Scilab Textbook Companion for Electonic 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.

Contents

List of Scilab Codes

Chapter 2

Energy Bands And Charge Carriers in Semiconductor

Scilab code Exa 2.1 Energy gap

```
// Exa 2.1
format('v',7)
clc;
clear;
close;
// Given data
lembda = 11000;// in
lembda = lembda * 10^-10;// in m
h = 6.625*10^-34;// Planck constant
c = 3*10^8;//speed of light in m/s
e = 1.6*10^-19;//charge of electron in C
// Energy of the incident photon should at least be,
    h*v= Eg, so
E_g = (h*c)/(lembda*e);// in eV
disp(E_g,"The energy gap in eV is");
```

Scilab code Exa 2.2 Wavelength

```
// Exa 2.2
format('v',6)
clc;
clear;
close;
// Given data
E_g = 0.75;// in eV
e = 1.6*10^-19;// in C
h = 6.63*10^-34;// in J
c = 3*10^8;// in m/s
//Formula E_g = (h*c)/(lembda*e);
lembda = (h*c)/(E_g*e);// in m
lembda = lembda * 10^10;// in
disp(lembda,"The wavelength in  is");
```

Scilab code Exa 2.3 Position of Fermi level

```
//Exa 2.3
format('v',6)
clc;
clear;
close;
// Given data
del_E = 0.3;// in eV
T1 = 300;// in K
T2 = 330;// in K
// del_E = K * T1 * log(N/N_c) where del_E= E_C-E_F
// del_E1 = K * T2 * log(N/N_c) where del_E1= E_C-E_F at T= 330 K
del_E1 = del_E*(T2/T1);// in eV
disp("The Fermi level will be "+string(del_E1)+" eV below the conduction band")
```

Scilab code Exa 2.4 Probability

```
//Exa 2.4
clc;
clear;
close;
format('e',8)
// Given data
N_c = 2.8 * 10^19;// in cm^-3
del_E = 0.25;// fermi energy in eV
KT = 0.0259;// where K is Boltzmann constant
f_F = exp(-(del_E)/KT);
disp(f_F,"The probability in the conduction band is
    occupied by an electron is ");
// Evaluation of electron concentration
n_o = N_c * exp(-(del_E)/KT);// in cm^-3
disp(n_o,"The thermal equilibrium electron
    concentration in cm^-3 is");
```

Scilab code Exa 2.5 Thermal equilibrium hole concentration

```
//Exa2.5
clc;
clear;
close;
format('v',9)
// Given data
T1 = 300;// in K
T2 = 400;// in K
del_E = 0.27;// Fermi level in eV
KT = (0.0259) * (T2/T1);// in eV
N_v = 1.04 * 10^19;// in cm^-3
```

```
N_v = N_v * (T2/T1)^(3/2);// in cm^-3
// Hole concentration
p_o = N_v * exp(-(del_E)/KT);// in per cm^3
disp(p_o,"The thermal equilibrium hole concentration
    per cm^3 is");
```

Scilab code Exa 2.6 Mobility of electrons in copper

```
// Exa 2.6
clc;
clear;
close;
format('v',7)
// Given data
At = 63.5;// atomic weight
Rho = 1.7*10^-6;// in ohm cm
d = 8.96;// in gm/cc
N_A = 6.02*10^23;// in /gm.mole
e = 1.6*10^-19;// in C
//Number of atoms of copper persent per unit volume
n = (N_A/At)*d;
Miu_e = 1/(Rho*n*e);// in cm^2/volt.sec
disp(Miu_e,"The electron mobility in cm^2/volt-sec
   is");
```

Scilab code Exa 2.7 Density of free electrons

```
// Exa 2.7
clc;
clear;
close;
format('v',9)
// Given data
```

```
l = 0.1;// in m
A = 1.7;// in mm^2
A = A * 10^-6;// in m^2
R = 0.1;// in ohm
At = 63.5;// atomic weight
N_A = 6.02*10^23;
d = 8.96;// in gm/cc
n = (N_A/At)*d;// in /cc
n = n * 10^6;// in /m^3
e = 1.6*10^-19;//electron charge in C
// Resistivity of copper
//Formula R = Rho*(l/A);
Rho = (R*A)/l;// in ohm m
// Conductivity of copper
Sigma = 1/Rho;// in mho/m
// Formula Sigma = n*e*Miu_e
Miu_e = Sigma/(n*e);// in m^2/V.sec
disp(Miu_e,"The mobility in m^2/V-sec is");
```

Scilab code Exa 2.8 Drift velocity

```
// Exa 2.8
clc;
clear;
close;
format('v',7)
// Given data
d = 10.5;// in gm/cc
At = 108;// atomic weight
N_A = 6.025*10^23;// in /gm mole
r = 10^-3;// in m
q = 1.6*10^-19;// in C
// The number of electrons per unit volume
n = (N_A/At)*d;// in /cm^3
n = n * 10^6;// in /m^3
```

```
A = %pi*((r)^2);// in m^2
I = 2;// in A
// Evaluation of drivt velocity with the help of current
// I = q*n*A*V;
V = I/(n*q*A);// in m/s
disp(V,"The drift velocity in m/s is");

// Note: Calculation in the book is wrong, so the answer in the book is wrong.
```

Scilab code Exa 2.9 Mobility of charge carriers

```
// Exa 2.9
clc;
clear;
close;
format('v',8)
// Given data
d = 1.03;// in mm
d = d *10^-3;// in m
r = d/2;// in m
R = 6.51;// in ohm
l = 300;// in mm
e = 1.6*10^-19;// electron charge in C
n = 8.4*10^28;// in /m^3
A = %pi*r^2;// cross section area
//Formula  R = Rho*(l/A);
Rho = (R* A)/l;//in ohm m
Sigma = 1/Rho;// in mho/m
disp(Sigma,"The conductivity of copper in mho/m is");
// Evaluation of mobility
//Formula sigma = n*e*Miu_e
Miu_e = Sigma/(n*e);// in m^2/V.sec
```

```
disp(Miu_e,"The mobility in m^2/V-sec is");
```

Scilab code Exa 2.10 Conductivity of pure Si

```
// Exa 2.10
format('v',8)
clc;
clear;
close;
// Given data
Mu_e = 1500;// in cm^2/volt sec
Mu_h = 500;// in cm^2/volt sec
n_i = 1.6 * 10^10;// in per cm^3
e = 1.6 * 10^-19;// in C
// The conductivity of pure semiconductor
Sigma = n_i * (Mu_e + Mu_h) * e;// in mho/cm
disp(Sigma,"The conductivity of pure semiconductor
   in mho/cm is");
```

Scilab code Exa 2.11 Number of donor atoms

```
// Exa 2.11
format('v',9)
clc;
clear;
close;
// Given data
Rho = 10;// in  -cm
Mu_d = 500;// in cm^2/v.s.
e = 1.6*10^-19;// electron charge in C
// The number of donor atom
n_d = 1/(Rho * e * Mu_d);// in per cm^3
disp(n_d,"The number of donor atom per cm^3 is ");
```

