Scilab Textbook Companion for Electronic Devices by K. C. Nandi[1]

Created by
Mohd. Irfan
B.Tech
Electronics Engineering
UPTU
College Teacher
Mr. Sunil Kumar
Cross-Checked by
Muku Kulkarni & Lavitha Pereira

May 27, 2016

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Electronic Devices

Author: K. C. Nandi

Publisher: Tech-max Publications, Pune

Edition: 1

Year: 2013

ISBN: 978-93-5077-354-3

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Energy Bands And Charge Carriers

Scilab code Exa 1.7.1 Wavelength

```
//Exa 1.7.1
clc;
clear;
close;
// Given data
E_g = 0.75// in eV
E_g = 0.75 * 1.6 * 10^-19;// in J
h = 6.63 * 10^-34;// in J
c = 3 * 10^8;// in m/s
// hv = E_g
//E_g = (h*c)/lambda
lambda = (h*c)/E_g;// in m
lambda = lambda * 10^10;// in A
disp(lambda,"The wavelength at which germanium
    starts to absorb light in A  is");
```

Scilab code Exa 1.7.2 Energy gap of Si

```
// Exa 1.7.2
clc;
clear;
close;
// Given data
h = 6.625 * 10^-34;// in J
c = 3 * 10^8;// in J
lambda_Gr = 17760 * 10^-10;// in m
lambda_Si = 11000;// in A
lambda_Si = lambda_Si * 10^-10;// in m
E_g = (h*c)/lambda_Si;// in J
E_g = E_g /(1.6*10^-19);// in eV
disp(E_g,"The energy gap of Si in eV is ");
E_g1 = (h*c)/lambda_Gr;// in J
E_g1 = E_g1/(1.6 * 10^-19);// in eV
disp(E_g1,"The energy gap of Germanium in eV is ");
```

Scilab code Exa 1.18.1 Position of Fermi level

```
//Exa 1.18.1
clc;
clear;
close;
// Given data
del_E = 0.3;// in eV
T1 = 300;// in K
T2 = 330;// in K
// del_E = K * T1 * log(N/N_c) where del_E= E_C-E_F
// del_E1 = K * T2 * log(N/N_c) where del_E1= E_C-E_F at T= 330  K
del_E1 = del_E*(T2/T1);// in eV
disp("The Fermi level will be "+string(del_E1)+" eV below the conduction band")
```

Scilab code Exa 1.18.2 Probability

```
//Exa 1.18.2
clc;
clear;
close;
// Given data
N_c = 2.8 * 10^19;// in cm^-3
del_E = 0.25;// fermi energy in eV
KT = 0.0259;
f_F = exp(-(del_E)/KT);
disp(f_F,"The probbaility in the condition band is occupied by an electron is ");
n_o = N_c * exp(-(del_E)/KT);// in cm^-3
disp(n_o,"The thermal equilibrium electron concentration in cm^-3 is");
```

Scilab code Exa 1.18.3 Thermal equilibrium hole concentration

```
//Exa1.18.3
clc;
clear;
close;
// Given data
T1 = 300;// in K
T2 = 400;// in K
del_E = 0.27;// Fermi level in eV
KT = (0.0259) * (T2/T1);// in eV
N_v = 1.04 * 10^19;// in cm^-3
N_v = N_v * (T2/T1)^(3/2);// in cm^-3
p_o = N_v * exp(-(del_E)/KT);// in per cm^3
```

```
disp(p_o,"The thermal equilibrium hole concentration
    in per cm^3 is");
```

Scilab code Exa 1.21.1 Conductivity of pure Si

```
// Exa 1.21.1
clc;
clear;
close;
// Given data
Mu_e = 1500;// in cm^2/volt sec
Mu_h = 500;// in cm^2/volt sec
n_i = 1.6 * 10^10;// in per cm^3
e = 1.6 * 10^-19;// in C
Sigma = n_i * (Mu_e + Mu_h) * e;// in mho/cm
disp(Sigma,"The conductivity of pure semiconductor
   in mho/cm is");
```

Scilab code Exa 1.21.2 Number of donar atoms

```
// Exa 1.21.2
clc;
clear;
close;
// Given data
Rho = 10;// in  -cm
Mu_d = 500;// in cm^2/v.s.
e = 1.6*10^-19;
n_d = 1/(Rho * e * Mu_d);// in per cm^3
disp(n_d,"The number of donor atom must be added to
   achieve in per cm^3 is ");
```

Scilab code Exa 1.21.3 Conductivity of speciman

```
//Exa 1.21.3
clc;
clear;
close;
//Given data
AvagadroNumber = 6.02 * 10^23;// in atoms/gm.mole
at_Ge = 72.6;// atom weight of Ge
e = 1.6 * 10^-19;// in C
D_Ge = 5.32;// density of Ge in gm/c.c
Mu = 3800;// in cm^2/v.s.
C_Ge = (AvagadroNumber/at_Ge) * D_Ge;//
   concentration of Ge atoms in per cm^3
n_d = C_Ge/10^8;// in per cc
Sigma = n_d * Mu * e;// in mho/cm
disp(Sigma,"The conductivity in mho/cm is");
```

Scilab code Exa 1.21.4 Mobility of electrons in Ge

```
// Exa1.21.4
clc;
clear;
close;
// Given data
Rho = 0.3623 * 10^-3;// in Ohm m
Sigma = 1/Rho;//in mho/m
D = 4.42 * 10^28;// Ge density in atom/m^3
n_d = D / 10^6;// in atom/m^3
e = 1.6 * 10^-19;// in C
Mu = Sigma/(n_d * e);// in m^2/V.sec
```

```
disp(Mu,"The mobility of electron in germanium in m^2/V.sec is");
```

Scilab code Exa 1.21.5 Density and mobility of holes

```
//Exa 1.21.5
clc;
clear;
close;
// Given data
AvagadroNumber = 6.025 * 10^26;// in kg.Mole
W = 72.59;// atomic weight of Ge
D = 5.36 * 10^3;//density of Ge in kg/m^3
Rho = 0.42;// resistivity in Ohm m
e = 1.6 * 10^-19;// in C
Sigma = 1/Rho;// in mho/m
n = (AvagadroNumber/W) * D;// number of Ge atoms present per unit volume
// Holes per unit volume, H = n*10^-6%
H= n*10^-8;
a=H;
// Formula sigma= a*e*Mu_h
Mu_h = Sigma/(a * e);// in m^2/V.sec
disp(Mu_h,"Mobility of holes in m^2/V.sec is");
```

Scilab code Exa 1.21.6 Current produced

```
//Exa 1.21.6
clc;
clear;
close;
// Given data
e = 1.6 * 10^-19;// in C
```

```
n_i = 2 * 10^19;// in /m^3
Mu_e = 0.36;// in m^2/v.s
Mu_h = 0.17;// in m^2/v.s
A = 1 * 10^-4;// in  m^2
V = 2;//in volts
l = 0.3;// in mm
l = l * 10^-3;// in m
E=V/l;// in volt/m
Sigma = n_i * e * (Mu_e + Mu_h);// in mho/m
// J = I/A = Sigma * E
I= Sigma*E*A;
disp(I,"The current produced in a small germanium plate in amp is");
```

Scilab code Exa 1.21.7 Resitivity of doped Ge atoms

```
// Exa 1.21.7
clc;
clear;
close;
// Given data
D = 4.2 * 10^28;//density of Ge atoms in atoms/m^3
N_d = D / 10^6;// in atoms/m^3
e = 1.6 * 10^-19;// in C
Mu_e = 0.36;// in m^2/vs
Sigma_n = N_d *  e * Mu_e;// in mho/m
Rho_n = 1/Sigma_n;// in ohm m
disp(Rho_n,"The resistivity of drop Ge in ohm m is ");
```

Scilab code Exa 1.21.8 Current produced in Ge sample

```
// Exa 1.21.8
```

```
clc;
clear;
close;
// given data
e = 1.6 * 10^-19;// in C
n_i = 1 * 10^19;// in per m^3
Mu_e = 0.36;// in m^2/volt.sec
Mu_h = 0.17;// in m^2/volt.sec
A = 2;// in cm^2
A = A * 10^-4;// im m^2
t = 0.1;// in mm
t = t * 10^-3;// in m
V = 4;// in volts
Sigma_i = n_i * e * (Mu_e + Mu_h);// in mho/m
J = Sigma_i * (V/t);// in Amp/m^2
I = J * A;// in Amp
disp(I,"The current produced in a Ge sample in Amp
   is");
```

