Scilab Textbook Companion for Advance Semiconductor Devices by K. C. Nandi[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

Review of Fundamentals of Semiconductor

Scilab code Exa 1.5.1 Value of forbidden gap

```
//Ex 1.5.1
clc;clear;close;
format('v',6);

//Given :
t1=35;//degreeC
t2=60;//degreeC
T1=t1+273;//K
T2=t2+273;//K
disp("Forbidden gap for Si : ");
EG1_Si=1.21-3.6*10^-4*T1;//eV
disp(EG1_Si,"at 35 degree C in eV")
EG2_Si=1.21-3.6*10^-4*T2;//eV
disp(EG2_Si,"at 60 degree C in eV")
disp("Forbidden gap for Ge : ");
EG1_Ge=0.785-2.23*10^-4*T1;//eV
disp(EG1_Ge,"at 35 degree C in eV")
EG2_Ge=0.785-2.23*10^-4*T2;//eV
disp(EG2_Ge,"at 60 degree C in eV")
```

Scilab code Exa 1.9.1 Concentration and drift velocity

```
//Ex 1.9.1
clc;clear;close;
format('v',9);

//Given :
l=6*10^-2;//m
V=1;//Volt
A=10*10^-6;//m^2
I=10*10^-3;//A
q=1.602*10^-19;//Coulomb
mu_n=1300*10^-4;//m^2/V-s
E=V/l;//V/m
v=mu_n*E;//m/s
J=I/A;//A/m^2
n=J/(q*mu_n*E);//per m^3
disp(n,"(i) Concentration of electron(m^3) : ");
disp(v,"(ii) Drift velocity(m/s) : ");
```

Scilab code Exa 1.9.2 Electron Moility

```
//Ex 1.9.2
clc;clear;close;
format('v',9);

//Given :
l=6*10^-2;//m
V=12;//Volt
v=73;//m/s
E=V/l;//V/m
```

```
mu=v/E;//m^2/V-s
disp(mu,"Electron mobility(m^2/V-s) : ");
```

Scilab code Exa 1.10.1 Concentration and drift velocity

```
//Ex 1.10.1
clc;clear;close;
format('v',9);

//Given :
l=4*10^-2;//m
A=10*10^-6;//m^2
V=1;//Volt
I=5*10^-3;//A
q=1.6*10^-19;//Coulomb
mu=1300;//cm^2/V-s
J=I/A;//A/m^2
E=V/l;//V/m
n=J/(q*mu*10^-4*E);
v=mu*10^-4*E;//m/s
disp(n,"Concentration of electron(per m^3) : ");
disp(v,"Electron velocity(m/s) : ");
```

Scilab code Exa 1.11.1 Conductivity and Resistivity

```
//Ex 1.11.1
clc;clear;close;
format('v',9);

//Given :
ni=1.5*10^10/10^-6;//per m^3
mu_n=1800*10^-4;//m^2/V-s
mu_p=500*10^-4;//m^2/V-s
```

```
q=1.6*10^-19;//Coulomb
sigma_i=ni*(mu_n+mu_p)*q;//(ohm-m)^-1
disp(sigma_i,"Conductivity in (ohm-m)^-1 : ");
rho_i=1/sigma_i;//ohm-m
disp(rho_i,"Resistivity in ohm-m : ");
```

Scilab code Exa 1.11.2 Intrinsic Carrier Concentration

```
//Ex 1.11.2
clc;clear;close;
format('v',9);

//Given :
T=300;//K
Ao=2.735*10^31;//constant for Si
k=86*10^-6;//boltzman constant
EGO=1.1;//volt(Bandgap energy)
ni=sqrt(Ao*T^3*exp(-EGO/k/T));//per cm^3
disp(ni,"Intrinsic carrier concentration per cm^3 : ");
```

Scilab code Exa 1.11.3 Current Mobility Velocity Conductivity

```
//Ex 1.11.3
clc;clear;close;
format('v',9);

//Given :
A=1*10^-6;//m^2
R=3.6*10^-4/10^-2;//ohm/m
n=9*10^26;//electrons/m^3
J=3*10^6;//A/m^2
q=1.6*10^-19;//Coulomb
```

```
I=J*A;//A
disp(I,"(i) Current in A : ");
rho=R*A;//ohm-m
sigma=1/rho;//(ohm-m)^-1
disp(sigma,"(ii) Conductivity in (ohm-m)^-1");
v=J/n/q;//m/s
disp(v,"(iii) velocity of free electrons in m/s : ")
    ;
mu=sigma/n/q;//m^2/V-s
disp(mu,"(iv) Mobility in m^2/V-s ; ");
```

Scilab code Exa 1.11.4 Intrinsic Concentration

```
//Ex 1.11.4
clc;clear;close;
format('v',9);

//Given :
rho=3*10^5*10^-2;//ohm-m
T1=30+273;//K
mu_n=0.13;//m^2/V-s
mu_p=0.05;//m^2/V-s
q=1.6*10^-19;//Coulomb
T2=100+273;//K
sigma_i=1/rho;//(ohm-m)^-1
ni1=sigma_i/q/(mu_n+mu_p);//electrons/m^3
disp(ni1,"Intrinsic concentration at 30 degree C(per
     m^3) : ");
k=8.62*10^-5;//eV/K(Boltzman constant)
EG0=1.21;//V(Energy band gap)
Ao=ni1^2/(T1^3*exp(-EG0/k/T1));//constant
ni2=sqrt(Ao*T2^3*exp(-EG0/k/T2));//per cm^3
disp(ni2,"Intrinsic concentration at 100 degree C(
    per m^3) : ");
```

Scilab code Exa 1.11.5 Majority Carrier density

```
//Ex 1.11.5
clc;clear;close;
format('v',9);

//Given :
l=0.1*10^-2;//m
R=1.5*10^3;//ohm
mu_n=0.14;//m^2/V-s
mu_p=0.05;//m^2/V-s
A=8*10^-8;//m^2
ni=1.5*10^10*10^6;// per m^3
q=1.6*10^-19;//Coulomb
rho_n=R*A/l;//ohm-m
sigma_n=1/rho_n;//(ohm-m)^-1
ND=sigma_n/mu_n/q;//
disp(ND,"Majority Carrier density(per m^3) : ");
```

Scilab code Exa 1.11.6 Length of the bar

```
//Ex 1.11.6
clc;clear;close;
format('v',9);

//Given :
A=2.5*10^-4;//m^2
n=1.5*10^16;//per m^3
q=1.6*10^-19;//Coulomb
mu_n=0.14;//m^2/V-s
mu_p=0.05;//m^2/V-s
I=1.2*10^-3;//A
```

```
V=9;//Volts
ni=n;// per m^3
sigma_i=ni*q*(mu_n+mu_p);//(ohm-m)^-1
rho_i=1/sigma_i;//ohm-m
R=V/I;//ohm
l=R*A/rho_i;//m
disp(l*1000,"Length of the bar(mm) : ");
```

Scilab code Exa 1.11.7 Resistivity of intrinsic Si

```
//Ex 1.11.7
clc;clear;close;
format('v',8);

//Given :
n=5*10^22;//per cm^3
mu_n=1300;//cm^2/V-s
mu_p=500;//cm^2/V-s
ni=1.5*10^10;//per cm^3
T=300;//K
rho_n=9.5;//ohm-cm
q=1.6*10^-19;//Coulomb
sigma_i=ni*q*(mu_n+mu_p);//(ohm-cm)^-1
rho_i=1/sigma_i;//ohm-cm
disp(rho_i,"Resistivity in ohm-cm : ");
sigma_n=1/rho_n;//(ohm-cm)^-1
ND=sigma_n/mu_n/q;//per m^3
Ratio=ND/n;
disp(Ratio,"Ratio of donor impurity atom to Si atom
    : ");
```

