Scilab Textbook Companion for Semiconductor Devices Physics and Technology by S. M. Sze and M. K. Lee[1]

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Book Description

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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

Energy bands and carrier concetration in thermal equlibrium

Scilab code Exa 1.2 calculate no of silicon atoms per cubic centimeter

```
clc

T=300//K
a=5.43*10**-8//meter
w=28.09//g/mol..atomic weight
A=6.02*10^23 //atoms/mol....Avogadro's no.
s=8/a^3
disp(s,"atoms per unit cell in atoms/cm^3 is")
d=s*w/A
disp(d,"density in g/cm^3 is")
```

Scilab code Exa 1.4 carrier concentration

```
clc
```

```
2
3  T=300 //K
4  Nd=10**16//atoms/cm^3
5  Nc=2.86*10**19//cm^-3
6  ni=9.65*10**9//cm^-3
7  k=8.617*10^-5 //eV/K
8  e=1.6*10**-19 //C
9  n=Nd
10 disp(n,"in cm^-3 is")
11 p=ni^2/Nd
12 disp(p,"in cm^-3 is")
13 //Ec-Ef=z
14 z=k*T*log(Nc/Nd)
15 disp(z,"fermi level measured from bottom of
      conduction band in eV is")
16 //Ef-Ei=y
17 y=k*T*log(Nd/ni)
18 disp(y,"Fermi level measured from the intrinsic
      fermi level in eV is")
```

Chapter 2

Carrier Transport Phenomena

Scilab code Exa 2.1 mean free time

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
m0=0.91*10^-30//kg
un=1000*10^-4//m^2/Vs
vth=2.28*10**7//cm/sec
mn=0.26*m0
disp(mn)
tauc=(mn*un)/q
disp(tauc,"mean free time in sec is")
l=vth*tauc
disp(l,"mean free path in cm is")
```

Scilab code Exa 2.2 room temperature

```
clc
```

```
2
3 T=300 //K
4 k=8.617*10^-5 //eV/K
5 q=1.6*10**-19 //C
6 m0=0.91*10^-30//kg
7 un=1300//m^2/Vs
8 Nd=10^16//cm^3
9 n=Nd
10 disp(n,"donors are ionized in cm^3 is")
11 row=1/(q*n*un)
12 disp(row,"resistivity in ohm cm is")
```

Scilab code Exa 2.3 hall voltage

```
1 clc
2
3 T=300 //K
4 k=8.617*10^-5 //eV/K
5 q=1.6*10**-19 //C
6 m0=0.91*10^-30//kg
7 n=10^16//cm^3
8 W=500*10**-4//cm
9 A=2.5*10**-3//cm62
10 I=10**-3//A
11 Bz=10^-4//Wb/cm^2
12
13 RH=1/(q*n)
14 disp(RH,"Hall coefficient in cm^3/C is")
15 VH=W*RH*I*Bz/A
16 disp(VH,"Hall voltage in V is")
```

Scilab code Exa 2.4 diffusion current density

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
m0=0.91*10^-30//kg
Dn=22.5//cm^2/sec
deltan=1*10^18-7*10^17//cm^-3
deltax=0.1//cm
Jn=q*Dn*(deltan/deltax)
disp(Jn,"diffusion current density in A/cm^2 is ")
```

Scilab code Exa 2.5 drift velocity

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
m0=0.91*10^-30//kg
x=1//cm
t=100*10^-6//sec
epsilon=50//V/cm
vp=x/t
disp(vp,"drift velocity in cm/s is")
up=vp/epsilon
disp(up,"mobility in cm^2/Vs is")
Dp=(k*T*up)
disp(Dp,"diffusivity of minority carriers in cm^2/
   sec is")
```

Scilab code Exa 2.6 minority carrier concentration

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
m0=0.91*10^-30//kg
ni=9.65*10^9//cm^-3
nno=10^14//cm^-3
taun=2*10^-6//sec
taup=2*10^-6//sec

pno=ni^2/nno
disp(pno,"before illumination pno in cm^-3 is")
GL=(10^13)/(1*10^-6)
pn=pno+taup*GL
disp(pn,"after illumination deltapn in cm^-3 is")
```

Scilab code Exa 2.7 quasi fermi level

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
m0=0.91*10^-30//kg
ni=2.25*10^6//cm^-3
nn0=10^16//cm^-3
taun=2*10^-9//sec
taup=2*10^-9//sec

pn0=ni^2/nn0
disp(pn0,"before illumination pn0 in cm^-3 is")
GL=(10^13)/(1*10^-6)
nn=nn0+taun*GL
disp(nn,"after illumination nn in cm^-3 is")
```

```
    //textbook ans is wrong
17 pn=pn0+taup*GL
18 disp(pn,"after illumination pn in cm^-3 is")
```

Scilab code Exa 2.8 minority carrier lifetime

