

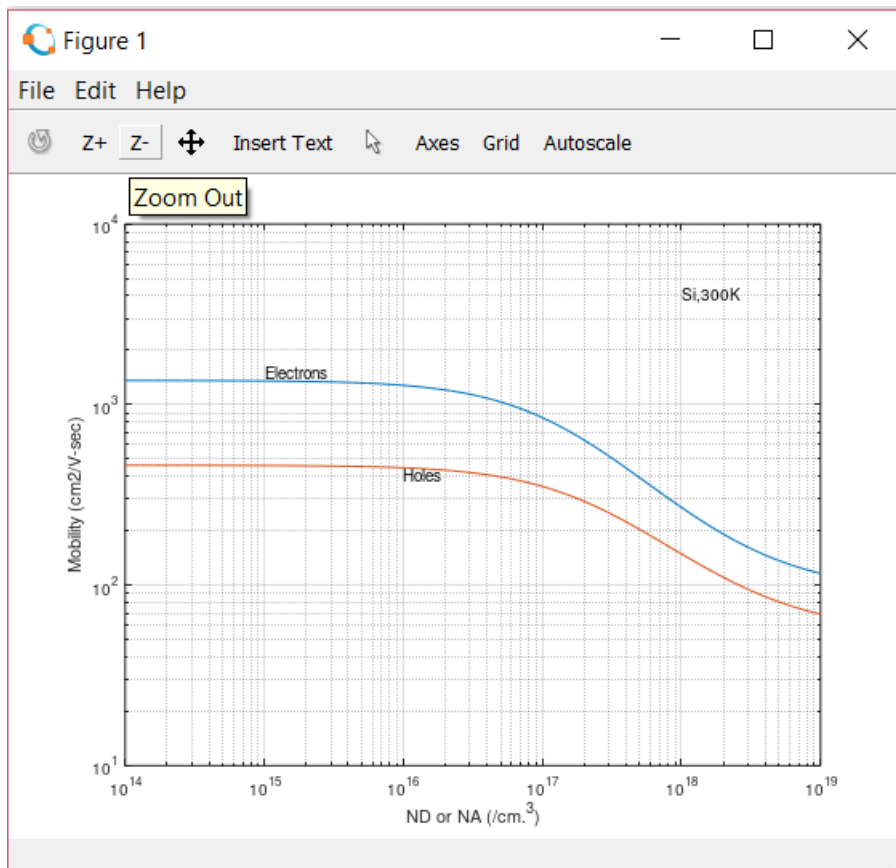
Assignment 2

Problem 3.1 (a) →

Octave Code →

```
prob3.1(a).m ×
1  # Graph of mobility vs doping concentration
2
3  # parameters
4
5  # For n-type
6  unmin=92;
7  un0=1268;
8  Ndref=1.3*(10.^17);
9  an=0.91;
10
11 # For p-type
12 upmin=54.3;
13 up0=406.9;
14 Naref=2.35*(10.^17);
15 ap=0.88;
16
17
18 # Calculation
19
20 N=logspace(14,19);
21 un=unmin + un0./((1+N/Ndref).^an);
22 up=upmin + up0./((1+N/Naref).^ap);
23
24
25 # Graph plotting
26
27 loglog(N, un, N, up);
28 grid;
29 axis([1.0e14 1.0e19 1.0e1 1.0e4]);
30 xlabel('ND or NA (/cm.^3)');
31 ylabel('Mobility (cm2/V-sec)');
32 text(1.0e15,1500,'Electrons');
33 text(1.0e16,400,'Holes');
34 text(1.0e18,4000,'Si,300K');
```