Scilab code Exa 2.12 Conductivity of speciman

```
//Exa 2.12
format('v',6)
clc;
clear;
close;
//Given data
AvagadroNumber = 6.02 * 10^23;// in atoms/gm.mole
at_Ge = 72.6;// atom weight of Ge
e = 1.6 * 10^-19;// in C
D_Ge = 5.32;// density of Ge in gm/c.c
Mu = 3800;// in cm^2/v.s.
C_Ge = (AvagadroNumber/at_Ge) * D_Ge;// concentration of Ge atoms in per cm^3
n_d = C_Ge/10^8;// in per cc
Sigma = n_d * Mu * e;// in mho/cm
disp(Sigma,"The conductivity in mho/cm is");
```

Scilab code Exa 2.13 Mobility of electrons in Ge

```
// Exa2.13
format('v',5)
clc;
clear;
close;
// Given data
Rho = 0.3623 * 10^-3;// in Ohm m
Sigma = 1/Rho;//in mho/m
D = 4.42 * 10^28;// Ge density in atom/m^3
n_d = D / 10^6;// in atom/m^3
```

```
e = 1.6 * 10^-19;// in C
// The mobility of electron in germanium
Mu = Sigma/(n_d * e);// in m^2/V.sec
disp(Mu,"The mobility of electron in germanium in m
    ^2/V.sec is");
```

Scilab code Exa 2.14 Density and mobility of holes

```
//Exa 2.14
format('v',7)
clc;
clear;
close;
// Given data
AvagadroNumber = 6.025 * 10^26;// in kg.Mole
W = 72.59;// atomic weight of Ge
D = 5.36 * 10^3;//density of Ge in kg/m^3
Rho = 0.42;// resistivity in Ohm m
e = 1.6 * 10^-19;// in C
Sigma = 1/Rho;// in mho/m
n = (AvagadroNumber/W) * D;// number of Ge atoms
    present per unit volume
// Holes per unit volume, H = n*10^-6%
H= n*10^-8;
a=H;
// Formula sigma= a*e*Mu_h
Mu_h = Sigma/(a * e);// in m^2/V.sec
disp(Mu_h,"Mobility of holes in m^2/V.sec is");
```

Scilab code Exa 2.15 Current produced

```
//Exa 2.15
format('v',5)
```

```
clc;
clear;
close;
// Given data
e = 1.6 * 10^-19;// in C
n_i = 2 * 10^19;// in /m^3
Mu_e = 0.36;// in m^2/v.s
Mu_h = 0.17;// in m^2/v.s
A = 1 * 10^-4;// in  m^2
V = 2;//in volts
l = 0.3;// in mm
l = l * 10^-3;// in m
E=V/l;// in volt/m
Sigma = n_i * e * (Mu_e + Mu_h);// in mho/m
// J = I/A = Sigma * E
I= Sigma*E*A;
disp(I,"The current produced in a small germanium
    plate in amp is");
```

Scilab code Exa 2.16 Resistivity of doped Ge

```
// Exa 2.16
format('v',9)
clc;
clear;
close;
// Given data
D = 4.2 * 10^28;//density of Ge atoms per m^3
N_d = D / 10^6;// per m^3
e = 1.6 * 10^-19;// in C
Mu_e = 0.36;// in m^2/V-sec
// Donor concentration is very large as compared to
    intrinsic carrier concentration
Sigma_n = N_d *  e * Mu_e;// in mho/m (intrinsic
    concentration can be neglected)
```

```
Rho_n = 1/Sigma_n;// in ohm m
disp(Rho_n,"The resistivity of drop Ge in ohm m is "
   );
```

Scilab code Exa 2.17 Current produced in Ge sample

```
// Exa 2.17
format('v',6)
clc;
clear;
close;
// given data
e = 1.6 * 10^-19;// in C
n_i = 1 * 10^19;// in per m^3
Mu_e = 0.36;// in m^2/volt.sec
Mu_h = 0.17;// in m^2/volt.sec
A = 2;// in cm^2
A = A * 10^-4;// im m^2
t = 0.1;// in mm
t = t * 10^-3;// in m
V = 4;// in volts
Sigma_i = n_i * e * (Mu_e + Mu_h);// in mho/m
J = Sigma_i * (V/t);// in Amp/m^2
// Current produced, I= J*A
I = J * A;// in Amp
disp(I,"The current produced in a Ge sample in Amp
   is");
```

Scilab code Exa 2.18 Conductivity of pure Si

```
//Exa 2.18
format('v',8)
clc;
```

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

Scilab code Exa 2.19 Hall voltage produced

```
//Exa 2.19
format('v',9)
clc;
clear;
close;
//Given data
l= 0.50*10^-2;// width of ribbon in m
d= 0.10*10^-3;// thickness of ribbon in m
A= l*d;// area of ribbon in m^2
B = 0.8;// in Tesla
D = 10.5;//density in gm/cc
I = 2;// in amp
q = 1.6 * 10^-19;// in C
n=6*10^28;// number of elec. per m^3
V_H = ( I * B * d)/(n * q * A);// in volts
disp(V_H,"The hall Voltage produced in volts is");
```

Scilab code Exa 2.20 Hall coefficient and mobility of electrons

```
//Exa 2.20
format('v',8)
clc;
clear;
close;
// Given data
l = 1;// in m
d = 1;// in cm
d = d * 10^-2;// in m
W = 1;// in mm
W = W * 10^-3;// in m
A = d * W;// in m^2
I= 1;// in A
B = 1;// Tesla
V_H = 0.074 * 10^-6;// in volts
Sigma = 5.8 * 10^7;// in mho/m
// The hall coefficient
R_H = (V_H * A)/(B*I*d);// in m^3/c
disp(R_H,"The hall coefficient in m^3/c is");
// Mobility of electrons in copper
Mu = Sigma * R_H;// in m^2/volt-sec
disp(Mu,"The mobility  of electrons in copper in m
    ^2/volt-sec is ");
```

Scilab code Exa 2.21 Concentration of holes in Si crystals

```
//Exa2.21
format('v',7)
clc;
clear;
close;
// Given data
n_i = 1.4 * 10^18;// in /m^3
n_D = 1.4 * 10^24;// in /m^3
// Concentration of electrons
```

```
n=n_D;// in /m^3
p = n_i^2/n;// in /m^3
// The ratio of electrons to hole concentration
R = n/p;
disp(R,"The ratio of electrons to hole concentration
    is");
```

Scilab code Exa 2.22 Hall angle

```
//Exa 2.22
format('v',10)
clc;
clear;
close;
//Given data
R = 9 * 10^-3;// in ohm-m
R_H = 3.6 * 10^-4;// in m^3
e = 1.6 * 10^-19;// in C
Sigma = 1/R;// in (ohm-m)^-1
Rho = 1/R_H;// in coulomb/m^3
// Density of charge carriers
n = Rho/e;// in /m^3
disp(n,"Density of charge carriers per m^3 is");
// Mobility of charge carriers
Mu = Sigma * R_H;// in m^2/v-s
disp(Mu,"Mobility of charge carriers in m^2/V-s is")
   ;
```

Scilab code Exa 2.23 Current density in speciman

```
//Exa 2.23
format('v',6)
clc;
```

