Scilab Textbook Companion for
Fundamentals of Electronic Devices
by P. Raja and P. Sharma[1]

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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List of Scilab Codes

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Chapter 1

Semiconductor Materials and Crystal Properties

Scilab code Exa 1.18.3 Volume density of Si

```
1  // Exa 1.18.3
2  clc;
3  clear;
4  close;
5  // Given data
6  At = 28;// Atomic weight
7  n = 4;
8  N_A = 6.023*10^23;
9  a = 5.3;// in
10 a = a * 10^-10;// in m
11 m = At/N_A;// in gm
12 m = m*10^-3;// in kg
13 V = (a)^3;// in m^3
14 Rho = (m*n)/V;// in gm/m^3
15 Rho = Rho * 10^-3;// in kg/m^3
16 disp(Rho,"The volume density in kg/m^3 is");
```

Scilab code Exa 1.18.4 Density of copper crystal

```
1  // Exa 1.18.4
2  clc;
3  clear;
4  close;
5  // Given data
6  r = 1.278;// in
7  a = (4*r)/(sqrt(2));// in
8  a = a * 10^-10;// in m
9  V = (a)^3;// in m^3
10 At = 63.5;// atomic weight
11 N_A = 6.023*10^23;
12 m = At/N_A;// in gm
13 m = m * 10^-3;// in kg
14 n = 4;
15 Rho = (m*n)/V;// in gm/m^3
16 Rho = Rho * 10^-3;// in kg/m^3
17 disp(Rho,"The density of copper crystal in kg/m^3 is
      ");
```

Scilab code Exa 1.21.1 Wavelength of X ray

```
1  // Exa 1.21.1
2  clc;
3  clear;
4  close;
5  // Given data
6  d = 2.82;// in
7  d = d * 10^-10;// in m
8  n = 1;
9  theta = 10;// in degree
10 //Formula 2*d*sin(theta) = n*lembda;
11 lembda = 2*d*sind(theta);// in m
12 lembda = lembda * 10^10;// in
```

```
13 disp(lembda,"The wavelength of X-ray in    is ");
```

Scilab code Exa 1.21.2 Spacing of atomic layer

```
1  // Exa 1.21.2
2  clc;
3  clear;
4  close;
5  // Given data
6  lembda = 1.6;// in
7  lembda = lembda * 10^-10;// in m
8  theta = 14.2;// in degree
9  n = 1;
10 //Formula 2*d*sin(theta) = n*lembda;
11 d = (n*lembda)/(2*sind(theta));// in m
12 d = d * 10^10;// in
13 disp(d,"The spacing of atomic layer in the crystal
       in    is");
```

Scilab code Exa 1.21.3 Interplaner spacing

```
1  // Exa 1.21.3
2  clc;
3  clear;
4  close;
5  // Given data
6  n = 1;
7  theta = 30;// in degree
8  lembda = 1.78;// in
9  lembda = lembda * 10^-10;// in m
10 //Formula 2*d*sin(theta) = n*lembda;
11 d = (n*lembda)/(2*sind(theta));// in m
12 d = d * 10^10;// in
```

```
13 disp(d,"The interplaner spacing in     is");
```

Scilab code Exa 1.21.4 Interplaner spacing

```
1 // Exa 1.21.4
2 clc;
3 clear;
4 close;
5 // Given data
6 lembda = 0.58;// in
7 n = 1;
8 theta1 = 6.45;// in degree
9 d = (n*lembda)/(2*sind(theta1));// in
10 disp(d,"Part (i) : At angle of 6.45  , Interplaner
      spacing of the crystal in    is ");
11 theta2 = 9.15;// in degree
12 d1 = (n*lembda)/(2*sind(theta2));// in
13 disp(d1,"Part(ii) : At angle of 9.15  , Interplaner
      spacing of the crystal in    is ");
14 theta3 = 13;// in degree
15 n2 = 1;
16 d2 = (n2*lembda)/(2*sind(theta3));// in
17 disp(d2,"Part(iii) : At angle of 13  , Interplaner
      spacing of the crystal in    is ");
18 // For
19 n=2;
20 d2 = (n*lembda)/(2*sind(theta3));// in
21 disp(d2,"Part (iv) : The interplaner spacing in
      is : ")
22 disp(d1,"The interplaner spacing for some other set
      of reflecting in    is : ")
```

Scilab code Exa 1.21.5 Glacing angle

11

```
1 // Exa 1.21.5
2 clc;
3 clear;
4 close;
5 // Given data
6 a = 2.814;// in
7 h = 1;
8 k = 0;
9 l = 0;
10 d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in
11 n = 2;
12 lembda = 0.710;// in
13 //Formula 2*d*sin(theta) = n*lembda;
14 theta = asind(n*lembda/(2*d) );// in degree
15 disp(theta,"The glacing angle in degree is");
```

Scilab code Exa 1.21.6 Wavelength of X ray

```
1 // Exa 1.21.6
2 clc;
3 clear;
4 close;
5 // Given data
6 a = 3.65;// in
7 h = 1;
8 k = 0;
9 l = 0;
10 d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in
11 n = 1;
12 theta = 60;// in degree
13 //Formula 2*d*sin(theta) = n*lembda;
14 lambda = 2*d*sind(theta);// in
15 disp(lambda,"Wavelength of X ray in      is");
```

Scilab code Exa 1.21.7 Glacing angle

```
1  // Exa 1.21.7
2  clc;
3  clear;
4  close;
5  // Given data
6  lembda = 1.54;// in
7  lembda= lembda*10^-8;// in cm
8  At = 63.54;// atomic weight
9  density = 9.024;// in gm/cc
10 n = 1;
11 N_A = 6.023*10^23;
12 m = At/N_A;// mass
13 a =(density*m)^(1/3);// in cm
14 h = 1;
15 k = 0;
16 l = 0;
17 d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in cm
18 n = 1;
19 //Formula 2*d*sin(theta) = n*lembda;
20 theta = asind( (lembda)/(2*d) );// in degree
21 disp(theta,"The glancing angle in degree is");
```

Scilab code Exa 1.21.8 Glacing angle

```
1  // Exa 1.21.8
2  clc;
3  clear;
4  close;
5  // Given data
6  a = 3.615;// in
```

13

```
7  theta = 22;// in degree
8  n = 1;
9  h = 1;
10 k = 1;
11 l = 1;
12 d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in
13 // 2*d*sin(theta) = n*lembda;
14 lembda = 2*d*sind(theta);// in
15 disp(lembda,"The wavelength in    is");
16 n = 2;
17 //Formula 2*d*sin(theta) = n*lembda;
18 theta = asind(n*lembda/(2*d) );// in degree
19 disp(theta,"The glacing angle for second order in
       degree is");
20 disp("To get the 2nd order spectrum the position of
       the detector should be "+string(2*theta)+"   ")
```

Scilab code Exa 1.21.9 Lattice constant

```
1  // Exa 1.21.9
2  clc;
3  clear;
4  close;
5  // Given data
6  n = 1;
7  lembda = 1.54;// in
8  theta = 21.7;// in degree
9  //Formula 2*d*sin(theta) = n*lembda;
10 d = (lembda*n)/(2*sind(theta));// in
11 h = 1;
12 k = 1;
13 l = 1;
14 // Formula d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2)
       ));
15 a =  d*(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in
```

```
16  disp(a,"Lattice  constant  in    is");
```

Scilab code Exa 1.22.1 Distance between d211 planes

```
1  // Exa  1.22.1
2  clc;
3  clear;
4  close;
5  // Given  data
6  a = 4.8;// in
7  h = 2;
8  k = 1;
9  l = 1;
10  d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in
11  disp(d,"The  distance  between  d_211  plains  in    is")
       ;
```

Scilab code Exa 1.22.2 Density

```
1  // Exa  1.22.2
2  clc;
3  clear;
4  close;
5  // Given  data
6  r = 1.28;// in
7  //Formula  r = (a*sqrt(2))/4;
8  a = (4*r)/(sqrt(2));// in
9  a = a * 10^-8;// in  cm
10  n = 4;
11  M = 63.5;
12  N_A = 6.023*10^23;
13  Rho = (n*M)/(N_A*((a)^3));// in  gm/cc
```

```
14  disp(Rho,"The density in gm/cc is");
```

Scilab code Exa 1.22.3 Number of atom per unit cell

```
1  // Exa 1.22.3
2  clc;
3  clear;
4  close;
5  // Given data
6  a = 2.9;// in
7  a = a * 10^-8;// in cm
8  Rho = 7.87;// in gm/cc
9  N_A = 6.023*10^23;
10 M = 55.85
11 // Rho = (n*M)/(N_A*((a)^3))
12 n = (Rho*N_A*((a)^3))/M;// in atoms per unit cell
13 disp(round(n),"The number of atoms per unit cell is
       ");
```

Scilab code Exa 1.22.4 Radius of element atom

```
1  // Exa 1.22.4
2  clc;
3  clear;
4  close;
5  // Given data
6  M =60;// in gm/mole
7  Rho = 6.23;// in gm/cc
8  n = 4;
9  N_A = 6.023*10^23;
10 // Rho = (n*M)/(N_A*((a)^3));
11 a = ( (n*M)/(N_A*Rho) )^(1/3);// in cm
12 r = (a*sqrt(2))/4;// in cm
```

16

```
13 r = r * 10^8;// in
14 disp(r,"The radius in      is");
```

Scilab code Exa 1.22.5 Packing factor

```
1 // Exa 1.22.5
2 clc;
3 clear;
4 close;
5 // Given data
6 Rho = 5.96;// in gm/cc
7 M = 50;
8 n = 2;
9 N_A = 6.023*10^23;
10 //Formula Rho = (n*M)/(N_A*((a)^3));
11 a = ( (n*M)/(N_A*Rho) )^(1/3);// in cm
12 r = (a*sqrt(3))/4;// in cm
13 P_F = (2*(4/3)*%pi*((r)^3))/((a)^3);// Packing
      factor
14 disp(P_F,"The Packing factor is");
```

Scilab code Exa 1.22.6 Number of unit cell

```
1 // Exa 1.22.6
2 clc;
3 clear;
4 close;
5 // Given data
6 d = 5.2;// in gm/cc
7 n = 2;
8 M = 120;
9 N_A = 6.023*10^23;
10 m = M/N_A;//mass of 1 atom in gm
```

```
11  m = n*m;//mass of unit cell in gm
12  g = 20;// in gm
13  m = g/m;// in unit cells
14  disp(m,"The number of unit cell in its 20 gm is : ")
        ;
```

Scilab code Exa 1.22.7 Distance between K and F

```
1  // Exa 1.22.7
2  clc;
3  clear;
4  close;
5  // Given data
6  Rho = 2.48;// in gm/cc
7  K = 39;// molecular weight of K
8  F = 19;  // molecular weight of F
9  M = K+F;// molecular weight of KF
10  n = 4;
11  N_A = 6.023*10^23;
12  //Formula Rho = (n*M)/(N_A*((a)^3));
13  a = ( (n*M)/(N_A*Rho) )^(1/3);// in cm
14  a = a * 10^8;// in
15  r = (a*sqrt(2))/4;// in
16  r = 2*r;// in
17  disp(r,"The distance between ions in    is");
```

