Scilab Textbook Companion for Semiconductor Physics and Devices Basic Principles by D. A. Neamen[1]

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Book Description

Title: Semiconductor Physics and Devices Basic Principles

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 1

The Crystal Structure of Solids

Scilab code Exa 1.1 find volume density of atoms

```
1 clc
2
3 a=5*10^-8// a=5A = 5*10^-8cm
4 n=2
5 d=n/a^3
6 disp(d,"the value of d in atoms per cm^3 is")
```

Scilab code Exa 1.3 Calculate suface density

```
1 clc
2
3 a1=5*10^-8// a=5A = 5*10^-8cm
4 n=2// number of atoms is 2
5 d=n/(a1*a1*2^0.5)
6 disp(d,"the value of d in atoms per cm^2 is")
```

Chapter 2

Introduction to Quantum Mechanics

Scilab code Exa 2.1 Calculate photon energy

```
1  clc
2
3  lambda=0.708*10^-8// cm
4  h=6.625*10^-34// J*s Plank's constant
5  c=3*10^10// cm/s
6  e=1.6*10^-19// eV
7  E=h*c/lambda// E=hv=hc/lambda
8  disp(E,"the value of E in J is")
9  E=E/e
10 disp(E,"the value of E in eV is")
```

Scilab code Exa 2.2 Calculate de broglie wavelength

```
1  clc
2
3  m=9.11*10^-31// kg*m/s
```

```
4  v=10^5//m/s
5  h=6.625*10^-34//js
6
7  p=m*v
8  disp(p,"momentum is")
9  lambda=h/p
10 disp(lambda,"de broglie wavelength in meter is")
```

Scilab code Exa 2.3 Calculate first three energy levels

```
1  clc
2
3  a=5*10^-8// a=5A = 5*10^-8cm
4  h=1.054*10^-34// J*s Plank's constant
5  m=9.11*10^-31// kg*m/s
6  e=1.6*10^-19// eV
7
8  n=1
9  En=(h^2*n^2*%pi^2)/(2*m*a^2)
10 disp(En,"the value of En in J")
11 En=(En/e)
12 disp(En,"the value of En in eV")
13
14 n=2
15 E2=(h^2*n^2*%pi^2)/(2*m*a^2)
16 disp(En,"the value of E2 in J")
17 E2=(E2/e)
18 disp(E2,"the value of E2 in eV")
19
20 n=3
21 E3=(h^2*n^2*%pi^2)/(2*m*a^2)
22 disp(E3,"the value of E3 in J")
23 E3=(E3/e)
24 disp(E3,"the value of E3 in eV")
```

Scilab code Exa 2.4 Calculate penetration depth

```
clc

v=10^5// m/s
m=9.11*10^-31// kg*m/s
e=1.6*10^-19// eV
h=1.054*10^-34
E=0.5*m*v*v
disp(E,"the value of E in J is eV")
E1=E/e // value of E in eV
disp(E1,"eV=")
d=sqrt((h*h)/(2*m*E))
disp(d,"the value of d in m is ")
```

Scilab code Exa 2.5 Calculate probability

```
clc

E=2// eV
V0=20// eV
a=3*10^-10// a=3A = 3*10^-10 m
m=9.11*10^-31// kg*m/s
e=1.6*10^-19// eV
h=1.054*10^-34// J*s
K2=((2*m*(V0-E)*e)/(h*h))^0.5
disp(K2,"the value of K2 in m^-1 is")
T=16*(E/V0)*(1-E/V0)*exp(-2*K2*a)
disp(T,"the value of T is")
```

Chapter 3

Introduction to the Quantum Theory of Solids

Scilab code Exa 3.1 Calculate change in KE

```
1  clc
2
3  v1=10^5 //m per sec
4  deltav=0.01 //m per sec
5  m=9.11*10^-31// kg*m/s
6  e=1.6*10**-9 //Coulombs
7
8  //deltaE=0.5*m*(v2**2-v1**2)
9  //deltav=v2-v1 ..... deltav<<v1
10
11 deltaE=m*v1*deltav
12 disp(deltaE,"in J is")
13 deltaE=deltaE/e
14 disp(deltaE,"in eV is")
```

Scilab code Exa 3.2 Determine lowest energy bandwidth

```
clc

P=10
a=5*10^-10 // a=5 Armstrong
h=1.054*10^-34
m=9.11*10^-31 //kg

//alpha*a=%pi
//sqrt((2*m*E2)/h^2)*a=%pi
E2=(%pi^2*h^2)/(2*m*a^2)
disp(E2,'E2= %f J\n')
E2=E2*6.2415*10^18
disp(E2,'E2= %f eV')

E1=1.053 //eV
AE=E2-E1
disp(AE,'AE= %f eV')
```

Scilab code Exa 3.3 Calculate density of states

```
clc

m=9.11*10^-31 //kg
E=1.6*10^-19 //C
h=6.625*10^-34 //J sec
N=(4*%pi*(2*m)^(3/2)*2*E^(3/2))/(h^3*3)
disp(N,'E2= %f per meter^3\n')
```

Scilab code Exa 3.4 Determine possible no of ways

```
clc

y=10
```

```
4 Ni=10
5 gi=10
6 //(gi-Ni)!=1
7 z=(factorial(gi)/factorial(Ni)*factorial(gi-Ni))
8 printf('z=%f\n',z)
```

Scilab code Exa 3.5 Determine possible no of ways

```
1 clc
2 gi=10
3 Ni=9
4 x=gi-Ni
5
6 //factorial(gi-Ni)=1
7 z=(factorial(gi)/factorial(Ni)*factorial(gi-Ni))
8 printf('z=%f\n',z)
```

Scilab code Exa 3.6 Calculate probability

```
1 clc
2
3 T=300 //K
4 //a=E-Ef
5 //a=3*k*T
6 //fF(E)=1/(1+exp(E-Ef/kT))
7 z=exp(3)
8 y=1/(1+z)                          //y=fF(E)
9 printf('fF(E)=%f\n',y)
```