Scilab code Exa 1.21.9 Conductivity of pure Si

```
//Exa 1.21.9
clc;
clear;
close;
// Given data
e = 1.6 * 10^-19;// in C
Mu_h = 500;// in cm^2/V.s.
Mu_e = 1500;// in cm^2/V.s.
n_i = 1.6 * 10^10;// in per cm^3
Sigma_i = n_i * e * ( Mu_h + Mu_e);// in mho/cm
disp(Sigma_i,"Conductivity of pure silicon at room
   temperature in mho/cm is");
```

Scilab code Exa 1.23.1 Hall voltage produced

```
//Exa 1.23.1
clc;
clear;
close;
//Given data
l= 0.50*10^-2;// width of ribbon in m
d= 0.10*10^-3;// thickness of ribbon in m
A= l*d;// area of ribbon in m^2
B = 0.8;// in Tesla
D = 10.5;//density in gm/cc
I = 2;// in amp
q = 1.6 * 10^-19;// in C
n=6*10^28;// number of elec. per m^3
V_H = ( I * B * d)/(n * q * A);// in volts
disp(V_H,"The hall Voltage produced in volts is");
```

Scilab code Exa 1.23.2 Hall coefficient and mobility of electrons

```
//Exa 1.23.2
clc;
clear;
close;
// Given data
l = 1;// in m
d = 1;// in cm
d = d * 10^-2;// in m
W = 1;// in mm
W = W * 10^-3;// in m
A = d * W;// in m^2
I= 1;// in Amp
```

```
B = 1;// Tesla
V_H = 0.074 * 10^-6;// in Volts
Sigma = 5.8 * 10^7;// in mho/m
R_H = (V_H * A)/(B*I*d);// in m^3/c
disp(R_H,"The hall coefficient in m^3/c is");
Mu = Sigma * R_H;// in m^2/volt.sec
disp(Mu,"The mobility  of electrons in copper in m
    ^2/volt-sec is ");
```

Scilab code Exa 1.23.3 Concentration of holes in Si crystals

```
//Exa1.23.3
clc;
clear;
close;
// Given data
n_i = 1.4 * 10^18;// in /m^3
n_D = 1.4 * 10^24;// in /m^3
n=n_D;// in /m^3
p = n_i^2/n;// in /m^3
R = n/p;
disp(R,"The ratio of electrons to hole concentration
    is");
```

Scilab code Exa 1.23.4 Hall angle

```
//Exa 1.23.4
clc;
clear;
close;
// Given data
B = 0.48;// in wb/m^2
R_H = 3.55 * 10^-4;// in m^3/c
```

```
Rho = 0.00912;// in ohm-m
Sigma = 1/Rho;// in (ohm-m)^-1
theta_H = atand( Sigma * B * R_H);// in degree
disp(theta_H,"The hall angle for a hall coefficient in degree is");
```

Scilab code Exa 1.23.5 Mobility and density of charge carriers

```
//Exa 1.23.5
clc;
clear;
close;
//Given data
R = 9 * 10^-3;// in ohm-m
R_H = 3.6 * 10^-4;// in m^3
e = 1.6 * 10^-19;// in C
Sigma = 1/R;// in (ohm-m)^-1
Rho = 1/R_H;// in coulomb/m^3
n = Rho/e;// in /m^3
disp(n,"Density of charge carriers in per m^3 is");
Mu = Sigma * R_H;// in m^2/v-s
disp(Mu,"Mobility of charge carriers in m^2/V-s is");
```

Scilab code Exa 1.23.6 Current density in speciman

```
//Exa 1.23.6
clc;
clear;
close;
// Given data
e = 1.6 * 10^-19;// in C
R_H = 0.0145;// in m^3/coulomb
```

```
Mu_e = 0.36;// in m^2/v-s
E = 100;// in V/m
n = 1/(e * R_H);// in /m^3
J = n * e * Mu_e * E;// in A/m^2
disp(J,"The current density of specimen in A/m^2 is"
   );
```

Scilab code Exa 1.23.7 Relaxation time

```
//Exa 1.23.7
clc;
clear;
close;
//Given data
Mu_e = 7.04 * 10^-3;// in m^2/v-s
m = 9.1 * 10^-31;
E_F = 5.5;// in eV
n = 5.8 * 10^28;
e = 1.6 * 10^-19;// in C
Torque = (Mu_e/e) * m;// in sec
disp(Torque,"Relaxation Time in sec is ");
Rho = 1 /(n * e * Mu_e);// in ohm-m
disp(Rho,"Resistivity of conductor in ohm-m is ");
V_F = sqrt((2 * E_F * e)/m);// in m/s
disp(V_F,"Velocity of electrons with fermi-energy in
    m/s is");
```

Scilab code Exa 1.23.8 Temperature

```
//Exa 1.23.8
clc;
clear;
close;
```

```
// Given data
E= 5.95;// in eV
EF= 6.25;// in eV
delE= 0.01;
 // delE= 1-1/(1+exp((E-EF)/KT))
K=1.38*10^-23;// Boltzman Constant in J/K
T = ((E-EF)/log(1/(1-delE) -1)*1.6*10^-19)/K;// in K
disp(T,"The temperature in K is : ")
```

Scilab code Exa 1.23.9 Thermal equilibrium hole concentration

```
//Exa 1.23.9
clc;
clear;
close;
// Given data
N_V = 1.04 * 10^19;// in cm^-3
T1 = 300;// in K
T2 = 400;// in K
del_E = 0.27;// in eV
N_V = N_V * (T2/T1)^1.5;// in cm^-3
KT = (0.0259) * (T2/T1);// in eV
P_o = N_V * exp(-(del_E)/KT);// in cm^-3
disp(P_o,"The thermal equilibrium hole concentration
    in silicon in cm^-3 is ");
```

Scilab code Exa 1.23.10 Required doping concentration

```
//Exa 1.23.10
clc;
clear;
close;
//Given data
```

```
N_c = 2.8 * 10^19;
N_V = 1.04 *10^19;
T1 = 550;// in K
T2 = 300;// in K
E_g = 1.12;
KT = (0.0259) ;
n_i = sqrt(N_c *N_V *(T1/T2)^3* exp(-(E_g)/KT*T2/T1));// in cm^-3
// n_o = N_d/2 + sqrt((N_d/2)^2 + (n_i)^2)
// 1.05*N_d -N_d/2= sqrt((N_d/2)^2 + (n_i)^2)
N_d=sqrt((n_i)^2/((0.55)^2-1/4));
disp(N_d,"Minimum donor concentration required in cm^-3 is");
```

Scilab code Exa 1.23.11 Quasi Fermi energy levels

```
//Exa 1.23.11
clc;
clear;
close;
//Given data
T = 300;// in K
n_o = 10^15;// in cm^-3
n_i = 10^10;// in cm^-3
p_o = 10^5;// in cm^-3
del_n = 10^13;// in cm^-3
del_p = del_n;// in cm^-3
KT = 0.0259;// in eV
delta_E1= KT*log(n_o/n_i);// value of E_F-E_Fi in eV
delta_E2= KT*log((n_o+del_n)/n_i);// value of E_Fn-E_Fi in eV
delta_E3= KT*log((p_o+del_p)/n_i);// value of E_Fi-E_Fp in eV
disp(delta_E1,"The Fermi level for thermal equillibrium in eV is : ")
```

```
disp(delta_E2,"The quase-Fermi level for electrons in non equillibrium in eV is : ")
disp(delta_E3,"The quasi-Fermi level for holes in non equillibrium in eV is : ")
disp("The quasi-Fermi level for electrons is above E_Fi ")
disp("While the quasi-Fermi level for holes is below E_Fi")
```

Scilab code Exa 1.23.12 Equilibrium hole concentration

```
// Exa 1.23.12
clc;
clear;
close;
//Given data
n_i = 1.5 * 10^10;
n_o = 10^17;
KT = 0.0259;
P_o = (n_i)^2/n_o;// in cm^-3
del_E = KT * log(n_o/n_i);// in eV
disp(del_E,"equilibrium hole concentration in eV is");
```

Scilab code Exa 1.23.13 Current

```
//exa 1.23.13
clc;
clear;
close;
//Given data
Mu_n = 700;//in cm^2/v-s
n_o = 10^17;// in /cm^3
```

```
q = 1.6 * 10^-19;// in C
l = 0.1;// in cm
A = 10^-6;
V = 10;// in V
Sigma = q * Mu_n * n_o;// in (ohm cm)^-1
Rho = 1/Sigma;//in ohm cm
R = Rho * (l/A);// in ohm
I = V/R;// in A
disp(I*10^3,"The current in mA is");
```

