Superconducting Critical Temperature Measurements and Observations

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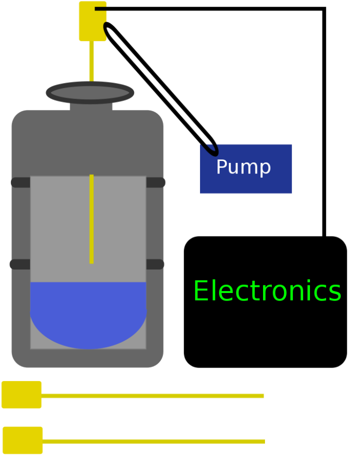
Outline

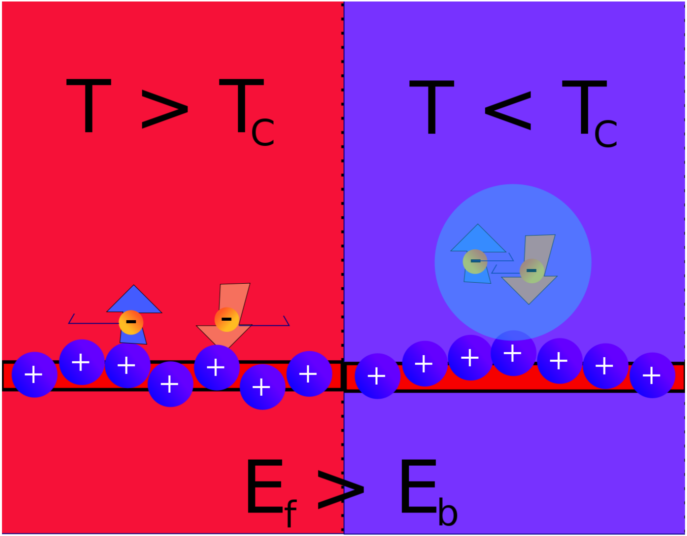
- Goals & Objectives
- Experimental Setup
- Superconductivity & BCS Theory
- Measuring Critical Temperatures
- The Critical Field
- Persistent Current
- Error Analysis and Conclusions

Goals & Objectives

- Measure the critical temperatures for vanadium, lead, and niobium
- Measure the suppression constant for the critical temperature of vanadium in a magnetic field
- Observe the persistent current effect in lead


Pump
Electronics

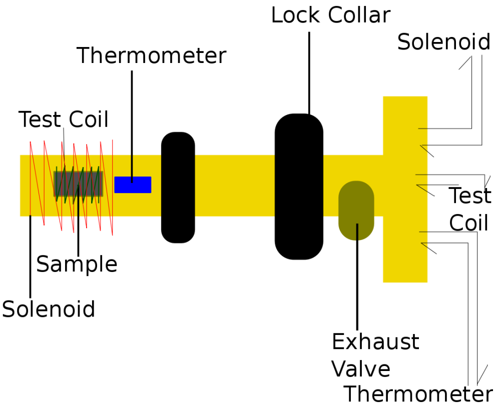
Superconductivity and BCS Theory



Measuring Critical Temperatures

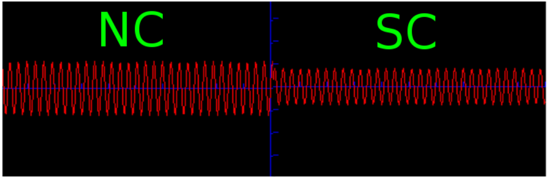
Setup

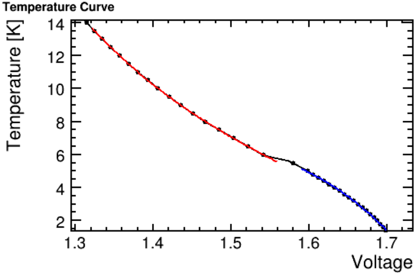
Using probe I. . .