Scilab code Exa 3.7 Determine temp

```
clc

Ef=6.25 //eV
E=5.95  //eV
p=0.01
k= 8.617 *10^-5 //eV K^-1

//p=1-fF(E)
//fF(E)=1/(1+exp(E-Ef/kT))
//p=1-1/(1+exp(E-Ef/kT))                    equation 1
x=E-Ef

y=(1/(1-p))-1      // solving the above equtaion 1

T=x/(k*log(y))
printf('T=%f K\n',T)
```

Chapter 4

The Semiconductor in Equilibrium

Scilab code Exa 4.1 Calculate probability

```
clc

T=300 //K
Nc=2.8*10^19 //cm^-3
k=8.617 *10^-5 //eV K^-1
//E=Ec
//a=Ec-Ef
a=-0.25
//fF(E)=1/(1+exp(Ec-Ef/kT)) =exp(-(Ec-Ef)/kT)
//b=k*T
//disp(b)
c=k*T
fFE=exp(a/c)
disp(fFE,"fF(E) value is=")
n0=Nc*exp(-a/(k*T))
disp(n0,"n0 value in cm^-3 is")
```

Scilab code Exa 4.2 Calculate thermal equlilibrium

```
clc

T1=400 //K
T2=300 //K
N=1.04*10^19 //cm^-3
k=8.617*10^-5 //eV/K

Nv=N*(T1/T2)^(3/2)
disp(Nv,'Nv=%f cm^-3\n\n')

a=k*T2*(T1/T2)
disp(a,'kT=%f eV\n\n')

//p0=Nv*exp(-(Ef-Ev)/kT)
p0=Nv*exp(-0.27/a)
disp(p0,'p0=%f cm^-3 \n')
```

Scilab code Exa 4.3 Calculate intrinsic carrier

```
clc

T1=300 //K
T2=450 //K
Nc=4.7*10^17 //cm^-3
N=7*10^18 //cm^-3
k=8.617*10^-5 //eV/K
a=k*T1*(T2/T1)
disp(a,'kT=%f eV\n\n')

ni=sqrt(Nc*N*exp(-1.42/(k*T1)))
disp(ni,'ni=%f cm^-3\n\n')

ni=sqrt(Nc*N*(T2/T1)^3*exp(-1.42/a))
```

```
15 disp(ni,'ni=%f cm^-3\n\n')
```

Scilab code Exa 4.4 Calculate position

```
1  clc
2
3  T=300 //K
4  mn=1.08 //m0
5  mp=0.56 //m0
6  k=8.617*10^-5 //eV/K
7
8  //Efi-Emidgap=(3/4)k*T*log(mp/mn)
9  //a=Efi-Emidgap
10
11 a=(0.75)*k*T*log(mp/mn)
12 printf('Efi-Emidgap=%f eV',a)      //textbook ans is
       wrong
```

Scilab code Exa 4.5 Calculate thermal equlilibrium

```
1  clc
2
3  T=300 //K
4  Nn=2.8*10^19 //cm^-3
5  Np=1.04*10^19 //cm^-3
6  //a=Ef-Ev
7  an=0.25 //eV
8  ap=0.87 //eV
9  k=8.617*10^-5 //eV/K
10
11 n0=Nn*exp(-an/(k*T))
12 disp(n0,"n0 in cm^-3 is=")
13
```

```
14 p0=Np*exp(-ap/(k*T))
15 disp(p0,"p0 in cm^-3 is=")
```

Scilab code Exa 4.6 Calculate electron concentration

```
1  clc
2
3  nf=2
4  T=300 //K
5  Nc=2.8*10**19 //cm^-3
6
7  //n0=(2/sqrt(%pi))*Nc*F12(nf)
8  //x=F12(nf)=2.3
9  x=2.3
10 n0=(2/sqrt(%pi))*Nc*x
11 disp(n0,"n0 in cm^-3 is= ")
```

Scilab code Exa 4.7 Determine fraction of total electron

```
1  clc
2
3  Nd=10**16 //cm^-3
4  Ne=2.8*10**19 //cm^-3
5  T=300 //K
6
7  //(nd/(n0+nd))=z=1/(1+(Ne/2*Nd)*exp(-(Ec-Ed)/kT))
8  //y=Ec-Ed
9  y=0.045
10 k=8.617*10^-5 //eV/K
11 z=1/(1+(Ne/(2*Nd))*exp(-y/(k*T)))
12 disp(z,"the donor states is=")
```

Scilab code Exa 4.9 Calculate thermal equlilibrium

```
clc

Nd=10**16 //cm^-3
Na=0
ni=1.5*10**10 //cm^-3
T=300 //K
k=8.617*10^-5 //eV/K

n0=((Nd-Na)/2)+sqrt((((Nd-Na)/2)^2)+ni^2)
disp(n0,"n0 in cm^-3 is")

p0=(ni^2)/n0
disp(p0,"p0 in cm^-3")
```

Scilab code Exa 4.10 Calculate thermal equlilibrium

```
clc

Nd=5*10**13 //cm^-3
Na=0
ni=2.4*10**13 //cm^-3
T=300 //K
k=8.617*10^-5 //eV/K

n0=((Nd-Na)/2)+sqrt((((Nd-Na)/2)^2)+ni^2)
disp(n0,"n0 in cm^-3 is")

p0=(ni^2)/n0
disp(p0,"p0 in cm^-3")
```

Scilab code Exa 4.11 Calculate thermal equlilibrium

```
clc

T=300 //K
Nd=3*10**15 //cm**-3
Na=10**16 //cm**-3
k=8.617*10^-5 //eV/K
ni=1.5*10**16 //cm^-3

a=((Na-Nd)/2)
disp(a)
b=sqrt(((Na-Nd)/2)^2+(ni^2))
disp(b)

p0=a+b
disp(p0,"p0 in cm^-3 is=")          //textbook ans is
    wrpng

n0=(ni^2)/p0
disp(n0,"n0 in cm^-3 is=")          //textbook ans is
    wrpng
```

