Scilab Textbook Companion for Advance Semiconductor Devices by S. Sharma[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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List of Scilab Codes

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Chapter 1

Semiconductor Materials and Their Properties

Scilab code Exa 1.3 Volume density of Si

```
1  // Exa 1.3
2  clc;
3  clear;
4  close;
5  // Given data
6  a = 5.3;// in
7  a= a * 10^-10;// in m
8  N_A = 6.023*10^23;
9  At_Si = 28;// atomic weight of Si
10 n = 4;
11 m = At_Si/N_A;// in gm
12 m= m*10^-3;// in kg
13 V = a^3;// in m^3
14 Rho = (m*n)/V;// in kg/m^3
15 disp(Rho,"Density of silicon crystal in kg/m^3 is");
16
17 // Note: There is calculation error to find the
       value of density. So the answer in the book is
       wrong.
```

Scilab code Exa 1.4 Density of copper crystal

```
1  // Exa 1.4
2  clc;
3  clear;
4  close;
5  // Given data
6  n = 4;
7  r = 1.278;// in
8  a = (4*r)/(sqrt(2));// in
9  a = a * 10^-10;// in m
10 V = (a)^3;// in m^3
11 At_W = 63.5;// atomic weight
12 N_A = 6.023*10^23;
13 m = At_W /N_A;// in gm
14 m = m*10^-3;// in kg
15 Rho = (m*n)/V;// in kg/m^3
16 disp(Rho,"Density of the crystal in kg/m^3 is");
17
18
19 // Note: There is calculation error to find the
       value of density. So the answer in the book is
       wrong.
```

Scilab code Exa 1.5 Wavelength of X ray

```
1  // Exa 1.5
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  theta1 = 10; // in degree
10  lembda = 2*d*sind(theta1); // in m
11  lembda = lembda  * 10^10; // in
12  disp(lembda,"Wavaelength of X ray in    is");
```

Scilab code Exa 1.6 Spacing of automatic layer in the crystal

```
 1  // Exa 1.6
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  lembda = 1.6; // in
 7  theta = 14.2; // in degree
 8  n = 1;
 9  d = (n*lembda)/(2*sind(theta)); // in
10  disp(d,"The spacing of atomic layer in crystal in
        is");
11
12  // Note: The unit of the answer in the book is wrong
        .
```

Scilab code Exa 1.7 Interplaner spacing

```
 1  // Exa 1.7
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  n = 1;
```

```scilab
7  theta1 = 30;// in degree
8  lembda = 1.78;// in
9  d = (n*lembda)/(2*sind(theta1));// in
10 disp(d,"The interplanner spacing in    is");
```

Scilab code Exa 1.8 Interplaner spacing

```scilab
1  // Exa 1.8
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 1.9 Glacing angle

```
1  // Exa 1.9
2  clc;
3  clear;
4  close;
5  // Given data
6  a = 2.814; // in
7  l = 0;
8  h = l;
9  k = 0;
10 //d= a/( sqrt (h^2+k^2+l^2)), So
11 d=a; // in
12 n = 2;
13 lembda = 0.710; // in
14 theta = asind(n*lembda/(2*d));
15 disp(theta,"The glancing angle for a cubic in degree
       is :");
```

Scilab code Exa 1.10 Wavelength of X ray

```
1  //Exa 1.10
2  clc;
3  clear;
4  close;
5  // Given data
6  a = 3.65; // in
7  a = 3.65*10^-10; // in m
8  h = 1;
9  k = 0;
10 l = 0;
11 d= a/(sqrt(h^2+k^2+l^2)); // in m
```

```
12  n = 1;
13  theta = 60;// in degree
14  lembda = 2*d*sind(theta);// in m
15  lembda = lembda * 10^10;// in
16  disp(lembda,"Wavelength of X ray in      is");
```

Scilab code Exa 1.11 Glacing angle

```
1  // Exa 1.11
2  clc;
3  clear;
4  close;
5  // Given data
6  lembda = 1.54;// in
7  density = 9.024;// in gm/cc
8  n = 1;
9  MI = 100;
10 At_W = 63.54;// atomic weight
11 N_A = 6.023*10^23;
12 m = At_W/N_A;// in gm
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));
18 theta = asind( (lembda * 10^-8)/(2*d) );// in degree
19 disp(theta,"The glancing angle in degree is");
```

Scilab code Exa 1.12 Wavelength of X ray

```
1  // Exa 1.12
2  clc;
3  clear;
```

```
 4 close;
 5 // Given data
 6 a = 3.615;// in
 7 theta = 22;// in degree
 8 n = 1;
 9 h = 1;
10 k = h;
11 l = k;
12 d = a/(sqrt( ((h)^2) + ((k)^2) + ((l)^2) ));// in
13 lembda = 2*d*sind(theta);// in
14 disp(lembda,"The wavelength of X ray in     is");
15 theta2 =asind( lembda/d );// in degree
16 theta2 = theta2 * 2;// in degree
17 disp(theta2,"To get the 2nd order spectrum the
       position of the detector in degree is");
```

Scilab code Exa 1.13 Lattice constant

```
 1 // Exa 1.13
 2 clc;
 3 clear;
 4 close;
 5 // Given data
 6 n = 1;
 7 lembda = 1.54;// in
 8 theta = 21.7;// in degree
 9 d = lembda/(2*sind(theta));// in
10 h = 1;
11 k = h;
12 l = k;
13 a = d*sqrt(h^2+k^2+l^2);// in
14 disp(a,"Lattice constant in     is");
```

15

Scilab code Exa 1.14 Distance between d211 planes

```
1 // Exa 1.14
2 clc;
3 clear;
4 close;
5 // Given data
6 h = 2;
7 k = 1;
8 l = 1;
9 a = 4.8;// in
10 d_211 = a/(sqrt(h^2+k^2+l^2));// in
11 disp(d_211,"The distance between planes in    is");
```

Scilab code Exa 1.15 Density of copper

```
1 // Exa 1.15
2 clc;
3 clear;
4 close;
5 // Given data
6 r = 1.28;// in
7 a = (4*r)/(sqrt(2));// in
8 a = a * 10^-8;// in cm
9 n = 4;
10 M = 63.5;
11 N_A = 6.023*10^23;
12 Rho = (n*M)/( N_A*((a)^3) );// in gm/cc
13 disp(Rho,"Density in gm/cc is");
```

Scilab code Exa 1.16 Number of atom per unit cell

```
1 // Exa 1.16
```

16

```
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  M = 55.85;
 7  a = 2.9;// in
 8  a = a * 10^-8;// in cm
 9  Rho = 7.87;// in gm/cc
10  N_A = 6.023*10^23;
11  n = (Rho*N_A*((a)^3))/M;// atom per unit
12  disp("A lattice having "+string(round(n))+" atom per
        unit cell is a BCC structure");
```

Scilab code Exa 1.17 Radius of element atom

```
 1  // Exa 1.17
 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  a = ((n*M)/(N_A * Rho))^(1/3);// in cm
11  r = (a*sqrt(2))/n;//radius of atom in cm
12  r = r * 10^8;// in
13  disp(r,"Radius of atom in    is");
```

Scilab code Exa 1.18 Packing factor

```
 1  // Exa 1.18
 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 a =((n*M)/(Rho*N_A))^(1/3);// in cm
11 r = (a*sqrt(3))/4;// in cm
12 P_f = (2*(4/3)*%pi*((r)^3))/((a)^3);// packing
     factor
13 disp(P_f,"Packing factor is ");
```

Scilab code Exa 1.19 Number of unit cell

```
 1 // Exa 1.19
 2 clc;
 3 clear;
 4 close;
 5 // Given data
 6 M = 120;
 7 n = 2;
 8 N_A = 6.023*10^23;
 9 m1 = M/N_A;//mass of 1 atom in gm
10 m2 = n*m1;//mass of unit cell in gm
11 disp(20/m2,"Number of unit cell in 20 gms of element
        is : ")
```

Scilab code Exa 1.20 Distance between K and F

```
 1 // Exa 1.20
 2 clc;
 3 clear;
```

```
 4  close;
 5  // Given data
 6  Rho = 2.48; // in gm/c.c
 7  n = 4;
 8  M = 58;
 9  N_A = 6.023*10^23;
10  a = ( (n*M)/(Rho*N_A) )^(1/3); // in cm
11  a = a * 10^8; // in
12  r = (a*sqrt(2))/n; // in
13  r = 2*r; // in
14  disp(r,"The center to center distance between ions
        in     is");
```

Chapter 2

Carrier Transport in Semiconductor

Scilab code Exa 2.1 Energy gap

```
1  // Exa 2.1
2  clc;
3  clear;
4  close;
5  // Given data
6  lembda = 11000; // in
7  lembda = lembda * 10^-10;
8  h = 6.625*10^-34;
9  c = 3*10^8;
10 q = 1.6*10^-19; // in C
11 E_g = h*c/lembda; // in J
12 E_g= E_g/q; // in eV
13 disp(E_g,"The energy gap in Si in eV is");
14
15 // Note: The answer in the book is not correct
```

Scilab code Exa 2.2 Wavelength

```
1  // Exa 2.2
2  clc;
3  clear;
4  close;
5  // Given data
6  E_g = 0.75;// in eV
7  q=1.6*10^-19;// in C
8  E_g = E_g*q;// in J
9  h = 6.63*10^-34;// in J
10 c = 3*10^8;// in m/s
11 lembda = (h*c)/E_g;// in m
12 lembda = lembda * 10^10;// in
13 disp(lembda,"The wavelength in    is");
```

Scilab code Exa 2.3 Position of Fermi level

```
1  // Exa 2.3
2  clc;
3  clear;
4  close;
5  // Given data
6  del_E = 0.3;//value of E_C-E_F in eV
7  T1 = 330;// in K
8  T = 300;// in K
9  del_E1 = del_E*(T1/T);//value of E_C-E_F in eV
10 disp(del_E1,"The position of fermi level in eV is");
11 disp("Hence the Fermi level will be "+string(del_E1)
      +" eV below the conduction band")
```

Scilab code Exa 2.4 Probability

```
1  // Exa 2.4
2  clc;
3  clear;
4  close;
5  // Given data
6  K = 8.63*10^-5;
7  T = 300;// in K
8  N_C = 2.8*10^19;// in cm^-3
9  del_E = 0.25;
10 f_F = exp( (-del_E)/(K*T) );
11 disp(f_F,"The probability is : ");
12 n_o = N_C*exp( (-del_E)/(K*T) );// in cm^-3
13 disp(n_o,"The thermal equillibrium electron
       concentration in cm^-3 is");
```

Scilab code Exa 2.5 Thermal equilibrium hole concentration

```
1  // Exa 2.5
2  clc;
3  clear;
4  close;
5  // Given data
6  N_V = 1.04*10^19;// in cm^-3
7  T1 = 400;// in K
8  T2 = 300;// in K
9  del_E = 0.27;//value of E_F-E_V in eV
10 K = 0.0259;
11 N_V= N_V*(T1/T2)^(3/2);// in cm^-3
12 KT = K*(T1/T2);// in eV
13 p_o = N_V*exp( (-del_E)/(KT) );// in /cm^3
14 disp(p_o,"The hole concentration per cm^3 is");
```

Scilab code Exa 2.6 Mobility of electrons in copper

```
1  // Exa  2.6
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  N = 6.02*10^23;
7  A = 63.5;// atomic weight
8  Rho = 1.7*10^-6;// in ohm cm
9  d = 8.96;// in gm/cc
10 n = (N/A)*d;// in /cc
11 e = 1.6*10^-19;// in C
12 Miu_e = 1/(Rho*n*e);// in cm^2/volt−sec
13 disp(Miu_e ,"The mobility of electron in cm^2/volt .
      sec is");
```

Scilab code Exa 2.7 Density of free electrons

