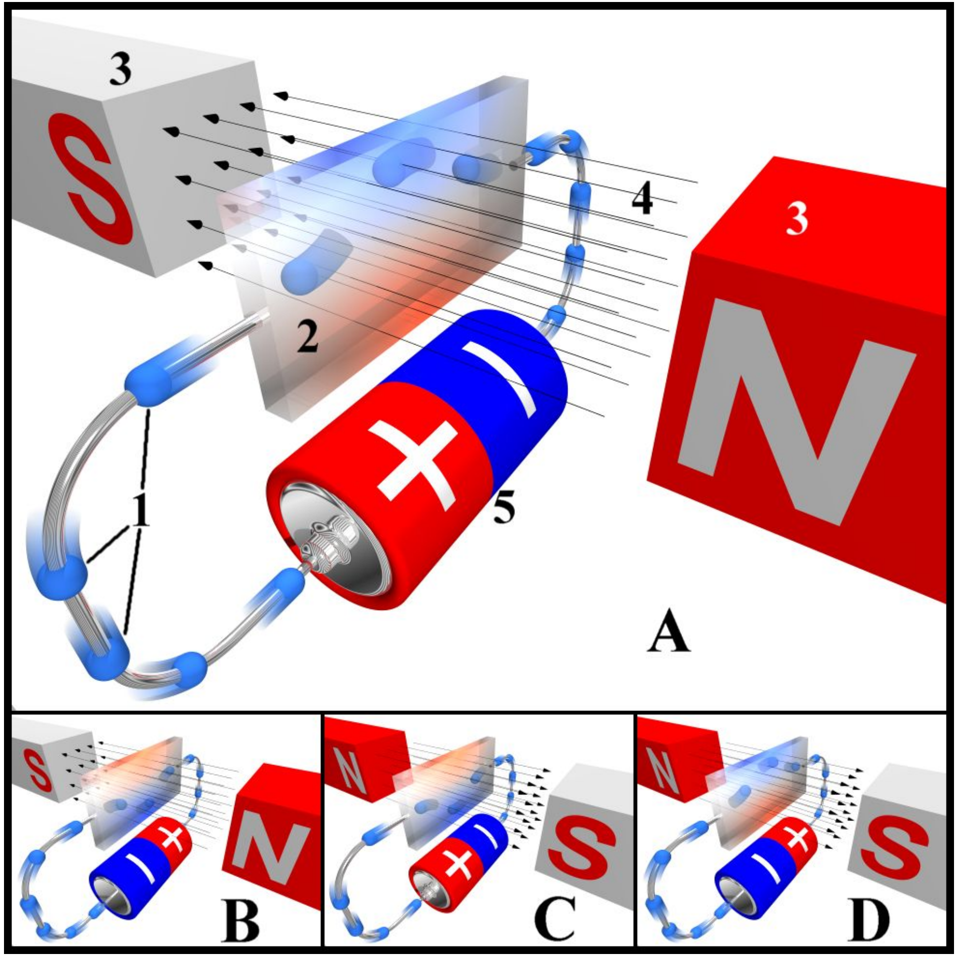
Hall Effect

James Amidei

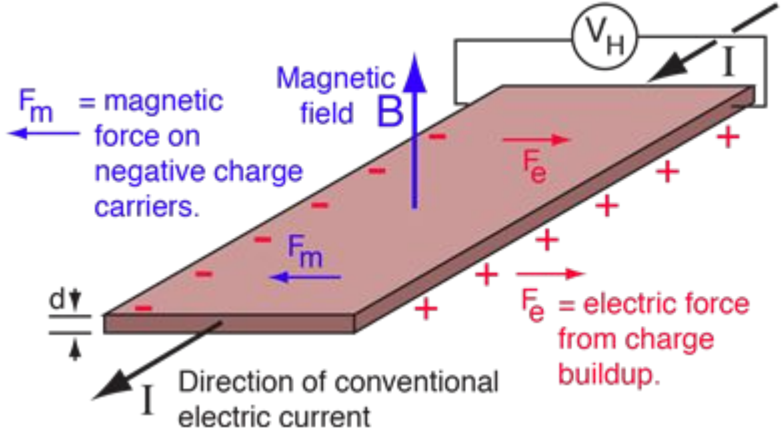


Theory

- Charged particles in motion experience a force when in the presence of a magnetic field.
- This force results in a voltage difference that is orthogonal to the current.
- We can use this voltage to find the resistivity, mobility, as well as the number and type of majority charge carriers.

