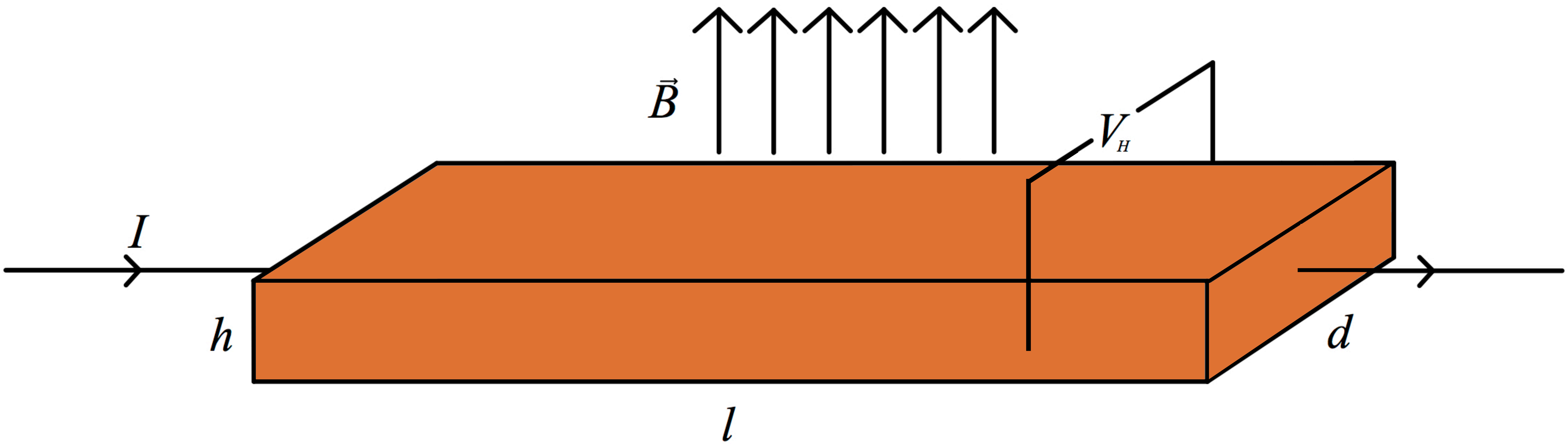


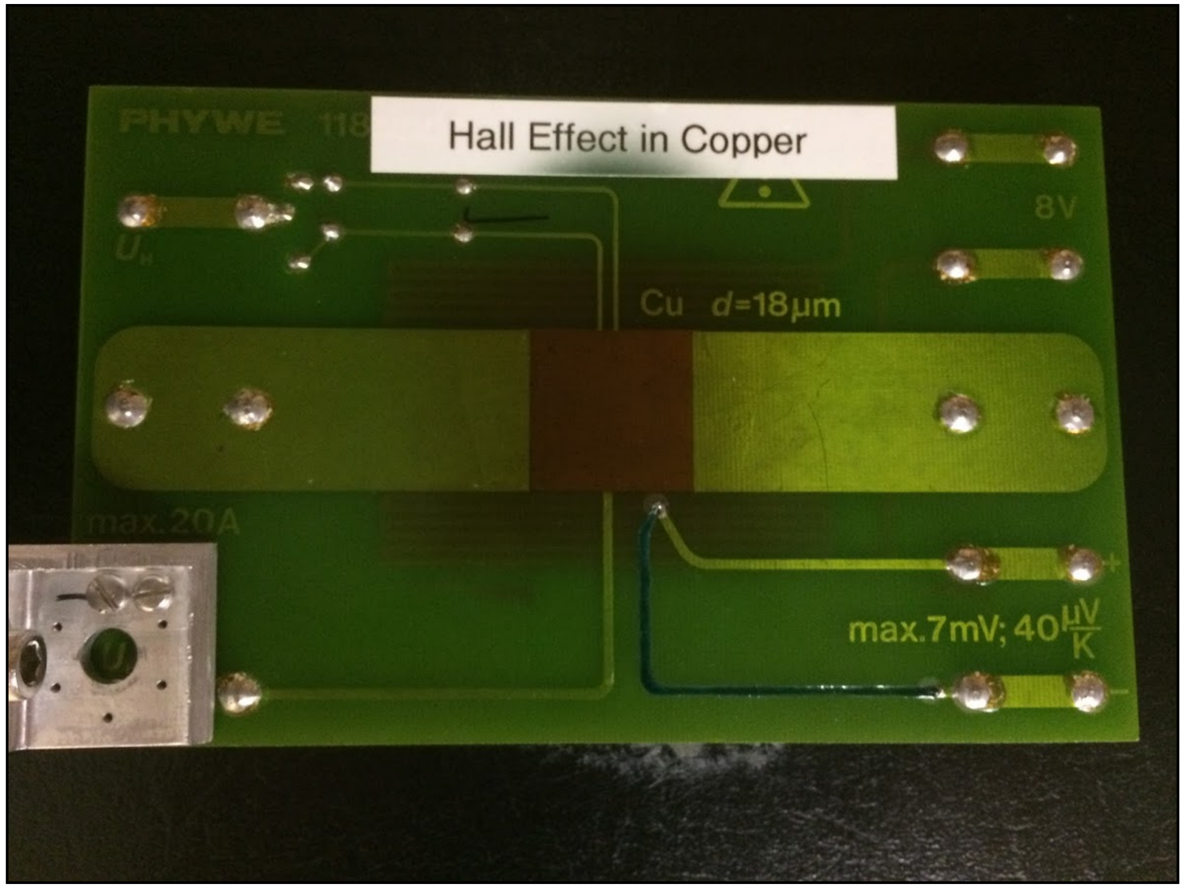
Observation of the Hall effect in Copper