Scilab code Exa 4.12 Determine impurity concentration

```
clc

T1=550 //K
T2=300 //K
Nc=2.8*10**19 //cm**-3
Ne=1.04*10**19 //cm**-3
k=8.617*10^-5 //eV/K
```

```
Eg=1.12

//ni^2=Nc*Ne*exp(-Eg/(k*T))

ni=sqrt(Nc*Ne*(T1/T2)^3*exp((-Eg/(k*T2))*(T2/T1)))
disp(ni ,"ni in cm^-3 is = ")

//n0=1.05*Nd
//n0=(Nd/2)+sqrt((Nd/2)^2+ni^2)       equation 1

a=(((1.05*2)-1)/2)^2                  //simplifying and
   sloving the about equaton 1
b=ni^2
c=((4*a)-1)/4
Nd=sqrt(b/c)
disp(Nd,"Nd value in cm^-3 is=")
```

Scilab code Exa 4.13 Determine impurity concentration

```
clc

T=300 //K
Na=10**16 //cm^-3
Nc=2.8*10**19 //cm**-3
k=8.617*10^-5 //eV/K

//a=Ec-Ef
a=0.20 //eV
//Ec-Ef=k*T*log(Ne/(Nd-Na))
//Nd-Na=Nc*exp(-(Ec-Ef)/k*T)

Nd=Na+Nc*exp(-a/(k*T))
disp(Nd,"Nd in cm^-3 is= ")
```

Scilab code Exa 4.14 Determine fermi level position

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
ni=1.5*10**10 //cm^-3
//Ef-Ea=a
a=3*k*T
//Ea-Ev=b
b=0.045 //eV
Eg=1.12 //eV

//Efi-Ef=(Eg/2)-(Ea-Ev)-(Ef-Ea)=kT*log(Na/ni)
c=(Eg/2)-(b)-(a)
Na=ni*exp(c/(k*T))
disp(Na,"Na in cm^-3 is= ")
```

Chapter 5

Carrier Transport Phenomena

Scilab code Exa 5.1 Drift current density

```
clc

Nd=10**16 //cm^-3
Na=0
ni=1.8*10**6 //cm^-3
T=300 //K
k=8.617*10^-5 //eV/K
E=10 //V/cm^2
e=1.6*10**-19
un=8500

n0=((Nd-Na)/2)+sqrt((((Nd-Na)/2)^2)+ni^2)
disp(n0,"n0 in cm^-3 is")

p0=(ni^2)/n0
disp(p0,"p0 in cm^-3")

//Jdrf=e*(un*n0+up*p0)*E= e*un*Nd*E
Jdrf=e*un*Nd*E
disp(Jdrf,"Jdrf in A/cm^2 is= ")
```

Scilab code Exa 5.2 doping concentration

```
clc

Na=10**17 //cm**-3
T=300 //K
k=8.617*10^-5 //eV/K
E=10 //V/cm^2
e=1.6*10**-19 //C


//sigma=e*un*n0=e*un*(Nd-Na)
 //if
Nd=2*10**17 //cm**-3
sigma=8.16//ohm/cm
un=sigma/(e*(Nd-Na))
disp(un,"un in cm^2/Vs is=")

//if
Nd=5*10**17 //cm^-3
sigma=20.8//ohm/cm
un=sigma/(e*(Nd-Na))
disp(un,"un in cm^2/Vs is=")

//if
Nd=3.5*10**17 //cm^-3
sigma=16//ohm/cm
un=sigma/(e*(Nd-Na))
disp(un,"un in cm^2/Vs is=")
```

Scilab code Exa 5.3 design semiconductor resistor

```
clc

V=5 //v
R=10*10^3 //ohm
J=50 //A/cm^2
E=100
Na=1.25*10**16 //cm^-3
Nd=5*10**15 //cm^-3
e=1.6*10**-19 //C
up=410 //cm**2/Vs

I=V/R
disp(I,"I current in Ampere is=")

A=I/J
disp(A,"A cross sectional area in cm^2 is=")

L=V/E
disp(L,"L length of resistor in cm is= ")

sigma=L/(R*A)
disp(sigma,"sigma conductivity in per ohm cm is=")

//sigma=e*up*p0=e*up*(Na-Nd)
sigma=e*up*(Na-Nd)
disp(sigma,"sigma conductivity in per ohm cm is=")
```

Scilab code Exa 5.4 diffusion current density

```
clc

T=300 // ..K
Dn=225 //cm^2/s
e=1.6*10^-19// C
deltax=0.10 //cm
```

```
deltan=(1*10**18-7*10**17)//cm^-3

//Jnxdif=e*Dx*derivative (n,x)=e*Dn*(deltan/deltax)
Jnxdif=e*Dn*(deltan/deltax)
disp(Jnxdif,"diffusion current density in A/cm^2 is=
    ")
```

Scilab code Exa 5.5 Determine induced electric field

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
//derivative(Ndx,x)=a
a=-10**19 //cm**-4
Ndx=(10^16-10^19) //cm^3
l=1

//Ex=-(k*T/l)*(1/Ndx)*derivative(Ndx,x)
Ex=-(k*T/l)*(1/Ndx)*a*10^3
disp(Ex,"induced electric field in V/cm is= ")
```

Scilab code Exa 5.6 Determine diffusion coefficient

```
clc

T=300 //K
u=1000 //cm^2/s
k=8.617*10^-5 //eV/K
e=1.6*10**-19 //C

//D=((k*T)/e)*u
D=k*T*u
```

```
10 disp(D,"diffusion coefficient in cm^2/s is =")
```

Scilab code Exa 5.7 determine majority carrier

```
1  clc
2
3  I=10^-3 //A
4  Bz=5*10**-2 //500gauss
5  e=1.6810*10**-19 //C
6  Vh=-6.25*10^-3 //V
7  Vx=12.5 //V
8  W=10**-4//m
9  d=10**-5 //m
10
11 u=-(I*Bz)/(e*Vh*d)
12 disp(u,"electron concemtration in m^-3 is= ")
13
14 un=(I*I)/(e*Bz*Vx*W*d)
15 disp(un,"electron mobility in /Vs is=")//
      textbook ans is wrong
```

Chapter 6

Nonequilibrium Excess Carriers in Semiconductors

Scilab code Exa 6.5 dielechic relaxation time constant

```
clc

k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
un=1200
Nd=10^16 //cm^-3
esp0=8.85*10^-14
espr=11.7

sigma=e*un*Nd
disp(sigma,"conductivity in per ohm cm is= ")

esp=espr*esp0
disp(esp,"permittivity of silicon in F/cm")

taud=esp/sigma
disp(taud,"dielectric relaxtion time constant in sec
    is= ")
```