```
1 clc
2
3 t1=100*10^-6//sec
4 t2=200*10^-6//sec
5 N=5
6 //deltap=(N/sqrt(4*%pi*Dp*t))*exp(t/taup)
7 taup=(t2-t1)/log(N/sqrt(2))
8 disp(taup,"minority carrier lifetime taup in sec is=
    ")
```

Scilab code Exa 2.9 thermionically emitted electron density

```
1 clc
2
3 T=300 //K
4 k=8.617*10^-5 //eV/K
5 q=1.6*10**-19 //C
6 qx=4.05 //eV
7 qVn=0.2 //eV
8 Nc=2.86*10^19
9 a=(qx+qVn)/(k*T)
10 nth=exp(a)*Nc
11 disp(nth,"the thermionically emitted electron
    density for nth at 4.05 in cm^3=")     //textbook
     ans is wrong
12
13 qx=0.6 //eV
```

```
nth=exp(qx/(k*T))*Nc
disp(nth,"the thermionically emitted electron
    density for nth at 0.6  in cm^3=")      //textbook
     ans is wrong
```

Chapter 3

pn Junction

Scilab code Exa 3.1 calculate the built in potential

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
NA=10^18 //cm^-3
ND=10^15//cm^-3
ni=9.65*10^9
Vbi=(k*T)*log(NA*ND/ni^2)
disp(Vbi,"the built in potential in V=")
```

Scilab code Exa 3.2 depletion layer width

```
clc

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

```
NA=10^19 //cm^-3
ND=10^16//cm^-3
ni=9.65*10^9
epsilonx=8.854*10^-12 //F/m
Vbi=(k*T)*log(NA*ND/ni^2)
disp(Vbi,"the built in potential in V=")
W=sqrt(2*Vbi/q*ND)
disp(W,"W in cm =")          // ans in textbook is
   wrong
epsilonm=((q*ND*W))
disp(epsilonm,"epsilonm in V/cm") // ans in textbook
    is wrong
```

Scilab code Exa 3.3 depletion layer width

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
a=10^20// cm^-4
W=0.809*10^-4
epsilonx=8.85*10^-14
epsilonm=((q*a*W^2)/(8*epsilonx*11.9))
disp(epsilonm,"epsilonm in V/cm =")
```

Scilab code Exa 3.4 calculate the junction capacitance

```
clc

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

```
NA=2*10^19 //cm^-3
ND=8*10^15 //cm^-3
V=4//V
ni=9.65*10^9
epsilonx=8.854*10^-14 //F/cm
Vbi=(k*T)*log(NA*ND/ni^2)
disp(Vbi,"the built in potential in V=")
W=sqrt((2*Vbi*11.9*epsilonx)/(q*ND))
disp(W,"W in cm =")          // ans in textbook is
   wrong
Cj=sqrt((q*epsilonx*11.9*ND)/(2*Vbi))
disp(Cj,"Cj in F/cm^2 =")
W1=sqrt((2*(Vbi+V)*11.9*epsilonx)/(q*ND))
disp(W1,"W1 in cm=")
Cj1=sqrt((q*epsilonx*11.9*ND)/(2*(Vbi+V)))
disp(Cj1,"Cj1 in F/cm^2")
```

Scilab code Exa 3.5 ideal reverse saturation current

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
NA=5*10^16 //cm^-3
ND=10^16 //cm^-3
A=2*10^-4//cm^2
V=4//V
ni=9.65*10^9//cm^-3
epsilonx=8.854*10^-14 //F/cm
Dn=21//cm^2/sec
Dp=10//cm^2/sec
taup=5*10^-7//sec
taun=5*10^-7//sec
Lp=sqrt(Dp*taup)
```

```
17 Js=q*ni^2*[(1/ND)*sqrt(Dp/taup)+(1/NA)*sqrt(Dn/taun)
     ]
18 disp(Js,"Js in A/cm=")
19 Is=A*Js
20 disp(Is,"Is in A =")
```

Scilab code Exa 3.6 generation current density

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  NA=5*10^16 //cm^-3
7  ND=10^16 //cm^-3
8  A=2*10^-4//cm^2
9  V=4//V
10 taug=5*10^-7
11 ni=9.65*10^9//cm^-3
12 epsilonx=8.854*10^-14 //F/cm
13 W=sqrt((2*epsilonx*11.9/q)*[(NA+ND)/(NA*ND)]*[(k*T/q
     )*log(NA*ND/ni^2)+V])          //value of V is
     not substituted in textbook
14 disp(W,"W in cm=")
15 Jgen=(q*ni*W/taug)
16 disp(Jgen,"Jgen in A/cm^2")          //value of V is
     not substituted in textbook
```

Scilab code Exa 3.7 stored minority carriers