Chapter 2

Energy Bands And Charge Carriers in Semiconductor

Scilab code Exa 2.6.1 Energy Gap

```scilab
1  // Exa 2.6.1
2  clc;
3  clear;
4  close;
5  // Given data
6  lembda = 11000; // in
7  lembda = lembda * 10^-10; // in m
8  h = 6.625*10^-34;
9  c = 3*10^8; // in m/s
10 e = 1.6*10^-19; // in C
11 E_g = (h*c)/(lembda*e); // in eV
12 disp(E_g,"The energy gap in eV is");
13
14 // Note: In the book, there is calculation error to
      evaluate the value of Eg, so the answer in the
      book is wrong and the answer of coding is correct
      .
```

Scilab code Exa 2.6.2 Wavelength

```
1  // Exa 2.6.2
2  clc;
3  clear;
4  close;
5  // Given data
6  E_g = 0.75;// in eV
7  e = 1.6*10^-19;// in C
8  h = 6.63*10^-34;// in J
9  c = 3*10^8;// in m/s
10 //Formula E_g = (h*c)/(lembda*e);
11 lembda = (h*c)/(E_g*e);// in m
12 lembda = lembda * 10^10;// in
13 disp(lembda,"The wavelength in    is");
```

Scilab code Exa 2.15.1 Position of fermi level

```
1  //Exa 2.15.1
2  clc;
3  clear;
4  close;
5  // Given data
6  del_E = 0.3;// in eV
7  T1 = 300;// in K
8  T2 = 330;// in K
9  // del_E = K * T1 * log(N/N_c) where del_E= E_C-E_F
10 // del_E1 = K * T2 * log(N/N_c) where del_E1= E_C-
     E_F at T= 330   K
11 del_E1 = del_E*(T2/T1);// in eV
12 disp("The Fermi level will be "+string(del_E1)+" eV
     below the conduction band")
```

20

Scilab code Exa 2.15.2 Thermal equilibrium electron concentration

```
1  //Exa 2.15.2
2  clc;
3  clear;
4  close;
5  // Given data
6  N_c = 2.8 * 10^19;// in cm^-3
7  del_E = 0.25;// fermi energy in eV
8  KT = 0.0259;
9  f_F = exp(-(del_E)/KT);
10 disp(f_F,"The probbaility in the condition band is
      occupied by an electron is ");
11 n_o = N_c * exp(-(del_E)/KT);// in cm^-3
12 disp(n_o,"The thermal equilibrium electron
      concentration in cm^-3 is");
```

Scilab code Exa 2.15.3 Thermal equilibrium hole concentration

```
1  //Exa2.15.3
2  clc;
3  clear;
4  close;
5  // Given data
6  T1 = 300;// in K
7  T2 = 400;// in K
8  del_E = 0.27;// Fermi level in eV
9  KT = (0.0259) * (T2/T1);// in eV
10 N_v = 1.04 * 10^19;// in cm^-3
11 N_v = N_v * (T2/T1)^(3/2);// in cm^-3
12 p_o = N_v * exp(-(del_E)/KT);// in per cm^3
```

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

Scilab code Exa 2.16.1 Mobility of electrons in copper

```
1  // Exa 2.16.1
2  clc;
3  clear;
4  close;
5  // Given data
6  At = 63.5;// atomic weight
7  Rho = 1.7*10^-6;// in ohm cm
8  d = 8.96;// in gm/cc
9  N_A = 6.02*10^23;// in /gm.mole
10 e = 1.6*10^-19;// in C
11 n = (N_A/At)*d;
12 Miu_e = 1/(Rho*n*e);// in cm^2/volt.sec
13 disp(Miu_e ,"The electron mobility in cm^2/volt-sec
      is");
```

Scilab code Exa 2.16.2 Charge density of free electrons

```
1  // Exa 2.16.2
2  clc;
3  clear;
4  close;
5  format('e',9)
6  // Given data
7  l = 0.1;// in m
8  A = 1.7;// in mm^2
9  A = A * 10^-6;// in m^2
10 R = 0.1;// in ohm
11 At = 63.5;// atomic weight
```

```
12  N_A = 6.02*10^23;
13  d = 8.96; // in gm/cc
14  n = (N_A/At)*d; // in /cc
15  n = n * 10^6; // in /m^3
16  // Formula R = Rho*(l/A);
17  Rho = (R*A)/l; // in ohm m
18  Sigma = 1/Rho; // in mho/m
19  e = 1.6*10^-19;
20  // Formula Sigma = n*e*Miu_e
21  Miu_e = Sigma/(n*e); // in m^2/V.sec
22  disp(Miu_e,"The mobility in m^2/V-sec is");
```

Scilab code Exa 2.16.3 Drift velocity

```
1  // Exa 2.16.3
2  clc;
3  clear;
4  close;
5  // Given data
6  format('v',7)
7  d = 10.5; // in gm/cc
8  At = 108; // atomic weight
9  N_A = 6.025*10^23; // in /gm mole
10 r = 10^-3; // in m
11 q = 1.6*10^-19; // in C
12 n = (N_A/At)*d; // in /cm^3
13 n = n * 10^6; // in /m^3
14 A = %pi*((r)^2); // in m^2
15 I = 2; // in A
16 // I = q*n*A*v;
17 v = I/(n*q*A); // in m/s
18 disp(v,"The drift velocity in m/s is");
19
20 // Note: There is calculation error to find the
       value of drift velocity (i.e v), so the answer in
```

Scilab code Exa 2.16.4 Mobily of charge carriers

```
1  // Exa 2.16.4
2  clc;
3  clear;
4  close;
5  format('e',10)
6  // Given data
7  d = 1.03;// in mm
8  d = d *10^-3;// in m
9  r = d/2;// in m
10 R = 6.51;// in ohm
11 l = 300;// in mm
12 e = 1.6*10^-19;
13 n = 8.4*10^28;// in /m^&3
14 A = %pi*r^2;
15 // R = Rho*(l/A);
16 Rho = (R* A)/l;//in ohm m
17 Sigma = 1/Rho;// in mho/m
18 disp(Sigma,"The conductivity of copper in mho/m is")
     ;
19 //Formula sigma = n*e*Miu_e
20 Miu_e = Sigma/(n*e);// in m^2/V.sec
21 disp(Miu_e,"The mobility in m^2/V-sec is");
```

Scilab code Exa 2.16.5 Resistivity of Copper

```
1  // Exa 2.16.5
2  clc;
3  clear;
4  close;
```

```
5  format('e',8)
6  // Given data
7  At = 63.5;// atomic weight
8  d = 8.96;// in gm/cc
9  Miu_e = 43.28;// in cm^2/V.sec
10 N_A = 6.02*10^23;// in /gm mole
11 e = 1.6*10^-19;// in C
12 n = (N_A/At)*d;// in /cc
13 Rho = 1/(n*e*Miu_e);// in ohm-cm
14 disp(Rho,"The resistivity in ohm-cm is");
```

Scilab code Exa 2.17.1 Conductivity of pure Si

```
1  // Exa 2.17.1
2  clc;
3  clear;
4  close;
5  format('e',9)
6  // Given data
7  Mu_e = 1500;// in cm^2/volt sec
8  Mu_h = 500;// in cm^2/volt sec
9  n_i = 1.6 * 10^10;// in per cm^3
10 e = 1.6 * 10^-19;// in C
11 Sigma = n_i * (Mu_e + Mu_h) * e;// in mho/cm
12 disp(Sigma,"The conductivity of pure semiconductor
       in mho/cm is");
```

Scilab code Exa 2.17.2 Number of donor atoms

```
1  // Exa 2.17.2
2  clc;
3  clear;
4  close;
```

```
5  // Given data
6  Rho = 10;// in  −cm
7  Mu_d = 500;// in cm^2/v.s.
8  e = 1.6*10^-19;
9  n_d = 1/(Rho * e * Mu_d);// in per cm^3
10 disp(n_d,"The number of donor atom must be added to
      achieve in per cm^3 is ");
```

Scilab code Exa 2.17.3 Conductivity of specimen

```
1  //Exa 2.17.3
2  clc;
3  clear;
4  close;
5  //Given data
6  AvagadroNumber = 6.02 * 10^23;// in atoms/gm.mole
7  at_Ge = 72.6;// atom weight of Ge
8  e = 1.6 * 10^-19;// in C
9  D_Ge = 5.32;// density of Ge in gm/c.c
10 Mu = 3800;// in cm^2/v.s.
11 C_Ge = (AvagadroNumber/at_Ge) * D_Ge;//
      concentration of Ge atoms in per cm^3
12 n_d = C_Ge/10^8;// in per cc
13 Sigma = n_d * Mu * e;// in mho/cm
14 disp(Sigma,"The conductivity in mho/cm is");
```

Scilab code Exa 2.17.4 Mobility of electrons in Ge

```
1  // Exa2.17.4
2  clc;
3  clear;
4  close;
5  // Given data
```

```
 6  Rho = 0.3623 * 10^-3;// in Ohm m
 7  Sigma = 1/Rho;//in mho/m
 8  D = 4.42 * 10^28;// Ge density in atom/m^3
 9  n_d = D / 10^6;// in atom/m^3
10  e = 1.6 * 10^-19;// in C
11  Mu = Sigma/(n_d * e);// in m^2/V.sec
12  disp(Mu,"The mobility of electron in germanium in m
        ^2/V.sec is");
```

Scilab code Exa 2.17.5 Density and mobility of holes

```
 1  //Exa 2.17.5
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  AvagadroNumber = 6.025 * 10^26;// in kg.Mole
 7  W = 72.59;// atomic weight of Ge
 8  D = 5.36 * 10^3;//density of Ge in kg/m^3
 9  Rho = 0.42;// resistivity in Ohm m
10  e = 1.6 * 10^-19;// in C
11  Sigma = 1/Rho;// in mho/m
12  n = (AvagadroNumber/W) * D;// number of Ge atoms
        present per unit volume
13  // Holes per unit volume, H = n*10^-6%
14  H= n*10^-8;
15  a=H;
16  // Formula sigma= a*e*Mu_h
17  Mu_h = Sigma/(a * e);// in m^2/V.sec
18  disp(Mu_h,"Mobility of holes in m^2/V.sec is");
```

Scilab code Exa 2.17.6 Current produced

```
1  //Exa 2.17.6
2  clc;
3  clear;
4  close;
5  // Given data
6  e = 1.6 * 10^-19;// in C
7  n_i = 2 * 10^19;// in /m^3
8  Mu_e = 0.36;// in m^2/v.s
9  Mu_h = 0.17;// in m^2/v.s
10 A = 1 * 10^-4;// in  m^2
11 V = 2;//in volts
12 l = 0.3;// in mm
13 l = l * 10^-3;// in m
14 E=V/l;// in volt/m
15 Sigma = n_i * e * (Mu_e + Mu_h);// in mho/m
16 // J = I/A = Sigma * E
17 I= Sigma*E*A;
18 disp(I,"The current produced in a small germanium
       plate in amp is");
```

