Solid state physics (*winter term 2015/2016*)

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Exercise sheet 5

1. Elastic Waves in Cubic Crystals

a. Calculate the propagation velocities of longitudinal and transverse waves along the [100] direction in a cubic crystal.

b. Repeat part (a) for a longitudinal and transverse wave in the [110] direction.

2. 2D square lattice

Atoms in a membrane are arranged in a two dimensional square lattice. The membrane is stretched so that Newton's law for transverse motion of atoms is:

$$M\frac{d^2u_{n,m}}{dt^2} = C\left[\left(u_{n+1,m} - 2u_{n,m} + u_{m-1,m}\right) + \left(u_{n,m+1} - 2u_{n,m} + u_{n,m-1}\right)\right].$$

Here $\boldsymbol{u_{n,m}}$ is the motion of atom (n, m) perpendicular to the plane, **"M"** is the mass of the atoms spaced by a distance **"a"** and **"C"** is the spring constant. Only nearest neighbour connections are considered.

Assume a harmonic form for the solution of $u_{n,m}$ and show that the dispersion relation for the out-of-plane transverse modes is:

$$w = \sqrt{\frac{2C}{M}\left(2 - cosk_x a - cosk_y a\right)}$$

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3. Brillouin Scattering

A laser beam of wavelength λ = 694 nm passes through a quartz crystal. The laser beam can be scattered by the mechanical vibrations in the crystal. An elastic interaction between photons and phonons takes place, with no recoil in the lattice. Calculate the maximum frequency of the mechanical vibrations induced in the lattice and the relative frequency change of the scattered light. Make use of momentum and energy conservation laws and the fact that the scattering is elastic ($k = k'$).

(Speed of sound: v_s = 6000 m/s, refractive index: n = 1.54)

Please return on 25/11/2015