Scilab code Exa 1.11.8 Resistivity of intrinsic Si

```
//Ex 1.11.8
clc;clear;close;
format('v',9);

//Given :
n=5*10^22;//per cm^3
ni=1.52*10^10*10^6;//per m^3
q=1.6*10^-19;//Coulomb
mu_n=0.135;//m^2/V-s
mu_p=0.048;//m^2/V-s
impurity=1/10^8;//atoms
sigma_i=ni*q*(mu_n+mu_p);//(ohm-cm)^-1
rho_i=1/sigma_i;//ohm-cm
disp(rho_i,"Resistivity of intrinsic Si in ohm-m : "
   );
ND=n*impurity*10^6;//per m^3
sigma_n=ND*mu_n*q;//(ohm-m)^-1
rho_n=1/sigma_n;//ohm-m
disp(rho_n,"Resistivity of doped Si in ohm-m : ");
//Answer in the book is not accurate.
```

Scilab code Exa 1.11.9 Ratio of donor atom to Si atom

```
//Ex 1.11.9
clc;clear;close;
format('v',7);

//Given :
rho=9.6*10^-2;//ohm-m
mu_n=1300*10^-4;//m^2/V-s
sigma_n=1/rho;//(ohm-cm)^-1
TotalAtoms=5*10^28;//per m^3
q=1.6*10^-19;//Coulomb
ND=sigma_n/mu_n/q;//per m^3
ratio=ND/TotalAtoms;
```

```
disp(ratio,"Ratio of doner atom to Si atom per unit volume : ");
```

Scilab code Exa 1.11.10 Resistivity of Ge

```
//Ex 1.11.10
clc;clear;close;
format('v',9);

//Given :
ni=2.5*10^13;//per cm^3
mu_p=1800;//cm^2/V-s
mu_n=3800;//cm^2/V-s
q=1.6*10^-19;//Coulomb
sigma_i=ni*q*(mu_n+mu_p);//(ohm-cm)^-1
rho_i=1/sigma_i;//ohm-cm
disp(round(rho_i),"Resistivity of Ge(ohm-cm) : ");
```

Scilab code Exa 1.11.11 Concentration and Cnductivity

```
//Ex 1.11.11
clc;clear;close;
format('v',9);

//Given :
ni=1.2*10^16;//per m^3
p=10^22;//per m^3
mu_p=500*10^-4;//cm^2/V-s
mu_n=1350*10^-4;//cm^2/V-s
q=1.6*10^-19;//Coulomb
n=ni^2/p;//per m^3
disp(n,"Electron concentration per m^3 : ");
sigma=q*(n*mu_n+p*mu_p);//(ohm-m)^-1
```

```
disp(sigma,"Conductivity of Si(ohm-m)^-1 : ");
```

Scilab code Exa 1.12.1 Thermal equillibrium concentrations

```
//Ex 1.12.1
clc;clear;close;
format('v',9);

//Given :
T=27+273;//K
ND=10^17;//per cm^3
ni=1.5*10^10;//per cm^3
n=ND;//per m^3//ND>>n
disp(n,"Electron concentration per cm^3 : ");
p=ni^2/n;//per m^3
disp(p,"Holes per cm^3 : ");
```

Scilab code Exa 1.12.2 Free electrons

```
//Ex 1.12.2
clc;clear;close;
format('v',9);

//Given :
Vol=4*50*1.5;//mm^3
ni=2.4*10^19;//per m^3
p=7.85*10^14;//per m^3
n=ni^2/p;//per m^3
Vol=Vol*10^-9;//m^3
TotalElectron=n*Vol;//no. of electrons
disp(TotalElectron,"Total free electrons per m^3 : "
  );
```

Scilab code Exa 1.13.1 Total Current Density

```
//Ex 1.13.1
clc;clear;close;
format('v',9);

//Given :
ND=10^14;//per cm^3
NA=7*10^13;//per cm^3
rho_i=60;//ohm-cm
E=2;//V/cm
q=1.6*10^-19;//Coulomb
mu_p=1800;//cm^2/V-s
mu_n=3800;//cm^2/V-s
sigma_i=1/rho_i;//(ohm-cm)^-1
ni=sigma_i/q/(mu_n+mu_p);//per cm^3
//n=p+(ND-NA);//per cm^3
//n*p=ni^2 implies (p+(ND-NA))*p=ni^2
//p^2+(ND-NA)*p-ni^2=0
m=[1 (ND-NA) -ni^2];//polynomial
p=roots(m);//per m^3
p=p(2);//taking only +ve value
n=ni^2/p;//per m^3
J=(n*mu_n+p*mu_p)*q*E/10^-4;//A/m^2
disp(J,"Total current density(A/m^2) : ");
//Answer in the textbook is not accurate.
```

Scilab code Exa 1.13.2 Applied electric field

```
//Ex 1.13.2
clc;clear;close;
format('v',9);
```

```

//Given :
ND=10^14;//per cm^3
NA=7*10^3;//per cm^3
rho_i=60;//ohm-cm
J=52;//mA/cm^2
q=1.6*10^-19;//Coulomb
mu_p=1800;//cm^2/V-s
mu_n=3800;//cm^2/V-s
sigma_i=1/rho_i;//(ohm-cm)^-1
ni=sigma_i/q/(mu_n+mu_p);//per cm^3
//n=p+(ND-NA);//per cm^3
//n*p=ni^2 implies (p+(ND-NA))*p=ni^2
//p^2+(ND-NA)*p-ni^2=0
m=[1 (ND-NA) -ni^2];//polynomial
p=roots(m);//per m^3
p=p(2);//taking only +ve value
n=ni^2/p;//per m^3
E=J*10^-3/q/(n*mu_n+p*mu_p);//V/m
disp(E,"Value of electrical field,E(V/cm) : ");
```

Scilab code Exa 1.13.3 Total Current density

```
//Ex 1.13.3
clc;clear;close;
format('v',9);

//Given :
ND=10^14;//per cm^3
NA=7*10^13;//per cm^3
rho_i=60;//ohm-cm
E=2;//V/cm
q=1.6*10^-19;//Coulomb
mu_p=500;//cm^2/V-s
mu_n=1300;//cm^2/V-s
```

```
sigma_i=1/rho_i;//(ohm-cm)^-1
ni=sigma_i/q/(mu_n+mu_p);//per cm^3
//n=p+(ND-NA);//per cm^3
//n*p=ni^2 implies (p+(ND-NA))*p=ni^2
//p^2+(ND-NA)*p-ni^2=0
m=[1 (ND-NA) -ni^2];//polynomial
p=roots(m);//per m^3
p=p(2);//taking only +ve value
n=ni^2/p;//per m^3
J=(n*mu_n+p*mu_p)*q*E/10^-4;//A/m^2
disp(J,"Total current density(A/m^2) : ");
```

Scilab code Exa 1.13.4 Electron Mobility

```
//Ex 1.13.4
clc;clear;close;
format('v',9);

//Given :
l=6*10^-2;//m
V=12;//volts
v=73;//m/s
E=V/l;//V/m
mu=v/E;//m^2/V-s
disp(mu,"Electron mobilitym^2/V-s) : ");
```

