

Scilab Textbook Companion for
Semiconductor Physics and Devices Basic
Principles
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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	4
1 The Crystal Structure of Solids	7
2 Introduction to Quantum Mechanics	8
3 Introduction to the Quantum Theory of Solids	11
4 The Semiconductor in Equilibrium	15
5 Carrier Transport Phenomena	23
6 Nonequilibrium Excess Carriers in Semiconductors	28
7 The pn Junction	32
8 The pn Junction Diode	36
9 Metal Semiconductor and Semiconductor Heterojunctions	41
10 The Bipolar Transistor	47
11 Fundamentals of the Metal Oxide Semiconductor Field Effect Transistor	54

List of Scilab Codes

Exa 1.1	find volume density of atoms	7
Exa 1.3	Calculate surface density	7
Exa 2.1	Calculate photon energy	8
Exa 2.2	Calculate de broglie wavelength	8
Exa 2.3	Calculate first three energy levels	9
Exa 2.4	Calculate penetration depth	10
Exa 2.5	Calculate probability	10
Exa 3.1	Calculate change in KE	11
Exa 3.2	Determine lowest energy bandwidth	11
Exa 3.3	Calculate density of states	12
Exa 3.4	Determine possible no of ways	12
Exa 3.5	Determine possible no of ways	13
Exa 3.6	Calculate probability	13
Exa 3.7	Determine temp	13
Exa 4.1	Calculate probability	15
Exa 4.2	Calculate thermal equilibrium	16
Exa 4.3	Calculate intrinsic carrier	16
Exa 4.4	Calculate position	17
Exa 4.5	Calculate thermal equilibrium	17
Exa 4.6	Calculate electron concentration	18
Exa 4.7	Determine fraction of total electron	18
Exa 4.9	Calculate thermal equilibrium	19
Exa 4.10	Calculate thermal equilibrium	19
Exa 4.11	Calculate thermal equilibrium	20
Exa 4.12	Determine impurity concentration	20
Exa 4.13	Determine impurity concentration	21
Exa 4.14	Determine fermi level position	22
Exa 5.1	Drift current density	23

Exa 5.2	doping concentration	24
Exa 5.3	design semiconductor resistor	24
Exa 5.4	diffusion current density	25
Exa 5.5	Determine induced electric field	26
Exa 5.6	Determine diffusion coefficient	26
Exa 5.7	determine majority carrier	27
Exa 6.5	dielectric relaxation time constant	28
Exa 6.6	calculate the quasi Fermi energy levels	29
Exa 6.8	determine the steady state excess carrier concentration	29
Exa 6.10	determine the value of surface recombination velocity	30
Exa 7.1	calculate the built in potential barrier	32
Exa 7.2	calculate the space charge width	32
Exa 7.3	To calculate the width of the space charge region	33
Exa 7.4	design a pn junction	33
Exa 7.5	calculate the junction capacitance	34
Exa 7.6	determine the impurity doping concentrations	35
Exa 8.1	calculate the minority carrier hole concentration	36
Exa 8.2	ideal reverse saturation current density	36
Exa 8.3	design a pn junction diode	37
Exa 8.4	calculate the electric field	38
Exa 8.5	determine the change in the forward bias voltage	39
Exa 8.6	calculate the small signal admittance	39
Exa 8.7	determine the relative magnitudes	40
Exa 9.1	calculate the theoretical barrier height	41
Exa 9.2	calculate the semiconductor doping	42
Exa 9.3	calculate the Schottky barrier lowering	43
Exa 9.4	calculate the effective Richardson constant	43
Exa 9.5	calculate the reverse saturation current densities	44
Exa 9.6	calculate the forward bias voltage	44
Exa 9.7	calculate the space charge width	45
Exa 9.8	determine A_E , A_t and V_{bi}	46
Exa 10.1	design the ratio of emitter doping	47
Exa 10.2	design the base width	47
Exa 10.3	calculate the forward biased	48
Exa 10.4	calculate the common emitter current gain	48
Exa 10.5	calculate the change in the neutral base width	49
Exa 10.7	determine the increase in pE_0	50
Exa 10.8	design the collector doping	51

Exa 10.9	design a bipolar transistor	51
Exa 10.10	calculate the collector zmitter saturation voltage	52
Exa 10.12	calculate the emitter to collector transit time	52
Exa 11.1	calculate the maximum space charge width	54
Exa 11.2	calculate the metal semiconductor work function differ- ence	54
Exa 11.3	calculate the flat band voltage	55
Exa 11.4	design the oxide thickness	56
Exa 11.5	calculate the threshold voltage	56
Exa 11.6	design the semiconductor dnping concentration	57
Exa 11.7	calculate C_{ox}	58
Exa 11.8	design the width	59
Exa 11.9	determine the inversion carrier mobility	59
Exa 11.10	calculate the change in the threshold voltage	60
Exa 11.11	calculate the cutoff frequency	61

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=5Å = 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 surface density

```
1 clc
2
3 a1=5*10^-8 // a=5Å = 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(E2,"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