Chapter 2

Excess Carriers In Semiconductors

Scilab code Exa 2.21.1 Hole concentration at equilibrium

```
// Exa 2.21.1
clc;
clear;
close;
// Given data
N_d = 10^17;// atoms/cm^3
n_i = 1.5 * 10^10;// in /cm^3
n_o = 10^17;// in cm^3
// p_o * n_o = (n_i)^2
p_o = (n_i)^2 / n_o;//in holes/cm^3
disp(p_o,"The holes concentration at equilibrium in
   holes/cm^3 is");
```

Scilab code Exa 2.21.3 Fermi level

```
// Exa 2.21.3
```

```
clc;
clear;
close;
// Given data
n_i = 1.5 * 10 ^10;// in /cm^3 for silicon
N_d = 10^17;// in atoms/cm^3
n_o = 10^17;// electrons/cm^3
KT = 0.0259;
// E_r - E_i = KT * log(n_o/n_i)
del_E = KT * log(n_o/n_i);// in eV
disp("The energy band for this type material is Ei + "+string(del_E)+" eV");
```

Scilab code Exa 2.21.4 Diffusion coefficients of electrons

```
// Exa 2.21.4
clc;
clear;
close;
// Given data
K = 1.38 * 10^-23;// in J/K
T = 27;// in degree
T = T + 273;// in K
e = 1.6 * 10^-19;// in C
Mu_e = 0.17;// in m^2/v-s
Mu_e1 = 0.025;// in m^2/v-s
D_n = ((K * T)/e) * Mu_e;// in m^2/s
disp(D_n,"The diffusion coefficient of electrons in m^2/s is");
D_p = ((K * T)/e) * Mu_e1;// in m^2/s
disp(D_p,"The diffusion coefficient of  holes in m^2/s is ");
```

Scilab code Exa 2.21.5 Diffusion length

```
// Exa 2.21.5
clc;
clear;
close;
// Given data
Mu_n = 0.15;// in m^2/v-s
K = 1.38 * 10^-23; // in J/K
T = 300;// in K
del_n = 10^20;// in per m^3
Toh_n = 10^-7;// in s
e = 1.6 * 10^-19;// in C
D_n = Mu_n * ((K * T)/e);// in m^2/s
disp(D_n,"The diffusion coefficient in m^2/s is");
L_n = sqrt(D_n * Toh_n);// in m
disp(L_n,"The Diffusion length in m is");
J_n = (e * D_n * del_n)/L_n;// in A/m^2
disp(J_n,"The diffusion current density in A/m^2 is"
   );
// Note : The value of diffusion coefficient in the
   book is wrong.
```

Scilab code Exa 2.21.6 Concentration of holes and electrons

```
// Exa 2.21.6
clc;
clear;
close;
// Given data
Sigma = 0.1;// in (ohm-m)^-1
Mu_n = 1300;
n_i = 1.5 * 10^10;
q = 1.6 * 10^-19;// in C
n_n = Sigma/(Mu_n * q);// in electrons/cm^3
```

```
disp(n_n*10^6,"The concentration of electrons per m^3 is");
p_n = (n_i)^2/n_n;// in per cm^3
p_n = p_n * 10^6;// in perm^3
disp(p_n,"The concentration of holes per m^3 is");
```

Scilab code Exa 2.21.7 Electron transit time

```
// Exa 2.21.7
clc;
clear;
close;
// Given data
Mu_e = 0.13;// in m^2/v-s
Mu_h = 0.05;// in m^2/v-s
Toh_h = 10^-6;// in s
L = 100;// in  m
L = L * 10^-6;// in m
V = 2;// in V
t_n =L^2/(Mu_e * V);// in s
disp(t_n,"Electron transit time in seconds is");
p_g = (Toh_h/t_n) * (1 + Mu_h/Mu_e);//photo conductor gain
disp(p_g,"Photo conductor gain is");

// Note: There is a calculation error to evaluate the value of t_n. So the answer in the book is wrong
```

Scilab code Exa 2.21.8 Resistivity of intrinsic Ge

```
// Exa 2.21.8
clc;
```

```
clear;
close;
//Given data
n_i = 2.5 * 10^13;
Mu_n = 3800;
Mu_p = 1800;
q = 1.6 * 10^-19;// in C
Sigma = n_i * (Mu_n + Mu_p) * q;// in (ohm-cm)^-1
Rho = 1/Sigma;// in ohm-cm
Rho= round(Rho);
disp(Rho,"The resistivity of intrinsic germanium in ohm-cm is");
N_D = 4.4 * 10^22/(1*10^8);// in atoms/cm^3
Sigma_n = N_D * Mu_n * q;// in (ohm-cm)^-1
Rho_n = 1/Sigma_n;// in ohm-cm
disp(Rho_n,"If a donor type impurity is added to the extent of 1 atom per 10^8 Ge atoms, then the resistivity drops in ohm-cm is");
```

Scilab code Exa 2.21.9 Hole and electron concentration

```
// Exa 2.21.9
clc;
clear;
close;
// Given data
n_i = 10^16;// in /m3
N_D = 10^22;// in /m^3
n = N_D;// in /m^3
disp(n,"Electron concentration per m^3 is");
p = (n_i)^2/n;// in /m^3
disp(p,"Hole concentration per m^3 is");
```

Scilab code Exa 2.21.10 Ratio of donot atoms to Si atoms

```
// Exa 2.21.10
clc;
clear;
close;
// Given data
Rho = 9.6 * 10^-2;// in ohm-m
Sigma_n = 1/Rho;// in (ohm-m)^-1
q = 1.6 * 10^-19;// in C
Mu_n = 1300 * 10^-4;// in m^2/v-s
N_D = Sigma_n / (Mu_n * q);// in atoms/m^3
A_D = N_D;// Atom density in atoms/cm^3
A_D = A_D * 10^6;// atoms/m^3
R_si = N_D/A_D;// ratio
disp(R_si,"the ratio of donor atom to silicon atom is");

// Note: In the book the wrong value of N_D (5*10^22) is putted to evaluate the value of Atom Density (A_D) whereas the value of N_D is calculated as 5*10^20.
//          So the answer in the book is wrong
```

Scilab code Exa 2.21.11 Equilibrium electron and hole densities

```
// Exa 2.21.11
clc;
clear;
close;
// Given data
n_i = 1.5 * 10^10;// in per cm^3
n_n = 2.25 * 10^15;// in per cm^3
p_n = (n_i)^2/n_n;// in per cm^3
disp(p_n,"The equilibrium electron per cm^3 is");
```

```
h_n = n_n;// in cm^3
disp(h_n,"Hole densities in per cm^3 is");
```

Scilab code Exa 2.21.12 Carrier concentration

```
// Exa 2.21.12
clc;
clear;
close;
// Given data
N_A = 2 * 10^16;// in atoms/cm^3
N_D = 10^16;// in atoms/cm^3
C_c = N_A-N_D;// C_c stands for Carrier
    concentration in /cm^3
disp(C_c,"Carrier concentration per cm^3 is");
```

Scilab code Exa 2.21.13 Generation rate due to irradiation

```
// Exa 2.21.13
clc;
clear;
close;
// Given data
del_n = 10^15;// in cm^3
Torque_p = 10 * 10^-6;// in sec
R_g = del_n/Torque_p;// in hole pairs/sec/cm^3
disp(R_g,"The rate of generation of minority carrier
     in electron hole pairs/sec/cm^3 is ");
```

Scilab code Exa 2.21.14 Mobility of minority charge carrier

```
// Exa 2.21.14
clc;
clear;
close;
// Given data
v = 1/(20 * 10^-6);// in cm/sec
E = 10;// in V/cm
Mu= v/E;// in cm^2/V-sec
disp(Mu,"The mobility of minority charge carrier in
   cm^2/V-sec is ");
```

