General Physics II: Tutorial Material

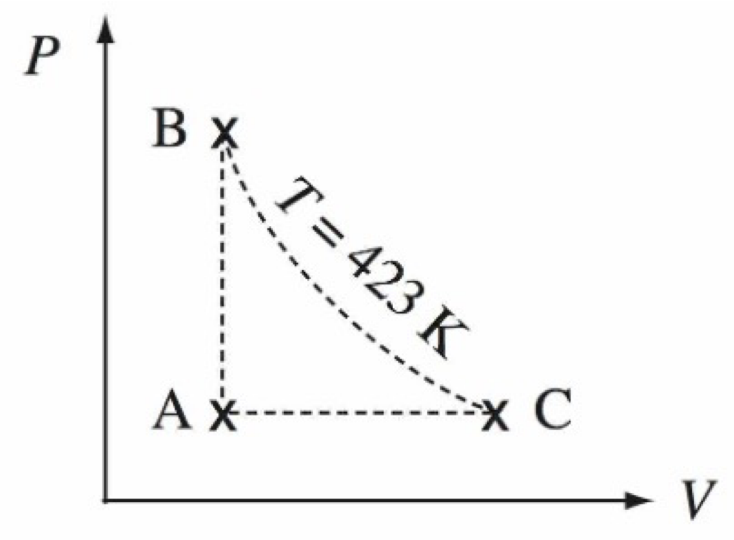
Lecture 9 (Chapter 8 & Chapter 9, Entropy and thermal machines)

1) Follow-up question on problem 1.2 in Lecture exercise:
An isolated system of volume V_0 consists of two subsystems, labelled 1 and 2 separated by an impermeable (no particle flow) and moving diathermal (exchange of heat) wall of mass M and of negligible volume. Both subsystems contain ideal gas. Initially, both subsystems are at the temperature T_i. Subsystem 1 is in a state characterised by a volume V_{1i} and pressure P_{1i}. Likewise, subsystem 2 is characterised by a volume V_{2i} and pressure P_{2i}. When the system has reached equilibrium, the final temperature is equal to the initial temperature. We had already computed the number of moles n_1 and n_2, the final temperature T_f, the final volumes and final pressure P_f when the system has reached equilibrium. Now determine the entropy variation between the initial state and final equilibrium state. In particular show that for the specific case where $n_1 = n_2 = n$, the result implies an increase in entropy.

2) Entropy production by heat transfer: An isolated system consists of two subsystems labelled 1 and 2, analysed in Chapter 8.5 ("stationary heat transfer between two blocks"). Using the second law, show that in a stationary state, when $T_1 > T_2$, the entropy production dS_{prod} of the whole system is positive when heat flows across these two subsystems despite the fact that the entropy production within individual subsystems is constant (as net heat flow in each subsystem is 0), i.e. $dS_{prod,1} = dS_{prod,2} = 0$.

3) An n-mole ideal gas with a volume V_1 expands adiabatically ($Q = 0$) into the vacuum (free expansion) and its volume becomes V_2. Is this process a reversible process? Show that the entropy change is positive, i.e. $\Delta S > 0$. Is this result paradoxical? How can we explain this?

4) The figure below shows the P-V diagram of a heat engine with 1 mol of a diatomic molecule ideal gas. At point A, it is at STP (273 K and 1 atm). Points B and C are on the isothermal line at T = 423 K. The process A-B is with a constant volume and A-C with a constant pressure.



a) Obtain the volume, pressure and temperature for the state B and C.

b) Which is the path to generate the work, A-B-C or A-C-B, and why?

c) What is the efficiency, ϵ, of the engine where $\epsilon = \frac{W}{Q_{in}}$?

d) Show that total heat minus total work is zero.

5) We consider now a similar heat engine starting from A as defined above, but the B-C path is done adiabatically. The temperature of B is kept at T = 423 K and on the isovolumetric line with A. The state C remains on the isobaric line with A.

a) Obtain the volume, pressure and temperature of C.

b) Calculate the efficiency.