Scilab code Exa 6.6 calculate the quasi Fermi energy levels

```
clc

T=300//K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
n0=10^15 //cm^-3
p0=10^5 //cm^-3
ni=10^10 //cm^-3
deltan=10**13 //cm**-3
deltap=10**13 //cm**-3

//Ef-Efi=a
a=(k*T)*log(n0/ni)
disp(a,"fermi level for thermal equlibrium in eV is=
    ")

//Efn-Efi=b
b=(k*T)*log((n0+deltan)/ni)
disp(b,"quasi fermi level for electrons in eV is= ")

//Efi-Efp=c
c=(k*T)*log((p0+deltap)/ni)
disp(c,"quasi fermi level for holes in eV is= ")
```

Scilab code Exa 6.8 detrrminr the steady state excess carrier concentration

```
clc

k=8.617*10**-5//eV/K
```

```
e=1.6*10**-19 //C
x=0
taup0=10**-6//ses
taup01=10**-7 //sec
deltapb=10**14 //cm**-3
Dn=10 //cm^2/sec
Dp=10 //cm^2/sec
B=-9*10^13

deltap=deltapb*(taup01/taup0)
disp(deltap,"deltap in cm^-3 is=")

g=deltap/taup0
disp(g,"g generation in cm^-3s^-1 is= ")

//deltapx=10^14*(1-0.9*exp(-x/Lp))
Lp=sqrt(Dp*taup0)
disp(Lp,"Lp in meter is=")

deltapx=10^14*(1-0.9*exp(-x/Lp))
disp(deltapx,"distance from the surface is =")
```

Scilab code Exa 6.10 determine the value of surface recombinaion velocity

```
clc

k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Dp=10//cm^2/sec
Lp=31.6*10**-4 //m
g1taup0=10^14 //cm^-3
deltap0=10^13 //cm6-3

//deltap0=g1taup0*[g/((Dp/Lp)+s)]
s=(Dp/Lp)*((g1taup0/deltap0)-1)
```

```
12 disp(s,"surface recombination velocity in cm per sec
       is= ")
```

Chapter 7

The pn Junction

Scilab code Exa 7.1 calculate the built in potential barrier

```
clc

T=300//K
Na=1*10^18// Na=L*10^18 cm^-3
Nd=1*10^15// cm^-3
ni=1.5*10^10// cm^-3
e=1.6*10^-19// eV
k=1.3806*10^-23// JK^-1
Vbi=(((k*T)/e)*log(Na*Nd/ni^2))
disp(Vbi,"the value of Vbi in V is")

//changing the Na value
Na=10^16// Na=l*10^16 cm^1
Vbi=(((k*T)/e)*log(Na*Nd/ni^2))
disp(Vbi,"the value of Vbi in V is")
```

Scilab code Exa 7.2 calculate the space charge width

```
clc

T=300//K
Na=10^16// cm^-3
Nd=10^15// cm^-3
e=1.6*10^-19// eV
epsilon0=8.85*10^-14// F/m
epsilons=11.7
Vbi=0.635// V
W=(((2*(epsilons*epsilon0)*Vbi)/e)*((Na+Nd)/(Na*Nd))
   )^0.5
disp(W,"W spacing charge width in meter is")
xn=0.864*10^-4// xp=0.086 micro m
Emax=-e*Nd*xn/(epsilons*epsilon0)
disp(Emax,"the value of Emax in V/cm is")
```

Scilab code Exa 7.3 Tocalculate the width of the space charge region

```
clc

T=300//K
Na=10^16//  cm^-3
Nd=10^15// cm^-3
e=1.6*10^-19// eV
epsilon0=8.85*10^-14// F/m
epsilons=11.7
Vbi=0.635// V
Vr=5// V
W=(((2*(epsilons*epsilon0)*(Vbi+Vr))/e)*((Na+Nd)/(Na
   *Nd)))^0.5
disp(W,"the value of W in m is")
```

Scilab code Exa 7.4 design a pn junction

```
clc

T=300//K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Vr=25 //V
Emax=3*10^5//V/cm
Na=10^18//cm^-3
esp=11.7
esp0=8.85*10^-14

//Emax=sqrt((2*e*Vr*(Na+Nd))/(esp*(Na+Nd))
x=((Emax^2)*esp*esp0)/(2*e*Vr)              //solving
   the above equation we get

Nd=(Na*x)/(Na-x)
disp(Nd,"doping concentration in cm^-3 is =")
```

Scilab code Exa 7.5 calculate the junction capacitance

```
clc

T=300//K
Na=10^16//  cm^-3
Nd=10^15// cm^-3
e=1.6*10^-19// eV
epsilon0=8.85*10^-14// F/m
epsilons=11.7
Vbi=0.635// V
Vr=5// V
C=((e*(epsilons*epsilon0)*Na*Nd)/(2*(Vbi+Vr)*(Na+Nd)
   ))^0.5
A=10^-4// cm^2
C=C*A
disp(C,"the value of c with cross section area in F
```

```
is")
```

Scilab code Exa 7.6 determine the impurity doping concentrations

```
clc

T=300//K
ni=1.5*10^10// cm^-3
Nd=10^15// cm^-3
Vbi=0.855// V
e=1.6*10^-19// eV
k=1.3806*10^-23// JK^-1
S=1.32*10^15// Slope=1.32*10^-15 (F/cm^2)^-2*(V)-1
epsilon0=8.85*10^-14// F/m
epsilons=11.7
Nd=2/((e*(epsilons*epsilon0))*S)
Na=((ni*ni)/Nd)*exp((e*Vbi)/(k*T))
disp(Na,"the value of Na in cm^-3 is")
```

Chapter 8

The pn Junction Diode

Scilab code Exa 8.1 calculate the minority carrier hole concentration

```
1  clc
2
3  T=300// K
4  ni=1.5*10^10 //cm^-3
5  k=8.617*10^-5 //eV/K
6  Nd=10^16 //cm^-3
7  Va=0.60 //V
8
9  //pn=pn0*exp(e*Va/k*T)
10 pn0=ni^2/Nd
11 disp(pn0,"thermal equlibrium minority carrier hole
       concentration in cm^-3 is= ")
12
13 pn=pn0*exp(Va/(k*T))
14 disp(pn,"minority carrier hole concentration in cm
       ^-3 is= ")
```

