PHYS 140B HW #8

1.

(a) $H_{c2} = 1.6 \times 10^6 \ A/m$

(i) $B_{c2} = \mu_0 H_{c2}/2 = \dfrac{1.6 \times 10^6 \ A/m}{2 \times \frac{1}{4\pi} \times 10^{-7} \ A/mT} \doteq 1 \ T$

$\Phi_0 = \dfrac{h}{2e} = \dfrac{6.63 \times 10^{-34} \ JS}{2 \times 1.6 \times 10^{-19} \ C} \doteq 2 \times 10^{-15} \ JS/C$

$\Rightarrow \dfrac{B}{\Phi_0} = \dfrac{1 \ T}{2 \times 10^{-15} \ JS/C} = 5 \times 10^{-14} \ \dfrac{TC}{JS} = 5 \times 10^{14} \ /m^2 \approx \dfrac{1}{(500 \ \text{Å})^2}$

One flux quantum in every 500 Å × 500 Å area

(ii) $B_{c2} = \mu_0 H_{c2} \doteq 2T$

$\Rightarrow \dfrac{B}{\Phi_0} = \dfrac{2 \ T}{2 \times 10^{-15} \ JS/C} = 10^{15} \ /m^2.$

(b) (i) $d = \sqrt{\dfrac{1}{5 \times 10^{14} \ m^{-2}}} \doteq 4.5 \times 10^{-8} \ m = 45 \ nm = 450 \ \text{Å}$

(ii) $d = \sqrt{\dfrac{1}{10^{15} \ m^{-2}}} \doteq 3.2 \times 10^{-8} \ m$

eqn. (16.22)

$H_{c2} = \dfrac{\Phi_0}{2\pi \mu_0 \xi^2} \Rightarrow \xi^2 = \dfrac{\Phi_0}{2\pi \mu_0 H_{c2}}$

$= \dfrac{2 \times 10^{-15} \ JS/C}{2\pi \times 1.257 \times 10^{-6} \ N/A^2 \times 1.6 \times 10^6 \ A/m} \doteq 1.58 \times 10^{-16} \ m^2$

$\Rightarrow \xi = \sqrt{1.58 \times 10^{-16} \ m^2} = 1.3 \times 10^{-8} \ m = 13 \ nm = 130 \ \text{Å}$

d and ξ are of the same order ($\sim 10^{-8}$ m or 100 Å)

2.

$Y\ Ba_2\ Cu_3\ O_{7-x}$

$Y^{+3}\quad Ba^{+2}\quad Cu^{+2}\quad O^{-2}$

$\times 1$	$\times 2$	$\times 3$	$\times(7-x)$
$+3$	$+4$	$+6$	$-14+2x$

$+13 - 14 + 2x = -1 + 2x$

$x = 0$: -1 excess charge (hole)

$x = \frac{1}{2}$: 0 " "

$x = 1$: $+1$ " " (electron)

$-1+2x = -(1-2x)$ so, in some sense

$1-2x$ holes, positive # of holes for $x < \frac{1}{2}$

negative # of holes for $x > \frac{1}{2}$

$x = 0$, 1 hole

$x = \frac{1}{4}$, $\frac{1}{2}$ hole

$x = \frac{1}{2}$, 0 hole

3. (a)

La	Sr	Cu	O
3	2	11	4
$\times 1.7$	$\times 0.7$	$\times 1$	$\times 3.9$
5.1	1.4	11	15.6

La : trivalent in most solids

Sr : divalent

Cu : 3 d^{10} are not core electrons

total # of electrons per formula = $5.1 + 1.4 + 11 + 15.6 = 33.1$

(b)

La	Sr	Cu	O
5.1	1.4	11	15.6

↳ # of electrons contributed by each ion.

(c)

$La_{1.7}^{+3} Sr_{0.7}^{+2} Cu^{V} O_{3.9}^{-2}$

$3 \times 1.7 + 2 \times 0.7 + V - 2 \times 3.9 = 0$

$\Rightarrow \quad V = 1.3$

(d) $La_{1.7}^{+3} Sr_{0.7}^{+2} Cu^{+2} O_{3.9}^{-2}$

$3 \times 1.7 + 2 \times 0.7 + 2 - 2 \times 3.9 = 0.7$

So there is -0.7 hole per formula.

There is a typo on this problem, the chemical compound should have been $La_{1.7} Sr_{0.3} Cu O_{3.9}$.

(a)

La	Sr	Cu	O	
3	2	11	4	
$\times 1.7$	$\times 0.3$	$\times 1$	$\times 3.9$	
5.1	0.6	11	15.6	$\rightarrow$ total 32.3

(b)

La	Sr	Cu	O
5.1	0.6	11	15.6

(c) $La_{1.7}^{+3} Sr_{0.3}^{+2} Cu^{V} O_{3.9}^{-2}$

$5.1 + 0.6 + V - 7.8 = 0$

$\Rightarrow V = 2.1$

(d) $La_{1.7}^{+3} Sr_{0.3}^{+2} Cu^{+2} O_{3.9}^{-2}$

$5.1 + 0.6 + 2 - 7.8 = -0.1$

So there is 0.1 hole per formula.