```
1  // Exa  2.7
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  d = 8.96;// in gm/cc
7  At = 63.5;// atomic weight
8  N_A = 6.02*10^23;// in /gm mole
9  l = 0.1;// in m
10 e = 1.6*10^-19;// in C
11 A = 1.7*10^-6;// in m^2
12 R = 0.1;// in ohm
13 n = (N_A/At)*d;// in /cc
14 n = n * 10^6;// in /m^3
15 Rho = (R*A)/l;// in ohm.m
16 Sigma = 1/Rho;// in mho/m
17 Miu_e = Sigma/(n*e);// in m^2/V−sec
18 disp(Miu_e ,"The electron mobility in m^2/V−sec is ")
```

```
        ;
```

Scilab code Exa 2.8 Drift velocity

```
1  // Exa 2.8
2  clc;
3  clear;
4  close;
5  // Given data
6  N_A = 6.025*10^23;// in /gm mole
7  d = 10.5;// in gm/cc
8  At = 108;// atomic weight of
9  n = (N_A/At)*d;// in /cm^3
10 n = n * 10^6;// in /m^3
11 r = 10^-3;// in m
12 A = %pi * ((r)^2);// in m^2
13 q = 1.6*10^-19;
14 I = 2;// in A
15 V = I/(n*q*A);// in m/s
16 disp(V,"The drift velocity of an electron in m/s is"
      );
17
18 // Note: There is calculation error to find the
      value of V (i.e. drift velocity), So the answer
      in the book is wrong
```

Scilab code Exa 2.9 Mobility of charge carriers

```
1  // Exa 2.9
2  clc;
3  clear;
4  close;
5  // Given data
```

```
6  e= 1.6*10^-19;// in C
7  d= 1.03;// in mm
8  d= d*10^-3;// in m
9  R= 6.51;// in ohm
10 l= 300;// in m
11 n= 8.4*10^28;// per m^3
12 r= d/2;// in m (radius)
13 A= %pi*r^2;// in m^2
14 rho= R*A/l;// in ohm meter
15 sigma=  1/rho;// in mho/m
16 disp(sigma,"The coductivity of copper in mho/m is :
      ")
17 miu_e= sigma/(n*e);// m^2/V-sec
18 disp(miu_e,"The mobility of charge carriers in m^2/V
      -sec is : ")
```

Scilab code Exa 2.10 Conductivity of pure Si

```
1  // Exa 2.10
2  clc;
3  clear;
4  close;
5  // Given data
6  Miu_e = 1500;// in cm^2/volt.sec
7  Miu_h = 500;// in cm^2/volt.sec
8  n_i = 1.6*10^10;// in /cm^3
9  e = 1.6*10^-19;// in C
10 Sigma_i = n_i*(Miu_e+Miu_h)*e;// in mho/cm
11 Sigma = Sigma_i;// in mho/cm
12 disp(Sigma,"The conductivity of pure silicon in mho/
      cm is");
```

Scilab code Exa 2.11 Number of donor atoms

```
1  // Exa 2.11
2  clc;
3  clear;
4  close;
5  // Given data
6  Miu_d = 500;// in cm^2/V.S
7  Rho = 10;// in ohm cm
8  e = 1.6*10^-19;// in C
9  n_d = 1/(Rho*e*Miu_d);// in /cm^3... correction
10 disp(n_d,"The number of donor atom per cm^3 is");
```

Scilab code Exa 2.12 Conductivity of speciman

```
1  // Exa 2.12
2  clc;
3  clear;
4  close;
5  // Given data
6  d = 5.32;// in gm/cc
7  N_A = 6.02*10^23;// in atoms/gm.mole
8  At = 72.6;//atomic weight
9  Miu = 3800;// in cm^2/v.s
10 n_d = (N_A/At) * d;// in /cm^3
11 n_d = n_d * 10^-8;// in /cc
12 e = 1.6*10^-19;// in C
13 Sigma = n_d * Miu * e;// in mho/cm
14 disp(Sigma,"The conductivity of specimen in mho/cm
        is");
```

Scilab code Exa 2.13 Mobility of electrons in Ge

```
1  // Exa 2.13
2  clc;
```

```
3 clear;
4 close;
5 // Given data
6 Rho = 0.3623*10^-3;// in ohm m
7 d = 4.42*10^28;// Ge density in atoms/m^3
8 Sigma = 1/Rho;// in mho/m
9 n_d = d*10^-6;// in atoms/m^3
10 e = 1.6*10^-19;// in C
11 Miu = Sigma/(n_d*e);// in m^2/V.sec
12 disp(Miu,"The electron mobility in m^2/V-sec is");
```

Scilab code Exa 2.14 Density and mobility of holes

```
1 // Exa 2.14
2 clc;
3 clear;
4 close;
5 // Given data
6 N_A = 6.025*10^26;// in /kg.Mole
7 At = 72.59;// atomic weight
8 d = 5.36*10^3;// in kg/m^3
9 R = 0.42;// in ohm m
10 B_i = 10^-6;//rate of boron impurity in %
11 e = 1.6*10^-19;// in C
12 n = (N_A/At)*d;// number of Ge atoms
13 h = n/10^8;//holes per unit volume
14 Miu_h = 1/(R*h*e);// in m^2/V.sec
15 disp(Miu_h,"The Mobility of holes in m^2/V-sec is");
```

Scilab code Exa 2.15 Current produced

```
1 // Exa 2.15
2 clc;
```

```
 3  clear;
 4  close;
 5  // Given data
 6  n_i = 2*10^19;// in /m^3
 7  Miu_e = 0.36;// in m^2/v.s
 8  Miu_h = 0.17;// in m^2/v.s
 9  A = 1*10^-4;// in m^2
10  V = 2;// in Volts
11  l = 0.3;// in mm
12  l = l * 10^-3;// in m
13  e = 1.6*10^-19;// in C
14  Sigma_i = n_i * e * (Miu_e+Miu_h);// in mho/m
15  I = (Sigma_i * V*A)/l;// in amp
16  disp(I,"The current in amp is");
```

Scilab code Exa 2.16 Resistivity of doped Ge

```
 1  // Exa 2.16
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  d = 4.2*10^28;// in atoms/m^3
 7  n_d = d/10^6;// in atoms/m^3
 8  e = 1.6*10^-19;// in C
 9  Miu_e = 0.36;// in m^2/V-sec
10  Sigma_n = n_d *e *Miu_e;// in mho/m
11  Rho_n = 1/Sigma_n;// in ohm m
12  disp(Rho_n,"The resistivity in  m is");
```

Scilab code Exa 2.17 Current produced

```
 1  // Exa 2.17
```

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

Scilab code Exa 2.18 Conductivity of pure Si

```
1 // Exa 2.18
2 clc;
3 clear;
4 close;
5 // Given data
6 Miu_h = 500;// in cm^2/V.s
7 Miu_e = 1500;// in cm^2/V.s
8 n_i = 1.6*10^10;// in /cm^3
9 e = 1.6*10^-19;// in C
10 Sigma_i = n_i * e * (Miu_e+Miu_h);// in mho/cm
11 disp(Sigma_i,"The conductivity of pure silicon in
     mho/cm is");
```

Scilab code Exa 2.19 Hall voltage produced

```
1  // Exa 2.19
2  clc;
3  clear;
4  close;
5  // Given data
6  Si_density = 10.5;// in gm/cc
7  N_A = 6.025*10^23;
8  At = 108;//atomic weight
9  B = 0.8;// in Tesla
10 w = 0.50;// in cm
11 w = w * 10^-2;// in m
12 t = 0.10;// in mm
13 t = t * 10^-3;// in m
14 A = w*t;// in m^2
15 q = 1.6*10^-19;// in C
16 I = 2;// in ampere
17 n = (N_A/At) * Si_density ;// in /cc
18 n = n * 10^6;// in /m^3
19 V_H = (B*I*t)/(n*q*A);// in volts
20 disp(V_H,"The hall voltage produced in volts is");
```

Scilab code Exa 2.20 Hall coefficient and mobility of electrons

```
1  // Exa 2.20
2  clc;
3  clear;
4  close;
5  // Given data
6  Sigma = 5.8*10^7;// in mho/m
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  I = 1;// in Amp
13  B = 1;// in Tesla
14  V_H = 0.074*10^-6;// in Volts
15  A = 10^-2 * 10^-3;// in m^2
16  R_H = (V_H*A)/(B*I*d);// in m^3/c
17  disp(R_H,"Hall coefficient in m^3/c is");
18  Miu = Sigma * R_H;// in m^2/volt.sec
19  disp(Miu,"The mobility of electron in m^2/volt.sec
       is");
```

Scilab code Exa 2.21 Ratio of electron to hole concentration

```
1  // Exa 2.21
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 disp(p,"Concentration of holes per m^3 is");
11 R_e = n/p;// Ratio of electron
12 disp(R_e,"Ratio of electron to hole concentration is
       ");
```

Scilab code Exa 2.22 Hall angle

```
1  // Exa 2.22
2  clc;
3  clear;
4  close;
```

```
5  // Given data
6  B = 0.48;// in Wb/m^2
7  R_H = 3.6 * 10^-4;// in m^3/c
8  R = 9*10^-3;// in ohm-m
9  Sigma = 1/R;// in (ohm-m)^-1
10 Rho = 1/R_H;// in coulomb/m^3
11 e = 1.6*10^-19;// in C
12 n = Rho/e;// in /m^3
13 Miu = Sigma * R_H;// in m^2/volt-s
14 disp(Miu,"The mobility of electron in m^2/volt-s is"
       );
```

Scilab code Exa 2.23 Current density in speciman

```
1  // Exa 2.23
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  Miu_e = 0.36;// m^2/v-s
9  E = 100;// V/m
10 n = 1/(e*R_H);// in /m^3
11 J= n*e*Miu_e*E;// in A/m^2
12 disp(J,"The current density in A/m^2 is");
```

Scilab code Exa 2.24 Relaxation time

```
1  // Exa 2.24
2  clc;
3  clear;
4  close;
```

```
5  // Given data
6  e = 1.6*10^-19;// in C
7  Miu_e = 7.04*10^-3;// in m^2/volt-sec
8  n = 5.8*10^28;// number of electron/m^3
9  m = 9.1*10^-31;
10 E_F = 5.5;// in eV
11 Torque = (Miu_e/e)*m;// in sec
12 disp(Torque,"Relaxtion time in sec is");
13 Rho = 1/(n*e*Miu_e);// in ohm cm
14 disp(Rho,"Resistivity of conductor in  m is");
15 V_F = sqrt( (2*E_F*e)/m );// in m/s
16 disp(V_F,"Velocity of electron with the fermi energy
       in m/s is");
17
18 // Note: The calculation of Part (ii) is wrong also
       the unit of resistivity of conductor is wrong
```

Scilab code Exa 2.25 Temperature

```
1  // Exa 2.25
2  clc;
3  clear;
4  close;
5  // Given data
6  E= 5.95;// in eV
7  EF= 6.25;// in eV
8  delE= 0.01;
9   // delE= 1-1/(1+exp((E-EF)/KT))
10 K=1.38*10^-23;// Boltzman Constant in J/K
11 T = ((E-EF)/log(1/(1-delE) -1)*1.6*10^-19)/K;// in K
12 disp(T,"The temperature in K is : ")
```

Scilab code Exa 2.26 Thermal equilibrium hole concentration

```
1  // Exa 2.26
2  clc;
3  clear;
4  close;
5  // Given data
6  T1 = 400;// in K
7  T2 = 300;// in K
8  N_V = 1.04*10^19;// in cm^-3
9  N1 = N_V*((T1/T2)^(3/2));// in cm^-3
10 KT = 0.0259*(T1/T2);// in eV
11 FermiLevel= 0.27;// in eV
12 P_O = N1*exp( (-FermiLevel)/KT );// in cm^-3
13 disp(P_O,"The thermal equillibrium hole
       concentration in cm^-3 is");
```

Scilab code Exa 2.27 Required doping concentration

