Háskóli Íslands
Raunvísindadeild
Eðlisfræði

Haust 2014

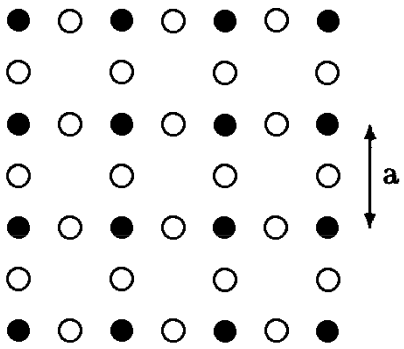
Eðlisfræði þéttefnis I

Dæmablað 8

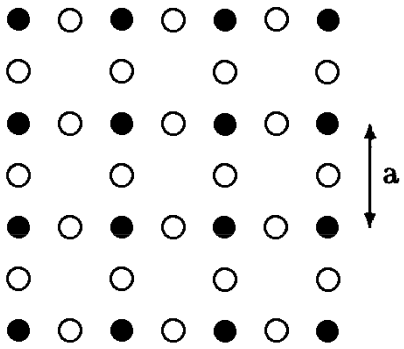
Skilafrestur 21. October 2014 kl. 15:00

1. **Copper Oxide Layers** (15)

   The common building blocks for most high temperature (high T_c) superconductors are copper oxide layers, as shown below. Assume the distance between copper atoms (filled circles) is a. For simplicity let us also assume that in the third dimension these CuO_2 layers are simply stacked with spacing c, and there are no other atoms in the crystal. In first approximation the layers have a four-fold symmetry; the crystal is tetragonal.



   (a) Sketch the Bravais lattice and indicate a possible set of primitive vectors for this crystal. What is the unit cell, and what is the basis ?



(b) In $LaCuO_4$ one discovers, at closer inspection, that the CuO_2 lattice is actually not flat, but that the oxygen atoms are moved a small amount out of the plane ("up" or "down") in an alternating fashion (in the figure a + meand up and a - means down). What is the primitive cell and lattice spacing for this crystal ? What is the reciprocal lattice ? Describe (qualitatively) what happens in the X-ray diffraction pattern as the distortion is decreased gradually to zero.

$LaCuO_4$ is an antiferromagnetic insulator. High temperature superconductivity was discovered in a closely related compound $La_{1-x}Ba_xCuO_4$. See J. G. Bednorz and K. A. Müller, *Z. Physik B* **64**, 189 (1986).

2. **Fermi temperature** (10)

   Calculate the Fermi temperatures T_F for Cu, Na, and Ag. Also calculate the ratio T/T_F in each case for $T = 300$ K. The effective mass of Cu and Na are 1.0 and 1.2 times m_0.

3. **Einstein and quantum theory** (10)

   Describe how Einstein used quantum theory to explain the low-temperature behavior of the specific heat in solids. Use more than four sentences in your response.

4. **Thermal motion and resistivity** (10)

   Show that if the random velocity of the electrons were due to thermal motion of a classical electron gas, the electrical resistivity would increase with the temperature as $T^{3/2}$.

5. **Fermi velocity** (10)

   Estimate the ratio of the drift velocity to the Fermi velocity for a 2 mm^2 Cu wire carrying a 20 A current.