Condensed matter physics 2013
Exercise 5

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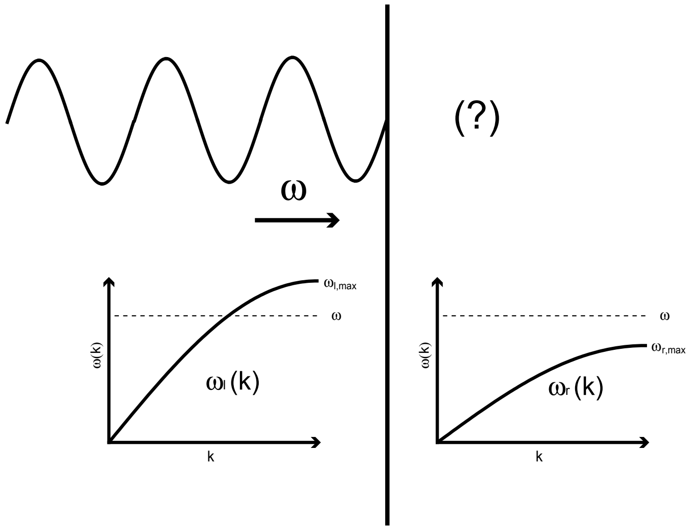
Problem 19

a) Assume two crystals with different phonon dispersion relations $\omega_l(k)$ and $\omega_r(k)$ in perfect contact with each other. Assume a lattice vibration (phonon) with frequency ω incident from



the left to the right crystal. What will happen, if $\omega > \omega_{r,max}$, meaning that there are no allowed lattice vibrations at the frequency of the incident oscillation in the right crystal ?
b) For a quantitative solution, use a complex Ansatz for the wave vector k_r in the right crystal. Use the conditions for the reflection and transmission coefficient, that have been derived in the lecture. Use the continuum approximation, and consider only acoustic phonons.

* Problem 20 (3)

We consider a linear 1D chain with identical masses m connected by two different kind of springs to the left and right (force constants f_1 and f_2). The distance between two masses is $a/2$, the periodicity of the chain is a. Assume that forces are only exerted between nearest neighbours.

(a) Find the equation of motion for longitudinal oscillations, and derive the dispersion relation from it. Sketch and discuss the two limits $k = 0$ and $k = \pi/a$. What are the amplitudes at these two points ? Give an expression for the phase- and group velocity v_ϕ and v_g.

(b) Discuss the case $f_1 = f_2 = f$ and show the transition to a linear chain with identical spring constants!

(c) Compare the above results with the ones derived in the lecture for a linear chain with two different masses m_1 and m_2.

(d) Compare the dispersion relation with that of the monatomic linear chain when $m_1 = m_2$

* Problem 21 (1)

Consider a linear KCl-chain with a distance between K and Cl of 3.1Å and a spring constant $f = 8.8$ N/m. The atomic weight of K is 39, that of Cl 35.5.
a) How wide are the phonon bands, and how big is the energy gap between the acoustic and the optical branch ?
b) Calculate the wavelength of a photon, that has the same energy as the optical phonons at $k = 0$!

* Problem 22 (2)

Determine the phonon density of states in k-space $\rho_k(k)$ for two dimensions! How does the density of states in frequency space $\rho_\omega(\omega)$ look like for the case of a linear dispersion relation $\omega \propto k$ (for one, two and three dimensions) ?