```
1  // Exa 2.27
2  clc;
3  clear;
4  close;
5  // Given data
6  T1 = 550;// in K
7  T2 = 300;// in K
8  N1 = 1.04*10^19;
9  N_V = N1*((T1/T2)^(3));
10 N_C = 2.8*10^19;
11 E_g = -1.12;
12 KT = 0.0259*(T1/T2);
13 n_i = sqrt(N_C*N_V*exp(E_g/KT));// in cm^-3
14 disp(n_i,"The value of n_i in cm^-3 is : ")
15 //Formula n_o= Nd/2+sqrt((Nd/2)^2+n_i^2) and n_o =
       1.05*N_d;
16 Nd= sqrt(n_i^2/((1.05-1/2)^2-(1/2)^2))
17 disp(Nd,"The value of N_d in cm^-3 is : ")
```

Scilab code Exa 2.28 Quasi Fermi energy levels

```scilab
1  // Exa 2.28
2  clc;
3  clear;
4  close;
5  // Given data
6  n_o = 10^15;// in cm^-3
7  n_i = 10^10;// in cm^-3
8  p_o = 10^5;// in cm^-3
9  del_p = 10^13;// in cm^-3
10 del_n = del_p;// in cm^-3
11 KT= 0.0259;// in eV
12 Fermi_level= KT*log(n_o/n_i);// in eV
13 disp(Fermi_level,"Fermi level for thermal
       equillibrium in eV is :")
14 Fermi_level= KT*log((n_o+del_n)/n_i);// in eV
15 disp(Fermi_level,"Quasi-Fermi level for electrons in
        non equillibrium in eV is :")
16 Fermi_level= KT*log((p_o+del_p)/n_i);// in eV
17 disp(Fermi_level,"Quasi-Fermi level for holes in non
       equillibrium in eV is :")
```

Chapter 3

Excess Carriers In Semiconductors

Scilab code Exa 3.1 Hole concentration at equilibrium

```
1  // Exa 3.1
2  clc;
3  clear;
4  close;
5  // Given data
6  n_o = 10^17;// in /cm^3
7  n_i = 1.5*10^10;// in /cm^3
8  p_o = ((n_i)^(2))/n_o;// in holes/cm^3
9  disp(p_o,"The hole concentration in holes/cm^3 is ")
      ;
```

Scilab code Exa 3.3 Position of Fermi level

```
1  // Exa 3.3
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 3.4 Diffusion coefficients of electrons

```
1  // Exa 3.4
2  clc;
3  clear;
4  close;
5  // Given data
6  K = 1.38*10^-23;// in J/K
7  T = 27;// in degree C
8  T = T + 273;// in K
9  e = 1.6*10^-19;
10 Miu = 0.17;// in m^2/v-s
11 Miu1 = 0.025;// in m^2/v-s
12 D_n = ((K*T)/e)*Miu;// in m^2/s
13 disp(D_n,"The diffusion coefficient  of electrons in
        m^2/s is");
14 D_p = ((K*T)/e)*Miu1;// in m^2/s
15 disp(D_p,"The diffusion coefficient of holes in m^2/
        s is");
```

Scilab code Exa 3.5 Diffusion length

```
1  // Exa 3.5
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  Miu_n = 0.15; // in m^2/v-s
7  K = 1.38*10^-23;
8  T = 300; // in K
9  e = 1.6*10^-19; // in C
10 D_n = Miu_n*((K*T)/e); // in m^2/s
11 Torque_n = 10^-7; // in s
12 L_n = sqrt(D_n*Torque_n); // in m
13 disp(L_n,"The diffusion length in m is");
14 del_n = 10^20; // in electrons/m^3
15 J_n = (e*D_n*del_n)/L_n; // in A/m^2
16 disp(J_n,"The diffusion current density in A/m^2 is"
     );
```

Scilab code Exa 3.6 Concentration of holes and electrons

```
1  // Exa 3.6
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  Sigma_n = 0.1; // in (ohm-cm)^-1
7  Miu_n = 1300;
8  q = 1.6*10^-19; // in C
9  n_n = Sigma_n/(Miu_n*q); // in electrons/cm^3
10 disp(n_n*10^6,"Concentration of electrons per m^3 is
     ");
11 n_i = 1.5*10^10;
12 p_n = ((n_i)^2)/n_n; // in holes/cm^3
13 p_n = p_n * 10^6; // in holes/m^3
14 disp(p_n,"Concentration of holes per m^3 is");
```

Scilab code Exa 3.7 Electron transit time

```
1  // Exa 3.7
2  clc;
3  clear;
4  close;
5  // Given data
6  L = 100*10^-6;// in m
7  Miu_e = 0.13;// in m^2/V-s
8  Torque_h = 10^-6;// in s
9  Miu_h = 0.05;// in m^2/v-s
10 V = 12;// in V
11 Torque_n = ((L)^2)/(Miu_e*V);// in s
12 disp(Torque_n,"Electron transit time in sec is");
13 P = (Torque_h/Torque_n)*(1+(Miu_h/Miu_e));
14 disp(P,"Photoconductor gain is");
```

Scilab code Exa 3.8 Resistivity drops

```
1  //Exa 3.8
2  clc;
3  clear;
4  close;
5  // Given data
6  q = 1.6*10^-19;// in C
7  n_i = 2.5*10^13;
8  Miu_n = 3800;// in cm^2/V-s
9  Miu_p = 1800;// in cm^2/V-s
10 Sigma = n_i*(Miu_n + Miu_p)*q;// in (ohm-cm)^-1
11 Rho = 1/Sigma;// in ohm-cm
12 disp(Rho,"The resistivity in ohm-cm is");
```

```
13  N_D =4.4*10^22/10^8 ;// in atoms/cm^3
14  Sigma_n = N_D * Miu_n*q;// in (ohm-cm)^-1
15  Rho1 = 1/Sigma_n;// in ohm cm
16  disp(Rho1,"The resistivity drops in ohm cm is");
```

Scilab code Exa 3.9 Electron concentration

```
1  // Exa 3.9
2  clc;
3  clear;
4  close;
5  // Given data
6  n_i = 10^16;// in /m^3
7  N_D = 10^22;// in /m^3
8  n = N_D;// in /m^3
9  disp(n,"The concentration of electrons per m^3 is");
10  p = ((n_i)^2)/n;// in /m^3
11  disp(p,"The concentration of holes per m^3 is");
```

Scilab code Exa 3.10 Ratio of donor atoms to Si atom

```
1  // Exa 3.10
2  clc;
3  clear;
4  close;
5  // Given data
6  Rho = 9.6*10^-2;// ohm-m
7  Sigma_n = 1/Rho;// in (ohm-m)^-1
8  Miu_n = 1300;// in cm^2/V-s
9  Miu_n = Miu_n * 10^-4;// in m^2/V-s
10  q = 1.6*10^-19;// in C
11  N_D = Sigma_n/(Miu_n*q);// in atoms/m^3
12  d = 5*10^22;// in atoms/cm^3
```

```
13 d = d * 10^6;// in atoms/m^3
14 R_d = N_D/d;// Ratio
15 disp(R_d,"Ratio of donor atom to silicon atoms per
       unit volume is");
```

Scilab code Exa 3.11 Equillibrium electron and hole densities

```
1 // Exa 3.11
2 clc;
3 clear;
4 close;
5 // Given data
6 n_i = 1.5*10^10;// in /cm^3
7 n_n = 2.25*10^15;//in /cm^3
8 p_n = ((n_i)^2)/n_n;// in /cm^3
9 disp(p_n,"The concentration of holes per cm^3 is");
10 disp(n_n,"Donor impurity per cm^3 is");
```

Scilab code Exa 3.12 Carrier concentration

```
1 // Exa 3.12
2 clc;
3 clear;
4 close;
5 // Given data
6 N_A = 2*10^16;// in /cm^3
7 N_D = 10^16;// in /cm^3
8 C = N_A-N_D;// in /cm^3
9 disp(C,"Carrier concentration in holes/cm^3 is");
```

Scilab code Exa 3.13 Generation rate due to irradiation

```
1  // Exa 3.13
2  // GIven data
3  clc;
4  clear;
5  close;
6  del_n = 10^15;// in /cm^3
7  Torque_p = 10*10^-6;// in sec
8  R_G = del_n/Torque_p;// in electron hole pairs/sec/
     cm^3
9  disp("The rate of generation of minority carrier is
     : "+string(R_G)+" electron hole pairs/sec/cm^3");
```

Scilab code Exa 3.14 Mobility of minority charge carrier

```
1   // Exa 3.14
2   clc;
3   clear;
4   close;
5   // Given data
6   V = 1/20;// in cm/ sec
7   V=V*10^6;// in cm/sec
8   E = 10;// in V/cm
9   Miu = V/E;// in cm^2/V-sec
10  disp(Miu,"The mobility of minority charge carrier in
      cm^2/V-sec is");
```

Scilab code Exa 3.15 Hole and electron diffusion current

```
1  // Exa 3.15
2  clc;
3  clear;
```

```scilab
 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 check this also
      .............................
32 disp(dnBYdx,"Concentration gradient of electrons in
      per cm^4 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/cmˆ2 is");
```

Scilab code Exa 3.16 Energy band gap of semiconductor material used

```
1  // Exa 3.16
2  clc;
3  clear;
4  close;
5  // Given data
6  h = 6.626 * 10^-34;// in J-s
7  q= 1.6*10^-19;// in C
8  h= h/q;// in eV
9  c = 3*10^8;
10 lembda = 5490*10^-10;// in m
11 E = h*c/lembda;// in eV
12 disp(E,"The energy band gap in eV is");
```

Scilab code Exa 3.17 Current density in Si

```
1  // Exa 3.17
2  clc;
3  clear;
4  close;
5  // Gievn data
6  D_n = 35;// in cm^2/sec
7  q = 1.6*10^-19;// in C
8  y2 = 6*10^16;// in /cm^3
9  y1 = 10^17;// in /cm^3
10 x2 = 2*10^-4;
11 x1 = 0;
12 dnBYdx = (y2-y1)/(x2-x1);
13 J_n = q*D_n*dnBYdx;// in A/cm^2
14 disp(J_n,"The current density in A/cm^2 is");
```

Scilab code Exa 3.18 Resistance of the bar

```
1  // Exa 3.18
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  Miu_n = 0.13;// in m^2/V-sec
10 Miu_n = Miu_n * 10^4;// in cm^2/V-sec
11 Sigma_n = q*n_n*Miu_n;// in ohm-cm^-1
12 Rho = 1/Sigma_n;
13 A = 100;// in  m^2
14 A = A * 10^-8;// in cm^2
15 l = 0.1;// in cm
16 R = Rho * (l/A);// in ohm
17 disp(round(R*10^-6),"The resistance of the bar in M
       ohm is");
```

Scilab code Exa 3.19 Depletion width

```
1  // Exa 3.19
2  clc;
3  clear;
4  close;
5  // Given data
6  w = 3;// in  m
7  D = w/9;// in  m
8  disp(D,"Depletion width on P side in  m is");
```

Scilab code Exa 3.20 Minority carrier density

```
1 // Exa 3.20
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 minority carrier density per m^3 is");
```

Scilab code Exa 3.21 Collector current density

```
1 // Exa 3.21
2 clc;
3 clear;
4 close;
5 // Given data
6 y2 = 10^14;// in /cm^3
7 y1 = 0;
8 x1=-0.5;// in   m
9 x1= x1*10^-4;// in cm
10 x2=0;
11 dnBYdx = (y2-y1)/(x2-x1);// in /cm^4
12 q = 1.6*10^-19;// in C
13 D_n = 25;// in cm^2/sec
14 J_n = q*D_n*dnBYdx;// in A/cm^2
15 disp(J_n,"The collector current density in A/cm^2 is
     ");
```

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Scilab code Exa 3.22 Band gap

```
1  // Exa 3.22
2  clc;
3  clear;
4  close;
5  // Given data
6  h = 6.64*10^-34;// in J-s
7  q=1.6*10^-19;// in C
8  h= h/q;// in eV
9  c = 3*10^8;// in m/s
10 lembda = 0.87*10^-6;// in m
11 E_g = (h*c)/lembda;// in eV
12 disp(E_g,"The band gap in eV is");
```