```
1  clc
2
3  T=300 //K
```

```
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
Lp=5*10^-4
V=1//V
ND=8*10^15 //cm^-3
ni=9.65*10^9//cm^-3
epsilonx=8.854*10^-14 //F/cm
Qp=q*Lp*(ni^2/ND)*(exp(V/(k*T))-1)
disp(Qp,"Qp in C/cm^2")   //textbook ans is wrong
```

Scilab code Exa 3.8 breakdown voltage

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
ND=5*10^16//cm^-3
epsilonx=8.854*10^-14 //F/cm
epsilonc=5.7*10^5//F/cm
Vb=(epsilonx*11.9*epsilonc^2)/(ND*2*q)
disp(Vb,"Vb breakdown in V=")
```

Scilab code Exa 3.9 breakdown voltage

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
ND=8*10^14//cm^-3
Vb=500 //V
W=20*10^-6//m
```

```
epsilonx=8.854*10^-14 //F/cm
Wm=sqrt((2*epsilonx*12.4*Vb)/(q*ND))
Wm1=Wm*10^-2          //to convert into micrometer
disp(Wm1,"W in meter=")
Vb1=Vb*(W/Wm1)*(2-W/Wm1)
disp(Vb1,"Vb1 in V=")
```

Scilab code Exa 3.10 electrostatic potential

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
N1=1*10^16//cm^-3
N2=3*10^19//cm^-3
Vbi=1.6//V
epsilon1=12
epsilon2=13
epsilonx=8.854*10^-14 //F/cm
Vb1=(epsilon2*N2*Vbi)/(epsilon1*N1+epsilon2*N2)
disp(Vb1,"Vb1 in V=")
Vb2=(epsilon1*N1*Vbi)/(epsilon1*N1+epsilon2*N2)
disp(Vb2,"Vb2 in V=")
x1=sqrt((2*epsilon1*epsilon2*N2*Vbi)/(q*N1*(epsilon1
   *N1+epsilon2*N2)))              //textbook ans is
    wrong
disp(x1,"x1 in cm=")
x2=sqrt([2*epsilon1*epsilon2*N1*Vbi]/[q*N2*(epsilon1
   *N1+epsilon2*N2)])
disp(x2,"x2 in cm=")    //texbook ans is wrong
```

Chapter 4

Bipolar Transistor an related Devices

Scilab code Exa 4.1 emitter efficiency

```
1  clc
2
3  Iep=3//mA
4  Ieh=0.01//mA
5  Ich=0.001//mA
6  Icp=2.99//mA
7  gamma=Iep/(Iep+Ieh)
8  disp(gamma,"gamma =")
9  alphaT=Icp/Iep
10 disp(alphaT,"alphaT =")
11 alpha0=gamma*alphaT
12 disp(alpha0,"alpha0 =")
13 IE=Iep+Ieh
14 disp(IE,"IE in mA=")
15 IC=Icp+Ich
16 disp(IC,"IC in mA=")
17 ICBO=IC-alpha0*IE
18 disp(ICBO,"ICBO in mA")
```

Scilab code Exa 4.2 common base current gain

```
clc

T=300//K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
A=5*10^-4//m^2
V=0.6//V
Dp=10//cm^2/sec
De=1//cm^2/sec
Dc=2//cm^2/sec
taup=10^-7//sec
taue=10^-8//sec
ND=10^17
NE=10^19
W=0.5*10^-4//cm
ni=9.65*10^9
Lp=sqrt(Dp*taup)
disp(Lp,"Lp in cm=")
pn0=ni^2/ND
disp(pn0,"pn0 in cm^-3=")
Le=sqrt(De*taue)
disp(Le,"Le in cm=")
nE0=ni^2/NE
disp(nE0,"nE0 in cm^-3=")
IEp=exp(V/(k*T))*(q*pn0*Dp*A/W)
disp(IEp,"IEp in A")
Icp=IEp
disp(Icp,"Icp in A =")
IEn=(q*nE0*De*A/10^-4)*(exp(V/(k*T))-1)
disp(IEn,"IEn in A =")
alpha0=Icp/(IEp+IEn)
disp(alpha0,"alpha0 is= ")
```

Scilab code Exa 4.3 value of Iceo

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
alpha0=0.9933
Icbo=1*10^-6//A
beta0=alpha0/(1-alpha0)
disp(beta0,"beta0 =")
Iceo=(beta0+1)*Icbo
disp(Iceo,"Iceo in A =")
```

Scilab code Exa 4.4 base doping

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
Ege=1.62
Egb=1.42
Nb=10^15
//beta0HBT/beta0BJT=a
a=exp((Ege-Egb)/(k*T))
disp(a,"beta0HBT/beta0BJT =")     //since the k*T
   value has taken as 0.025851 so the ans changes in
    last two digits
Nb1=Nb*a
disp(Nb1,"Nb1 in cm^-3=")      //since the ans
   differs in"a" so Nb1 changes
```