Generated Plot →



Problem 3.1 (b) →

(i) *n-type* ---->

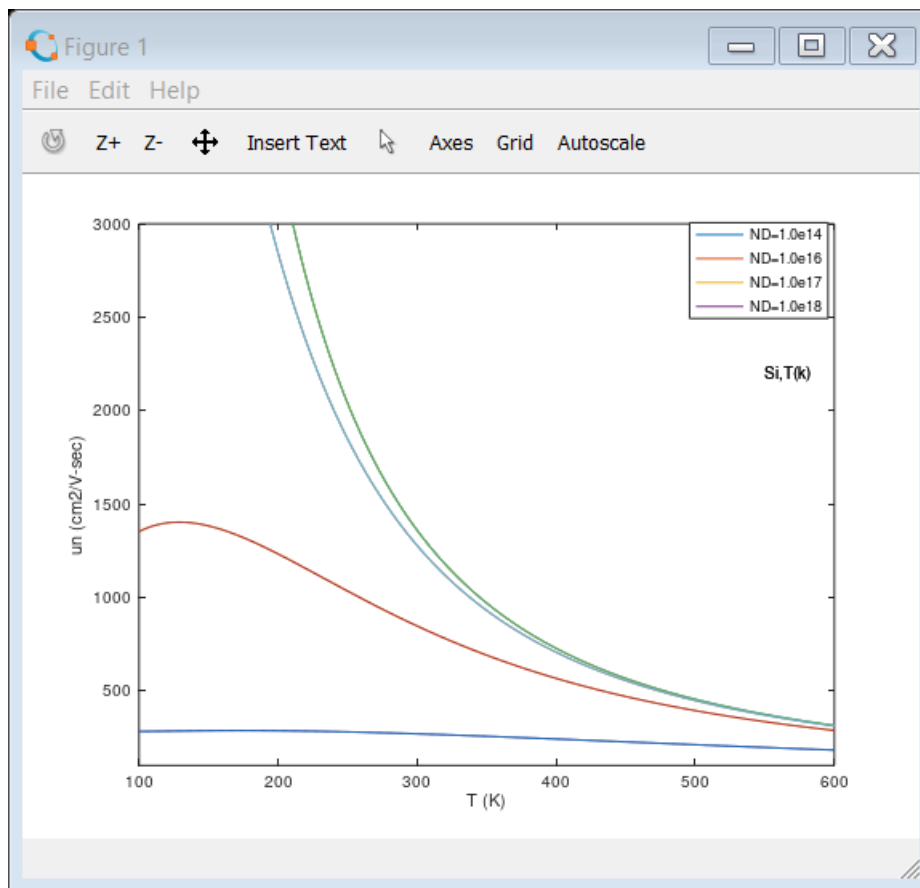
Octave Code →

```

1  # Plotting of Mobility vs T(K);
2
3  # Values at T=300K
4  unmin300=92;
5  un0300=1268;
6  Ndref300=1.3*(10.^17);
7  an300=0.91;
8  T=100:1:600;
9
10 # Values at T(k)
11 unmin=unmin300*((T/300).^(-0.57));
12 un0=un0300*((T/300).^(-2.33));
13 Ndref=Ndref300*((T/300).^2.4);
14 an=an300*((T/300).^(-0.146));
15
16 ND=1.0e14;
17 un=unmin + un0./((1+ND./Ndref).^an);
18 plot(T,un);
19 axis([100 600 1.0e2 3000]);
20 xlabel('T (K)');
21 ylabel('un (cm2/V-sec)');
22 legend('ND=1.0e14');
23 hold on
24
25 ND=1.0e16;
26 un=unmin + un0./((1+ND./Ndref).^an);
27 plot(T,un);
28 axis([100 600 1.0e2 3000]);
29 legend('ND=1.0e16');
30 hold on
31
32 ND=1.0e17;
33 un=unmin + un0./((1+ND./Ndref).^an);
34 plot(T,un);
35 axis([100 600 1.0e2 3000]);
36 legend('ND=1.0e17');
37 hold on
38
39 ND=1.0e18;
40 un=unmin + un0./((1+ND./Ndref).^an);
41 plot(T,un);
42 axis([100 600 1.0e2 3000]);
43 legend('ND=1.0e14', 'ND=1.0e16', 'ND=1.0e17', 'ND=1.0e18');
44
45 text(550,2200,'Si,T(k)');