Scilab code Exa 2.21.15 Hole and electron diffusion current

```
// Exa 2.21.15
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
N_D = 4.5 * 10^15;// in /cm^3
del_p = 10^21;
e=10;// in cm
A = 1;// in mm^2
A = A * 10^-14;// cm^2
l = 10;// in cm
Torque_p = 1;// in microsec
Torque_p = Torque_p * 10^-6;// in sec
Torque_n = 1;// in microsec
Torque_n = Torque_n * 10^-6;// in  sec
n_i = 1.5 * 10^10;// in /cm^3
D_n = 30;// in cm^2/sec
D_p = 12;// in cm^2/sec
n_o = N_D;// in /cm^3
p_o = (n_i)^2/n_o;// in /cm^3
disp(p_o,"Hole concentration at thermal equilibrium
```

```
    per cm^3 is");
l_n = sqrt(D_n * Torque_n);// in cm
disp(l_n,"Diffusion length of electron in cm is");
l_p = sqrt(D_p * Torque_p);// in cm
disp(l_p,"Diffusion length of holes in cm is");
x=34.6*10^-4;// in cm
dpBYdx = del_p *e;// in cm^4
disp(dpBYdx,"Concentration gradient of holes at
    distance in cm^4 is");
e1 = 1.88 * 10^1;// in cm
dnBYdx = del_p * e1;// in cm^4 check this also
    ............................
disp(dnBYdx,"Concentration gradient of electrons in
    per cm^4 is");
J_P = -(q) * D_p * dpBYdx;// in A/cm^2
disp(J_P,"Current density of holes due to diffusion
    in A/cm^2 is");
J_n = q * D_n * dnBYdx;// in A/cm^2
disp(J_n,"Current density of electrons due to
    diffusion in A/cm^2 is");
```

Scilab code Exa 2.21.16 Energy band gap of semiconductor material used

```
// Exa 2.21.16
clc;
clear;
close;
// Given data
e= 1.6*10^-19;// electron charge in C
h = 6.626 * 10^-34;// in J-s
h= h/e;// in eV
c = 3 * 10^8;// in m/s
lembda = 5490 * 10^-10;// in m
f = c/lembda;
E = h * f;// in eV
```

```
disp(E,"The energy band gap of the semiconductor
    material in eV is");
```

Scilab code Exa 2.21.17 Current density

```
// Exa 2.21.17
clc;
clear;
close;
// Given data
y2 = 6 * 10^16;// in /cm^3
y1 = 10^17;// in /cm^3
x2 = 2;// in  m
x1 = 0;// in  m
D_n = 35;// in cm^2/sec
q = 1.6 *10^-19;// in C
dnBYdx = (y2 - y1)/((x2-x1) * 10^-4);
J_n = q * D_n * dnBYdx;// in A/cm^2
disp(J_n,"The current density in silicon in A/cm^2
    is");
```

Scilab code Exa 2.21.18 Resistance of the bar

```
// Exa 2.21.18
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
n_n = 5 * 10^20;// in /m^3
n_n = n_n * 10^-6;// in cm^3
Mu_n = 0.13;// in m^2/V-sec
Mu_n = Mu_n * 10^4;// in cm^2/V-sec
```

```
Sigma_n = q * n_n * Mu_n;// in (ohm−cm)ˆ−1
Rho = 1/Sigma_n;// in   −cm
l = 0.1;// in cm
A = 100;//  m ˆ2
A = A * 10^-8;// in cmˆ2
R = Rho * (l/A);// in Ohm
R=round(R*10^-6);// in M
disp(R,"The resistance of the bar in M  is");
```

Scilab code Exa 2.21.19 Depletion width

```
// Exa 2.21.19
clc;
clear;
close;
// Given data
t_d = 3;// total depletion in  m
D = t_d/9;// in  m
disp(D,"Depletion width in  m is");
```

Scilab code Exa 2.21.20 Majority carrier density

```
// Exa 2.21.20
clc;
clear;
close;
// Given data
n_i = 1.5 * 10^16;// in /mˆ3
n_n = 5 * 10^20;// in /mˆ3
p_n = (n_i)^2/n_n;// in /mˆ3
disp(p_n,"The majority carrier density per mˆ3 is");
```

Scilab code Exa 2.21.21 Collector current density

```
// Exa 2.21.21
clc;
clear;
close;
// Given data
D_n = 25;// in cm^2/sec
q = 1.6 * 10^-19;// in C
y2 = 10^14;// in /cm^3
y1 = 0;// in /cm^3
x2 = 0;//in   m
x1 = 0.5;// in   m
x1 = x1 * 10^-4;// in cm
dnBYdx = abs((y2-y1)/(x2-x1));// in /cm^4
J_n = q * D_n * (dnBYdx);// in /cm^4
J_n = J_n * 10^-1;// in A/cm^2
disp(J_n,"the collector current density in A/cm^2 is
   ");

// Note: In the book, the calculated value of dn by
   dx (2*10^19) is wrong. Correct value is 2*10^18
   so the answer in the book is wrong.
```

Scilab code Exa 2.21.22 Band gap

```
//Exa 2.21.22
clc;
clear;
close;
// Given data
h = 6.64 * 10^-34;// in J-s
```

```
e= 1.6*10^-19;// electron charge in C
c= 3 * 10^8;// in m/s
lembda = 0.87;// in  m
lembda = lembda * 10^-6;// in m
E_g = (h * c)/lembda;// in J-s
E_g= E_g/e;// in eV
disp(E_g,"The band gap of the material in eV is");
```

Scilab code Exa 2.21.23 Rate of excess thermal energy

```
// Exa 2.21.23
clc;
clear;
close;
// Given data
I_o = 10;// in mW
e = 1.6 * 10^-19;// in J/eV
hv = 2;// in eV
hv1=1.43;// in eV
alpha = 5 * 10^4;// in cm^-1
l = 46;// in  m
l = l * 10^-6;// in m
I_t = round(I_o * exp(-(alpha) * l));// in mW
AbsorbedPower= I_o-I_t;// in mW
AbsorbedPower=AbsorbedPower*10^-3;// in W or J/s
disp(AbsorbedPower,"The absorbed power in watt or J/
    s is");
F= (hv-hv1)/hv;// fraction of each photon energy
    unit
EnergyConToHeat= AbsorbedPower*F;// in J/s
disp(EnergyConToHeat,"The amount of energy converted
     to heat per second in J/s is : ")
A= AbsorbedPower/(e*hv1);
disp(A,"the number of photon per sec given off from
    recombination events in photons/s is");
```

Scilab code Exa 2.21.24 Hole current

```
// Exa 2.21.24
clc;
clear;
close;
// Given data
format('v',13)
Mu_p = 500;// in cm^2/v-s
kT = 0.0259;
Toh_p = 10^-10;// in sec
p_o = 10^17;// in cm^-3
q= 1.6*10^-19;// in C
A=0.5;// in square meter
del_p = 5 * 10^16;// in cm^-3
n_i= 1.5*10^10;// in cm^-3
D_p = kT * Mu_p;// in cm/s
L_p = sqrt(D_p * Toh_p);// in cm
x = 10^-5;// in cm
p = p_o+del_p* %e^(x/L_p);// in cm^-3
// p= n_i*%e^(Eip)/kT where Eip=E_i-F_p
Eip= log(p/n_i)*kT;// in eV
Ecp= 1.1/2-Eip;// value of E_c-E_p in eV
Ip= q*A*D_p/L_p*del_p*%e^(x/L_p);// in A
disp(Ip,"The hole current in A is : ")
Qp= q*A*del_p*L_p;// in C
disp(Qp,"The value of Qp in C is : ")

// Note: There is a calculation error to evalaute
   the value of hole current but they putted correct
    value of it to evaluate the value of Qp.
//          Hence the value of hole current in the
   book is wrong
```

Scilab code Exa 2.21.25 Hole current

```
// Exa 2.21.25
clc;
clear;
close;
// Given data
format('v',13)
KT = 0.0259;
A = 0.5;// in cm^2
Toh_p = 10^-10;// in sec
p_o = 10^17;// in per cm^3
del_p = 5 * 10^16;// in per cm^3
x = 10^-5;// in cm
Mu_p = 500;// in cm^2/V-S
q = 1.6 * 10^-19;// in C
D_p = KT * Mu_p;// in cm/s
L_p = sqrt(D_p * Toh_p);// in cm
p = p_o * del_p * (%e^(x/L_p));// in per cm^3
I_p =q * A * (D_p/L_p) * del_p * (%e^(x/L_p));// in
    A
disp(I_p,"The hole current in A is");
Q_p = q * A * del_p * L_p;// in C
disp(Q_p,"The hole charge in C is");

// Note: There is a calculation error to evalaute
    the value of hole current but they putted correct
     value of it to evaluate the value of Qp.
//          Hence the value of hole current in the
    book is wrong
```