Sean Foster and Owen Burek (collaborator)

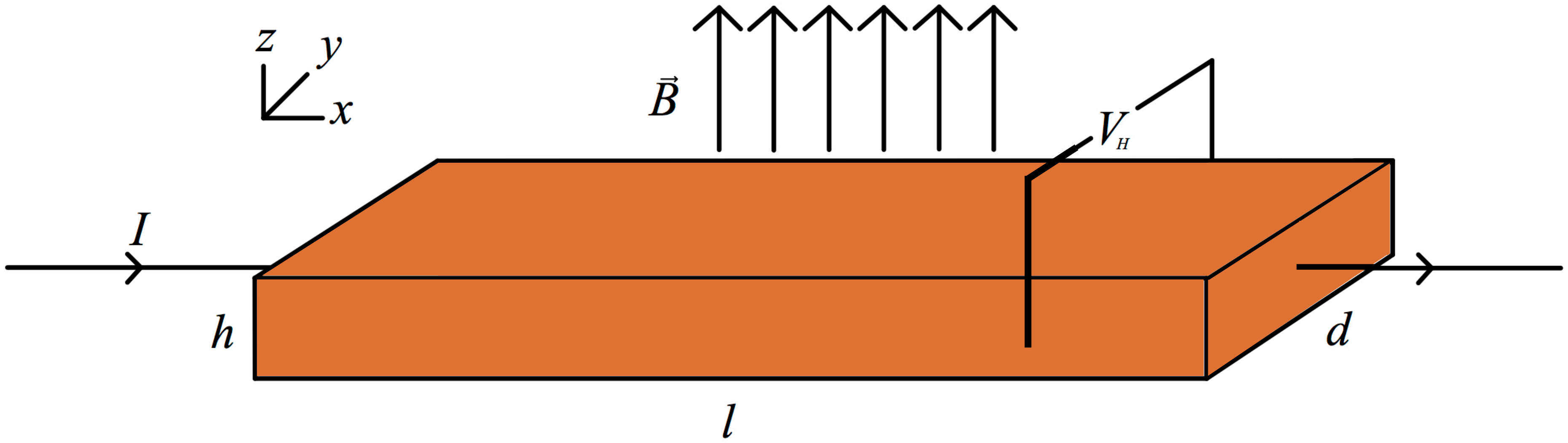
PY 961 Advanced Laboratory Seminar Series
Boston University
November 6, 2017

Outline

- Background on Hall effect
- Apparatus
- Nanovoltmeter fluctuations
- Measurement method
- Measurements and analysis
- Conclusion and future work