```

Generated Plot →



(ii) *p*-type --- \rightarrow

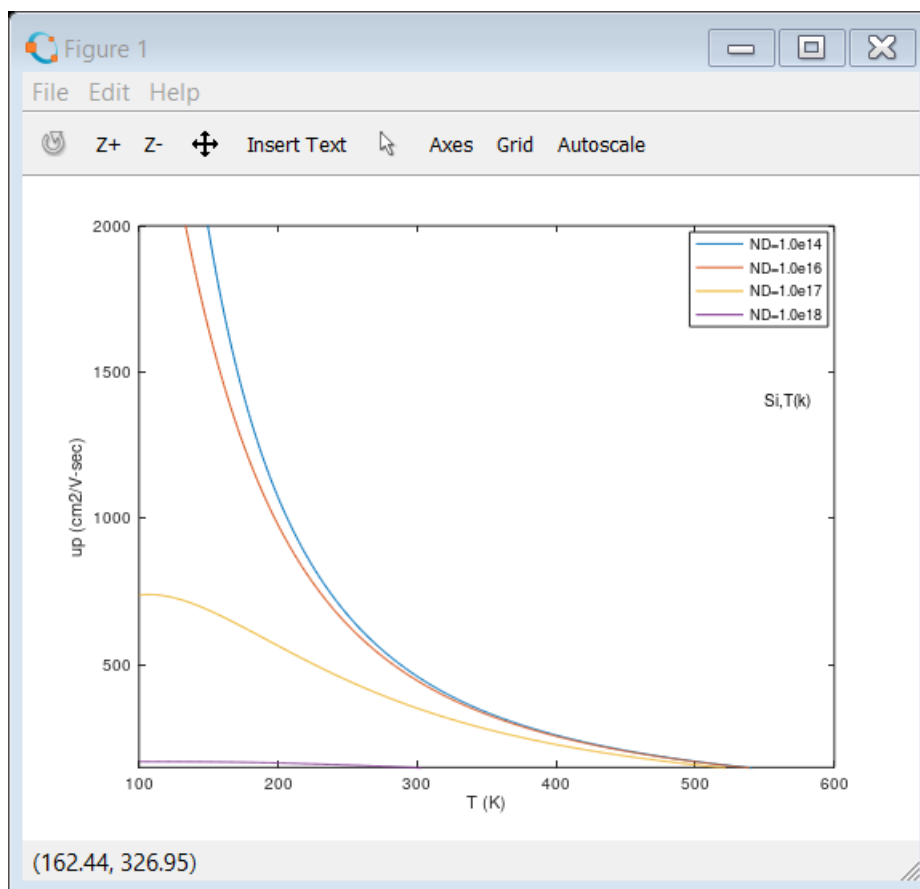
Octave Code \rightarrow

```

1  # Plotting of Mobility vs T(K);
2
3  # Values at T=300K
4  upmin300=54.3;
5  up0300=406.9;
6  Naref300=2.35*(10.^17);
7  ap300=0.88;
8  T=100:1:600;
9
10 # Values at T(k)
11 upmin=upmin300*( (T/300).^(-0.57) );
12 up0=up0300*( (T/300).^(-2.23) );
13 Naref=Naref300*( (T/300).^2.4 );
14 ap=ap300*( (T/300).^(-0.146) );
15
16 NA=1.0e14;
17 up=upmin + up0./((1+NA./Naref).^ap);
18 plot(T,up);
19 axis([100 600 150 2000]);
20 xlabel('T (K)');
21 ylabel('up (cm2/V-sec)');
22 hold on
23
24 NA=1.0e16;
25 up=upmin + up0./((1+NA./Naref).^ap);
26 plot(T,up);
27 axis([100 600 150 2000]);
28 hold on
29
30 NA=1.0e17;
31 up=upmin + up0./((1+NA./Naref).^ap);
32 plot(T,up);
33 axis([100 600 150 2000]);
34 hold on
35
36 NA=1.0e18;
37 up=upmin + up0./((1+NA./Naref).^ap);
38 plot(T,up);
39 axis([100 600 150 2000]);
40 legend('ND=1.0e14', 'ND=1.0e16', 'ND=1.0e17', 'ND=1.0e18');
41
42 text(550,1400,'Si,T(k)');