Measuring Critical Temperatures

T_C Measurements for V and Pb





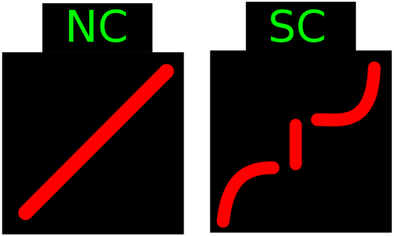
Critical Temperatures

Vanadium : $T_C = 5.36 \pm 0.13$ K

Lead : $T_C = 7.30 \pm 0.05$ K

Measuring Critical Temperatures

T_C Measurements for Nb



Critical Temperatures

Niobium : $T_C = 9.6 \pm 0.6$ K

The Critical Field

The Phenomenon

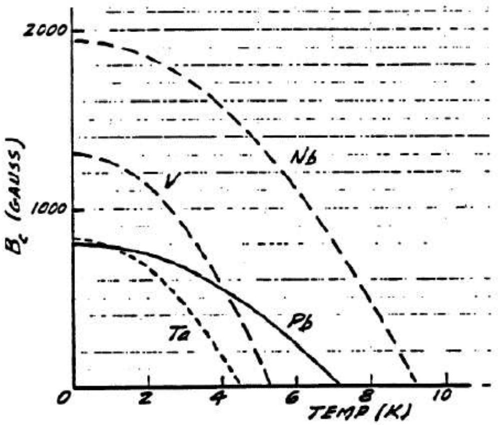


Figure: "Superconductivity: The Meissner Effect, Persistent Currents and the Josephson Effect", MIT Department of Physics, 1/29/09

The Critical Field

. . . More Quantitatively

$$\frac{\Delta E(T)}{\Delta E(0)} \approx \cos\left(\frac{\pi T^2}{2T_c^2}\right)$$

Taylor expanding the right side and noticing $\frac{\Delta E(T)}{\Delta E(0)} = \frac{H_T}{H_0}$ gives us

Critical Field

$$H_T = H_0\left(1 - \left(\frac{T}{T_C}\right)^2\right) \qquad (1)$$

The Critical Field
Data

$$H_T = \frac{A_1}{e^{-(T-T_C)/A_2} + 1} \quad (2)$$

Finding the T_C at $H_T = 0$ and at $H_T = 62.41 Oe \Rightarrow$

Critical Field

$$H_0 = 1482 \pm 105 \text{ Oe}$$

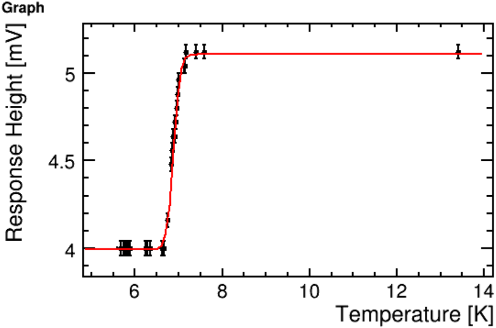
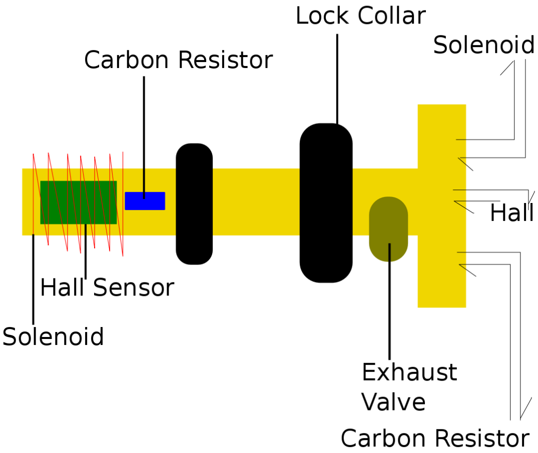
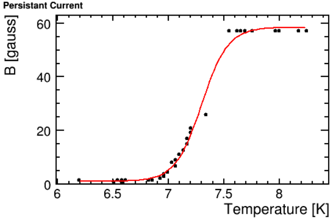
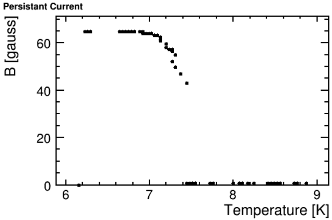


Figure: χ^2/NDF = .3, Probability = 99.9%


Lock Collar
Solenoid
Carbon Resistor
Hall
Hall Sensor
Solenoid
Exhaust Valve
Carbon Resistor

Persistent Current
Observations





Error Analysis

- Dominated almost entirely by random error from fitting to data (including voltage-temperature conversion) and temperature fluctuations ($\approx$ 2.5% for T_C measurements to around 7% for H_0 measurements)
- Small, unknown systematic error due to temperature gradient in probe, dominated over random error for T_C measurement of Pb
- Small random error due to digitization of about .6%

Conclusions

	Value	Error	Accepted	Deviation
V T_C	5.36 K	0.13 K	5.4 K	0.3σ
Pb T_C	7.30 K	0.05 K	7.20 K	2σ
Nb T_C	9.7 K	0.6 K	9.2 K	0.83σ
V H_0	1482 Oe	105 Oe	1408 Oe	0.7σ

- Observed critical temperature suppression in a magnetic field
- Observed persistent current in a superconducting metal

Acknowledgements

We would gratefully like to thank the Junior Lab faculty for helping us understand this experiment and learn what to do