Prof. Dr. R. Berndt
T. Jasper-Tönnies

Problems for *Physik der Materie III*

Due by May 29, 2019

Series 6: Hall effect and free electron Fermi gas

6.1 Hall effect

Hall's experiment is depicted in Fig. 1. An electric field E_x is applied to a metallic wire extending in the x-direction and a current density j_x flows in the wire. In addition, a magnetic field $\mathbf{B}$ is applied along the positive z-direction.

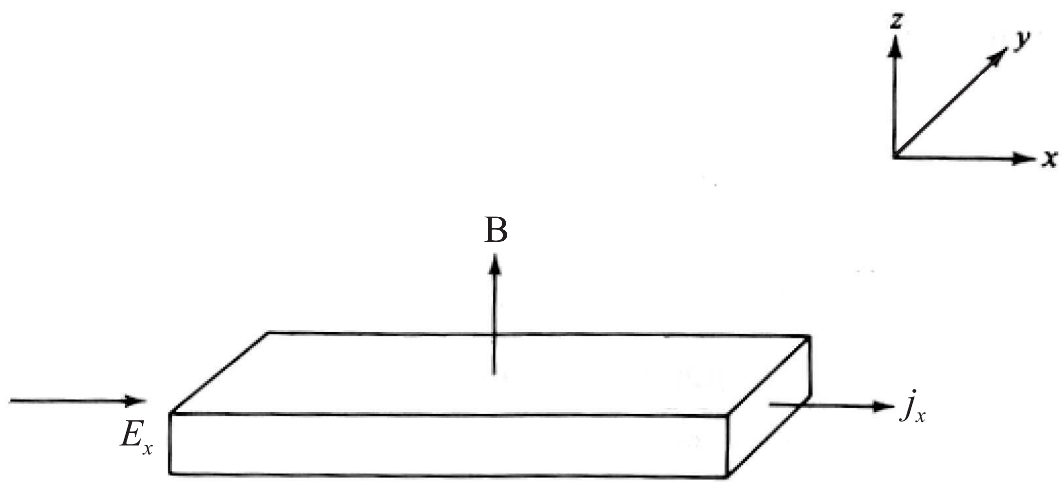

Figure 1: Schematic view of Hall's experiment.

(a) Using Drude's model (equation in Problem 5.2b), show that in the steady state regime, there is a balancing transverse electric field E_y, called the Hall field which is proportional to E_x in equilibrium.

(b) Determine the direction of the Hall field and show that by measuring the polarity of the voltage along the y-axis it is possible to determine the sign of the charge of the carriers ($q = \pm e$).

(c) Using the results from a), show that the resistance $\rho_o = E_x/j_x$ along the x-axis does not depend on the magnetic field, i. e. the magnetoresistance is zero.

(d) The Hall field is usually expressed by $E_y = R_H j_x B$, where R_H is the Hall constant. Determine R_H and the relation between R_H and $\sigma_o = \tau n e^2/m$. Show that the mobility of the charge carriers $\mu = e\tau/m$ can be obtained from R_H and σ_o.

(e) For $B = 1$ T and $j_x = 1$ A/mm^2, estimate the Hall constant R_H and the Hall field E_y for a metal with a density of charge carriers (electrons) of $n \sim 10^{22}$ cm^{-3}, and of a semiconductor with a density of charge carriers (electrons or holes) of $n \sim 10^{16}$ cm^{-3}.

6.2 Density of states

Determine the expression of the density of states $D(E)$ of a free electron gas in one and two dimensions in a square well potential. Express $D(E)$ in terms of the Fermi energy E_F and the number of electrons N.