```
1  clc
2
3  v=10^5 // m/s
4  m=9.11*10^-31 // kg*m/s
5  e=1.6*10^-19 // eV
6  h=1.054*10^-34
7  E=0.5*m*v*v
8  disp(E,"the value of E in J is eV")
9  E1=E/e // value of E in eV
10 disp(E1,"eV=")
11 d=sqrt((h*h)/(2*m*E))
12 disp(d,"the value of d in m is ")
```

Scilab code Exa 2.5 Calculate probability

```
1  clc
2
3  E=2 // eV
4  V0=20 // eV
5  a=3*10^-10 // a=3A = 3*10^-10 m
6  m=9.11*10^-31 // kg*m/s
7  e=1.6*10^-19 // eV
8  h=1.054*10^-34 // J*s
9  K2=((2*m*(V0-E)*e)/(h*h))^0.5
10 disp(K2,"the value of K2 in m^-1 is")
11 T=16*(E/V0)*(1-E/V0)*exp(-2*K2*a)
12 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

```

1  clc
2
3  P=10
4  a=5*10^-10 // a=5 Armstrong
5  h=1.054*10^-34
6  m=9.11*10^-31 //kg
7
8  // alpha*a=%pi
9  // sqrt((2*m*E2)/h^2)*a=%pi
10 E2=(%pi^2*h^2)/(2*m*a^2)
11 disp(E2, 'E2= %f J\n')
12 E2=E2*6.2415*10^18
13 disp(E2, 'E2= %f eV')
14
15 E1=1.053 //eV
16 AE=E2-E1
17 disp(AE, 'AE= %f eV')

```

Scilab code Exa 3.3 Calculate density of states

```

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

```

Scilab code Exa 3.4 Determine possible no of ways

```

1  clc
2
3  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

```

1  clc
2
3  Ef=6.25 //eV
4  E=5.95 //eV
5  p=0.01
6  k= 8.617 *10^-5 //eV K^-1
7
8  //p=1-fF(E)
9  //fF(E)=1/(1+exp(E-Ef/kT))
10 //p=1-1/(1+exp(E-Ef/kT)) equation 1
11 x=E-Ef
12
13 y=(1/(1-p))-1 // solving the above equataion 1
14
15 T=x/(k*log(y))
16 printf('T=%f K\n',T)

```

Chapter 4

The Semiconductor in Equilibrium

Scilab code Exa 4.1 Calculate probability

```
1  clc
2
3  T=300 //K
4  Nc=2.8*10^19 //cm^-3
5  k=8.617 *10^-5 //eV K^-1
6  //E=Ec
7  //a=Ec-Ef
8  a=-0.25
9  //fF(E)=1/(1+exp(Ec-Ef/kT)) =exp(-(Ec-Ef)/kT)
10 //b=k*T
11 //disp(b)
12 c=k*T
13 fFE=exp(a/c)
14 disp(fFE,"fF(E) value is=")
15 n0=Nc*exp(-a/(k*T))
16 disp(n0,"n0 value in cm^-3 is")
```

Scilab code Exa 4.2 Calculate thermal equilibrium

```
1  clc
2
3  T1=400  //K
4  T2=300  //K
5  N=1.04*10^19  //cm^-3
6  k=8.617*10^-5  //eV/K
7
8  Nv=N*(T1/T2)^(3/2)
9  disp(Nv, 'Nv=%f cm^-3\n\n')
```

```
10
11 a=k*T2*(T1/T2)
12 disp(a, 'kT=%f eV\n\n')
```

```
13
14 //p0=Nv*exp(-(Ef-Ev)/kT)
15 p0=Nv*exp(-0.27/a)
16 disp(p0, 'p0=%f cm^-3 \n')
```

Scilab code Exa 4.3 Calculate intrinsic carrier

```
1  clc
2
3  T1=300  //K
4  T2=450  //K
5  Nc=4.7*10^17  //cm^-3
6  N=7*10^18  //cm^-3
7  k=8.617*10^-5  //eV/K
8  a=k*T1*(T2/T1)
9  disp(a, 'kT=%f eV\n\n')
```

```
10
11 ni=sqrt(Nc*N*exp(-1.42/(k*T1)))
12 disp(ni, 'ni=%f cm^-3\n\n')
```

```
13
14 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 equilibrium

```
1 clc
2
3 T=300 //K
4 Nn=2.8*1019 //cm-3
5 Np=1.04*1019 //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 equilibrium

```
1 clc
2
3 Nd=10**16 //cm-3
4 Na=0
5 ni=1.5*10**10 //cm-3
6 T=300 //K
7 k=8.617*10-5 //eV/K
8
9 n0=((Nd-Na)/2)+sqrt((((Nd-Na)/2)2+ni2)
10 disp(n0,"n0 in cm-3 is")
11
12 p0=(ni2)/n0
13 disp(p0,"p0 in cm-3")
```

Scilab code Exa 4.10 Calculate thermal equilibrium