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

Scilab code Exa 2.24 Relaxation time

```
//Exa 2.24
format('v',9)
clc;
clear;
close;
//Given data
Mu_e = 7.04 * 10^-3;// in m^2/v-s
m = 9.1 * 10^-31;
E_F = 5.5;// in eV
n = 5.8 * 10^28;
e = 1.6 * 10^-19;// in C
// Relaxation Time
Torque = (Mu_e/e) * m;// in sec
disp(Torque,"Relaxation Time in sec is ");
// Resistivity of conductor
Rho = 1 /(n * e * Mu_e);// in ohm-m
disp(Rho,"Resistivity of conductor in ohm-m is ");
// Velocity of electrons with fermi-energy
V_F = sqrt((2 * E_F * e)/m);// in m/s
disp(V_F,"Velocity of electrons with fermi-energy in
```

```
m/s is");

//Note: The calculated value of Resistivity of conductor is wrong.
```

Scilab code Exa 2.25 Temperature

```
//Exa 2.25
format('v',6)
clc;
clear;
close;
// Given data
E= 5.95;// in eV
EF= 6.25;// in eV
delE= 0.01;
 // delE= 1-1/(1+exp((E-EF)/KT))
K=1.38*10^-23;// Boltzmann Constant in J/K
// The temperature at which there is a 1 % probability that a state 0.30 eV below the Fermi energy level
T = ((E-EF)/log(1/(1-delE) -1)*1.6*10^-19)/K;// in K
disp(T,"The temperature in K is : ")
```

Scilab code Exa 2.26 Thermal equilibrium hole concentration

```
//Exa 2.26
format('v',9)
clc;
clear;
close;
// Given data
N_V = 1.04 * 10^19;// in cm^-3
```

```
T1 = 300;// in K
T2 = 400;// in K
del_E = 0.27;// in eV
// The value of N_V at T=400 K,
N_V = N_V * (T2/T1)^1.5;// in cm^-3
KT = (0.0259) * (T2/T1);// in eV
// The thermal equilibrium hole concentration in
    silicon
P_o = N_V * exp(-(del_E)/KT);// in cm^-3
disp(P_o,"The thermal equilibrium hole concentration
     in silicon in cm^-3 is ");
```

Scilab code Exa 2.27 Required doping concentration

```
//Exa 2.27
format('v',10)
clc;
clear;
close;
//Given data
N_c = 2.8 * 10^19;
N_V = 1.04 *10^19;
T1 = 550;// in K
T2 = 300;// in K
E_g = 1.12;
KT = (0.0259) ;
n_i = sqrt(N_c *N_V *(T1/T2)^3* exp(-(E_g)/KT*T2/T1)
    );// in cm^-3
// n_o = N_d/2 + sqrt((N_d/2)^2 + (n_i)^2)
// 1.05*N_d -N_d/2= sqrt((N_d/2)^2 + (n_i)^2)
// Minimum donor concentration required
N_d=sqrt((n_i)^2/((0.55)^2-1/4));
disp(N_d,"Minimum donor concentration required in cm
    ^-3 is");
```

Scilab code Exa 2.28 Quasi Fermi energy levels

```
//Exa 2.28
format('v',7)
clc;
clear;
close;
//Given data
T = 300;// in K
n_o = 10^15;// in cm^-3
n_i = 10^10;// in cm^-3
p_o = 10^5;// in cm^-3
del_n = 10^13;// in cm^-3
del_p = del_n;// in cm^-3
KT = 0.0259;// in eV
delta_E1= KT*log(n_o/n_i);// value of E_F-E_Fi in eV
delta_E2= KT*log((n_o+del_n)/n_i);// value of E_Fn-
    E_Fi in eV
delta_E3= KT*log((p_o+del_p)/n_i);// value of E_Fi-
    E_Fp in eV
disp(delta_E1,"The Fermi level for thermal
    equillibrium in eV is : ")
disp(delta_E2,"The quase-Fermi level for electrons
    in non equillibrium in eV is : ")
disp(delta_E3,"The quasi-Fermi level for holes in
    non equillibrium in eV is : ")
disp("The quasi-Fermi level for electrons is above
    E_Fi ")
disp("While the quasi-Fermi level for holes is below
     E_Fi")
```

Chapter 3

Excess Carriers In Semiconductors

Scilab code Exa 3.1 Hole concentration at equilibrium

```
// Exa 3.1
format('v',6)
clc;
clear;
close;
// Given data
N_d = 10^17;// atoms/cm^3
n_i = 1.5 * 10^10;// in /cm^3
n_o = 10^17;// in cm^3
// p_o * n_o = (n_i)^2
p_o = (n_i)^2 / n_o;//in holes/cm^3
disp(p_o,"The hole concentration at equilibrium in
   holes/cm^3 is");
```

Scilab code Exa 3.3 Position of Fermi level

```
// Exa 3.3
format('v',6)
clc;
clear;
close;
// Given data
n_i = 1.5 * 10 ^10;// in /cm^3 for silicon
N_d = 10^17;// in atoms/cm^3
n_o = 10^17;// electrons/cm^3
KT = 0.0259;
// E_r - E_i = KT * log(n_o/n_i)
del_E = KT * log(n_o/n_i);// in eV
disp("The energy band for this type material is Ei +
    "+string(del_E)+" eV");
```

Scilab code Exa 3.4 Diffusion coefficients of electrons and holes

```
// Exa 3.4
format('v',7)
clc;
clear;
close;
// Given data
K = 1.38 * 10^-23;// in J/K
T = 27;// in degree
T = T + 273;// in K
e = 1.6 * 10^-19;// in C
Mu_e = 0.17;// in m^2/v-s
Mu_e1 = 0.025;// in m^2/v-s
D_n = ((K * T)/e) * Mu_e;// in m^2/s
disp(D_n,"The diffusion coefficient of electrons in
   m^2/s is");
D_p = ((K * T)/e) * Mu_e1;// in m^2/s
disp(D_p,"The diffusion coefficient of  holes in m
    ^2/s is ");
```

Scilab code Exa 3.5 Diffusion length

```
// Exa 3.5
format('v',8)
clc;
clear;
close;
// Given data
Mu_n = 0.15;// in m^2/v-s
K = 1.38 * 10^-23; // in J/K
T = 300;// in K
del_n = 10^20;// in per m^3
Toh_n = 10^-7;// in s
e = 1.6 * 10^-19;// in C
D_n = Mu_n * ((K * T)/e);// in m^2/s
disp(D_n,"The diffusion coefficient in m^2/s is");
L_n = sqrt(D_n * Toh_n);// in m
disp(L_n,"The Diffusion length in m is");
J_n = (e * D_n * del_n)/L_n;// in A/m^2
disp(J_n,"The diffusion current density in A/m^2 is"
    );
// Note : The value of diffusion coefficient in the
    book is wrong.
```

Scilab code Exa 3.6 Concentration of holes and electrons

```
// Exa 3.6
format('v',8)
clc;
clear;
close;
```

```
// Given data
Sigma = 0.1;// in (ohm-m)^-1
Mu_n = 1300;
n_i = 1.5 * 10^10;
q = 1.6 * 10^-19;// in C
n_n = Sigma/(Mu_n * q);// in electrons/cm^3
n_n= n_n*10^6;// per m^3
disp(n_n,"The concentration of electrons per m^3 is");
p_n = (n_i)^2/n_n;// in per cm^3
p_n = p_n * 10^6;// in per m^3
disp(p_n,"The concentration of holes per m^3 is");
```