Scilab code Exa 2.17.7 Resistivity of dopped Ge

```
1  // Exa 2.17.7
2  clc;
3  clear;
4  close;
5  format('e',10)
6  // Given data
7  D = 4.2 * 10^28;//density of Ge atoms in atoms/m^3
8  N_d = D / 10^6;// in atoms/m^3
9  e = 1.6 * 10^-19;// in C
10 Mu_e = 0.36;// in m^2/vs
11 Sigma_n = N_d *  e * Mu_e;// in mho/m
12 Rho_n = 1/Sigma_n;// in ohm m
13 disp(Rho_n,"The resistivity of drop Ge in ohm m is "
```

```
    );
```

Scilab code Exa 2.17.8 Current produced in Ge sample

```
1  // Exa 2.17.8
2  clc ;
3  clear ;
4  close ;
5  // given data
6  e = 1.6 * 10^-19;// in C
7  n_i = 1 * 10^19;// in per m^3
8  Mu_e = 0.36;// in m^2/volt.sec
9  Mu_h = 0.17;// in m^2/volt.sec
10 A = 2;// in cm^2
11 A = A * 10^-4;// im m^2
12 t = 0.1;// in mm
13 t = t * 10^-3;// in m
14 V = 4;// in volts
15 Sigma_i = n_i * e * (Mu_e + Mu_h);// in mho/m
16 J = Sigma_i * (V/t);// in Amp/m^2
17 I = J * A;// in Amp
18 disp(I,"The current produced in a Ge sample in Amp
      is");
```

Scilab code Exa 2.17.9 Conductivity of pure Si

```
1  //Exa 2.17.9
2  clc ;
3  clear ;
4  close ;
5  format('e',9)
6  // Given data
7  e = 1.6 * 10^-19;// in C
```

```
 8  Mu_h = 500;// in cm^2/V.s.
 9  Mu_e = 1500;// in cm^2/V.s.
10  n_i = 1.6 * 10^10;// in per cm^3
11  Sigma_i = n_i * e * ( Mu_h + Mu_e);// in mho/cm
12  disp(Sigma_i,"Conductivity of pure silicon at room
        temperature in mho/cm is");
```

Scilab code Exa 2.19.1 Hall voltage produced

```
 1  //Exa 2.19.1
 2  clc;
 3  clear;
 4  close;
 5  //Given data
 6  l= 0.50*10^-2;// width of ribbon in m
 7  d= 0.10*10^-3;// thickness of ribbon in m
 8  A= l*d;// area of ribbon in m^2
 9  B = 0.8;// in Tesla
10  D = 10.5;//density in gm/cc
11  I = 2;// in amp
12  q = 1.6 * 10^-19;// in C
13  n=6*10^28;// number of elec. per m^3
14  V_H = ( I * B * d)/(n * q * A);// in volts
15  disp(V_H,"The hall Voltage produced in volts is");
```

Scilab code Exa 2.19.2 Hall coefficient and mobility of electrons

```
 1  //Exa 2.19.2
 2  clc;
 3  clear;
 4  close;
 5  format('e',8)
 6  // Given data
```

```
 7  l = 1;// in m
 8  d = 1;// in cm
 9  d = d * 10^-2;// in m
10  W = 1;// in mm
11  W = W * 10^-3;// in m
12  A = d * W;// in m^2
13  I= 1;// in Amp
14  B = 1;// Tesla
15  V_H = 0.074 * 10^-6;// in Volts
16  Sigma = 5.8 * 10^7;// in mho/m
17  R_H = (V_H * A)/(B*I*d);// in m^3/c
18  disp(R_H,"The hall coefficient in m^3/c is");
19  Mu = Sigma * R_H;// in m^2/volt.sec
20  disp(Mu,"The mobility  of electrons in copper in m
        ^2/volt-sec is ");
```

Scilab code Exa 2.20.1 Ratio of electron to hole concentration

```
 1  //Exa2.20.1
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  n_i = 1.4 * 10^18;// in /m^3
 7  n_D = 1.4 * 10^24;// in /m^3
 8  n=n_D;// in /m^3
 9  p = n_i^2/n;// in /m^3
10  R = n/p;
11  disp(R,"The ratio of electrons to hole concentration
        is");
```

Scilab code Exa 2.20.2 Hall angle

```
1  //Exa  2.20.2
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  B = 0.48; // in wb/m^2
7  R_H = 3.55 * 10^-4; // in m^3/c
8  Rho = 0.00912; // in ohm-m
9  Sigma = 1/Rho; // in (ohm-m)^-1
10 theta_H = atand( Sigma * B * R_H); // in degree
11 disp( theta_H ,"The  hall  angle  for  a  hall  coefficient
       in  degree  is ") ;
```

Scilab code Exa 2.20.3 Mobility and density of charge carriers

```
1  //Exa  2.20.3
2  clc ;
3  clear ;
4  close ;
5  //Given data
6  R = 9 * 10^-3; // in ohm-m
7  R_H = 3.6 * 10^-4; // in m^3
8  e = 1.6 * 10^-19; // in C
9  Sigma = 1/R; // in (ohm-m)^-1
10 Rho = 1/R_H; // in coulomb/m^3
11 n = Rho/e; // in /m^3
12 disp(n ,"Density  of  charge  carriers  in  per  m^3  is ") ;
13 Mu = Sigma * R_H; // in m^2/v-s
14 disp(Mu ,"Mobility  of  charge  carriers  in  m^2/V-s  is ")
       ;
```

Scilab code Exa 2.24.1 Current density in speciman

```
1  //Exa  2.24.1
2  clc;
3  clear;
4  close;
5  //  Given  data
6  e = 1.6 * 10^-19;//  in  C
7  R_H = 0.0145;//  in  m^3/coulomb
8  Mu_e = 0.36;//  in  m^2/v-s
9  E = 100;//  in  V/m
10  n = 1/(e * R_H);//  in  /m^3
11  J = n * e * Mu_e * E;//  in  A/m^2
12  disp(J,"The  current  density  of  specimen  in  A/m^2  is"
       );
```

Scilab code Exa 2.24.2 Relaxation time and resistivity of conductor

```
1  //Exa  2.24.2
2  clc;
3  clear;
4  close;
5  //Given  data
6  Mu_e = 7.04 * 10^-3;//  in  m^2/v-s
7  m = 9.1 * 10^-31;
8  E_F = 5.5;//  in  eV
9  n = 5.8 * 10^28;
10  e = 1.6 * 10^-19;//  in  C
11  Torque = (Mu_e/e) * m;//  in  sec
12  disp(Torque,"Relaxation  Time  in  sec  is  ");
13  Rho = 1 /(n * e * Mu_e);//  in  ohm-m
14  disp(Rho,"Resistivity  of  conductor  in  ohm-m  is  ");
15  V_F = sqrt((2 * E_F * e)/m);//  in  m/s
16  disp(V_F,"Velocity  of  electrons  with  fermi-energy  in
       m/s  is");
```

Scilab code Exa 2.24.3 Temperature

```
1  //Exa 2.24.3
2  clc;
3  clear;
4  close;
5  format('v',5)
6  // Given data
7  E= 5.95;// in eV
8  EF= 6.25;// in eV
9  delE= 0.01;
10  // delE= 1-1/(1+exp((E-EF)/KT))
11  K=1.381*10^-23;// Boltzman Constant in J/K
12  T = ((E-EF)/log(1/(1-delE) -1)*1.6*10^-19)/K;// in K
13  T= round(T)
14  disp(T,"The temperature in K is : ")
```

Scilab code Exa 2.24.4 Thermal equilibrium hole concentration

```
1  //Exa 2.24.4
2  clc;
3  clear;
4  close;
5  // Given data
6  N_V = 1.04 * 10^19;// in cm^-3
7  T1 = 300;// in K
8  T2 = 400;// in K
9  del_E = 0.27;// in eV
10  N_V = N_V * (T2/T1)^1.5;// in cm^-3
11  KT = (0.0259) * (T2/T1);// in eV
12  P_o = N_V * exp(-(del_E)/KT);// in cm^-3
```

```
13  disp ( P_o ,"The thermal equilibrium hole concentration
        in silicon in cm^−3 is ");
```

Scilab code Exa 2.24.5 Minimum donor concentration

```
1  //Exa 2.24.5
2  clc ;
3  clear ;
4  close ;
5  //Given data
6  N_c = 2.8 * 10^19;
7  N_V = 1.04 *10^19;
8  T1 = 550;// in K
9  T2 = 300;// in K
10 E_g = 1.12;
11 KT = (0.0259) ;
12 n_i = sqrt(N_c *N_V *(T1/T2)^3* exp(-(E_g)/KT*T2/T1)
        );// in cm^−3
13 // n_o = N_d/2 + sqrt((N_d/2)^2 + (n_i)^2)
14 // 1.05*N_d −N_d/2= sqrt((N_d/2)^2 + (n_i)^2)
15 N_d=sqrt((n_i)^2/((0.55)^2-1/4));
16 disp (N_d ,"Minimum donor concentration required in cm
        ^−3 is");
```

Scilab code Exa 2.24.6 Quasi fermi energy levels

```
1  //Exa 2.24.6
2  clc ;
3  clear ;
4  close ;
5  //Given data
6  T = 300;// in K
7  n_o = 10^15;// in cm^−3
```

```
 8  n_i = 10^10;// in cm^-3
 9  p_o = 10^5;// in cm^-3
10  del_n = 10^13;// in cm^-3
11  del_p = del_n;// in cm^-3
12  KT = 0.0259;// in eV
13  delta_E1= KT*log(n_o/n_i);// value of E_F-E_Fi in eV
14  delta_E2= KT*log((n_o+del_n)/n_i);// value of E_Fn-
        E_Fi in eV
15  delta_E3= KT*log((p_o+del_p)/n_i);// value of E_Fi-
        E_Fp in eV
16  disp(delta_E1,"The Fermi level for thermal
        equillibrium in eV is : ")
17  disp(delta_E2,"The quase-Fermi level for electrons
        in non equillibrium in eV is : ")
18  disp(delta_E3,"The quasi-Fermi level for holes in
        non equillibrium in eV is : ")
19  disp("The quasi-Fermi level for electrons is above
        E_Fi ")
20  disp("While the quasi-Fermi level for holes is below
         E_Fi")
```

Chapter 3

Excess Carriers In Semiconductor

Scilab code Exa 3.21.1 Hole concentration at equilibrium

```
1  // Exa 3.21.1
2  clc;
3  clear;
4  close;
5  format('e',9)
6  // Given data
7  N_d = 10^17; // atoms/cm^3
8  n_i = 1.5 * 10^10; // in /cm^3
9  n_o = 10^17; // in cm^3
10 // p_o * n_o = (n_i)^2
11 p_o = (n_i)^2 / n_o; //in holes/cm^3
12 disp(p_o,"The holes concentration at equilibrium in
      holes/cm^3 is");
```

