HW-3 solutions (26/02/2015)

1. Carriers in Equilibrium: Assume a parabolic conduction band with m*=0.5m_o with band edge at E=Eo at 300K;

a. Please plot parabolic band E(k);
b. If E_O-E_F=0.4eV, please use MATLAB to plot E vs f(E) i.e. probability function to compare Fermi Dirac vs Boltzmann distribution on the same plot;
c. For same E_O-E_F=0.5eV, plot N(E) Vs E, f(E)*N(E) Vs E on same using FD distribution;
d. Please repeat b-c for E_O-E_F=0.05eV;
e. Compare f(E)*N(E) plots using FD and MB distribution functions on same graph for 2 cases E0-EF=0.5eV and E0-EF=0.05eV;
f. Can you tell at what E_O-E_F is there a 10% difference in n between FD and Boltzmann Distributions?

Assume E0=0eV (bottom of Conduction band). T=300K

NOTE: All above plots to be made are for conduction band only; no need to plot valence band. Please ignore the parameter n(E) in the question.
Use Nc=3E19cm^-3

Solution 1:

A. Parabolic conduction band:

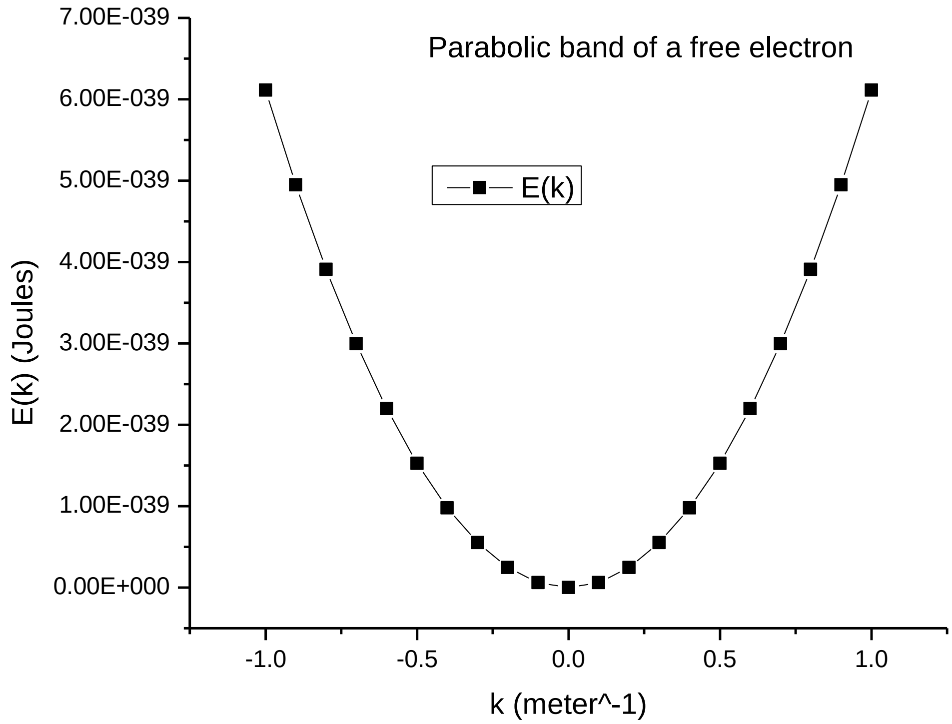
$$E(k) = \frac{\hbar^2 k^2}{2m^*}, \qquad where\ m^* = 0.5m_0$$

$$\hbar = h/2\pi = 1.055 * E-34\ J-s$$

$$m_0 = 9.1E-31kg$$

$$Hence,$$

$$E(k) = 6.11E-39 * k^2\ (Joules)\ (k : meter^{-1})$$



B. For the case of Fermi level EF, E0-EF=0.4eV at 300K, let E0 (bottom of conduction band)=0; hence EF=-0.4eV; selecting range of E=-1.2 to 0.2 eV covering the silicon conduction band;

Statistical Dist. functions :