The Hall Effect



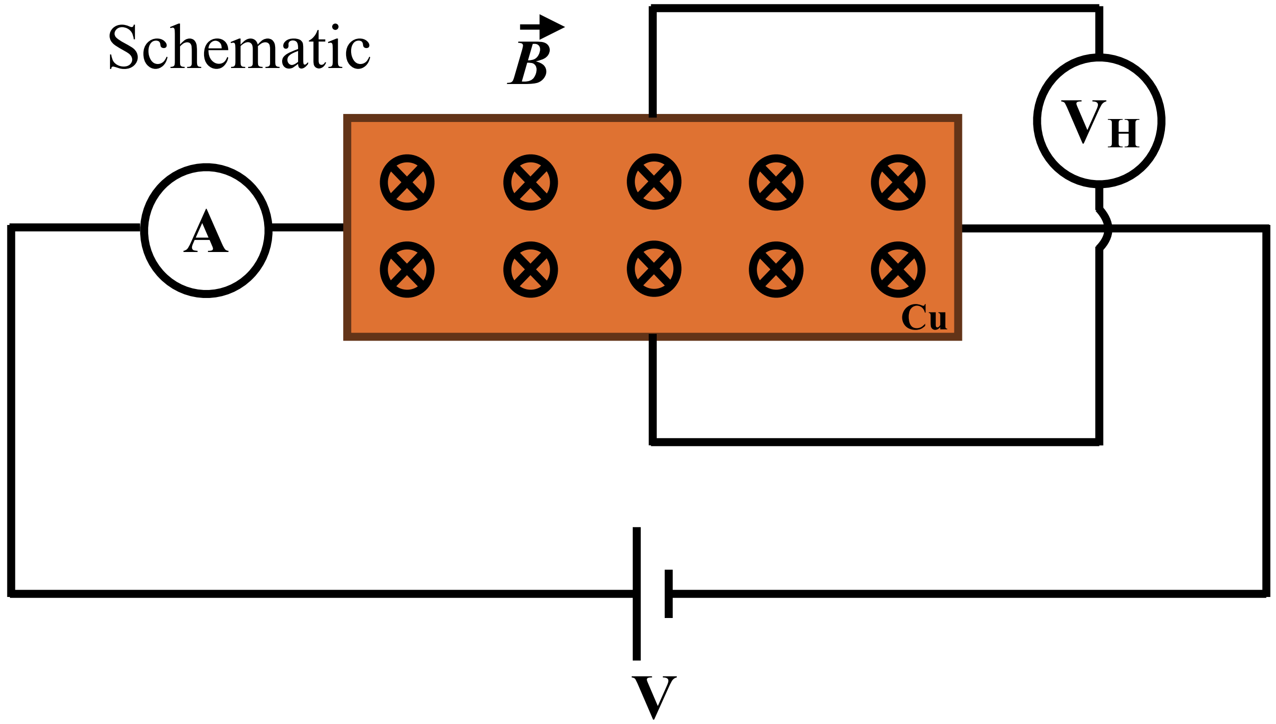
- Discovered in 1879 by E. H. Hall
- Supply current through sample (I)
- Turn on external magnetic field (B) to deflect charge carriers
- Voltage difference produced, forces balance ⇒ Hall voltage
- Define Hall coefficient (R_{H}) ⇒ sign determined by sign of charge carriers