```
1 clc
2
3 Nd=5*10**13 //cm-3
4 Na=0
5 ni=2.4*10**13 //cm-3
6 T=300 //K
7 k=8.617*10-5 //eV/K
8
9 n0=((Nd-Na)/2)+sqrt((((Nd-Na)/2)2+ni2)
10 disp(n0,"n0 in cm-3 is")
11
12 p0=(ni2)/n0
13 disp(p0,"p0 in cm-3")
```

Scilab code Exa 4.11 Calculate thermal equilibrium

```
1  clc
2
3  T=300 //K
4  Nd=3*10**15 //cm**-3
5  Na=10**16 //cm**-3
6  k=8.617*10^-5 //eV/K
7  ni=1.5*10**16 //cm^-3
8
9  a=((Na-Nd)/2)
10 disp(a)
11 b=sqrt(((Na-Nd)/2)^2+(ni^2))
12 disp(b)
13
14 p0=a+b
15 disp(p0,"p0 in cm^-3 is=") //textbook ans is
    wrpng
16
17 n0=(ni^2)/p0
18 disp(n0,"n0 in cm^-3 is=") //textbook ans is
    wrpng
```

Scilab code Exa 4.12 Determine impurity concentration

```
1  clc
2
3  T1=550 //K
4  T2=300 //K
5  Nc=2.8*10**19 //cm**-3
6  Ne=1.04*10**19 //cm**-3
7  k=8.617*10^-5 //eV/K
```

```

8 Eg=1.12
9
10 //ni^2=Nc*Ne*exp(-Eg/(k*T))
11
12 ni=sqrt(Nc*Ne*(T1/T2)^3*exp((-Eg/(k*T2))*(T2/T1)))
13 disp(ni , "ni in cm^-3 is = ")
14
15 //n0=1.05*Nd
16 //n0=(Nd/2)+sqrt((Nd/2)^2+ni^2)           equation 1
17
18 a=((1.05*2)-1)/2)^2                       //simplifying and
      sloving the about equaton 1
19 b=ni^2
20 c=((4*a)-1)/4
21 Nd=sqrt(b/c)
22 disp(Nd,"Nd value in cm^-3 is=")

```

Scilab code Exa 4.13 Determine impurity concentration

```

1 clc
2
3 T=300 //K
4 Na=10**16 //cm^-3
5 Nc=2.8*10**19 //cm**-3
6 k=8.617*10^-5 //eV/K
7
8 //a=Ec-Ef
9 a=0.20 //eV
10 //Ec-Ef=k*T*log(Ne/(Nd-Na))
11 //Nd-Na=Nc*exp(-(Ec-Ef)/k*T)
12
13 Nd=Na+Nc*exp(-a/(k*T))
14 disp(Nd,"Nd in cm^-3 is= ")

```

Scilab code Exa 4.14 Determine fermi level position

```
1  clc
2
3  T=300 //K
4  k=8.617*10^-5 //eV/K
5  ni=1.5*10**10 //cm^-3
6  //Ef-Ea=a
7  a=3*k*T
8  //Ea-Ev=b
9  b=0.045 //eV
10 Eg=1.12 //eV
11
12 // Efi-Ef=(Eg/2)-(Ea-Ev)-(Ef-Ea)=kT*log(Na/ni)
13 c=(Eg/2)-(b)-(a)
14 Na=ni*exp(c/(k*T))
15 disp(Na,"Na in cm^-3 is= ")
```

Chapter 5

Carrier Transport Phenomena

Scilab code Exa 5.1 Drift current density

```
1  clc
2
3  Nd=10**16 //cm-3
4  Na=0
5  ni=1.8*10**6 //cm-3
6  T=300 //K
7  k=8.617*10-5 //eV/K
8  E=10 //V/cm2
9  e=1.6*10**-19
10 un=8500
11
12 n0=((Nd-Na)/2)+sqrt((((Nd-Na)/2)2+ni2)
13 disp(n0,"n0 in cm-3 is")
14
15 p0=(ni2)/n0
16 disp(p0,"p0 in cm-3")
17
18 // Jdrf=e*(un*n0+up*p0)*E= e*un*Nd*E
19 Jdrf=e*un*Nd*E
20 disp(Jdrf,"Jdrf in A/cm2 is= ")
```

Scilab code Exa 5.2 doping concentration

```
1  clc
2
3  Na=10**17 //cm**-3
4  T=300 //K
5  k=8.617*10^-5 //eV/K
6  E=10 //V/cm^2
7  e=1.6*10**-19 //C
8
9
10 //sigma=e*un*n0=e*un*(Nd-Na)
11 // if
12 Nd=2*10**17 //cm**-3
13 sigma=8.16 //ohm/cm
14 un=sigma/(e*(Nd-Na))
15 disp(un,"un in cm^2/Vs is=")
16
17 // if
18 Nd=5*10**17 //cm^-3
19 sigma=20.8 //ohm/cm
20 un=sigma/(e*(Nd-Na))
21 disp(un,"un in cm^2/Vs is=")
22
23 // if
24 Nd=3.5*10**17 //cm^-3
25 sigma=16 //ohm/cm
26 un=sigma/(e*(Nd-Na))
27 disp(un,"un in cm^2/Vs is=")
```

Scilab code Exa 5.3 design semiconductor resistor