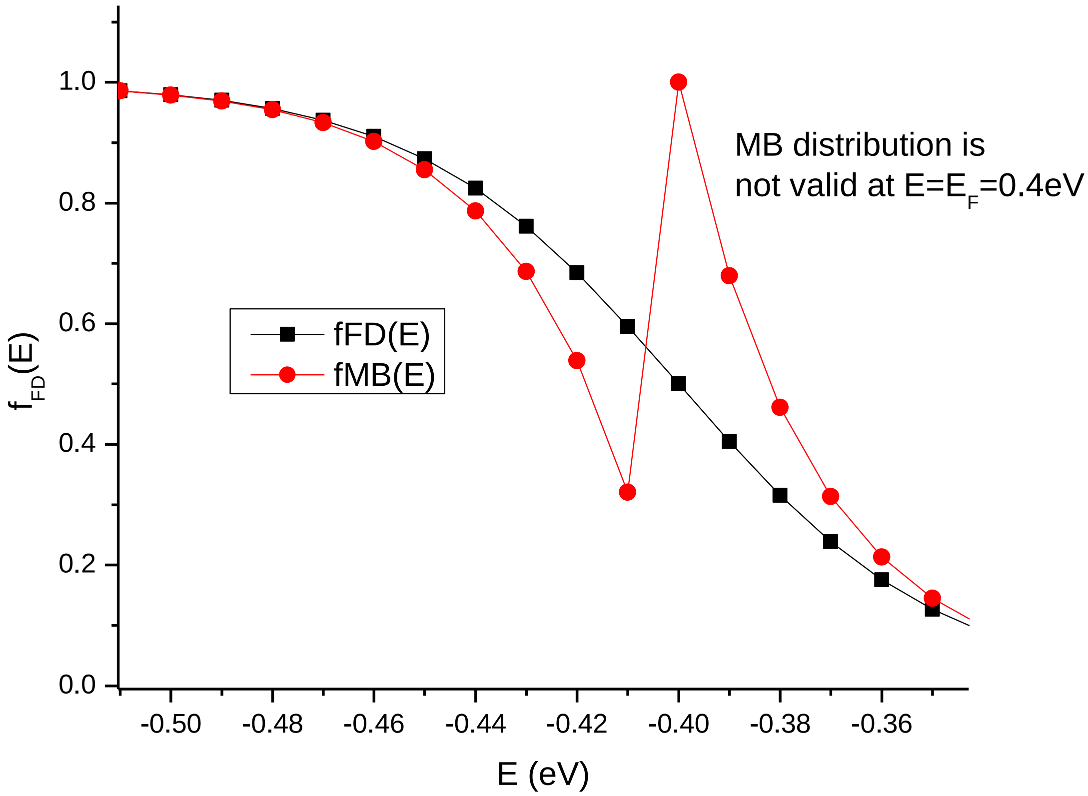
1.*FermiDirac function* :

$$f(E) = \frac{1}{1 + \exp(\frac{E - E_F}{kT})}$$

2.*Maxwell Boltzmann dist function* (*valid when EF is atleast* 3*kT away from band edges*)

$$f(E) = \exp(-\frac{(E - E_F)}{kT}) \ \ for\ E > EF$$

$$f(E) = 1 - \exp(\frac{(E - E_F)}{kT}) \ \ for\ E < EF$$



Note that the MB is discontinuous at EF.