$$V_{\mathrm{H}} = R_{\mathrm{H}} \frac{BI}{d}$$

$$R_{\mathrm{H}} = \frac{1}{nq}$$

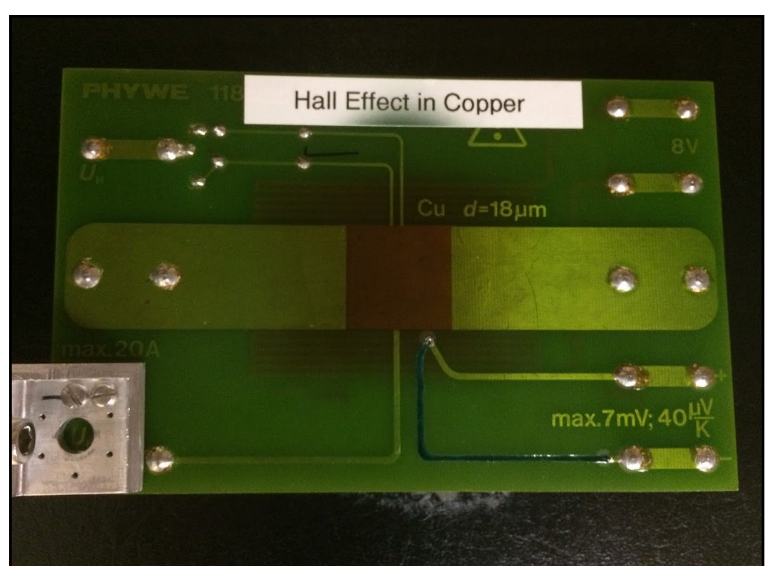
Apparatus

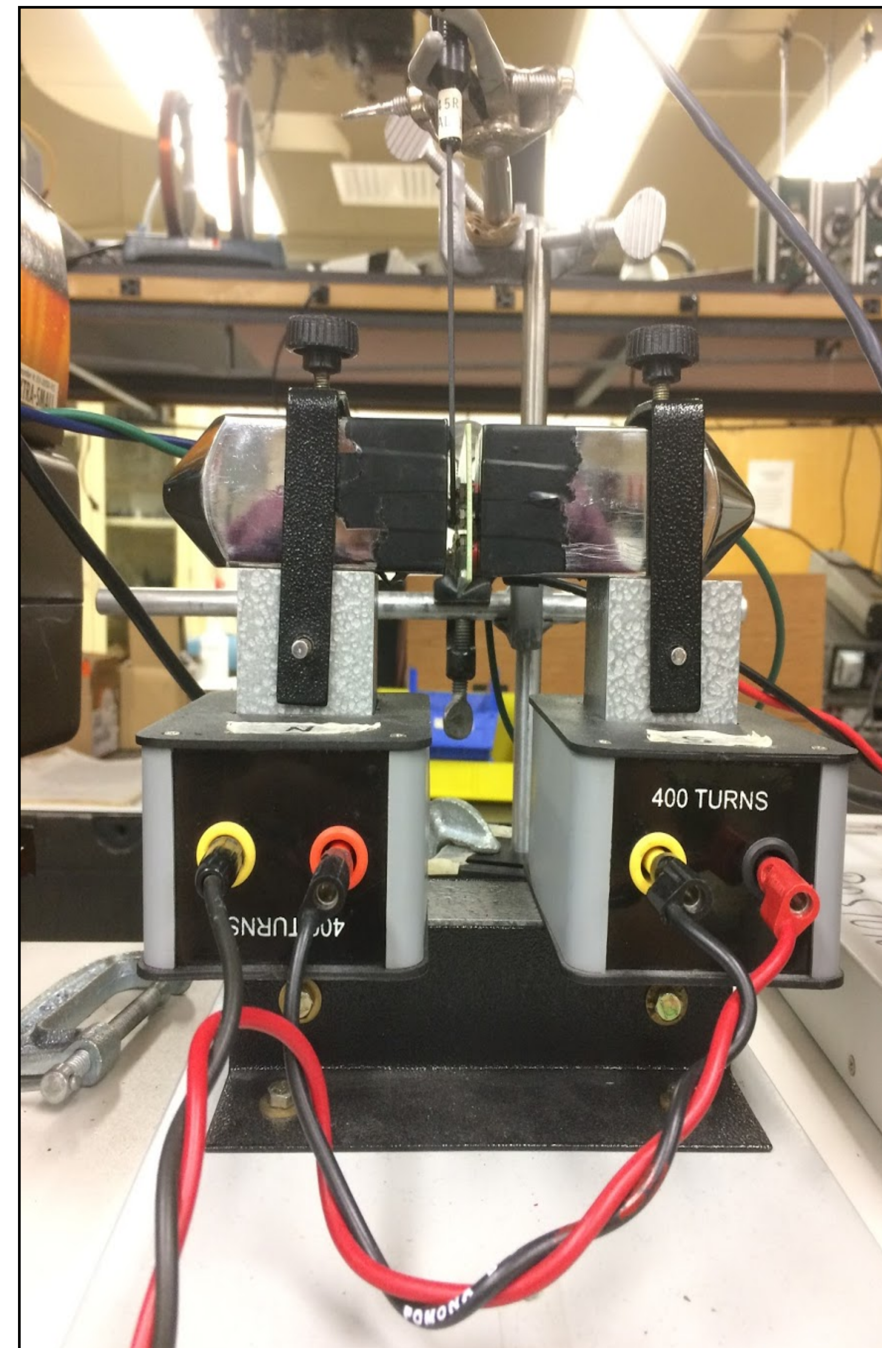
Schematic



Copper sample

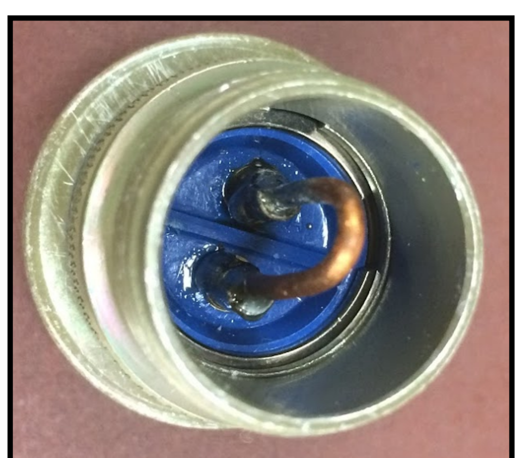
- 18 µm thick
- high number of charge carriers ⇒ small R_H
- small R_H ⇒ small V_H, ~1-15 µV
- requires nanovoltmeter

