8. Repetition

- Which two models of charge screening did you encounter in the lecture and what is the difference between them?
- Describe in your own words: What is a Peierls instability and what are the ingredients?
- What is a Kohn Anomaly?
- Explain the notion of effective mass. What contributes to it?
- Explain the difference between a hole and an electron in a solid?
- What is the Boltzmann equation used for? Can you write it and explain its terms?

9. Charge density waves

a) In the lecture, we introduced the Lindhard response function

$$\chi(q) = \int \frac{d\boldsymbol{k}}{(2\pi)^d} \frac{f(\boldsymbol{k}) - f(\boldsymbol{k}+\boldsymbol{q})}{\varepsilon(\boldsymbol{k}) - \varepsilon(\boldsymbol{k}+\boldsymbol{q})}$$

Calculate $\chi(\boldsymbol{q})$ for 1 and 3 dimensions for a simple dispersion $\varepsilon_F = \frac{\hbar^2}{2m}\left(\frac{N_0 \pi}{2L}\right)^2 = \frac{\hbar^2 k_F^2}{2m_e}$. Compare your result with the graph shown in the lecture. Assume low temperatures. Plot for both cases $\chi(q)/\chi(0)$. [Hint I: remember that the Fermi functions act like a cutoff function at the Fermi level. Hint II: rescale the boundaries of the integral and look up the expression].

b) In the lecture we introduced the reduced frequency of phonon modes

$$\omega_{ren,2k_F}^2 = \omega_{2k_F}^2 - \frac{g^2 n(\varepsilon_F)\omega_{2k_F}}{\hbar} \cdot ln\left(\frac{1.14\epsilon_0}{k_B T}\right)$$

The critical exponent for $\omega_{ren,2k_F}(T)$ approaching T_{CDW} is resulting from this is (Gruener, p. 36)

$$\omega_{\mathrm{ren},2k_F} = \omega_{2k_F}\left(\frac{T - T_{\mathrm{CDW}}^{\mathrm{MF}}}{T_{\mathrm{CDW}}^{\mathrm{MF}}}\right)^{1/2}$$

The figure shows a measurement of the phonon dispersion in ZrTe3 [Hoesch et al., PRL 102, 086402 (2009)]. What phenomenon is seen here? How is it measured? What information can you deduce from the figure? How is this discussed in the paper?

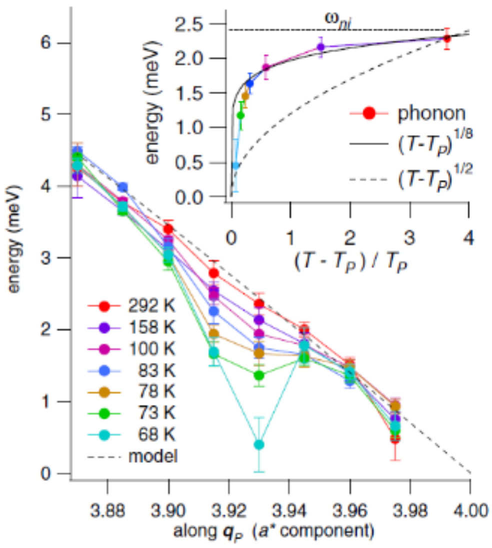

FIG. 2 (color online). Phonon dispersion from $(40\bar{1})$ in the direction of $\vec{q}_P$ at various temperatures $T > T_P$ above the transition. The inset shows the phonon energy $\hbar\omega_q$ at $\vec{q}_P$ as a function of reduced temperature $(T - T_P)/T_P$. The solid and dashed lines represent a $1/8$ and a $1/2$ power law, respectively.

10. Hall Effect using Boltzmann equation

In order to find the Hall coefficient in the context of the Boltzmann equation, one may proceed in the following way: write the Boltzmann equation and reduce it by suppressing the terms that will not contribute (search a stationary solution, assume the system is homogenous).

Now assume $\boldsymbol{B} = (0,0,B)$ and $\boldsymbol{E} = (E_x,E_y,0)$ and guess a solution of the form $g(\mathbf{k}) = ak_x + bk_y$.

a) Determine a and b.

b) Compute currents along x and y and find the total conductivity tensor. Express the resistivity sensor in terms of the Hall coefficient R.

How does the result changes in the case of $\boldsymbol{E}$ assumed to be parallel to $\boldsymbol{B}$.