

Superconductivity

1 Introduction

In this lab we will do some very simple experiments involving superconductors. You will not have to take much data; much of what you do will be qualitative. However, in order to understand *what* you are doing, and *why* it is important to read this lab carefully. There is one part of the lab which involves determining the resistance as a function of temperature for the superconducting sample. We only have one sample with the appropriate connections, so please take turns.

This is a new lab your comments on how to improve it are welcome.

2 Safety:

While it may seem like a lot of fun to work with liquid nitrogen, you should remember that it is a dangerous substance. It is extremely cold, and can damage flesh by freezing it. Please keep the following safety rules:

- Do not move liquid nitrogen containers in a manner that causes splashing. Be careful when transferring from one container to another.
- Never store liquid nitrogen in a container with a tight fitting lid.
- You may have seen people briefly dip their hands into liquid nitrogen: their skin is protected by a layer of nitrogen that flash-boils, blowing the bulk liquid back. It is therefore very dangerous to spill significant quantities of liquid nitrogen onto your clothing, which will hold the cold fluid close to your skin.
- While nitrogen gas is non-toxic, it can asphyxiate through displacement of oxygen. Make sure the room is well ventilated when you are using liquid nitrogen.
- Do not touch anything metal or ceramic that has been cooled down to liquid nitrogen temperatures. Use the tweezers provided.
- Do not pour liquid nitrogen onto any surface except those designed to hold it. The extreme cold can cause glass to shatter.

3 Theory:

Superconductivity was discovered in 1911, by H. Kamerlingh-Onnes in Holland (see Appendix 1). Its hallmark was the abrupt disappearance of electrical resistance at a critical temperature, T_c .

Superconductors possess many other unusual properties, such as perfect diamagnetism (they expel magnetic fields from their interior, causing magnets to “levitate” above them) and high thermal conductivity.

For a while it was thought that a superconductor was merely a material that somehow became a “perfect conductor” at low temperatures. Magnetic levitation was explained in the following fashion: when you bring a magnet up to the surface of a conductor, you are creating a time dependent magnetic field within the conductor as the magnet approaches the surface. You will learn/have learned that a time dependent magnetic field can create an electric field in a conductor. This electric field in turn creates currents that oppose the original magnetic field. The magnitude of these currents should depend on the resistivity of the material. If the material has *no* resistance, the currents are very large; large enough to entirely cancel out the magnetic field from within the sample. These surface *screening currents* are something like the screening charges that cancel a static electric field inside a conductor. The currents create a counter magnetic field that repels the approaching magnet.

Actually the story is more complicated than that, as you may see in this lab. A superconductor is *different* from a perfect conductor. It is more that just the absence of resistivity it is another state. The transition to this new state occurs at a specific temperature much like the boiling of a liquid or the melting of a solid. In this lab you will determine this transition temperature.

4 Equipment

In order to investigate superconductivity you will need the following equipment:

- a superconductor in a brass housing with red and blue wires.
- a small disk of ceramic superconductor.
- two tiny, rare earth magnets: one cubic and one cylindrical.
- plastic tweezers.
- styrofoam cups
- liquid nitrogen
- digital multimeters and several wires.

Note that there are several tiny parts to this lab (such as the magnets) and several fragile ones (the superconductors). You will be held responsible for taking care of your equipment!

5 Care and Feeding of High T_c Superconductors

These high T_c materials are delicate and easily damaged. They are ceramic materials, like porcelain or china. **You must obey the following rules while handling these samples.**

You should obtain your samples from your TA at the beginning of lab, and return them to the TA at the end of lab.

1. Do not expose your superconducting samples to water. These means you should not touch them with your fingers.
2. When you are finished with the samples, be sure to wipe off the condensation on them using paper towels. Return them to the container with the dessicator (silica gel).
3. Do not drop, saw or pound the superconductors. They will shatter.
4. Do not heat them up to a temperature above 110F.

6 The Meissner Effect:

The expulsion of magnetic fields from a superconductor is called the Meissner effect. You will observe this both quantitatively and qualitatively.

1. Cut the bottom 3-4 cm off a styrofoam cup so that you have a shallow container in which to hold your samples. Fill a second, intact cup with liquid nitrogen from the TA's dewar.
2. Place a superconducting sample in the shallow cup and fill it with liquid nitrogen. (Use the large sample that is not bound in a brass casing.) Wait until the sample comes into equilibrium with the liquid. Pour off any excess until the sample is just in a shallow puddle.
3. Place the cylindrical magnet on top of sample using the tweezers. It should levitate. (You can also do this with the cubic magnet.)
4. Give the magnet a tap and set it rotating. Is the rotation damped? Make rough measurement of the number of rotations the magnet makes in 5 seconds. Wait at least a minute, and repeat the measurement. Wait an equivalent interval and repeat the measurement a third time.

Trial	Time	Rotations/5 sec	Period
1			
2			
3			