Scilab code Exa 3.21.3 Fermi level

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```
1 // Exa 3.21.3
2 clc;
3 clear;
4 close;
5 // Given data
6 n_i = 1.5 * 10 ^10;// in /cm^3 for silicon
7 N_d = 10^17;// in atoms/cm^3
8 n_o = 10^17;// electrons/cm^3
9 KT = 0.0259;
10 // E_r - E_i = KT * log(n_o/n_i)
11 del_E = KT * log(n_o/n_i);// in eV
12 disp("The energy band for this type material is Ei +
       "+string(del_E)+" eV");
```

Scilab code Exa 3.21.4 Diffusion coefficients of electrons and holes

```
1 // Exa 3.21.4
2 clc;
3 clear;
4 close;
5 format('e',9)
6 // Given data
7 K = 1.38 * 10^-23;// in J/K
8 T = 27;// in degree
9 T = T + 273;// in K
10 e = 1.6 * 10^-19;// in C
11 Mu_e = 0.17;// in m^2/v-s
12 Mu_e1 = 0.025;// in m^2/v-s
13 D_n = ((K * T)/e) * Mu_e;// in m^2/s
14 disp(D_n,"The diffusion coefficient of electrons in
     m^2/s is");
15 D_p = ((K * T)/e) * Mu_e1;// in m^2/s
16 disp(D_p,"The diffusion coefficient of  holes in m
       ^2/s is ");
```

Scilab code Exa 3.21.5 Diffusion length

```
1  // Exa 3.21.5
2  clc;
3  clear;
4  close;
5  format('e',9)
6  // Given data
7  Mu_n = 0.15;// in m^2/v-s
8  K = 1.38 * 10^-23; // in J/K
9  T = 300;// in K
10 del_n = 10^20;// in per m^3
11 Toh_n = 10^-7;// in s
12 e = 1.6 * 10^-19;// in C
13 D_n = Mu_n * ((K * T)/e);// in m^2/s
14 disp(D_n,"The diffusion coefficient in m^2/s is");
15 L_n = sqrt(D_n * Toh_n);// in m
16 disp(L_n,"The Diffusion length in m is");
17 J_n = (e * D_n * del_n)/L_n;// in A/m^2
18 disp(J_n,"The diffusion current density in A/m^2 is"
      );
19 // Note : The value of diffusion coefficient in the
      book is wrong.
```

Scilab code Exa 3.21.6 Concentration of holes and electrons

```
1  // Exa 3.21.6
2  clc;
3  clear;
4  close;
5  // Given data
6  Sigma = 0.1;// in (ohm-m)^-1
```

```
 7 Mu_n = 1300;
 8 n_i = 1.5 * 10^10;
 9 q = 1.6 * 10^-19;// in C
10 n_n = Sigma/(Mu_n * q);// in electrons/cm^3
11 disp(n_n*10^6,"The concentration of electrons per m
      ^3 is");
12 p_n = (n_i)^2/n_n;// in per cm^3
13 p_n = p_n * 10^6;// in perm^3
14 disp(p_n,"The concentration of holes per m^3 is");
```

Scilab code Exa 3.21.7 Electron transit time

```
 1 // Exa 3.21.7
 2 clc;
 3 clear;
 4 close;
 5 // Given data
 6 Mu_e = 0.13;// in m^2/v-s
 7 Mu_h = 0.05;// in m^2/v-s
 8 Toh_h = 10^-6;// in s
 9 L = 100;// in  m
10 L = L * 10^-6;// in m
11 V = 2;// in V
12 t_n =L^2/(Mu_e * V);// in s
13 disp(t_n,"Electron transit time in seconds is");
14 p_g = (Toh_h/t_n) * (1 + Mu_h/Mu_e);//photo
      conductor gain
15 disp(p_g,"Photo conductor gain is");
16
17 // Note: There is a calculation error to evaluate
      the value of t_n. So the answer in the book is
      wrong
```

Scilab code Exa 3.21.8 Resistivity of intrinsic Ge

```
1  // Exa 3.21.8
2  clc;
3  clear;
4  close;
5  //Given data
6  n_i = 2.5 * 10^13;
7  Mu_n = 3800;
8  Mu_p = 1800;
9  q = 1.6 * 10^-19;// in C
10 Sigma = n_i * (Mu_n + Mu_p) * q;// in (ohm-cm)^-1
11 Rho = 1/Sigma;// in ohm-cm
12 Rho= round(Rho);
13 disp(Rho,"The resistivity of intrinsic germanium in
       ohm-cm is");
14 N_D = 4.4 * 10^22/(1*10^8);// in atoms/cm^3
15 Sigma_n = N_D * Mu_n * q;// in (ohm-cm)^-1
16 Rho_n = 1/Sigma_n;// in ohm-cm
17 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 3.21.9 Concentration of holes and electrons

```
1  // Exa 3.21.9
2  clc;
3  clear;
4  close;
5  // Given data
6  n_i = 10^16;// in /m3
7  N_D = 10^22;// in /m^3
8  n = N_D;// in /m^3
9  disp(n,"Electron concentration per m^3 is");
10 p = (n_i)^2/n;// in /m^3
```

```
11 disp(p,"Hole concentration per m^3 is");
```

Scilab code Exa 3.21.10 Ratio of donor atoms to Si atom

```
1  // Exa 3.21.10
2  clc;
3  clear;
4  close;
5  format('e',8)
6  // Given data
7  Rho = 9.6 * 10^-2;// in ohm-m
8  Sigma_n = 1/Rho;// in (ohm-m)^-1
9  q = 1.6 * 10^-19;// in C
10 Mu_n = 1300 * 10^-4;// in m^2/v-s
11 N_D = Sigma_n / (Mu_n * q);// in atoms/m^3
12 A_D = N_D;// Atom density in atoms/cm^3
13 A_D = A_D * 10^6;// atoms/m^3
14 R_si = N_D/A_D;// ratio
15 disp(R_si,"The ratio of donor atom to silicon atom
       is");
16
17 // 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.
18 //           So the answer in the book is wrong
```

Scilab code Exa 3.21.11 Equilibrium electron and hole densities

```
1  // Exa 3.21.11
2  clc;
3  clear;
4  close;
```

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```
5 // Given data
6 n_i = 1.5 * 10^10;// in per cm^3
7 n_n = 2.25 * 10^15;// in per cm^3
8 p_n = (n_i)^2/n_n;// in per cm^3
9 disp(p_n,"The equilibrium electron density per cm^3
    is");
10 h_n = n_n;// in cm^3
11 disp(h_n,"Hole density in per cm^3 is");
```

Scilab code Exa 3.21.12 Carrier concentration

```
1 // Exa 3.21.12
2 clc;
3 clear;
4 close;
5 // Given data
6 N_A = 2 * 10^16;// in atoms/cm^3
7 N_D = 10^16;// in atoms/cm^3
8 C_c = N_A-N_D;// C_c stands for Carrier
    concentration in /cm^3
9 disp(C_c,"Carrier concentration per cm^3 is");
```

Scilab code Exa 3.21.13 Generation rate due to irradiation

```
1 // Exa 3.21.13
2 clc;
3 clear;
4 close;
5 // Given data
6 del_n = 10^15;// in cm^3
7 Torque_p = 10 * 10^-6;// in sec
8 R_g = del_n/Torque_p;// in hole pairs/sec/cm^3
```

```
9 disp(R_g,"The rate of generation of minority carrier
      in electron hole pairs/sec/cm^3 is ");
```

Scilab code Exa 3.21.14 Mobility of minority charge carriers

```
1  // Exa 3.21.14
2  clc;
3  clear;
4  close;
5  // Given data
6  v = 1/(20 * 10^-6);// in cm/sec
7  E = 10;// in V/cm
8  Mu= v/E;// in cm^2/V-sec
9  disp(Mu,"The mobility of minority charge carrier in
      cm^2/V-sec is ");
```

Scilab code Exa 3.21.15 Hole and electron diffusion current

```
1  // Exa 3.21.15
2  clc;
3  clear;
4  close;
5  // Given data
6  q = 1.6 * 10^-19;// in C
7  N_D = 4.5 * 10^15;// in /cm^3
8  del_p = 10^21;
9  e=10;// in cm
10 A = 1;// in mm^2
11 A = A * 10^-14;// cm^2
12 l = 10;// in cm
13 Torque_p = 1;// in microsec
14 Torque_p = Torque_p * 10^-6;// in sec
15 Torque_n = 1;// in microsec
```

```
16  Torque_n = Torque_n * 10^-6;// in   sec
17  n_i = 1.5 * 10^10;// in  /cm^3
18  D_n = 30;// in cm^2/sec
19  D_p = 12;// in cm^2/sec
20  n_o = N_D;// in  /cm^3
21  p_o = (n_i)^2/n_o;// in  /cm^3
22  disp(p_o,"Hole concentration at thermal equilibrium
        per cm^3 is");
23  l_n = sqrt(D_n * Torque_n);// in cm
24  disp(l_n,"Diffusion length of electron in cm is");
25  l_p = sqrt(D_p * Torque_p);// in cm
26  disp(l_p,"Diffusion length of holes in cm is");
27  x=34.6*10^-4;// in cm
28  dpBYdx = del_p *e;// in cm^4
29  disp(dpBYdx,"Concentration gradient of holes at
        distance in cm^4 is");
30  e1 = 1.88 * 10^1;// in cm
31  dnBYdx = del_p * e1;// in cm^4
32  disp(dnBYdx,"Concentration gradient of electrons in
        per cm is");
33  J_P = -(q) * D_p * dpBYdx;// in A/cm^2
34  disp(J_P,"Current density of holes due to diffusion
        in A/cm^2 is");
35  J_n = q * D_n * dnBYdx;// in A/cm^2
36  disp(J_n,"Current density of electrons due to
        diffusion in A/cm^2 is");
```

Scilab code Exa 3.21.16 Energy band gap of semiconductor material used

```
1  // Exa 3.21.16
2  clc;
3  clear;
4  close;
5  // Given data
6  e= 1.6*10^-19;// electron charge in C
```

```
7  h = 6.626 * 10^-34;// in J-s
8  h= h/e;// in eV
9  c = 3 * 10^8;// in m/s
10 lembda = 5490 * 10^-10;// in m
11 f = c/lembda;
12 E = h * f;// in eV
13 disp(E,"The energy band gap of the semiconductor
       material in eV is");
```

Scilab code Exa 3.21.17 Current density in Si

```
1  // Exa 3.21.17
2  clc;
3  clear;
4  close;
5  // Given data
6  y2 = 6 * 10^16;// in /cm^3
7  y1 = 10^17;// in /cm^3
8  x2 = 2;// in  m
9  x1 = 0;// in  m
10 D_n = 35;// in cm^2/sec
11 q = 1.6 *10^-19;// in C
12 dnBYdx = (y2 - y1)/((x2-x1) * 10^-4);
13 J_n = q * D_n * dnBYdx;// in A/cm^2
14 disp(J_n,"The current density in silicon in A/cm^2
       is");
```

Scilab code Exa 3.21.18 Resistance of the bar

