Theorie der Kondensierten Materie I WS 2012/2013

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Blatt 14
Besprechung 08.02.2013

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1. Kinetic equation (40 + 20 + 40 = 100 Bonuspunkte)

The kinetic equation for the distribution function $f(\boldsymbol{p}, \boldsymbol{x}, t)$ of electrons (or fermionic quasi-particles) is given by $df/dt = I(f)$. Using the relaxation time approximation for the collision integral $I[f]$, this becomes

$$\frac{\partial f}{\partial t} + \frac{\partial f}{\partial \boldsymbol{x}} \cdot \frac{d\boldsymbol{x}}{dt} + \frac{\partial f}{\partial \boldsymbol{p}} \cdot \frac{d\boldsymbol{p}}{dt} = -\frac{f - f_0}{\tau}\,.$$

Here, f_0 is the equilibrium distribution function that depends on energy ϵ alone, and τ is the relaxation time towards equilibrium.

(a) Find the kinetic equation in the presence of a small constant and uniform electric field $\boldsymbol{E}$. Use that the work done by the applied field equals the energy gained by the electron $\frac{\partial \epsilon}{\partial t}$ and $\boldsymbol{v} = \frac{\partial \epsilon}{\partial \boldsymbol{p}}$.

(b) Assuming the applied field is weak, we may write $f = f_0 + f_1$ with $|f_1| \ll f_0$. Using this assumption solve the stationary kinetic equation for f_1.

(c) Determine the electric current $\boldsymbol{j}$ and the electric conductivity σ from $\boldsymbol{j} = \sigma \boldsymbol{E}$ with

$$\boldsymbol{j} = 2e \int \boldsymbol{v} f d^3p = 2e \int \boldsymbol{v} f \nu(\epsilon) d\epsilon \frac{d\Omega}{4\pi}\,,$$

where $\nu(\epsilon)$ is the density of states and $d\Omega$ denotes the integration over the solid angle. Use that f_0 depends on energy alone, that $\frac{\partial f_0}{\partial \epsilon} \approx -\delta(\epsilon)$ and that $\int \boldsymbol{n}(\boldsymbol{n} \cdot \boldsymbol{E})\frac{d\Omega}{4\pi} = \boldsymbol{E}/3$, where $\boldsymbol{n} = (\sin\theta\cos\phi, \sin\theta\sin\phi, \cos\theta)$.