```

1  clc
2
3  V=5 //v
4  R=10*103 //ohm
5  J=50 //A/cm2
6  E=100
7  Na=1.25*10**16 //cm-3
8  Nd=5*10**15 //cm-3
9  e=1.6*10**-19 //C
10 up=410 //cm**2/Vs
11
12 I=V/R
13 disp(I,"I current in Ampere is=")
14
15 A=I/J
16 disp(A,"A cross sectional area in cm2 is=")
17
18 L=V/E
19 disp(L,"L length of resistor in cm is=")
20
21 sigma=L/(R*A)
22 disp(sigma,"sigma conductivity in per ohm cm is=")
23
24 //sigma=e*up*p0=e*up*(Na-Nd)
25 sigma=e*up*(Na-Nd)
26 disp(sigma,"sigma conductivity in per ohm cm is=")

```

Scilab code Exa 5.4 diffusion current density

```

1  clc
2
3  T=300 // ..K
4  Dn=225 //cm2/s
5  e=1.6*10-19// C
6  deltax=0.10 //cm

```

```

7 deltan=(1*10**18-7*10**17) //cm^-3
8
9 // Jnxdif=e*Dx*derivative (n,x)=e*Dn*(deltan/deltax)
10 Jnxdif=e*Dn*(deltan/deltax)
11 disp(Jnxdif,"diffusion current density in A/cm^2 is=
    ")

```

Scilab code Exa 5.5 Determine induced electric field

```

1 clc
2
3 T=300 //K
4 k=8.617*10^-5 //eV/K
5 // derivative (Ndx,x)=a
6 a=-10**19 //cm**-4
7 Ndx=(10^16-10^19) //cm^3
8 l=1
9
10 //Ex=-(k*T/l)*(1/Ndx)*derivative(Ndx,x)
11 Ex=-(k*T/l)*(1/Ndx)*a*10^3
12 disp(Ex,"induced electric field in V/cm is= ")

```

Scilab code Exa 5.6 Determine diffusion coefficient

```

1 clc
2
3 T=300 //K
4 u=1000 //cm^2/s
5 k=8.617*10^-5 //eV/K
6 e=1.6*10**-19 //C
7
8 //D=((k*T)/e)*u
9 D=k*T*u

```

10 `disp(D,"diffusion coefficient in cm2/s is =")`

Scilab code Exa 5.7 determine majority carrier

```
1 clc
2
3 I=10^-3 //A
4 Bz=5*10**-2 //500 gauss
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 concentration 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 dielehc relaxation time constant

```
1  clc
2
3  k=8.617*10**-5 //eV/K
4  e=1.6*10**-19 //C
5  un=1200
6  Nd=10^16 //cm^-3
7  esp0=8.85*10^-14
8  espr=11.7
9
10 sigma=e*un*Nd
11 disp(sigma,"conductivity in per ohm cm is= ")
12
13 esp=espr*esp0
14 disp(esp,"permittivity of silicon in F/cm")
15
16 taud=esp/sigma
17 disp(taud,"dielectric relaxtion time constant in sec
    is= ")
```

Scilab code Exa 6.6 calculate the quasi Fermi energy levels

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  n0=10^15 //cm^-3
7  p0=10^5 //cm^-3
8  ni=10^10 //cm^-3
9  deltan=10**13 //cm**-3
10 deltap=10**13 //cm**-3
11
12 //Ef-Efi=a
13 a=(k*T)*log(n0/ni)
14 disp(a,"fermi level for thermal equilibrium in eV is="
      ")
15
16 //Efn-Efi=b
17 b=(k*T)*log((n0+deltan)/ni)
18 disp(b,"quasi fermi level for electrons in eV is=")
19
20 //Efi-Efp=c
21 c=(k*T)*log((p0+deltap)/ni)
22 disp(c,"quasi fermi level for holes in eV is=")
```

Scilab code Exa 6.8 detrrminr the steady state excess carrier concentra-
tion

```
1  clc
2
3  k=8.617*10**-5 //eV/K
```

```

4 e=1.6*10**-19 //C
5 x=0
6 taup0=10**-6 //ses
7 taup01=10**-7 //sec
8 deltapb=10**14 //cm**-3
9 Dn=10 //cm^2/sec
10 Dp=10 //cm^2/sec
11 B=-9*10^13
12
13 deltap=deltapb*(taup01/taup0)
14 disp(deltap,"deltap in cm^-3 is=")
15
16 g=deltap/taup0
17 disp(g,"g generation in cm^-3s^-1 is= ")
18
19 //deltapx=10^14*(1-0.9*exp(-x/Lp))
20 Lp=sqrt(Dp*taup0)
21 disp(Lp,"Lp in meter is=")
22
23 deltapx=10^14*(1-0.9*exp(-x/Lp))
24 disp(deltapx,"distance from the surface is =")

```

Scilab code Exa 6.10 determine the value of surface recombinaion velocity