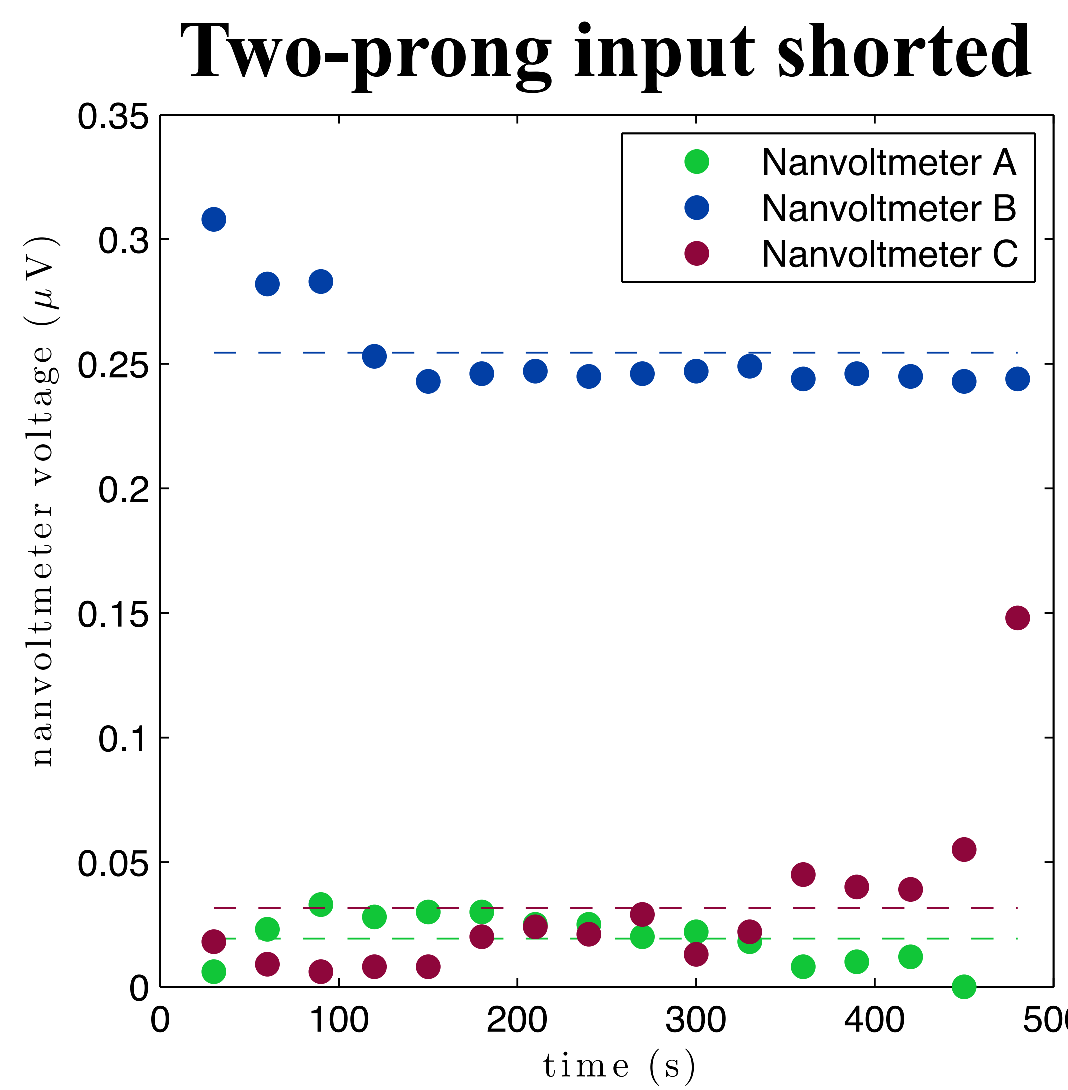




2×400 turn U-shaped electromagnet

Nanovoltmeter fluctuations