Scilab code Exa 3.23 Total energy absorbed by sample

```
1  // Exa 3.23
2  clc;
3  clear;
4  close;
5  // Given data
6  alpha = 5*10^4;// in cm^-1
7  l = 0.46*10^-4;// in cm
8  hv = 2;// in eV
9  I_o = 10^-2;// in W
10 I_t = I_o*exp(-alpha*l);// in W
11 A_p = I_o-I_t;//absorbed power in W or J/s
12 disp(A_p,"Total energy absorbed in J/s is");
13 c = 1.43;
14 A_E = (hv-c)/hv*A_p;// in J/s
15 disp(A_E,"Rate of excess thermal energy in J/s is");
```

```
16  e = 1.6*10^-19; // in C
17  P = A_p/(e*hv); // Perfect quantum efficiency in
        photon/s
18  disp(P,"Perfect quantum efficiency in photon/s is");
```

Scilab code Exa 3.24 Hole current

```
1  // Exa 3.24
2  clc;
3  clear;
4  close;
5  // Given data
6  format('v',13)
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 hence the value of hole
```

current in the book is wrong

Chapter 4

Junctions and Interfaces

Scilab code Exa 4.2 Junction width

```
1  // Exa 4.2
2  clc;
3  clear;
4  close;
5  // Given data
6  N_D = 10^17 * 10^6; // in atoms/m^3
7  N_A = 0.5*10^16*10^6; // in atoms/m^3
8  Epsilon_r = 10;
9  Epsilon_o = 8.85*10^-12;
10 Epsilon = Epsilon_r*Epsilon_o; // in F/m
11 e = 1.602*10^-19; // in C
12 V = 0;
13 V_B = 0.7; // in V
14 W = sqrt( ((2*Epsilon*V_B)/e)*(1/N_A+1/N_D) ); // in
      m
15 disp(W,"The junction width in meter when no external
       voltage is applied is");
16 V_o = V_B; // in V
17 V1 = -10; // in V
18 V_B1 = V_o-V1; // in V
19 W = sqrt( ((2*Epsilon*V_B1)/e)*(1/N_A+1/N_D) ); // in
```

```
        m
20 disp (W," Junction  width  in  meter  with  an  external
        voltage  of  −10V  is ") ;
```

Scilab code Exa 4.4 Diode voltage

```
1  // Exa  4.4
2  clc ;
3  clear ;
4  close ;
5  // Given  data
6  V = 5; // in  V
7  V_Gamma = 0.6; // in  V
8  r_F = 12; // in  ohm
9  R = 1; // in  k  ohm
10 R = R * 10^3; // in  ohm
11 I_F = (V-V_Gamma)/(R+r_F) ; // in  A
12 disp (I_F*10^3," The  forward  diode  current  in  mA  is ") ;
13 V_F = V_Gamma + (I_F*r_F) ; // in  V
14 disp (V_F," The  diode  voltage  in  V  is ") ;
```

Scilab code Exa 4.5 Contact difference of potential

```
1  // Exa  4.5
2  clc ;
3  clear ;
4  close ;
5  // Given  data
6  n = 4.4*10^22; // total  number  of  Ge  atoms/cm^3
7  n_a = 1*10^8; // number  of  impurity  atoms
8  N_A = n/n_a; // in  atoms/cm^3
9  N_A = N_A * 10^6; // in  atoms/m^3
10 n_i = 2.5*10^13; // in  atoms/cm^3
```

```
11  n_i = n_i * 10^6;// in atoms/m^3
12  N_D = 10^3 * N_A;// in atoms/m^3
13  V_T = 26*10^-3;// in A
14  V_J = V_T*log( (N_A*N_D)/((n_i)^2) );// in V
15  disp(V_J,"The contact difference of potential in V
      is");
16  disp("For a silicon P-N junction")
17  n = 5*10^22;
18  N_A = n/n_a;// in atoms/cm^3
19  N_A = N_A * 10^6;// in atoms/m^3
20  N_D = 10^3 * N_A;// in atoms/m^3
21  n_i = 1.5*10^10;// in /cm^3
22  V_J = V_T*log(N_A*N_D/n_i^2);// in V
23  disp(V_J,"The contact difference of potential in V
      is");
24
25  // Note: There is a calculation error to find the
      value of V_J in the book, so the answer in the
      book is wrong.
```

Scilab code Exa 4.6 Height of the potential energy barrier

```
1  // Exa 4.6
2  clc;
3  clear;
4  close;
5  // Given data
6  Rho_p = 2;// in ohm-cm
7  Rho_n = 1;// in ohm cm
8  q = 1.6*10^-19;// in C
9  n_i = 2.5*10^13;// atoms per cm^3
10  Miu_p = 1800;
11  Miu_n = 3800;
12  N_A = 1/(Rho_p*q*Miu_p);// in /cm^3
13  N_D = 1/(Rho_n*q*Miu_n);// in /cm^3
```

```
14  V_T = 26;//in mV
15  V_T= V_T*10^-3;// in V
16  V_J = V_T*log((N_A*N_D)/((n_i)^2));//in V
17  disp(V_J,"The height of the potential energy barrier
        in V is");
18  Miu_p = 500;
19  N_A = 1/(Rho_p*q*Miu_p);// in /cm^3
20  Miu_n = 1300;
21  N_D = 1/(Rho_n*q*Miu_n);// in /cm^3
22  n_i = 1.5*10^10;
23  V_J = V_T*log((N_A*N_D)/((n_i)^2));//in V
24  disp("For silicon P-N juction")
25  disp(V_J,"The height of the potential energy barrier
        in V is");
```

Scilab code Exa 4.7 Voltage

```
1  //Exa 4.7
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 4.8 Anticipated factor

```
1  //Exa 4.8
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 4.9 Leakage resistance

```
1  //Exa 4.9
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 4.10 Dynamic resistance

```
1  //Exa 4.10
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 4.11 Barrier capacitance of a Ge pn junction

```
1  // Exa 4.11
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 4.12 Width of the depletion layer

```
1  //Exa 4.12
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 4.13 Current in the junction

```
1  // Exa 4.13
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 4.14 Forward biasing voltage

```
1  // Exa 4.14
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 4.15 Theoretical diode current

```
1  // Exa 4.15
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 Diode dynamic resistance

```
1  // Exa 4.16
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 4.17 DC load line and operating point

```
1  // Exa 4.17
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 4.18 AC resistance of a Ge diode

```
1  // Exa 4.18
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 4.19 Width of the depletion layer

```
1  // Exa 4.19
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 4.20 Diameter

```
1  // Exa 4.20
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 4.21 Temperature of junction

```
1  // Exa 4.21
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 4.22 Reverse saturation current

```
1  // Exa 4.22
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 6

Microwave Diodes

Scilab code Exa 6.1 Tuning range of circuit

```
1  // Exa 6.1
2  clc;
3  clear;
4  close;
5  // Given data
6  C1_min= 5;// in pF
7  C1_max= 50;// in pF
8  C2_min= 5;// in pF
9  C2_max= 50;// in pF
10 C1_min=C1_min*10^-12;// in F
11 C2_min=C2_min*10^-12;// in F
12 C1_max=C1_max*10^-12;// in F
13 C2_max=C2_max*10^-12;// in F
14 L = 10;// in mH
15 L = L * 10^-3;// in H
16 C_T_min = (C1_min*C2_min)/(C2_min+C2_min);// in F
17 f_o_max = 1/( 2*%pi*(sqrt(L*C_T_min)) );//in Hz
18 f_o_max = f_o_max * 10^-6;// in MHz
19 C_T_max = (C1_max*C2_max)/(C2_max+C2_max);// in F
20 f_o_min = 1/( 2*%pi*(sqrt(L*C_T_max)) );//in Hz
21 f_o_min = f_o_min * 10^-3;// in kHz
```

```
22  disp("The tuning range for circuit will be : "+
        string(round(f_o_min))+" kHz to "+string(round(
        f_o_max))+" MHz")
```

Chapter 7

Optoelectonic Devices

Scilab code Exa 7.1 Component value

```
1  // Exa 7.1
2  clc;
3  clear;
4  close;
5  // Given data
6  Vout = 5;// in V
7  V = 1.5;//ON state voltage drop across LED in V
8  I = 5;// in mA
9  I = I*10^-3;// in A
10 R = (Vout-V)/I;// in ohm
11 disp(R,"Resistance in ohm is");
```

Scilab code Exa 7.2 Open circuit voltage

```
1  // Exa 7.2
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  D_e = 25*10^-4;// in m^2/s
 9  D_n = 1*10^-3;// in m^2/s
10  V_T = 26*10^-3;// in V
11  Torque_eo = 500*10^-9;// in sec
12  Torque_ho = 100*10^-9;// in sec
13  e = 1.6*10^-19;  // in C
14  n_i = 1.5*10^16;// in /m^3
15  I_lambda = 12.5;// in mA/cm^2
16  I_lambda= I_lambda*10^-3;// in A/cm^2
17  L_e = sqrt(D_e*Torque_eo);// in m
18  L_n = sqrt(D_n*Torque_ho);// in m
19  J_s = e*((n_i)^2)*( ((D_e)/(L_e*N_A)) + ((D_n)/(L_n*
        N_D)) );// in A/m^2
20  J_s= J_s*10^-4;// in A/cm^2
21  V_OC = V_T*(log(1+(I_lambda/J_s)));// in V
22  disp(V_OC,"Open circuit voltage in volts is");
```

Scilab code Exa 7.3 Photocurrent density

```
 1  // Exa 7.3
 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  e= 1.6*10^-19;// in C
 9  G_L1 = alpha*Phi_o;// in m^-3s^-1
10  W = 26;// in   m
11  W = W * 10^-6;// in m
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 * 10^3*10^-4; // in mA/cm^2
15  disp(J_L,"Photo current density in mA/cm^2 is ");
```

Chapter 8

Metal Semiconductor Field Effect Transistor

Scilab code Exa 8.1 Drain current

```
1  // Exa 8.1
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 15;// in mA
7  V_GS_off = -5;// in V
8  V_GS = 0;// in V
9  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
10 disp(I_D,"When V_GS=0, the drain current in mA is");
11 V_GS = -1;// in V
12 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
13 disp(I_D,"When V_GS=-1V, the drain current in mA is"
      );
14 V_GS = -4;// in V
15 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
16 disp(I_D,"When V_GS=-4 V, the drain current in mA is
      ");
```

Scilab code Exa 8.2 Transconductance curve

```
1  // Exa 8.2
2  clc;
3  clear;
4  close;
5  // Given data
6  V_GS_off = -20;// in V
7  I_DSS = 12;// in mA
8  V_GS = 0;// in V
9  // For
10 V_GS= -20;
11 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
12 disp(I_D,"When V_GS = -20 V, the drain current in mA
       is");
13 // For
14 V_GS= -15;
15 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
16 disp(I_D,"When V_GS = -15 V, the drain current in mA
       is");
17 // For
18 V_GS= -10;
19 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
20 disp(I_D,"When V_GS = -10 V, the drain current in mA
       is");
21 // For
22 V_GS= -5;
23 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
24 disp(I_D,"When V_GS = -5 V, the drain current in mA
      is");
25 // For
26 V_GS= 0;
27 I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
28 disp(I_D,"When V_GS = 0 V, the drain current in mA
```

```
          is " ) ;
29  V_GS= 0: -0.1: -20
30  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
31  plot(V_GS,I_D);
32  xlabel("Gate to source voltage in V")
33  ylabel("Drain current in mA")
34  title("The transconductance curve")
35  disp("The transconductance curve shown in figure")
```

Scilab code Exa 8.3 Maximum and minimum transconductance

```
 1  // Exa 8.3
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  // For maximum transconductance curve
 7  disp("For Maximum Transconductance curve")
 8  V_GS_off = -2;// in V
 9  I_DSS = 8;// in mA
10  V_GS = 0;// in V
11  // For
12  V_GS= -2;
13  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
14  disp(I_D,"When V_GS = -2 V, the drain current in mA
         is");
15  // For
16  V_GS= -1.5;
17  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
18  disp(I_D,"When V_GS = -1.5 V, the drain current in
        mA is");
19  // For
20  V_GS= -1;
21  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
22  disp(I_D,"When V_GS = -1 V, the drain current in mA
```