$$\vec{F}_B = q\vec{v} \times \vec{B} \quad \text{(force due to magnetic field)}$$

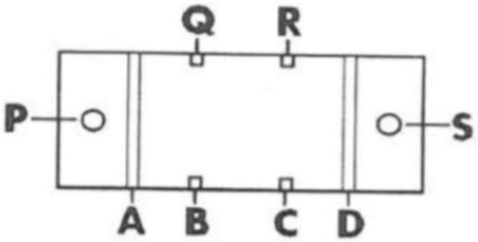
$$\vec{F}_E = q\vec{E}_u\hat{u} = q\frac{V_H}{w}\hat{u} \quad \text{(electrostatic force)}$$



Instrumentation: Source Measure Unit

- We used a Keithley 2450 SourceMeter
- Functions as voltage source, a current source, a voltmeter, and an ammeter.
- Used to generate a current in order to detect a voltage.
  - Current set between 0-500 microamps with 10 microamp step size.
  - Source limit set to 2 volts with a source delay of 0.1 seconds.

Data Analysis



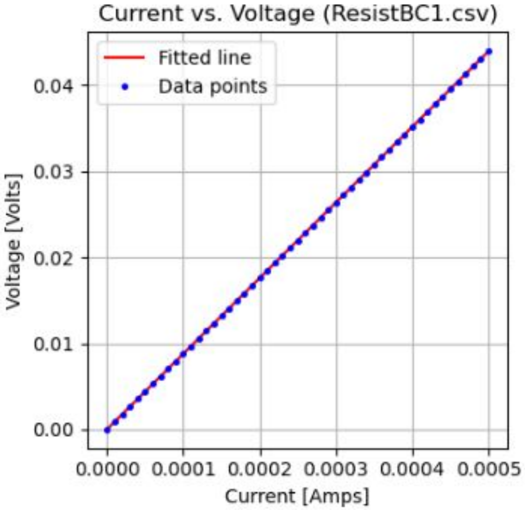
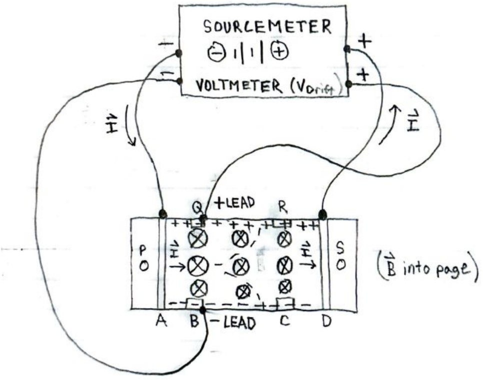


Figure A: Measurement for B-C. Resistance is slope of line of best fit: V = 87.851 I. This was used, along with the area and length to find the resistivity.



Drawing of experimental setup.

- Voltage source connected from A-D and Voltmeter connected across B-Q, B-R, C-Q, and C-R.
- Resistivity found by measuring voltage from B-C and Q-R.
  - **Resistivity: 0.00729 Ohm-meter +/- 0.0013 Ohm-meters**

$$\rho = R\frac{A}{l} = R\frac{wt}{l} \quad \text{(resistivity)} \qquad n = \frac{B}{qtR_H} \quad \text{(carrier number)}$$

