

Final Exam (PY 413, Spring 2006)

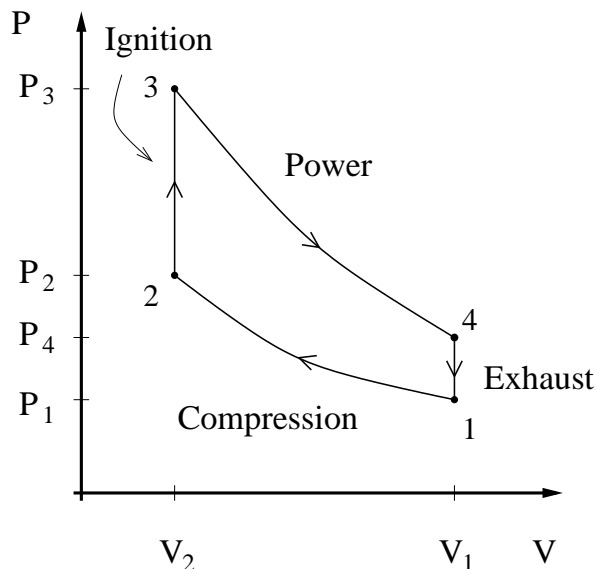
1. (10pts) A glass containing 150g of water is heated in a 600 Watt microwave oven.
 - (a) Starting from room temperature, $T = 20^\circ\text{C}$, how long does it take for the water to boil (assume that no energy is wasted)?
 - (b) After taking the glass out of the microwave, you put a 30g silver spoon into the boiling water. After the water and the spoon reach thermal equilibrium, what is the temperature of the water (assuming that no heat is lost to the environment)?

The specific heats are $c(H_2O) = 4.186 \text{ J/g/K}$ and $c(Ag) = 0.235 \text{ J/g/K}$.

2. (10pts) A hydrogen fuel cell is based on the reaction $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$.
 - (a) How much electrical energy W_{el} and heat Q are produced if 1 mole of H_2 and 1/2 mole of O_2 are converted to H_2O at room temperature? Is Q positive or negative? How much work is done by the atmosphere (assume that the gases are kept at room temperature, and that the volume of liquid water is negligible as compared to the volume of the gases)?
 - (b) The reaction at the anode is $H_2 \rightarrow 2e^- + 2H^+$. What is the voltage of the fuel cell?

The enthalpy and Gibbs free energy of formation for one mole of liquid water are $\Delta H = -285.83 \text{ kJ}$ and $\Delta G = -237.13 \text{ kJ}$.

3. (10pts) The figure shows an approximate PV diagram for a gasoline (Otto) engine. In the following we shall assume that the working substance is an ideal gas and that the power and compression strokes are adiabatic.



- (a) Compute Q and W for the four steps indicated in the figure. Express your result in terms of V_i and P_i .
 - (b) What is the efficiency of an Otto engine with a compression ratio $V_1/V_2 = 10$? Assume that the working substance is a diatomic gas with $f = 5$.
4. (10pts) Water molecules vibrate at a characteristic frequency $f = 4.8 \cdot 10^{13}$ Hz. We shall assume that the vibrational energy levels are $E_n = hf n$, where h is Planck's constant and $n = 0, 1, 2, \dots$
- (a) Determine the vibrational partition function of one water molecule as a function of T . Also compute the free energy and entropy.
 - (b) What is the vibrational contribution to the entropy of one mole of water at 700°C ?