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```
        is");
23  // For
24  V_GS= -0.5;
25  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
26  disp(I_D,"When V_GS = −0.5 V, the drain current in
        mA is");
27  // For
28  V_GS= 0;
29  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
30  disp(I_D,"When V_GS = 0 V, the drain current in mA
        is");
31
32  // For maximum transconductance curve
33  disp("For Maximum Transconductance curve")
34  V_GS_off = -6;// in V
35  I_DSS = 20;// in mA
36  V_GS = 0;// in V
37  // For
38  V_GS= -6;
39  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
40  disp(I_D,"When V_GS = −6 V, the drain current in mA
        is");
41  // For
42  V_GS= -4;
43  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
44  disp(I_D,"When V_GS = −4 V, the drain current in mA
        is");
45  // For
46  V_GS= -2;
47  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
48  disp(I_D,"When V_GS = −2 V, the drain current in mA
        is");
49  // For
50  V_GS= 0;
51  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
52  disp(I_D,"When V_GS = 0 V, the drain current in mA
        is");
53  // For maximum transconductance curve
```

```
54  V_GS_off =-6;// in V
55  I_DSS= 20;// in mA
56  V_GS= 0:-0.1:-6;// in volt
57  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
58  // For minimum transconductance curve
59  plot(V_GS,I_D);
60  V_GS_off =-2;// in V
61  I_DSS= 8;// in mA
62  V_GS= 0:-0.1:-2;// in volt
63  I_D = I_DSS*((1-(V_GS/V_GS_off))^2);// in mA
64  plot(V_GS,I_D);
65  xlabel("Gate to source voltage in V")
66  ylabel("Drain current in mA")
67  title("The minimum and maximum transconductance
        curve")
68  disp("The minimum and maximum transconductance curve
        shown in figure")
69
70  // Note: For maximum transconductance curve the
        value of drain current at V_GS =-2 is wrong.
```

Scilab code Exa 8.4 Drain current

```
1  // Exa 8.4
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 20;// in mA
7  V_P = -8;// in V
8  g_mo = 5000;// in  s
9  V_GS = -4;// in V
10  I_D = I_DSS*((1-(V_GS/V_P))^2);// in mA
11  disp(I_D,"The value of drain current in mA is");
12  g_m = g_mo*(1-(V_GS/V_P));// in  s
```

```
13 disp(g_m,"The transconductance in   s  is");
```

Scilab code Exa 8.5 Drain current

```
1  // Exa 8.5
2  clc;
3  clear;
4  close;
5  // Given data
6  I_D1 = 10;// in mA
7  V_GS = -12;// in V
8  V_GSth = -3;// in V
9  K = I_D1/( (V_GS-V_GSth)^2 );// in mA/V
10 V_GS= -6;// in V
11 I_D = K*((V_GS-V_GSth)^2);// in mA
12 disp(I_D,"The value of I_D in mA is");
```

Scilab code Exa 8.7 Minimum value of VDS

```
1  // Exa 8.7
2  clc;
3  clear;
4  close;
5  // Given data
6  V_GS = -2;// in V
7  V_P = -5;// in V
8  V_DS = V_GS-V_P;// in V
9  I_DSS = 8;// in mA
10 disp(V_DS,"The minimum value of V_DS in V is");
11 I_D = I_DSS*((1-(V_GS/V_P))^2);// in mA
12 disp(I_D,"The drain current in mA is");
```

Scilab code Exa 8.8 Value of Vgs and gm

```
1  // Exa 8.8
2  clc;
3  clear;
4  close;
5  // Given data
6  V_P = -2;// in V
7  I_DSS = 1.65;// in mA
8  I_D = 0.8;// in mA
9  V_DD = 24;// in V
10 V_GS = V_P*(1- sqrt(I_D/I_DSS) );// in V
11 disp(V_GS,"The value of V_GS in V is");
12 g_mo = -(2*I_DSS)/V_P;// in mS
13 g_m = g_mo*(1-(V_GS/V_P));// in mS
14 disp(g_m,"The value of g_m in mS is");
```

Scilab code Exa 8.9 Gate source voltage

```
1  // Exa 8.9
2  clc;
3  clear;
4  close;
5  // Given data
6  V_P = 5;// in V
7  I_DSS = -40;// in mA
8  I_D = -15;// in mA
9  V_GS = V_P*(sqrt(I_D/I_DSS)-1 );// in V
10 disp(abs(V_GS),"The gate source voltage in V is");
```

Scilab code Exa 8.10 Value of transconductance

```
1  // Exa 8.10
2  clc;
3  clear;
4  close;
5  // Given data
6  I_D1 = 1.9;// in mA
7  I_D2 = 1;// in mA
8  del_I_D = I_D1-I_D2;// in mA
9  V_GS2 = -3.3;// in V
10 V_GS1 = -3;// in V
11 del_V_GS = V_GS1-V_GS2;// in V
12 g_m = del_I_D/del_V_GS;// in mA/V
13 g_m = g_m * 10^3;// in   mhos
14 disp(g_m,"The value of transconductance in   mhos
      is");
```

Scilab code Exa 8.11 AC drain resistance

```
1  // Exa 8.11
2  clc;
3  clear;
4  close;
5  // Given data
6  V_DS1 = 14;// in V
7  V_DS2 = 5;// in V
8  del_V_DS = V_DS1-V_DS2;// in V
9  I_D1 = 3.3;// in mA
10 I_D2 = 3;// in mA
11 del_I_D = I_D1-I_D2;// in mA
12 r_d = del_V_DS/del_I_D;// in k ohms
13 disp(r_d,"The drain resistance in k ohms is");
14 V_GS1 = 0.4;// in V
15 V_GS2 = 0.1;// in V
```

```
16  del_V_GS = V_GS1-V_GS2;// in V
17  I_D1 = 3.3;// in mA
18  I_D2 = 0.71;// in mA
19  del_I_D = I_D1-I_D2;// in mA
20  g_m = del_I_D/del_V_GS;// in mA/V
21  g_m = g_m * 10^3;// in   mhos
22  disp(g_m,"The transconductance in   mhos is");
23  Miu =r_d*10^3*g_m*10^-6;
24  disp(Miu,"Amplification factor is");
```

Scilab code Exa 8.12 Pinch off voltage

```
1  // Exa  8.12
2  clc;
3  clear;
4  close;
5  // Given data
6  q = 1.6*10^-19;// in C
7  N_D = 10^15*10^6;//electrons/m^3
8  a = 3*10^-4;// in cm
9  a=a*10^-2;// in m
10 Epsilon_o  = (36 * %pi * 10^9)^-1;
11 Epsilon = 12*Epsilon_o;
12 V_P = (q*N_D*((a)^2))/(2*Epsilon);// in V
13 disp(V_P,"Pinch off voltage in V is");
14 V_GS = 1;// in V
15 V_P = 2;// in V
16 // Formula V_GS= V_P*(1-b/a)^2
17 b = a*( 1-sqrt(V_GS/V_P) );// in m
18 b = b * 10^6;// in   m
19 disp(b,"The channel half width in   m is");
20
21 // Note: In the book, the unit of channel half width
        is wrong.
```

Scilab code Exa 8.13 Value of VGS

```
1  // Exa 8.13
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 8;// in mA
7  V_P = -4;// in V
8  a = 3*10^-4;// in cm
9  N_D = 10^15;// in electrons/cm^3
10 I_D = 3;// in mA
11 V_GS = V_P*( 1-sqrt(I_D/I_DSS) );// in V
12 disp(V_GS,"The value of V_GS in V is");
13 V_DS_sat = V_GS-V_P;// in V
14 disp(V_DS_sat,"The value of V_DS_sat in V is");
```

Scilab code Exa 8.14 Drain current

```
1  // Exa 8.14
2  clc;
3  clear;
4  close;
5  // Given data
6  V_P = -4;// in V
7  I_DSS = 9;// in mA
8  V_GS = -2;// in V
9  I_D = I_DSS*(( 1-(V_GS/V_P) )^2);// in mA
10 disp(I_D,"The drain current in mA is");
```

Scilab code Exa 8.15 Value of transconductance

```
1  // Exa 8.15
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 12;// in mA
7  V_P = -6;// in V
8  V_GS = -1;// in V
9  g_mo = (-2*I_DSS)/V_P;// in mA/V
10 g_m = g_mo*(1-(V_GS/V_P));// in mS
11 disp(g_m,"The value of transconductance in mS is");
```

Scilab code Exa 8.16 Value of transconductance

```
1  // Exa 8.16
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DSS = 10;// in mA
7  V_P = -5;// in V
8  V_GS = -2.5;// in V
9  g_m = ((-2*I_DSS)/V_P)*(1-(V_GS/V_P));// in mS ....
       correction
10 disp(g_m,"The transconductance in mS is");
11 I_D = I_DSS * ((1-(V_GS/V_P))^2);// in mA
12 disp(I_D,"The drain current in mA is");
```

Chapter 9

MOS Transistors

Scilab code Exa 9.1 Value of current

```
1  // Exa 9.1
2  clc;
3  clear;
4  close;
5  // Given data
6  V_TN = 0.7; // in V
7  W = 45*10^-4; // in cm
8  L = 4; // in  m
9  L = L * 10^-4; // in cm
10 t_ox = 450; // in
11 t_ox = t_ox*10^-8; // in cm
12 V_GS = 1.4; // in V
13 Miu_n = 700; // in cm^2/V-s
14 Epsilon_ox = (8.85*10^-14)*(3.9); // in F/cm
15 k_n = (W*Miu_n*Epsilon_ox)/(2*L*t_ox); // A/V^2
16 disp(k_n*10^3,"The value of k_n in mA/V^2 is : ")
17 I_D = k_n*((V_GS-V_TN)^2); // in A
18 disp(I_D*10^3,"The current in mA is ");
19
20 // Note: There is a calculation error to find the
      value of k_n, So the answer in the book is wrong
```

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Scilab code Exa 9.2 IDQ and VDSQ

```
1  // Exa 9.2
2  clc;
3  clear;
4  close;
5  // Given data
6  I_Don = 6;// in mA
7  I_Don= I_Don*10^-3;// in A
8  V_GSon = 8;// in V
9  V_GSth = 3;// in V
10 V_DD = 12;// in V
11 R_D= 2*10^3;// in
12 k= I_Don/(V_GSon-V_GSth)^2;// in A/V^2
13 // I_D= k*[V_GS-V_GSth]^2 but V_GS= V_DD-I_D*R_D, So
14 // I_D= k*(V_DD-I_D*R_D-V_GSth)^2 or
15 // I_D^2*R_D^2+I_D*(2*R_D*V_GSth-2*R_D*V_DD-1/k)+(
      V_DD-V_GSth)^2
16 A= R_D^2;// assumed
17 B= 2*R_D*V_GSth-2*R_D*V_DD-1/k;// assumed
18 C= (V_DD-V_GSth)^2;// assumed
19 root= [A B C]
20 root= roots(root);// in A
21 I_DQ= root(2);// in A
22 disp(I_DQ*10^3,"The value of I_DQ in mA is : ")
23 V_DSQ= V_DD-I_DQ*R_D;// in V
24 disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 9.3 Biasing circuit

```
1  // Exa 9.3
```

```
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  V_GS = 6;// in V
7  I_D = 4;// in mA
8  V_GSth = 2;// in V
9  V_DS = V_GS;// in V
10 V_DD = 2*V_DS;// in V
11 disp(V_DD,"The value of V_DD in V is")
12 R_D = (V_DD-V_DS)/I_D;// in k ohm
13 disp(R_D,"The value of R_D in k ohm is ");
14 disp("The very high value for the gate to drain
       resistance is : 10 M ")
```

