Investigating the Hall effect in silver

Objectives:

1-Validation of the proportionality of the Hall voltage and the magnetic flux density.
2-Determining the polarity of the charge carriers
3-calculating the Hall constant RH and the charge carrier concentration n.

Principle:

The Hall effect is basic to solid-state physics and an important diagnostic tool for the characterization of materials – particularly semi-conductors. It provides a direct determination of both the sign of the charge carriers, e.g. electron or holes , and their density in a given sample.
The basic setup is shown in Fig. 1: A thin strip (thickness d) of the material to be studied is placed in a magnetic field B oriented at right angles to the strip

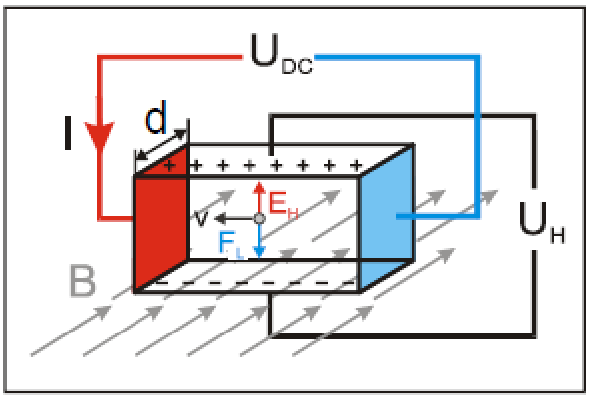


figure 1 :Hall effect schematically: inside a charge carrying metallic conductor which is located in the magnetic field B the Lorentz force F_L is causing an electric field E_H resulting in a Hall voltage U_H (I denotes a transverse current).

A current I is arranged to flow through the strip from left to right, and the voltage difference between the top and bottom is measured. Assuming the voltmeter probes are vertically aligned, the voltage difference is zero when B = 0.
The current I flows in response to an applied electric field, with its direction established by convention. However, on the microscopic scale I is the result of either positive charges moving in the direction of I, or negative charges moving backwards. In either case, the magnetic Lorentz force $qv\times B$ causes the carriers to curve upwards. Since charge cannot leave the top or bottom of the strip, a vertical charge imbalance builds up in the strip. This charge imbalance produces a vertical electric field which counteracts the magnetic force, and a steady-state situation is reached. The vertical electric field can be measured as a transverse potential difference on the voltmeter.
Suppose now that the charge carriers where electrons ($q = -e$). In this case

negative charge accumulates on the strip’s top so the voltmeter would read a negative potential difference. Alternately, should the carriers be holes (q = +e) we measure a positive voltage.

In this experiment, a current carrying metallic conductor strip is located in a magnetic field B perpendicular to the direction of the current I,a transverse electric field E_H and a potential difference is produced (Hall effect)

the following equation holds for the Hall voltage U_H

$$U_H = \frac{1}{n\,e}\,\frac{B\,I}{d} \qquad 1$$

B=magnetic flux density.

I:current through the metallic conductor.

d:thickness of band-shaped conductor.

n:concentration of the charge carrier.

e:elementary charge=1.602×10^{-19}C

The Hall voltage U_H is caused by the deflection of the moving charge carriers in the magnetic field due to the lorentz force, whose direction may be predicted by the right hand rule. The factor $\frac{1}{n\,e}$ is called Hall constant R_H

$$R_H = \frac{1}{n\,e} \qquad 2$$

the sign of the Hall constant is determined by the polarity of the charge carriers.

The Hall constant depends on the material and the temperature .For metals R_H is very small ,however, for semiconductors R_H becomes significantly large.

The polarity of the charge carriers can be determined from the direction of the hall voltage. The concentration of the charge carriers n can be determined experimentally by measuring the Hall voltage as function of the magnetic field B for various currents

Apparatus:

Hall effect apparatus(silver)
U-core with yoke
Pair of bored pole pieces
2coil with 250 turns
High current power supply
Variable extra low-voltage transformer
multimeter
pair cables
connecting leads
Leybold multiclamp
stand rod
stand base ,V-shape
microvoltmeter
combi B-sensor S

Extension cables,15 pole

carrying out the experiment:

a)calibration of the magnetic field

1-set up the U-core with yoke. The pair of bored pole pieces and the coil with 250 turns as shown in fig2.set the pole piece spacing of the electromagnet exactly to the thickness of the support plate of the Hall effect apparatus.

2-connect the coils with 250 turns in series to the extra low voltage transformer and locate the Combi B-sensor S between the pole piece. and to measure the current connect the ammeter between the positive pole of the voltage transformer and the coil.

3-demagenetize the iron of the electromagnets before recording the magnetic field as a function of the current I by allowing to flow a I= 5 A AC current through the field coils for a short time; then steadily reduce the current to zero.

4-measure the magnetic flux density B as a function of the current I by increasing the current I in steps of 0.5 A DC.

