University of California Santa Cruz — Physics Department

Condensed Matter 232 WQ 2019

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14 February 2018

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1. When metallic Na crystallises, it forms a cubic lattice with the lattice constant $d = 0.37nm$. Compute the Fermi energy assuming that the quasiparticle dispersion is quadratic with the effective mass $m^* = 1.08m_e$.

2. A Weyl semimetal is a 3D system with the quasiparticle dispersion $\varepsilon_{\mathbf{k}} = v\mathbf{k} \cdot \hat{\boldsymbol{\sigma}}$, where v is a constant, called "Fermi velocity", $\mathbf{k}$ is the quasimomentum measured from some point (Weyl node) in the Brillouin zone and $\hat{\boldsymbol{\sigma}}$ is a degree of freedom equivalent to spin-1/2. A Weyl semimetal necessarily has an even number N of Weyl nodes. In some sense, a Weyl semimetals is the 3D version of graphene.

(a) Find the density of quasiparticle states near a Weyl node.

(b) Compute the heat capacity of a Weyl semimetal, assuming the chemical potential lies exactly at the node.

Hint: if you find it difficult to compute the heat capacitance, try to obtain first its temperature dependence from a qualitative argument.

3. A system of two touching rectangular frames, made of impurity-free 1D wires, is placed in magnetic field B, as shown in Fig. 1. The area of each rectangular wire is S. Plot the dependence of the conductance between points A and B as a function of the magnetic field.

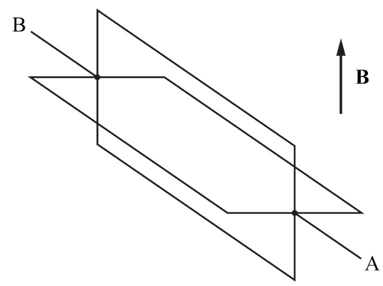

Figure 1: A system of 1D metallic wires.

4. A short pulse of voltage $V(t) = V_0\delta(t)$ is applied to a disordered conductor with the elastic scattering time τ. How does the current $\mathbf{j}(t)$ in the conductor depend on time?

Hint: the system may be described by the kinetic equation with the collision integral in the τ-approximation.

5. The dephasing time in a disordered metal is given by $\tau_\varphi = aT^{-\alpha}$ and leads to the temperature dependency of conductivity $\sigma(T) \propto const - \ln T$. Estimate the characteristic magnetic field B at which the conductivity becomes temperature-independent.