# Investigating the Hall effect to identify an unknown conductor

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## Introduction and background

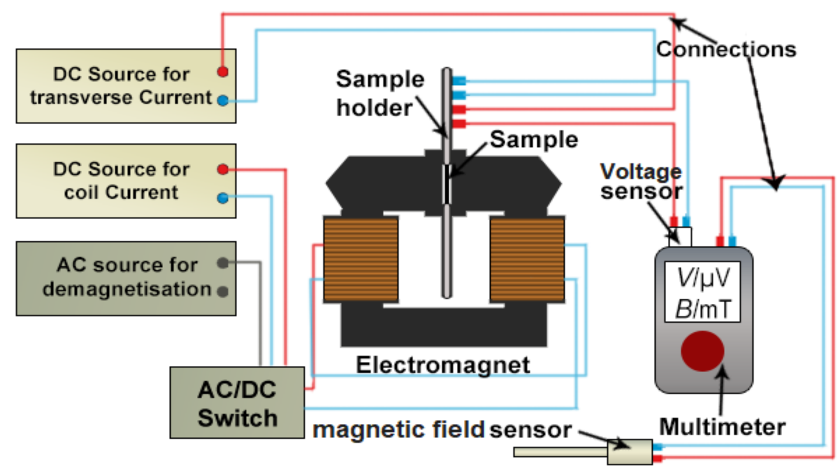
When a magnetic field is applied at a right angle to a current-carrying sample, a potential difference called the Hall voltage could be measured across the sample. This phenomenon, known as **the Hall effect,** and is useful in measuring magnetic fields and the electronics industry.

The magnetic force applied to the charge carriers in the sample deflects them to one edge, causing an accumulation of the opposite charge on the opposite edge of the sample, which creates an electric field across the width with an electric force that balances the magnetic force. In this steady state, the Hall voltage $V_H$ could be calculated as $V_H = \frac{IB}{nqt}$, where $I$ is the current flowing through the sample, $B$ is the strength of the magnetic field, $t$ is the thickness of the sample, $n$ is the carrier density and $q$ is the charge. The quantity $R_H = \frac{1}{nq}$ is known as the Hall coefficient and is characteristic of the conductor (The Open University, 2022).

By investigating the Hall effect in an unknown conductor, the aim of this experiment is to identify the conductor by determining its characteristic quantities and comparing the results to standard values.

## Methods

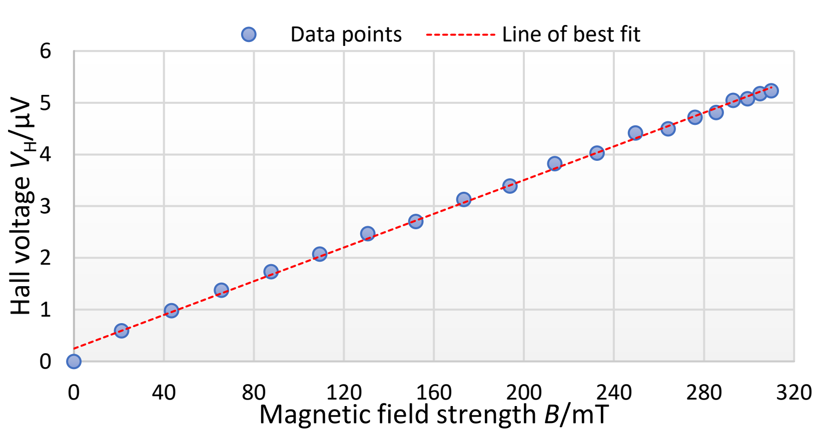
Using an electromagnet connected to current sources, sensors and a multimeter (shown in the schematic), currents ranging from 0 A to 10 A with spacings of 0.5 A were applied to the electromagnet coils, and the resulting magnetic field was measured by the sensor. The same coil current values were applied again while a fixed current of 10 A was applied to the 50 µm thick sample. The voltage $V$ reading was recorded for each current applied to the coils, and the data of the voltage, the coil current and the corresponding magnetic field was processed.




Schematic of the Hall effect experimental set up

## Results and discussion

In this graph, a trend line was fitted to the data, with the Hall coefficient as the gradient and calculated as (8.14 ± 0.09) × $10^{-11}$ m$^3$ C$^{-1}$. This gave a carrier density of (7.68 ± 0.08) × $10^{28}$ m$^{-3}$. The uncertainty is estimated based on the precision of the equipment, considering possible fluctuations and thermal effects.




The Hall voltage ($V_H = V - V_0$) as a function of the magnetic field

- Compared to the standard values, the quantities measured for the sample are closer to those of silver, whose Hall coefficient is 8. 9 × $10^{-11}$ m$^3$ C$^{-1}$ and number density is 6.6 x $10^{28}$ m$^{-3}$. The difference could be due to underestimation of the error and errors in determining the Hall voltage, especially as the intercept in the graph indicates an error in determining the zero-point voltage $V_0$. The polarity inferred from the geometry of the set up, however, matched the negative carrier polarity of silver.
- In repeat readings of the voltage, the voltmeter gave odd readings that were significantly higher than the previous reading. By examining the live readings, an error was found in the voltmeter offset and the voltmeter was re-zeroed properly to give more consistent readings.
- The current applied to the sample was chosen before the experiment considering its proportionality with the resistive voltage. The experiment could be improved by testing a range of the sample current to choose an appropriate value experimentally.

## Conclusions

- The magnetic field strength was measured, as well as the Hall voltage it gave rise to in a sample carrying a current of 10 A.
- The data analysis showed that the Hall coefficient and charge carrier density were (8.14 ± 0.09) × $10^{-11}$ m$^3$ C$^{-1}$ and (7.68 ± 0.08) × $10^{28}$ m$^{-3}$, respectively, while the polarity was found to be negative. These results indicate that the sample is silver.

## References


The Open University (2022) 'Hall effect investigation Task 2: Background reading and planning: 2.1 The physics of the Hall effect', *SM381: Electromagnetism*. Available at: https://learn2.open.ac.uk/mod/oucontent/view.php?id=2046178&section=2 (Accessed: 4 January 2023)