Scilab code Exa 3.7 Electron transit time

```
// Exa 3.7
format('v',9)
clc;
clear;
close;
// Given data
Mu_e = 0.13;// in m^2/v-s
Mu_h = 0.05;// in m^2/v-s
Toh_h = 10^-6;// in s
L = 100;// in  m
L = L * 10^-6;// in m
V = 2;// in V
t_n =L^2/(Mu_e * V);// in s
disp(t_n,"Electron transit time in seconds is");
p_g = (Toh_h/t_n) * (1 + Mu_h/Mu_e);//photo conductor gain
disp(p_g,"Photo conductor gain is");

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

wrong

Scilab code Exa 3.8 `Resistivity of intrinsic Ge`

```
// Exa 3.8
format('v',5)
clc;
clear;
close;
//Given data
n_i = 2.5 * 10^13;
Mu_n = 3800;
Mu_p = 1800;
q = 1.6 * 10^-19;// in C
Sigma = n_i * (Mu_n + Mu_p) * q;// in (ohm-cm)^-1
Rho = 1/Sigma;// in ohm-cm
Rho= round(Rho);
disp(Rho,"The resistivity of intrinsic germanium in
    ohm-cm is");
N_D = 4.4 * 10^22/(1*10^8);// in atoms/cm^3
Sigma_n = N_D * Mu_n * q;// in (ohm-cm)^-1
Rho_n = 1/Sigma_n;// in ohm-cm
disp(Rho_n,"If a donor type impurity is added to the
     extent of 1 atom per 10^8 Ge atoms, then the
    resistivity drops in ohm-cm is");
```

Scilab code Exa 3.9 `Hole and electron concentration`

```
// Exa 3.9
format('v',8)
clc;
clear;
close;
```

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

Scilab code Exa 3.10 Ratio of donor atoms to Si atom

```
// Exa 3.10
format('v',8)
clc;
clear;
close;
// Given data
Rho = 9.6 * 10^-2;// in ohm-m
Sigma_n = 1/Rho;// in (ohm-m)^-1
q = 1.6 * 10^-19;// in C
Mu_n = 1300 * 10^-4;// in m^2/V-sec
N_D = Sigma_n / (Mu_n * q);// in atoms/m^3
A_D = 5*10^22;// Atom density in atoms/cm^3
A_D = A_D * 10^6;// atoms/m^3
R_si = N_D/A_D;// ratio
disp(R_si,"The ratio of donor atom to silicon atom
   is");
```

Scilab code Exa 3.11 Equillibrium electron and hole densities

```
// Exa 3.11
format('v',9)
clc;
clear;
```

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

Scilab code Exa 3.12 Carrier concentration

```
// Exa 3.12
format('v',7)
clc;
clear;
close;
// Given data
N_A = 2 * 10^16;// in atoms/cm^3
N_D = 10^16;// in atoms/cm^3
C_c = N_A-N_D;// C_c stands for Carrier
    concentration in /cm^3
disp(C_c,"Carrier concentration per cm^3 is");
```

Scilab code Exa 3.13 Generation rate due to irradiation

```
// Exa 3.13
format('v',7)
clc;
clear;
close;
// Given data
del_n = 10^15;// in cm^3
Torque_p = 10 * 10^-6;// in sec
```

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

Scilab code Exa 3.14 Mobility of minority charge carrier

```
// Exa 3.14
format('v',6)
clc;
clear;
close;
// Given data
v = 1/(20 * 10^-6);// in cm/sec
E = 10;// in V/cm
Mu= v/E;// in cm^2/V-sec
disp(Mu,"The mobility of minority charge carrier in
   cm^2/V-sec is ");
```

Scilab code Exa 3.15 Hall and electron diffusion current

```
// Exa 3.15
format('v',8)
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
N_D = 4.5 * 10^15;// in /cm^3
del_p = 10^21;
e=10;// in cm
A = 1;// in mm^2
A = A * 10^-14;// cm^2
l = 10;// in cm
```

```
Torque_p = 1;// in microsec
Torque_p = Torque_p * 10^-6;// in sec
Torque_n = 1;// in microsec
Torque_n = Torque_n * 10^-6;// in  sec
n_i = 1.5 * 10^10;// in /cm^3
D_n = 30;// in cm^2/sec
D_p = 12;// in cm^2/sec
n_o = N_D;// in /cm^3
p_o = (n_i)^2/n_o;// in /cm^3
disp(p_o,"Hole concentration at thermal equilibrium
   per cm^3 is");
l_n = sqrt(D_n * Torque_n);// in cm
disp(l_n,"Diffusion length of electron in cm is");
l_p = sqrt(D_p * Torque_p);// in cm
disp(l_p,"Diffusion length of holes in cm is");
x=34.6*10^-4;// in cm
dpBYdx = del_p *e;// in cm^4
disp(dpBYdx,"Concentration gradient of holes at
   distance in cm^4 is");
e1 = 1.88 * 10^1;// in cm
dnBYdx = del_p * e1;// in cm^4
disp(dnBYdx,"Concentration gradient of electrons in
   per cm^4 is");
J_P = -(q) * D_p * dpBYdx;// in A/cm^2
disp(J_P,"Current density of holes due to diffusion
   in A/cm^2 is");
J_n = q * D_n * dnBYdx;// in A/cm^2
disp(J_n,"Current density of electrons due to
   diffusion in A/cm^2 is");
```

Scilab code Exa 3.16 Energy band gap of semiconductor material used

```
// Exa 3.16
format('v',5)
clc;
```

```
clear;
close;
// Given data
e= 1.6*10^-19;// electron charge in C
h = 6.626 * 10^-34;// in J-s
h= h/e;// in eV
c = 3 * 10^8;// in m/s
lembda = 5490 * 10^-10;// in m
f = c/lembda;
E = h * f;// in eV
disp(E,"The energy band gap of the semiconductor
   material in eV is");
```

Scilab code Exa 3.17 `Current density in Si`

```
// Exa 3.17
format('v',6)
clc;
clear;
close;
// Given data
y2 = 6 * 10^16;// in /cm^3
y1 = 10^17;// in /cm^3
x2 = 2;// in  m
x1 = 0;// in  m
D_n = 35;// in cm^2/sec
q = 1.6 *10^-19;// in C
dnBYdx = (y2 - y1)/((x2-x1) * 10^-4);
J_n = q * D_n * dnBYdx;// in A/cm^2
disp(J_n,"The current density in silicon in A/cm^2
   is");
```

Scilab code Exa 3.18 `Resistance of the bar`

