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.

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Chapter 1

Energy bands and carrier concetration in thermal equlibrium

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

```
1  clc
2
3  T=300 //K
4  a=5.43*10**-8 //meter
5  w=28.09 //g/mol.. atomic weight
6  A=6.02*10^23 //atoms/mol....Avogadro's no.
7  s=8/a^3
8  disp(s,"atoms per unit cell in atoms/cm^3 is")
9  d=s*w/A
10 disp(d,"density in g/cm^3 is")
```

Scilab code Exa 1.4 carrier concentration

```
1  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

```
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  un=1000*10^-4//m^2/Vs
8  vth=2.28*10**7//cm/sec
9  mn=0.26*m0
10 disp(mn)
11 tauc=(mn*un)/q
12 disp(tauc,"mean free time in sec is")
13 l=vth*tauc
14 disp(l,"mean free path in cm is")
```

Scilab code Exa 2.2 room temperature

```
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 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

```
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  Dn=22.5//cm^2/sec
8  deltan=1*10^18-7*10^17//cm^-3
9  deltax=0.1//cm
10 Jn=q*Dn*(deltan/deltax)
11 disp(Jn,"diffusion current density in A/cm^2 is ")
```

Scilab code Exa 2.5 drift velocity

```
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  x=1//cm
8  t=100*10^-6//sec
9  epsilon=50//V/cm
10 vp=x/t
11 disp(vp,"drift velocity in cm/s is")
12 up=vp/epsilon
13 disp(up,"mobility in cm^2/Vs is")
14 Dp=(k*T*up)
15 disp(Dp,"diffusivity of minority carriers in cm^2/
      sec is")
```

Scilab code Exa 2.6 minority carrier concentration

```
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  ni=9.65*10^9//cm^-3
8  nno=10^14//cm^-3
9  taun=2*10^-6//sec
10 taup=2*10^-6//sec
11
12 pno=ni^2/nno
13 disp(pno,"before illumination pno in cm^-3 is")
14 GL=(10^13)/(1*10^-6)
15 pn=pno+taup*GL
16 disp(pn,"after illumination deltapn in cm^-3 is")
```

Scilab code Exa 2.7 quasi fermi level

```
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  ni=2.25*10^6//cm^-3
8  nn0=10^16//cm^-3
9  taun=2*10^-9//sec
10 taup=2*10^-9//sec
11
12 pn0=ni^2/nn0
13 disp(pn0,"before illumination pn0 in cm^-3 is")
14 GL=(10^13)/(1*10^-6)
15 nn=nn0+taun*GL
16 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
```

```
14  nth=exp(qx/(k*T))*Nc
15  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

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

Scilab code Exa 3.2 depletion layer width

```
1 clc
2
3 T=300 //K
4 k=8.617*10^-5 //eV/K
5 q=1.6*10**-19 //C
```

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

Scilab code Exa 3.3 depletion layer width

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

Scilab code Exa 3.4 calculate the junction capacitance

```
 1  clc
 2
 3  T=300  //K
 4  k=8.617*10^-5  //eV/K
 5  q=1.6*10**-19  //C
```

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

Scilab code Exa 3.5 ideal reverse saturation current

```
 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  ni =9.65*10^9//cm^-3
11  epsilonx =8.854*10^-14  //F/cm
12  Dn=21//cm^2/sec
13  Dp=10//cm^2/sec
14  taup =5*10^-7// sec
15  taun =5*10^-7// sec
16  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
```

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

Scilab code Exa 3.8 breakdown voltage

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

Scilab code Exa 3.9 breakdown voltage

```
1  clc
2
3  T=300  //K
4  k=8.617*10^-5  //eV/K
5  q=1.6*10**-19  //C
6  ND=8*10^14//cm^-3
7  Vb=500  //V
8  W=20*10^-6//m
```

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

Scilab code Exa 3.10 electrostatic potential

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

