Analysis of the Anomalous Hall Effect in MnSi and $La_{2-2x}Sr_{1+2x}Mn_2O_7$ (x=0.36)

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Background

The Hall Effect, in which a transverse voltage develops across a current-carrying wire in a magnetic field, is a well-understood phenomenon which provides a simple way to measure the sign and density of the charge carriers in a material. The Anomalous Hall Effect (AHE) is a related effect which occurs only in ferromagnetic materials and is directly related to the spontaneous magnetization of the material. However, the exact nature of how the material's properties affect the AHE is still unknown. My project will study the AHE in two ferromagnetic materials; MnSi and $La_{2-2x}Sr_{1+2x}Mn_2O_7$ x=0.36 (LSMO).

MnSi is a high-purity ferromagnetic metal with Curie temperature T_c=30 K. Its electronic properties remain consistent over wide ranges above and below its ferromagnetic transition temperature, making it a valuable baseline material for AHE studies. Additionally, this transition temperature is located far below the Debye temperature, meaning that the behavior of the AHE can be observed free from electron-phonon interactions. Increasing the pressure on MnSi reduces its transition temperature, with T_c finally reaching 0 K at p_c=14.6 kbar.[1] Rather than vanishing entirely, however, partial order in the material persists from the p_c up to 22 kbar.[2]

LSMO is a colossally magnetoresistant material with a transition temperature at 160 K. The large change in resistivity as the material transitions to a ferromagnetic state will allow us to study how electron transport is related to magnetization in the material.

Project

My project will focus on measuring the behavior of the AHE in MnSi below its T_c of 30 K in the region between 14.6 kbar to 22 kbar. At ambient pressure and below T_c, MnSi exhibits Fermi liquid behavior, characterized by a squared temperature (T^2) dependence of the resistivity. However, above p_c=14.6 kbar, the Fermi liquid behavior breaks down, giving rise to a near-Fermi liquid region in which resistivity depends on $T^{1.5}$. To perform this study, I have written control code in Matlab to automate data acquisition and will assist in constructing the pressure cell for the MnSi sample. I will take resistivity and Hall voltage measurements of the MnSi sample under pressure, focusing on the region in which near-Fermi liquid behavior occurs. Fermi-liquid behavior may be recovered at several times the p_c[3], so even higher pressures may be studied as time permits.

LSMO resistivity and hall measurements will be carried out from 300 K-4 K with a focus on the LSMO's ferromagnetic transition temperature at 160 K. The primary goal in this research will be to determine how the AHE in LSMO is affected by forcing magnetization above the transition temperature using a 13 T solenoid. I will also analyze the effect of phonon-electron scattering on the AHE in LSMO, as its transition temperature may be high enough that the phonon interaction in the material is not completely frozen out.

Timeline

- Fall 2010 – Literature review, learn Matlab, begin setting up lab
- January-February 2011 – Finalize Matlab control code and finish setting up lab
- March 2011 – Initial measurements of MnSi sample
- April 2011 – Construct pressure cell, continue MnSi measurements
- Summer 2011 – Finish MnSi measurements, begin LSMO measurements
- Fall 2011 – Finish writing thesis and presentation
- November 2011 – Defend thesis

References

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