HOMEWORK 2, THERMAL PHYSICS (PHY306)

1. (a) The binding energy of an electron in hydrogen atom is 13.6 eV. What fraction of atoms would be ionized at room temperature $T = 300K$ and in the Sun's photosphere $T_S = 6000K$?
(b) The energy of rotational state of certain diatomic molecule is $10^{-4}\, eV$. What is the probability of its excitation at temperature of microwave background radiation filling the Universe, $T = 2.7K$?

2.A photon of energy 1 eV is absorbed by a room's wall which is at room temperature and its energy is equilibrated among the wall's atoms. By what factor does the number of states of the wall Ω_{wall} has changed?

3. The masses and radii of the Earth and the Sun are

$$M_E = 5.972 \times 10^{24} kg,\;\; R_E = 6.371 \times 10^6 m\;\; M_S = 1.989 \times 10^{30} kg,\;\; R_S = 695.508 \times 10^6 m$$

(a) Using Newton's gravitational potential and energy conservation, calculate the escape velocities from Earth and Sun, v_E, v_S.
(b) For molecular hydrogen (H_2), atomic helium (^4He) and molecular oxygen (O_2) at room temperature $T = 300K$ calculate their r.m.s. velocities and compare them to the escape velocities for Earth found in (a)
(c) Repeat the same for the Sun, using its surface temperature $T_S = 6000K$.

4. You are in the office of size $3 \times 4 \times 5\, m^3$ at $T = 20^oC$ and $p = 10^5\, Pa$. Feeling cold, you switched a heater on and raised the air temperature to $T = 24^oC$. What was the number of atoms and their total kinetic energy in the room before heating N_{before}, E_{before} and is after the heating N_{after}, E_{after}?
Consider two cases: (a) the room's door is tightly closed, so no air can escape; (b) the room's door is slightly open, so that the pressure remains constant (same as outside $p = 10^5\, Pa$).

5.The so called Magdeburg hemispheres are a pair of large copper hemispheres, with mating rims. They were used to demonstrate the power of atmospheric pressure, the demonstration was 8 May 1654 in Regensburg, in front of German emperor's court. When the rims were sealed with grease and the air was pumped out, the sphere contained a vacuum and could not be pulled apart by two teams of many horses. Assuming that the diameter of the sphere was $d = 0.5\, m$ and that pressure applies to corresponding disk (inside the rim) and atmospheric pressure, calculate how many horses N_{horses} were needed to pull them apart. Assume that one horse can produce maximal force which can pull a weight of $M = 100\, kg$ vertically (say a heavy person or large bucket of water from the well). Horses were divided symmetrically, half and half on each side.