Physics 504: Statistical Mechanics and Kinetic Theory

HOMEWORK SHEET 1

Due 5pm Thur Feb 13 2020 in the 504 box.

Please attempt these questions without looking at textbooks, as much as you can. If you do need to refer to my notes or textbooks, the most effective way to do this is to read the relevant section, and then try the question again without looking at the book/notes.

Question 1–1.

Show that the conditions for two systems to be in mechanical equilibrium and diffusive equilibrium (particle exchange), in addition to thermal equilibrium, are the equality of pressure and of chemical potential respectively.

Question 1–2.

This question is an elementary exercise in combinatorial counting. In a monatomic crystalline solid, each atom can occupy two sorts of site: either a regular lattice site or an interstitial site (a site which is in between the regular lattice sites). The number of regular lattice sites is N. The number of interstitial sites is N. The number of atoms is N.

(a) What is the entropy of the crystal when exactly n of the N atoms are in interstitial sites?

(b) Now suppose that the energy of an atom in an interstitial site exceeds the energy of an atom in a lattice site by an amount ϵ. Find how n depends on temperature.

Question 1–3.

Consider the N particle quantum ideal gas with periodic boundary conditions and mass m for each particle. This is just like what we did in class, but there I used hard wall boundary conditions.

(a) Solve for the energy levels in terms of the appropriate quantum numbers, and be sure to give the range of allowed values of the quantum numbers. Compare and contrast your result with the corresponding one with hard wall boundary conditions.

(b) Calculate the density of states at energy E

(c) Calculate the entropy in the large system limit.

Question 1–4.

A bucket of water is standing in a shop window on a bright summer's day. You go into the shop and find that the bucket is warmer *on the side facing into the shop*. How is this possible? Why am I asking this question? (*Do not spend more than half an hour on this question. If you know the answer, please do not reveal it to other students. Don't get help from your friends or from people who did my course last year!)*