```

Generated Plot →

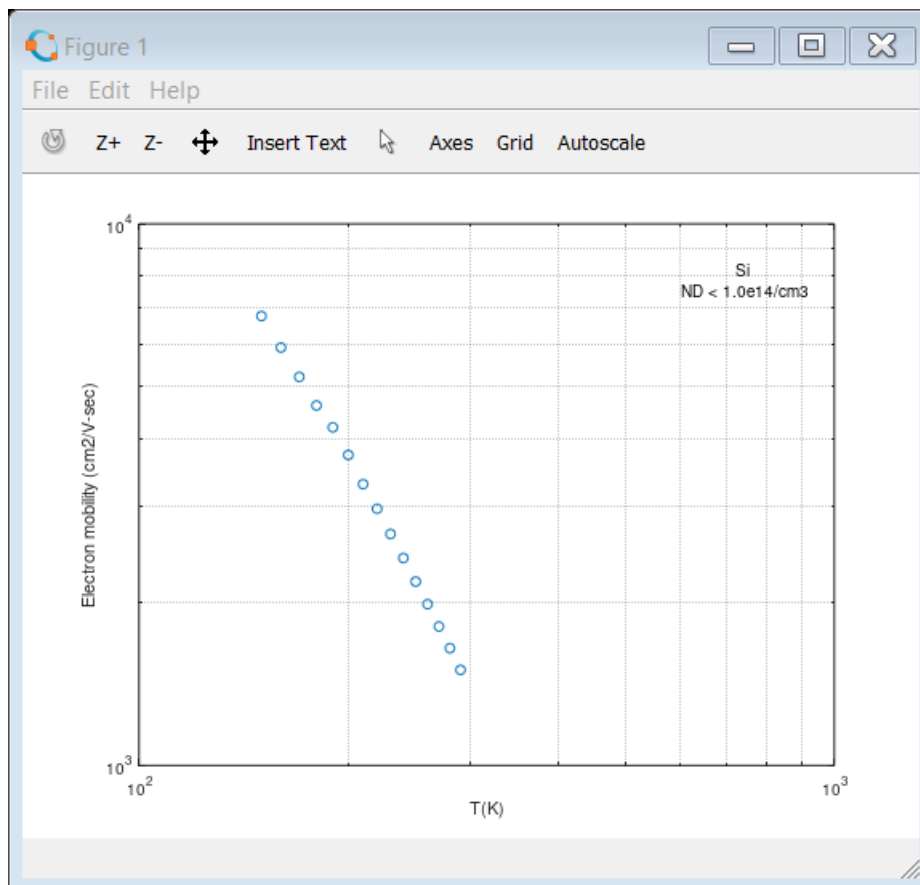


Problem 3.4 (b) →

Octave Code →

```
1 # taking values
2
3 T=150:10:290;
4 un=[6757 5910 5216 4619 4209 3743 3306 2978 2675 2415 2185 1985 1805 1646 1501];
5
6 # taking log of values
7 u=log(T);
8 v=log(un);
9
10 # Fitting this in equation
11 x=polyfit(u,v,1); # v=x(1)+x(2)*u
12 a=x(1);
13 b=-x(2); # log(un)=-b*log(T)+a
14
15 T1=120:10:350;
16 y1=exp(a).*(T1.^(-b));
17
18
19 # Plotting
20 loglog(T,un, 'o', T1, y1);
21 grid;
22 axis([100,1000,1000,10000]);
23 xlabel('T(K)');
24 ylabel('Electron mobility (cm2/V-sec)');
25
26 text(600, 7500, 'ND < 1.0e14/cm3');
27 text(720, 8200, 'Si');
```

Generated Plot →



Problem 3.4 (c) →

By this plot, we almost found accurately same value. This plot is very impressive.

The experimentally determined b fit value is almost same to the b-value noted on text-plot (2.29 versus 2.3).

The magnitude is also in close with the fig 3.7(a) plot.

A lowly-doped sample was employed, so that lattice scattering would dominate and a power-law dependence would be observed.