```
// Exa 3.18
format('v',6)
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
n_n = 5 * 10^20;// in /m^3
n_n = n_n * 10^-6;// in cm^3
Mu_n = 0.13;// in m^2/V-sec
Mu_n = Mu_n * 10^4;// in cm^2/V-sec
Sigma_n = q * n_n * Mu_n;// in (ohm-cm)^-1
Rho = 1/Sigma_n;// in  -cm
l = 0.1;// in cm
A = 100;//  m ^2
A = A * 10^-8;// in cm^2
R = Rho * (l/A);// in Ohm
R=round(R*10^-6);// in M
disp(R,"The resistance of the bar in M  is");
```

Scilab code Exa 3.19 Depletion width

```
// Exa 3.19
format('v',5)
clc;
clear;
close;
// Given data
t_d = 3;// total depletion in  m
// The depletion width ,
D = t_d/9;// in  m
disp(D,"Depletion width in  m  is");
```

Scilab code Exa 3.20 Minority carrier density

```
// Exa 3.20
format('v',8)
clc;
clear;
close;
// Given data
n_i = 1.5 * 10^16;// in /m^3
n_n = 5 * 10^20;// in /m^3
p_n = (n_i)^2/n_n;// in /m^3
disp(p_n,"The majority carrier density per m^3 is");
```

Scilab code Exa 3.21 Collector current density

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

```

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

Scilab code Exa 3.22 Band gap

```
//Exa 3.22
format('v',6)
clc;
clear;
close;
// Given data
h = 6.64 * 10^-34;// in J-s
e= 1.6*10^-19;// electron charge in C
c= 3 * 10^8;// in m/s
lembda = 0.87;// in  m
lembda = lembda * 10^-6;// in m
E_g = (h * c)/lembda;// in J-s
E_g= E_g/e;// in eV
disp(E_g,"The band gap of the material in eV is");
```

Scilab code Exa 3.23 Total energy absorbed by sample

```
// Exa 3.23
format('v',8)
clc;
clear;
close;
// Given data
I_o = 10;// in mW
e = 1.6 * 10^-19;// in J/eV
hv = 2;// in eV
hv1=1.43;// in eV
```

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

Scilab code Exa 3.24 Hole current

```
// Exa 3.24
format('v',9)
clc;
clear;
close;
// Given data
Mu_p = 500;// in cm^2/V-sec
kT = 0.0259;
Toh_p = 10^-10;// in sec
p_o = 10^17;// in cm^-3
q= 1.6*10^-19;// in C
A=0.5;// in square meter
del_p = 5 * 10^16;// in cm^-3
n_i= 1.5*10^10;// in cm^-3
D_p = kT * Mu_p;// in cm/s
L_p = sqrt(D_p * Toh_p);// in cm
```

```
x = 10^-5;// in cm
p = p_o+del_p* %e^(x/L_p);// in cm^-3
// p= n_i*%e^(Eip)/kT where Eip=E_i-F_p
Eip= log(p/n_i)*kT;// in eV
Ecp= 1.1/2-Eip;// value of E_c-E_p in eV
Ip= q*A*D_p/L_p*del_p/%e^(x/L_p);// in A
disp(Ip,"The hole current in A is : ")
Qp= q*A*del_p*L_p;// in C
disp(Qp,"The value of Qp in C is : ")
```

Chapter 4

Junctions

Scilab code Exa 4.2 Tuning range

```
// Exa 4.2
format('v',6)
clc;
clear;
close;
// Given data
C1= 5*10^-12;// in F
C2= 5*10^-12;// in F
L= 10*10^-3;// in H
C_Tmin= C1*C2/(C1+C2);// in F
f_omax= 1/(2*%pi*sqrt(L*C_Tmin));// in Hz
C1= 50*10^-12;// in F
C2= 50*10^-12;// in F
C_Tmax= C1*C2/(C1+C2);// in F
f_omin= 1/(2*%pi*sqrt(L*C_Tmax));// in Hz
f_omax= f_omax*10^-6;// in MHz
f_omin= f_omin*10^-3;// in kHz
disp(f_omax,"The maximum value of resonant frequency
    in MHz is : ")
disp(f_omin,"The minimum value of resonant frequency
    in kHz is : ")
```

Scilab code Exa 4.3 Contact difference of potential

```
// Exa 4.3
format('v',6)
clc;
clear;
close;
// Given data
t = 4.4 * 10^22;// total number of Ge atoms/cm^3
n = 1 * 10^8;// number of impurity atoms
N_A = t/n;// in atoms/cm^3
N_A = N_A * 10^6;// in atoms/m^3
N_D = N_A * 10^3;// in atoms/m^3
n_i = 2.5 * 10^13;// in atoms/cm^3
n_i = n_i * 10^6;// in atoms/m^3
V_T = 26;//in mV
V_T= V_T*10^-3;// in V
// The contact potential for Ge semiconductor,
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"The contact potential for Ge semiconductor
    in V is");
// Part (b)
t = 5* 10^22;// total number of Si atoms/cm^3
N_A = t/n;// in atoms/cm^3
N_A = N_A * 10^6;// in atoms/m^3
N_D = N_A * 10^3;// in atoms/m^3
n_i = 1.5 * 10^10;// in atoms/cm^3
n_i = n_i * 10^6;// in atoms/m^3
V_T = 26;//in mV
V_T= V_T*10^-3;// in V
// The contact potential for Si P-N junction,
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"The contact potential for Si P-N junction
   in V is");
```

Scilab code Exa 4.4 Height of the potential energy barrier

```
// Exa 4.4
format('v',6)
clc;
clear;
close;
// Given data
V_T = 26;// in mV
V_T=V_T*10^-3;// in V
n_i = 2.5 * 10^13;
Sigma_p = 1;
Sigma_n = 1;
Mu_n = 3800;
q = 1.6 * 10^-19;// in C
Mu_p = 1800;
N_A = Sigma_p/(2* q * Mu_p);// in /cm^3
N_D = Sigma_n /(q * Mu_n);// in /cm^3
// The height of the energy barrier for Ge,
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"For Ge the height of the energy barrier in
    V is");
// For Si p-n juction
n_i = 1.5 * 10^10;
Mu_n = 1300;
Mu_p = 500;
N_A = Sigma_p/(2* q * Mu_p);// in /cm^3
N_D = Sigma_n /(q * Mu_n);// in /cm^3
// The height of the energy barrier for Si p-n
    junction,
V_J = V_T * log((N_A * N_D)/(n_i)^2);// in V
disp(V_J,"For Si p-n junction  the height of the
    energy barrier in V is");
```

Scilab code Exa 4.5 Forward current

```
//Exa 4.5
format('v',6)
clc;
clear;
close;
// Given data
Eta = 1;
V_T = 26;// in mV
V_T= V_T*10^-3;// in V
//From equation of the diode current,  I = I_o * (%e^(V/(Eta*V_T)) - 1) and I = -(0.9) * I_o
V= log(1-0.9)*V_T;//voltage in V
disp(V,"The voltage in volts is : ")
// Part (ii)
V1=0.05;// in V
V2= -0.05;// in V
// The ratio of the current for a forward bias to reverse bias
ratio= (%e^(V1/(Eta*V_T))-1)/(%e^(V2/(Eta*V_T))-1)
disp(ratio,"The ratio of the current for a forward bias to reverse bias is : ")
// Part (iii)
Io= 10;// in  A
Io=Io*10^-3;// in mA
//For
V=0.1;// in V
// Diode current
I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
disp(I,"For V=0.1 V , the value of I in mA is : ")
//For
V=0.2;// in V
// Diode current
```

```
I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
disp(I,"For V=0.2 V , the value of I in mA is : ")
//For
V=0.3;// in V
// Diode current
I = Io * (%e^(V/(Eta*V_T)) - 1);// in mA
disp(I*10^-3,"For V=0.3 V , the value of I in A is :
    ")
disp("From three value of I, for small rise in
    forward voltage, the diode current increase
    rapidly")
```

