

PHYS4450 Solid State Physics

SAMPLE QUESTION FOR DISCUSSION in Week 3 EXERCISE CLASS on 30 January 2013

You may want to think about them before attending exercise class.

SQ5 and SQ6 are related. They refer to the direct and reciprocal lattices of that of graphene (graphene structure was given in Problem Set 1).

SQ4 hcp structure. Consider the hcp structure. Describe the structure. Work out the c to a ratio. Illustrate that it has a high packing, sometimes quantified by the atomic packing factor (APF).

SQ5 Graphene's lattice, Wigner-Seitz cell, lattice planes In Problem Set 1, students described the crystal structure of graphene.

Now, take the lattice of graphene and do the following.

- (a) Construct a Wigner-Seitz cell.
- (b) Select a choice of primitive unit vectors \mathbf{a}_1 and \mathbf{a}_2 . Construct a parallelogram using these vectors. This is also a primitive unit cell. Show that the area of this unit cell is the same as the Wigner-Seitz cell constructed in part (a). You may want to do it by intuition AND by formally expressing \mathbf{a}_1 and \mathbf{a}_2 in terms of unit vectors \hat{x} and \hat{y} and work out the area mathematically (introducing an auxiliary vector $\mathbf{a}_3 = \hat{z}$).
- (c) Illustrate a set of parallel lattice planes in a figure and find the corresponding Miller indices.

SQ6 Reciprocal lattice, Reciprocal lattice vectors, Brillouin zones

- (a) Now construct the reciprocal lattice corresponding to the direct lattice in SQ5 for graphene. Using the vectors \mathbf{b}_1 and \mathbf{b}_2 to map out the reciprocal lattice. What is the lattice type? Point out how the reciprocal lattice differs from the direct lattice.
- (b) Let (hkl) be the Miller indices of the set of planes in SQ5 part (c). Draw a reciprocal lattice vector $\mathbf{G}(hkl) = h\mathbf{b}_1 + k\mathbf{b}_2 + l\mathbf{b}_3$.
- (c) Illustrate (find some way to do it) that the reciprocal lattice vector $\mathbf{G}(hkl)$ is (i) perpendicular to the set of (hkl) planes in the direct lattice, and (ii) the shortest reciprocal lattice vector with this property (apart from one that points in the opposite direction). Also point out that multiples of $\mathbf{G}(hkl)$ are also perpendicular to the planes, but they are longer ones.

[Remark: Students have done such an illustration on a rectangular lattice in class.]

- (d) Construct the 1st Brillouin zone.
- (e) Also construct the 2nd and 3rd Brillouin zones.