Physics 301: Problems #11
Nov. 8, 2019

1. Use the Boltzmann factor to derive the formula for the density of an isothermal atmosphere (already derived in problems 1.16, 3.37 in different ways).

2. In the early universe, the temperatures are so high that the proton and neutron can be thought of as two states of the same particle, the "nucleon". Calculate the ratio of protons to neutrons at a temperature 10^{11} K or $kT = 8.6$ MeV and the proton, neutron rest energies are $m_p c^2 = 938.272$ MeV and $m_n c^2 = 939.965$ MeV. Are the nucleons relativistic at this temperature?

3. Heat capacity of Einstein solid with N atoms. Each atom has 3 vibrational modes quantized as $E_n = n\epsilon$ where $n = 0, 1, ...$ and ϵ characterizes the "spring" strength.

   - Write the partition function for a single oscillator.
   - Find the mean energy per oscillator then get the total energy U.
   - Find the heat capacity. (the answer is eq. 7.103)