Scilab code Exa 4.6 Anticipated factor

```
//Exa 4.6
format('v',6)
clc;
clear;
close;
// Given data
// Part (i)
T1= 25;// in C
T2= 80;// in C
// Formula Io2= Io1*2^((T2-T1)/10)
AntiFactor= 2^((T2-T1)/10);
disp(round(AntiFactor),"Anticipated factor for Ge is
    : ")
// Part (ii)
T1= 25;// in C
T2= 150;// in C
AntiFactor= 2^((T2-T1)/10);
disp(round(AntiFactor),"Anticipated factor for Si is
    : ")
```

Scilab code Exa 4.7 Leakage resistance

```
//Exa 4.7
format('v',6)
clc;
clear;
close;
// Given data
I=5;// in  A
V=10;// in V
T1= 0.11;// in  C ^-1
T2= 0.07;// in  C ^-1
// Io+I_R=I                           (i)
// dI_by_dT= dIo_by_dT          (ii)
// 1/Io*dIo_by_dT = T1 and 1/I*dI_by_dT = T2, So
Io= T2*I/T1;// in  A
I_R= I-Io;// in  A
R= V/I_R;// in  M
disp(R,"The leakage resistance in M  is : ")
```

Scilab code Exa 4.8 Dynamic resistance

```
//Exa 4.8
format('v',6)
clc;
clear;
close;
// Given data
Eta = 1;
T = 125;// in  C
T = T + 273;// in K
V_T = 8.62 * 10^-5 * 398;// in V
```

```
I_o = 30;// in  A
I_o= I_o*10^-6;// in A
v = 0.2;// in V
// The dynamic resistance in the forward direction
r_f = (Eta * V_T)/(I_o * %e^(v/(Eta* V_T)));// in
    ohm
disp(r_f,"The dynamic resistance in the forward
    direction in ohm is ");
// The dynamic resistance in the reverse direction
r_r = (Eta * V_T)/(I_o * %e^(-v/(Eta* V_T)));// in
    ohm
r_r= r_r*10^-3;// in k ohm
disp(r_r,"The dynamic resistance in the reverse
    direction in kohm is");
```

Scilab code Exa 4.9 Barrier capacitance

```
// Exa 4.9
format('v',6)
clc;
clear;
close;
// Given data
epsilon = 16/(36 * %pi * 10^11);// in F/cm
A = 1 * 10^-2;
W = 2 * 10^-4;
// The barrier capacitance
C_T = (epsilon * A)/W;// in F
C_T= C_T*10^12;// in pF
disp(C_T,"The barrier capacitance in pF is");
```

Scilab code Exa 4.10 Width of the depletion layer

```
//Exa 4.10
format('v',6)
clc;
clear;
close;
//Given data
A = 1;// in mm^2
A = A * 10^-6;// in m^2
N_A = 3 * 10^20;// in atoms/m^3
q = 1.6 *10^-19;// in C
V_o = 0.2;// in V
epsilon_r=16;
epsilon_o= 8.854*10^-12;// in F/m
epsilon=epsilon_r*epsilon_o;
// Part (a)
V=-10;// in V
// V_o - V = 1/2*((q * N_A )/epsilon) * W^2
W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
W= W*10^6;// in  m
disp(W,"The width of the depletion layer  for an applied reverse voltage of 10V in  m  is ");
W= W*10^-6;// in m
C_T1 = (epsilon * A)/W;// in F
C_T1= C_T1*10^12;// in pF
// Part (b)
V=-0.1;// in V
W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
W= W*10^6;// in  m
disp(W,"The width of the depletion layer  for an applied reverse voltage of 0.1V in  m  is ");
W= W*10^-6;// in m
C_T2 = (epsilon * A)/W;// in F
C_T2= C_T2*10^12;// in pF
// Part (c)
V=0.1;// in V
W = sqrt(((V_o - V) * 2 * epsilon)/(q * N_A));// m
W= W*10^6;// in  m
disp(W,"The width of the depletion layer  for an
```

```
applied for a forward bias of 0.1V in  m  is ");
// Part (d)
disp(C_T1,"The space charge capacitance for an
   applied reverse voltage of 10V  in pF is");
disp(C_T2,"The space charge capacitance for an
   applied reverse voltage of 0.1V  in pF is");
```

Scilab code Exa 4.11 `Current in the junction`

```
// Exa 4.11
format('v',6)
clc;
clear;
close;
// Given data
I_o = 1.8 * 10^-9;// A
v = 0.6;// in V
Eta = 2;
V_T = 26;// in mV
V_T=V_T*10^-3;// in V
// The current in the junction
I = I_o *(%e^(v/(Eta * V_T)));// in A
I= I*10^3;// in mA
disp(I,"The current in the junction in mA is");
```

Scilab code Exa 4.12 `Forward biasing voltage`

```
// Exa 4.12
format('v',7)
clc;
clear;
close;
// Given data
```

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

Scilab code Exa 4.13 `Theoretical diode current`

```
// Exa 4.13
format('v',6)
clc;
clear;
close;
// Given data
I_o = 10;// in nA
// I = I_o * ((e^(v/(Eta * V_T))) - 1) as diode is
    reverse biased by large voltage
// e^(v/(Eta * V_T)<< 1, so neglecting it
I = I_o * (-1);// in nA
disp(I,"The Diode current in nA is  ");
```

Scilab code Exa 4.14 `Diode dynamic resistance`

```
// Exa 4.14
format('v',6)
clc;
clear;
close;
```

```
// Given data
R = 4.5;// in ohm
I = 44.4;// in mA
I=I*10^-3;// in A
V = R * I;// in V
Eta = 1;
V_T = 26;//in mV
V_T=V_T*10^-3;// in V
// Reverse saturation current ,
I_o = I/((%e^(V/(Eta * V_T))) -1);// in A
// Dynamic resistance at 0.1 V forward bias
V = 0.1;// in V
// The diode dynamic resistance ,
r_f = (Eta * V_T)/(I_o * ((%e^(V/(Eta * V_T))-1)); // in ohm
disp(r_f,"The diode dynamic resistance in    is");
```

Scilab code Exa 4.15 `DC load line and operating point`

```
// Exa 4.15
format('v',6)
clc;
clear;
close;
// Given data
V_D = 10;// in V
// V_S = i*R_L + V_D
V_S = V_D;// in V (i * R_L = 0)
disp(V_S,"when diode is OFF, the voltage in volts is : ");
R_L = 250;// in ohm
I = V_S/R_L;// in A
disp(I*10^3,"when diode is ON, the current in mA is");
V_D= 0:0.1:10;// in V
```

```
I= (V_S-V_D)/R_L*1000;// in mA
plot(V_D,I)
xlabel("V_D in volts");
ylabel("Current in mA")
title("DC load line");
disp("DC load line shown in figure")
```