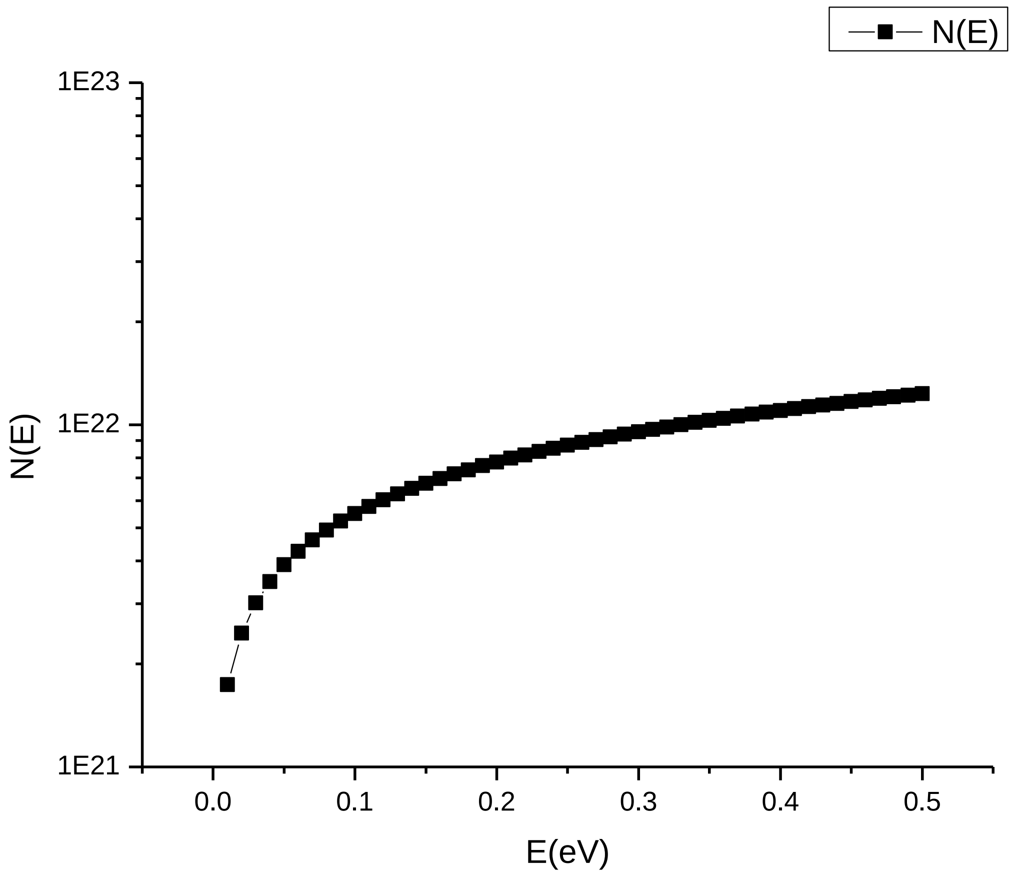
C. For same E_O-E_F=0.5eV, please plot N(E).f(E) and calculate electron concentration by numerical integration; ml*=0.98m0; mt*=0.19m0; let bottom of CB=Ec=0eV;