Problem 3.9 (a) →

(i) **n-type** →

Octave Code →

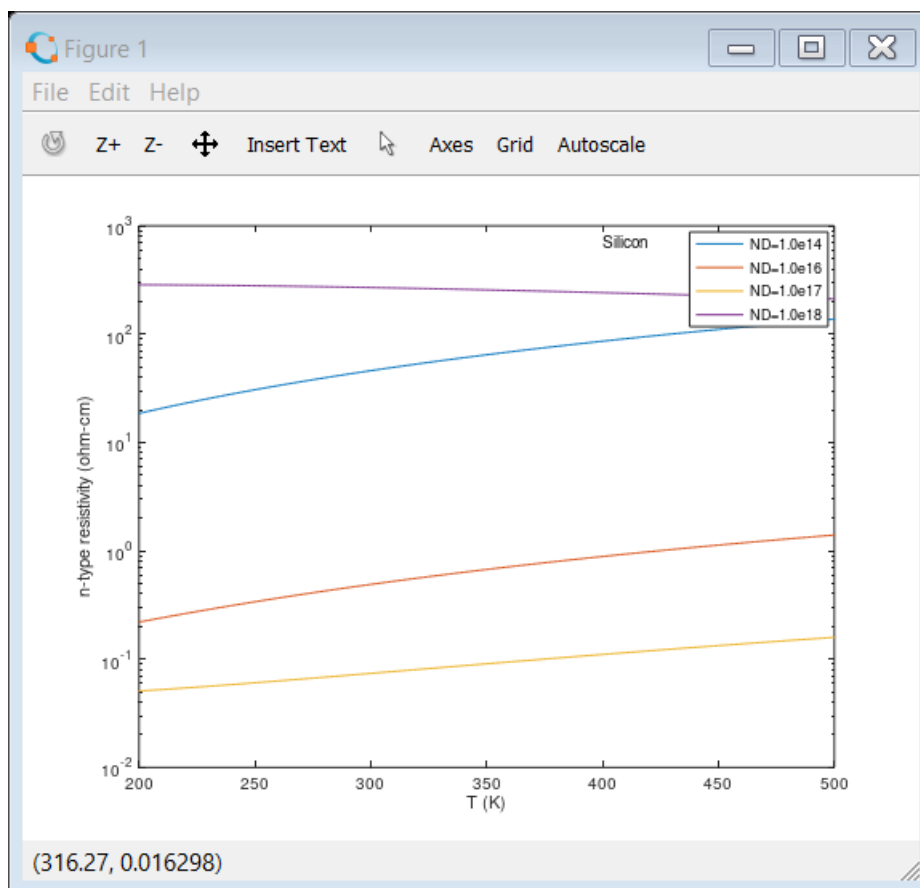
```
1 # Plotting of Resistivity vs T(K);
2
3 # Values at T=300K
4 unmin300=92;
5 un0300=1268;
6 Ndref300=1.3*(10.^17);
7 an300=0.91;
8 T=100:1:600;
9 q=1.6e-19;
10
11 # Values at T(k)
12 unmin=unmin300*((T/300).^(-0.57));
13 un0=un0300*((T/300).^(-2.33));
14 Ndref=Ndref300*((T/300).^2.4);
15 an=an300*((T/300).^(-0.146));
16 pn=logspace(-2,3);
17
18 ND=1.0e14;
19 un=unmin + un0./((1+ND./Ndref).^an);
20 pn=1./(q*un*ND);
21 semilogy(T,pn);
22 axis([200 500 1.0e-2 1.0e3]);
23 xlabel('T (K)');
24 ylabel('n-type resistivity (ohm-cm)');
25 hold on
26
27 ND=1.0e16;
28 un=unmin + un0./((1+ND./Ndref).^an);
29 pn=1./(q*un*ND);
30 plot(T,pn);
31 axis([200 500 1.0e-2 1.0e3]);
32 hold on
33
34 ND=1.0e17;
35 un=unmin + un0./((1+ND./Ndref).^an);
36 pn=1./(q*un*ND);
```

```

37 plot(T,pn);
38 axis([200 500 1.0e-2 1.0e3]);
39 legend('ND=1.0e17');
40 hold on
41
42 ND=1.0e18;
43 un=unmin + un0./((1+ND./Ndref).^an);
44 plot(T,un);
45 axis([200 500 1.0e-2 1.0e3]);
46 legend('ND=1.0e14', 'ND=1.0e16', 'ND=1.0e17', 'ND=1.0e18');
47
48 text(400,700,'Silicon');