Scilab code Exa 9.4 IDQ VGSQ and VDS

```
1  // Exa 9.4
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  I_Don = 3*10^-3;
7  V_GSon = 10;// in V
8  V_GSth= 5;// in V
9  R2= 18*10^6;// in
10 R1= 22*10^6;// in
11 R_S=820;// in
12 R_D=3*10^3;// in
13 V_DD= 40;// in V
14 V_G= V_DD*R2/(R1+R2);// in V
15 k= I_Don/(V_GSon-V_GSth)^2;// in A/V^2
16 // V_G= V_GS+V_RS= V_GS+I_D*R_S or V_GS= V_G-I_D*R_S
17 // I_D= k*[V_GS-V_GSth]^2 or
18 // I_D= k*(V_G-I_D*R_D-V_GSth)^2 or
```

```
19 // I_D^2*R_D^2+I_D*(2*R_D*V_GSth-2*R_D*V_DD-1/k)+(
      V_DD-V_GSth)^2
20 A= R_S^2;// assumed
21 B= 2*R_S*V_GSth-2*R_S*V_G-1/k;// assumed
22 C= (V_G-V_GSth)^2;// assumed
23 I_D= [A B C]
24 I_D= roots(I_D);// in A
25 I_D= I_D(2);// in A
26 I_DQ= I_D;// in A
27 disp(I_DQ*10^3,"The value of I_DQ in mA is : ")
28 V_GSQ= V_G-I_D*R_S;// in V
29 disp(V_GSQ,"The value of V_GSQ in volts is : ")
30 V_DSQ= V_DD-I_DQ*(R_D+R_S);// in V
31 disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 9.5 IDSQ VGSQ and VDSQ

```
 1 // Exa 9.5
 2 clc;
 3 clear;
 4 close;
 5 // Given data
 6 I_D= '0.3*(V_GS-V_P)^2';// given expression
 7 V_DD= 30;// in V
 8 V_P= 4;// in V
 9 R_GS = 1.2*10^6;// in
10 R_G = 1.2*10^6;// in
11 Req= R_GS/(R_GS+R_G);// in
12 R_D= 15;// in
13 // V_DS= V_DD-I_D*R_D (applying KVL to drain circuit
      )
14 // V_GS= Req*V_DS= (V_DD-I_D*R_D)*Req
15 // from given expression
16 //I_D^2*(R_D*Req)^2 - I_D*(2*R_D*Req*(V_DD*Req-V_P)
      +1/0.3 + (V_DD*Req-V_P)^2)
```

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```
17  A= (R_D*Req)^2;// assumed
18  B= -(2*R_D*Req*(V_DD*Req-V_P)+1/0.3);// assumed
19  C= (V_DD*Req-V_P)^2;// assumed
20  I_D= [A B C]
21  I_D= roots(I_D);// in mA
22  I_D= I_D(2);// in mA
23  I_DSQ= I_D;// in mA
24  disp(I_DSQ,"The value of I_DSQ in mA is : ")
25  V_GS= (V_DD-I_D*R_D);// in V
26  disp(V_GS,"The value of V_GS in volts is : ")
27  V_DS= Req*V_GS;// in V
28  disp(V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 9.6 Value of ID and VDS

```
1  // Exa 9.6
2  clc;
3  clear;
4  close;
5  // Given data
6  k = 0.1;// in mA/V^2
7  V_T  = 1;// in V
8  R1 = 33;//in k ohm
9  R2 = 21;// in k ohm
10 V_DD = 6;// in V
11 R_D = 18;// in k ohm
12 V_G = (R2/(R2+R1))*V_DD;// in V
13 V_S = 0;// in V
14 V_GS = V_G-V_S;// in V
15 I_D = k*((V_GS-V_T)^2);// in mA
16 disp(I_D,"The value of I_D in mA is");
17 V_DS = V_DD - (I_D*R_D);// in V
18 disp(V_DS,"The value of V_DS in V is");
19 V_DSsat = V_GS-V_T;// in V
20 disp(V_DSsat,"The value of V_DS(sat) in V is");
```

```
21 if V_DS > V_DSsat then
22     disp("MOSFET is in saturation region")
23 end
```

Scilab code Exa 9.7 DC load line and operating point

```
1 // Exa 9.7
2 clc;
3 clear;
4 close;
5 // Given data
6 V_DD= 6;// in V
7 R_D= 18;// in kohm
8 // for maximum value of I_D
9 V_DS=0;// in V
10 I_Dmax= (V_DD-V_DS)/R_D;// in mA
11 // for maximum value of V_DS
12 I_D=0;// in mA
13 V_DSmax=V_DD-I_D*R_D;// in V
14 V_DS= 0:0.1:V_DSmax;// in V
15 I_D= (V_DD-V_DS)/R_D;// in mA
16 plot(V_DS,I_D)
17 xlabel("V_DS in volts")
18 ylabel("I_D in mA")
19 title("DC load line")
20 disp("DC load line shown in figure");
21 disp("Q-points are : 2.8V,0.178 mA")
```

Scilab code Exa 9.8 Region of MOSFET

```
1 // Exa 9.8
2 clc;
3 clear;
```

```
4  close;
5  // Given data
6  R2 = 18;// in k ohm
7  R1 = 33;// in k ohm
8  V_DD = 6;// in V
9  V_G = (R2/(R1+R2))*V_DD;// in V
10 V_S = V_DD;// in V
11 V_SG = V_S-V_G;// in V
12 disp(V_SG,"The value of V_SG in V is");
13 k = 0.1;
14 V_T = -1;// in V
15 I_D = k*((V_SG+V_T)^2);// in mA
16 disp(I_D,"The value of I_D in mA is");
17 R_D = 3;// in k ohm
18 V_SD = V_DD - (I_D*R_D);// in V
19 disp(V_SD,"The value of V_SD in V is");
20 V_SDsat  = V_SG+V_T;// in V
21 disp(V_SDsat,"The value of V_SD(sat) in V is");
22 if V_SD>V_SDsat then
23     disp("The p MOSFET is indeed biased in the
             saturation region")
24 end
```

Scilab code Exa 9.9 IDQ and VDSQ

```
1  // Exa 9.9
2  clc;
3  clear;
4  close;
5  // Given data
6  V_G= 1.5;// in V
7  V_P= -3;// in V
8  R_S= 750;// in
9  R_D= 1800;// in
10 I_DSS= 6*10^-3;// in A
```

```
11  V_DD= 18;// in V
12  // V_GS= V_G−I_D*R_S
13  // I_D= I_DSS*(1−V_GS/V_P)^2 or I_DSS*(1−(V_G−I_D*
       R_S)/V_P)^2
14  //I_D^2*R_S^2+I_D*(2*R_S*(V_P−V_G)−V_P^2/I_DSS)+(V_P
       −V_G)^2
15  A= R_S^2
16  B=(2*R_S*(V_P-V_G)-V_P^2/I_DSS)
17  C=(V_P-V_G)^2
18  I_D= [A B C]
19  I_D= roots(I_D);// in A
20  I_D= I_D(2);// in A
21  I_DQ= I_D;// in A
22  V_DS= V_DD-I_D*(R_D+R_S);// in V
23  V_DSQ= V_DS;// in V
24  disp(I_DQ*10^3,"The value of I_DQ in mA is : ")
25  disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 9.10 Value of Rs

```
1  // Exa 9.10
2  clc;
3  clear;
4  close;
5  // Given data
6  V_GS = 4;// in V
7  V_P = 2;// in V
8  R2 = 10;// in k ohm
9  R1 = 30;// in k ohm
10 R_D= 2.5;// in kohm
11 I_D= 15;// in mA
12 I_D= I_D*10^-3;// in A
13 V_DD = 25;// in V
14 V_G = (V_DD/R_D)*V_DD/(R1+R2);// in V
15 R_S = (V_G-V_GS)/I_D;// in ohm
```

```
16 disp(R_S ,"The value of R_S in ohm is");
```

Scilab code Exa 9.11 ID and VDS

```
1 // Exa 9.11
2 clc;
3 clear;
4 close;
5 // Given data
6 k= 0.1; // in mA/V^2
7 V_T= 1; // in V
8 R2= 87*10^3; // in
9 R1= 110*10^3; // in
10 R_S=2; // in k
11 R_D=2; // in k
12 //R_D=3*10^3; // in
13 V_DD= 6; // in V
14 V_SS= 6; // in V
15 V_G= (V_DD+V_SS)*R2/(R1+R2); // in V
16 // V_S= I_D*R_S-V_SS
17 // V_GS= V_G-V_S= V_G+V_SS-(I_D*R_S)
18 // I_D= k*[V_GS-V_T]^2 = k*[(V_G+V_SS-V_T)-(I_D*R_S)
       ]^2
19 //(I_D*R_S)^2- I_D*(2*R_S*(V_G+V_SS-V_T)+1/k)   +(
       V_G+V_SS-V_T)^2
20 A= R_S^2; // assumed
21 B= -(2*R_S*(V_G+V_SS-V_T)+1/k); // assumed
22 C= (V_G+V_SS-V_T)^2; // assumed
23 I_D= [A B C]
24 I_D= roots(I_D); // in mA
25 I_D= I_D(2); // in mA
26 disp(I_D,"The value of I_D in mA is : ")
27 // Applying KVL to drain source loop, V_DD+V_SS= I_D
       *R_D+V_DS+I_D*R_S
28 V_DS=V_DD+V_SS-I_D*R_D-I_D*R_S; // in V
```

```
29  disp (V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 9.12 NMOS CS circuit

```
1   // Exa 9.12
2   clc;
3   clear;
4   close;
5   // Given data
6   k = 0.16;// in mA/V^2
7   V_T = 2;// in V
8   I_D = 0.5;// in mA
9   V_DD = 6;// in V
10  V_SS = -6;// in V
11  V_GS = V_T + (sqrt(I_D/k));// in V
12  R_S = 2;// in k ohm
13  V_S = (I_D*R_S) - V_DD;// in V
14  V_G = V_GS+V_S;// in V
15  I = 0.1*I_D;// in mA
16  R2 = (V_G+V_DD)/I;// in k ohm
17  disp(R2,"The value of R2 in k ohm is");
18  R1 = (V_DD - V_G)/I;// in k ohm
19  disp(R1,"The value of R1 in k ohm is");
20  R_D = 10;// in k ohm
21  V_DS = (V_DD-V_SS) - (I_D*(R_S+R_D));// in V
22  disp(V_DS,"The value of V_DS in V is");
23  V_DSsat = V_GS-V_T;// in V
24  disp(V_DSsat,"The value of V_DS(sat) in V is");
25  if V_DS>V_DSsat then
26      disp("The MOSFET is in saturation region")
27  end
28
29  // Note: The value of R1 is in k ohm but in the book
        it is wrong.
```

Scilab code Exa 9.13 Value of IDQ and VDS

```
1  // Exa 9.13
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  V_DD = 6;// in V
7  V_D = 3;// in V
8  R_D = 10;// in k ohm
9  I_DQ = (V_DD - V_D)/R_D;// in mA
10 disp(I_DQ ,"The value of I_DQ in mA is");
11 V_T = 0.8;// in V
12 k = 0.12;// in mA/V^2
13 V_GS = sqrt(I_DQ/k) + V_T;// in V
14 V_S = -V_GS;// in V
15 V_DS = V_D - V_S;// in V
16 disp(V_DS ,"The value of V_DS in V is");
```

Scilab code Exa 9.14 Region of MOSFET

```
1  // Exa 9.14
2  clc ;
3  clear ;
4  close ;
5  // Given data
6  I_D = 0.3;// in mA
7  k = 0.12;// in mA/V^2
8  V_T = 1;// in V
9  V_GS = V_T + (sqrt(I_D/k));// in V
10 V_S = -V_GS;// in V
11 V_DD = 6;// in V
```

```
12  V_D = 3;// in V
13  I_DQ = 0.3;// in mA
14  R_D = (V_DD-V_D)/I_DQ;// in k ohm
15  disp(R_D,"The value of R_D in k ohm is");
16  V_DS = V_D - V_S;// in V
17  disp(V_DS,"The value of V_DS in V is");
18  V_DSsat = V_GS - V_T;// in V
19  disp(V_DSsat,"The value of V_DS(sat) in V is");
20  if V_DS>V_DSsat then
21      disp("The MOSFET is in saturation region")
22  end
```

Scilab code Exa 9.15 VGS VDS and ID

