8.512 Theory of Solids II
Spring 2009

Lectures 11: Effect of Disorder on Superconductors

We discuss the effect of disorder on the electromagnetic response of a superconductor and show that the Meissner effect survives in the presence of disorder. The method we use is called the exact eigenstate method, where we work with the exact eigenstate of the one-body Hamiltonian including the random potential. The pairing theory can proceed on this basis. An important outcome is the Anderson theorem, which states that the energy gap Δ and T_c are unaffected by nonmagnetic impurities, as long as localization effects can be ignored. On the other hand, disorder has a strong effect on the superfluid density. This effect can be calculated quantitatively by recognizing that the matrix elements also appear in the expression for the normal state conductivity. For $\frac{1}{\tau\Delta} \gg 1$, where $\frac{1}{\tau}$ is the impurity scattering rate,

$$n_s = n(\tau\Delta), \tag{1}$$

and is greatly reduced from the total electron density. This can be understood from the fact that by opening up an energy gap, a piece of width Δ is cut out of the Drude conductivity (Lorentzian with width $\frac{1}{\tau}$) of the normal metal and goes into the delta function in the superconductor. The weight of the delta function is $\frac{n_s}{m}\delta(\omega)$. Equation (1) follows from the conductivity sum rule.

Reading: de Gennes, *Superconductivity of Metals and Alloys*, Chapters 5.2 and 5.3.

Lecture 12: Quasiparticles and Coherence Factors

In the calculation of the superfluid density in the last chapter, coherence factors appear which are typical in the expression for many properties of superconductors. Famous examples are ultrasonic attenuation and nuclear spin relaxation rate. The latter shows a peak just below T_c due to the singular density of states of the superconductor, while the former does not show such a peak due to cancellation by the coherence factors.

Reading: Schrieffer, *Theory of Superconductivity*, Chapters 3.2 – 3.5.