2.7 PROBLEMS

Problem 2.7.1. In the Joule mechanical equivalence of heat experiment, a 30 W motor powers the paddles. The paddles heat up 1×10^{-3} m^3 water and 200 g of copper container. What will be the increase in temperature of water if the motor is run for 30 minutes, and 5% of the energy used by the motor is lost as heating in the motor.

Problem 2.7.2. Two moles of Helium gas are placed in a cylindrical container with piston. The gas is at room temperature 25°C and under a pressure of 3×10^5 Pa. When the pressure from outside is decreased while keeping the temperature same as the room temperature, the volume of the gas doubles. (a) Find the work the external agent does on the gas in the process. (b) Find the heat exchanged by the gas, and indicate, whether the gas takes in or gives up heat. Assume ideal gas behavior.

Problem 2.7.3. An n moles of a monatomic ideal gas in a conducting container with a movable piston is placed in a large thermal heat bath at temperature T_1 and the gas is allowed to come to equilibrium. After the equilibrium has reached, the pressure on the piston is lowered so that the gas expands at constant temperature. The process is continued quasi-statically until the final pressure is $\frac{3}{4}$ of the initial pressure p_1. (a) Find the change in the internal energy of the gas. (b) Find the work done by the gas. (c) Find the heat exchanged by the gas, and indicate, whether the gas takes in or gives up heat.

Problem 2.7.4. A monatomic ideal gas undergoes a quasi-static process which is described by the function $p(V) = p_1 + 3\,(V - V_1)^2$, where the starting state is (p_1, V_1) and the final state (p_2, V_2). Assume the system consists of n moles of the gas in a container which can exchange heat with the environment and whose volume can change freely. (a) Evaluate the work done by the gas during the change in the state. (b) Find the change in internal energy of the gas. (c) Find the heat input to the gas during the change. (d) What are initial and final temperatures?

Problem 2.7.5. A metallic container of fixed volume of 2.5×10^{-3} m^3 immersed in a large tank of temperature 27°C contains two compartments separated by a freely movable wall. Initially the wall is kept in place by a stopper so that there are 0.02 moles of the Nitrogen gas on one side and 0.03 moles of the Oxygen gas on the other side, each occupying half the volume. When the stopper is removed, the wall moves and comes to a final position. The movement of the wall is controlled so that the wall moves in infinitesimal quasi-static steps. (a) Find the final volumes of the two sides assuming the ideal gas behavior for the two gases. (b) How much work does each gas does on the other? (c) What is the change in the internal energy of each gas? (d) Find the amount of heat that enters or leaves each gas.

Problem 2.7.6. A gas in a cylindrical closed container is adiabatically and quasi-statically expanded from a state A (3 MPa, 2 L) to a state B with volume of 6 L along the path $pV^{1.8}$ = constant. (a) Plot the path in the pV plane. (b) Find the amount of work done by the gas and the change in the internal energy of the gas during the process.

Problem 2.7.7. The system in problem above goes from A to B on a curve $pV^{1.8}$ = constant in the pV plane. In this problem we will conduct the transformation from same A to the same B in the following two steps instead. First, the pressure will be lowered from 3 MPa to pressure corresponding to state B, while keeping the volume at 2 L, by cooling the system. The state reached will be labeled C. Then the system will be heated at a constant pressure to reach the volume of the state B. (a) Find the amount of work done on the A-C-B path. (b) Find the amount of heat exchanged by the system when it goes from A to B on A-C-B path. (c) Compare the change in the internal energy when A-B process occurs adiabatically with the A-B change through the two-step process on A-C-B path.

Problem 2.7.8. Two moles of monatomic ideal gas at (5 MPa, 5 L) is expanded isothermally until the volume is doubled. Then, it is cooled isochorically till the pressure is 1 MPa. The temperature drops in this process. The gas is now compressed isothermally till its volume is back to 5 L, but its pressure is now 2 MPa. Finally, the gas is heated isochorically to return to the initial state. (a) Draw the four processes in the pV-plane. (b) Find the total work done by the gas, the net change in the internal energy and the net heat entering the gas in the cycle.

Problem 2.7.9. An n moles of helium gas, assumed a monatomic ideal gas, contained in a rigid container with fixed volume is heated in a quasi-static process. As a result, the pressure inside the container doubles with respect to the initial pressure. (a) Find the change in the internal energy of the gas in terms of the initial temperature T_0. (b) Find the change in enthalpy of the gas in terms of the initial temperature T_0.

Problem 2.7.10. Consider a cylinder with a movable piston containing n moles of an ideal gas. The entire apparatus is immersed in a constant temperature bath of temperature T degrees Kelvin. The piston is then pushed slowly so that the pressure of the gas changes quasi-statically from p_1 to p_2 at constant temperature T. Find the work done by the gas in terms of n, R, T, p_1 and p_2.

Problem 2.7.11. A 100 g ice cube from freezer at -15°C is dropped into 500-g water in a 250 g insulated aluminum container at 20°C. Find the temperature and phase of the final state.

Problem 2.7.12. A copper ball of mass 250 g heated to a temperature of 400°C is introduced into 600 g of water in a glass container which is at room temperature of 27°C. The container is insulated so that there is no loss of heat to the environment. Assume the heat capacity of the glass container to be 210 J/K. Find the temperature and phase of the final state of water.