```

1 clc
2
3 k=8.617*10**-5 //eV/K
4 e=1.6*10**-19 //C
5 Dp=10 //cm^2/sec
6 Lp=31.6*10**-4 //m
7 g1taup0=10^14 //cm^-3
8 deltap0=10^13 //cm6-3
9
10 //deltap0=g1taup0*[g/((Dp/Lp)+s)]
11 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

```
1  clc
2
3  T=300 //K
4  Na=1*10^18 // Na=L*10^18 cm^-3
5  Nd=1*10^15 // cm^-3
6  ni=1.5*10^10 // cm^-3
7  e=1.6*10^-19 // eV
8  k=1.3806*10^-23 // JK^-1
9  Vbi=(((k*T)/e)*log(Na*Nd/ni^2))
10 disp(Vbi,"the value of Vbi in V is")
11
12 //changing the Na value
13 Na=10^16 // Na=l*10^16 cm^1
14 Vbi=(((k*T)/e)*log(Na*Nd/ni^2))
15 disp(Vbi,"the value of Vbi in V is")
```

Scilab code Exa 7.2 calculate the space charge width

```

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

```

Scilab code Exa 7.3 To calculate the width of the space charge region

```

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

```

Scilab code Exa 7.4 design a pn junction

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Vr=25 //V
7  Emax=3*10^5 //V/cm
8  Na=10^18 //cm^-3
9  esp=11.7
10 esp0=8.85*10^-14
11
12 //Emax=sqrt((2*e*Vr*(Na+Nd))/(esp*(Na+Nd)))
13 x=((Emax^2)*esp*esp0)/(2*e*Vr) //solving
    the above equation we get
14
15 Nd=(Na*x)/(Na-x)
16 disp(Nd,"doping concentration in cm^-3 is =")

```

Scilab code Exa 7.5 calculate the junction capacitance

```

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

```

is”)

Scilab code Exa 7.6 determine the impurity doping concentrations

```
1  clc
2
3  T=300 //K
4  ni=1.5*10^10 // cm^-3
5  Nd=10^15 // cm^-3
6  Vbi=0.855 // V
7  e=1.6*10^-19 // eV
8  k=1.3806*10^-23 // JK^-1
9  S=1.32*10^15 // Slope=1.32*10^-15 (F/cm^2)^-2*(V)-1
10 epsilon0=8.85*10^-14 // F/m
11 epsilons=11.7
12 Nd=2/((e*(epsilons*epsilon0))*S)
13 Na=((ni*ni)/Nd)*exp((e*Vbi)/(k*T))
14 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 equilibrium 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

```

1  clc
2
3  T=300 //K
4  Na=10**16 //cm-3
5  Nd=10**16 //cm-3
6  ni=1.5*10**10 //cm-3
7  Dn=25 //cm2/s
8  Dp=10 //cm2/s
9  taup0=5*10-7 //s
10 taun0=5*10-7 //s
11 epsilon=11.7
12 e=1.6*10**-19 //C
13
14 //J=(E*D*np0/Ln)+(E*D*pn0/Lp)
15 Js=e*ni2*[(1/Na)*sqrt(Dn/taun0)+(1/Nd)*sqrt(Dp/
    taup0)]
16 disp(Js,"reverse saturation current density in A/cm
    ^2 is=")

```

Scilab code Exa 8.3 design a pn junction diode

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Jp=5 //A/cm2
7  Jn=20 //A/cm2
8  Va=0.65 //V
9  ni=1.5*10**10 //cm-3
10 Dn=25 //cm2/s
11 Dp=10 //cm2/s
12 taup0=5*10-7 //s
13 taun0=5*10-7 //s
14

```

```

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 electron 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

```
1  clc
2
3  T1=300 //K
4  T2=310 //K
5  k=8.617*10**-5 //eV/K
6  e=1.6*10**-19 //C
7  Va1=0.60 //V
8  Va2=0.5827 //V
9  E=1.12 //eV
10
11 //J=exp(-Eg/(k*T))*exp((e*Va)/(k*T))
12
13 a=( [e*Va2*k*T1]+[e*Va1*k*T2] ) / ((k*T1)-(k*T2))
14 disp(a)
```