Scilab code Exa 4.16 AC resistance of a Ge diode

```
// Exa 4.16
format('v',6)
clc;
clear;
close;
// Given data
V = 0.25;// in V
I_o = 1.2;// in  A
I_o = I_o * 10^-6;// in A
V_T = 26;// in mV
V_T = V_T * 10^-3;// in V
Eta = 1;
// The ac resistance of the diode
r = (Eta * V_T)/(I_o * (%e^(V/(Eta * V_T))));// in
    ohm
disp(r,"The ac resistance of the diode in ohm is");
```

Scilab code Exa 4.17 Junction potential

```
// Exa 4.17
format('v',6)
clc;
clear;
close;
```

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

Scilab code Exa 4.18 Dynamic resistance

```
// Exa 4.18
format('v',6)
clc;
clear;
close;
// Given data
Eta = 1;
I_o = 30;// in MuA
I_o = I_o * 10^-6;// in A
v = 0.2;// in V
K = 1.381 * 10^-23;// in J/degree K
T = 125;// in  C
T = T + 273;// in K
q = 1.6 * 10^-19;// in C
V_T = (K*T)/q;// in V
// The forward dynamic resistance ,
r_f = (Eta * V_T)/(I_o * (%e^(v/(Eta * V_T))));// in
    ohm
disp(r_f,"The forward dynamic resistance in ohm is")
    ;
```

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

Scilab code Exa 4.19 `Width of the depletion layer`

```
// Exa 4.19
format('v',6)
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
N_A = 3 * 10^20;// in /m^3
A = 1;// in  m ^2
A = A * 10^-6;// in m^2
V = -10;// in V
V_J = 0.25;// in V
V_B = V_J - V;// in V
epsilon_o = 8.854;// in pF/m
epsilon_o = epsilon_o * 10^-12;// in F/m
epsilon_r = 16;
epsilon = epsilon_o * epsilon_r;
// The width of depletion layer,
W = sqrt((V_B * 2 * epsilon)/(q * N_A));// in m
W=W*10^6;// in  m
disp(W,"The width of depletion layer in  m  is");
W=W*10^-6;// in m
// The space charge capacitance,
C_T = (epsilon * A)/W;// in pF
C_T=C_T*10^12;// in pF
disp(C_T,"The space charge capacitance in pF is");
```

Scilab code Exa 4.20 Barrier capacitance of a Ge pn junction

```
// Exa 4.20
format('v',6)
clc;
clear;
close;
// Given data
W = 2 * 10^-4;// in cm
W = W * 10^-2;// in m
A = 1;// in mm^2
A = A * 10^-6;// in m^2
epsilon_r = 16;
epsilon_o = 8.854 * 10^-12;// in F/m
epsilon = epsilon_r * epsilon_o;
C_T = (epsilon * A)/W;// in F
C_T= C_T*10^12;// in pF
disp(C_T,"The barrier capacitance in pF is");
```

Scilab code Exa 4.21 Diameter

```
// Exa 4.21
format('v',6)
clc;
clear;
close;
// Given data
C_T = 100;// in pF
C_T=C_T*10^-12;// in F
epsilon_r = 12;
epsilon_o = 8.854 * 10^-12;// in F/m
```

```
epsilon = epsilon_r * epsilon_o;
Rho_p = 5;// in ohm-cm
Rho_p = Rho_p * 10^-2;// in ohm-m
V_j = 0.5;// in V
V = -4.5;// in V
Mu_p = 500;// in cm^2
Mu_p = Mu_p * 10^-4;// in m^2
Sigma_p = 1/Rho_p;// in per ohm-m
qN_A = Sigma_p/ Mu_p;
V_B = V_j - V;
W = sqrt((V_B * 2 * epsilon)/qN_A);// in m
//C_T = (epsilon * A)/W;
A = (C_T * W)/ epsilon;// in m
D = sqrt(A * (4/%pi));// in m
D = D * 10^3;// in mm
disp(D,"The diameter in mm is");
```

Scilab code Exa 4.22 Temperature of junction

```
// Exa 4.22
format('v',7)
clc;
clear;
close;
// Given data
q = 1.6 * 10^-19;// in C
Mu_p = 500;// in cm^2/V-sec
Rho_p = 3.5;// in ohm-cm
Mu_n = 1500;// in cm^2/V-sec
Rho_n = 10;// in ohm-cm
N_A = 1/(Rho_p * Mu_p * q);// in /cm^3
N_D = 1/(Rho_n * Mu_n * q);// in /cm^3
V_J = 0.56;// in V
n_i = 1.5 * 10^10;// in /cm^3
V_T = V_J/log((N_A * N_D)/(n_i)^2);// in V
```

```
// V_T = T/11600
T = V_T * 11600;// in K
T = T - 273;// in  C
disp(T,"The Temperature of junction in  C  is");
```

Scilab code Exa 4.23 `Voltage`

```
// Exa 4.23
format('v',7)
clc;
clear;
close;
// Given data
V_T = 26;// in mV
V_T = V_T * 10^-3;// in V
Eta = 1;
// I = -90% for Io, so
IbyIo= 0.1;
// I  = I_o * ((e^(v/(Eta * V_T)))-1)
V = log(IbyIo) * V_T;// in V
disp(V,"The reverse bias voltage in volts is");
```

Scilab code Exa 4.24 `Reverse saturation current`

```
// Exa 4.24
format('v',6)
clc;
clear;
close;
// Given data
R = 5;// in ohm
I = 50;// in mA
I=I*10^-3;// in A
```

```
V = R * I;// in V
Eta = 1;
V_T = 26;// in mV
V_T=V_T*10^-3;// in V
// The reverse saturation current
I_o = I/((%e^(V/(Eta * V_T))) - 1);// in A
I_o= I_o*10^6;// in  A
disp(I_o,"Reverse saturation current in  A  is");
I_o= I_o*10^-6;// in A
v1 = 0.2;// in V
// The dynamic resistance of the diode,
r = (Eta * V_T)/(I_o * (%e^(v1/(Eta * V_T))));// in ohm
disp(r,"Dynamic resistance of the diode in    is");
```

Chapter 5

MOSFETs

Scilab code Exa 5.1 Current

```
// Exa 5.1
format('v',6)
clc;
clear;
close;
// Given data
V_TN = 0.7;// in V
W = 45*10^-4;// in cm
L = 4;// in  m
L = L * 10^-4;// in cm
t_ox = 450;// in
t_ox = t_ox*10^-8;// in cm
V_GS = 1.4;// in V
Miu_n = 700;// in cm^2/V-s
Epsilon_ox = (8.85*10^-14)*(3.9);// in F/cm
// Conduction parameter can be expressed as,
k_n = (W*Miu_n*Epsilon_ox)/(2*L*t_ox);// A/V^2
k_n= k_n*10^3;// in mA/V^2
disp(k_n,"The value of k_n in mA/V^2 is : ")
k_n= k_n*10^-3;// in A/V^2
// The drain current ,
```

```
I_D = k_n*((V_GS-V_TN)^2);// in A
I_D= I_D*10^3;// in mA
disp(I_D,"The current in mA is ");

// Note: There is a calculation error to find the
   value of k_n, So the answer in the book is wrong
```