```
1  // Exa 9.15
2  clc;
3  clear;
4  close;
5  // Given data
6  k= 0.05;// in mA/V^2
7  V_T= 1;// in V
8  V_DD= 6;// in V
9  R_S= 9.1;//in k
10 //V_GS= V_DD-I_D*R_S
11 //I_D= k*(V_DD-I_D*R_S)^2
12 //I_D^2*R_S^2-I_D*(2*V_DD*R_S+1/k)+V_DD^2
13 A= R_S^2;// assumed
14 B=-(2*V_DD*R_S+1/k);// assumed
15 C= V_DD^2;// assumed
16 I_D= [A B C];
17 I_D= roots(I_D);// in mA
18 I_D= I_D(2);// in mA
19 V_GS= V_DD-I_D*R_S;// in V
20 V_DS= V_GS;// in V
21 disp(I_D,"The value of I_D in mA is : ")
```

```
22  disp(V_GS,"The  value  of  V_GS  in  volts  is  :  ")
23  disp(V_DS,"The  value  of  V_DS  in  volts  is  :  ")
```

Scilab code Exa 9.16 All dc voltages

```
1   // Exa  9.16
2   clc;
3   clear;
4   close;
5   // Given  data
6   k1=  0.01; //  in  mA/V^2
7   k2=  0.05; //  in  mA/V^2
8   V_DD=  5; //  in  V
9   V_T1=1; //  in  V
10  V_T2=1; //  in  V
11  //  Analysis  for  Vi= 5V
12  Vi=  5; //  in  V
13  //I_D1=  k1*(V_GS1-V_T1)^2  and  I_D2=  k2*(2*(V_GS2-
        V_T2)*V_DS2-V_DS2^2)
14  //  But  V_GS2=  Vi,  V_DS2=  Vo,  V_GS1=  V_DS1=  V_DD-Vo
15  //Vo^2*(k1+k2)-Vo*[2*k1*(V_DD-V_T1)+2*k2*(Vi-V_T2)]+
        k1*(V_DD-V_T1)^2
16  A=(k1+k2);
17  B=-[2*k1*(V_DD-V_T1)+2*k2*(Vi-V_T2)];
18  C=k1*(V_DD-V_T1)^2;
19  Vo=  [A  B  C]
20  Vo=  roots(Vo); //  in  V
21  Vo=  Vo(2); //  in  V
22  V_GS2=  Vi; //  in  V
23  V_DS2=  Vo; //  in  V
24  V_GS1=  V_DD-Vo; //  in  V
25  I_D1=  k1*(V_GS1-V_T1)^2; //  in  mA
26  I_D2=  I_D1; //  in  mA
27  disp("Part  (i)  For  Vi  =  5  V")
28  disp(Vo,"The  output  voltage  in  volts  is  :  ")
```

```
29  disp(I_D1,"The value of I_D1 in mA is : ")
30  disp(I_D2,"The value of I_D2 in mA is : ")
31  // Analysis for Vi= 1.5V
32  Vi= 1.5;// in V
33  //I_D2= k2*(V_GS2-V_T2)^2 and I_D1= k1*(V_GS1-V_T1)
        ^2
34  // But V_GS2= Vi, V_DS2= Vo, V_GS1= V_DS1= V_DD-Vo
35  //k2*(Vi-V_T2)^2= k1*(V_DD-Vo-V_T1)^2 or
36  Vo= V_DD-V_T1-sqrt(k2/k1)*(Vi-V_T2);// in V
37  I_D2= k2*(Vi-V_T2)^2;//in mA
38  I_D1= I_D2;// in mA
39  disp("Part (ii) For Vi = 1.5 V")
40  disp(Vo,"The output voltage in volts is : ")
41  disp(I_D1,"The value of I_D1 in mA is : ")
42  disp(I_D2,"The value of I_D2 in mA is : ")
```

Scilab code Exa 9.17 Value of ID and VDS

```
1  // Exa 9.17
2  clc;
3  clear;
4  close;
5  // Given data
6  k = 0.12;// in mA/V^2
7  V_T = -2.5;// in V
8  V_GS = 0;
9  I_D = k*((V_GS-V_T)^2);// in mA
10 disp(I_D,"The value of I_D in mA is");
11 V_DD = 6;// in V
12 R_S = 4.7;// in k ohm
13 V_DS = V_DD -(I_D*R_S);// in V
14 disp(V_DS,"The value of V_DS in V is ");
15 V_S = 0;// in V
16 V_DSsat = V_S - V_T;// in V
17 disp(V_DSsat,"The value of V_DS(sat) in V is");
```

```
18  if V_DS < V_DSsat then
19      disp ("The device is in the non saturation region
          ")
20  end
```

Scilab code Exa 9.18 Various voltage and current

```
1  // Exa 9.18
2  clc;
3  clear;
4  close;
5  // Given data
6  k4 = 0.125;// in mA/V^2
7  k3 = k4;// in mA/V^2
8  k2 = k4;// in mA/V^2
9  k1 = 0.25;// in mA/V^2
10 V_T1 = 0.8;// in V
11 V_T2 = V_T1;// in V
12 V_T3 = V_T1;// in V
13 V_T4 = V_T1;// in V
14 V_SS = -5;// in V
15 V_DD = 5;// in V
16 R_D = 10;// in k ohm
17 V_GS3 = ((sqrt(k4/k3) * (-V_SS - V_T4))+V_T3)/(1+
      sqrt(k4/k3));// in V
18 I_Q = k2*((V_GS3-V_T2)^2);// in mA
19 I_D1 = I_Q;// in mA
20 V_GS1 = V_T1 + (sqrt(I_D1/k1));// in V
21 disp(V_GS1,"The value of V_GS1 in V is");
22 V_DS2 = (-V_SS-V_GS1);// in V
23 disp(V_DS2,"The value of V_DS2 in V is");
24 V_DS1 = V_DD - (I_Q*R_D) - (V_SS + V_DS2);// in V
25 disp(V_DS1,"The value of V_DS1 in V is");
```

Scilab code Exa 9.19 Q point values

```
1  // Exa 9.19
2  clc;
3  clear;
4  close;
5  // Given data
6  R2 = 20;// in  k ohm
7  R1 = 30;// in  k ohm
8  R_D = 20;// in  k ohm
9  R_D=R_D*10^3;// in ohm
10 V_DD = 5;// in V
11 V_G = (R2/(R1+R2))*V_DD;// in V
12 V_S = 0;// in V
13 V_GS = V_G;// in V
14 k = 100*10^-6;// in A/V^2
15 V_T = 1;// in V
16 I_DQ = k*((V_GS-V_T)^2);// in A
17 disp(I_DQ * 10^6,"The value of I_DQ in  A  is");
18 //R_D =R_D * 140^3;// in ohm
19 V_DSQ = V_DD - (I_DQ*R_D);// in V
20 disp(V_DSQ,"The value of V_DSQ in V is");
```

Scilab code Exa 9.20 IDQ VGSQ and VD

```
1  // Exa 9.20
2  clc;
3  clear;
4  close;
5  // Given data
6  V_P= -8;// in V
7  R_S= 2.4;// in  k
```

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```
8  //R_D= 1800;// in
9  I_DSS= 8;// in mA
10 V_DD= 20;// in V
11 R_D= 6.2;// in  k
12 // V_GS= -I_D*R_S
13 // I_D= I_DSS*(1-V_GS/V_P)^2 or I_DSS*(1-(-I_D*R_S)/
       V_P)^2
14 //I_D^2*R_S^2+I_D*(2*R_S*(V_P-V_G)-V_P^2/I_DSS)+(V_P
       )^2
15 A= R_S^2
16 B=(2*R_S*(V_P)-V_P^2/I_DSS)
17 C=(V_P)^2
18 I_D= [A B C]
19 I_D= roots(I_D);// in mA
20 I_D= I_D(2);// in mA
21 I_DQ= I_D;// in mA
22 disp(I_DQ,"The value of I_DQ in mA is : ")
23 V_GSQ= -I_D*R_S;
24 disp(V_GSQ,"The value of V_GSQ in volts ")
25 V_D= V_DD-I_D*R_D;// in V
26 disp(V_D,"The value of V_D in volts is : ")
```

Scilab code Exa 9.21 ID VD VS and VG

```
1  // Exa 9.21
2  clc;
3  clear;
4  close;
5  // Given data
6  k= 75*10^-3;//in mA/V^2
7  Vth= -0.8;// in V
8  R2 = 100;// in k ohm
9  R1 = 100;// in  k ohm
10 R_S= 6;// in  k
11 R_D= 3;// in  k
```

```
12  V_SS = 10;// in V
13  V_G = (R2/(R1+R2))*V_SS;// in V
14  I_D= poly(0,'I_D');
15  V_S= V_SS-I_D*R_S;// in V
16  V_GS= V_G-V_S;//in V
17  I_D= I_D-k*(V_GS-Vth)^2;
18  I_D= roots(I_D);// in mA
19  I_D= I_D(2);// in mA
20  V_DS= -V_SS+I_D*(R_D+R_S);// in V
21  V_D= I_D*R_D;// in V
22  V_S= I_D*R_S;// in V
23  disp(I_D,"The value of I_D in mA is : ")
24  disp(V_DS,"The value of V_DS in volts is : ")
25  disp(V_D,"The value of V_D in volts is : ")
26  disp(V_S,"The value of V_S in volts is : ")
```

Scilab code Exa 9.22 Value of RD

```
1  // Exa 9.22
2  clc;
3  clear;
4  close;
5  // Given data
6  V_T = 1;// in V
7  k = 160*10^-6;// in A/V^2
8  I_DQ = 160*10^-6;// in A
9  V_GS = V_T + sqrt(I_DQ/k);// in V
10  V_DD = 5;// in V
11  V_DSQ = 3;// in V
12  R_D = (V_DD - V_DSQ)/(I_DQ);// in ohm
13  R_D = R_D * 10^-3;// in k ohm
14  disp(R_D,"The value of R_D in k ohm is");
```

Scilab code Exa 9.23 Coordinates of operating point

```
1  // Exa 9.23
2  clc;
3  clear;
4  close;
5  // Given data
6  V_DD= 12;// in V
7  V_T= 2;// in V
8  kn= 0.5;// in mA/V^2
9  R1 = 2.2;// in M ohm
10 R2 = 1.8;// in M ohm
11 R_S= 1.5;// in k
12 R_D= 3.9;// in k
13 V_G = (R2/(R1+R2))*V_DD;// in V
14 I_D= poly(0,'I_D')
15 V_GS= V_G-I_D*R_S;// V
16 I_D= I_D-kn*(V_GS-V_T)^2;// in mA
17 I_D= roots(I_D);// in mA
18 I_D= I_D(2);// in mA
19 I_DQ= I_D;// in mA
20 V_DSQ= V_DD-I_D*(R_D+R_S);// in V
21 disp(I_DQ,"The value of I_DQ in mA is : ")
22 disp(V_DSQ,"The value of V_DSQ in volts is : ")
23 V_GS= V_G-I_D*R_S;// V
24 V_DSsat= V_GS-V_T;// in V
25 disp("The value of  V_DS ( "+string(V_DSQ)+" V ) is
       greater than the value of ")
26 disp("V_DSsat ( "+string(V_DSsat)+" V ), So the
       MOSFET is in saturation region")
```

Scilab code Exa 9.24 IDSQ VGSQ and VDSQ

```
1  // Exa 9.24
2  clc;
```

```
3  clear;
4  close;
5  // Given data
6  kn= 0.5; // in mA/V^2
7  V_T= 1; // in V
8  R2 = 40; // in k ohm
9  R1 = 60; // in k ohm
10  R_S= 1; // in k ohm
11  R_D= 2; // in k ohm
12  V_DD = 5; // in V
13  V_SS = -5; // in V
14  V_R2 = (R2/(R2+R1))*(V_DD-V_SS); // in V
15  V_G = V_R2 - V_DD; // in V
16  I_D= poly(0,'I_D');
17  V_S= I_D*R_S+V_SS; // in V
18  V_GS= V_G-V_S; // in V
19  I_D=I_D-kn*(V_GS-V_T)^2; // in mA
20  I_D= roots(I_D); // in mA
21  I_D= I_D(2); // in mA
22  I_DQ= I_D; // in mA
23  V_S= I_D*R_S+V_SS; // in V
24  V_GS= V_G-V_S; // in V
25  V_DSQ= V_DD-V_SS-I_D*(R_D+R_S); // in V
26  disp(I_DQ,"The value of I_DQ in mA is : ")
27  disp(V_GS,"The value of V_GS in volts is : ")
28  disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 9.25 ID VDS VGS and Av