```
1  clc
2
3  T=300//K
4  k=8.617*10^-5 //eV/K
5  q=1.6*10**-19 //C
6  A=5*10^-4//m^2
7  V=0.6//V
8  Dp=10//cm^2/sec
9  De=1//cm^2/sec
10 Dc=2//cm^2/sec
11 taup=10^-7//sec
12 taue=10^-8//sec
13 ND=10^17
14 NE=10^19
15 W=0.5*10^-4//cm
16 ni=9.65*10^9
17 Lp=sqrt(Dp*taup)
18 disp(Lp,"Lp in cm=")
19 pn0=ni^2/ND
20 disp(pn0,"pn0 in cm^-3=")
21 Le=sqrt(De*taue)
22 disp(Le,"Le in cm=")
23 nE0=ni^2/NE
24 disp(nE0,"nE0 in cm^-3=")
25 IEp=exp(V/(k*T))*(q*pn0*Dp*A/W)
26 disp(IEp,"IEp in A")
27 Icp=IEp
28 disp(Icp,"Icp in A =")
29 IEn=(q*nE0*De*A/10^-4)*(exp(V/(k*T))-1)
30 disp(IEn,"IEn in A =")
31 alpha0=Icp/(IEp+IEn)
32 disp(alpha0,"alpha0 is= ")
```

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Scilab code Exa 4.3 value of Iceo

```
1  clc
2
3  T=300  //K
4  k=8.617*10^-5  //eV/K
5  q=1.6*10**-19  //C
6  alpha0=0.9933
7  Icbo=1*10^-6//A
8  beta0=alpha0/(1-alpha0)
9  disp(beta0,"beta0 =")
10 Iceo=(beta0+1)*Icbo
11 disp(Iceo,"Iceo in A =")
```

Scilab code Exa 4.4 base doping

```
1  clc
2
3  T=300  //K
4  k=8.617*10^-5  //eV/K
5  q=1.6*10**-19  //C
6  Ege=1.62
7  Egb=1.42
8  Nb=10^15
9  //beta0HBT/beta0BJT=a
10 a=exp((Ege-Egb)/(k*T))
11 disp(a,"beta0HBT/beta0BJT =")     //since the k*T
       value has taken as 0.025851 so the ans changes in
        last two digits
12 Nb1=Nb*a
13 disp(Nb1,"Nb1 in cm^-3=")      //since the ans
       differs in"a" so Nb1 changes
```

Scilab code Exa 4.5 find current

```
 1 clc
 2
 3 T=300  //K
 4 k=8.617*10^-5  //eV/K
 5 q=1.6*10**-19  //C
 6 I1=0.4*10^-3//A
 7 I2=0.6*10^-3//A
 8 alpha1=0.01
 9 alpha2=0.9999
10 I=(I1+I2)/(1-alpha1)
11 disp(I,"I in mA")
12 I=(I1+I2)/(1-alpha2)
13 disp(I,"I in A")
```

Chapter 5

MOS capacitor and MOSFET

Scilab code Exa 5.1 maxi width

```
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  epsilonx=8.854*10^-14  //F/cm
8  ni=9.65*10^9//cm^-3
9  W=2*sqrt(11.9*epsilonx*k*T*log(NA/ni)/(q*NA))
10 disp(W,"W in  meter =")          //textbook  ans  is
       wrong
```

Scilab code Exa 5.2 mini capacitance of CV

```
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 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

```
 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  epsilonox=3.9//F/cm
13  epsilonx=8.854*10^-14 //F/cm
14  deltaVfb=(q/(epsilonox*epsilonx))
        *[(0.5*10^18*(2*10^-6)^2)
        -(0.333*5*10^23*(2*10^-6)^3)]
15  disp(deltaVfb,"deltaVfb in V is= ")
```

Scilab code Exa 5.5 calculate Vdsat

```
 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  VG=3//V
```