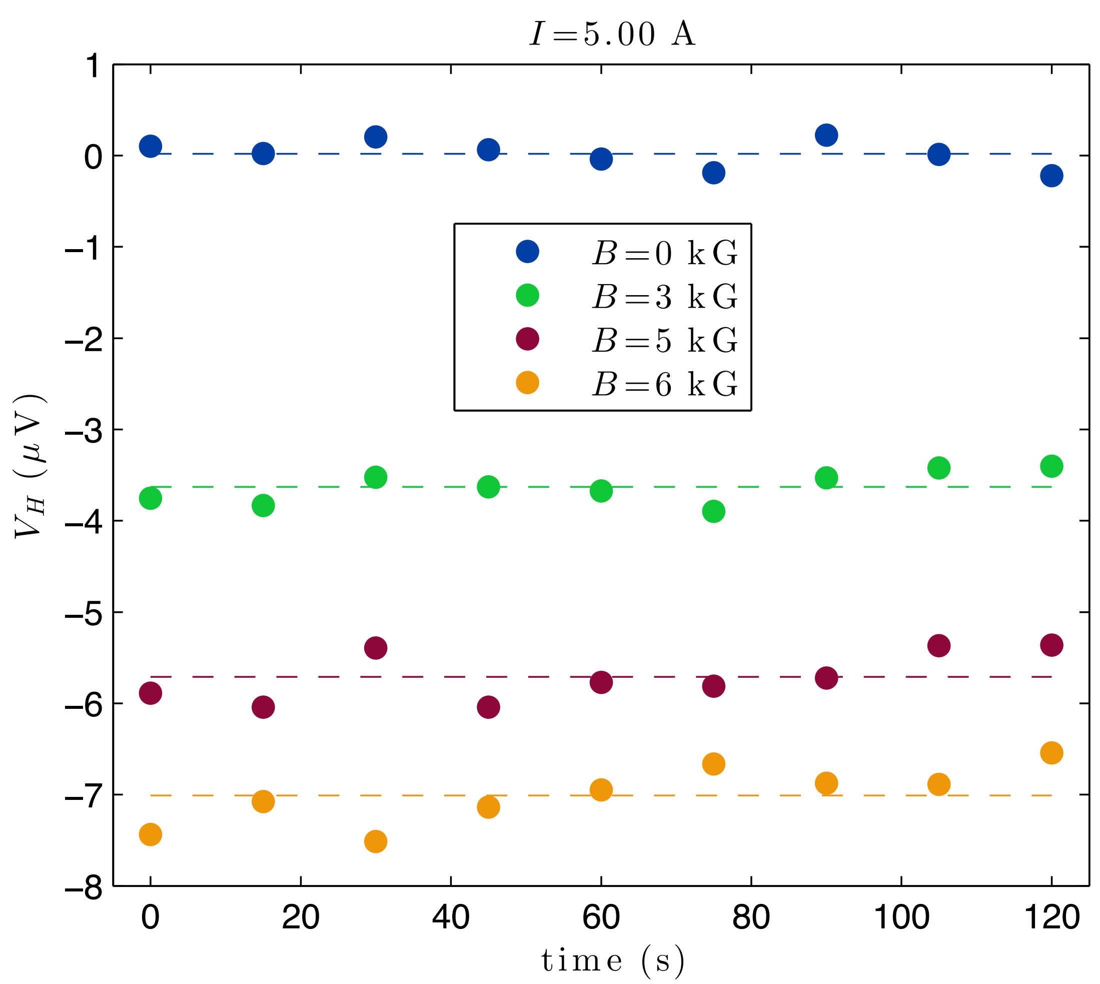


- Voltage recorded every 30 seconds for ~8.5 minutes
- Dotted line ⇒ time average of data points