Scilab code Exa 1.15.1 Hall Voltage

```
//Ex 1.15.1
clc;clear;close;
format('v',9);

//Given :
```

```
ND=10^13;//per cm^3
Bz=0.2;//Wb/m^2
d=5;//mm
E=5;//V/cm
q=1.6*10^-19;//Coulomb
mu_n=1300;//cm^2/V-s
rho=ND*q;//Coulomb/cm^3
J=rho*mu_n*E;//A/cm^2
VH=Bz*10^-4*J*d*10^-1/rho;//V
disp(VH*10^3,"Magnitude of hall voltage(mV) : ");
```

Scilab code Exa 1.15.2 Mobility of holes

```
//Ex 1.15.2
clc;clear;close;
format('v',9);

//Given :
rho=220*10^3*10^-2;//ohm/m
d=2.2*10^-3;//m
w=2*10^-3;//m
B=0.1;//Wb/m^2
I=5*10^-6;//A
VH=28*10^-3;//V
sigma=1/rho;//(ohm-m)^-1
RH=VH*w/(B*I);//ohm
mu=sigma*RH;//m^2/V-s
disp(mu,"Mobility(m^2/V-s) : ");
```

Scilab code Exa 1.16.1 Concentration and drift velocity

```
//Ex 1.16.1
clc;clear;close;
```

```
format('v',9);

//Given :
l=4*10^-2;//m
A=10*10^-6;//m^2
V=1;//Volt
I=5*10^-3;//A
q=1.6*10^-19;//Coulomb
mu=1300;//cm^2/V-s
J=I/A;//A/m^2
E=V/l;//V/m
n=J/(q*mu*10^-4*E)
v=mu*10^-4*E;//m/s
disp(n,"Concentration of electron(per m^3) : ");
disp(v,"Electron velocity(m/s) : ");
```

Scilab code Exa 1.16.2 Resistivity of intrinsic Ge

```
//Ex 1.16.2
clc;clear;close;
format('v',9);

//Given :
mu_n=3800;//cm^2/V-s
mu_p=1300;//cm^2/V-s
ni=2.5*10^13;//per cm^3
q=1.6*10^-19;//Coulomb
ND=4.4*10^22/10^8;//per cm^3
sigma_n=ND*q*mu_n;//(ohm-m)^-1
rho_n=1/sigma_n;//ohm-cm
disp(rho_n,"Resistivity of doped Ge(ohm-cm) : ");
```

Scilab code Exa 1.16.3 Minority Carrier Density

```
//Ex 1.16.3
clc;clear;close;
format('v',9);

//Given :
ni=1.5*10^16;//per m^3
n=5*10^20;//per m^3
p=ni^2/n;//per m^3
disp(p,"Minor carrier density(per m^3) : ");
```

Scilab code Exa 1.16.4 Concentration and current

```
//Ex 1.16.4
clc;clear;close;
format('v',9);

//Given :
ni=1.5*10^10;//per cm^3
mu_n=1400;//cm^2/V-s
mu_p=500;//cm^2/V-s
l=1;//cm
a=1;//mm^2
q=1.6*10^-19;//Coulomb
del_n=10^14;//per cm^3
del_p=10^14;//per cm^3
Nd=8*10^15;//per cm^3
n=Nd;//per cm^3(Nd>>ni)
disp(n,"Electron concentration, n(per cm^3) : ");
p=ni^2/n;//per m^3
disp(p,"Hole concentration, p(per cm^3) : ");
nT=Nd+del_n;//per cm^3
disp(nT,"Total electron concentration, nT(per cm^3)
    : ");
pT=p+del_p;//per cm^3
disp(pT,"Total hole concentration, pT(per cm^3) : ")
```

```
    ;
sigma=(nT*mu_n+pT*mu_p)*q;//(ohm−cm)^−1
rho=1/sigma;//ohm−cm
R=rho*l/(a*10^-2);//ohm
V=2;//volt
I=V/R;//A
disp(I*1000,"Current, I(mA) : ");
```

Scilab code Exa 1.16.5 Find out current

```
//Ex 1.16.5
clc;clear;close;
format('v',9);

//Given :
A=2.3*10^-4;//m^2
n=1.5*10^16;//per m^3
l=1;//mm
mu_n=1400;//cm^2/V−s
mu_p=500;//cm^2/V−s
p=n;//per m^3
ni=n;//per m^3
q=1.6*10^-19;//Coulomb
sigma_i=ni*(mu_n*10^-4+mu_p*10^-4)*q;//(ohm−m)^−1
rho_i=1/sigma_i;//ohm−m
R=rho_i*l*10^-3/A;//ohm
V=9;//volt
I=V/R;//A
disp(I*1000,"Current, I(mA) : ");
```

Scilab code Exa 1.16.6 Find Concentration gradient

```
//Ex 1.16.6
```

```
clc;clear;close;
format('v',9);

//Given :
ND=10^14;//per m^3
Jn=10;//mA/cm^2
E=3;//V/cm
T=27+273;//K
q=1.6*10^-19;//Coulomb
mu_n=1500;//cm^2/V-s
Dn=mu_n/39;//Diffusion constant
n=ND;//per m^3
dnBYdx=((Jn*10^-3/10^-4)-n*q*mu_n*E)/q/Dn;//
   concentration gradient
disp(dnBYdx,"Concentration gradient, dn/dx : ");
```

Scilab code Exa 1.16.7 Total Current Density

```
//Ex 1.16.7
clc;clear;close;
format('v',9);

//Given :
ND=10^13;//per m^3
NA=10^14;//per m^3
rho_i=44;//ohm-cm
E=3;//V/cm
q=1.6*10^-19;//Coulomb
mu_n=0.38;//m^2/V-s
mu_p=0.18;//m^2/V-s
ni=2.5*10^19;//per m^3
//n=p+(ND-NA);//per cm^3
//n*p=ni^2 implies (p+(ND-NA))*p=ni^2
//p^2+(ND-NA)*p-ni^2=0
m=[1 (ND-NA) -ni^2];//polynomial
```

```
p=roots(m);//per m^3
p=p(1);//taking only +ve value
n=ni^2/p;//per m^3
J=(n*mu_n+p*mu_p)*q*(E/10^-2);//A/m^2
disp(J,"Total current density(A/m^2) : ");
//Ans in the textbook is not accurate.
```

Scilab code Exa 1.16.8 Find conductivity of Ge

```
//Ex 1.16.8
clc;clear;close;
format('v',9);

//Given :
T=300;//K
ni=2.5*10^13;//per cm^3
mu_n=3800;//cm^2/V-s
mu_p=1800;//cm^2/V-s
q=1.6*10^-19;//Coulomb
sigma_i=ni*(mu_n+mu_p)*q/10^-2;//(ohm-m)^-1
disp(sigma_i,"Conductivity of intrinsic Ge in (ohm-m
   )^-1 : ");
ND=4.4*10^22/10^7;//per cm^3
n=ND;//per cm^3
sigma_n=n*mu_n*q/10^-2;//(ohm-m)^-1
disp(sigma_n,"Conductivity after adding donor
   impurity in (ohm-m)^-1 : ");
NA=4.4*10^22/10^7;//per cm^3
p=NA;//per cm^3
sigma_p=p*mu_p*q/10^-2;//(ohm-m)^-1
disp(sigma_p,"Conductivity after adding acceptor
   impurity in (ohm-m)^-1 : ");
```

Scilab code Exa 1.40.1 Hole concentration at equillibrium

```
//Ex 1.40.1
clc;clear;close;
format('v',9);

//Given :
ND=10^17;//per cm^3
ni=1.5*10^10;//per cm^3
no=ND;//per cm^3///Nd>>ni
po=ni^2/no;//per cm^3
disp(po,"Equilibrium hole concentration (per cm^3) :
    ");
```

