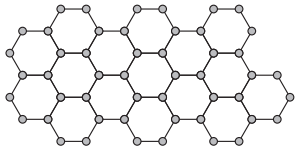
Condensed matter physics 2013
Exercise 1

Release: 17. Sept. 2013
Discussion: 24. Sept. 2013

*Problem 1

Graphene consists of a single layer of carbon atoms and is one of the most prominent materials in current solid state physics research, and was even the research subject of the Nobel Prize for Physics in 2010 [A. Geim *et al.*, Physics Today **60**, 35, 2007]. Here is a schematic representation of the graphene crystal lattice. Determine two possible sets of the primitive basis vectors and the primitive unit cells of this two-dimensional (2D) lattice, respectively.



*Problem 2

Draw and label the stereographic projections of the following symmetry groups: C_4, D_4 and S_6 ($\overline{3}$). Why is D_4 also called 422?

Problem 3

a) Find all symmetry transformations of a tetrahedron.

b) Construct the Wigner-Seitz cell in 2D for
(i) a rectangular lattice with a=2b and
(ii) a parallelogram grid with a=2b and $\alpha = 45°$

Problem 4

Show that a 5-fold rotation symmetry is not compatible with the translation properties of a Bravais Lattice.

*Problem 5

In Problem 1, we looked at the crystal lattice of Graphene. Now we will study its conductivity tensor $\sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix}$. This tensor relates the electric field to the the current density: $\vec{j} = \sigma \vec{E}$

Show that the conductivity tensor of graphene has the following form: $\sigma = \begin{pmatrix} \sigma_{11} & 0 \\ 0 & \sigma_{22} \end{pmatrix}$, with $\sigma_{11} = \sigma_{22}$.

Hint: The conductivity tensor is invariant under a symmetry transformation, C, of the crystal, i.e. $\hat{\sigma} = C^{-1}\sigma C$.