

# Physics 140B: Problem Set 8

6/3/05. Due 6/8/05.

June 3, 2005

## 1. Vortex Density. 20 Points.

(a) Calculate the density of vortices per unit area  $B/\Phi_0$  for the following values of  $B$ , the average flux density present in the mixed state of a superconductor. Take  $H_{c2} = 1.6 \text{ MA/m}$ , and first convert  $H_{c2}$  into the equivalent  $B_{c2}$  (Tesla) in free space (zero magnetization).

(i) calculate for  $B = \mu_0 H_{c2}/2$ .

(ii) calculate for  $B = \mu_0 H_{c2}$ .

(b) Calculate the average separation  $d$  between the vortices from your answers (both of them) in part (a) and compare your answers with the coherence length  $\xi$ . Hint: obtain  $\xi$  from Eq. (16.22).

**2. Holes in a High Temperature Superconductor. 20 Points.** Calculate the number of holes  $N_{hole}$  per Cu ion in the  $\text{CuO}_2$  copper-oxygen layers in the superconductor  $\text{YBa}_2\text{Cu}_3)_{7-x}$  for the cases  $x = 0.0, 0.25,$  and  $0.5$ . Use the common valence states of the ions (as from chemistry and a periodic table) but use  $\text{Cu}^{2+}$ . [Consult the text, Chapter 16, as necessary.]

**3. Valence Electrons and Holes. 20 Points.** For the compound with chemical formula  $\text{La}_{1.7}\text{Sr}_{0.7}\text{CuO}_{3.9}$ :

(a) What is the total number of electrons per formula unit outside closed shells? This is a crystal average, of course, since actual atoms are whole; the fractions are cell averages.

(b) How many electrons are contributed by each ion?

(c) What is the average valence of the Cu atoms?

(d) Assuming that all copper ions have a charge of +2, what is the number of holes per formula unit?