. Initially the piston is clamped in the middle with the Nitrogen gas at different temperatures and pressures on the two side. The initial pressure and temperatures on the left and right sides are (3 atm, 330 K) and (2 atm, 250 K) respectively. (a) Find the temperature and pressure of the final state when the two sides are in thermal and mechanical equilibrium. (b) Find the net change in the entropy of the gas.