Chapter 3

Junction Properties

Scilab code Exa 3.10.1 Contect difference of potential

```
// EXa 3.10.1
clc;
clear;
close;
// Given data
t = 4.4 * 10^22;// total number of Ge atoms/cm^3
n = 1 * 10^8;// number of impurity atoms
N_A = t/n;// in atoms/cm^3
N_A = N_A * 10^6;// in atoms/m^3
N_D = N_A * 10^3;// in atoms/m^3
n_i = 2.5 * 10^13;// in atoms/cm^3
n_i = n_i * 10^6;// in atoms/m^3
V_T = 26;//in mV
V_T= V_T*10^-3;// in V
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"The contact potential in V is");
// Part (b)
t = 5* 10^22;// total number of Si atoms/cm^3
N_A = t/n;// in atoms/cm^3
N_A = N_A * 10^6;// in atoms/m^3
N_D = N_A * 10^3;// in atoms/m^3
```

```
n_i = 1.5 * 10^10;// in atoms/cm^3
n_i = n_i * 10^6;// in atoms/m^3
V_T = 26;//in mV
V_T= V_T*10^-3;// in V
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"The contact potential  in V is");
```

Scilab code Exa 3.10.2 Height of the potential energy barrier

```
// Exa 3.10.2
clc;
clear;
close;
// Given data
V_T = 26;// in mV
V_T=V_T*10^-3;// in V
n_i = 2.5 * 10^13;
Sigma_p = 1;
Sigma_n = 1;
Mu_n = 3800;
q = 1.6 * 10^-19;// in C
Mu_p = 1800;
N_A = Sigma_p/(2* q * Mu_p);// in /cm^3
N_D = Sigma_n /(q * Mu_n);// in /cm^3
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"For Ge the height of the energy barrier in
    V is");
// For Si p-n juction
n_i = 1.5 * 10^10;
Mu_n = 1300;
Mu_p = 500;
N_A = Sigma_p/(2* q * Mu_p);// in /cm^3
N_D = Sigma_n /(q * Mu_n);// in /cm^3
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"For Si p-n junction  the height of the
```

```
    energy barrier in V is");
```

Scilab code Exa 3.10.3 Ratio of current for a forward bias to reverse bias

```
//Exa 3.10.3
clc;
clear;
close;
// Given data
Eta = 1;
V_T = 26;// in mV
V_T= V_T*10^-3;// in V
// I = I_o * (%e^(V/(Eta*V_T)) - 1) and I = -(0.9) * I_o;
V= log(1-0.9)*V_T;// in V
disp(V,"The voltage in volts is : ")
// Part (ii)
V1=0.05;// in V
V2= -0.05;// in V
ratio= (%e^(V1/(Eta*V_T))-1)/(%e^(V2/(Eta*V_T))-1)
disp(ratio,"The ratio of the current for a forward bias to reverse bias is : ")
// Part (iii)
Io= 10;// in  A
Io=Io*10^-3;// in mA
//For
V=0.1;// in V
I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
disp(I,"For v=0.1 V , the value of I in mA is : ")
//For
V=0.2;// in V
I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
disp(I,"For v=0.2 V , the value of I in mA is : ")
//For
V=0.3;// in V
```

```
I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
disp(I*10^-3,"For v=0.3 V , the value of I in A is :
    ")
disp("From three value of I, for small rise in
    forward voltage, the diode current increase
    rapidly")
```

Scilab code Exa 3.10.4 Anticipated factor

```
//Exa 3.10.4
clc;
clear;
close;
// Given data
// Part (i)
T1= 25;// in  C
T2= 80;// in  C
// Formula Io2= Io1*2^((T2-T1)/10)
AntiFactor= 2^((T2-T1)/10);
disp(round(AntiFactor),"Anticipated factor for Ge is
    : ")
// Part (ii)
T1= 25;// in  C
T2= 150;// in  C
AntiFactor= 2^((T2-T1)/10);
disp(round(AntiFactor),"Anticipated factor for Si is
    : ")
```

Scilab code Exa 3.10.5 Leakage resistance

```
//Exa 3.10.5
clc;
clear;
```

```
close;
// Given data
I=5;// in  A
V=10;// in V
T1= 0.11;// in  C ^-1
T2= 0.07;// in  C ^-1
// Io+I_R=I                              (i)
// dI_by_dT= dIo_by_dT         (ii)
// 1/Io*dIo_by_dT = T1 and 1/I*dI_by_dT = T2, So
Io= T2*I/T1;// in  A
I_R= I-Io;// in  A
R= V/I_R;// in M
disp(R,"The leakage resistance in M  is : ")
```

Scilab code Exa 3.10.6 Dynamic resistance

```
//Exa 3.10.6
clc;
clear;
close;
// Given data
Eta = 1;
T = 125;// in  C
T = T + 273;// in K
V_T = 8.62 * 10^-5 * 398;// in V
I_o = 30;// in  A
I_o= I_o*10^-6;// in A
v = 0.2;// in V
r_f = (Eta * V_T)/(I_o * %e^(v/(Eta* V_T)));// in
    ohm
disp(r_f,"The dynamic resistance in the forward
    direction in ohm is ");
r_r = (Eta * V_T)/(I_o * %e^(-v/(Eta* V_T)));// in
    ohm
disp(r_r*10^-3,"The dynamic resistance in the
```

```
reverse direction in kohm is");
```

Scilab code Exa 3.10.7 Barrier capacitance

```
// Exa 3.10.7
clc;
clear;
close;
// Given data
epsilon = 16/(36 * %pi * 10^11);// in F/cm
A = 1 * 10^-2;
W = 2 * 10^-4;
C_T = (epsilon * A)/W;// in F
disp(C_T*10^12,"The barrier capacitance in pF is");
```

Scilab code Exa 3.10.8 Width of the depletion layer

```
//Exa 3.10.8
clc;
clear;
close;
//Given data
A = 1;// in mm^2
A = A * 10^-6;// in m^2
N_A = 3 * 10^20;// in atoms/m^3
q = 1.6 *10^-19;// in C
V_o = 0.2;// in V
epsilon_r=16;
epsilon_o= 8.854*10^-12;// in F/m
epsilon=epsilon_r*epsilon_o;
// Part (a)
V=-10;// in V
// V_o - V = 1/2*((q * N_A )/epsilon) * W^2
```

```
W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
C_T1 = (epsilon * A)/W;// in F
disp(W*10^6,"The width of the depletion layer for an applied reverse voltage of 10V in  m is ");
// Part (b)
V=-0.1;// in V
W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
C_T2 = (epsilon * A)/W;// in F
disp(W*10^6,"The width of the depletion layer for an applied reverse voltage of 0.1V in  m is ");
// Part (c)
V=0.1;// in V
W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
disp(W*10^6,"The width of the depletion layer for an applied for a forward bias of 0.1V in  m is ");
// Part (d)
disp(C_T1*10^12,"The space charge capacitance for an applied reverse voltage of 10V  in pF is");
disp(C_T2*10^12,"The space charge capacitance for an applied reverse voltage of 0.1V  in pF is");
```

Scilab code Exa 3.10.9 Current in the junction

```
// Exa 3.10.9
clc;
clear;
close;
// Given data
I_o = 1.8 * 10^-9;// A
v = 0.6;// in V
Eta = 2;
V_T = 26;// in mV
V_T=V_T*10^-3;// in V
I = I_o *(%e^(v/(Eta * V_T)));// in A
```

```
disp(I*10^3,"The current in the junction in mA is");
```

Scilab code Exa 3.10.10 Forward biasing voltage

```
// Exa 3.10.10
clc;
clear;
close;
// Given data
I_o = 2.4 * 10^-14;
I = 1.5;// in mA
I=I*10^-3;// in A
Eta = 1;
V_T = 26;// in mV
V_T= V_T*10^-3;// in V
v =log((I + I_o)/I_o) * V_T;// in V
disp(v,"The forward biasing voltage across the
    junction in V is");
```

Scilab code Exa 3.10.11 Theoretical diode current

```
// Exa 3.10.11
clc;
clear;
close;
// Given data
I_o = 10;// in nA
// I = I_o * ((e^(v/(Eta * V_T))) - 1)
// e^(v/(Eta * V_T)<< 1, so neglecting it
I = I_o * (-1);// in nA
disp(I,"The Diode current in nA is  ");
```

Scilab code Exa 3.10.12 Diode dynamic resistance

```
// Exa 3.10.12
clc;
clear;
close;
// Given data
R = 4.5;// in ohm
I = 44.4;// in mA
I=I*10^-3;// in A
V = R * I;// in V
Eta = 1;
V_T = 26;//in mV
V_T=V_T*10^-3;// in V
I_o = I/((%e^(V/(Eta * V_T))) -1);// in A
// At
V = 0.1;// in V
r_f = (Eta * V_T)/(I_o * ((%e^(V/(Eta * V_T)))-1));
    // in ohm
disp(r_f,"The diode dynamic resistance in    is");
```