Scilab code Exa 8.2 ideal reverse saturation current density

```
clc

T=300//K
Na=10**16 //cm^-3
Nd=10**16 //cm^-3
ni=1.5*10**10 //cm^-3
Dn=25 //cm^2/s
Dp=10 //cm^2/s
taup0=5*10^-7 //s
taun0=5*10^-7 //s
epsilon=11.7
e=1.6*10**-19 //C

//J=(E*D*np0/Ln)+(E*D*pn0/Lp)
Js=e*ni^2*[(1/Na)*sqrt(Dn/taun0)+(1/Nd)*sqrt(Dp/
   taup0)]
disp(Js,"reverse saturation current density in A/cm
   ^2 is=")
```

Scilab code Exa 8.3 design a pn junction diode

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Jp=5 //A/cm^2
Jn=20 //A/cm^2
Va=0.65 //V
ni=1.5*10**10 //cm^-3
Dn=25 //cm^2/s
Dp=10 //cm^2/s
taup0=5*10^-7 //s
taun0=5*10^-7 //s

```

```
15 //Jn=(e*Dn*np0/Ln)*[exp(e*Va/k*T)-1]==e*sqrt(Dn/
   taun0)*(ni^2/Na)*[exp(e*Va/k*T)-1]
16
17 Na=e*sqrt(Dn/taun0)*(ni^2/Jn)*[(exp(Va/(k*T)))-1]
18 disp(Na,"Na elctron diffusion current density in cm
   ^-3 is= ")
19
20 //Jp=(e*Dp*pn0/Lp)*[exp(e*Va/k*T)-1]==e*sqrt(Dp/
   taup0)*(ni^2/Nd)
21
22 Nd=e*sqrt(Dp/taup0)*(ni^2/Jp)*[(exp(Va/(k*T)))-1]
23 disp(Nd,"Nd hole diffusion current density in cm^-3
   is= ")
```

Scilab code Exa 8.4 calculate the electric field

```
1 clc
2
3 T=300 //K
4 k=8.617*10**-5//eV/K
5 e=1.6*10**-19 //C
6 Va=0.65 //V
7 Js=4.15*10^-11// A/cm^2
8 Nd=10**16 //cm**-3
9 un=1350 //cm^2/Vs
10 Jn=3.29 //A/cm^2
11
12 J=Js*[exp(Va/(k*T))-1]
13 disp(J,"current density in A/cm^2 is= ")
14
15 E=Jn/(e*Nd*un)
16 disp(E,"electric field in V/cm is= ")
```

Scilab code Exa 8.5 determine the change in the forward bias voltage

```
clc

T1=300 //K
T2=310 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Va1=0.60 //V
Va2=0.5827 //V
E=1.12 //eV

//J=exp(-Eg/(k*T))*exp((e*Va)/(k*T))

a=([e*Va2*k*T1]+[e*Va1*k*T2])/((k*T1)-(k*T2))
disp(a)
```

Scilab code Exa 8.6 calculate thc small signal admittance

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Vt=0.0259 //v
lp0=10^-3 //A
taup0=10^-7 //s
Idq=1*10**-3//A

Cd=(1*lp0*taup0)/(2*Vt)
disp(Cd,"diffusion capacitance in F is= ")

vd=(Vt/Idq)
disp(vd,"diffusion in ohm is= ")
```

Scilab code Exa 8.7 determine the relative magnitudes

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Na=10**16 //cm^-3
Nd=10**16 //cm^-3
ni=1.5*10**10 //cm^-3
tau0=5*10^-7 //s
eps=11.7
//Vbr+Vr=z
z=5 //V

W=sqrt(((2*eps))*((Na+Nd)/Na*Nd)*z)
disp(W,"depletion width in cm is= ")//
   textbook ans is wrong

Jgen=(e*ni*W)/(2*tau0)
disp(Jgen,"generation current density in A/cm^2 is=
   ")//       textbook ans is wrong
```

Chapter 9

Metal Semiconductor and Semiconductor Heterojunctions

Scilab code Exa 9.1 calculate the ilieorelical harrier height

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5//eV/K
5  e=1.6*10**-19 //C
6  Nd=10**16 //cm^-3
7  Nr=2.8*10**19 //cm^-3
8  Vbi=0.33
9  phim=4.55 //V
10 psi=4.01 //V
11 esp=11.7
12 esp0=8.85*10^-14
13
14 hb=phim-psi
15 disp(hb,"barrier height in V is= ")
16
17 phiu=(k*T)*log(Nr/Nd)
18 disp(phiu,"schottky barrier height in V is= ")
19
```

```
Vbt=hb-phiu
disp(Vbt,"in V is=")

xn=sqrt((2*esp*esp0*Vbi)/(e*Nd))
disp(xn,"space charge in cm is= ")

Emax=(e*Nd*xn)/(esp*esp0)
disp(Emax,"maxi electric field in V/cm is= ")
```

Scilab code Exa 9.2 calculate thc semiconductor doping

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
esp=11.7
esp0=8.85*10^-14
Nd=2.7*10**17 //cm^-3
Na=2.8*10**19 //cm^-3
Vbi=0.40

//(1/C)^2=2*(Vbi+Vr)/(e*esp*Nd)
//delta(1/C)^2/deltaVr=z
z=4.4*10**13
Nd=2/(e*esp*esp0*z)
disp(Nd,"semiconductor doping in cm^-3 is= ")

phin=(k*T)*log(Na/Nd)
disp(phin,"in v is=")

phibn=Vbi+phin
disp(phibn,"schottky barrier height in V is=")
```

Scilab code Exa 9.3 calculalr the Schottky barrier lowering

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
esp=11.7
esp0=8.85*10^-14
E=6.8*10**4 //V/cm

deltaphi=sqrt((e*E)/(4*%pi*esp*esp0))
disp(deltaphi,"schottky barrier lowring in V is =")

xm=sqrt(e/(16*%pi*esp*esp0*E))
disp(xm,"maxi barrier height in meter is=")
```

