ELEG240- Spring, 2005
Homework 9
Due 5/3, noon

1. If a crystal has a lattice constant (distance between atoms) of 5 Å, and an effective mass of 0.1*m*, where *m* is the mass of a free electron, and a scattering time of 10^{-14} seconds, what is the resistance of a sample with length 1 centimeter and 1x1 mm^2 (please, this is 10^{-6} m^2), find the resistance if it is doped 1 part per billion, 1 part per million, and 1 part per thousand.
ANSWER:

$$R = \frac{L}{\sigma S} = \frac{Lm^*}{Ne^2\tau S}.$$

$N = f(1/5x10^{-10})^3 \;\; 1/m^3$, where *f* is the fraction of atoms in the crystal that are dopant atoms. Thus, for 1 part per billion, *N*=8x10^{18} $1/m^3$, for 1 part per million, *N*=8x10^{21} $1/m^3$, and for 1 part per thousand, *N*=8x10^{24} $1/m^3$. Thus, *R*=440000 ohms for 1 per billion, 440 ohms for 1 part per million, and 0.44 ohms for 1 part per thousand.

2. You obtain a diode and measure that it has a current of -10^{-14} amps at V=-1 volt. List the current in steps of 0.2 volts from -1 to 1 volt at 25 C.
ANSWER:

$$I = I_0(e^{eV/k_BT} - 1).$$

At 25 C, or 298 K, k_BT/e=0.0257 volts, so

$$I = I_0(e^{V/0.0257} - 1) \text{ at 25 C.}$$

Now, for V=-1 volt, the first term in this equation is nearly zero, so

$$I \cong I_0(-1) \;\; (V<<0).$$

Thus, $I_0 = 10^{-14}$ amps. Now, just plug in:

V	I
-1.0	-10^{-14}
-0.8	-10^{-14}
-0.6	-10^{-14}
-0.4	-10^{-14}
-0.2	$-9.996x10^{-15}$
0	0
0.2	$2.4x10^{-11}$
0.4	$5.7x10^{-8}$
0.6	$1.4x10^{-4}$
0.8	0.33
1.0	790

where V is in volts and I is in amps.

3. Now list the current in steps of 0.2 volts from -1 to 1 volt at 150 C.
ANSWER:

$$I = I_0(e^{eV/k_BT} - 1) = I_0 * e^{-E_{GAP}/k_BT}(e^{eV/k_BT} - 1) .$$

Since the band gap of silicon is 1.12 eV (from textbook) we have from problem 1 that $I_0* = 84100$ amps. Thus at 150 C (423 K), I_0=3.9x10^{-9} amps.

At 150 C, k_BT/e=0.0365 volts, so

$I = 3.9x10^{-9}(e^{V/0.0365} - 1)$ at 150 C.

Now, just plug in:

V	I
-1.0	$-3.9x10^{-9}$
-0.8	$-3.9x10^{-9}$
-0.6	$-3.9x10^{-9}$
-0.4	$-3.9x10^{-9}$
-0.2	$-3.88x10^{-9}$

0	0
0.2	$9.3x10^{-7}$
0.4	$2.2x10^{-4}$
0.6	0.054
0.8	12
1.0	3100

where V is in volts and I is in amps.