$$\mu = \frac{1}{nq\rho} \quad \text{(mobility)}$$

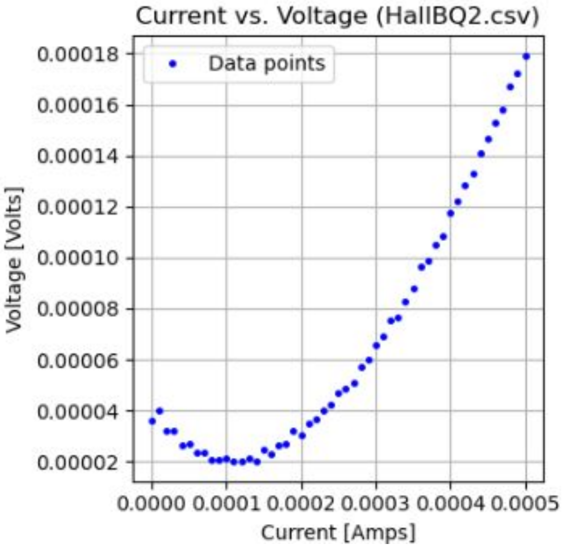


Figure B): From B-Q, w/ magnetic field present.

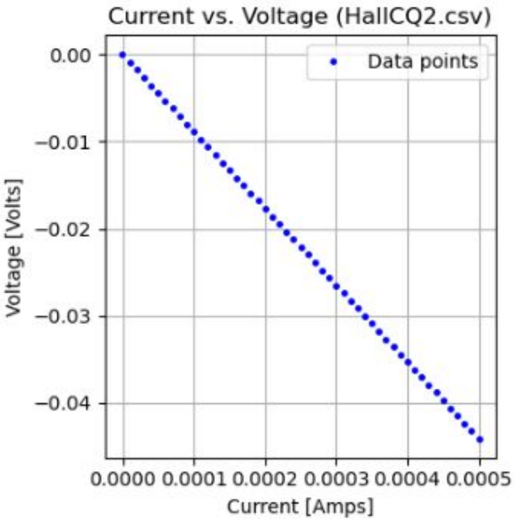


Figure C): From C-Q w/ magnetic field present.

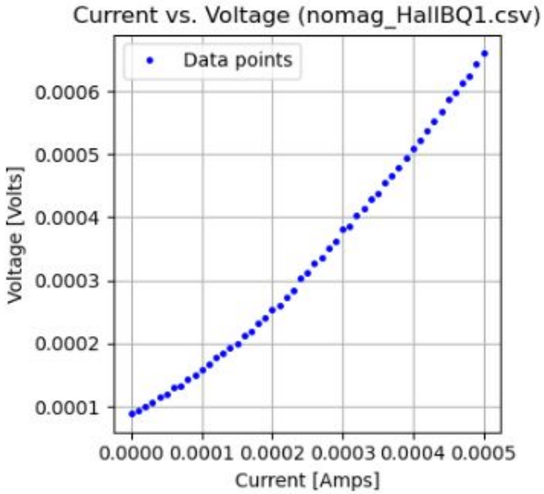


Figure D): From B-Q w/o magnetic field present.

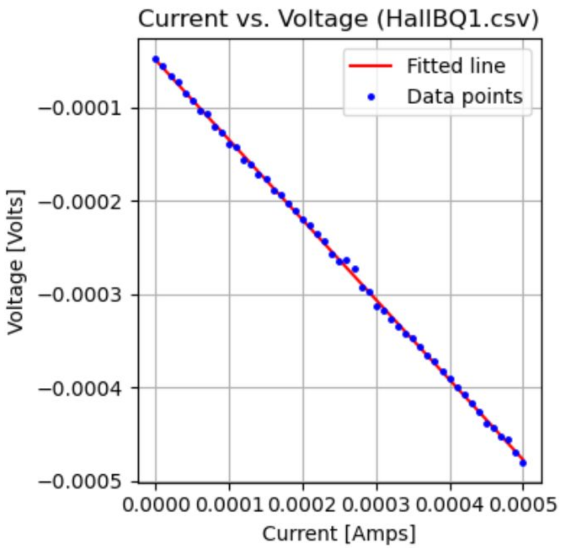


Figure E): B-Q w/ magnetic field minus B-Q w/o magnetic field. **V = (-0.857 +/- 0.003) I**