Scilab code Exa 9.4 calculate the effective Richardson constant

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
esp=11.7
esp0=8.85*10^-14
phibe=0.67 //V
Jst=6*10**-5 //A/cm^2

A=exp(phibe/(k*T))*(Jst/T^2)
disp(A,"Richardson constant in A/K^2-cm^2 is=")
   //textbook ans is different
```

Scilab code Exa 9.5 calculate the reverse saturation current densities

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
esp=11.7
esp0=8.85*10^-14
phibe=0.67 //V
A=114 //A/K^2-cm^2
Na=10^18 //cm^-3
Nd=10^16 //cm^-3
taup0=10^-7
taun0=10^-7
Dp=10 //cm^2/s
Dn=25 //cm^2/s
Lp=1.0*10**-3 //cm
Ln=1.58*10**-3 //cm
pn0=2.25*10**4 //cm^-3
np0=2.25*10**2 //cm^-3


a=k*T
Jst=(A*T^2)*exp(-phibe/a)
disp(Jst,"Richardson constant in A/K^2-cm^2 is=")

Js=((e*Dn*np0)/Ln)+((e*Dp*pn0)/Lp)
disp(Js,"reverse saturation current density in A/cm
    ^2 is=")
```

Scilab code Exa 9.6 calculate the forward bias voltage

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
esp=11.7
esp0=8.85*10^-14
J=10 //A/K^2-cm^2
Jst=5.98*10^-5//A/K^2-cm^2
Js=3.66*10^-11 //A/K^2-cm^2

//J=Jst*[exp(e*Va/k*T)-1]
//Va=(k*T/e)*log(J/Jst)
Va=(k*T)*log(J/Jst)
disp(Va,"forward bias voltage in V is= ")

Va=(k*T)*log(J/Js)
disp(Va,"forward bias voltage in V is= ")
```

Scilab code Exa 9.7 calculate the space charge width

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Nd=7*10^18 //cm^3
esp=11.7
esp0=8.85*10^-14
phibn=0.67 //V
Vbi=0.67

xn=sqrt((2*esp*esp0*Vbi)/(e*Nd))
disp(xn,"space charge width in cm is= ")
```

Scilab code Exa 9.8 detcmminc AE At and Vbi

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
ni=2.4*10^13 //cm^-3
Na=7*10^18 //cm^3
Nd=10^16 //cm^-3
pp0=6*10^18 //cm^-3
esp=11.7
esp0=8.85*10^-14
xn=4.13
xp=4.07

//AE1=e*(xn-xp)
AE=(xn-xp)
disp(AE,"AE in eV is=")

deltaE=1.43-0.67

AE1=deltaE-AE
disp(AE1,"AE1 in eV is= ")

pn0=(ni^2)/Nd
disp(pn0,"pn0 in cm^-3 is=")

Vbi=AE1+(k*T)*log((Nd*pp0)/(pn0*Na))
disp(Vbi,"Vbi in V is=")
```

Chapter 10

The Bipolar Transistor

Scilab code Exa 10.1 design the ratio of emitter doping

```
1 clc
2
3 T=300 //K
4 k=8.617*10**-5//eV/K
5 e=1.6*10**-19 //C
6 y=0.9967
7 //NB/NC=z
8 z=(1/y)-1
9 disp(z,"NB/NE value is=")
```

Scilab code Exa 10.2 design the base width

```
1 clc
2
3 T=300 //K
4 k=8.617*10**-5//eV/K
5 e=1.6*10**-19 //C
6 DB=10//cm^2/s
```

```
7  tauB0=10^-7//sec
8  alphatau=0.9967
9  //(xB/LB)=z
10 z=acosh(1/alphatau)
11 disp(z,"xB/LB is=")
12
13 LB=sqrt(DB*tauB0)
14 disp(LB,"LB in cm is=")
15 xB=z*10^-4
16 disp(xB,"xB in meter is=")
```

Scilab code Exa 10.3 calculate the forujard biased

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5//eV/K
5  e=1.6*10**-19 //C
6  Js0=10^-11//A/cm^2
7  Jr0=10^-8//A/cm^2
8  delta=0.9967
9  VBE=2*k*T*log(delta*10^3/(1-delta))
10 disp(VBE,"VBE in V is=")
```

Scilab code Exa 10.4 calculate the common emitter current gain

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5//eV/K
5  e=1.6*10**-19 //C
6  DE=10//cm^2/s
7  DB=25//cm^2/s
```

```
xB=0.70*10^-6//m
xE=0.50*10^-6//m
NE=1*10^18//cm^-3
NB=1*10^16//cm^-3
VBE=0.65//V
tauB0=5*10^-7//s
tauE0=1*10^-7//s
Jr0=5*10^-8//A/cm62
pE0=2.25*10^2//cm^-3
nB0=2.25*10^4//cm^-3
LE=10^-3//cm
LB=3.54*10^-3//cm

gamma1=1/(1+(pE0*DE*LB*tanh(0.0198))/(nB0*DB*LE*tanh
   (0.050)))
disp(gamma1,"gamma1 is=")
alphatau=1/cosh(xB/LB)
disp(alphatau,"alphatau is=")
Js0=(e*DB*nB0)/(LB*tanh(xB/LB))
disp(Js0,"Js0 is A/cm^2")
delta=1/(1+(Jr0/Js0)*exp(-VBE/(2*0.0259)))
disp(delta,"delta is=")
a=gamma1*alphatau*delta
disp(a,"a is=")
beta1=a/(1-a)
disp(beta1,"beta1 is=")//          ans varies cause
   of long no.of digits
```

Scilab code Exa 10.5 calculate the change in the neutral base width

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
```

```
NB=5*10^16//cm^-3
NC=2*10^15//cm^-3
epsilons=11.7
eps=8.85*10^-14 //V
ni=1.5*10**10 //cm^-3
x=0.70*10^-6
a=9.96*10^-12///solving the equation
Vbi=((k*T))*log((NB*NC)/ni^2)
disp(Vbi,"Vbi in V is=")

//for
VCB=2 //V
xdB1=sqrt(a*(Vbi+VCB))
disp(xdB1,"xdB in meter is=")
xB1=x-xdB1
disp(xB1,"xB in meter is=")//        textbook ans
   are wrong

//for
VCB=10 //V
xdB2=sqrt(a*(Vbi+VCB))
disp(xdB2,"xdB in meter is=")
xB2=x-xdB2
disp(xB2,"xB in meter is=")//        textbook ans
   are wrong
```