Scilab code Exa 1.40.3 Fermi level Ef

```
//Ex 1.40.3
clc;clear;close;
format('v',9);

//Given :
ni=1.5*10^10;//per cm^3
ND=10^17;//per cm^3
no=ND;//per cm^3///Nd>>ni
po=ni^2/no;//per cm^3
KT=0.0259;//constant
delEf=KT*log(no/ni);//eV
disp("Fermi level , Ef = Ei+"+string(delEf)+" eV");
```

Scilab code Exa 1.40.4 Find diffusion coefficients

```
//Ex 1.40.4
clc;clear;close;
```

```
format('v',9);

//Given :
K=1.38*10^-23; //J/K
T=27+273; //K
e=1.6*10^-19; //constant
mu_n=0.17; //m^2/V-s
mu_p=0.025; //m^2/V-s
Dn=K*T/e*mu_n; //m^2/s
disp(Dn,"Diffusion coffiecients of electron(m^2/s) :
    ");
Dp=K*T/e*mu_p; //m^2/s
disp(Dp,"Diffusion coffiecients of holes(m^2/s) : ")
    ;
```

Scilab code Exa 1.40.5 Diffusion length and diffusion current density

```
//Ex 1.40.5
clc;clear;close;
format('v',9);

//Given :
K=1.38*10^-23; //J/K
T=27+273; //K
e=1.6*10^-19; //constant
del_no=10^20; //per.m^3
tau_n=10^-7; //s
mu_n=0.15; //m^2/V-s
Dn=K*T/e*mu_n; //m^2/s
Ln=sqrt(Dn*tau_n); //m
Jn=e*Dn*del_no/Ln; //A/m^2
disp(Jn,"Diffusion current density(A/m^2) : ");
```

Scilab code Exa 1.40.6 Concentration of holes and electrons

```
//Ex 1.40.6
clc;clear;close;
format('v',9);

//Given :
sigma_n=0.1;//(ohm-cm)^-1
mu_n=1300;//m^2/V-s
ni=1.5*10^10;//per cm^3
q=1.6*10^-19;//Coulomb
n_n=sigma_n/q/mu_n;//per cm^3
p_n=ni^2/n_n;//per cm^3
p_n=p_n*10^6;//per m^3
disp(p_n,"Concentration of holes(per m^3) : ");
```

Scilab code Exa 1.40.7 Electron transit time and photo conductor gain

```
//Ex 1.40.7
clc;clear;close;
format('v',9);

//Given :
L=100*10^-6;//m
A=10^-7*10^-6;//m^2
mu_e=0.13;//m^2/V-s
mu_h=0.05;//m^2/V-s
tau_h=10^-6;//sec
V=12;//volt
E=V/L;//v/m
tn=L^2/(mu_e*V);//sec
Gain=tau_h/tn*(1+mu_h/mu_e);//
disp(Gain,"Photoconductor gain : ");
```

Scilab code Exa 1.40.8 Resistivity of intrinsic Ge

```
//Ex 1.40.8
clc;clear;close;
format('v',7);

//Given :
T=300;//K
rho_i=45;//ohm-cm
//part (i)
mu_n=3800;//cm^2/V-s
mu_p=1800;//cm^2/V-s
ni=2.5*10^13;//per cm^3
q=1.6*10^-19;//Coulomb
sigma=ni*q*(mu_n+mu_p);//(ohm-cm)^-1
rho=1/sigma;//ohm-cm
disp(round(rho),"Resistivity of intrinsic Ge at 300K
    (ohm-cm) : ");
//part (ii)
ND=4.4*10^22/10^8;//per cm^3
sigma=ND*q*mu_n;//(ohm-cm)^-1
rho=1/sigma;//ohm-cm
disp(rho,"Resistivity of doped Ge(ohm-cm) : ");
```

Scilab code Exa 1.40.9 Electron and hole concentration

```
//Ex 1.40.9
clc;clear;close;
format('v',9);

//Given :
ni=10^16;//per m^3
```

```
ND=10^22;//per m^3
n=ND;//per m^3//ND>>ni
disp(n,"Electron concentration(per m^3) : ");
p=ni^2/n;//per m^3
disp(p,"Electron concentration(per m^3) : ");
```

Scilab code Exa 1.40.10 Ratio of donor atom to Si atom

```
//Ex 1.40.10
clc;clear;close;
format('v',9);

//Given :
rho=9.6*10^-2;//ohm-m
mu_n=1300;//cm^2/V-s
q=1.6*10^-19;//Coulomb
sigma_n=1/rho;//(ohm-m)^-1
ND=sigma_n/q/(mu_n*10^-4);//per m^3
ni=5*10^22*10^6;//per m^3
disp(ND/ni,"Ratio of donor atom to Si atom : ");
```

Scilab code Exa 1.40.11 Equillibrium electron and hole density

```
//Ex 1.40.11
clc;clear;close;
format('v',9);

//Given :
ni=1.5*10^10;//per cm^3
n_n=2.25*10^15;//per cm^3
disp(n_n,"Equillibrium electron density(per cm^3) :
   ");
p_n=ni^2/n_n;//per cm^3
```

```
disp(p_n,"Equillibrium hole density(per cm^3) : ");
```

Scilab code Exa 1.40.12 Carrier Concentration

```
//Ex 1.40.12
clc;clear;close;
format('v',9);

//Given :
NA=2*10^16;//per cm^3
ND=10^16;//per cm^3
p=NA-ND;//per cm^3
disp(p,"Material is p-type & Carrier concentration(
    holes per cm^3) : ");
```

Scilab code Exa 1.40.13 Generation rate due to irradiation

```
//Ex 1.40.13
clc;clear;close;
format('v',9);

//Given :
del_n=10^15;//per cm^3
tau_p=10*10^-6;//sec
rate=del_n/tau_p;//rate of generation minority
    carrier
disp(rate,"Rate of generation of minority carrier(
    electron hole pair/sec/cm^3) : ");
```

Scilab code Exa 1.40.14 Mobility of minority charge carrier

```
//Ex 1.40.14
clc;clear;close;
format('v',9);

//Given :
E=10;//V/cm
v=1/(20*10^-6);//m/s
mu=v/E;//cm^2/V-s
disp(mu,"Mobility(cm^2/V-s) : ");
```

Scilab code Exa 1.40.15 Hole and electron diffusion current

```
//Ex 1.40.15
clc;clear;close;
format('v',9);

//Given :
ND=4.5*10^15;//per cm^3
A=1*10^-2;//cm^2
l=10;//cm
tau_p=1*10^-6;//sec
tau_n=1*10^-6;//sec
Dp=12;//cm^2/sec
Dn=30;//cm^2/sec
q=1.6*10^-19;//Coulomb
del_p=10^21;//electron hole pair/cm^3/sec
x=34.6*10^-4;//cm
Kdash=26;//mV(Kdash is taken as K*T/q)
ni=1.5*10^10;//per cm^3
no=ND;//per cm^3//ND<<ni
po=ni^2/no;//per cm^3
ln=sqrt(Dn*tau_n);//cm
lp=sqrt(Dp*tau_p);//cm
dpBYdx=del_p*exp(-x/lp);//per cm^4
dnBYdx=del_p*exp(-x/ln);//per cm^4
```

```
Jp=-q*Dp*dpBYdx;//A/cm^2
Ip=Jp*A;//A
disp(Ip,"Hole diffusion current (A) : ");
Jn=q*Dn*dnBYdx;//A/cm^2
In=Jn*A;//A
disp(In,"Electron diffusion current (A) : ");
//Solution is not complete in the book and value of
    Jp & Jn is due to wrong calculation for dpBYdx
    and dnBYdx.
```