Scilab code Exa 4.5 `find current`

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
I1=0.4*10^-3//A
I2=0.6*10^-3//A
alpha1=0.01
alpha2=0.9999
I=(I1+I2)/(1-alpha1)
disp(I,"I in mA")
I=(I1+I2)/(1-alpha2)
disp(I,"I in A")
```

Chapter 5

MOS capacitor and MOSFET

Scilab code Exa 5.1 maxi width

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
NA=10^17//cm^-3
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
W=2*sqrt(11.9*epsilonx*k*T*log(NA/ni)/(q*NA))
disp(W,"W in meter =")          //textbook ans is
   wrong
```

Scilab code Exa 5.2 mini capacitance of CV

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
```

```
5  q=1.6*10**-19 //C
6  NA=10^17//cm^-3
7  Wm=1*10^-5
8  d=5*10^-7//cm
9  epsilonx=8.854*10^-14 //F/cm
10 epsilonox=3.9
11 ni=9.65*10^9//cm^-3
12 Co=epsilonox*epsilonx/d
13 disp(Co,"Co in F/cm^2 =")
14 Qsc=q*NA*Wm
15 disp(Qsc,"Qsc")     //textbook ans is wrong
16 psis=2*k*T*log(NA/ni)
17 disp(psis,"psis in V =")
18 Cmin=epsilonox*epsilonx/(d+(epsilonox/11.9)*Wm)
19 disp(Cmin,"Cmin in F/cm^2 =")
```

Scilab code Exa 5.3 calculate the flat band voltage

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  NA=10^17//cm^-3
7  d=5*10^-7//cm
8  Co=6.9*10^-7
9  Qf=5*10^11//cm^-2
10 Qm=0
11 Qot=0
12 epsilonx=8.854*10^-14 //F/cm
13 phims=-0.98 //V
14 Vfb=phims-(Qf*q+Qm+Qot)/Co
15 disp(Vfb,"Vfb in V is= ")
```

Scilab code Exa 5.4 change in flat band

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
NA=10^17//cm^-3
d=5*10^-7//cm
Co=6.9*10^-7
Qf=5*10^11//cm^-2
Qm=0
Qot=0
epsilonox=3.9//F/cm
epsilonx=8.854*10^-14 //F/cm
deltaVfb=(q/(epsilonox*epsilonx))
   *[(0.5*10^18*(2*10^-6)^2)
   -(0.333*5*10^23*(2*10^-6)^3)]
disp(deltaVfb,"deltaVfb in V is= ")
```

Scilab code Exa 5.5 calculate Vdsat

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
NA=10^17 //cm^-3
d=8*10^-7//cm
VG=3//V
```

```
11 //2*phis=p
12 p=0.84//V
13 Co=epsilonx*3.9/d
14 disp(Co,"Co in F/cm^2 is=")
15 K=sqrt((epsilonx*11.9*NA*q))/Co
16 disp(K,"K is=")
17 Vdsat=VG-p+K^2*(1-sqrt(1+(2*VG/K^2)))
18 disp(Vdsat,"Vdsat in V is=")
```

Scilab code Exa 5.6 VT for gate oxide

```
1 clc
2
3 T=300 //K
4 k=8.617*10^-5 //eV/K
5 q=1.6*10**-19 //C
6 epsilonx=8.854*10^-14 //F/cm
7 ni=9.65*10^9//cm^-3
8 NA=10^17 //cm^-3
9 d=8*10^-7//cm
10 VFB=-1.1//V
11 Co=6.9*10^-7//F/cm^2
12 //2*phis=p
13 //Qf/q=m
14 p=0.84//V
15 m=5*10^11//cm^2
16 VT=VFB+p+(sqrt(2*epsilonx*11.9*q*NA*p)/Co)
17 disp(VT,"VT in V is=")
18 FB=(0.62*Co)/q
19 disp(FB,"FB in cm^-2 is=")
```

Scilab code Exa 5.7 VT for gate oxide

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
NA=10^17 //cm^-3
d=8*10^-7//cm
Co=6.9*10^-9//F/cm^2
phims=-0.98
//2*phis=p
p=0.84//V
Qf=5*10^11//cm^2
VFB=phims-(q*Qf/Co)          //texbook ans is wrong
disp(VFB,"VFB in V is=")
VT=VFB+p+(sqrt(2*epsilonx*11.9*q*NA*p)/Co)
disp(VT,"VT in V is=")          //texbook ans is
   wrong
```

Scilab code Exa 5.8 calculate the change in the threshold voltage

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
NA=10^17 //cm^-3
d=8*10^-7//cm
Co=6.9*10^-7//F/cm^2
VBS=2//V
phims=-0.98
//2*phis=p
```

```
14 p=0.84//V
15 Qf=5*10^11//cm^2
16 deltaVT=sqrt(2*epsilonx*11.9*q*NA)/Co*(sqrt(p+VBS)-
      sqrt(p))
17 disp(deltaVT,"deltaVT in V is= ")
```

