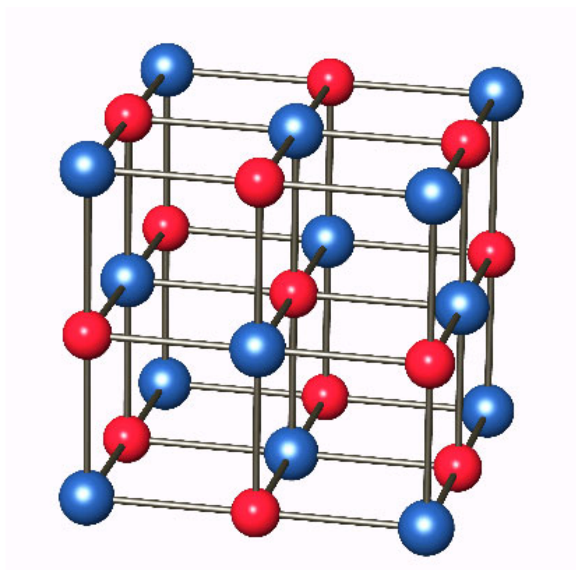
Condensed Matter Physics I
final written test
academic year 2017/2018
February 12, 2018

(*Time: 3 hours*)

NOTE:
Give all the steps necessary to understand in detail the solution procedure. Answers with the final result only or with insufficient details will not be considered valid.

Exercise 1: *Crystalline lattices*



The Figure above represents the typical crystalline structure of alkali halides, e.g. NaCl. Using a, the side of the cube, as the length unit, find:

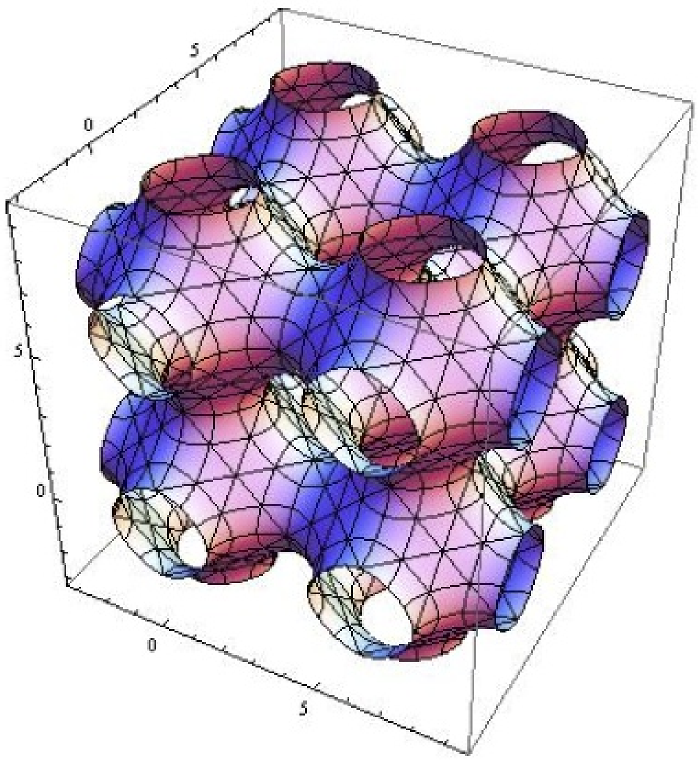
1. the type of Bravais lattice and the primitive vectors
2. the number, type and position of the atoms of the basis in the primitive unit cell
3. the atomic density
4. the structure factor for a generic reciprocal lattice vector
5. the values that the structure factor can assume, specifying the corresponding reciprocal lattice vectors (considering different form factors for Na and Cl)
6. the values that the structure factor can assume if the form factors of Na and Cl were equal, commenting the result
7. Is NaCl a centrosymmetric crystal (i.e., with inversion symmetry)? Justify your answer
8. Show that for a centrosymmetric crystal the structure factor can be always written as a real number.

Exercise 2: *Tight binding*

1. Write the expression for the dispersion of the s-type energy band in a simple cubic 3D crystal in the tight binding model, with the first neighbors interaction and neglecting the overlap integrals.

2. Show that the electronic velocity at each point on a face of the Brillouin zone is parallel to that face.

3. A constant energy surface (in k-space) is shown in the Figure below. Sketch on the Figure a closed orbit in a constant magnetic field in the z-direction. Sketch an open orbit.



Exercise 3: *Semiclassical model of electron dynamics*

Consider a two-dimensional semimetal where the dispersion relation for the energy band is linear in k: $E(\mathbf{k})=\pm B|\mathbf{k}|$, where B>0 is a constant. (for instance, graphene, although in that case the linear dispersion occurs near the corners of the Brillouin zone and not at the origin). Considering the semiclassical model of the electron dynamics:

1. Which is the shape of the orbits in case of a uniform magnetic field $\mathbf{H}$ applied perpendicular to the plane of the two-dimensional semimetal? *(Hint: you can justify your answer without doing calculations)*

2. Calculate the electron velocity, giving in particular its modulus.

3. Calculate $\dot{\mathbf{k}}$ and its modulus.

4. What is the period of the orbits for a given $E=E^*$?