Scilab code Exa 1.40.16 Energy Band gap

```
//Ex 1.40.16
clc;clear;close;
format('v',9);

//Given :
h=6.626*10^-34;//J-s
lambda=5490;//Angstrum
c=3*10^8;//m/s(speed of light)
f=c/(lambda*10^-10);//Hz
E=(h/1.6/10^-19)*f;//eV
disp(E,"Energy band gap(eV) : ");
```

Scilab code Exa 1.40.17 Current density in the Si

```
//Ex 1.40.17
clc;clear;close;
format('v',9);

//Given :
q=1.6*10^-19;//Coulomb
Dn=35;//cm^2/s
```

```
x=[0 2];//micro meter
n=[10^17 6*10^16];//per cm^3
plot(x,n);
title('n Vs x');
xlabel('x(micro meter)');
ylabel('n(electrons per cm^3)');
dnBYdx=(n(2)-n(1))/(x(2)-x(1))/10^-4;//gradient
Jn=q*Dn*dnBYdx;//A/cm^2
disp(Jn,"Current density(A/cm^2) : ");
```

Scilab code Exa 1.40.18 Resistance of the bar

```
//Ex 1.40.18
clc;clear;close;
format('v',9);

//Given :
q=1.6*10^-19;//Coulomb
l=0.1;//cm
A=100*10^-8;//cm^2
n_n=5*10^20*10^-6;//per cm^3
mu_n=0.13*10^4;//cm^2/V-s
sigma_n=q*n_n*mu_n;//(ohm-cm)^-1
rho=1/sigma_n;//ohm-cm
R=rho*l/A;//ohm
disp(round(R/10^6),"Resistance of the bar(Mohm) : ")
    ;
```

Scilab code Exa 1.40.19 Depletion width on p side

```
//Ex 1.40.19
clc;clear;close;
format('v',9);
```

```

//Given :
NA=9*10^16;//per cm^3
ND=1*10^16;//per cm^3
w_total=3;//micro meter
w_p=w_total*ND/NA;//micro meter
disp(w_p,"Answer is (B). Depletion width on p−side(
    micro meter) : ");
```

Scilab code Exa 1.40.20 Majority Carrier Density

```
//Ex 1.40.20
clc;clear;close;
format('v',9);

//Given :
ni=1.5*10^16;//per m^3
n_n=5*10^20;//per m^3
p_n=ni^2/n_n;//per m^3
disp(p_n,"Majority carrier density(per m^3) : ");
```

Scilab code Exa 1.40.21 Collector current density

```
//Ex 1.40.21
clc;clear;close;
format('v',9);

//Given :
q=1.6*10^-19;//Coulomb
Dn=25;//cm^2/s
x=[0 0.5];//micro meter(base width)
n=[10^14 0];//per cm^3
plot(x,n);
```

```
title('n Vs x');
xlabel('x(micro meter)');
ylabel('n(electrons per cm^3)');
dnBYdx=(n(2)-n(1))/(x(1)-x(2))/10^-4;//gradient
Jn=q*Dn*dnBYdx;//A/cm^2
disp(Jn,"Current density(A/cm^2) : ");
```

Scilab code Exa 1.40.22 Band gap of the material

```
//Ex 1.40.22
clc;clear;close;
format('v',9);

//Given :
h=6.64*10^-34;//planks constant
c=3*10^8;//m/s(speed of light)
lambda=0.87*10^-6;//m
Eg=h*c/lambda/(1.6*10^-19);//eV
disp(Eg,"Band gap(eV)  : ");
```

Scilab code Exa 1.40.23 Rate of thermal energy and photons

```
//Ex 1.40.23
clc;clear;close;
format('v',9);

//Given :
t=0.46*10^-4;//cm
E=2;//eV
alfa=5*10^4;//cm^-1
Io=10;//mW
q=1.6*10^-19;//Coulomb
It=Io*exp(-alfa*t);//mW
```

```
Pabs=Io-It;//mW
disp(round(Pabs),"(a) Absorbed power(mW) : ");
Eg=1.43;//eV(Band gap)
heat_fraction=(E-Eg)/E;
E_heat=heat_fraction*Pabs*10^-3;//J/s(energy
    converted to heat)
disp(E_heat,"(b) Rate of excess thermal energy(J/s)
    : ");
photons=Pabs*10^-3/q/E;//no. of photons per sec
disp(photons,"(c) No. of photons per sec : ");
```

Scilab code Exa 1.40.24 Hole current and charge stored

```
//Ex 1.40.24
clc;clear;close;
format('v',9);

//Given :
Kdash=0.0259;//constant(taken as K*T/q)
A=0.5;//cm^2
Na=10^17;//per cm^3
ni=1.5*10^10;//per cm^3
delta_p=5*10^16;//per cm^3
x=1000;//Angstrum
mu_p=500;//cm^2/V-s
tau_p=10^-10;//sec
q=1.6*10^-19;//Coulomb

Dp=Kdash*mu_p;//cm/s
Lp=sqrt(Dp*tau_p);//cm
p0=Na;//per cm^3
p=p0+delta_p*exp(x*10^-8/Lp);//per cm^3
delE1=log(p/ni)*Kdash;//eV(taken as Ei-Fp)
Eg=1.12;//eV(Band gap)
delE2=Eg-delE1;//eV(taken as Ec-Fp)
```

```
disp(delE2,"Steady state separation between Fp & Ec
    in eV : ");
Ip=q*A*Dp/Lp*delta_p*exp(x*10^-8/Lp);//A
disp(Ip,"Hole current in A : ");
Qp=q*A*delta_p*Lp;//C
disp(Qp,"Excess stored hole charge(Coulomb)");
//Answer in the book is wrong beacause of
    calculation mistake in the value of p & Ip.
```

Scilab code Exa 1.40.25 Hole Current

```
//Ex 1.40.25
clc;clear;close;
format('v',9);

//Given :
Kdash=0.0259;//constant(taken as K*T/q)
A=0.5;//cm^2
Na=10^17;//per cm^3
ni=1.5*10^10;//per cm^3
delta_p=5*10^16;//per cm^3
x=1000;//Angstrum
mu_p=500;//cm^2/V-s
tau_p=10^-10;//sec
q=1.6*10^-19;//Coulomb

Dp=Kdash*mu_p;//cm/s
Lp=sqrt(Dp*tau_p);//cm
p0=Na;//per cm^3
p=p0+delta_p*exp(x*10^-8/Lp);//per cm^3
delE1=log(p/ni)*Kdash;//eV(taken as Ei-Fp)
Eg=1.12;//eV(Band gap)
delE2=Eg-delE1;//eV(taken as Ec-Fp)
disp(delE2,"Steady state separation between Fp & Ec
    in eV : ");
```

```
Ip=q*A*Dp/Lp*delta_p*exp(x*10^-8/Lp);//A
disp(Ip,"Hole current in A : ");
Qp=q*A*delta_p*Lp;//C
disp(Qp,"Excess stored hole charge(Coulomb)");
//Answer in the book is wrong beacause of
    calculation mistake in the value of p & Ip.
```

Chapter 2

Junctions and Interfaces

Scilab code Exa 2.6.1 Junction Potential

```
//Ex 2.6.1
clc;clear;close;
format('v',6);

//Given :
Ge=4.4*10^22;//atoms/cm^3
NA=Ge/10^8;//per cm^3
NA=NA*10^6;//per m^3
ND=NA*10^3;//per m^3
ni=2.5*10^13;//per cm^3
ni=ni*10^6;//per m^3
VT=26;//mV
Vj=VT*log(NA*ND/ni^2);//mV
disp(Vj,"Junction potential in mV : ");
```