Chapter 6

Advanced MOSFET and related devices

Scilab code Exa 6.1 calculate the threshold voltage

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
NA=10^17 //cm^-3
d=8*10^-7//cm
Co=6.9*10^-7//F/cm^2
VFB=-1.1//V
//2*phis=p
p=0.84//V
dsi=5*10^-6//cm^2
VT=VFB+p+(q*NA*dsi/Co)
disp(VT,"VT in V is=")
```

Chapter 7

MESFET and related devices

Scilab code Exa 7.1 donor concentration

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  epsilonx=8.854*10^-14 //F/cm
7  ni=9.65*10^9//cm^-3
8  NA=10^17 //cm^-3
9  d=8*10^-7//cm
10 Nc=2.86*10^19
11 Co=6.9*10^-7//F/cm^2
12 C1=1.8*10^15//(cm^2/F)^2
13 C2=6.2*10^15//(cm^2/F)^2
14 V1=0//V
15 V2=-1//V
16 Vbi=0.42
17 //d(1/C^2)/dv=a
18 a=(C2-C1)/(V2-V1)
19 disp(a,"a in (cm^2/F)^2")
20 ND=(2/(q*epsilonx*11.9))*(-1/(a))
21 disp(ND,"ND in ")
```

```
Vn=k*T*log(Nc/ND)
disp(Vn,"Vn in V is=")
phibn=Vbi+Vn
disp(phibn,"phibn in V is= ")
```

Scilab code Exa 7.2 barrier height and depletion layer

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
ND=10^16 //cm^-3
Nc=2.86*10^19
Dp=10//cm^2/s
Lp=3.1*10^-3
d=8*10^-7//cm
Js=6.5*10^-5//A/cm^2
V=0.67//V
phibn=k*T*log((110*300^2)/Js)
disp(Js,"Js in V is=")          //textbook ans is
   wrong
Vn=k*T*log(Nc/ND)
disp(Vn,"Vn in V is=")          //textbook ans is
   wrong
Vbi=phibn-Vn
disp(Vbi,"Vbi in V is=")          //textbook ans is
   wrong
W=sqrt((2*epsilonx*11.9*Vbi)/(q*ND))
disp(W,"W in cm is =")          //textbook ans is
   wrong
Jpo=(q*Dp*ni^2)/(Lp*ND)
disp(Jpo,"Jpo in A/cm^2 is=")
```

```
25 z=Js/Jpo
26 disp(z,"Js/Jpo ratio of current densities is=")
```

Scilab code Exa 7.3 voltage drop

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  epsilons=8.854*10^-31 //F/cm
7  ni=9.65*10^9//cm^-3
8  ND=5*10^19//cm^-3
9  phibn=0.8//V
10 I=1//A
11 mn=0.26
12 Rc=10^-6//ohm cm^2
13 A=10^-5//cm^2
14 h=1.05*10^-34
15 a=Rc/A
16 disp(a,"Rc/A in ohm is=")
17 C2=(4*sqrt(mn*epsilons*(1.05*10^-10)))/h
18 disp(C2,"C2 in m^(3/2)/V is= ")                    //
   texbook ans is wrong
19 I0=(A/Rc)*(sqrt(ND*10^6)/C2)*exp((C2*phibn)/sqrt(ND
   *10^6))
20 disp(I0,"I0 in A is= ")          //textbook ans is
   wrong
21 V=phibn-(sqrt(ND)/C2)*log(I0/I)
22 disp(V,"V in V is= ")
```

Scilab code Exa 7.4 pinch off volt

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
ND=2*10^15//cm^-3
Nc=4.7*10^17//cm^-3
a=0.6*10^-4
fbn=0.89//V
Vp=(q*ND*a^2)/(2*epsilonx*12.4)
disp(Vp,"Vp in V is=")
Vn=(k*T)*log(Nc/ND)
disp(Vn,"Vn in V is=")
Vbi=fbn-Vn
disp(Vbi,"Vbi in V is=")
```

Scilab code Exa 7.5 two dimensional electron

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
epsilonx=8.854*10^-14 //F/cm
ni=9.65*10^9//cm^-3
ND=2*10^18//cm^-3
d1=40*10^-7//cm
d2=8*10^-7//cm
u=3*10^-7//cm
Va=0//V
//deltaEc/q=a
a=0.23//V
phibn=0.85//V
```

```
16 Vp=(q*ND*d1^2)/(2*epsilonx*12.3)
17 disp(Vp,"Vp in V is=")
18 VT=phibn-a-Vp
19 disp(VT,"VT in V is= ")
20 ns=((12.3*epsilonx)/(q*(d1+u+d2)))*(Va-VT)
21 disp(ns,"ns in cm^-2 is= ")
```

