General Physics II at EPFL

(2018-2019 SS, Wed 17:15-19:00 and Thu 8:15-10:00, Exercise Thu 10:15-12:00)

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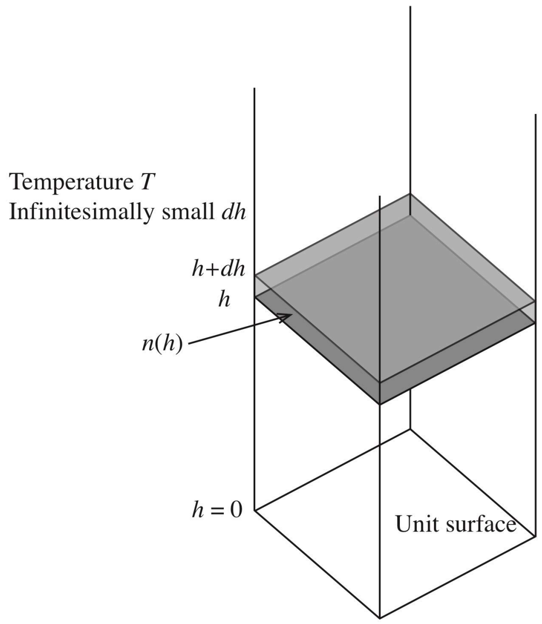
Mock examination 2

Date: Friday 15 May 2019, 17:15-19:00
Room: CE1
3 Problems
Thermodynamics

Problem 1

Boltzmann factor gives that the number of gas molecules with an energy E, for a gas at an absolute temperature T to be $\propto e^{-E/kT}$, where k is the Boltzmann constant. A gas molecule on the earth gains potential energy mgh, where h is the altitude of the molecule position measured from the sea level, m the mass of the gas molecule and g gravitational constant. By assuming that the energy of the gas molecule is totally given by the earth gravity (a reasonable assumption since the earth atmosphere does not escape to the outer space) and the temperature does not depend on the altitude:

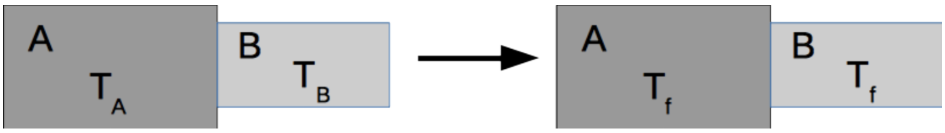
1) Obtain the number of gas molecules for a unit surface with an infinitesimally small thickness at an altitude of h, $n(h)$, using n_0, which is the number of gas molecules per unit surface with an infinitesimally small thickness at $h = 0$.
2) Assuming that the gas is an ideal gas, obtain the pressure of the gas, $P(h)$, at an altitude h from $n(h)$.
3) Show that the gas pressure at the sea level is equal to the gravity force acting on the total mass of the gas molecules (altitudes from 0 to ∞) per unit surface.



Problem 2

We consider a system of two solid bodies, A and B, with their masses, m_A and m_B, and specific heats per mass, c_A and c_B, respectively. And their initial absolute temperatures are T_A and T_B. Now the two bodies are put together under thermal contact while the system is thermally isolated from the environment.

1) Using the 1st law of thermodynamics, calculate the temperature T_f, when the system has reached thermal equilibrium.
2) Show that T_f is always in between T_A and T_B.
3) Calculate the entropy changes for A and B, ΔS_A and ΔS_B, between the initial and the final thermal equilibrium states.
4) From ΔS_A and ΔS_B obtained above, show that the total entropy change, $\Delta S_A + \Delta S_B$, is always ≥ 0.



Problem 4

Consider an isolated system with a 10 kg ice block in 20 kg of water, which is in a thermal equilibrium state. In the following, assume that the specific heat and heat of fusion of the ice are $0.5\ \text{kcal}/(\text{kg}\cdot\text{C})$ and $80\ \text{kcal}/\text{kg}$, respectively, and specific heat of the water is $1\ \text{kcal}/(\text{kg}\cdot\text{C})$.

1) What is the temperature of the system?

2) If we add 20 kg of water at 90° C to the system, what will be the temperature of the system after reaching its equilibrium and what are the constituents of the system?