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```
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

```
 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  Co=6.9*10^-9//F/cm^2
11  phims=-0.98
12  //2*phis=p
13  p=0.84//V
14  Qf=5*10^11//cm^2
15  VFB=phims-(q*Qf/Co)          //texbook ans is wrong
16  disp(VFB,"VFB in V is=")
17  VT=VFB+p+(sqrt(2*epsilonx*11.9*q*NA*p)/Co)
18  disp(VT,"VT in V is=")          //texbook ans is
        wrong
```

Scilab code Exa 5.8 calculate the change in the threshold voltage

```
 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  Co=6.9*10^-7//F/cm^2
11  VBS=2//V
12  phims=-0.98
13  //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

```
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 Co=6.9*10^-7//F/cm^2
11 VFB=-1.1//V
12 //2*phis=p
13 p=0.84//V
14 dsi=5*10^-6//cm^2
15 VT=VFB+p+(q*NA*dsi/Co)
16 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 ")
```

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

Scilab code Exa 7.2 barrier height and depletion layer

```
 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  ND=10^16  //cm^-3
 9  Nc=2.86*10^19
10  Dp=10//cm^2/s
11  Lp=3.1*10^-3
12  d=8*10^-7//cm
13  Js=6.5*10^-5//A/cm^2
14  V=0.67//V
15  phibn=k*T*log((110*300^2)/Js)
16  disp(Js,"Js in V is=")           //textbook ans is
        wrong
17  Vn=k*T*log(Nc/ND)
18  disp(Vn,"Vn in V is=")           //textbook ans is
        wrong
19  Vbi=phibn-Vn
20  disp(Vbi,"Vbi in V is=")             //textbook ans is
        wrong
21  W=sqrt((2*epsilonx*11.9*Vbi)/(q*ND))
22  disp(W,"W in cm is =")           //textbook ans is
        wrong
23  Jpo=(q*Dp*ni^2)/(Lp*ND)
24  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

35

```
 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  ND=2*10^15//cm^-3
 9  Nc=4.7*10^17//cm^-3
10  a=0.6*10^-4
11  fbn=0.89//V
12  Vp=(q*ND*a^2)/(2*epsilonx*12.4)
13  disp(Vp,"Vp in V is=")
14  Vn=(k*T)*log(Nc/ND)
15  disp(Vn,"Vn in V is=")
16  Vbi=fbn-Vn
17  disp(Vbi,"Vbi in V is=")
```

Scilab code Exa 7.5 two dimensional electron

```
 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  ND=2*10^18//cm^-3
 9  d1=40*10^-7//cm
10  d2=8*10^-7//cm
11  u=3*10^-7//cm
12  Va=0//V
13  //deltaEc/q=a
14  a=0.23//V
15  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 //cmˆ−2
8  v =10^7 // sec
9  n0 =10^12/ L
10 disp ( n0 ," n0  in  cmˆ−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

```
1  clc
2
3  alpha =100// per  cm
4  betaa =0.1// per  cm  A
5  Tau =0.9
6  g0 =100// per  cm
7  L=300*10^-4//cm
8  w=5*10^-4//cm
9  R1 =0.44
10 R2 =0.99
11 Jth =(( g0*Tau )/ betaa )+(1/ betaa )*( alpha +(1/(2* L))*log
       (1/R1*R2))
12 disp (Jth ,"Jth  in  A/cm^2  is=")
13 Ith =Jth*L*w
14 disp (Ith ,"Ith  in  A  is=")
```

Scilab code Exa 9.6 Determine temp

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

Chapter 10

Photodetectors and solar cells

Scilab code Exa 10.1 photocurrent

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

Scilab code Exa 10.2 depth

```
1  clc
2
```

```
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

```
 1  clc
 2
 3  T =300  //K
 4  k =8.617*10^-5  //eV/K
 5  q =1.6*10**-19  //C
 6  I =10^9//A
 7  Is =1*10^-9//A
 8  V =0.35//V
 9  IL =100*10^-3//A
10  Voc=k*T*log(IL/Is)
11  disp(Voc,"Voc in V is= ")
12  P =I*V*exp((V/(k*T))-1)*IL*V
13  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