```
1  // Exa 3.21.18
2  clc;
3  clear;
4  close;
```

```
5  // Given data
6  q = 1.6 * 10^-19;// in C
7  n_n = 5 * 10^20;// in /m^3
8  n_n = n_n * 10^-6;// in cm^3
9  Mu_n = 0.13;// in m^2/V-sec
10 Mu_n = Mu_n * 10^4;// in cm^2/V-sec
11 Sigma_n = q * n_n * Mu_n;// in (ohm-cm)^-1
12 Rho = 1/Sigma_n;// in   -cm
13 l = 0.1;// in cm
14 A = 100;//   m^2
15 A = A * 10^-8;// in cm^2
16 R = Rho * (l/A);// in Ohm
17 R=round(R*10^-6);// in  M
18 disp(R,"The resistance of the bar in  M  is");
```

Scilab code Exa 3.21.19 Depletion width

```
1  // Exa  3.21.19
2  clc;
3  clear;
4  close;
5  // Given data
6  t_d = 3;// total depletion in   m
7  D = t_d/9;// in   m
8  disp(D,"Depletion width in   m is");
```

Scilab code Exa 3.21.20 Minority carrier density

```
1  // Exa  3.21.20
2  clc;
3  clear;
4  close;
5  // Given data
```

```
6 n_i = 1.5 * 10^16;// in /m^3
7 n_n = 5 * 10^20;// in /m^3
8 p_n = (n_i)^2/n_n;// in /m^3
9 disp(p_n,"The majority carrier density per m^3 is");
```

Scilab code Exa 3.21.21 Collector current density

```
1  // Exa 3.21.21
2  clc;
3  clear;
4  close;
5  // Given data
6  D_n = 25;// in cm^2/sec
7  q = 1.6 * 10^-19;// in C
8  y2 = 10^14;// in /cm^3
9  y1 = 0;// in /cm^3
10 x2 = 0;//in   m
11 x1 = 0.5;// in   m
12 x1 = x1 * 10^-4;// in cm
13 dnBYdx = abs((y2-y1)/(x2-x1));// in /cm^4
14 J_n = q * D_n * (dnBYdx);// in /cm^4
15 J_n = J_n * 10^-1;// in A/cm^2
16 disp(J_n,"The collector current density in A/cm^2 is
     ");
17
18 // 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 3.21.22 Band gap

```
1  //Exa 3.21.22
2  clc;
```

```
 3  clear;
 4  close;
 5  // Given data
 6  h = 6.64 * 10^-34;// in J-s
 7  e= 1.6*10^-19;// electron charge in C
 8  c= 3 * 10^8;// in m/s
 9  lembda = 0.87;// in  m
10  lembda = lembda * 10^-6;// in m
11  E_g = (h * c)/lembda;// in J-s
12  E_g= E_g/e;// in eV
13  disp(E_g,"The band gap of the material in eV is");
```

Scilab code Exa 3.21.23 Total energy absorbed by sample

```
 1  // Exa 3.21.23
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  I_o = 10;// in mW
 7  e = 1.6 * 10^-19;// in J/eV
 8  hv = 2;// in eV
 9  hv1=1.43;// in eV
10  alpha = 5 * 10^4;// in cm^-1
11  l = 46;// in   m
12  l = l * 10^-6;// in m
13  I_t = round(I_o * exp(-(alpha) * l));// in mW
14  AbsorbedPower= I_o-I_t;// in mW
15  AbsorbedPower=AbsorbedPower*10^-3;// in W or J/s
16  disp(AbsorbedPower,"The absorbed power in watt or J/
        s is");
17  F= (hv-hv1)/hv;// fraction of each photon energy
        unit
18  EnergyConToHeat= AbsorbedPower*F;// in J/s
19  disp(EnergyConToHeat,"The amount of energy converted
```

```
           to heat per second in J/s is : ")
20  A= ( AbsorbedPower - EnergyConToHeat )/( e * hv1 );
21  disp (A ," The number of photon per sec given off from
        recombination events in photons/s is");
```

Scilab code Exa 3.21.24 Hole current

```
 1  // Exa 3.21.24
 2  clc ;
 3  clear ;
 4  close ;
 5  // Given data
 6  format ('e',9)
 7  Mu_p = 500; // in cm^2/v-s
 8  kT = 0.0259;
 9  Toh_p = 10^-10; // in sec
10  p_o = 10^17; // in cm^-3
11  q= 1.6*10^-19; // in C
12  A=0.5; // in square meter
13  del_p = 5 * 10^16; // in cm^-3
14  n_i= 1.5*10^10; // in cm^-3
15  D_p = kT * Mu_p; // in cm/s
16  L_p = sqrt (D_p * Toh_p ); // in cm
17  x = 10^-5; // in cm
18  p = p_o+del_p* %e^(x/L_p); // in cm^-3
19  // p= n_i*%e^(Eip)/kT where Eip=E_i-F_p
20  Eip= log (p/n_i)*kT; // in eV
21  Ecp= 1.1/2- Eip; // value of E_c-E_p in eV
22  Ip= q*A*D_p/L_p*del_p*%e^(x/L_p); // in A
23  disp (Ip ," The hole current in A is : ")
24  Qp= q*A*del_p*L_p; // in C
25  disp (Qp ," The value of Qp in C is : ")
26
27  // 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 .
28  //                Hence  the  value  of  hole  current  in  the
    book  is  wrong
```
___

Chapter 4

Junction Properties

Scilab code Exa 4.16.1 Contact difference of potential

```
1  // EXa 4.16.1
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  t = 4.4 * 10^22; // total number of Ge atoms/cm^3
7  n = 1 * 10^8; // number of impurity atoms
8  N_A = t/n; // in atoms/cm^3
9  N_A = N_A * 10^6; // in atoms/m^3
10 N_D = N_A * 10^3; // in atoms/m^3
11 n_i = 2.5 * 10^13; // in atoms/cm^3
12 n_i = n_i * 10^6; // in atoms/m^3
13 V_T = 26; //in mV
14 V_T= V_T*10^-3; // in V
15 V_J = V_T * log((N_A * N_D)/(n_i)^2); // in V
16 disp(V_J,"The contact potential in V is");
17 // Part (b)
18 t = 5* 10^22; // total number of Si atoms/cm^3
19 N_A = t/n; // in atoms/cm^3
20 N_A = N_A * 10^6; // in atoms/m^3
21 N_D = N_A * 10^3; // in atoms/m^3
```

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

Scilab code Exa 4.16.2 Height of potential energy barrier

```
 1  // Exa 4.16.2
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  V_T = 26;// in mV
 7  V_T=V_T*10^-3;// in V
 8  n_i = 2.5 * 10^13;
 9  Sigma_p = 1;
10  Sigma_n = 1;
11  Mu_n = 3800;
12  q = 1.6 * 10^-19;// in C
13  Mu_p = 1800;
14  N_A = Sigma_p/(2* q * Mu_p);// in /cm^3
15  N_D = Sigma_n /(q * Mu_n);// in /cm^3
16  V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
17  disp(V_J,"For Ge the height of the energy barrier in
        V is");
18  // For Si p-n juction
19  n_i = 1.5 * 10^10;
20  Mu_n = 1300;
21  Mu_p = 500;
22  N_A = Sigma_p/(2* q * Mu_p);// in /cm^3
23  N_D = Sigma_n /(q * Mu_n);// in /cm^3
24  V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
25  disp(V_J,"For Si p-n junction  the height of the
```

energy barrier in V is");

___

Scilab code Exa 4.16.3 Forward current

```
1  //Exa 4.16.3
2  clc;
3  clear;
4  close;
5  // Given data
6  Eta = 1;
7  V_T = 26;// in mV
8  V_T= V_T*10^-3;// in V
9  // I = I_o * (%e^(V/(Eta*V_T)) - 1) and I = -(0.9) *
       I_o;
10 V= log(1-0.9)*V_T;// in V
11 disp(V,"The voltage in volts is : ")
12 // Part (ii)
13 V1=0.05;// in V
14 V2= -0.05;// in V
15 ratio= (%e^(V1/(Eta*V_T))-1)/(%e^(V2/(Eta*V_T))-1)
16 disp(ratio,"The ratio of the current for a forward
     bias to reverse bias is : ")
17 // Part (iii)
18 Io= 10;// in  A
19 Io=Io*10^-3;// in mA
20 //For
21 V=0.1;// in V
22 I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
23 disp(I,"For V=0.1 V , the value of I in mA is : ")
24 //For
25 V=0.2;// in V
26 I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
27 disp(I,"For V=0.2 V , the value of I in mA is : ")
28 //For
29 V=0.3;// in V
```

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

Scilab code Exa 4.16.4 Anticipated Factor

```
1  //Exa 4.16.4
2  clc;
3  clear;
4  close;
5  // Given data
6  // Part (i)
7  T1= 25;// in   C
8  T2= 80;// in   C
9  // Formula Io2= Io1*2^((T2-T1)/10)
10 AntiFactor= 2^((T2-T1)/10);
11 disp(round(AntiFactor),"Anticipated factor for Ge is
       : ")
12 // Part (ii)
13 T1= 25;// in   C
14 T2= 150;// in   C
15 AntiFactor= 2^((T2-T1)/10);
16 disp(round(AntiFactor),"Anticipated factor for Si is
       : ")
```

Scilab code Exa 4.16.5 Leakage resistance

```
1  //Exa 4.16.5
2  clc;
3  clear;
```

```
4 close ;
5 // Given data
6 I =5;// in   A
7 V =10;// in V
8 T1= 0.11;// in   C^-1
9 T2= 0.07;// in   C^-1
10 // Io+I_R=I                              (i)
11 // dI_by_dT= dIo_by_dT        (ii)
12 // 1/Io*dIo_by_dT = T1 and 1/I*dI_by_dT = T2, So
13 Io= T2*I/T1;// in   A
14 I_R= I-Io;// in   A
15 R= V/I_R;// in  M
16 disp(R,"The leakage resistance in M  is : ")
```

Scilab code Exa 4.16.6 Dynamic resistance

```
1 //Exa  4.16.6
2 clc ;
3 clear ;
4 close ;
5 // Given data
6 Eta = 1;
7 T = 125;// in   C
8 T = T + 273;// in K
9 V_T = 8.62 * 10^-5 * 398;// in V
10 I_o = 30;// in   A
11 I_o= I_o*10^-6;// in A
12 v = 0.2;// in V
13 r_f = (Eta * V_T)/(I_o * %e^(v/(Eta* V_T)));// in
     ohm
14 disp(r_f,"The dynamic resistance in the forward
     direction in ohm is ");
15 r_r = (Eta * V_T)/(I_o * %e^(-v/(Eta* V_T)));// in
     ohm
16 disp(r_r*10^-3,"The dynamic resistance in the
```

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

Scilab code Exa 4.16.7 Barrier capacitance

```
1  // Exa 4.16.7
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  epsilon = 16/(36 * %pi * 10^11);// in F/cm
7  A = 1 * 10^-2;
8  W = 2 * 10^-4;
9  C_T = (epsilon * A)/W;// in F
10 disp(C_T*10^12,"The barrier capacitance in pF is");
```