Chapter 8

Microwave diodes Quantum effect and hot electron devices

Scilab code Exa 8.1 dc breakdown volt

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  epsilonx=8.85*10^-14 //F/cm
7  epsilonm=3.3*10^5 //V/cm
8  ni=9.65*10^9//cm^-3
9  ND=2*10^18//cm^-3
10 b=1*10^-4//cm
11 W=6*10^-4//cm
12 Q=2*10^12//charges/cm^2
13 xA=1*10^-4//cm
14 vx=10^7//Hz
15 Vb=(epsilonm*b)+[epsilonm-((q*Q)/(epsilonx*11.9))]*(
      W-b)
16 disp(Vb,"Vb in V is= ")
17 d=([epsilonm-((q*Q)/(epsilonx*11.9))]*(W-b))/(W-b)
18 disp(d,"drift region in V/cm is= ")
```

```
19 f=vx/[2*(W-xA)]
20 disp(f,"f in Hz is= ")
```

Scilab code Exa 8.2 `mini electron density`

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  epsilonx=8.854*10^-14 //F/cm
7  L=10*10^-4//cm^-2
8  v=10^7//sec
9  n0=10^12/L
10 disp(n0,"n0 in cm^-3 is=")
11 t=L/v
12 disp(t,"t in sec is=")
```

Chapter 9

Light Emitting diodes and lasers

Scilab code Exa 9.1 total energy absorbed

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  epsilonx=8.854*10^-14 //F/cm
7  hv=3//eV
8  phi=10^-2
9  ra=2.4*10^-3//W
10 Eg=1.12//eV
11 alpha=-4*10^4//cm
12 W=0.25*10^-4//cm
13 a=phi*(1-exp(alpha*W))
14 disp(a,"a in J/sec is= ")
15 z=(hv-Eg)/hv
16 disp(z,"z in % is= ")
17 l=a*z
18 disp(l,"l in Watt is= ")
19 r=ra/(q*Eg)
```

```
20 disp(r,"r in photons/sec is= ")
```

Scilab code Exa 9.2 modulation bandwidth

```
1 clc
2
3 tau=500*10^-12//sec
4 deltaf=1/(2*%pi*tau)
5 disp(deltaf,"deltaf in Hz is= ")     //texbook
    printing mistake
```

Scilab code Exa 9.3 calculate R

```
1 clc
2
3 n=3.6
4 R=[(n-1)/(n+1)]^2
5 disp(R,"R is= ")
```

Scilab code Exa 9.4 mode spacing

```
1 clc
2
3 lambda=0.94*10^-6//m
4 n=3.6
5 L=300*10^-6//m
6 deltalambda=(lambda^2)/(2*n*L)
7 disp(deltalambda,"deltalambda in meter is= ")
```

Scilab code Exa 9.5 calculate the threshold current

```
clc

alpha=100//per cm
betaa=0.1//per cm A
Tau=0.9
g0=100//per cm
L=300*10^-4//cm
w=5*10^-4//cm
R1=0.44
R2=0.99
Jth=((g0*Tau)/betaa)+(1/betaa)*(alpha+(1/(2*L))*log
   (1/R1*R2))
disp(Jth,"Jth in A/cm^2 is=")
Ith=Jth*L*w
disp(Ith,"Ith in A is=")
```

Scilab code Exa 9.6 Determine temp

```
clc

T0=110//degree C
T=27+T0*log(2)
disp(T,"T in degree C is= ")
```

Chapter 10

Photodetectors and solar cells

Scilab code Exa 10.1 photocurrent

```
clc

Popt=5*10^12//phtons/sec
n=0.8
un=2500//cm^2/Vs
epsilon=5000//V/cm
L=10*10^-4//cm
q=1.6*10**-19 //C
tau=5*10^-10//sec
Ip=q*n*Popt*(un*tau*epsilon)/L
disp(Ip,"Ip in A is= ")
gain=(un*tau*epsilon)/L
disp(gain,"gain is= ")
```

Scilab code Exa 10.2 depth

```
clc

```

```
3 alpha=10^4//cm^-1
4 R=0.1
5 Px=1
6 P0=2
7 x=(-1/alpha)*log(Px/(P0*(1-R)))
8 disp(x,"x in meter is =")
```

Scilab code Exa 10.3 responsivity