Scilab code Exa 10.7 determine the increase in pE0

```
clc

T=300// K
k=1.3806*10^-23// JK^-1
e=1.6*10^-19// eV
ni=1.5*10^10// cm^-3
NE=10^18// cm^-3
```

```
pE01=(ni*ni)/NE// neglecting bandgap
disp(pE01,"pE01 the value of pE01 in cm^-3 is")
NE=10^19// cm^-3
pE03=(ni*ni)/NE// neglecting bandgap
disp(pE03,"pE03 the value of pE03 in cm^-3 is")
pE02=((ni*ni)/NE)*exp(0.030/(k*(T/e)))// including
   bandgap
disp(pE02,"pE02 the value of pE02 in cm^-3 is")
pE04=((ni*ni)/NE)*exp(0.1/(k*(T/e)))// including
   bandgap
disp(pE04,"pE04 the value of pE04 in cm^-3 is")
```

Scilab code Exa 10.8 desipn the collector doping

```
clc

T=300// K
k=1.3806*10^-23// JK^-1
e=1.6*10^-19// eV
epsilon=8.85*10^-14 //V
eps=11.7
NB=10^16//cm^-3
Vpt=25//V
WB=0.5*10^-4


//Vpt=(e*WB^2*NB*(NC+NB))/(2*epsilon*eps*NC)
a=(Vpt*2*epsilon*eps)/(e*WB^2*NB)
disp(a)
NC=NB/(a-1)
disp(NC,"NC in cm^-3 is=")
```

Scilab code Exa 10.9 design a bipolar transistor

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
NB=10^17//cm^-3
beta=100
BVCEO=15//V

BVCBO=(beta)^(1/3)*BVCEO
disp(BVCBO,"in V is=")
```

Scilab code Exa 10.10 calculate the collector zmitter saturation voltage

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
alphaF=0.99
alphaR=0.20
Ic=1//mA
IB=0.050//mA

Vcesat=k*T*log(((Ic*(1-alphaR)+IB)*alphaF)/((alphaF*
   IB-(1-alphaF)*Ic)*alphaR))
disp(Vcesat,"VCEsat in V is=")
```

Scilab code Exa 10.12 calculate the emitter to collector transit time

```
clc

T=300 //K
```

```
k=8.617*10**-5//eV/K
e=1.6*10**-19  //C
IE=1*10^-3//A
Cje=1*10^-12//F
xB=0.5*10^-4//cm
Dn=25//  cm2/s
xdc=2.4*10^-4//cm
vs=10^7
rc=20//ohm
Cu=0.1*10^-12//F
Cs=0.1*10^-12//F
beta=100

re1=(k*T)/IE
disp(re1,"re1 in ohm is=")
taue=re1*Cje
disp(taue,"taue in sec is=")
taub=xB^2/(2*Dn)
disp(taub,"taub in sec is=")
taub1=xdc/vs
disp(taub1,"taub in sec is=")
tauc=rc*(Cu+Cs)
disp(tauc,"tauc in sec is=")
tauec=taue+taub+taub1+tauc
disp(tauec,"tauec in sec is=")
ftau=1/(2*%pi*tauec)
disp(ftau,"ftau in GHz is=")
fbeta=ftau/beta
disp(fbeta,"fbeta in Hz is=")
```

Chapter 11

Fundamentals of the Metal Oxide Semiconductor Field Effect Transistor

Scilab code Exa 11.1 calculate the maximum space charge width

```
clc

T=300//K
Na=10^16// cm^-3
ni=1.5*10^10 // cm^-3
epsilon0=8.85*10^-14// F/m
epsilons=11.7
e=1.6*10^-19// eV
Vt=0.0259 // V
phifp=Vt*log(Na/ni)
disp(phifp,"the value of phisp in V is")
xdT=(4*(epsilons*epsilon0)*phifp/(e*Na))^0.5
disp(xdT,"the value of xdT in meter is")
```

Scilab code Exa 11.2 calculate the metal semiconductor work function difference

```
clc

phim=3.20// v
x=3.25// v
Eg=1.11//eV
Na=10^14// cm^-3
k=1.3806*10^-23// JK^-1
T=300// K
ni=1.5*10^10// cm^-3
e=1.6*10^-19// eV
phifp=(((k*T)/e)*log(Na/ni))
disp(phifp,"the value of phifp in V is")
phims=phim-(x+(Eg/2)+phifp)
disp(phims,"work function difference in V is ")
```

Scilab code Exa 11.3 calculate the flat band voltage

```
clc

Nd=10^16// cm^-3
tox=500*10^-8// a=500A =500*10^-8 cm
Qss=10^11// electronic charge per cm
phims=-1.1// V
e=1.6*10^-19// eV
epsilonox=3.9
epsilon0=8.85*10^-14// F/m
C=((epsilonox*epsilon0)/tox)
disp(C,"the value of C in F/cm^2 is")
Qss=10^11*e
disp(Qss,"the value of Qss in C/cm^2 is")
VFB=phims-(Qss/C)
disp(VFB,"the value of VFB in V is" )
```

Scilab code Exa 11.4 design the oxide thickness

```
clc

T=300// K
k=1.3806*10^-23// JK^-1
Na=3*10^16// cm^-3
Qss=10^11// cm^-2
VTN=0.65// V
phims=-1.13// V
epsilon0=8.85*10^-14// F/m
epsilons=11.7
epsilonox=3.9
ni=1.5*10^10// cm^-3
e=1.6*10^-19// eV
phifp=(((k*T)/e)*log(Na/ni))
disp(phifp,"the value of phifp in V is")
xdT=(4*(epsilons*epsilon0)*phifp/(e*Na))^0.5
disp(xdT,"the value of xdT in meter is")
QSD=e*Na*xdT// [QSD(max)]=e*Na*xdT
disp(QSD,"the value of QSD in C.cm^2 is")
tox=((VTN-phims-2*phifp)*(epsilonox*epsilon0))/(QSD
   -(Qss*e))
disp(tox,"in meter is")
```

