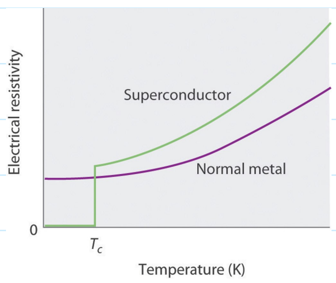
Homework 1-3

Sunday, May 10, 2020 5:31 PM

小レポート課題 No. 0 [課題]

超伝導の物理学的概念として重要な特徴（特徴的な現象、超伝導ギャップ、クーパー対など）につい ての解説を、A4 用紙 2 枚程度にまとめよ。必要に応じて、図を用いても良い。

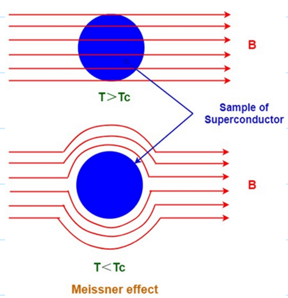
1. **Elementary properties of superconductors**



1) Zero electrical DC resistance and Electric field

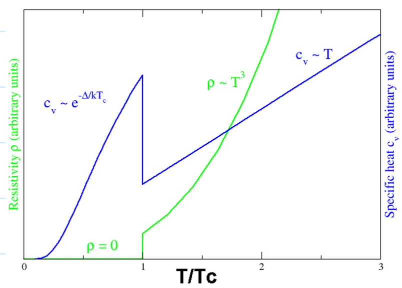
For normal metal, the resistance of the sample is given by Ohm's law as R = V / I. The resistance will decrease with the temperature drop, but it will never reach to 0. But for superconductors, their resistance will suddenly drop to 0 under the critical temperature(Tc). This means in the superconductors, current can travel without any degradation.

In a normal conductor, an electric current may be visualized as a fluid of electrons moving across a heavy ionic lattice. The electrons are constantly colliding with the ions in the lattice, and during each collision some of the energy carried by the current is absorbed by the lattice and converted into heat, which is essentially the vibrational kinetic energy of the lattice ions. As a result, the energy carried by the current is constantly being dissipated. This is the phenomenon of electrical resistance and Joule heating.



2) Meissner effect

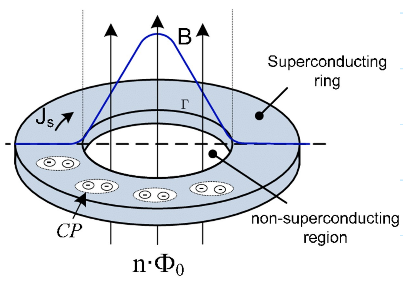
When a superconductor is placed in a weak external magnetic field H, and cooled below its transition temperature, the magnetic field is ejected. The Meissner effect does not cause the field to be completely ejected but instead the field penetrates the superconductor but only to a very small distance, characterized by a parameter λ, called the London penetration depth, decaying exponentially to zero within the bulk of the material. The Meissner effect is a defining characteristic of superconductivity. For most superconductors, the London penetration depth is on the order of 100 nm.



3)Phase transition

In superconducting materials, the characteristics of superconductivity appear when the temperature T is lowered below a critical temperature T_c. The value of this critical temperature varies from material to material. Conventional superconductors usually have critical temperatures ranging from around 20 K to less than 1 K. Solid mercury, for example, has a critical temperature of 4.2 K.

The onset of superconductivity is accompanied by abrupt changes in various physical properties, which is the hallmark of a phase transition. For example, the electronic heat capacity is proportional to the temperature in the normal (non-superconducting) regime. At the superconducting transition, it suffers a discontinuous jump and thereafter ceases to be linear. At low temperatures, it varies instead as $e^{-\alpha/T}$ for some constant, α. This exponential behavior is one of the pieces of evidence for the existence of the energy gap.



4)Magnetic Flux quantization

The magnetic flux, represented by the symbol Φ, threading some contour or loop is defined as the magnetic field B multiplied by the loop area S, i.e. Φ = B•S. Both B and S can be arbitrary and so is Φ. However, if one deals with the superconducting loop or a hole in a bulk superconductor, it turns out that the magnetic flux threading such a hole/loop is quantized. The (superconducting) magnetic flux quantum $\Phi_0 = h/(2e) \approx 2.067833848... \times 10^{-15}$ Wb.

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