Scilab code Exa 8.6 calculate the small signal admittance

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Vt=0.0259 //v
7  lp0=10^-3 //A
8  taup0=10^-7 //s
9  Idq=1*10**-3 //A
10
11 Cd=(1*lp0*taup0)/(2*Vt)
12 disp(Cd,"diffusion capacitance in F is= ")
13
14 vd=(Vt/Idq)
15 disp(vd,"diffusion in ohm is= ")
```

Scilab code Exa 8.7 determine the relative magnitudes

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Na=10**16 //cm^-3
7  Nd=10**16 //cm^-3
8  ni=1.5*10**10 //cm^-3
9  tau0=5*10^-7 //s
10 eps=11.7
11 //Vbr+Vr=z
12 z=5 //V
13
14 W=sqrt(((2*eps))*((Na+Nd)/Na*Nd)*z)
15 disp(W,"depletion width in cm is= ")//
    textbook ans is wrong
16
17 Jgen=(e*ni*W)/(2*tau0)
18 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
```

```

20 Vbt=hb-phiu
21 disp(Vbt,"in V is=")
22
23 xn=sqrt((2*esp*esp0*Vbi)/(e*Nd))
24 disp(xn,"space charge in cm is=")
25
26 Emax=(e*Nd*xn)/(esp*esp0)
27 disp(Emax,"maxi electric field in V/cm is=")

```

Scilab code Exa 9.2 calculate the semiconductor doping

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  esp=11.7
7  esp0=8.85*10^-14
8  Nd=2.7*10**17 //cm^-3
9  Na=2.8*10**19 //cm^-3
10 Vbi=0.40
11
12 // (1/C)^2=2*(Vbi+Vr)/(e*esp*Nd)
13 // delta(1/C)^2/delta Vr=z
14 z=4.4*10**13
15 Nd=2/(e*esp*esp0*z)
16 disp(Nd,"semiconductor doping in cm^-3 is=")
17
18 phin=(k*T)*log(Na/Nd)
19 disp(phin,"in v is=")
20
21 phibn=Vbi+phin
22 disp(phibn,"schottky barrier height in V is=")

```

Scilab code Exa 9.3 calculatr the Schottky barrier lowering

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  esp=11.7
7  esp0=8.85*10^-14
8  E=6.8*10**4 //V/cm
9
10 deltaphi=sqrt((e*E)/(4*pi*esp*esp0))
11 disp(deltaphi,"schottky barrier lowring in V is =")
12
13 xm=sqrt(e/(16*pi*esp*esp0*E))
14 disp(xm,"maxi barrier height in meter is=")
```

Scilab code Exa 9.4 calculate the effective Richardson constant

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  esp=11.7
7  esp0=8.85*10^-14
8  phibe=0.67 //V
9  Jst=6*10**-5 //A/cm^2
10
11 A=exp(phibe/(k*T))*(Jst/T^2)
12 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

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  esp=11.7
7  esp0=8.85*10^-14
8  phibe=0.67 //V
9  A=114 //A/K^2-cm^2
10 Na=10^18 //cm^-3
11 Nd=10^16 //cm^-3
12 taup0=10^-7
13 taun0=10^-7
14 Dp=10 //cm^2/s
15 Dn=25 //cm^2/s
16 Lp=1.0*10**-3 //cm
17 Ln=1.58*10**-3 //cm
18 pn0=2.25*10**4 //cm^-3
19 np0=2.25*10**2 //cm^-3
20
21
22 a=k*T
23 Jst=(A*T^2)*exp(-phibe/a)
24 disp(Jst,"Richardson constant in A/K^2-cm^2 is=")
25
26 Js=((e*Dn*np0)/Ln)+((e*Dp*pn0)/Lp)
27 disp(Js,"reverse saturation current density in A/cm
    ^2 is=")
```

Scilab code Exa 9.6 calculate the forward bias voltage

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  esp=11.7
7  esp0=8.85*10^-14
8  J=10 //A/K^2-cm^2
9  Jst=5.98*10^-5 //A/K^2-cm^2
10 Js=3.66*10^-11 //A/K^2-cm^2
11
12 //J=Jst*[exp(e*Va/k*T)-1]
13 //Va=(k*T/e)*log(J/Jst)
14 Va=(k*T)*log(J/Jst)
15 disp(Va,"forward bias voltage in V is= ")
16
17 Va=(k*T)*log(J/Js)
18 disp(Va,"forward bias voltage in V is= ")

```

Scilab code Exa 9.7 calculate the space charge width

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Nd=7*10^18 //cm^3
7  esp=11.7
8  esp0=8.85*10^-14
9  phibn=0.67 //V
10 Vbi=0.67
11
12 xn=sqrt((2*esp*esp0*Vbi)/(e*Nd))
13 disp(xn,"space charge width in cm is= ")

```

Scilab code Exa 9.8 detemmine AE At and Vbi

```
1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  ni=2.4*10^13 //cm^-3
7  Na=7*10^18 //cm^3
8  Nd=10^16 //cm^-3
9  pp0=6*10^18 //cm^-3
10 esp=11.7
11 esp0=8.85*10^-14
12 xn=4.13
13 xp=4.07
14
15 //AE1=e*(xn-xp)
16 AE=(xn-xp)
17 disp(AE,"AE in eV is=")
18
19 deltaE=1.43-0.67
20
21 AE1=deltaE-AE
22 disp(AE1,"AE1 in eV is=")
23
24 pn0=(ni^2)/Nd
25 disp(pn0,"pn0 in cm^-3 is=")
26
27 Vbi=AE1+(k*T)*log((Nd*pp0)/(pn0*Na))
28 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

```

