Project Assignment 4

Last week, you completed your summary of two more papers. At this point, you should have read and summarized at least 4 papers describing the phenomenon that you are interested in. You should have also developed a sense of what resources you need to further understand the phenomenon that you are investigating in this paper.

To help you start building your paper, this homework problem asks you to summarize your background research so far. I am looking for about 4-5 paragraphs on what you have learned so far with references. Think about writing this as part of your eventual paper, so work to write something that is coherent and tells a complete story. Make sure you check it for spelling and grammar. This is your chance to make headway on the eventual project that you will turn in soon.

In writing this think about:

• What are people saying about this phenomenon? Is there agreement about how it is explained?

• What are the relevant models? How are the models described?

• How do people investigate it theoretically? Experimentally? Computationally?

• What are open questions surrounding the phenomenon?

Note: The beginning of my introduction was taken from a previous paper I wrote on superconductivity. I don’t intend on taking too much from that paper, but I am not very good at writing hooks and I found that this one was the best I could come up with. Also, I’d like to include my previous explanation of Cooper Pairs but I won’t to avoid being lazy. I really think my last paper was my Citizen Kane.

Superconductivity and the Meissner Effect

**1. Introduction**

On July 10, 1908 liquid helium was produced for the first time, allowing for experiments to be done on the ultra-low temperature scale. On April 8, 1911 Heike Kamerlingh Onnes set out to measure the resistivity of mercury at cryogenic temperatures. He discovered that at about 4.2 K the resistance fell abruptly to 0. This was the first observation of the phenomenon dubbed superconductivity. Since its inception, superconductivity has been proven to be one of the most important discoveries of the 20th century. Although it is not completely understood, there are numerous theories with experimental backing that offer an explanation for the mechanisms behind the phenomenon. This paper will briefly explain the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity, however the main focus of this paper is to offer an overview of the Meissner Effect.

**2. BCS Theory**

The BCS theory of superconductivity is the most widely accepted explanation for conventional superconductors which awarded the three physicist who wrote it the Nobel Prize in 1972. The theory goes something like this: Electrons flow freely in a metal when an electric field is applied. When these travelling electrons encounter impurities in the metal they collide and produce heat. This is what is known as electrical resistance. When a superconducting material (which doesn’t have to be a metal) is cooled down below its transition temperature Tc, it experiences a sudden phase change where its electrical resistance drops down to exactly zero. The electrons in the solid interact with phonons which cause neighboring electrons to pair up. The two electrons, both with spin ½, create a composite particle with spin 0. This integer spin particle acts like a boson which condenses into a superfluid. Just like how a traditional superfluid can flow with no viscosity, Cooper Pairs can flow in a superconductor with no resistance.

**3. Meissner Effect**

Superconductivity is defined by two properties; the first is exactly zero electrical resistance, the second is the expulsion of magnetic flux lines. This second property, called the Meissner Effect, is perhaps the most confusing of the two.

3.1 Classical Diamagnetism and the Meissner Effect

In the classical theory of electricity and magnetism, magnet fields cannot do work on the system. Meaning, magnetscannot add energy to the system. In diamagnetic systems, an opposite magnetic field is induced, and energy is added to the system. Because of this, it is often claimed that there is no explanation of classical magnetism. However, the Darwin Hamiltonian given by

Where Be is the external magnetic field and Bi is the internal magnetic field due to the moving charged particles. This gives rise to a magnetic energy term and can therefore, model diamagnetism. This in disagreement with the previously accepted Bohr-van Leeuwen theorem which states that the Hamiltonian of interacting charged particles does not depend on the external vector potential.

I know I didn’t answer all of your questions but if I did I would end up writing the whole paper! I don’t like to write outlines and subsequently keep adding information. To me, that creates an incoherent paper that lacks chronology. I did my best to write the first part of my paper as requested even though I did not get to the heart of the math behind the Meissner Effect such as limits of the critical field and