Scilab code Exa 4.16.8 Width of depletion layer

```
1  //Exa 4.16.8
2  clc ;
3  clear ;
4  close ;
5  //Given data
6  A = 1;// in mm^2
7  A = A * 10^-6;// in m^2
8  N_A = 3 * 10^20;// in atoms/m^3
9  q = 1.6 *10^-19;// in C
10 V_o = 0.2;// in V
11 epsilon_r=16;
12 epsilon_o= 8.854*10^-12;// in F/m
13 epsilon=epsilon_r*epsilon_o;
14 // Part (a)
15 V=-10;// in V
16 // V_o - V = 1/2*((q * N_A )/epsilon) * W^2
```

```
17  W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
18  C_T1 = (epsilon * A)/W;// in F
19  disp(W*10^6,"The width of the depletion layer  for
        an applied reverse voltage of 10V in  m is ");
20  // Part (b)
21  V=-0.1;// in V
22  W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
23  C_T2 = (epsilon * A)/W;// in F
24  disp(W*10^6,"The width of the depletion layer  for
        an applied reverse voltage of 0.1V in  m is ");
25  // Part (c)
26  V=0.1;// in V
27  W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
28  disp(W*10^6,"The width of the depletion layer  for
        an applied for a forward bias of 0.1V in  m is "
        );
29  // Part (d)
30  disp(C_T1*10^12,"The space charge capacitance for an
          applied reverse voltage of 10V  in pF is");
31  disp(C_T2*10^12,"The space charge capacitance for an
          applied reverse voltage of 0.1V  in pF is");
```

Scilab code Exa 4.16.9 Current in the junction

```
1  // Exa 4.16.9
2  clc;
3  clear;
4  close;
5  // Given data
6  I_o = 1.8 * 10^-9;// A
7  v = 0.6;// in V
8  Eta = 2;
9  V_T = 26;// in mV
10 V_T=V_T*10^-3;// in V
11 I = I_o *(%e^(v/(Eta * V_T)));// in A
```

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

Scilab code Exa 4.16.10 Forward biasing current

```
1 // Exa 4.16.10
2 clc;
3 clear;
4 close;
5 // Given data
6 I_o = 2.4 * 10^-14;
7 I = 1.5;// in mA
8 I=I*10^-3;// in A
9 Eta = 1;
10 V_T = 26;// in mV
11 V_T= V_T*10^-3;// in V
12 v =log((I + I_o)/I_o) * V_T;// in V
13 disp(v,"The forward biasing voltage across the
       junction in V is");
```

Scilab code Exa 4.16.11 Theoretical diode current

```
1 // Exa 4.16.11
2 clc;
3 clear;
4 close;
5 // Given data
6 I_o = 10;// in nA
7 // I = I_o * ((e^(v/(Eta * V_T))) - 1)
8 // e^(v/(Eta * V_T)<< 1, so neglecting it
9 I = I_o * (-1);// in nA
10 disp(I,"The Diode current in nA is  ");
```

Scilab code Exa 4.16.12 Diode dynamic resistance

```
1  // Exa 4.16.12
2  clc;
3  clear;
4  close;
5  // Given data
6  R = 4.5; // in ohm
7  I = 44.4; // in mA
8  I=I*10^-3; // in A
9  V = R * I; // in V
10 Eta = 1;
11 V_T = 26; //in mV
12 V_T=V_T*10^-3; // in V
13 I_o = I/((%e^(V/(Eta * V_T))) -1); // in A
14 // At
15 V = 0.1; // in V
16 r_f = (Eta * V_T)/(I_o * ((%e^(V/(Eta * V_T)))-1));
       // in ohm
17 disp(r_f,"The diode dynamic resistance in    is");
```

Scilab code Exa 4.16.13 Q point

```
1  // Exa 4.16.13
2  clc;
3  clear;
4  close;
5  // Given data
6  V_D = 10; // in V
7  // V_S = i*R_L + V_D
8  V_S = V_D; // in V (i * R_L = 0)
```

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

Scilab code Exa 4.16.14 AC resistance of the Ge diode

```
1  // Exa 4.16.14
2  clc;
3  clear;
4  close;
5  // Given data
6  V = 0.25;// in V
7  I_o = 1.2;// in   A
8  I_o = I_o * 10^-6;// in A
9  V_T = 26;// in mV
10  V_T = V_T * 10^-3;// in V
11  Eta = 1;
12  r = (Eta * V_T)/(I_o * (%e^(V/(Eta * V_T))));// in
      ohm
13  disp(r,"The  ac  resistance  of  the  diode  in  ohm  is");
```

Scilab code Exa 4.16.15 Junction potential

```
1  // Exa 4.16.15
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  t = 4.4 * 10^22;// in total number of atoms/cm^3
7  n = 1 * 10^8;// number of impurity
8  N_A = t/n;// in atoms/cm^3
9  N_A = N_A * 10^6;// in atoms/m^3
10 N_D = N_A * 10^3;// in atoms/m^3
11 V_T = 26;// in mV
12 V_T = V_T * 10^-3;// in V
13 n_i = 2.5 * 10^19;// in /cm^3
14 V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
15 disp(V_J,"The junction potential in V is")
```

Scilab code Exa 4.16.16 Dynamic resistance

```
1  // Exa 4.16.16
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  Eta = 1;
7  I_o = 30;// in MuA
8  I_o = I_o * 10^-6;// in A
9  v = 0.2;// in V
10 K = 1.381 * 10^-23;// in J/degree K
11 T = 125;// in   C
12 T = T + 273;// in K
13 q = 1.6 * 10^-19;// in C
14 V_T = (K*T)/q;// in V
15 r_f = (Eta * V_T)/(I_o * (%e^(v/(Eta * V_T))));// in
       ohm
16 disp(r_f,"The forward dynamic resistance in ohm is")
```

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

Scilab code Exa 4.16.17 Space charge capacitance

```
1  // Exa 4.16.17
2  clc;
3  clear;
4  close;
5  // Given data
6  q = 1.6 * 10^-19; // in C
7  N_A = 3 * 10^20; // in /m^3
8  A = 1; // in  m^2
9  A = A * 10^-6; // in m^2
10 V = -10; // in V
11 V_J = 0.25; // in V
12 V_B = V_J - V; // in V
13 epsilon_o = 8.854; // in pF/m
14 epsilon_o = epsilon_o * 10^-12; // in F/m
15 epsilon_r = 16;
16 epsilon = epsilon_o * epsilon_r;
17 W = sqrt((V_B * 2 * epsilon)/(q * N_A)); // in m
18 disp(W*10^6,"The width of depletion layer in   m is"
      );
19 C_T = (epsilon * A)/W; // in pF
20 disp(C_T*10^12,"the space charge capacitance in pF
      is");
```

Scilab code Exa 4.16.18 Barrier capacitance

```
1  // Exa 4.16.18
2  clc;
3  clear;
4  close;
5  // Given data
6  W = 2 * 10^-4;// in cm
7  W = W * 10^-2;// in m
8  A = 1;// in mm^2
9  A = A * 10^-6;// in m^2
10 epsilon_r = 16;
11 epsilon_o = 8.854 * 10^-12;// in F/m
12 epsilon = epsilon_r * epsilon_o;
13 C_T = (epsilon * A)/W;// in F
14 disp(C_T*10^12,"The barrier capacitance in pF is");
```

Scilab code Exa 4.16.19 Diameter

```
1  // Exa 4.16.19
2  clc;
3  clear;
4  close;
5  // Given data
6  C_T = 100;// in pF
7  C_T=C_T*10^-12;// in F
8  epsilon_r = 12;
9  epsilon_o = 8.854 * 10^-12;// in F/m
10 epsilon = epsilon_r * epsilon_o;
11 Rho_p = 5;// in ohm-cm
12 Rho_p = Rho_p * 10^-2;// in ohm-m
13 V_j = 0.5;// in V
14 V = -4.5;// in V
15 Mu_p = 500;// in cm^2
16 Mu_p = Mu_p * 10^-4;// in m^2
17 Sigma_p = 1/Rho_p;// in per ohm-m
18 qN_A = Sigma_p/ Mu_p;
```

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

Scilab code Exa 4.16.20 Temperature of junction

```
1  // Exa 4.16.20
2  clc;
3  clear;
4  close;
5  // Given data
6  q = 1.6 * 10^-19;// in C
7  Mu_p = 500;// in cm^2/V−sec
8  Rho_p = 3.5;// in ohm−cm
9  Mu_n = 1500;// in cm^2/V−sec
10 Rho_n = 10;// in ohm−cm
11 N_A = 1/(Rho_p * Mu_p * q);// in /cm^3
12 N_D = 1/(Rho_n * Mu_n * q);// in /cm^3
13 V_J = 0.56;// in V
14 n_i = 1.5 * 10^10;// in /cm^3
15 V_T = V_J/log((N_A * N_D)/(n_i)^2);// in V
16 // V_T = T/11600
17 T = V_T * 11600;// in K
18 T = T - 273;// in  C
19 disp(T,"The Temperature of junction in  C is");
```

Scilab code Exa 4.16.21 Voltage

```
1  // Exa 4.16.21
```

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

Scilab code Exa 4.16.22 Reverse saturation current

```
1  // Exa 4.16.22
2  clc;
3  clear;
4  close;
5  // Given data
6  R = 5;// in ohm
7  I = 50;// in mA
8  I=I*10^-3;// in A
9  V = R * I;// in V
10 Eta = 1;
11 V_T = 26;// in mV
12 V_T=V_T*10^-3;// in V
13 I_o = I/((%e^(V/(Eta * V_T))) - 1);// in A
14 disp(I_o*10^6,"Reverse saturation current in  A is"
      );
15 v1 = 0.2;// in V
16 r = (Eta * V_T)/(I_o * (%e^(v1/(Eta * V_T))));// in
      ohm
17 disp(r,"Dynamic resistance of the diode in    is");
```

Chapter 5

Bipolar Junction Transistors

Scilab code Exa 5.9.1 IC and VCB

```
1  // Exa 5.9.1
2  clc;
3  clear;
4  close;
5  // Given data
6  V_EE = 8;// in V
7  V_BE = 0.7;// in V
8  R_E = 1.5;// in k ohm
9  I_E = (V_EE - V_BE)/R_E;// in mA
10 I_C = I_E;// in mA
11 disp(I_C,"The value of I_C in mA is");
12 V_CC = 18;// in V
13 R_C = 1.2;// in k
14 V_CB = V_CC - (I_C * R_C);// in V
15 disp(V_CB,"The value of V_CB in V is");
```

Scilab code Exa 5.9.2 Value of base current

```
1  // Exa 5.9.2
2  clc;
3  clear;
4  close;
5  // Given data
6  alpha = 0.9;
7  I_E = 1;// mA
8  I_C = alpha * I_E;// in mA
9  I_B = I_E - I_C;// in mA
10 disp(I_B,"The value of base current in mA is");
```

