Problem Sheet 4

1. Using general notions relating a quantum critical point (QCP) in d dimensions to the corresponding classical one in $d+1$ dimensions, show that close to the QCP the resistivity should depend on electric field $\mathcal{E}$ as

$$R(\mathcal{E}, \delta) = R_c\, f(\delta\ \mathcal{E}^{-1/\nu(z+1)})$$

where ν is the exponent of the (spatial) correlation length in the classical problem, z is the "dynamical scaling exponent", and δ is a control parameter such as film thickness. What is the behavior as a function of $\mathcal{E}$ and T at the critical value of δ?

[Hint: Relate the electric field to some "characteristic" energy.]

2. Dependence of $T_c(n)$ in cuprates on number of CuO_2 planes per unit cell:

   (a) Show that a model based on the KT mechanism in individual multilayers produces, with "reasonable" approximations, the relation

$$T_c(n) = T_c(1) + \Delta T_c(1 - 1/n) \tag{1}$$

   (b) For the KT mechanism of (a), find as quantitatively as possible the difference between the T_c's for $n = 2$ and $n = 3$ for the Hg series.

   [You will need to look up some experimental numbers.]

3. (a) (easy) Show that the "full-blooded" Anderson inter-layer tunneling (ILT) model (i.e. that in which *all* the superconducting condensation energy is due to a "pseudo-Josephson" interplane coupling of the form of eqn. (7) from lecture 15) also leads naturally to a formula of the form (1).

   (b) What would this model predict for the c-axis London penetration depth of Tl-2201?

Solutions to be put in 598PTD homework box (2nd floor Loomis) by 9 a.m. on Mon. 26 Oct.