```

8  xB=0.70*10^-6 //m
9  xE=0.50*10^-6 //m
10 NE=1*10^18 //cm^-3
11 NB=1*10^16 //cm^-3
12 VBE=0.65 //V
13 tauB0=5*10^-7 //s
14 tauE0=1*10^-7 //s
15 Jr0=5*10^-8 //A/cm62
16 pE0=2.25*10^2 //cm^-3
17 nB0=2.25*10^4 //cm^-3
18 LE=10^-3 //cm
19 LB=3.54*10^-3 //cm
20
21 gamma1=1/(1+(pE0*DE*LB*tanh(0.0198))/(nB0*DB*LE*tanh
    (0.050)))
22 disp(gamma1,"gamma1 is=")
23 alphatau=1/cosh(xB/LB)
24 disp(alphatau,"alphatau is=")
25 Js0=(e*DB*nB0)/(LB*tanh(xB/LB))
26 disp(Js0,"Js0 is A/cm^2")
27 delta=1/(1+(Jr0/Js0)*exp(-VBE/(2*0.0259)))
28 disp(delta,"delta is=")
29 a=gamma1*alphatau*delta
30 disp(a,"a is=")
31 beta1=a/(1-a)
32 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

```

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

```

```

6 NB=5*10^16 //cm^-3
7 NC=2*10^15 //cm^-3
8 epsilons=11.7
9 eps=8.85*10^-14 //V
10 ni=1.5*10**10 //cm^-3
11 x=0.70*10^-6
12 a=9.96*10^-12 ///solving the equation
13 Vbi=((k*T))*log((NB*NC)/ni^2)
14 disp(Vbi,"Vbi in V is=")
15
16 //for
17 VCB=2 //V
18 xdB1=sqrt(a*(Vbi+VCB))
19 disp(xdB1,"xdB in meter is=")
20 xB1=x-xdB1
21 disp(xB1,"xB in meter is=") //          textbook ans
    are wrong
22
23 //for
24 VCB=10 //V
25 xdB2=sqrt(a*(Vbi+VCB))
26 disp(xdB2,"xdB in meter is=")
27 xB2=x-xdB2
28 disp(xB2,"xB in meter is=") //          textbook ans
    are wrong

```

Scilab code Exa 10.7 determine the increase in pE0

```

1 clc
2
3 T=300 // K
4 k=1.3806*10^-23 // JK^-1
5 e=1.6*10^-19 // eV
6 ni=1.5*10^10 // cm^-3
7 NE=10^18 // cm^-3

```

```

8 pE01=(ni*ni)/NE// neglecting bandgap
9 disp(pE01,"pE01 the value of pE01 in cm-3 is")
10 NE=1019// cm-3
11 pE03=(ni*ni)/NE// neglecting bandgap
12 disp(pE03,"pE03 the value of pE03 in cm-3 is")
13 pE02=((ni*ni)/NE)*exp(0.030/(k*(T/e)))// including
    bandgap
14 disp(pE02,"pE02 the value of pE02 in cm-3 is")
15 pE04=((ni*ni)/NE)*exp(0.1/(k*(T/e)))// including
    bandgap
16 disp(pE04,"pE04 the value of pE04 in cm-3 is")

```

Scilab code Exa 10.8 design the collector doping

```

1 clc
2
3 T=300// K
4 k=1.3806*10-23// JK-1
5 e=1.6*10-19// eV
6 epsilon=8.85*10-14//V
7 eps=11.7
8 NB=1016//cm-3
9 Vpt=25//V
10 WB=0.5*10-4
11
12
13 //Vpt=(e*WB2*NB*(NC+NB))/(2*epsilon*eps*NC)
14 a=(Vpt*2*epsilon*eps)/(e*WB2*NB)
15 disp(a)
16 NC=NB/(a-1)
17 disp(NC,"NC in cm-3 is=")

```

Scilab code Exa 10.9 design a bipolar transistor

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  NB=10^17 //cm^-3
7  beta=100
8  BVCEO=15 //V
9
10 BVCEO=(beta)^(1/3)*BVCEO
11 disp(BVCEO," in V is=")

```

Scilab code Exa 10.10 calculate the collector zmitter saturation voltage

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  alphaF=0.99
7  alphaR=0.20
8  Ic=1 //mA
9  IB=0.050 //mA
10
11 Vcesat=k*T*log(((Ic*(1-alphaR)+IB)*alphaF)/((alphaF*
    IB-(1-alphaF)*Ic)*alphaR))
12 disp(Vcesat," VCEsat in V is=")

```

Scilab code Exa 10.12 calculate the emitter to collector transit time

```

1  clc
2
3  T=300 //K

