[1.] If you insert “appropriate” numbers into the London formula for the penetration length, \( \lambda_L^2 = \frac{m}{(ne^2 \mu_0)} \), what sorts of lengths do you get? Assume all the conduction electron density \( n \) is available to form the superfluid, and pick values for \( n \) of a typical metal. The different materials you looked at in Problem Set 1 have different values of \( n \). Is there any rough consistency between the \( \lambda_L \) values you obtain for these different \( n \) and the experimental values for the penetration length?

[2.] In class we discussed the fact that the suppression of \( C(T) \) at low \( T \) from a linear to exponential behavior which occurs as a result of the superconducting transition should be accompanied by an enhancement of \( C(T) \) for some other \( T \) range in order to keep \( S(\infty) = \int_0^\infty dT \frac{C(T)}{T} \) fixed. Sketch \( C(T) \) for the two level system \( E = 0, \Delta \) of Problem Set 1 for \( \Delta = 3 \). Where is the peak? Why is it there? Suppose something happens to the system (the analog of a superconducting transition) which shifts \( \Delta \) from \( \Delta = 3 \) to \( \Delta = 7 \). What happens to \( C(T) \)? Is the suppression of a peak for one range of \( T \) accompanied by a reappearance elsewhere? How does \( \int_0^\infty dT \frac{C(T)}{T} \) differ for the two values \( \Delta = 3 \) and \( \Delta = 7 \)?

[3.] In class we saw that the tight binding Hamiltonian describing hopping of electrons between near neighbor sites on a one dimensional lattice in real space,

\[
H = -t \sum_l (c_{l+1}^\dagger c_l + c_l^\dagger c_{l+1}),
\]

could be transformed to momentum space,

\[
H = \sum_k \epsilon(k) c_k^\dagger c_k,
\]

where the “energy band” \( \epsilon(k) = -2tcos(k) \).

Do the same transcription to momentum space for a two dimensional square lattice with near neighbor hopping. What is \( \epsilon(k_x, k_y) \)? What happens if there is an additional next near neighbor hopping \( t' \) across the diagonal of a square? (You can begin to see how the band structure of a material might be fit by assigning appropriate hoppings of various ranges in a tight binding model.)

[4.] Draw the Fermi surface (the curve of constant energy \( E \)) for the two dimensional square lattice of the preceding problem. Sketch the result for \( E = -3t, E = -2t, E = -t \), and \( E = 0 \). We will discuss the significance of the \( E = 0 \) case in class. This model, and the special properties of its Fermi surface, are fundamental to many theories of high temperature superconductors, as we shall discuss in several weeks.