Scilab code Exa 3.10.13 Q point

```
// Exa 3.10.13
clc;
clear;
close;
// Given data
V_D = 10;// in V
// V_S = i*R_L + V_D
V_S = V_D;// in V (i * R_L = 0)
```

```
disp(V_S,"when diode is OFF, the voltage in volts is
    : ");
R_L = 250;// in ohm
I = V_S/R_L;// in A
disp(I*10^3,"when diode is ON, the current in mA is"
   );
V_D= 0:0.1:10;// in V
I= (V_S-V_D)/R_L*1000;// in mA
plot(V_D,I)
xlabel("V_D in volts");
ylabel("Current in mA")
title("DC load line");
disp("DC load line shown in figure")
```

Scilab code Exa 3.10.14 AC resistance of a Ge diode

```
// Exa 3.10.14
clc;
clear;
close;
// Given data
V = 0.25;// in V
I_o = 1.2;// in  A
I_o = I_o * 10^-6;// in A
V_T = 26;// in mV
V_T = V_T * 10^-3;// in V
Eta = 1;
r = (Eta * V_T)/(I_o * (%e^(V/(Eta * V_T))));// in
   ohm
disp(r,"The ac resistance of the diode in ohm is");
```

Scilab code Exa 3.10.15 Junction potential

```
// Exa 3.10.15
clc;
clear;
close;
// Given data
t = 4.4 * 10^22;// in total number of atoms/cm^3
n = 1 * 10^8;// number of impurity
N_A = t/n;// in atoms/cm^3
N_A = N_A * 10^6;// in atoms/m^3
N_D = N_A * 10^3;// in atoms/m^3
V_T = 26;// in mV
V_T = V_T * 10^-3;// in V
n_i = 2.5 * 10^19;// in /cm^3
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"The junction potential in V is")
```

Scilab code Exa 3.10.16 Dynamic resistance

```
// Exa 3.10.16
clc;
clear;
close;
// Given data
Eta = 1;
I_o = 30;// in MuA
I_o = I_o * 10^-6;// in A
v = 0.2;// in V
K = 1.381 * 10^-23;// in J/degree K
T = 125;// in  C
T = T + 273;// in K
q = 1.6 * 10^-19;// in C
V_T = (K*T)/q;// in V
r_f = (Eta * V_T)/(I_o * (%e^(v/(Eta * V_T))));// in
    ohm
disp(r_f,"The forward dynamic resistance in ohm is")
```

```
    ;
r_f1 = (Eta * V_T)/(I_o * (%e^(-(v)/(Eta * V_T))));
    // in ohm
disp(r_f1*10^-3,"The Reverse dynamic resistance in
    k   is");
```

Scilab code Exa 3.10.17 Width of the depletion layer

```
// Exa 3.10.17
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
N_A = 3 * 10^20;// in /m^3
A = 1;// in   m ^2
A = A * 10^-6;// in m^2
V = -10;// in V
V_J = 0.25;// in V
V_B = V_J - V;// in V
epsilon_o = 8.854;// in pF/m
epsilon_o = epsilon_o * 10^-12;// in F/m
epsilon_r = 16;
epsilon = epsilon_o * epsilon_r;
W = sqrt((V_B * 2 * epsilon)/(q * N_A));// in m
disp(W*10^6,"The width of depletion layer in   m is"
    );
C_T = (epsilon * A)/W;// in pF
disp(C_T*10^12,"the space charge capacitance in pF
    is");
```

Scilab code Exa 3.10.18 Barrier capacitance of a Ge pn junction

```
// Exa 3.10.18
clc;
clear;
close;
// Given data
W = 2 * 10^-4;// in cm
W = W * 10^-2;// in m
A = 1;// in mm^2
A = A * 10^-6;// in m^2
epsilon_r = 16;
epsilon_o = 8.854 * 10^-12;// in F/m
epsilon = epsilon_r * epsilon_o;
C_T = (epsilon * A)/W;// in F
disp(C_T*10^12,"The barrier capacitance in pF is");
```

Scilab code Exa 3.10.19 Diameter

```
// Exa 3.10.19
clc;
clear;
close;
// Given data
C_T = 100;// in pF
C_T=C_T*10^-12;// in F
epsilon_r = 12;
epsilon_o = 8.854 * 10^-12;// in F/m
epsilon = epsilon_r * epsilon_o;
Rho_p = 5;// in ohm-cm
Rho_p = Rho_p * 10^-2;// in ohm-m
V_j = 0.5;// in V
V = -4.5;// in V
Mu_p = 500;// in cm^2
Mu_p = Mu_p * 10^-4;// in m^2
Sigma_p = 1/Rho_p;// in per ohm-m
qN_A = Sigma_p/ Mu_p;
```

```
V_B = V_j - V;
W = sqrt((V_B * 2 * epsilon)/qN_A);// in m
//C_T = (epsilon * A)/W;
A = (C_T * W)/ epsilon;// in m
D = sqrt(A * (4/%pi));// in m
D = D * 10^3;// in mm
disp(D,"The diameter in mm is");
```

Scilab code Exa 3.10.20 Temperature of junction

```
// Exa 3.10.20
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
Mu_p = 500;// in cm^2/V-sec
Rho_p = 3.5;// in ohm-cm
Mu_n = 1500;// in cm^2/V-sec
Rho_n = 10;// in ohm-cm
N_A = 1/(Rho_p * Mu_p * q);// in /cm^3
N_D = 1/(Rho_n * Mu_n * q);// in /cm^3
V_J = 0.56;// in V
n_i = 1.5 * 10^10;// in /cm^3
V_T = V_J/log((N_A * N_D)/(n_i)^2);// in V
// V_T = T/11600
T = V_T * 11600;// in K
T = T - 273;// in  C
disp(T,"The Temperature of junction in  C is");
```

Scilab code Exa 3.10.21 Voltage

```
// Exa 3.10.21
```

```
clc;
clear;
close;
// Given data
V_T = 26;// in mV
V_T = V_T * 10^-3;// in V
Eta = 1;
// I = -90% for Io, so
IbyIo= 0.1;
// I  = I_o * ((e^(v/(Eta * V_T)))-1)
V = log(IbyIo) * V_T;// in V
disp(V,"The reverse bias voltage in volts is");
```

Scilab code Exa 3.10.22 Reverse saturation current

```
// Exa 3.10.22
clc;
clear;
close;
// Given data
R = 5;// in ohm
I = 50;// in mA
I=I*10^-3;// in A
V = R * I;// in V
Eta = 1;
V_T = 26;// in mV
V_T=V_T*10^-3;// in V
I_o = I/((%e^(V/(Eta * V_T))) - 1);// in A
disp(I_o*10^6,"Reverse saturation current in  A is");
v1 = 0.2;// in V
r = (Eta * V_T)/(I_o * (%e^(v1/(Eta * V_T))));// in ohm
disp(r,"Dynamic resistance of the diode in   is");
```

Chapter 4

Junction Contd

Scilab code Exa 4.12.1 Pinch off voltage

```
//Exa 4.12.1
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
N_D = 10^15;// in electrons/cm^3
N_D = N_D * 10^6;// in electrons/m^3
epsilon_r = 12;
epsilon_o = (36 * %pi * 10^9)^-1;
epsilon = epsilon_o * epsilon_r;
a = 3 * 10^-4;// in cm
a = a * 10^-2;// in m
V_P = (q * N_D * a^2)/( 2 * epsilon);// in V
disp(V_P,"The Pinch off voltage in V is");
// V_GS = V_P * (1-(b/a))^2
b = (1-0.707) *a;// in m
disp(b*10^6,"The value of b in  m is : ")
disp("Hence the channel width has been reduced to
   about one third of its value for V_GS = 0");//
// Note : The unit of b in the book is wrong since
```

```
the value of b is calculated in  m.
```

Scilab code Exa 4.12.2 Value of VGS and VDS

```
// Exa 4.12.2
clc;
clear;
close;
// Given data
I_DSS = 8;// in mA
V_P = -4;// in V
I_D = 3;// in mA
V_GS = V_P * (1 - sqrt(I_D/I_DSS));// in V
disp(V_GS,"The value of V_GS in V is");
V_DS = V_GS - V_P;// in V
disp(V_DS,"The value of V_DS in V is");
```

Scilab code Exa 4.12.3 Drain current

```
// Exa 4.12.3
clc;
clear;
close;
// Given data
V_P = -4;// in V
I_DSS = 9;// in mA
I_DSS = I_DSS * 10^-3;// in A
V_GS = -2;// in V
I_D = I_DSS * ((1 - (V_GS/V_P))^2);// in A
disp(I_D*10^3,"The drain current in mA is ");
```

