Statistical Physics I
WS 2015/16, FUB

Problem sheet 9

Please hand in your solutions before the lecture on Wednesday, 16th of November.

Problem 1 - Quasi-statical Processes

(a) The following figure shows a quasi-static cyclic path in the P-V diagram of an ideal gas. How much work is done on the gas during this cyclic process? *(3 points)*

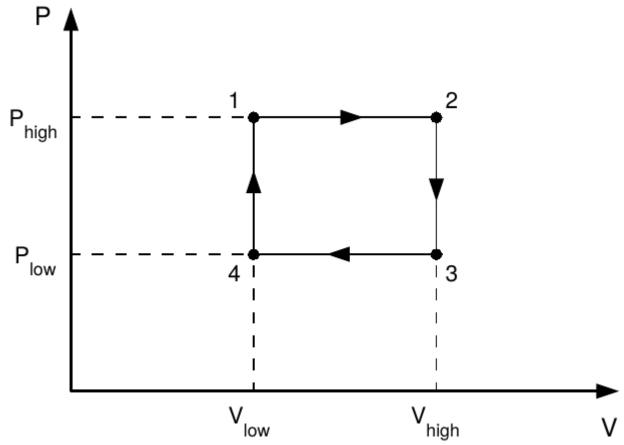

Abbildung 1:

(b) Calculate the entropy change in each part of the cycle, and in the full cycle. *(3 points)*

(c) Plot the cycle but now in a T-S diagram, indicating where there is exchange of heat, if there is any. *(4 points)*

Problem 2 - Heat transfer

(a) Consider the transfer of heat from one system at initial temperature T_{10} to another at initial temperature T_{20}, with $T_{10} < T_{20}$. Further, let the heat capacities (at constant volume) of both systems be different, $C_1(T)$ and $C_2(T)$. Then if a quantity of heat dQ_1 is quasi-statically transfered from system 2 to system 1, what is the change in entropy of the system? Show that ΔS is possitive, how does this relate to the second law of thermodynamics? What happens in the limit $C \to \infty$? *(4 points)*

(b) One mole of an ideal gas is to be taken by an unspecified process from the state T_0, V_0 to the state T_f, V_f. A system constrained to have a fixed volume, whose initial temperature is T_{20} and heat capacity is linear in the temperature, $C_2(T) = DT$ with $D =$ constant is used as a reversible heat reservoir. If part of the energy extracted from the gas is transformed into work, what would be the maximum work that could be delivered? *(4 points)*

Hint: The system can be understood more easily by looking at figure 2.

Problem 3 - Carnot cycle

N moles of a monatomic ideal gas are to be employed as the auxiliary system in a Carnot cycle. The ideal gas is initially in contact with the hot reservoir, and in the first stage of the cycle it is expanded from volume V_A to volume V_B. Calculate the work and heat transfers in each of the four steps of the cycle, in terms of T_h, T_c, V_A, V_B, and N. Directly corroborate that the efficiency of the cycle is the Carnot efficiency. *(4 points)*

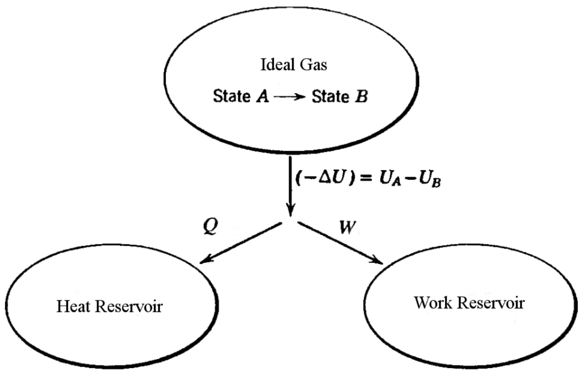

Abbildung 2:

Problem 4- Non-Carnot cycles

(a) Determine the efficiency of the Otto and Diesel cycles. Compare them with the efficiency found in problem 3. Which cycle is better? Why? *(4 points)*

The step of each cycle are:

Otto cycle: adiabatic expansion, isochoric ëxpansion", adiabatic compression, isochoric "compression".

Diesel: isobaric expansion, adiabatic expansion, isochoric compression", adiabatic compression.

(b) The cycle of a hypothetical engine is illustrated in the following figure

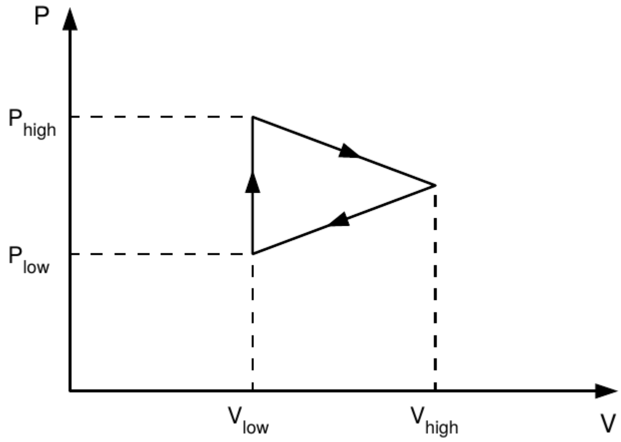

Abbildung 3:

Let $P_{low} = 1 \times 10^6 Pa$, $P_{high} = 2 \times 10^6 Pa$, $V_{low} = 5 \times 10^{-3} m^3$, and $V_{high} = 25 \times 10^{-3} m^3$. If the energy absorbed by heating the engine is $5 \times 10^4 J$, what is the efficiency of the engine? *(4 points)*