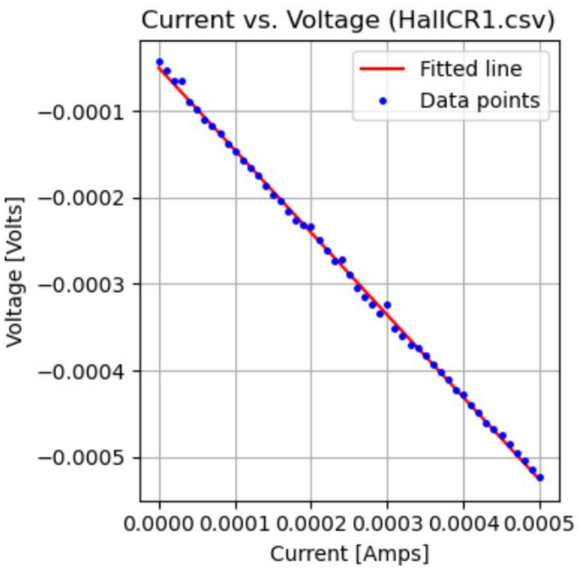
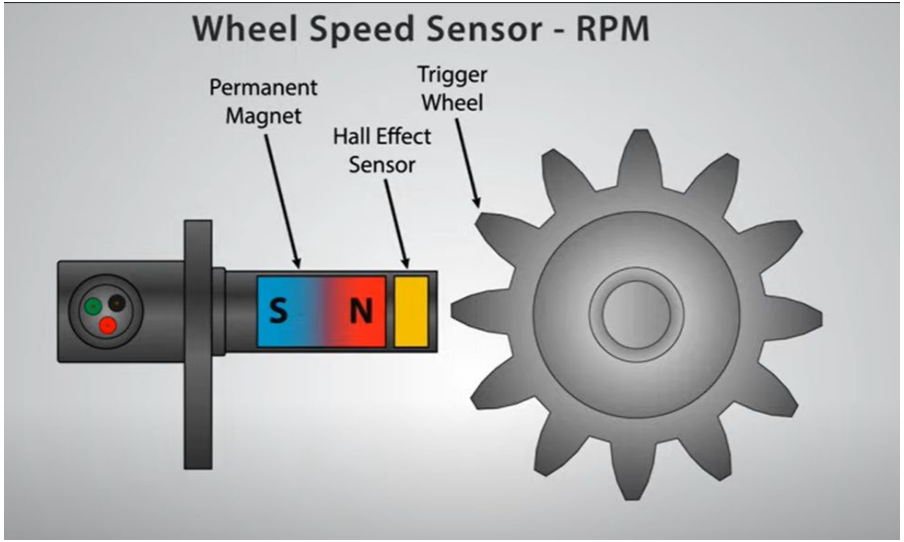


Figure F): C-R w/ magnetic field minus B-Q w/o magnetic field. **V = (-0.954 +/- 0.004) I**

- Charge carrier number and type found using the Hall voltage and Hall resistance.
  - **R_h = 0.8525 Ohms +/- 0.0035 Ohms** (B-Q) -and- **0.971 Ohms +/- 0.006 Ohms** (C-R)
  - **N = 1.4e21 +/- 4.46e19** (B-Q) -and- **1.22e21 +/- 4.51e19** (C-R)
  - Majority charge carriers: positively charged holes.
- Mobility found once we knew carrier number and resistivity.
  - **Mobility: 0.615 (Coulomb-Ohm-meter)^-1 +/- 0.107 (Coulomb-Ohm-meter)^-1** (B-Q) -and- **0.701 (Coulomb-Ohm-meter)^-1 +/- 0.123 (Coulomb-Ohm-meter)^-1** (C-R)

Hall Effect Sensors

- Used to detect the strength and direction of external magnetic fields.
- Especially effective in environments where there is dust, water, or any other distorting elements.
- Used in automobiles as wheel speed sensors or crankshaft position sensors.



References

- Picture on title slide: https://commons.wikimedia.org/wiki/File:Hall_effect.png
- Picture on “Theory” slide: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/Hall.html
- Picture on “Instrumentation” slide: Keithley 2450 Sourcemeter manual.
- Picture on “Hall effect sensor” slide: https://www.youtube.com/watch?v=wpAA3qeOYiI (Screenshot from 3:20)