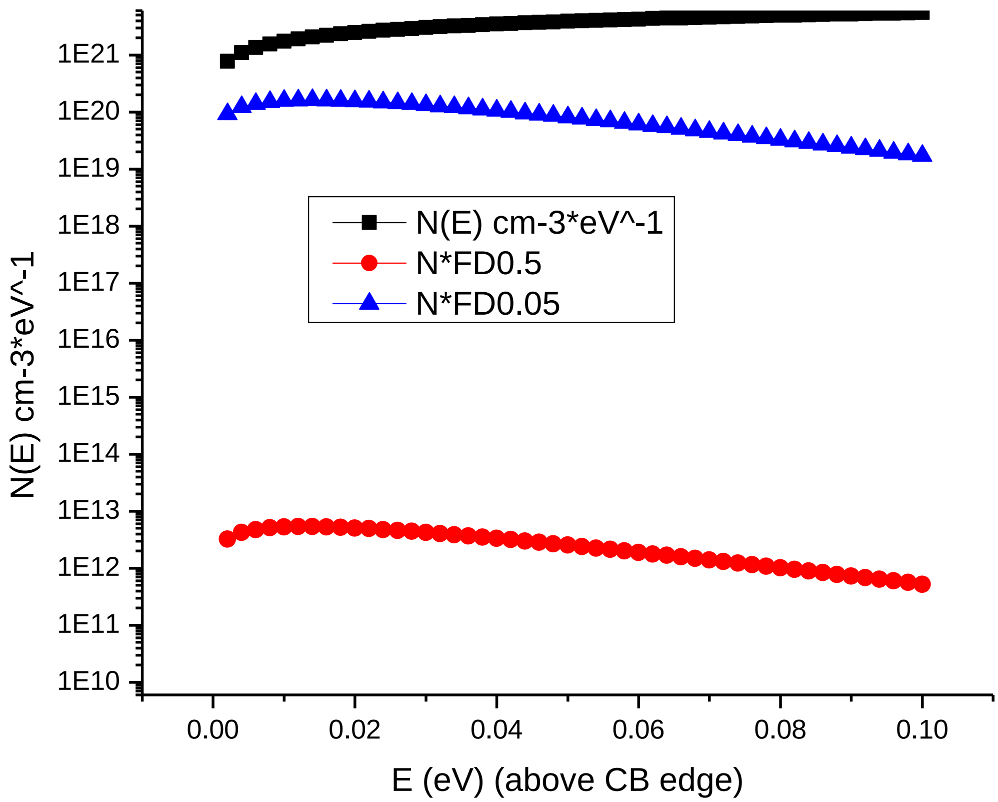
$$For \quad CB,$$

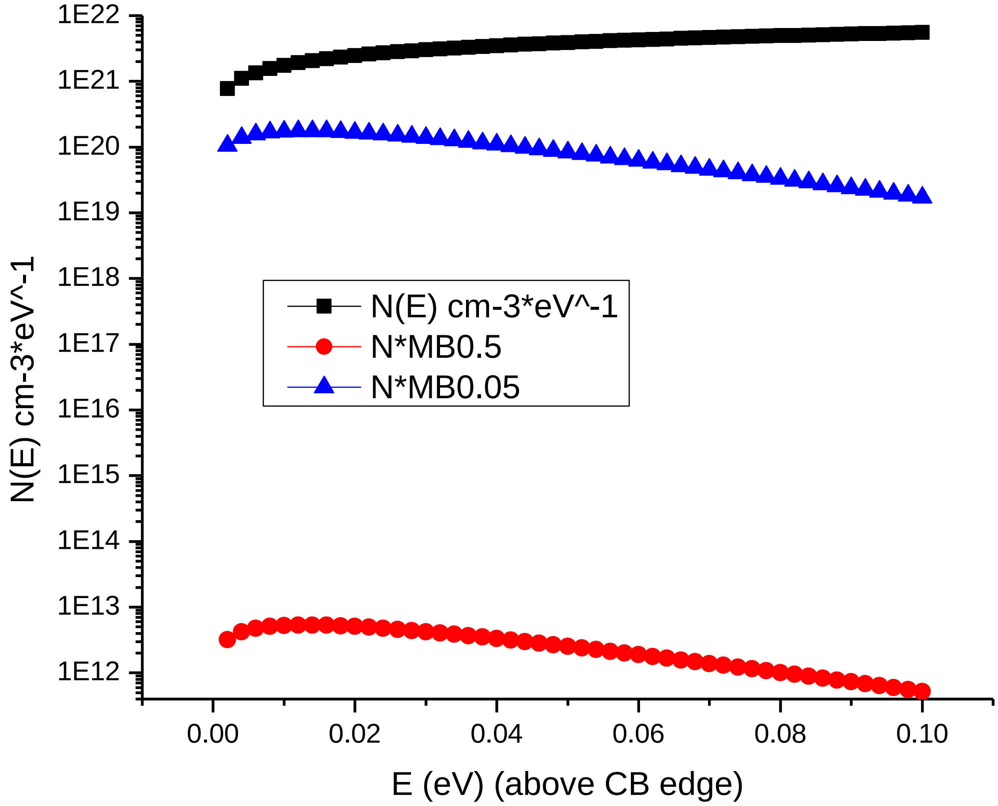
$$N(E) = \frac{8\pi g\sqrt{2(m_t^*)(m_t^*)^2}}{h^3}\sqrt{E-E_c}$$

