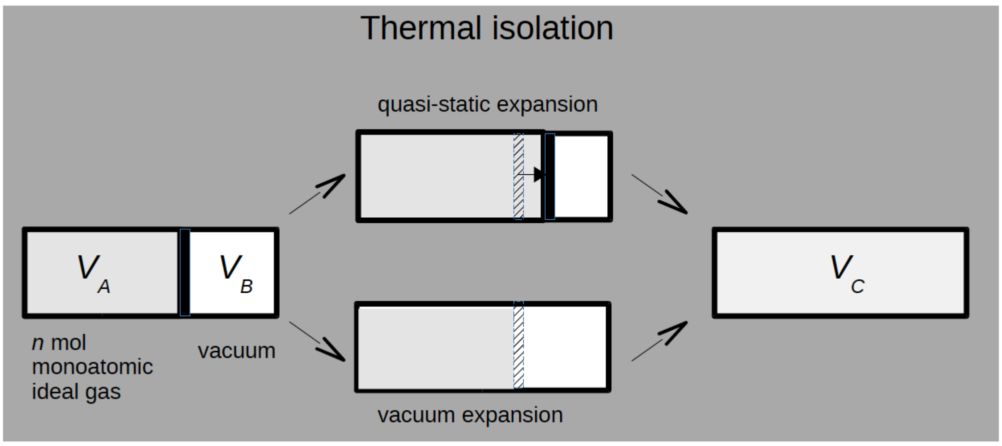
General Physics II: Tutorial Material 11

1) Let us consider a rigid and hermetic room with a volume of 22.6 m^3 and filled with air with a pressure of 1 atm at 0° C. We assume that air is an ideal gas. In the following, assume that $0^\circ\mathrm{C} = 273^\circ\mathrm{K}$ and $1\ \mathrm{atm} = 1.013\times 10^5\ \mathrm{N/m^2}$, and for the air, the molecular specific heat $C_p = 7\,\mathrm{cal}/(\mathrm{mole}\cdot\mathrm{K})$ and $\gamma = C_P/C_V = 1.4$ are assumed to be constant. Another useful number is $1\ \mathrm{Nm} = 1\ \mathrm{J} = 2.39\times 10^{-4}\ \mathrm{kcal}$. (*)
   a) The air temperature in the room is quasi-statically increased from 0° to 20° C. Draw the *P-V* (pressure versus volume) diagram of this process and calculate the heat, *Q*, necessary for this process.
   b) Fixture of one of the walls is removed and the wall can move freely such that the pressure of the air inside can be fixed to 1 atm. However, it is still hermetic so that the air inside cannot leak outside. How large is the heat, *Q*, needed to quasi-statically increase the air temperature of the room from 0 to 20° C?
   c) Instead of removing the wall fixture, we make a very small hole on the wall, which allows the air in the room to escape outside very slowly if required, such that the pressure of the air inside the room is always kept at 1 atm. How large is the heat, *Q*, needed to quasi-statically increase the air temperature of the room to 20° C.

2) We consider a system of a hermetic cylinder with a volume V_C placed in a thermally isolated environment. The cylinder is split into two volumes, V_A and V_B with a hermetic wall. The volume V_A is filled with an *n* mol ideal gas with a pressure P_A and volume V_B kept in vacuum.
   a) The wall is moved quasi-statically so that the volume V_A becomes V_C.
      i. What are the pressure and temperature of the gas when it reaches to the volume V_C?
      ii. Calculate the entropy change, ΔS, for this process.
   b) Instead of moving the wall quasi-statically, it is removed suddenly to let the gas make vacuum expansion for its volume to become V_C. After the system reaching equilibrium:
      i. What is the pressure and temperature of the system for the final state?
      ii. Calculate the entropy change for this process.



3) Gas molecules are moving randomly due to thermal motion. Using the Boltzmann factor, $e^{-E/kT}$, where E is the kinetic energy, k is the Boltzmann constant and T is the temperature of the gas, probability for a monoatomic gas molecule has three vector-velocity with a value between $\vec{v}$ and $\vec{v} + \overrightarrow{dv}$, is given by

$$P(v_x,\ v_y,\ v_z)dv_x dv_y dv_z = \left(\frac{m}{2\pi kT}\right)^{3/2} \exp\left[-\frac{m}{2kT}\left(v_x^2 + v_y^2 + v_z^2\right)\right] dv_x dv_y dv_z\ .$$

a) What is the probability for a molecule to have a velocity in z direction between v_z and $v_z + dv_z$, while it can have any values in x and y direction?

b) What is the average velocity in z for the atoms moving toward the positive z direction? What is the average velocity in z for the atoms moving toward the negative z direction?

c) Would these two velocities be different if the gas molecule were diatomic? Why?