```
1 clc
2
3 Ip=3*10^-4//mA
4 I0=0.2//*
5 h=6.62*10^-34//Jsec
6 q=1.6*10^-19//C
7 c=3*10^8//m/sec
8 lambda=80*10^-9//m
9 Popt=%pi*(0.03)^2*I0
10 disp(Popt,"Popt in Watt is= ")
11 R=Ip/Popt
12 disp(R,"R in A/W is= ")
13 n=R*(h*c/(q*lambda))
14 disp(n,"n in % is= ")  //textbook ans is wrong
```

Scilab code Exa 10.4 air mass

```
1 clc
2
3 s=1.118//m
4 h=1.00//m
5 a=sqrt(1+(s/h)^2)
6 disp(a,"a is= ")
```

Scilab code Exa 10.5 open circuit voltage

```
clc

T=300 //K
k=8.617*10^-5 //eV/K
q=1.6*10**-19 //C
I=10^9//A
Is=1*10^-9//A
V=0.35//V
IL=100*10^-3//A
Voc=k*T*log(IL/Is)
disp(Voc,"Voc in V is= ")
P=I*V*exp((V/(k*T))-1)*IL*V
disp(P,"P in watt is= ")          //textbook ans is
   not printed proper
```

Chapter 11

Crystal growth and epitaxy

Scilab code Exa 11.1 concentration in boron

```
clc

Cs=10^16//boron atoms/cm^3
k0=0.8
d=2.53//g/cm^3
aw=10.8//g/mol
s=60*10^3//kg
Ct=Cs/k0
disp(Ct,"Ct in boron atoms/cm^3 is= ")
v=s/d
disp(v,"v in cm^3 is= ")
tb=Ct*v
disp(tb,"tb in boron atoms is= ")
tb1=(tb*aw)/(6.02*10^23)
disp(tb1,"tb1 in g of boron is= ")
```

Scilab code Exa 11.3 time required

```
clc

T=300//K
M=3.64//Armstrong
Nx=(7.54*10^14)//cm^-2
P1=1//Pa
t1=(Nx*sqrt(M*T))/(2.64*10^20*P1)
disp(t1,"t1 at 1Pa in ms is= ")     //textbook ans is
    wrong
P2=10^-4//Pa
t2=(Nx*sqrt(M*T))/(2.64*10^20*P2)
disp(t2,"t2 at 10^-4Pa in s is= ")     //textbook ans
    is wrong
P3=10^-8//Pa
t3=(Nx*sqrt(M*T))/(2.64*10^20*P3)
disp(t3,"t3 at 10^-8Pa in hr is= ")     //textbook
   ans is wrong
```

Scilab code Exa 11.4 growth rate

```
clc

A=5//cm^2
L=10//cm
T=1173//K
d=6*10^14//cm^-2
P=5.5*10^-2//Pa
M=69.72          //for Ga
Ar=(2.64*10^20*P*A)/(sqrt(M*T)*%pi*L^2)
disp(Ar,"Ar in molecules /cm^2 is= ")
M1=74.92*2          //for As2
Ar1=(2.64*10^20*P*A)/(sqrt(M1*T)*%pi*L^2)
disp(Ar1,"Ar1 in molecules /cm^2 is= ")     //
   textbook ans is wrong
Gr=(Ar*2.8)/d
```

```
15 disp(Gr,"Gr in sec/min is= ")          //for Ga
     textbook ans is wrong
```

Chapter 12

Film formation

Scilab code Exa 12.1 thickness

```
clc

Msi=28.9//g/mole
Dsi=2.33//g/cm^3
Msidi=60.08//g/mole
Dsidi=2.21//g/cm^3

vsi=Msi/Dsi
disp(vsi,"vsi in cm^3/mole is= ")
vsidi=Msidi/Dsidi
disp(vsidi,"vsidi in cm^3/mole is= ")
T=vsi/vsidi
disp(T,"T is ratio of Thickness of Si to SiO2 is= ")
```

Scilab code Exa 12.3 intrinsic value

```
clc

```

```
3 row=2.7*10^-6//ohm cm
4 l=10^-1//cm
5 tm=0.5*10^-4//cm
6 sw=0.5*10^-4//cm
7 epsiloni=8.85*10^-14
8 RC=(row*l/tm^2)*epsiloni*2.7*(tm*l/sw)
9 disp(RC,"RC in sec is= ")
```

Scilab code Exa 12.4 equivalent cell area

```
1 clc
2
3 k=3.9
4 k1=25
5 A=1.28//um^2
6 E=(k*A)/k1
7 disp(E," equivalent cell size in um^2 is= ")
```

Scilab code Exa 12.5 find depth

```
1 clc
2 T=500//dC
3 t=30//min
4 ZL=16//um^2
5 Z=5//um
6 H=1//um
7 S=0.8//%
8 A=16
9 a=60//um
10 rowAl=2.7
11 rowSi=2.33
12 b=(2*a*H*Z*S*rowAl)/(A*rowSi*100)
13 disp(b,"b in um is= ")
```

Scilab code Exa 12.6 percentage od reduction