```

Generated Plot →

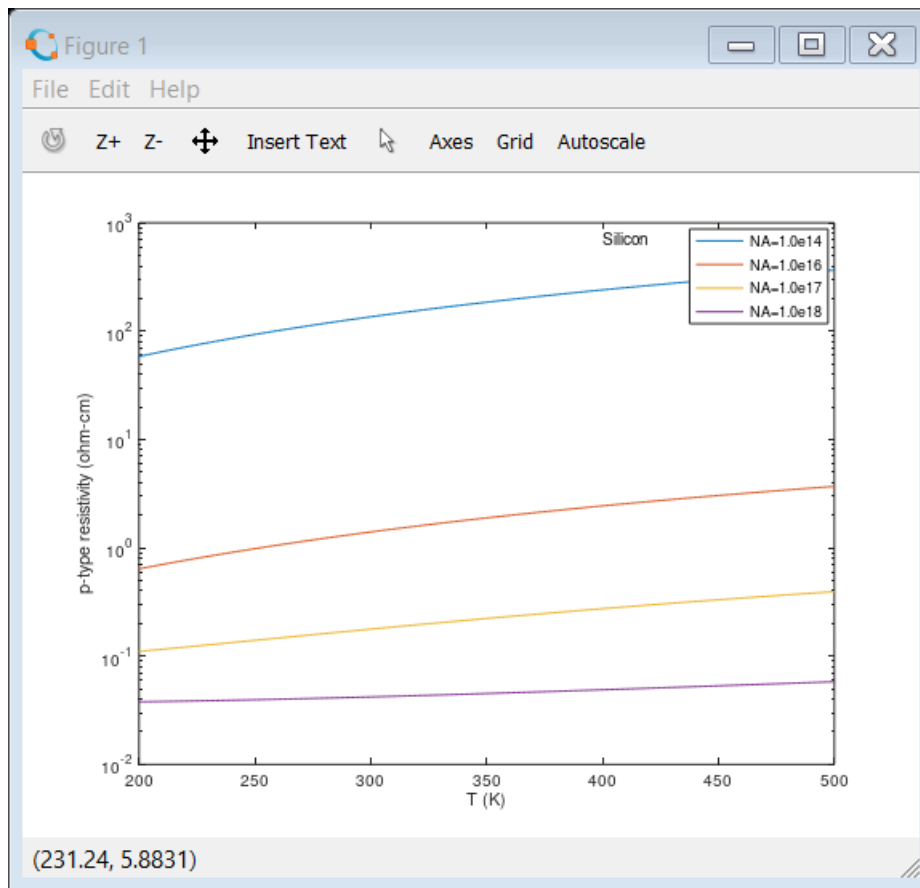


(ii) **p-type ---->**

Octave-Code →

```
1 # Plotting of Resistivity vs T(K);
2
3 # Values at T=300K
4 upmin300=54.3;
5 up0300=406.9;
6 Naref300=2.35*(10.^17);
7 ap300=0.88;
8 T=100:1:600;
9 q=1.6e-19;
10
11 # Values at T(k)
12 upmin=upmin300*((T/300).^(-0.57));
13 up0=up0300*((T/300).^(-2.23));
14 Naref=Naref300*((T/300).^2.4);
15 ap=ap300*((T/300).^(-0.146));
16
17 NA=1.0e14;
18 up=upmin + up0./((1+NA./Naref).^ap);
19 pn=1./(q*up*NA);
20 semilogy(T,pn);
21 axis([200 500 1.0e-2 1.0e3]);
22 xlabel('T (K)');
23 ylabel('p-type resistivity (ohm-cm)');
24 hold on
25
26 NA=1.0e16;
27 up=upmin + up0./((1+NA./Naref).^ap);
28 pn=1./(q*up*NA);
29 semilogy(T,pn);
30 axis([200 500 1.0e-2 1.0e3]);
31 hold on
32
33 NA=1.0e17;
34 up=upmin + up0./((1+NA./Naref).^ap);
35 pn=1./(q*up*NA);
36 semilogy(T,pn);
37
38 axis([200 500 1.0e-2 1.0e3]);
39 hold on
40
41 NA=1.0e18;
42 up=upmin + up0./((1+NA./Naref).^ap);
43 pn=1./(q*up*NA);
44 semilogy(T,pn);
45 axis([200 500 1.0e-2 1.0e3]);
46 legend('NA=1.0e14', 'NA=1.0e16', 'NA=1.0e17', 'NA=1.0e18');
47 text(400,700,'Silicon');
```

Generated Plot →



Prob 3.26 →

(a) Octave code →

```
1 # Given values
2 Eg=1.1; # eg of silicon
3 kT=0.0259;
4 ni=1e10;
5
6 # taking input
7 ND=input('Give the value of ND in cm-3, ND = ');
8 pn0=input('Give the value of pn0 in cm-3, pn0 = ');
9
10 p0= ni.^2/ND;
11 t=log(100*pn0/p0);
12 z=linspace(0,t);
13
14 # taking all energies related to Ev
15 Ec=Eg/kT;
16 FN=Eg/(2*kT) + log(ND/ni);
17 FP=Eg/(2*kT) - log(p0/ni+(pn0/ni).*exp(-z));
18
19 # plotting
20 plot(z,FP);
21 axis([0,t,-5,45])
22 xlabel('x/LP');
23 ylabel('(E-Ev)/kT');
24 hold on
25
26 # now comparing with Ec and Ev
27 x=[0,t];
28 a1=[Ec,Ec];
29 a2=[FN,FN];
30 plot(x,a1,x,a2);
31 a3=[Ec/2,Ec/2];
32 a4=[0,0];
33 plot(x,a3,'--',x,a4,'y');
34
35 # labelling
36 u=t+0.2;
37 text(u,43.4,'Ec');
38 text(u,21,'Ei');
39 text(u/2,FN+1,'FN');
40 text(u/2,FP(50)-1,'FP');
41 text(u,0,'Ev');
```

(b)

Taking $N_D = 10^{15} \text{ /cm}^{-3}$

And $p_{n0} = 10^{10} \text{ /cm}^{-3}$

Hence, Generated Plot →