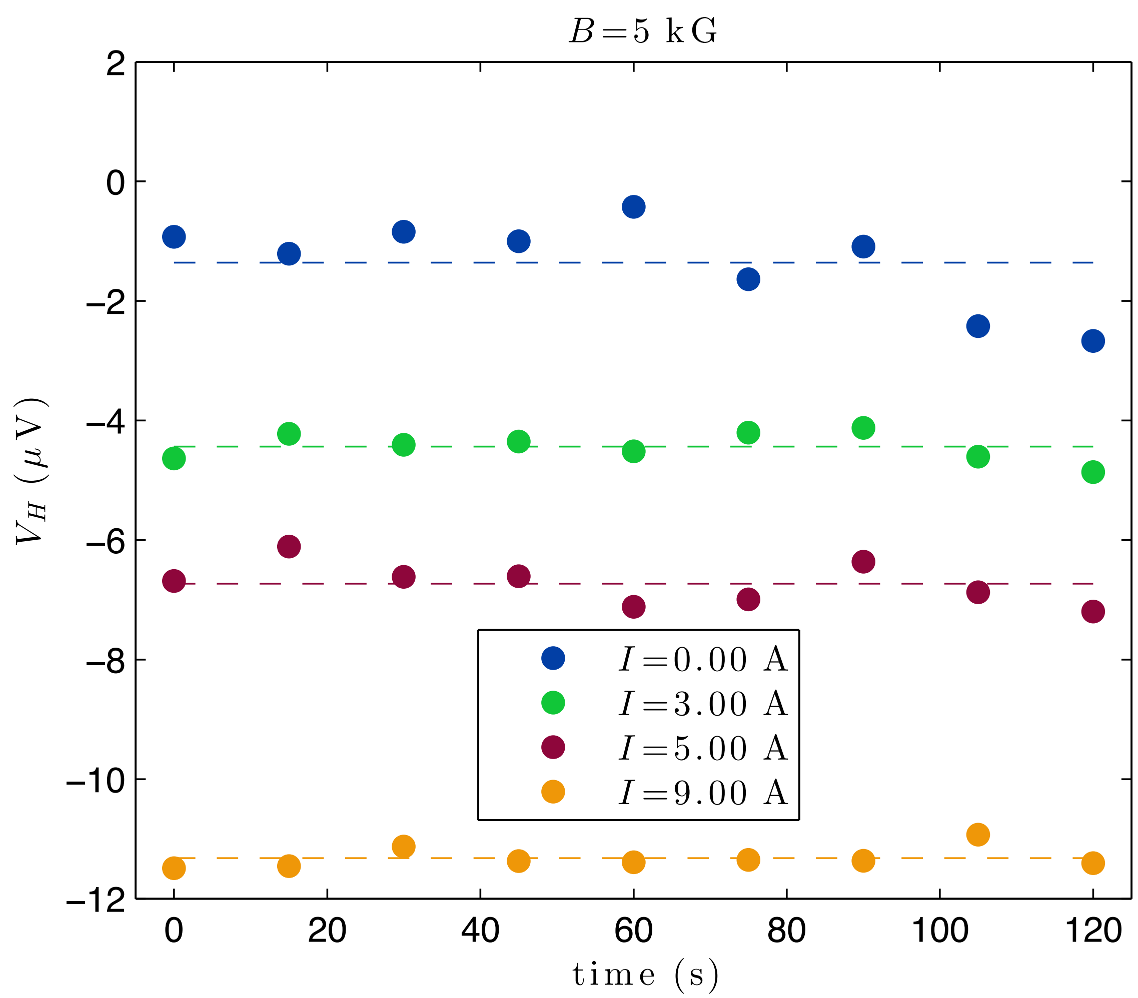
Nanovoltmeter fluctuations

Two-prong input connected to sample

Constant I



Constant B



- Data taken every 15 seconds for 2 minutes
- Dotted line $\Rightarrow$ time average of data points

Measurement method

1. Set current through sample (up to 10 A)

2. Remove the two ferromagnetic cores to ensure B=0

3. Zero nanovoltmeter using ZERO button

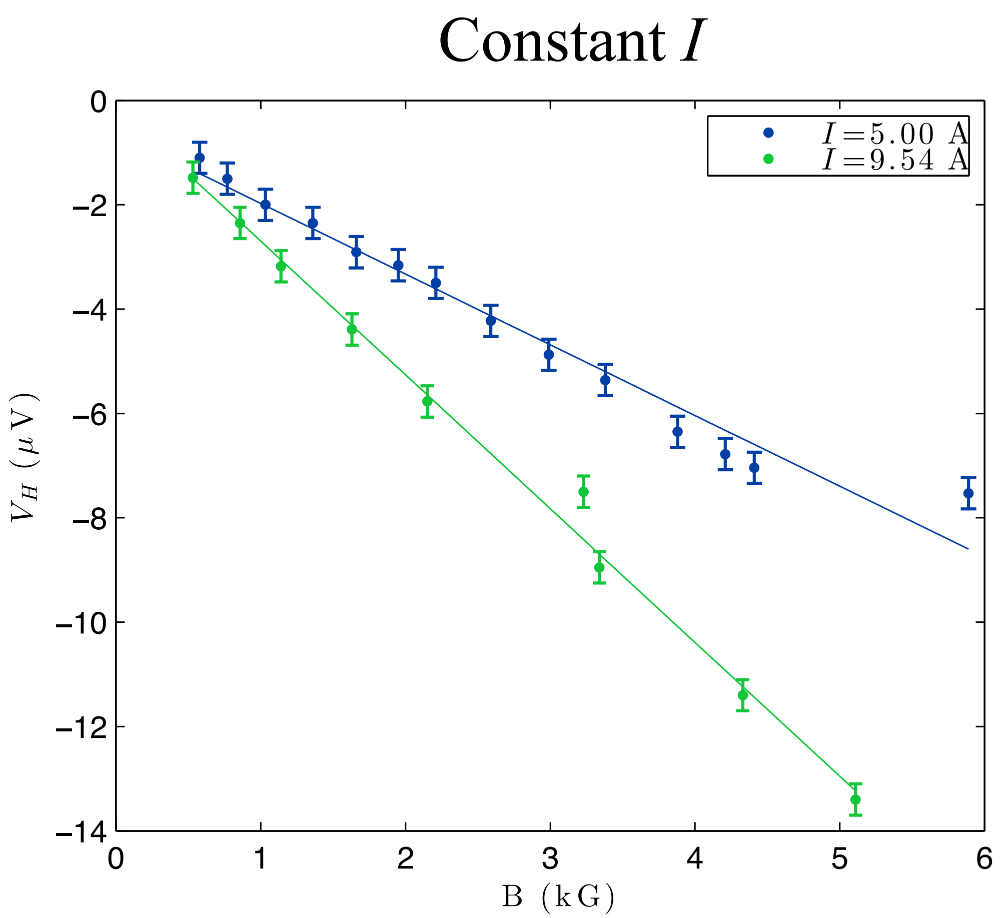
4. Return cores of electromagnet and turn on B-field (up to 6000 G = 0.6 T)