```
1  clc
2
3  Cs =10^16// boron  atoms/cm^3
4  k0 =0.8
5  d=2.53// g/cm^3
6  aw =10.8// g/mol
7  s=60*10^3// kg
8  Ct = Cs/k0
9  disp(Ct ,"Ct  in  boron  atoms/cm^3  is= ")
10 v=s/d
11 disp(v ,"v  in  cm^3  is= ")
12 tb = Ct*v
13 disp(tb ,"tb  in  boron  atoms  is= ")
14 tb1 =(tb*aw)/(6.02*10^23)
15 disp(tb1 ,"tb1  in  g  of  boron  is= ")
```

Scilab code Exa 11.3 time required

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

Scilab code Exa 11.4 growth rate

```
1  clc
2
3  A=5//cm^2
4  L=10//cm
5  T=1173//K
6  d=6*10^14//cm^-2
7  P=5.5*10^-2//Pa
8  M=69.72          //for Ga
9  Ar=(2.64*10^20*P*A)/(sqrt(M*T)*%pi*L^2)
10 disp(Ar,"Ar in molecules /cm^2 is= ")
11 M1=74.92*2          //for As2
12 Ar1=(2.64*10^20*P*A)/(sqrt(M1*T)*%pi*L^2)
13 disp(Ar1,"Ar1 in molecules /cm^2 is= ")      //
       textbook ans is wrong
14 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

```
1  clc
2
3  Msi =28.9 // g/ mole
4  Dsi =2.33 // g/cm^3
5  Msidi =60.08 // g/ mole
6  Dsidi =2.21 // g/cm^3
7
8  vsi = Msi / Dsi
9  disp ( vsi ," vsi  in  cm^3/ mole  is= ")
10 vsidi = Msidi / Dsidi
11 disp ( vsidi ," vsidi  in  cm^3/ mole  is= ")
12 T= vsi / vsidi
13 disp (T ,"T is  ratio  of  Thickness  of  Si  to  SiO2  is= ")
```

Scilab code Exa 12.3 intrinsic value

```
1  clc
2
```

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```
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

```
1  clc
2
3  kAl =2.6
4  kCu =3.9
5  rAl =2.7 //u  ohm  cm
6  rCu =1.7 //u  ohm  cm
7  reduction =( rCu * kAl *100) /( rAl * kCu )
8  disp ( reduction ," reduction  in% is= ")
```

Scilab code Exa 12.7 oxide removal rate

```
1  clc
2
3  //(1/ r )+(0.01/0.1 r )=5.5
4  r =1.1/5.5
5  disp (r ," r  in  um/ min  is  =  ")
```

Chapter 13

Lithography and etching

Scilab code Exa 13.1 how many dust particles

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

Scilab code Exa 13.2 parameter gamma

```
1 clc
2
3 ET=90 //mJ/cm^2
4 EI=45 //mJ/cm^2
5 gammma=1/[log(ET/EI)]
6 disp(gammma,"gamma is= ")
7 ET=7 //mJ/cm^2
8 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

```
1  clc
2
3  D=2*10^-14 //cm^2/sec
4  t=3600 //K
5  Cx=10^19
6  A=sqrt(D*t)
7  disp(A,"A in cm is= ")
8  Qt=1.13*Cx*A
9  disp(Qt,"Q(t) in atoms/cm^3")
10 //dC/dx=b
11 b=-(Cx/sqrt(%pi*D*t))
12 disp(b,"dC/dx in cm^-4 is= ")
13 xj=2*sqrt(D*t)*2.75
14 disp(xj,"xj in meter is= ")
15 b=-(Cx/sqrt(%pi*D*t))*exp(-xj^2/(4*D*t))
16 disp(b,"dC/dx in cm^-4 is= ")
```

Scilab code Exa 14.2 junction depth

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

Scilab code Exa 14.3 ion beam current

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

Scilab code Exa 14.4 thickness

```
1  clc
2
3  Rp=0.53//um
4  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= ")
```