HW No. 1 on Bandgap and Carriers. Due at my office: Sep 6, 3:30pm

1. Calculate and plot $E_g$ of Si as a function of temperature from 35 K to 400 K.

2. Write a matlab or C program that solves the equilibrium charge neutrality equation. The input is donor doping $N_d$, acceptor doping $N_a$, donor acceptor ionization energy $E_{I,d}$, acceptor ionization energy $E_{I,a}$, temperature $T$, $N_C$ at 300 K – $N_{C,300}$, and $N_V$ at 300 K – $N_{V,300}$. $N_{C,300} = 2.89e19/cm^3$, $N_{V,300} = 3.14e19/cm^3$. $E_{I,d} = E_{I,a} = 45$ meV. Use the $E_g$ model discussed in class.

Using the program,

(a) plot $n$ and $p$ as a function of $T$. Use log scale for $n$ and $p$. $N_d=5e16/cm^3$. $N_a=1e14/cm^3$. Donor is arsenic, acceptor is boron. $T$ is from 35 K to 1000 K.

(b) plot $n$ and $p$ as a function of 1000/T for the previous problem.

(c) plot $E_f$, $E_C$ and $E_V$ as a function of $N_d$ for $T=40$, 100, 200, 300 K. Assuming $N_a=0$. Use $E_I$ as zero for energy. $N_d$ range is from $1e10$ to $1e19/cm^3$.

(d) plot $E_f$, $E_C$ and $E_V$ as a function of $N_a$ for $T=40$, 100, 200, 300 K. Assuming $N_d=0$. Use $E_I$ as zero for energy. $N_a$ range is from $1e10$ to $1e19/cm^3$.

For all of your plots, use log scale for concentrations such as $n$, $p$, $N_d$ and $N_a$.

Below are some matlab codes you may use.

```matlab
eg = function bandgap(T)

eg0 = 1.166;
alpha = 0473e0-3;
beta = 636;

eg = eg0 - (alpha*T.^2)./(beta + T);

function nc = nc(T)
```

1
nc300 = 2.89e19;
nc = nc300 * (T./300).^(1.5);

function nv = nv(T)

nv300 = 3.14e19;
v = nv300 * (T./300).^(1.5);

ni = function ni(T)

kt300 = get_const('vt');
kt = kt * T/300;
nc = nc(T);
v = nv(T);
eg = bandgap(T);
ni2 = nc.*nv.*exp(-eg/kt);
i = sqrt(ni2);

function answer = get_const(constName)
% get_const: returns value of a physical constant
%
switch lower(constName)
case {'phi_t', 'thermalvoltage', 'vt', 'v_t'}
    answer = 25.8e-3; % V

case {'eps_si', 'epssi', 'epssilicon', 'epsilonsilicon'}
    answer = 1.04e-12; % F/cm

case {'eps_ox', 'epsilonoxide', 'epsox', 'epssio2', 'epsoxide'}
    answer = 3.45e-13; % F/cm

case {'ni', 'intrinsicn', 'n_i', 'intrinsicconcentration', 'intrinsicconc'}
    answer = 1.4e10; % /cm^3

case {'q', 'echarge', 'elementarycharge', 'electroncharge'}
    answer = 1.602e-19; % C

case {'sqrt_2qeps', 'sqrt2qeps'}
    answer = 5.79e-16; % FV^(-1/2)cm^(-1/2)
    otherwise
    display('Unknown constant name');
end