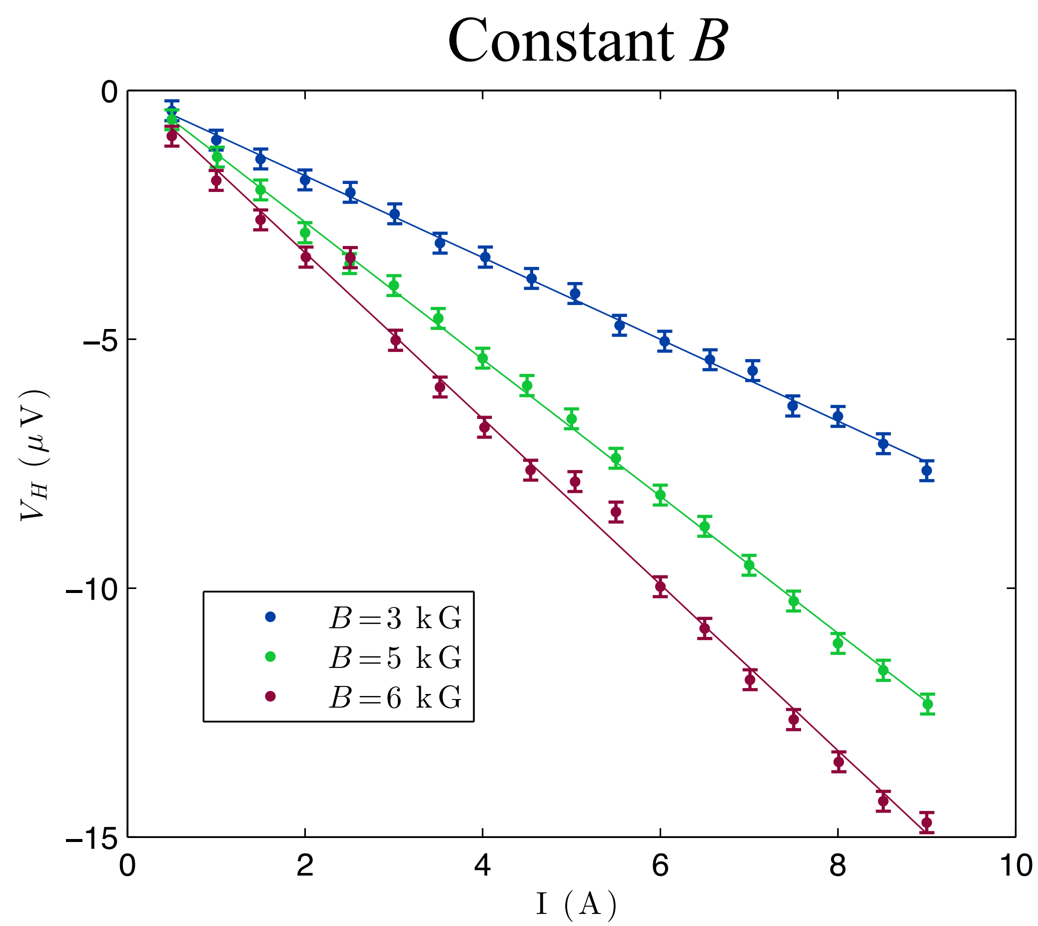
5. Record current through sample, B-field, and Hall voltage (nanovoltmeter reading)

6. Performed B and I sweeps to make V_{H} vs. I and V_{H} vs. B plots

$$V_{\mathrm{H}} = R_{\mathrm{H}} \frac{BI}{d}$$

Measurement and analysis





- **Weighted average:** R_H=-(4.93±0.04)×10^{-11} m^3/C
- **Simon (1992):** R_H=-5.12×10^{-11} m^3/C

⇒Within 4% of Simon (1992).

⇒R_H<0 implies charge carriers are **negative** for copper

⇒Density of charge carriers: n=(1.27 ± 0.10) × 10^{29} m^{-3}

$$V_{\rm H} = R_{\rm H}\frac{BI}{d}$$

$$R_{\rm H} = \frac{1}{nq}$$

Conclusion and future work

- Conclusion
  - Measured Hall coefficient of copper: $R_H=-(4.93\pm0.04)\times10^{-11}$ m^3/C
  - Investigated fluctuations of Keithley Model 181 nanonvoltmeter
- Future work
  - Investigate other materials e.g. semiconductors (larger R_H $\Rightarrow$ larger Hall voltage)
  - Quantify fluctuations of nanovoltmeter as a function of I and B
  - Investigate temperature dependence of R_H

Acknowledgements

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