Scilab code Exa 4.12.4 Value of transconductance

```
// Exa 4.12.4
clc;
clear;
close;
// Given data
I_DSS = 12;// in mA
I_DSS = I_DSS * 10^-3;// in A
V_P = -(6);// in V
V_GS = -(1);// in V
g_mo = (-2 * I_DSS)/V_P;// in A/V
g_m = g_mo * (1 - (V_GS/V_P));// in S
disp(g_m*10^3,"The value of transconductance in mS
    is");
```

Scilab code Exa 4.12.5 Transconductance and drain current

```
//Exa 4.12.5
clc;
clear;
close;
// Given data
I_DSS = 10;// in mA
I_DSS = I_DSS * 10^-3;// in A
V_P = -(5);// in V
V_GS = -(2.5);// in V
g_m = ((-2 * I_DSS)/V_P) * (1 -(V_GS/V_P));// in S
g_m = g_m * 10^3;// in mS
disp(g_m,"The Transconductance in mS is");
I_D = I_DSS * ((1 - (V_GS/V_P))^2);// in A
disp(I_D*10^3,"The drain current in mA is");
```

Chapter 5

Bipolar Junction Transistors

Scilab code Exa 5.8.1 Value of collector current and VCB

```
// Exa 5.8.1
clc;
clear;
close;
// Given data
V_EE = 8;// in V
V_BE = 0.7;// in V
R_E = 1.5;// in k ohm
I_E = (V_EE - V_BE)/R_E;// in mA
I_C = I_E;// in mA
disp(I_C,"The value of I_C in mA is");
V_CC = 18;// in V
R_C = 1.2;// in k
V_CB = V_CC - (I_C * R_C);// in V
disp(V_CB,"The value of V_CB in V is");
```

Scilab code Exa 5.8.2 Base current

```
// Exa 5.8.2
clc;
clear;
close;
// Given data
alpha = 0.9;
I_E = 1;// mA
I_C = alpha * I_E;// in mA
I_B = I_E - I_C;// in mA
disp(I_B,"The value of base current in mA is");
```

Scilab code Exa 5.10.1 Emitter current

```
// Exa 5.10.1
clc;
clear;
close;
// Given data
bita = 50;
I_B= 20;// in  A
I_B=I_B*10^-6;// in A
I_C= bita*I_B;// in A
I_E= I_C+I_B;// in A
I_E = I_E * 10^3;// in mA
disp(I_E,"The Emitter current in mA is");
```

Scilab code Exa 5.10.1a Base and emitter current

```
// Exa 5.10.1(a)
clc;
clear;
close;
// Given data
```

```
beta_dc = 90;
I_C = 15;// in mA
I_C = I_C * 10^-3;// in A
I_B = I_C/beta_dc;// in A
disp(I_B*10^6,"The base current in  A is");
I_E = I_C + I_B;// in A
I_E = I_E * 10^3;// in mA
disp(I_E,"The Emitter current in mA is");
alpha_dc = beta_dc/(1+beta_dc);
disp(alpha_dc,"The value of alpha_dc is");
```

Scilab code Exa 5.10.3 Change in base current

```
// Exa 5.10.3
clc;
clear;
close;
// Given data
del_ic = 1.8;// in mA
del_ie = 1.89;// in mA
alpha = del_ic / del_ie;
bita = alpha/(1 - alpha);
del_ib = del_ic/bita;// in mA
del_ib = del_ib * 10^3;// in  A
disp(del_ib,"The change in I_B in  A is");
```

Scilab code Exa 5.10.4 Transistor current

```
//Exa 5.10.4
clc;
clear;
close;
// Given data
```

```
V_CC = 10;// in V
R_C = 3;// in k
R_C= R_C*10^3;// in
bita = 100;
I_CO = 20;// in nA
I_CO = I_CO * 10^-9;// in A
V_BB = 5;// in V
R_B = 200;// in k
R_B= R_B*10^3;// in
V_BE = 0.7;// in V
// Applying KVL to the base circuit , V_BB= I_B*R_B+V_BE
I_B = (V_BB - V_BE)/R_B;// in A
disp(I_B*10^6,"The base current in  A is");
I_C = (bita * I_B) + I_CO;// in A
disp(I_C*10^3,"The collector current in mA is");
I_E = I_C + I_B;// in A
disp(I_E*10^3,"Emitter current in mA is");
V_CE = V_CC - (I_C * R_C);// in V
disp(V_CE,"Collector emitter voltage in V is");
```

Scilab code Exa 5.10.5 Collector current

```
//Exa 5.10.5
clc;
clear;
close;
// Given data
bita = 100;
I_CBO = 4;// in  A
I_B = 40;// in  A
I_C = (bita * I_B) + ((1+bita) * I_CBO);// in  A
I_C = I_C * 10^-3;// in msA
disp(I_C,"The collector current in mA is");
```

Scilab code Exa 5.10.6 Current gain

```
// Exa 5.10.6
clc;
clear;
close;
// Given data
del_IC = 1 * 10^-3;// in A
del_IB = 10 * 10^-6;// in A
CurrentGain= del_IC/del_IB;
disp(CurrentGain,"The current gain is");
del_IC= del_IC*10^3;// in mA
del_IB= del_IB*10^6;// in   A
I_B=0:0.1:50;// in   A
I_C= I_B/del_IB+del_IC;// in mA
plot(I_B,I_C)
xlabel("Base current in   A");
ylabel("Collector current in mA")
title("Transfer Characteristics ")
disp("Transfer Characteristics is shown in figure")
```

Scilab code Exa 5.10.7 Value of alphaDC and bitaDC

```
//Exa 5.10.7
clc;
clear;
close;
//Given data
I_CEo = 21;// in   A
I_CBO = 1.1;// in   A
beta_dc = (I_CEo/I_CBO) - 1;
disp(beta_dc,"Value of beta_dc is");
```

```
alpha_dc = beta_dc/(1 + beta_dc);
disp(alpha_dc,"The value of alpha_dc is");
```

Scilab code Exa 5.13.1 Value of alphaDC and emitter current

```
// Exa 5.13.1
clc;
clear;
close;
// Given data
I_CBO = 3;//in  A
I_CBO= I_CBO*10^-3;// in mA
I_C= 15;// in mA
// But it is given that I_C= 99.5% of I_E, SO
I_E= I_C/99.5*100;// in mA
alpha_dc= I_C/I_E;
disp(alpha_dc,"The value of alpha_dc is : ")
disp(I_E,"The value of I_E in mA is : ")
```

Scilab code Exa 5.13.2 Base and emitter current

```
//Exa 5.13.2
clc;
clear;
close;
//Given data
alpha_dc = 0.99;
I_CBO = 10;// in  A
I_CBO= I_CBO*10^-6;// in A
I_E = 10;// in mA
I_E= I_E*10^-3;// in A
I_C = (alpha_dc * I_E) + I_CBO;// in A
disp(I_C*10^3,"The value of I_C in mA is");
```

```
I_B = I_E - I_C;// in A
I_B = I_B * 10^6;// in  A
disp(I_B,"The value of I_B in  A is");
```

Scilab code Exa 5.13.3 Base current

```
// Exa 5.13.3
clc;
clear;
close;
// Given data
alpha_dc = 0.99;
I_C = 6;// in mA
I_C= I_C*10^-3;// in A
I_CBO = 15;// in  A
I_CBO= I_CBO*10^-6;// in A
I_E = (I_C - I_CBO)/alpha_dc;// in A
I_B = I_E - I_C;// in A
disp(I_B*10^6,"The value of I_B in  A is");
```

Scilab code Exa 5.13.5 Emitter current

```
//Exa 5.13.5
clc;
clear;
close;
// Given data
alpha_dc = 0.98;
I_CBO = 12;// in  A
I_CBO = I_CBO * 10^-6;// in A
I_B = 120;// in  A
I_B = I_B * 10^-6;// in A
beta_dc = alpha_dc/(1-alpha_dc);
```

```
I_E = ((1 + beta_dc) * I_B) + ((1 + beta_dc) * I_CBO);//in A
I_E = I_E * 10^3;// in mA
disp(I_E,"The value of I_E in mA is");
```