Scilab code Exa 5.11.1 Value of emitter current

```
1  // Exa 5.11.1
2  clc;
3  clear;
4  close;
5  // Given data
6  bita = 50;
7  I_B= 20;// in  A
8  I_B=I_B*10^-6;// in A
9  I_C= bita*I_B;// in A
10 I_E= I_C+I_B;// in A
11 I_E = I_E * 10^3;// in mA
12 disp(I_E,"The Emitter current in mA is");
```

Scilab code Exa 5.11.1.a Value of base and emitter current

```
1  // Exa 5.11.1(a)
2  clc;
3  clear;
4  close;
5  // Given data
```

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

Scilab code Exa 5.11.3 Change in base current

```
1  // Exa 5.11.3
2  clc;
3  clear;
4  close;
5  // Given data
6  del_ic = 1.8; // in mA
7  del_ie = 1.89; // in mA
8  alpha = del_ic / del_ie;
9  bita = alpha/(1 - alpha);
10 del_ib = del_ic/bita; // in mA
11 del_ib = del_ib * 10^3; // in  A
12 disp(del_ib,"The change in I_B in  A is");
```

Scilab code Exa 5.11.4 Transistor current

```
1  //Exa 5.11.4
2  clc;
3  clear;
4  close;
5  // Given data
```

```
6   V_CC = 10; // in V
7   R_C = 3; // in k
8   R_C= R_C*10^3; // in
9   bita = 100;
10  I_CO = 20; // in nA
11  I_CO = I_CO * 10^-9; // in A
12  V_BB = 5; // in V
13  R_B = 200; // in  k
14  R_B= R_B*10^3; // in
15  V_BE = 0.7; // in V
16  // Applying KVL to the base circuit , V_BB= I_B*R_B+
        V_BE
17  I_B = (V_BB - V_BE)/R_B; // in A
18  disp(I_B*10^6,"The base current in  A is");
19  I_C = (bita * I_B) + I_CO; // in A
20  disp(I_C*10^3,"The collector current in mA is");
21  I_E = I_C + I_B; // in A
22  disp(I_E*10^3,"Emitter current in mA is");
23  V_CE = V_CC - (I_C * R_C); // in V
24  disp(V_CE,"Collector emitter voltage in V is");
```

Scilab code Exa 5.11.5 Collector current

```
1   //Exa 5.11.5
2   clc;
3   clear;
4   close;
5   // Given data
6   bita = 100;
7   I_CBO = 4; // in  A
8   I_B = 40; // in  A
9   I_C = (bita * I_B) + ((1+bita) * I_CBO); // in  A
10  I_C = I_C * 10^-3; // in msA
11  disp(I_C,"The collector current in mA is");
```

Scilab code Exa 5.11.6 Current gain

```
1  // Exa 5.11.6
2  clc;
3  clear;
4  close;
5  // Given data
6  del_IC = 1 * 10^-3; // in A
7  del_IB = 10 * 10^-6; // in A
8  CurrentGain= del_IC/del_IB;
9  disp(CurrentGain,"The current gain is");
10 del_IC= del_IC*10^3; // in mA
11 del_IB= del_IB*10^6; // in  A
12 I_B=0:0.1:50; // in  A
13 I_C= I_B/del_IB+del_IC; // in mA
14 plot(I_B,I_C)
15 xlabel("Base current in  A ");
16 ylabel("Collector current in mA")
17 title("Transfer Characteristics ")
18 disp("Transfer Characteristics is shown in figure")
```

Scilab code Exa 5.11.7 AlphaDC and betaDC

```
1  //Exa 5.11.7
2  clc;
3  clear;
4  close;
5  //Given data
6  I_CEo = 21; // in  A
7  I_CBO = 1.1; // in  A
8  beta_dc = (I_CEo/I_CBO) - 1;
9  disp(beta_dc,"Value of beta_dc is");
```

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

Scilab code Exa 5.14.1 AlphaDc and emitter current

```
1  // Exa 5.14.1
2  clc;
3  clear;
4  close;
5  // Given data
6  I_CBO = 3;//in  A
7  I_CBO= I_CBO*10^-3;// in mA
8  I_C= 15;// in mA
9  // But it is given that I_C= 99.5% of I_E, SO
10  I_E= I_C/99.5*100;// in mA
11  alpha_dc= I_C/I_E;
12  disp(alpha_dc,"The value of alpha_dc is : ")
13  disp(I_E,"The value of I_E in mA is : ")
```

Scilab code Exa 5.14.2 Collector and base current

```
1  //Exa 5.14.2
2  clc;
3  clear;
4  close;
5  //Given data
6  alpha_dc = 0.99;
7  I_CBO = 10;// in  A
8  I_CBO= I_CBO*10^-6;// in A
9  I_E = 10;// in mA
10  I_E= I_E*10^-3;// in A
11  I_C = (alpha_dc * I_E) + I_CBO;// in A
12  disp(I_C*10^3,"The value of I_C in mA is");
```

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

Scilab code Exa 5.14.3 Base current

```
1   // Exa 5.14.3
2   clc;
3   clear;
4   close;
5   format('v',9)
6   // Given data
7   alpha_dc = 0.99;
8   I_C = 6;// in mA
9   I_C= I_C*10^-3;// in A
10  I_CBO = 15;// in   A
11  I_CBO= I_CBO*10^-6;// in A
12  I_E = (I_C - I_CBO)/alpha_dc;// in A
13  I_B = I_E - I_C;// in A
14  I_B= I_B*10^6;// in   A
15  I_B= round(I_B)
16  disp(I_B,"The value of I_B in   A is");
```

Scilab code Exa 5.14.5 Emitter current

```
1   //Exa 5.14.5
2   clc;
3   clear;
4   close;
5   // Given data
6   alpha_dc = 0.98;
7   I_CBO = 12;// in   A
8   I_CBO = I_CBO * 10^-6;// in A
```

```
 9  I_B = 120;// in   A
10  I_B = I_B * 10^-6;// in A
11  beta_dc = alpha_dc/(1-alpha_dc);
12  I_E = ((1 + beta_dc) * I_B) + ((1 + beta_dc) * I_CBO
        );//in A
13  I_E = I_E * 10^3;// in mA
14  disp(I_E,"The value of I_E in mA is");
```

Scilab code Exa 5.14.6 Region of operation of Si transistor

```
 1  //Exa 5.14.6
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  bita= 100;
 7  V_BEsat= 0.8;// in V
 8  V_CEsat= 0.2;// in V
 9  V_BEact= 0.7;// in V
10  V_CC = 10;// in V
11  V_BB=5;// in V
12  R_E = 2;// in  k
13  R_C = 3;// in  k
14  R_B= 50;// in  k
15  // Applying KVL to collector loop
16  // V_CC= I_Csat*R_C +V_CEsat +I_E*R_E and I_E=
        I_Csat+I_B, So
17  //I_B= ((V_CC-V_CEsat)-(R_C+R_E)*I_Csat)/R_E;
                  (i)
18  // Applying KVL to base loop
19  // V_BB-I_B*R_B -V_BEsat-I_E*R_E =0 and I_E= I_Csat+
        I_B, So
20  //V_BB-V_BEsat= R_E*I_Csat + (R_B+R_E)*I_B
                    (ii)
21  // From eq (i) and (ii)
```

```
22  I_B = ((V_BB-V_BEsat)*5- (V_CC-V_CEsat)*2) / ((R_B+
        R_E)*5 - R_E*2) ;// in mA
23  I_Csat= ((V_CC-V_CEsat)-R_E*I_B)/(R_C+R_E);// in mA
24  I_Bmin= I_Csat/bita;// in mA
25  if I_B<I_Bmin then
26      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 )");
27      disp("So the transistor is not in the saturation
            region. But it is conducting hence it can
            not be in cutoff.")
28      disp("Therefore the transistor is in the active
            region")
29  end
```

Scilab code Exa 5.14.7 IB IC and VCE

```
1  //Exa 5.14.7
2  clc;
3  clear;
4  close;
5  // Given data
6  bita= 100;
7  V_BEsat= 0.8;// in V
8  V_CEsat= 0.2;// in V
9  V_BEact= 0.7;// in V
10 V_CC = 10;// in V
11 V_BB=5;// in V
12 R_E = 2;// in  k
13 R_C = 3;// in  k
14 R_B= 50;// in  k
15 // Applying KVL to input loop
16 // V_BB= I_B*R_B+(1+bita)*I_B*R_E+V_BEact or
17 I_B= (V_BB-V_BEact)/(R_B+(1+bita)*R_E);// in mA
18 I_C= bita*I_B;// in mA
```

```
19 // Applying KVL to collector circuit
20 // V_CC= I_Csat*R_C +V_CEsat +(I_C+I_B)*R_E
21 V_CEact= V_CC-I_B*R_E-I_C*(R_C+R_E);// in V
22 disp(I_B*10^3,"The value of I_B in   A is : ")
23 disp(I_C,"The value of I_C in mA is  : ")
24 disp(V_CEact,"The value of V_CE in volts is : ")
```

Scilab code Exa 5.14.8 Region of operation of Value of IB and IC

```
1  //Exa 5.14.8
2  clc;
3  clear;
4  close;
5  //Given data
6  bita = 100;
7  V_CEsat = 0.2;// in V
8  R_B = 150;// in kohm
9  R_C = 2;// in kohm
10 V_CC  = 10;// in V
11 V_BEsat = 0.8;// in V
12 I_B = (V_CC - V_BEsat)/R_B;// in mA
13 I_C = (V_CC - V_CEsat)/R_C;// in mA
14 I_Bmin = I_C/bita;// in mA
15 if I_B>I_Bmin then
16     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 )");
17     disp("So the transistor is in the saturation
           region.")
18 end
```

Scilab code Exa 5.14.9 Value of VBB

```
1  //Exa 5.14.9
2  clc;
3  clear;
4  close;
5  //Given data
6  bita = 100;
7  V_CE = 0.2;//in V
8  V_BE = 0.8;// in V
9  R_C= 500;// in
10 R_B= 44*10^3;// in
11 R_E= 1*10^3;// in
12 V_CC= 15;// in V
13 V_GE= -15;// in V
14 // Applying KVL to collector circuit
15 // 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
16 I_Bmin= (V_CC-V_GE-V_CE)/(R_C*bita+(1+bita)*R_E);//
     in A
17 // Applying KVL to the base emitter circuit
18 // V_BB-I_Bmin*R_B-V_BE-I_E*R_E + V_CC=0
19 V_BB= I_Bmin*R_B + V_BE + (1+bita)*I_Bmin*R_E-V_CC;
     // in V
20 disp(I_Bmin*10^3,"The value of I_B(min) in mA is : "
     )
21 disp(V_BB,"The value of V_BB in volts is : ")
```