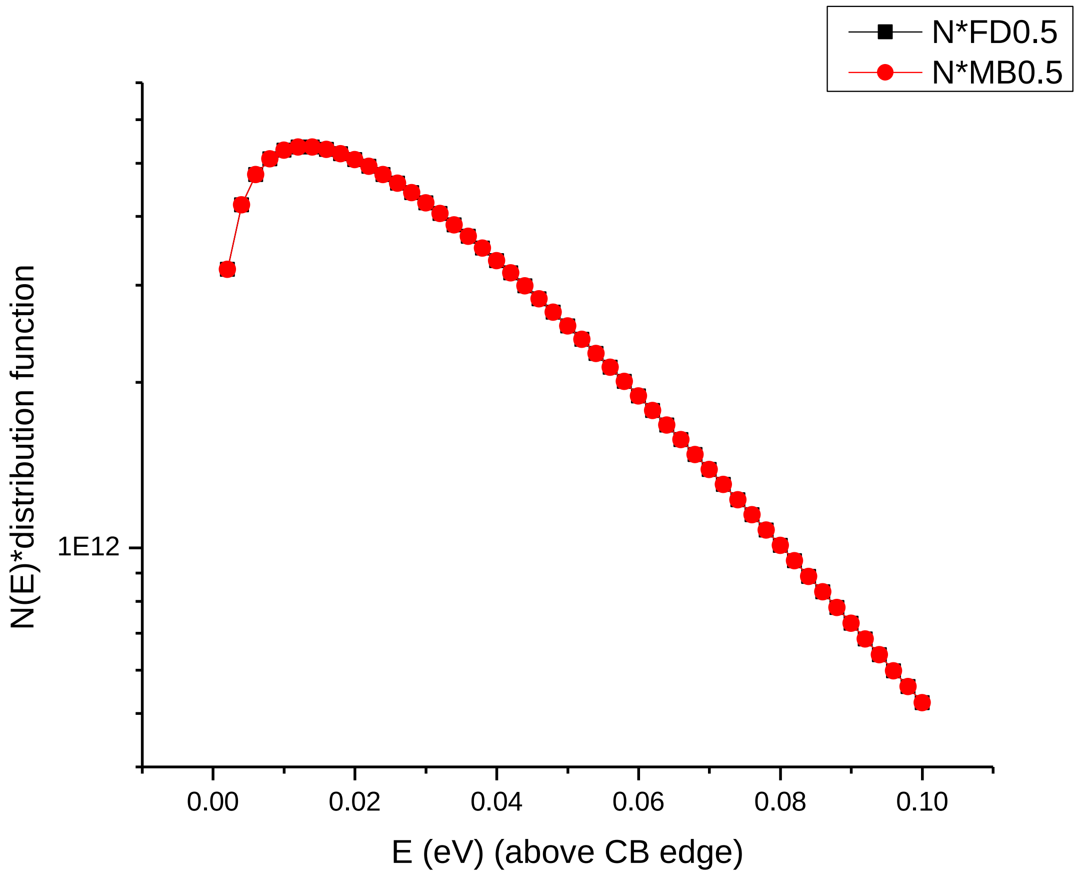
$$N(E) = 2.72E56\sqrt{E}\,(m^{-3}J^{-1})$$