Scilab code Exa 2.6.2 Contact Potential

```
//Ex 2.6.2
```

```
clc;clear;close;
format('v',6);

//Given :
ni=2.5*10^15;//per cm^3
Ge=4.4*10^22;//atoms/cm^3
NA=Ge/10^8;//per cm^3
NA=NA*10^6;//per m^3
ND=NA*10^3;//per m^3
ni=ni*10^6;//per m^3
T=27+273;//K
VT=T/11600;//V
Vo=VT*log(NA*ND/ni^2);//V
disp(Vo,"Contact potential in V : ");
```

Scilab code Exa 2.6.3 Height of Potential Barrier

```
//Ex 2.6.3
clc;clear;close;
format('v',6);

//Given :
mu_n=1500*10^-4;//m^2/V-s
mu_p=475*10^-4;//m^2/V-s
ni=1.45*10^10*10^6;//per m^3
q=1.6*10^-19;//Coulomb
rho_p=10;//ohm-cm
rho_p=rho_p*10^-2;//ohm-m
rho_n=3.5;//ohm-cm
rho_n=rho_n*10^-2;//ohm-m
sigma_p=1/rho_p;//(ohm-m)^-1
NA=sigma_p/q/mu_p;//m^3
sigma_n=1/rho_n;//(ohm-m)^-1
ND=sigma_p/q/mu_n;//m^3
VT=26*10^-3;//V
```

```
Vj=VT*log(NA*ND/ni^2);//V
disp(Vj,"Height of potential barrier in V : ");
//Anser in the book is wrong.
```

Scilab code Exa 2.6.4 Height of Potential barrier

```
//Ex 2.6.4
clc;clear;close;
format('v',6);

//Given :
rho_p=2;//ohm-cm
rho_p=rho_p*10^-2;//ohm-m
rho_n=1;//ohm-cm
rho_n=rho_n*10^-2;//ohm-m
mu_n=1500*10^-4;//m^2/V-s
mu_p=2100*10^-4;//m^2/V-s
ni=2.5*10^13;//per m^3
q=1.6*10^-19;//Coulomb
sigma_p=1/rho_p;//(ohm-m)^-1
NA=sigma_p/q/mu_p;//m^3
sigma_n=1/rho_n;//(ohm-m)^-1
ND=sigma_p/q/mu_n;//m^3
T=27+273;//K
VT=T/11600;//V
Vj=VT*log(NA*ND/ni^2);//V
disp(Vj,"Height of potential barrier in V : ");
//Anser in the book is wrong.
```

Scilab code Exa 2.7.1 Diode voltage and current

```
//Ex 2.7.1
clc;clear;close;
```

```
format('v',6);

//Given :
Vgamma=0.6;//volt
rf=12;//ohm
V=5;//volts
R=1;//kohm
IF=(V-Vgamma)/(R*1000+rf);//A
disp(IF*1000,"Diode current in mA :");
VF=Vgamma+IF*rf;//volts
disp(VF,"Diode voltage in volts :");
```

Scilab code Exa 2.7.2 Alternating and total voltage

```
//Ex 2.7.2
clc;clear;close;
format('v',7);

//Given :
Vgamma=0.6;//volt
Rf=10;//ohm
Eta=2;
Vm=0.2;//volts
Vdc=10;//volts
RL=1;//kohm
IDQ=(Vdc-Vgamma)/(RL*1000+Rf);//A
VT=25*10^-3;//volts
rd=Eta*VT/IDQ;//ohm
disp("Alternating component of voltage across RL, Vo
    (ac) = "+string(RL*1000/(RL*1000+rd)*Vm)+"*sin(
    omega*t)");
Vo_DC=IDQ*RL*1000;//volts
disp("Total load voltage = "+string(Vo_DC)+"+"+
    string(RL*1000/(RL*1000+rd)*Vm)+"*sin(omega*t)");
```

Scilab code Exa 2.7.3 Ratioo of Current

```
//Ex 2.7.3
clc;clear;close;
format('v',8);

//Given :
Eta=2;//for Si diode
T=300;//K
VT=T/11600;//V
IbyIo=90/100;
//I=Io*(exp(V/Eta/VT)-1)
V=log(IbyIo+1)*Eta*VT;//V
disp(V*1000,"Saturation value of voltage in mV : ");
VF=0.5;//volts
VR=-0.5;//volts
IFbyIR=(exp(VF/Eta/VT)-1)/(exp(VR/Eta/VT)-1);//ratio
disp(IFbyIR,"Ratio of forward to reverse current : "
    );
//Answer in the book is wrong.
```

Scilab code Exa 2.7.4 Ratio of Current

```
//Ex 2.7.4
clc;clear;close;
format('v',8);

//Given :
Eta=2;//for Si diode
T=300;//K
VT=T/11600;//V
IbyIo=90/100;
```

```
//I=Io*(exp(V/Eta/VT)-1)
V=log(IbyIo+1)*Eta*VT;//V
disp(V*1000,"Saturation value of voltage in mV : ");
VF=0.2;//volts
VR=-0.2;//volts
IFbyIR=(exp(VF/Eta/VT)-1)/(exp(VR/Eta/VT)-1);//ratio
disp(IFbyIR,"Ratio of forward to reverse current : "
  );
//Answer in the book is wrong.
```

Scilab code Exa 2.9.1 Reverse saturation current

```
//Ex 2.9.1
clc;clear;close;
format('v',6);

//Given :
IF=10;//mA
VF=0.75;//volts
T=27+273;//K
Eta=2;//for Si diode
VT=T/11600;//V
Io=IF/(exp(VF/Eta/VT)-1);//mA
disp(Io*10^6,"Reverse saturation current in nA : ");
```

Scilab code Exa 2.9.2 Reverse saturation current

```
//Ex 2.9.2
clc;clear;close;
format('v',6);

//Given :
IF=10;//mA
```

```
VF=0.3;//volts
T=27+273;//K
Eta=1;//for Ge diode
VT=T/11600;//V
Io=IF/(exp(VF/Eta/VT)-1);//mA
disp(Io*10^6,"Reverse saturation current in nA : ");
```

Scilab code Exa 2.9.3 Determine forward current

```
//Ex 2.9.3
clc;clear;close;
format('v',6);

//Given :
Io=1*10^-9;//A
T=27+273;//K
VT=T/11600;//V
VF=0.3;//volts
Eta=1;//for Ge diode
IF=Io*(exp(VF/Eta/VT)-1);//mA
disp(IF*10^3,"Forwad current in mA : ");
```

Scilab code Exa 2.9.4 Value of Io and Eta

```
//Ex 2.9.4
clc;clear;close;
format('v',8);

//Given :
T=27+273;//K
V1=0.4;//V
V2=0.42;//V
I1=10;//mA
```

```
I2=20; //mA
VT=T/11600; //V
Eta=1/log(I1/I2)*(V1-V2)/VT
disp(Eta,"Value of Eta : ");
Io=I1/(exp(V1/Eta/VT)-1)*10^-3; //A
disp(Io*10^9,"Current, Io in nA : ");
//Ans in the book is not accurate.
```