```
1  // Exa 9.25
2  clc;
3  clear;
4  close;
5  // Given data
6  R_S1 = 100*10^-3; // in k ohm
```

```
7  R_S2 = 100*10^-3;// in k ohm
8  R_S = R_S1+R_S2;// in k ohm
9  R_D= 1.8;// in k ohm
10 I_DSS= 12;// in mA
11 Vp= -3.5;// in V
12 V_DD= 22;// in V
13 rd= 25;// in k ohm
14 R_L= 47;// in k ohm
15 I_D= poly(0,'I_D');
16 V_GS= -I_D*R_S;// in V
17 I_D= I_D-I_DSS*(1-V_GS/Vp)^2;// in mA
18 I_D= roots(I_D);// in mA
19 I_D= I_D(2);// in mA
20 disp(I_D,"The value of I_D in mA is : ")
21 V_GS= -I_D*R_S;// in V
22 disp(V_GS,"The value of V_GS in volts is : ")
23 V_DS= V_DD-I_D*(R_D+R_S);// in V
24 disp(V_DS,"The value of V_DS in volts is : ")
25 gmo= -2*I_DSS/Vp;// in mS
26 gm= gmo*(1-V_GS/Vp);// in mS
27 miu= gm*rd;
28 Av= -miu*R_D*R_L/(R_D+R_L)/(rd+R_D*R_L/(R_D+R_L)+(1+
     miu)*R_S1);
29 disp(Av,"The value of Av is : ")
```

Scilab code Exa 9.26 VGS ID and VDS

```
1 // Exa 9.26
2 clc;
3 clear;
4 close;
5 // Given data
6 V_T = 1;// in V
7 k = 0.5;// in mA/V^2
8 R2 = 40;// in k ohm
```

```
 9  R1 = 60;// in k ohm
10  R_S= 1;// in k ohm
11  R_D= 2;// in k ohm
12  V_DD = 5;// in V
13  V_G = (R2/(R2+R1))*V_DD;// in V
14  I_D= poly(0,'I_D');
15  V_GS= V_G-I_D*R_S;// in V
16  I_D= I_D-k*(V_GS-V_T)^2;
17  I_D= roots(I_D);// in mA
18  I_D= I_D(2);// in mA
19  V_GS= V_G-I_D*R_S;// in V
20  V_DS= V_DD-I_D*(R_D+R_S);// in V
21  disp(I_D,"The value of I_D in mA is : ")
22  disp(V_GS,"The value of V_GS in volts is : ")
23  disp(V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 9.27 Drain current and source to drain voltage

```
 1  // Exa 9.27
 2  clc;
 3  clear;
 4  close;
 5  // Given data
 6  R_D = 7.5;// in k ohm
 7  V_T = -0.8;// in V
 8  k = 0.2;// in mA/V^2
 9  R2 = 50;// in ohm
10  R1 = 50;// in  ohm
11  V_DD = 5;// in V
12  V_S = 5;// in V
13  V_G = (R2/(R2+R1))*V_DD;// in V
14  V_GS = V_G - V_S;// in V
15  I_D = k*((V_GS-V_T)^2);// in mA
16  disp(I_D,"Drain current in mA is");
17  V_SD = V_DD - (I_D*R_D);// in V
```

```
18  disp(V_SD ,"Source to drain voltage in V is");
```

Scilab code Exa 9.28 IDQ VGSQ VD and VS

```
1  // Exa 9.28
2  clc;
3  clear;
4  close;
5  // Given data
6  I_Don = 5*10^-3;// in A
7  V_GSon = 6;// in V
8  V_GSth = 3;// in V
9  k = I_Don/(V_GSon-V_GSth)^2;// in A/V^2
10  R2 = 6.8;// in M ohm
11  R1 = 10;// in M ohm
12  R_S= 750;// in ohm
13  R_D= 2.2*10^3;// in ohm
14  V_DD = 24;// in V
15  R_S = 750;// in  ohm
16  V_G= R2*V_DD/(R1+R2);// in V
17  I_D= poly(0,'I_D');
18  V_GS= V_G-I_D*R_S;// in V
19  I_D= I_D-k*(V_GS-V_GSth)^2;
20  I_D= roots(I_D);// in A
21  I_D= I_D(2);// in A
22  I_DQ= I_D;// in A
23  V_GS= V_G-I_D*R_S;// in V
24  V_GSQ= V_GS;// in V
25  V_DSQ= V_DD-I_DQ*(R_D+R_S);// in V
26  disp(I_D*10^3,"The value of I_D in mA is : ")
27  disp(V_GSQ,"The value of V_GSQ in volts is : ")
28  disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 9.29 VDD RD and VGS

```
1  // Exa 9.29
2  clc;
3  clear;
4  close;
5  // Given data
6  I_Don = 4*10^-3;// in A
7  V_GSon = 6;// in V
8  V_GSth = 3;// in V
9  V_DS= 6;// in V
10 I_D= I_Don;// in A
11 k = I_Don/((V_GSon-V_GSth)^2);// in A/V^2
12 V_GS= poly(0,'V_GS')
13 V_GS= I_D-k*(V_GS-V_GSth)^2;
14 V_GS= roots(V_GS);// in V
15 V_GS= V_GS(1);// in V
16 V_DD= 2*V_DS;// in V
17 // V_GS= V_DD-I_D*R_D
18 R_D= (V_DD-V_GS)/I_D;// in ohm
19 disp(V_GS,"The value of V_GS in volts is : ")
20 disp(V_DD,"The value of V_DD in volts is : ")
21 disp(R_D*10^-3,"The value of R_D in k  is : ")
```

Scilab code Exa 9.30 ID VDS VG VS

```
1  // Exa 9.30
2  clc;
3  clear;
4  close;
5  // Given data
6  I_DD= 20;// in mA
7  R2 = 10;// in k ohm
8  R1 = 30;// in k ohm
9  R_S= 1.2;// in k ohm
```

```
10  R_D= 500*10^-3;// in k ohm
11  V_DD = 12;// in V
12  Vp= -6;// in V
13  V_G = (R2/(R2+R1))*V_DD;// in V
14  I_D= poly(0,'I_D')
15  V_GS= V_G-I_D*R_S;// in V
16  I_D=I_D-I_DD*(1-V_GS/Vp)^2;
17  I_D= roots(I_D);// in mA
18  I_D= I_D(2);// in mA
19  V_DS= V_DD-I_D*(R_D+R_S);// in V
20  V_D= V_DD-I_D*R_D;// in V
21  V_S= V_D-V_DS;// in V
22  disp(I_D,"The value of I_D in mA is : ")
23  disp(V_DS,"The value of V_DS in volts is : ")
24  disp(V_D,"The value of V_D in volts is : ")
25  disp(V_S,"The value of V_S in volts is : ")
```

Scilab code Exa 9.31 Voltage at all nodes and currents through all branches

```
1  // Exa 9.31
2  clc;
3  clear;
4  close;
5  // Given data
6  V_DD = 5;// in V
7  V_T= 1;// in V
8  k= 1;// in mA/V^2
9  R1 = 1;// in M ohm
10  R2 = 1;// in M ohm
11  R_S= 2;// in k ohm
12  R_D= 2;// in k ohm
13  I1 = V_DD/(R1+R2);// in A
14  disp(I1,"The value of I1 in  A is : ")
15  V_A = (R2/(R2+R1))*V_DD;// in V
16  disp(V_A,"The value of V_A and V_G in volts is : ")
```

```
17  I_D= poly(0,'I_D');
18  V_C= I_D*R_S;// in V
19  V_GS= V_A-V_C;// in V
20  I_D= I_D-k*(V_GS-V_T)^2;
21  I_D= roots(I_D);// in mA
22  I_D= I_D(2);// in mA
23  disp(I_D,"The value of I_D in mA is : ")
24  V_B= V_DD-I_D*R_D;// in V
25  V_C= I_D*R_S;// in V
26  V_DS= V_B-V_C;// in V
27  disp(V_B,"The value of V_B in volts is : ")
28  disp(V_C,"The value of V_C in volts is : ")
29  disp(V_DS,"The value of V_DS in volts is : ")
30
31  // Note: In the book, the calculated values are
        wrong, this is why the answer in the book is
        wrong.
```

Scilab code Exa 9.32 Value of Av Ri and Ro

```
1  // Exa 9.32
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 = -3;// in V
9  r_d = 45;// in k ohm
10 r_d= r_d*10^3;// in ohm
11 g_m = I_DSS/abs(V_P);// in S
12 // Part (i)
13 R1 = 91;// in M ohm
14 R1=R1*10^6;//in ohm
15 R2 = 10;// in M ohm
```

```
16  R2= R2*10^6;// in ohm
17  Ri= R1*R2/(R1+R2);// in ohm
18  disp(Ri*10^-6,"The value of Ri in Mohm is : ")
19  // Part (ii)
20  R_S = 1.1;// in k ohm
21  R_S = R_S * 10^3;// in ohm
22  R_o= (R_S*1/g_m)/(R_S+1/g_m);// in ohm
23  disp(R_o,"The value of R_C in ohm is : ")
24  // Part (iii)
25  R_desh_o= R_o*r_d/(R_o+r_d);// in ohm
26  disp(R_desh_o,"The value of R_desh_o in ohm is : ");
27  // Part (iv)
28  Av= g_m*(R_S*r_d/(R_S+r_d))/(1+g_m*(R_S*r_d/(R_S+r_d
      )));
29  disp(Av,"The value of Av is : ")
```

Scilab code Exa 9.34 Current flow through M1 MOSFET

```
1  // Exa 9.34
2  clc;
3  clear;
4  close;
5  // Given data
6  V_S2 = -2;// in V
7  V_GS2 = -V_S2;// in V
8  I_DS2 = (V_GS2-1)^2;// in mA
9  I = 2;// in mA
10 I_DS1 = I-I_DS2;// in mA
11 disp(I_DS1,"The current flow through M1 MOSFET in mA
       is");
```

Scilab code Exa 9.35 Value of R and VD

```
1  // Exa 9.35
2  clc;
3  clear;
4  close;
5  // Given data
6  V_DD= 10; // in V
7  I_D= 0.4*10^3; // in A
8  W= 100; // in  m
9  L= 10; // in  m
10 uACox= 20; // in A/V^2
11 Vt= 2; // in V
12 R= poly(0,'R')
13 V_GS= V_DD-I_D*R; // in V
14 R= I_D-1/2*uACox*W/L*(V_GS-Vt)^2;
15 R= roots(R); // in Mohm
16 R= R(2); // in Mohm
17 disp(R*10^3,"The value of R in  k   is : ")
18 V_D= V_DD-I_D*R; // in V
19 disp(V_D,"The value of V_D in volts is : ")
```

Scilab code Exa 9.36 ID and VDS

```
1  // Exa 9.36
2  clc;
3  clear;
4  close;
5  // Given data
6  V_GSth= 2; // in V
7  k= 2*10^-4; // in A/V^2
8  V_DD= 12; // in V
9  R_D= 5*10^3; // in ohm
10 I_D= poly(0,'I_D');
11 V_DS= V_DD-I_D*R_D; // in V
12 I_D= I_D-k*(V_DS-V_GSth)^2;
13 I_D= roots(I_D); // in A
```

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```
14  I_D= I_D(2);// in A
15  V_DS= V_DD-I_D*R_D;// in V
16  disp(I_D*10^3,"The value of I_D in mA is : ")
17  disp(V_DS,"The value of V_DS in volts is : ")
```