```
clc

kAl=2.6
kCu=3.9
rAl=2.7//u ohm cm
rCu=1.7//u ohm cm
reduction=(rCu*kAl*100)/(rAl*kCu)
disp(reduction,"reduction in% is= ")
```

Scilab code Exa 12.7 oxide removal rate

```
clc

//(1/r)+(0.01/0.1 r)=5.5
r=1.1/5.5
disp(r,"r in um/min is = ")
```

Chapter 13

Lithography and etching

Scilab code Exa 13.1 how many dust particles

```
clc

c=30//m/min
t=1//minute
w=300*10^-3//m
V=c*%pi*(w/2)^2*t
disp(V,"V in m^3 is= ")
```

Scilab code Exa 13.2 parameter gamma

```
clc

ET=90//mJ/cm^2
EI=45//mJ/cm^2
gammma=1/[log(ET/EI)]
disp(gammma,"gamma is= ")
ET=7//mJ/cm^2
EI=12//mJ/cm^2
```

```
9  gammma=1/[log(EI/ET)]
10 disp(gammma,"gamma is= ")
```

Scilab code Exa 13.3 Al average etch rate

```
1  clc
2
3  c=750//nm/min
4  l=812//nm/min
5  r=765//nm/min
6  t=743//nm/min
7  b=798//nm/min
8  Al=(c+l+r+t+b)/5
9  disp(Al,"Al average etch rate in nm/min is= ")
10 Er=[(l-t)/(l+t)]*100
11 disp(Er,"Etch rate uniformly in % is= ")
```

Chapter 14

Impurity Doping

Scilab code Exa 14.1 Qt and gradient

```
clc

D=2*10^-14//cm^2/sec
t=3600//K
Cx=10^19
A=sqrt(D*t)
disp(A,"A in cm is= ")
Qt=1.13*Cx*A
disp(Qt,"Q(t) in atoms/cm^3")
//dC/dx=b
b=-(Cx/sqrt(%pi*D*t))
disp(b,"dC/dx in cm^-4 is= ")
xj=2*sqrt(D*t)*2.75
disp(xj,"xj in meter is= ")
b=-(Cx/sqrt(%pi*D*t))*exp(-xj^2/(4*D*t))
disp(b,"dC/dx in cm^-4 is= ")
```

Scilab code Exa 14.2 junction depth

```
clc

T=1473//K
k=8.614*10^-5
D0=24//cm^2/sec
Ea=4.08//eV
D=D0*exp(-Ea/(k*T))
disp(D,"D in cm^2/sec")
//a=t*log(t)-10.09*t+8350              t=1190 solving
   this equation
```

Scilab code Exa 14.3 ion beam current

```
clc

w=20//m
q=1.6*10^-19
t=60//sec
nx=2.85*10^19
disp(nx,"nx in ions/cm^3")     //havent solved in
   textbook
d=5*10^14//ions/cm^2
Q=d*%pi*(20/2)^2
disp(Q,"Q in ions is= ")
I=(q*Q)/t
disp(I,"I in A is= ")
```

Scilab code Exa 14.4 thickness

```
clc

Rp=0.53//um
sigmap=0.093//um
```

```
5 d=Rp+3.96*sigmap
6 disp(d,"d in um is= ")
```

Chapter 15

Integrated devices

Scilab code Exa 15.1 value of resistor

```
1 clc
2
3 l=9
4 r=1.3//kohm
5 res=l+r
6 disp(res,"res in k ohm")
```

Scilab code Exa 15.2 stored charge

```
1 clc
2
3 q=1.6*10**-19 //C
4 epsilonox=8.85*10^-14//F/cm
5 V=5//V
6 d=1*10^-6//cm
7 A=4*10^-8//cm^2
8 Q=3.9*epsilonox*A*(V/d)
9 disp(Q,"Q in C is= ")
```

```
10 Qx=Q/q
11 disp(Qx,"Qx in electrons")
```

Scilab code Exa 15.3 radius

```
1 clc
2
3 L=10*10^-9//H
4 u0=1.2*10^-6
5 n=20
6 r=L/(u0*n^2)
7 disp(r,"r in m is= ")
```

Scilab code Exa 15.4 gate to source voltage

```
1 clc
2
3 epsilon=8*10^6//V/cm
4 d=5*10^-7//cm
5 V=epsilon*d
6 disp(V,"V in V is= ")
```

Scilab code Exa 15.5 oxide thickness

```
1 clc
2
3 epsilonox=3.9
4 epsilonnitride=7
5 dnitride=1.5*(epsilonnitride/epsilonox)
6 disp(dnitride,"dnitride in nm is= ")
```