Scilab code Exa 5.14.10 Minimum value of RC required

```
1  // Exa 5.14.10
2  clc;
3  clear;
4  close;
5  // Given data
6  V_ECsat= 0.2;// in V
7  V_CC= 10;// in V
```

```
8  V_EBsat= 0.8;// in V
9
10 // Part (i)
11 bita= 100;
12 R_B= 220;// in k
13 // Applying KVL to collector circuit, V_CC= V_EC+
     ICRC
14 ICRC= V_CC-V_ECsat;// in V
15 // Applying KVL to input loop, V_CC= V_EBsat+I_B*R_B
             (i)
16 I_B= (V_CC-V_EBsat)/R_B;// in mA
17 I_C= bita*I_B;// in mA
18 R_Cmin= ICRC/I_C;// in k
19 disp(R_Cmin,"The minimum value of R_C in k  is :  "
     )
20 // Part (ii)
21 R_C= 1.2;// in k
22 I_Csat= ICRC/R_C;// in mA
23 I_B= I_Csat/bita;// in mA
24 // From eq (i)
25 R_B= (V_CC-V_EBsat)/I_B;// in k
26 disp(R_B,"The maximum value of R_B in k  is : ")
```

Scilab code Exa 5.14.11 Value of RE

```
1  //Exa 5.14.11
2  clc;
3  clear;
4  close;
5  // Given data
6  bita= 100;
7  V_BEsat= 0.8;// in V
8  V_CEsat= 0.2;// in V
9  V_BEact= 0.7;// in V
10 V_CC = 10;// in V
```

```
11  R_E = 1;// in k
12  R_C = 2;// in k
13  R_B= 100;// in k
14  bita=100;
15  alpha= bita/(1+bita);
16  // Applying KVL to collector circuit
17  // V_CC= I_Csat*R_C +V_CE +R_E*I_E
18  // but I_E= alpha*I_Csat
19  I_Csat= (V_CC-V_CEsat)/(R_C+R_E*alpha);// in mA
20  I_Bmin= I_Csat/bita;// in mA
21  // Applying KVL to base loop
22  // V_CC= I_B*R_B +V_BEsat +I_E*R_E
23  // but I_E= I_Csat+I_B
24  I_B= (V_CC-V_BEsat-I_Csat*R_E)/(R_B+R_E);// in mA
25  disp(I_B*10^3,"The value of I_B in  A is : ")
26  disp(I_Bmin*10^3,"The minimum value of I_B in  A is
        : ")
27  if I_B>I_Bmin then
28      disp("Since the value of I_B is greater than the
             value of I_Bmin , ")
29      disp("Hence the transistor is in saturation .")
30  end
31  I_E= (1+bita)*I_Bmin;// in mA
32  R_E= (V_CC-V_BEact-I_Bmin*R_B)/I_E;// in k
33  disp(R_E,"The value of R_E in k  is : ")
34  disp("So R_E should be greater than this value in
        order to bring the transistor just out of
        saturation ")
```

Scilab code Exa 5.14.12 Collector voltage

```
1  // Exa 5.14.12
2  clc;
3  clear;
4  close;
```

```
 5  // Given data
 6  V_CC = 9; // in V
 7  V_BE = 0.8; // in V
 8  V_CE = 0.2; // in V
 9  R_B = 50; // in  k
10  R_C=2; // in  k
11  R_E = 1; // in  k
12  bita=70;
13  // Applying KVL to input loop, V_CC= I_B*R_B +V_BE +
        I_E*R_E
14  // V_CC- V_BE= (R_B+R_E)*I_B + R_E*I_C           (i)
15  // Applying KVL to output loop, V_CC= R_C*I_C +V_CE
        +I_C*R_E +I_B*R_E
16  //I_B = ((V_CC- V_CE)-(R_C+R_E)*I_C)/R_E          (ii
        )
17  // From eq (i) and (ii)
18  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
19  I_B = ((V_CC- V_CE)-(R_C+R_E)*I_C)/R_E // in mA
20  I_Bmin= I_C/bita; // in mA
21  if I_B>I_Bmin then
22      disp("Since the value of I_B ("+string(I_B)+" mA
            ) is greater than the value of I_Bmin ("+
            string(I_Bmin)+" mA)")
23      disp("So the transistor is in saturation ")
24  end
25  V_C= V_CC-I_C*R_C; // in V
26  disp(V_C,"The value of collector voltage in volts is
         : ")
27  bita= I_C/I_B;
28  disp(bita,"The minimum value of bita that will
        change the state of the trasistor is : ")
```

Chapter 6

Field Effect Transistor

Scilab code Exa 6.9.1 Pinch off voltage

```
1  //Exa 6.9.1
2  clc;
3  clear;
4  close;
5  // Given data
6  q = 1.6 * 10^-19;// in C
7  N_D = 10^15;// in electrons/cm^3
8  N_D = N_D * 10^6;// in electrons/m^3
9  epsilon_r = 12;
10 epsilon_o = (36 * %pi * 10^9)^-1;
11 epsilon = epsilon_o * epsilon_r;
12 a = 3 * 10^-4;// in cm
13 a = a * 10^-2;// in m
14 V_P = (q * N_D * a^2)/( 2 * epsilon);// in V
15 disp(V_P,"The Pinch off voltage in V is");
16 // V_GS = V_P * (1-(b/a))^2
17 b = (1-0.707) *a;// in m
18 disp(b*10^6,"The value of b in  m is : ")
19 disp("Hence the channel width has been reduced to
        about one third of its value for V_GS = 0");//
20 // Note : The unit of b in the book is wrong since
```

the value of b is calculated in m.

Scilab code Exa 6.9.2 Value of VGS

```
1  // Exa 6.9.2
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 8;// in mA
7  V_P = -4;// in V
8  I_D = 3;// in mA
9  V_GS = V_P * (1 - sqrt(I_D/I_DSS));// in V
10 disp(V_GS,"The value of V_GS in V is");
11 V_DS = V_GS - V_P;// in V
12 disp(V_DS,"The value of V_DS in V is");
```

Scilab code Exa 6.9.3 Drain current

```
1  // Exa 6.9.3
2  clc;
3  clear;
4  close;
5  // Given data
6  V_P = -4;// in V
7  I_DSS = 9;// in mA
8  I_DSS = I_DSS * 10^-3;// in A
9  V_GS = -2;// in V
10 I_D = I_DSS * ((1 - (V_GS/V_P))^2);// in A
11 disp(I_D*10^3,"The drain current in mA is ");
```

Scilab code Exa 6.9.4 Transconductance

```
1  // Exa 6.9.4
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 12;// in mA
7  I_DSS = I_DSS * 10^-3;// in A
8  V_P = -(6);// in V
9  V_GS = -(1);// in V
10 g_mo = (-2 * I_DSS)/V_P;// in A/V
11 g_m = g_mo * (1 - (V_GS/V_P));// in S
12 disp(g_m*10^3,"The value of transconductance in mS
       is");
```

Scilab code Exa 6.9.5 Value of transconductance and drain current

```
1  //Exa 6.9.5
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 10;// in mA
7  I_DSS = I_DSS * 10^-3;// in A
8  V_P = -(5);// in V
9  V_GS = -(2.5);// in V
10 g_m = ((-2 * I_DSS)/V_P) * (1 -(V_GS/V_P));// in S
11 g_m = g_m * 10^3;// in mS
12 disp(g_m,"The Transconductance in mS is");
13 I_D = I_DSS * ((1 - (V_GS/V_P))^2);// in A
14 disp(I_D*10^3,"The drain current in mA is");
```

Chapter 7

Optoelectronic Devices

Scilab code Exa 7.6.1 Component value

```
1 // Exa 7.6.1
2 clc ;
3 clear ;
4 close ;
5 // Given data
6 O_V = 5; // output voltage in V
7 V_D = 1.5; // voltage drop in V
8 R = (O_V - V_D)/O_V ;
9 R = R * 10^3; // in ohm
10 disp (R ,"The resistance value in     is");
11 disp ("As this is not standard value , use R=680
       which is a standard value")
```

Scilab code Exa 7.23.1 Open circuit voltage

```
1 // Exa 7.23.1
2 clc ;
3 clear ;
```

```
4  close ;
5  // Given data
6  N_A = 7.5*10^24; // in atoms/m^3
7  N_D = 1.5*10^22; // in atoms/m^3
8  I_lembda = 12.5*10^-3; // in A/cm^2
9  D_e = 25*10^-4; // in m^2/s
10 D_h = 1*10^-3; // in m^2/s
11 Torque_eo = 500; // in ns
12 Torque_ho = 100; // in ns
13 n_i = 1.5*10^16; // in /m^3
14 e = 1.6*10^-19;
15 P_C = 12.5; // in mA/cm^2
16 L_e = sqrt(D_e*Torque_ho*10^-9); // in m
17 L_e = L_e * 10^6; // in  m
18 L_h = sqrt(D_h*Torque_ho*10^-9); // in m
19 L_h = L_h * 10^6; // in  m
20 J_s = e*((n_i)^2)*( (D_e/(L_e*10^-6*N_A)) + (D_h/(
      L_h*10^-6*N_D)) ); // in A/m^2
21 J_s = J_s * 10^-4; // in A/cm^2
22 V_T = 26; // in mV
23 V_OC = V_T*log( 1+(I_lembda/J_s) ); // in mV
24 V_OC = V_OC * 10^-3; // in V
25 disp(V_OC,"Open circuit voltage in V is");
```

Scilab code Exa 7.23.2 Value of photocurrent density

```
1  // Exa 7.23.2
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  Phi_o = 1*10^21; // in m^-2s^-1
7  Alpha = 1*10^5; // in m^-1
8  W = 25; // in  m
9  W =W * 10^-6; // in m
```

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```
10  e = 1.6*10^-19;// in C
11  G_L1 = Alpha*Phi_o;// in m^-3s^-1
12  G_L2 = Alpha*Phi_o*%e^( (-Alpha*W) );// in m^-3s^-1
13  J_L = e*Phi_o*(1-%e^(-Alpha*W));// in A/m^2
14  J_L = J_L * 10^-1;// in mA/cm^2
15  disp(J_L,"Photo current density in mA/cm^2 is");
```

Chapter 8

Negative Conductance Micro Devices

Scilab code Exa 8.13.1 Value of the anode current

```
1  // Exa 8.13.1
2  clc;
3  clear;
4  close;
5  // Given data
6  R= 10;// in k
7  R= R*10^3;// in
8  // Part (i)
9  V=300;// in V
10 I_A= V/R;// in A
11 disp("Part (i) : For 300 V voltage : ")
12 disp(I_A*10^3,"The anode current in mA is : ");
13 // Part (ii)
14 V=100;// in V
15 I_A= V/R;// in A
16 disp("Part (ii) : For 100 V voltage : ")
17 disp(I_A*10^3,"The anode current in mA is : ");
```

Scilab code Exa 8.14.1 Value of the peak reverse recovery current

```scilab
1 // Exa 8.14.1
2 clc;
3 clear;
4 close;
5 // Given data
6 t_rr = 10;// in   s
7 Q_rr = 150;// in   c
8 I_rr = (2*Q_rr)/t_rr;// in A
9 disp(I_rr,"The peak reverse recovery current in A is
    ");
```