Problem 2.1 →

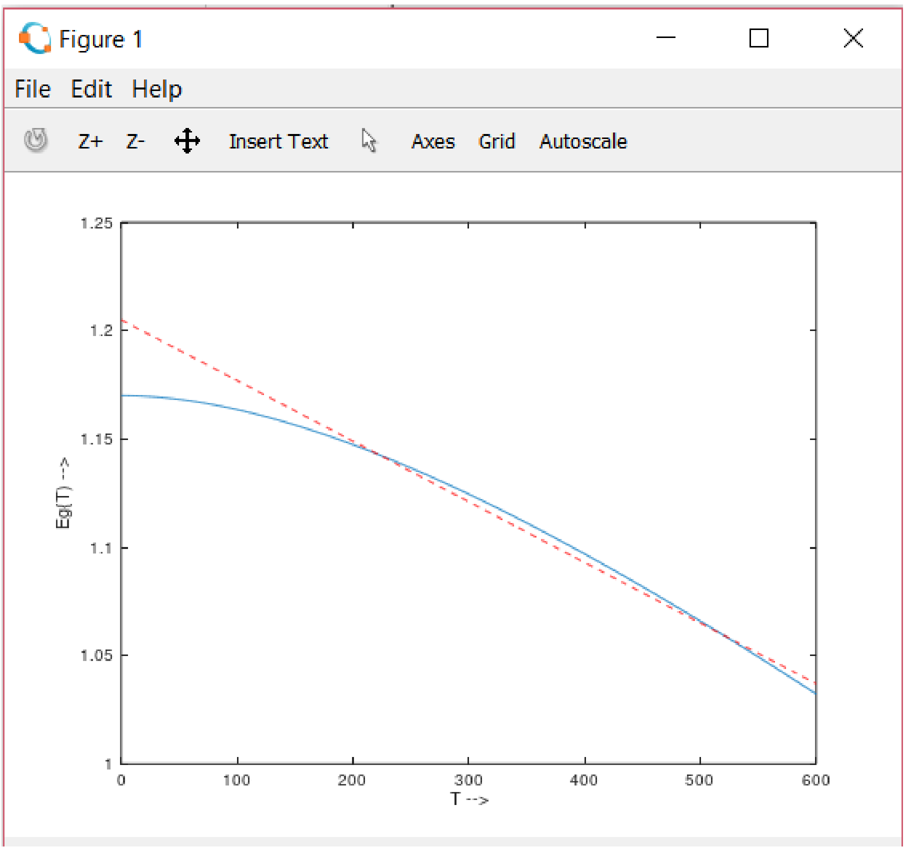
- With increasing temperature an expansion of the crystal lattice usually leads to a weakening of the interatomic bonds and an associated decrease in the band gap energy.
- So, we have to plot Eg(T) vs T graph for T=0 to T=600K.

Octave Code →

prob2.1.m

```
Eg0 = 1.170;          # Band Gap Energy at T=0K
T = 0:1:600;
a = 4.730*10.^-4;      # constant alpha
b = 636;               # constant beta
EgT = Eg0 - (a*T.^2)./(T+b) ;
plot(T,EgT);
xlabel("T -->");
ylabel("Eg(T) -->");
hold on      # to plot linear computation
Eg0 = 1.205;
a = 2.8*10.^-4;
EgT = Eg0 - a*T;
plot(T,EgT, 'r--')     # to plot in dotted lines
```

Generated Plot →



Discussion and Explanation →

- At T=300K, Eg(300)=1.1242 eV.
- Before T<300K, decrease in Eg is increasing but after T>300K, graph becomes almost linear w.r.t Temperature.

Problem 2.10 →

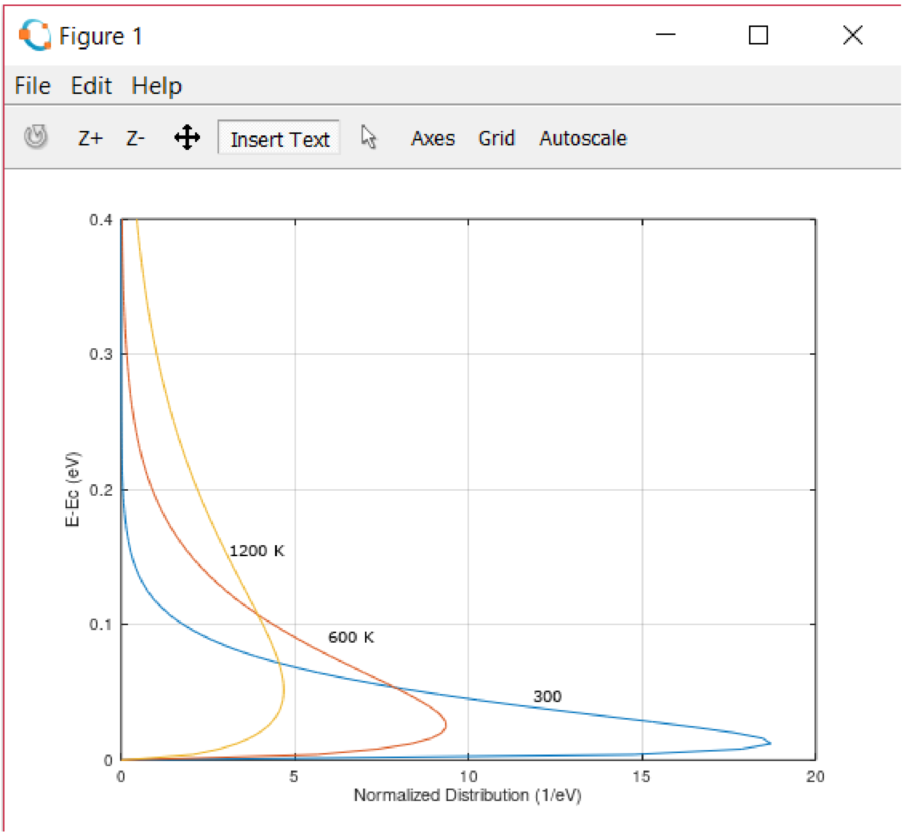
We are plotting the normalized electron distribution is the conduction band versus E-Ec for temperatures for T = 300 K, 600 K and 1200 K.