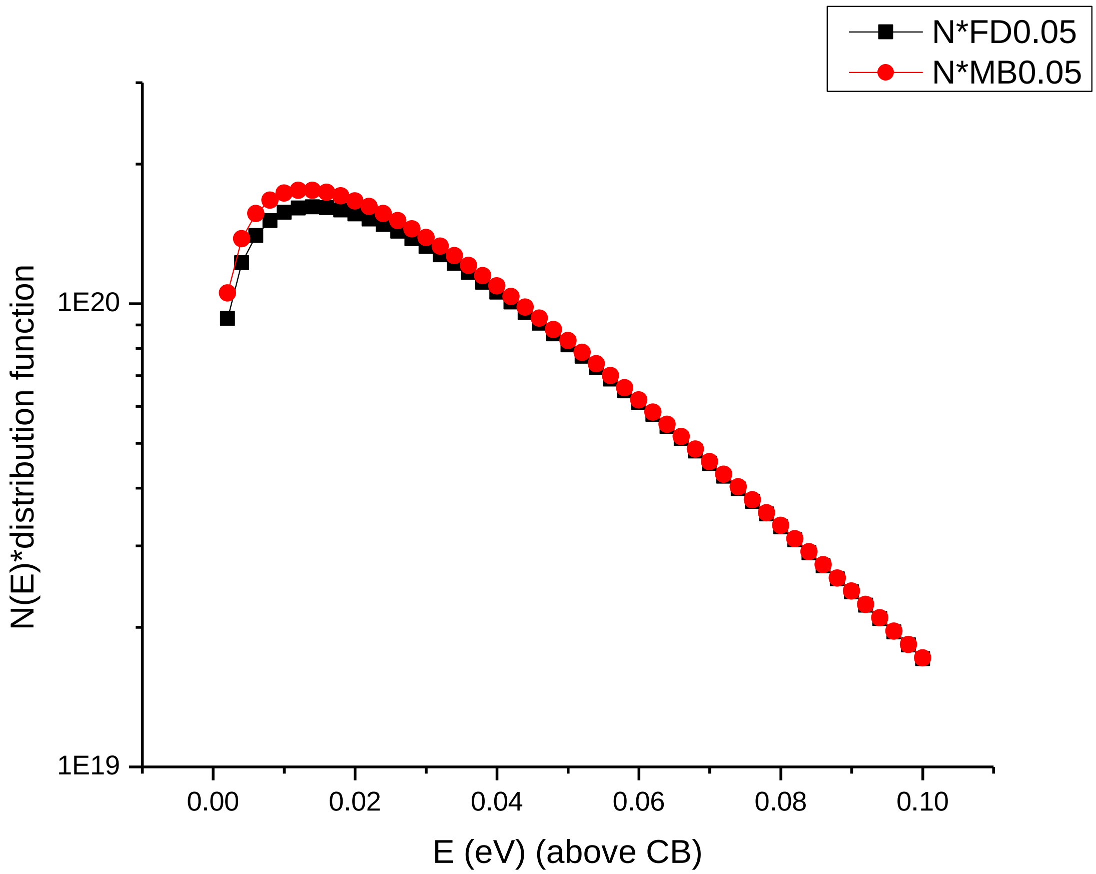
$$n(E) = N(E)\,f(E)$$


N(E)
1E23
1E22
1E21
0.0
0.1
0.2
0.3
0.4
0.5
E(eV)


N(E) cm-3*eV^-1
N*FD0.5
N*FD0.05
1E21
1E20
1E19
1E18
1E17
1E16
1E15
1E14
1E13
1E12
1E11
1E10
N(E) cm-3*eV^-1
0.00
0.02
0.04
0.06
0.08
0.10
E (eV) (above CB edge)

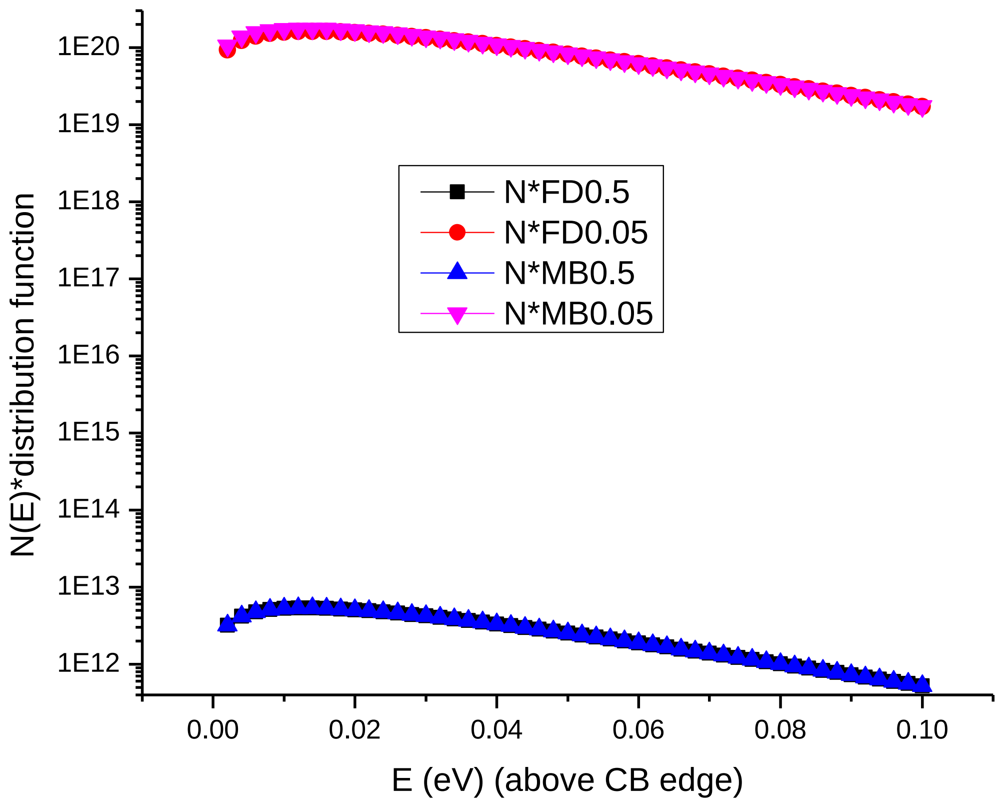

1E22
1E21
1E20
1E19
1E18
1E17
1E16
1E15
1E14
1E13
1E12
N(E) cm-3*eV^-1
N(E) cm-3*eV^-1
N*MB0.5
N*MB0.05
0.00
0.02
0.04
0.06
0.08
0.10
E (eV) (above CB edge)