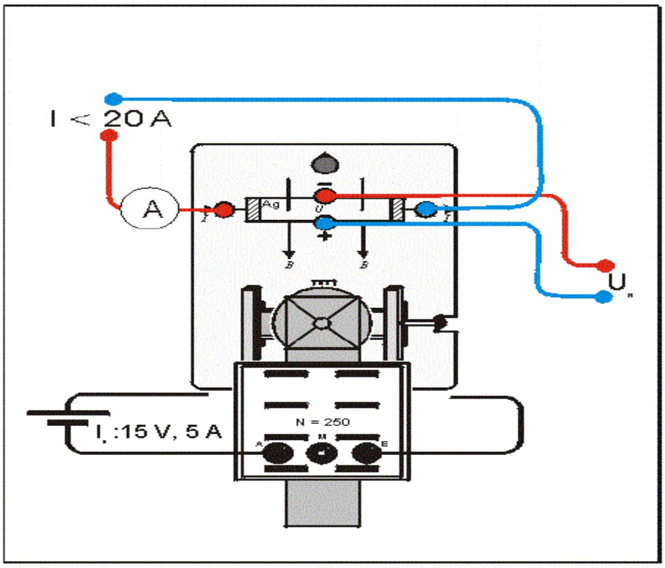


figure 2:experimental setup (wiring diagram)

b)Measuring the Hall voltage as a function of the magnetic field

1-Mount the Hall apparatus and push the pole piece so the gap between them is as close as possible and of the same width as for recording the calibration curve.

2-connect the microvoltmeter and the the high current power supply to the support plate of the Hall apparatus,

3-Before exposing the Hall effect apparatus to the magnetic field, adjust the zero point; Apply a transverse current I of e.g. 10 A and set the meter for measuring the

Hall voltage U_H to zero using using the black knob on the Ha; effect apparatus .If the display changes after switching the transverse current back on and repeat the zero-point adjustment.

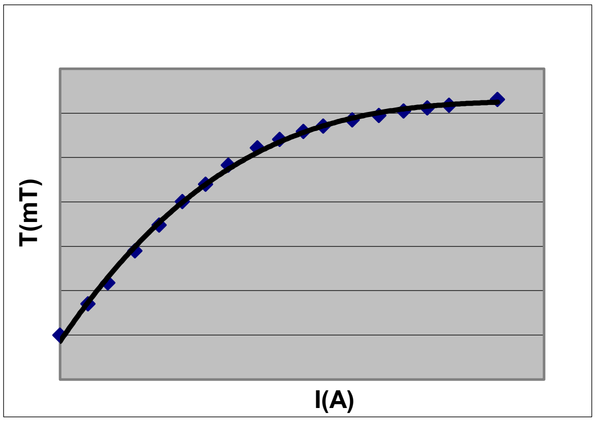
4-Apply a transverse current I=15 A to the Hall effect apparatus and measure the hall voltage U_H as a function of the magnetic field B(Read off the effective field value from the calibration curve).carry out several measurements to determine a mean value for the Hall voltage.

5-Repeat the measurements for a transverse current I=20A.

measurements and results:

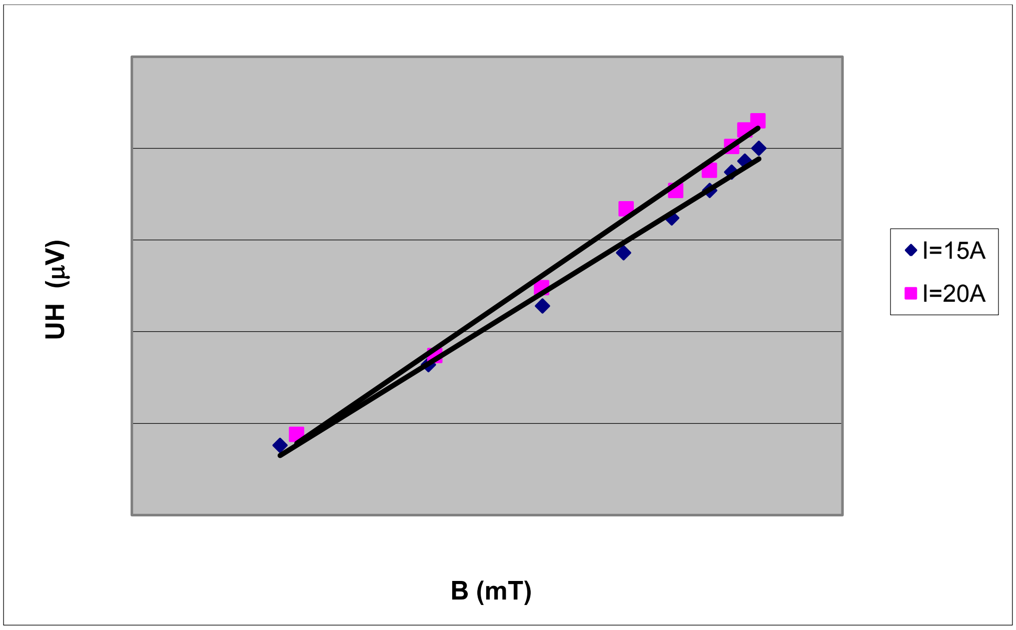
a)calibration of the magnetic field:

I(A)	B(T)



b)measuring the Hall voltage as a function of the magnetic field:

B(T)	U_H(μv)	B(T)	U_H(μv)



-find the slope A_H

-find $R_H = slope \frac{d}{I}$ where $d=5x10^{-5}$ m

-find $n=\frac{1}{e R_H}$

-determine the error in n where the literature value $=6.6x10^{28} m^{-3}$