Scilab code Exa 2.9.5 Voltage across the diode

```
//Ex 2.9.5
clc;clear;close;
format('v',8);

//Given :
Io1=10^-12; //A
Io2=10^-10; //A
I=2; //mA
Eta=1; //constant
T=27+273; //K
VT=26/1000; //V
//I=I1+I2
V=(log(I*10^-3/(Io1+Io2))+1)*Eta*VT; //V
disp(V,"Voltage across the diodes in V : ");
//Ans in the book is not accurate.
```

Scilab code Exa 2.9.6 Calculate the source current

```
//Ex 2.9.6
clc;clear;close;
format('v',8);

//Given :
```

```
Io1=10*10^-9;//A
Io2=10*10^-9;//A
Eta=1.1;//constant
T=25+273;//K
V=0.2;//V(assumed)
VT=T/11600;//V
I1=Io1*(exp(V/Eta/VT)-1);//A
I2=Io2*(exp(V/Eta/VT)-1);//A
I=I1+I2;//A
disp(I*10^6,"Source current in micro Ampere : ");
```

Scilab code Exa 2.9.7 Calculate Vin

```
//Ex 2.9.7
clc;clear;close;
format('v',8);

//Given :
Io=10^-13;//A
T=27+273;//K
Eta=1;//constant
V=0.6;//V
VT=26/1000;//V
I3=Io*(exp(V/Eta/VT)-1);//A
R=1*1000;//ohm
Ir=V/R;//A
Itotal=I3+Ir;//A
VD1=log(Itotal/Io)*Eta*VT;//V
VD2=VD1;//V
Vin=VD1+VD2+V;//V
disp(Vin,"Voltage Vin(V) : ");
```

Scilab code Exa 2.9.8 Voltage across diode

```
//Ex 2.9.8
clc;clear;close;
format('v',8);

//Given :
Vs=10; //V
disp("Case(i) : Vb=9.8V");
Vb=9.8; //V
//D1 forward & D2 reverse biased: Breakdown D2
VD2=Vb; //V
VD1=Vs-Vb; //V
disp(VD1,"VD1(V) : ");
disp(VD2,"VD2(V) : ");
disp("Case(ii) : Vb=10.2V");
Vb=10.2; //V
//D1 forward & D2 reverse biased: none will be
    breakdown
VD2=Vb; //V
//I=I0 so exp(V1/Eta/VT)-1=1
Eta=1; //constant
VT=26/1000; //V
VD1=log(1+1)*Eta*VT; //V
VD2=Vs-VD1; //V
disp(VD1,"VD1(V) : ");
disp(VD2,"VD2(V) : ");
```

Scilab code Exa 2.9.9 Voltage across diode

```
//Ex 2.9.9
clc;clear;close;
format('v',8);

//Given :
Vs=5; //Volt
Eta=1; //constant
```

```
VT=26/1000;//V
//I=I0 so exp(V1/Eta/VT)-1=1
V1=log(1+1)*Eta*VT;//Volt
V2=Vs-V1;//volt
disp(V1,"Voltage across diode D1 in V : ");
disp(V2,"Voltage across diode D2 in V : ");
```

Scilab code Exa 2.10.2 Temperature of junction

```
//Ex 2.10.2
clc;clear;close;
format('v',8);

//Given :
rho_n=10;//ohm-cm
rho_p=3.5;//ohm-cm
ni=1.5*10^10;//per cm^3
Vj=0.56;//volt
q=1.6*10^-19;//Coulomb
mu_n=1500;//cm^2/V-s
mu_p=500;//cm^2/V-s
sigma_p=1/rho_p;//(ohm-cm)^-1
NA=sigma_p/q/mu_p;//per cm^3
sigma_n=1/rho_n;//(ohm-cm)^-1
ND=sigma_n/q/mu_n;//per cm^3
VT=Vj/log(NA*ND/ni^2);//V
T=11600*VT;//K
disp(T,"Temperature of junction in degree K : ");
t=T-273;//degree C
disp(t,"Temperature of junction in degree C : ");
```

Scilab code Exa 2.11.1 Reverse saturation current

```
//Ex 2.11.1
clc;clear;close;
format('v',8);

//Given :
Io=10;//nA
T1=27+273;//K
T2=87+273;//K
VT=T1/11600;//V
Eta=2;//for Si
m=1.5;//for Si
VGO=-1.21;//volt
K=Io*10^-9/T1^m/exp(VGO/Eta/VT);//constant
VT=T2/11600;//V
Io2=K*T2^m*exp(VGO/Eta/VT);//A
disp(Io2*10^9,"Reverse saturation current at 87
    degree C in nA : ");
```

Scilab code Exa 2.11.2 Current multiplication factor

```
//Ex 2.11.2
clc;clear;close;
format('v',8);

//Given :
V=0.45;//volt
Eta=2;//for Si
T1=27+273;//K
T2=125+273;//K
VT1=T1/11600;//V
VT2=T2/11600;//V
I1BYIo1=exp(V/Eta/VT1);
I2BYIo2=exp(V/Eta/VT2);
m=1.5;//for Si
VGO=1.21;//volt
```

```
Io1BYIo2=(T1/T2)^m*exp(-VGO/Eta/VT1+VGO/Eta/VT2);//
    constant
I2BYI1=I2BYIo2/I1BYIo1/Io1BYIo2;
disp(I2BYI1,"Factor by which current increases : ");
//Answer is wrong in the textbook.
```

Scilab code Exa 2.11.3 Percent change in diode current

```
//Ex 2.11.3
clc;clear;close;
format('v',8);

//Given :
Io1=2;//nA
T1=10+273;//K
V=0.4;//volt
VT1=T1/11600;//V
m=1.5;//for Si
Eta=2;//for Si
VGO=-1.21;//volt
K=Io1*10^-9/T1^m/exp(VGO/Eta/VT1);//constant
I1=Io1*10^-9*[exp(V/Eta/VT1)-1];//nA
T2=70+273;//K
VT2=T2/11600;//V
Io2=K*T2^m*[exp(VGO/Eta/VT2)];//A
I2=Io2*[exp(V/Eta/VT2)-1];//nA
change=(I2-I1)/I1*100;//%
disp(change,"% change in diode current : ");
//Answer is wrong in the textbook.
```

Scilab code Exa 2.11.4 Parameters for diode

```
//Ex 2.11.4
```

```
clc;clear;close;
format('v',8);

//Given :
T=300;//K
m_Si=1.5;//for Si
m_Ge=1.5;//for Ge
EG0_Si=1.21;//volt
EG0_Ge=0.785;//volt
Eta_Si=2;
Eta_Ge=1;
VT=26/1000;//V
disp("Part(i) : ");
d_logIoBYdt_Ge=m_Ge/T+EG0_Ge/(Eta_Ge*T*VT);//per
    degree C
disp(d_logIoBYdt_Ge,"d(log(Io))/dt for Ge (per
    degree C) : ");
d_logIoBYdt_Si=m_Si/T+EG0_Si/(Eta_Si*T*VT);//per
    degree C
disp(d_logIoBYdt_Si,"d(log(Io))/dt for Si (per
    degree C) : ");
disp("Part(ii) : ");
V=0.2;//volt
dVBYdt_Ge=V/T-Eta_Ge*VT*d_logIoBYdt_Ge
disp(dVBYdt_Ge*1000,"dV/dt for Si (mV per degree C)
    : ");
V=0.6;//volt
dVBYdt_Si=V/T-Eta_Si*VT*d_logIoBYdt_Si
disp(dVBYdt_Si*1000,"dV/dt for Si (mV per degree C)
    : ");
```