N*FD0.5
N*MB0.5
N(E)*distribution function
1E12
0.00
0.02
0.04
0.06
0.08
0.10
E (eV) (above CB edge)



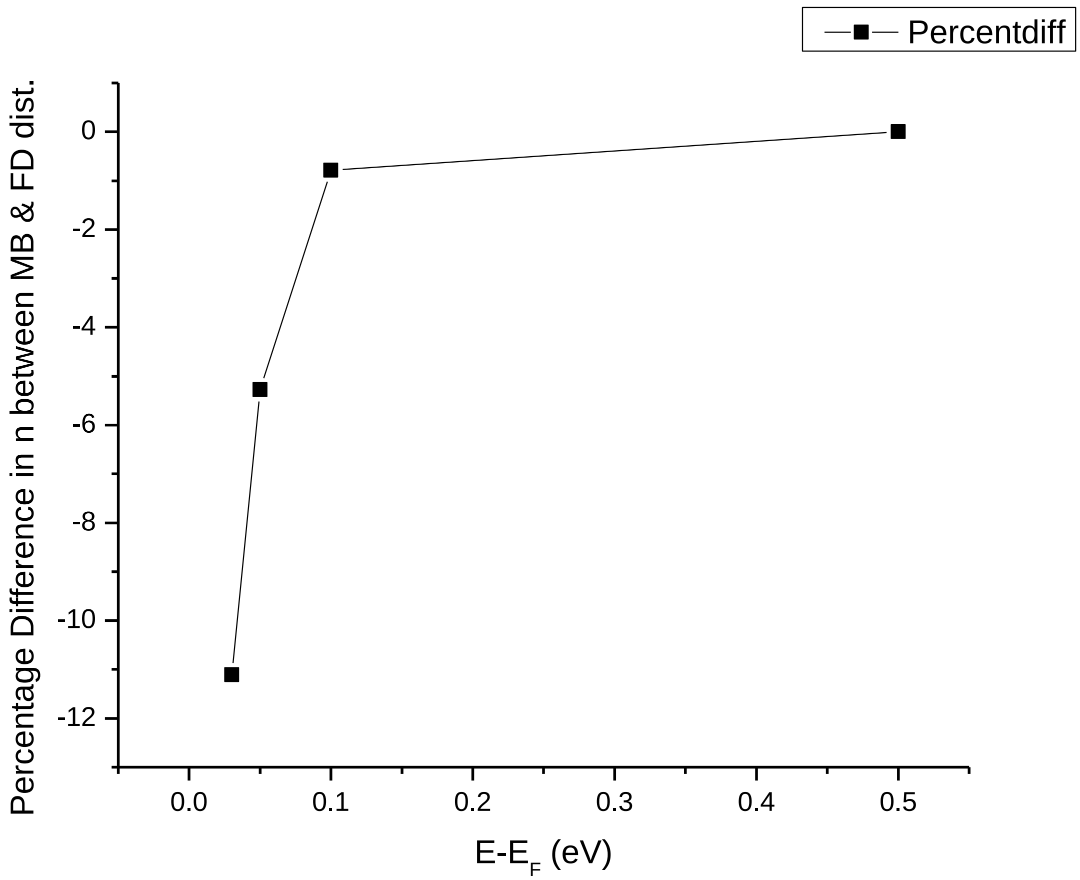
D. Please repeat b-c for E_O-E_F=0.05eV,

E. Compare f(E)*N(E) plots using FD and MB distribution functions on same graph for 2 cases E0-EF=0.5eV and E0-EF=0.05eV;



F. Can you tell at what E_O-E_F is there a 10% difference in electron concentration between FD and Boltzmann Distributions?

Note Vertical axis: Percent difference between electron concentration between FD and MB distributions; Horizontal axis : Fermi level;


Percentdiff
Percentage Difference in n between MB & FD dist.
0
-2
-4
-6
-8
-10
-12
0.0
0.1
0.2
0.3
0.4
0.5
E-E$_F$ (eV)