Scilab code Exa 11.5 calculate the threshold voltage

```
clc

T=300// K
k=1.3806*10^-23// JK^-1
```

```
Na=10^14// cm^-3
Qss=10^10// cm^-2
tox=500*10^-8// a=500A =500*10^-8 cm
phims=-0.83// V
epsilon0=8.85*10^-14// F/m
epsilons=11.7
epsilonox=3.9
ni=1.5*10^10// cm^-3
e=1.6*10^-19// eV
phifp=(((k*T)/e)*log(Na/ni))
disp(phifp,"the value of phifp in V is")
xdT=(4*(epsilons*epsilon0)*phifp/(e*Na))^0.5
disp(xdT,"the value of xdT in microm is")
QSD=e*Na*xdT// [QSD(max)]=e*Na*xdT
disp(QSD,"the value of QSD in C/cm^2")
VTN=(QSD-(Qss*e))*(tox/(epsilonox*epsilon0))+phims
   +2*phifp// VTN=(QSD(max)-Qss)*(tox/epsilonox)+
   phims+2*phifp
disp(VTN,"the value of VTN in V is")
```

Scilab code Exa 11.6 design the semiconductor dnping concentration

```
clc

T=300// K
k=1.3806*10^-23// JK^-1
Qss=10^10// cm^-2
tox=650*10^-8// tox=650A =650*10^-8 cm
epsilon0=8.85*10^-14// F/m
epsilons=11.7
epsilonox=3.9
ni=1.5*10^10// cm^-3
e=1.6*10^-19// eV
Nd=2.5*10^14// cm^-3
phifn=(((k*T)/e)*log(Nd/ni))//phifn=V1*log(Nd/ni)=((
```

```
    k*T)/e)*log(Nd/ni)
14 disp(phifn,"the value of phifn in V is")
15 xdT=(4*(epsilons*epsilon0)*phifn/(e*Nd))^0.5
16 disp(xdT,"the value of xdT in meter is")
17 QSD=e*Nd*xdT// [QSD(max)]=e*Na*xdT
18 disp(QSD,"the value of QSD in C/cm^2")
19 phims=-0.35// V
20 VTP=(-QSD-(Qss*e))*(tox/(epsilonox*epsilon0))+phims
    -(2*phifn)// VTP=(-QSD(max)-Qss)*(tox/epsilonox)+
    phims+2*phifn
21 disp(VTP,"the value of VTP in V is")
```

Scilab code Exa 11.7 calculate Cox

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5//eV/K
5  e=1.6*10**-19 //C
6  espox=3.9
7  esp0=8.85*10^-14
8  esp=11.7
9  tox=550*10^-8//550 Armstrong
10 Na=10^16//cm^-3
11 ni=1.5*10^10 //cm^-3
12
13 Cox=(espox*esp0)/tox
14 disp(Cox,"oxide capacitance in F/cm^2 is= ")
15
16 phi=(k*T)*log(Na/ni)
17 disp(phi,"mini capacitance in V is= ")
18
19 xdt=sqrt((4*esp*esp0*phi)/(e*Na))
20 disp(xdt,"in cm^-4 is= ")
21
```

```
Cmin=(espox*esp0)/(tox+(espox/esp)*xdt)
disp(Cmin,"in F/cm^2 is =")

a=Cmin/Cox
disp(a,"ratio of Cmin to Cox is= ")

Cfb=(espox*esp0)/(tox+(espox/esp)*sqrt((k*T*esp*esp0
   )/(e*Na)))
disp(Cfb,"Cfb in F/cm^2 is=")

b=Cfb/Cox
disp(b,"ratio of Cfb to Cox is= ")
```

Scilab code Exa 11.8 design the width

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Cox=6.9*10^-8//F/cm2
esp0=8.85*10^-14
Vtau=0.65//V
VGS=5//V
L=1.25*10^-4//cm
u=650//cm^2/Vs
IDsat=4*10^-3//A

W=(IDsat*2*L)/(u*Cox*(VGS-Vtau)^2)
disp(W,"W in meter is=")
```

Scilab code Exa 11.9 determine the inversion carrier mobility

```
clc

T=300 //K
k=8.617*10**-5//eV/K
e=1.6*10**-19 //C
Cox=6.9*10^-8//F/cm2
esp0=8.85*10^-14
Vtau=0.65//V
VGS1=1.5//V
VGS2=2.5//V
VDS=0.10//V
L=2*10^-6//cm
u=650//cm^2/Vs
ID1=35*10^-6//A
ID2=75*10^-6//A
W=15*10^-6//m

un=(ID2-ID1)*L/(W*Cox*(VGS2-VGS1)*VDS)
disp(un,"un in cm^2/Vs is=")
```

Scilab code Exa 11.10 calculate the change in the threshold voltage

```
clc

T=300// K
Na=3*10^16// cm^-3
tox=500*10^-8// tox=500A =500*10^-8 cm
k=1.3806*10^-23// JK^-1
VSB=1// V
epsilon0=8.85*10^-14// F/m
epsilons=11.7
epsilonox=3.9
ni=1.5*10^10// cm^-3
e=1.6*10^-19// eV
phifp=(((k*T)/e)*log(Na/ni))// phifp=V1*log(Na/ni)
```

```
    =((k*T)/e)*log(Na/ni)
disp(phifp,"the value of phifp in V is")
Cox=(epsilon0*epsilonox)/tox
disp(Cox,"the value of Cox in F/cm^2 is")
deltaVT=(sqrt(2*e*(epsilon0*epsilons)*Na))/Cox*((
    sqrt(2*phifp+VSB))-(sqrt(2*phifp)))
disp(deltaVT,"the value of deltaVT in V is")
```

Scilab code Exa 11.11 calculate the cutoff frequency

```
clc

micron=400// cm^2/V-s
L=4*10^-6// m
VT=1// V
VGS=3// V
ftau=(micron*(VGS-VT))/(2*%pi*L*L)
disp(ftau,"the value of fr is")
```