```

```

4 k=8.617*10**-5 //eV/K
5 e=1.6*10**-19 //C
6 IE=1*10^-3 //A
7 Cje=1*10^-12 //F
8 xB=0.5*10^-4 //cm
9 Dn=25 // cm2/s
10 xdc=2.4*10^-4 //cm
11 vs=10^7
12 rc=20 //ohm
13 Cu=0.1*10^-12 //F
14 Cs=0.1*10^-12 //F
15 beta=100
16
17 re1=(k*T)/IE
18 disp(re1,"re1 in ohm is=")
19 taue=re1*Cje
20 disp(taue,"taue in sec is=")
21 taub=xB^2/(2*Dn)
22 disp(taub,"taub in sec is=")
23 taub1=xdc/vs
24 disp(taub1,"taub in sec is=")
25 tauc=rc*(Cu+Cs)
26 disp(tauc,"tauc in sec is=")
27 tauec=taue+taub+taub1+tauc
28 disp(tauec,"tauec in sec is=")
29 ftau=1/(2*pi*tauec)
30 disp(ftau,"ftau in GHz is=")
31 fbeta=ftau/beta
32 disp(fbета,"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

```
1  clc
2
3  T=300 //K
4  Na=10^16 // cm^-3
5  ni=1.5*10^10 // cm^-3
6  epsilon0=8.85*10^-14 // F/m
7  epsilons=11.7
8  e=1.6*10^-19 // eV
9  Vt=0.0259 // V
10 phifp=Vt*log(Na/ni)
11 disp(phifp,"the value of phisp in V is")
12 xdT=(4*(epsilons*epsilon0)*phifp/(e*Na))^0.5
13 disp(xdT,"the value of xdT in meter is")
```

Scilab code Exa 11.2 calculate the metal semiconductor work function difference

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

Scilab code Exa 11.3 calculate the flat band voltage

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

Scilab code Exa 11.4 design the oxide thickness

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

Scilab code Exa 11.5 calculate the threshold voltage

```
1  clc
2
3  T=300 // K
4  k=1.3806*10^-23 // JK^-1
```

```

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

```

Scilab code Exa 11.6 design the semiconductor dnping concentration

```

1 clc
2
3 T=300 // K
4 k=1.3806*10^-23 // JK^-1
5 Qss=10^10 // cm^-2
6 tox=650*10^-8 // tox=650A =650*10^-8 cm
7 epsilon0=8.85*10^-14 // F/m
8 epsilons=11.7
9 epsilonox=3.9
10 ni=1.5*10^10 // cm^-3
11 e=1.6*10^-19 // eV
12 Nd=2.5*10^14 // cm^-3
13 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

```

```

22 Cmin=(espox*esp0)/(tox+(espox/esp)*xdt)
23 disp(Cmin,"in F/cm^2 is =")
24
25 a=Cmin/Cox
26 disp(a,"ratio of Cmin to Cox is= ")
27
28 Cfb=(espox*esp0)/(tox+(espox/esp)*sqrt((k*T*esp*esp0
    )/(e*Na)))
29 disp(Cfb,"Cfb in F/cm^2 is=")
30
31 b=Cfb/Cox
32 disp(b,"ratio of Cfb to Cox is= ")

```

Scilab code Exa 11.8 design the width

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Cox=6.9*10^-8 //F/cm2
7  esp0=8.85*10^-14
8  Vtau=0.65 //V
9  VGS=5 //V
10 L=1.25*10^-4 //cm
11 u=650 //cm^2/Vs
12 IDsat=4*10^-3 //A
13
14 W=(IDsat*2*L)/(u*Cox*(VGS-Vtau)^2)
15 disp(W,"W in meter is=")

```

Scilab code Exa 11.9 determine the inversion carrier mobility

```

1  clc
2
3  T=300 //K
4  k=8.617*10**-5 //eV/K
5  e=1.6*10**-19 //C
6  Cox=6.9*10^-8 //F/cm2
7  esp0=8.85*10^-14
8  Vtau=0.65 //V
9  VGS1=1.5 //V
10 VGS2=2.5 //V
11 VDS=0.10 //V
12 L=2*10^-6 //cm
13 u=650 //cm^2/Vs
14 ID1=35*10^-6 //A
15 ID2=75*10^-6 //A
16 W=15*10^-6 //m
17
18 un=(ID2-ID1)*L/(W*Cox*(VGS2-VGS1)*VDS)
19 disp(un,"un in cm^2/Vs is=")

```

Scilab code Exa 11.10 calculate the change in the threshold voltage

```

1  clc
2
3  T=300 // K
4  Na=3*10^16 // cm^-3
5  tox=500*10^-8 // tox=500A =500*10^-8 cm
6  k=1.3806*10^-23 // JK^-1
7  VSB=1 // V
8  epsilon0=8.85*10^-14 // F/m
9  epsilons=11.7
10 epsilonox=3.9
11 ni=1.5*10^10 // cm^-3
12 e=1.6*10^-19 // eV
13 phifp=((k*T)/e)*log(Na/ni) // phifp=V1*log(Na/ni)

```

```

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

```

Scilab code Exa 11.11 calculate the cutoff frequency

```

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

```