Scilab code Exa 2.12.1 New value of depletion region width

```
//Ex 2.12.1
clc;clear;close;
```

```
format('v',8);

//Given :
NA=4*10^20;//per m^3
Vj=0.2;//volt
V1=-1;//volts
V2=-5;//volts
epsilon_r=16;//for Ge
epsilon_o=8.85*10^-12;//permitivity
q=1.6*10^-19;//Coulomb
W1=sqrt(2*epsilon_r*epsilon_o*(Vj-V1)/q/NA);//m
disp(W1*10^6,"Width of depletion region(micro meter)
    : ");
W2=sqrt(2*epsilon_r*epsilon_o*(Vj-V2)/q/NA);//m
disp(W2*10^6,"New value of Width of depletion region
    (micro meter) : ");
```

Scilab code Exa 2.12.2 Transition Capacitance

```
//Ex 2.12.2
clc;clear;close;
format('v',8);

//Given :
NA=4*10^20;//per m^3
Vj=0.2;//Volt
V1=-1;//Volts
V2=-5;//Volts
A=0.8*10^-6;//m^2
epsilon_r=16;//for Ge
epsilon_o=8.85*10^-12;//permitivity
q=1.6*10^-19;//Coulomb
W1=sqrt(2*epsilon_r*epsilon_o*(Vj-V1)/q/NA);//m
CT1=epsilon_r*epsilon_o*A/W1;//
disp(CT1*10^12,"Transition capacitance(pF) : ");
```

```
W2=sqrt(2*epsilon_r*epsilon_o*(Vj-V2)/q/NA);//m
CT2=epsilon_r*epsilon_o*A/W2;//
disp(CT2*10^12,"New value of Transition capacitance(
    pF) : ");
```

Scilab code Exa 2.12.3 Space charge capacitance

```
//Ex 2.12.3
clc;clear;close;
format('v',8);

//Given :
NA=3*10^20;//per m^3
Vj=0.2;//Volt
V=-10;//Volts
A=1*10^-6;//m^2
epsilon_r=16;//for Ge
epsilon_o=8.854*10^-12;//permitivity
q=1.6*10^-19;//Coulomb
W=sqrt(2*epsilon_r*epsilon_o*(Vj-V)/q/NA);//m
disp(W*10^6,"Width of depletion region(micro meter)
    : ");
CT=epsilon_r*epsilon_o*A/W;//
disp(CT*10^12,"Transition capacitance(pF) : ");
//Answer is wrong in the textbook.
```

Scilab code Exa 2.12.4 Barrier Capacitance of Ge

```
//Ex 2.12.4
clc;clear;close;
format('v',8);

//Given :
```

```
W=2*10^-4*10^-2;//m
A=1*10^-6;//m^2
epsilon_r=16;//for Ge
epsilon_o=8.854*10^-12;//permitivity
q=1.6*10^-19;//Coulomb
CT=epsilon_r*epsilon_o*A/W;//
disp(CT*10^12,"Barrier capacitance(pF) : ");
//Answer is wrong in the textbook.
```

Scilab code Exa 2.12.5 Calculate Diameter

```
//Ex 2.12.5
clc;clear;close;
format('v',8);

//Given :
Vj=0.5;//Volt
V=-4.5;//Volt
rho_p=5*10^-2;//ohm-m
epsilon_r=12;//for Si
epsilon_o=8.854*10^-12;//permitivity
q=1.6*10^-19;//Coulomb
CT=100*10^-12;//F
mu_p=500*10^-4;//m^2/V-s
sigma_p=1/rho_p;//(ohm-m)^-1
NA=sigma_p/q/mu_p;//per m^3
W=sqrt(2*epsilon_r*epsilon_o*(Vj-V)/q/NA);//m
A=CT*W/(epsilon_r*epsilon_o);//
r=sqrt(A/%pi);//m
D=2*r;//m
disp(D*10^6,"Diameter(micro meter) : ");
//Answer is wrong in the textbook. Sqrt is not taken
    while calculatng W value and also other mistakes
    .
```

Scilab code Exa 2.12.6 Reverse voltage and current ratio

```
//Ex 2.12.6
clc;clear;close;
format('v',8);

//Given :
Eta=2;//for Si
T=300;//K
VT=26/1000;//V
IbyIo=0.9;
//part (i)
V=log(IbyIo+1)*Eta*VT;//volt
disp(V*1000,"Value of reverse voltage(mV) : ");
//part (ii)
VF=0.2;//volt
VR=-0.2;//volt
IFbyIR=(exp(VF/Eta/VT)-1)/(exp(VR/Eta/VT)-1)
disp(IFbyIR,"Ratio of forward bias current to
    reverse saturation current : ");
//Answer is wrong in the textbook.
```

Scilab code Exa 2.12.7 Find diode current

```
//Ex 2.12.7
clc;clear;close;
format('v',8);

//Given :
Vs=100;//V
Rf1=20;//ohm
Vgamma1=0.2;//Volts
```

```
Rf2=15;//ohm
Vgamma2=0.6;//Volts
Vb_Ge=0.2;//Volts
Vb_Si=0.6;//Volts
R1=10*10^3;//ohm
R2=1*10^3;//ohm
//Case(i)
Imax=Vs/R1;//A
//D1 ON & D2 off
V=Vb_Ge+Rf1*Imax;//Volt
//D2 off as V<Vb_Si
I2=0;//A
I1=(Vs-V)/(R1+Rf1);//A
disp("For R=10 kohm : ");
disp(I1*1000,"I1(mA)=");
disp(I2,"I2(mA)=");
//Case(ii)
R=R2;//ohm//D1 & D2 ON
//V=Vb_Ge+Rf1*I1//V=Vb_Si+Rf2*I2
///V=Vs-I*R//V=Vs-(I1+I2)*R
//20*I1-15*I2=Vb_Si-Vb_Ge
//1020*I1+1000*I2=99.8
A=[20 1020;-Rf2 R];
B=[Vb_Ge-Vb_Ge Vs-Vb_Ge ];
X=B*A^-1;//
I1=X(1)*1000;//mA
I2=X(2)*1000;//mA
disp("For R=1 kohm : ");
disp(I1,"I1(mA)=");
disp(I2,"I2(mA)=");
//Answer for 2nd part is not accurate in the book.
```

Scilab code Exa 2.12.8 Current in the circuit

```
//Ex 2.12.8
```

```
clc;clear;close;
format('v',8);

//Given :
Rf=10;//ohm
Vgamma=0.5;//Volt
RL=20;//ohm
V=3;//Volt
//Loop 1: 75*I1-50*I=V-Vgamma
//Loop 2: -50*I1+80*I=-Vgamma
A=[75 -50;-50 80];
B=[V-Vgamma -Vgamma];
X=B*A^-1;
I1=X(1);//A
I=X(2);//A
Vx=-Vgamma+50*I1;//Volt
disp(Vx,"DC source(Volts) : ");
//Answer is wrong in the textbook.
```

Chapter 5

Metal Semiconductor Field Effect Transistors

Scilab code Exa 5.6.1 Determine the current

```
//Ex 5.6.1
clc;clear;close;
format('v',6);

//Given :
VTN=0.7;//V
W=45;//micro m
L=4;//micro m
mu_n=700;//cm^2/V-s
t_ox=450;//Angstrum
epsilon_ox=3.9*8.85*10^-14;//F/cm
VGS=2*VTN;//V
Kn=(W*10^-4)*mu_n*epsilon_ox/(2*(L*10^-4)*(t_ox
    *10^-8));//A/V^2
Kn=Kn*10^3;//mA/V^2
ID=Kn*(VGS-VTN)^2;//A
disp(ID,"Current in mA : ");
//Answer is wrong in the book. Calculation mistake
    whle calculating value for Kn.
```