Many Particle Systems – Practice Problem Set 1

These problems are not for assessment. However, it is recommended that you attempt them as practice for the test and exam.

1. In lectures, it was shown that the amount of work done in an infinitesimal quasistatic compression or expansion is

$$đW = -p\,dV.$$

Prove that for the case of a *real* expansion or compression process (i.e. not infinitely slow),

$$đW > -p\,dV.$$

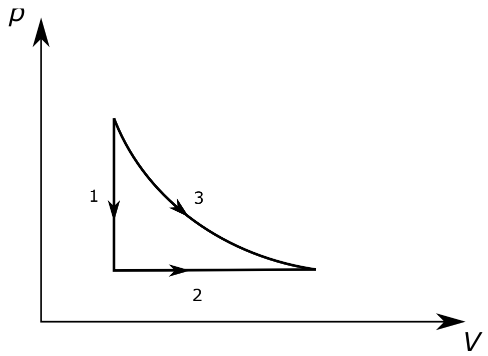
Hint: consider the cases of compression and expansion separately.

2. A cylinder contains 5 liters of compressed hydrogen gas at a pressure of 10^7 Pa. How much work can be extracted from this system by isothermally expanding the gas to a pressure of 10^5 Pa at a temperature of 300 K? Assume that hydrogen behaves as a diatomic ideal gas at these temperatures and pressures.
Compare this with the amount of energy that is released by burning the hydrogen (take the energy released on combustion of a mole of hydrogen to be 2.9×10^5 J).

3. A thermally isolated rigid cylinder is divided into two sections by a rigid partition which does not conduct heat. The volume V_1 to the left of the partition contains ν_1 moles of an ideal gas at a temperature T_1, and the volume V_2 to the right of the partition contains ν_2 moles of the same gas at a temperature T_2.

Determine the temperature of the equilibrium state which results when the partition is removed (express the temperature in terms of the appropriate variables selected from V_1, V_2, T_1, T_2, ν_1 and ν_2) .
Hint: consider conservation of energy and use what you know about the energy of an ideal gas as a function of temperature.

4. Consider an ideal gas, and the quasistatic processes shown below.



Process 1 is pressure reduction at constant volume, process 2 is expansion at constant pressure, and process 3 is isothermal expansion. Compute the change in the entropy of the gas for each of processes 1 and 2 and show that the sum of the changes is the same as that computed for process 3 in the lectures.

Note: for an infinitesimal quasistatic process for an ideal gas, $đQ = \nu c_V dT + pdV$.

5. An ideal monatomic gas is heated at constant pressure from a temperature T_1 to a temperature T_2.

   (a) Use the expression for the entropy of an ideal gas given in lectures in terms of ν, V and T to compute the change in the entropy of the gas in terms of the initial and final temperatures T_1 and T_2 and the number ν of moles of the ideal gas.

   (b) Use the formula
   $$dS = \frac{đQ}{T}$$
   to compute the change in entropy if the heat is added quasistatically and confirm the result is the same as in part (a).

   (c) Explain why the change in the entropy is the same regardless of whether the heat is added quasistatically or not.