Octave Code →

probl2.10.m

```
k=8.617*10.^-5;
T=300;
kT= k.*T;
E_Ec= linspace(0,0.4);
dist= 2*sqrt(E_Ec).*exp(-E_Ec/kT)/(sqrt(pi)*kT.^(1.5));
plot(dist,E_Ec)
xlabel('Normalized Distribution (1/eV)');
ylabel('E-Ec (eV)');
hold on
T=600;
kT= k.*T;
E_Ec= linspace(0,0.4);
dist1= 2*sqrt(E_Ec).*exp(-E_Ec/kT)/(sqrt(pi)*kT.^(1.5));
plot(dist1,E_Ec)
hold on
T=1200;
kT= k.*T;
E_Ec= linspace(0,0.4);
dist= 2*sqrt(E_Ec).*exp(-E_Ec/kT)/(sqrt(pi)*kT.^(1.5));
plot(dist,E_Ec)
hold on
```

Generated Plot →



Problem 2.19 →

Octave Code (General)

```
T= input('Enter the temperature (in K)=');
NA = input('Enter no. of acceptor elements =');
ND = input('Enter no. of donor elements =');
Nnet = ND - NA;
k=8.617*10.^-5;

# to find value of ni
E1 = 0.0074;
A= 2.510*10.^19;

# Band Gap vs T
a= 4.730*10.^-4;
b=636;
Eg0= 1.17;
Eg= Eg0 - a.*(T.^2)./(T+b);

# Effective mass ratio
# mnr= mn*/m0
# mpr= mp*/m0

mnr = 1.028 + (6.11*10.^-4).*T - (3.09*10.^-7).*T.^2;
mpr = 0.610 + (7.83*10.^-4).*T - (4.46*10.^-7).*T.^2;

# ni calculation -->
ni = A.*((T/300).^(1.5).*((mnr.*mpr).^(0.75)).*exp(-(Eg-E1)./(2.*k.*T));

# to find value of n, p , and Ef-Ei
if Nnet == 0;
  n= ni;
  p= ni;
  Efi=0;
elseif Nnet > 0;
  n = Nnet/2+sqrt((Nnet/2)^2+ni^2);
  p = ni^2/n;
  Efi=k*T*log(n/ni);
else
  p = Nnet/2+sqrt((Nnet/2)^2+ni^2);
  n = ni^2/p;
  Efi=-k*T*log(p/ni);
end

# printing of results
format compact;
n
p
Efi
```

(a) T=300, NA=0, ND=10.^15

Input →

```
>> T= input('Enter the temperature (in K)=');
Enter the temperature (in K)=300
>> NA = input('Enter no. of acceptor elements =');
Enter no. of acceptor elements =0
>> ND = input('Enter no. of donor elements =');
Enter no. of donor elements =10.^15
```

Output →

```
>> # printing of results
>> format compact;
>> n
n =  1000000000100000
>> p
p =  99999.99999
>> Efi
Efi =  0.29762
```

(b) T=300, NA=10.^16, ND=0

Input →

```
>> T= input('Enter the temperature (in K)=');
Enter the temperature (in K)=300
>> NA = input('Enter no. of acceptor elements =');
Enter no. of acceptor elements =10.^16
>> ND = input('Enter no. of donor elements =');
Enter no. of donor elements =0
```

Output →

```
>> # printing of results
>> format compact;
>> n
n =    1.0000e+16
>> p
p =  10000
>> Efi
Efi =  0.35714
```

(c) T=300, NA=9*10.^15, ND=10.^16

Input →

```
>> T= input('Enter the temperature (in K)=');
Enter the temperature (in K)=300
>> NA = input('Enter no. of acceptor elements =');
Enter no. of acceptor elements =9*10.^15
>> ND = input('Enter no. of donor elements =');
Enter no. of donor elements =10.^16
```

Output →

```
>> # printing of results
>> format compact;
>> n
n =  1000000000100000
>> p
p =  99999.99999
>> Efi
Efi =  0.29762
```

Problem 2.21 →

…. If ND >> NA, then it is donor-doped. Then Ef is above Ei.

….. if NA >> ND, then it is acceptor-doped. Then Ef is below Ei.

Octave Code →

```
kT = 0.0259;
ni = 1*10.^10;
NB = logspace(13,18);

EFid = kT.*log(NB./ni);      # ND >> NA
EFia = -EFid;

semilogx(NB, EFid, NB, EFia);
axis([10.^13, 10.^18, -0.56, 0.56]);
grid;
xlabel('ND or NA');
ylabel('Ef-Ei');
```

Generated Plot →