Physics with neutrons 1

Sebastian Mühlbauer, sebastian.muehlbauer@frm2.tum.de
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Exercise sheet 11
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Lukas Karge, lukas.karge@frm2.tum.de, Tel.: 089-289-11774

Exercise 11.1

Derive the intermediate scattering function, pair correlation function, and the scattering law $S(\mathbf{Q}, \omega) = \frac{1}{2\pi\hbar} \int dt\, e^{-i\omega t} I(\mathbf{Q}, t)$ for a single atom that oscillates harmonically in one dimension with a frequency ω_0. When you perform the Fourier transform, assume that the amplitude of the oscillation is very small.

Exercise 11.2

Prove that from the knowledge of the dispersion relation ω_q it is possible to determine the force constants k_n unsing the relation

$$k_n = -\frac{Ma}{2\pi} \int_{-\pi/a}^{\pi/a} \omega_q^2 \cos(nqa) dq.$$

Exercise 11.3

The acoustic phonon branches of many "simple" compounds are well explained by the sinusoidal dispersion relation derived in the lecture. The transverse acoustic phonon branches observed for germanium, however, exhibit an unusual flattening of the dispersion relation upon approaching the zone boundary (Fig. 2). Germanium is a semiconductor with covalent bonds which are usually formed from two electrons, one from each atom participating in the bond. These electrons tend to be partially localized midway between the two atoms and constitute the so-called bond charge (Fig. 1). Derive the phonon dispersion for the one-dimensional chain illustrated in Fig. 1 by following the procedure for a diatomic one-dimensional chain from the lecture.

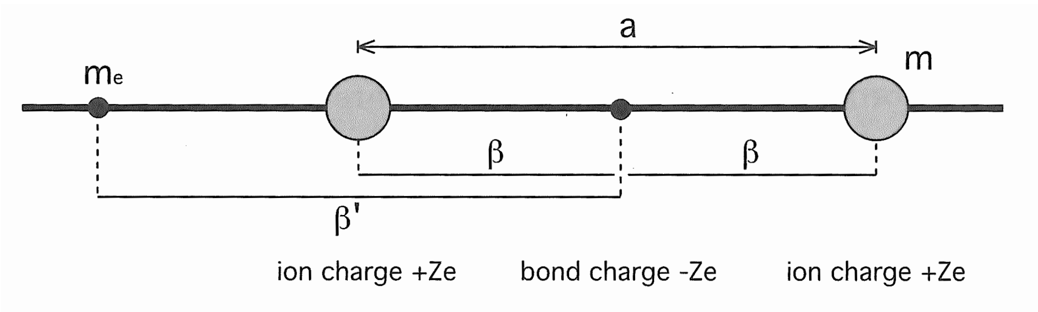

Figure 1: Linear chain formed by alternating ion and bond charges. Bond charges are connected via effective force constants β and β' to neighboring ion and bond charges, respectively.

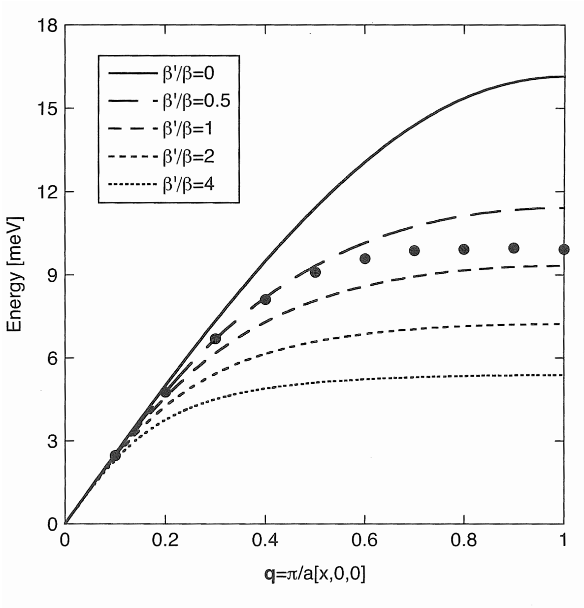

Figure 2: Dispersion relation of the lower transverse acoustic phonon branch measured for Ge at 80 K along the [100] direction (after [Nellin and Nilsson (1972)]).