Scilab code Exa 5.13.6 Region of operation of Si transistor

```
//Exa 5.13.6
clc;
clear;
close;
// Given data
bita= 100;
V_BEsat= 0.8;// in V
V_CEsat= 0.2;// in V
V_BEact= 0.7;// in V
V_CC = 10;// in V
V_BB=5;// in V
R_E = 2;// in k
R_C = 3;// in k
R_B= 50;// in k
// Applying KVL to collector loop
// V_CC= I_Csat*R_C +V_CEsat +I_E*R_E and I_E= I_Csat+I_B , So
//I_B= ((V_CC-V_CEsat)-(R_C+R_E)*I_Csat)/R_E;          (i)
// Applying KVL to base loop
// V_BB-I_B*R_B -V_BEsat-I_E*R_E =0 and I_E= I_Csat+I_B , So
//V_BB-V_BEsat= R_E*I_Csat + (R_B+R_E)*I_B          (ii)
// From eq (i) and (ii)
I_B = ((V_BB-V_BEsat)*5- (V_CC-V_CEsat)*2) / ((R_B+R_E)*5 - R_E*2) ;// in mA
I_Csat= ((V_CC-V_CEsat)-R_E*I_B)/(R_C+R_E);// in mA
```

```
I_Bmin= I_Csat/bita;// in mA
if I_B<I_Bmin then
    disp("Since the value of I_B ("+string(I_B*10^3)
       +" A ) is less than the value of I_Bmin ("+
       string(I_Bmin*10^3)+" A )");
    disp("So the transistor is not in the saturation
        region. But it is conducting hence it can
       not be in cutoff.")
    disp("Therefore the transistor is in the active
       region")
end
```

Scilab code Exa 5.13.7 Value of IB IC and VCE

```
//Exa 5.13.7
clc;
clear;
close;
// Given data
bita= 100;
V_BEsat= 0.8;// in V
V_CEsat= 0.2;// in V
V_BEact= 0.7;// in V
V_CC = 10;// in V
V_BB=5;// in V
R_E = 2;// in k
R_C = 3;// in k
R_B= 50;// in k
// Applying KVL to input loop
// V_BB= I_B*R_B+(1+bita)*I_B*R_E+V_BEact or
I_B= (V_BB-V_BEact)/(R_B+(1+bita)*R_E);// in mA
I_C= bita*I_B;// in mA
// Applying KVL to collector circuit
// V_CC= I_Csat*R_C +V_CEsat +(I_C+I_B)*R_E
V_CEact= V_CC-I_B*R_E-I_C*(R_C+R_E);// in V
```

```
disp(I_B*10^3,"The value of I_B in  A is : ")
disp(I_C,"The value of I_C in mA is : ")
disp(V_CEact,"The value of V_CE in volts is : ")
```

Scilab code Exa 5.13.8 Region of operation

```
//Exa 5.13.8
clc;
clear;
close;
//Given data
bita = 100;
V_CEsat = 0.2;// in V
R_B = 150;// in kohm
R_C = 2;// in kohm
V_CC  = 10;// in V
V_BEsat = 0.8;// in V
I_B = (V_CC - V_BEsat)/R_B;// in mA
I_C = (V_CC - V_CEsat)/R_C;// in mA
I_Bmin = I_C/bita;// in mA
if I_B>I_Bmin then
    disp("Since the value of I_B ("+string(I_B*10^3)+" A) is greater than the value of I_Bmin ("+string(I_Bmin*10^3)+" A)");
    disp("So the transistor is in the saturation region.")
end
```

Scilab code Exa 5.13.9 Value of VBB

```
//Exa 5.13.9
clc;
clear;
```

```
close;
//Given data
bita = 100;
V_CE = 0.2;//in V
V_BE = 0.8;// in V
R_C= 500;// in
R_B= 44*10^3;// in
R_E= 1*10^3;// in
V_CC= 15;// in V
V_GE= -15;// in V
// Applying KVL to collector circuit
// V_CC-V_GE - I_Csat*R_C-V_CE-I_E*R_E=0, but I_Csat = bita*I_Bmin and I_E= 1+bita
I_Bmin= (V_CC-V_GE-V_CE)/(R_C*bita+(1+bita)*R_E);// in A
// Applying KVL to the base emitter circuit
// V_BB-I_Bmin*R_B-V_BE-I_E*R_E + V_CC=0
V_BB= I_Bmin*R_B + V_BE + (1+bita)*I_Bmin*R_E-V_CC;// in V
disp(I_Bmin*10^3,"The value of I_B(min) in mA is : ")
disp(V_BB,"The value of V_BB in volts is : ")
```

Scilab code Exa 5.13.10 Minimum value of RC required

```
// Exa 5.13.10
clc;
clear;
close;
// Given data
V_ECsat= 0.2;// in V
V_CC= 10;// in V
V_EBsat= 0.8;// in V

// Part (i)
```

```
bita= 100;
R_B= 220;// in k
// Applying KVL to collector circuit , V_CC= V_EC+ICRC
ICRC= V_CC-V_ECsat;// in V
// Applying KVL to input loop , V_CC= V_EBsat+I_B*R_B (i)
I_B= (V_CC-V_EBsat)/R_B;// in mA
I_C= bita*I_B;// in mA
R_Cmin= ICRC/I_C;// in k
disp(R_Cmin,"The minimum value of R_C in k is : ")
// Part (ii)
R_C= 1.2;// in k
I_Csat= ICRC/R_C;// in mA
I_B= I_Csat/bita;// in mA
// From eq (i)
R_B= (V_CC-V_EBsat)/I_B;// in k
disp(R_B,"The maximum value of R_B in k is : ")
```

Scilab code Exa 5.13.11 Value of RE

```
//Exa 5.13.11
clc;
clear;
close;
// Given data
bita= 100;
V_BEsat= 0.8;// in V
V_CEsat= 0.2;// in V
V_BEact= 0.7;// in V
V_CC = 10;// in V
R_E = 1;// in k
R_C = 2;// in k
R_B= 100;// in k
```

```
bita=100;
alpha= bita/(1+bita);
// Applying KVL to collector circuit
// V_CC= I_Csat*R_C +V_CE +R_E*I_E
// but I_E= alpha*I_Csat
I_Csat= (V_CC-V_CEsat)/(R_C+R_E*alpha);// in mA
I_Bmin= I_Csat/bita;// in mA
// Applying KVL to base loop
// V_CC= I_B*R_B +V_BEsat +I_E*R_E
// but I_E= I_Csat+I_B
I_B= (V_CC-V_BEsat-I_Csat*R_E)/(R_B+R_E);// in mA
disp(I_B*10^3,"The value of I_B in  A is : ")
disp(I_Bmin*10^3,"The minimum value of I_B in  A is : ")
if I_B>I_Bmin then
    disp("Since the value of I_B is greater than the value of I_Bmin, ")
    disp("Hence the transistor is in saturation.")
end
I_E= (1+bita)*I_Bmin;// in mA
R_E= (V_CC-V_BEact-I_Bmin*R_B)/I_E;// in k
disp(R_E,"The value of R_E in k  is : ")
disp("So R_E should be greater than this value in order to bring the transistor just out of saturation ")
```

Scilab code Exa 5.13.12 Collector voltage and minimum value of bita

```
// Exa 5.13.12
clc;
clear;
close;
// Given data
V_CC = 9;// in V
V_BE = 0.8;// in V
```

```
V_CE = 0.2;// in V
R_B = 50;// in  k
R_C=2;// in  k
R_E = 1;// in  k
bita=70;
// Applying KVL to input loop, V_CC= I_B*R_B +V_BE + I_E*R_E
// V_CC- V_BE= (R_B+R_E)*I_B + R_E*I_C           (i)
// Applying KVL to output loop, V_CC= R_C*I_C +V_CE +I_C*R_E +I_B*R_E
//I_B = ((V_CC- V_CE)-(R_C+R_E)*I_C)/R_E           (ii)
// From eq (i) and (ii)
I_C= ( (V_CC- V_BE)-(R_B+R_E)* (V_CC- V_CE)/R_E) /(1-(R_B+R_E)*(R_C+R_E));// in mA
I_B = ((V_CC- V_CE)-(R_C+R_E)*I_C)/R_E// in mA
I_Bmin= I_C/bita;// in mA
if I_B>I_Bmin then
    disp("Since the value of I_B ("+string(I_B)+" mA) is greater than the value of I_Bmin ("+string(I_Bmin)+" mA)")
    disp("So the transistor is in saturation ")
end
V_C= V_CC-I_C*R_C;// in V
disp(V_C,"The value of collector voltage in volts is : ")
bita= I_C/I_B;
disp(bita,"The minimum value of bita that will change the state of the trasistor is : ")
```

Scilab code Exa 5.21.1 Inductor circuit

```
// Exa 5.21.1
clc;
clear;
```

```
close;
// Given data
O_V = 5;// output voltage in V
V_D = 1.5;//voltage drop in V
R = (O_V - V_D)/O_V;
R = R * 10^3;// in ohm
disp(R,"The resistance value in   is");
disp("As this is not standard value, use R=680
   which is a standard value")
```