Scilab code Exa 5.2 IDQ and VDSQ

```
// Exa 5.2
format('v',5)
clc;
clear;
close;
// Given data
I_Don = 6;// in mA
I_Don= I_Don*10^-3;// in A
V_GSon = 8;// in V
V_GSth = 3;// in V
V_DD = 12;// in V
R_D= 2*10^3;// in
k= I_Don/(V_GSon-V_GSth)^2;// in A/V^2
// I_D= k*[V_GS-V_GSth]^2 but V_GS= V_DD-I_D*R_D, So
// I_D= k*(V_DD-I_D*R_D-V_GSth)^2 or
// 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
A= R_D^2;// assumed
B= 2*R_D*V_GSth-2*R_D*V_DD-1/k;// assumed
C= (V_DD-V_GSth)^2;// assumed
// Evaluating the value of I_D
root= [A B C];
root= roots(root);// in A
disp("The value of I_D is : "+string(root(1)*10^3)+"
   mA or "+string(root(2)*10^3)+" mA")
I_DQ= root(2);// in A
```

```
disp(I_DQ*10^3,"The value of I_DQ in mA is : ")
V_DSQ= V_DD-I_DQ*R_D;// in V
disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 5.3 Designing of biasing circuit

```
// Exa 5.3
format('v',6)
clc;
clear;
close;
// Given data
V_GS = 6;// in V
I_D = 4;// in mA
V_GSth = 2;// in V
V_DS = V_GS;// in V
// For a good design
V_DD = 2*V_DS;// in V
disp(V_DD,"The value of V_DD in V is")
R_D = (V_DD-V_DS)/I_D;// in k ohm
disp(R_D,"The value of R_D in k ohm is ");
disp("The very high value for the gate to drain
    resistance is : 10 M ")
```

Scilab code Exa 5.4 IDQ VGSQ and VDS

```
// Exa 5.4
format('v',6)
clc;
clear;
close;
// Given data
I_Don = 3*10^-3;
```

```
V_GSon = 10;// in V
V_GSth= 5;// in V
R2= 18*10^6;// in
R1= 22*10^6;// in
R_S=820;// in
R_D=3*10^3;// in
V_DD= 40;// in V
V_G= V_DD*R2/(R1+R2);// in V
k= I_Don/(V_GSon-V_GSth)^2;// in A/V^2
// V_G= V_GS+V_RS= V_GS+I_D*R_S or V_GS= V_G-I_D*R_S
// I_D= k*[V_GS-V_GSth]^2 or
// I_D= k*(V_G-I_D*R_D-V_GSth)^2 or
// 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
A= R_S^2;// assumed
B= 2*R_S*V_GSth-2*R_S*V_G-1/k;// assumed
C= (V_G-V_GSth)^2;// assumed
// Evaluating the value of I_D
I_D= [A B C]
I_D= roots(I_D);// in A
I_D= I_D(2);// in A
I_DQ= I_D;// in A
I_DQ= I_DQ*10^3;// in mA
disp(I_DQ,"The value of I_DQ in mA is : ")
I_DQ= I_DQ*10^-3;// in A
V_GSQ= V_G-I_D*R_S;// in V
disp(V_GSQ,"The value of V_GSQ in volts is : ")
V_DSQ= V_DD-I_DQ*(R_D+R_S);// in V
disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 5.5 IDSQ VGSQ and VDSQ

```
// Exa 5.5
format('v',6)
clc;
```

```
clear;
close;
// Given data
I_D= '0.3*(V_GS-V_P)^2';// given expression
V_DD= 30;// in V
V_P= 4;// in V
R_GS = 1.2*10^6;// in
R_G = 1.2*10^6;// in
Req= R_GS/(R_GS+R_G);// in
R_D= 15;// in
// V_DS= V_DD-I_D*R_D (applying KVL to drain circuit
    )
// V_GS= Req*V_DS= (V_DD-I_D*R_D)*Req
// from given expression
//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)
A= (R_D*Req)^2;// assumed
B= -(2*R_D*Req*(V_DD*Req-V_P)+1/0.3);// assumed
C= (V_DD*Req-V_P)^2;// assumed
// Evaluating the value of I_D
I_D= [A B C]
I_D= roots(I_D);// in mA
I_D= I_D(2);// in mA
I_DSQ= I_D;// in mA
disp(I_DSQ,"The value of I_DSQ in mA is : ")
V_GS= (V_DD-I_D*R_D);// in V
disp(V_GS,"The value of V_GS in volts is : ")
V_DS= Req*V_GS;// in V
disp(V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 5.6 ID and VDS and region of operation

```
// Exa 5.6
format('v',6)
clc;
```

```
clear;
close;
// Given data
k = 0.1;// in mA/V^2
V_T  = 1;// in V
R1 = 33;//in k ohm
R2 = 21;// in k ohm
V_DD = 6;// in V
R_D = 18;// in k ohm
V_G = (R2/(R2+R1))*V_DD;// in V
V_S = 0;// in V
V_GS = V_G-V_S;// in V
I_D = k*((V_GS-V_T)^2);// in mA
disp(I_D,"The value of I_D in mA is");
V_DS = V_DD - (I_D*R_D);// in V
disp(V_DS,"The value of V_DS in V is");
V_DSsat = V_GS-V_T;// in V
disp(V_DSsat,"The value of V_DS(sat) in V is");
if V_DS>V_DSsat then
    disp("MOSFET is in saturation region")
end
```

Scilab code Exa 5.7 DC load line and operating point

```
// Exa 5.7
format('v',6)
clc;
clear;
close;
// Given data
V_DD= 6;// in V
R_D= 18;// in kohm
// for maximum value of I_D
V_DS=0;// in V
I_Dmax= (V_DD-V_DS)/R_D;// in mA
```

```
// for maximum value of V_DS
I_D=0;// in mA
V_DSmax=V_DD-I_D*R_D;// in V
V_DS= 0:0.1:V_DSmax;// in V
I_D= (V_DD-V_DS)/R_D;// in mA
plot(V_DS,I_D)
xlabel("V_DS in volts")
ylabel("I_D in mA")
title("DC load line")
disp("DC load line shown in figure");
disp("Q-points are : 2.8V, 0.178 mA")
```

Scilab code Exa 5.8 Region at which MOSFET ia biased

```
// Exa 5.8
format('v',5)
clc;
clear;
close;
// Given data
R2 = 18;// in k ohm
R1 = 33;// in k ohm
V_DD = 6;// in V
V_G = (R2/(R1+R2))*V_DD;// in V
V_S = V_DD;// in V
V_SG = V_S-V_G;// in V
disp(V_SG,"The value of V_SG in V is");
k = 0.1;
V_T = -1;// in V
I_D = k*((V_SG+V_T)^2);// in mA
disp(I_D,"The value of I_D in mA is");
R_D = 3;// in k ohm
V_SD = V_DD - (I_D*R_D);// in V
disp(V_SD,"The value of V_SD in V is");
V_SDsat  = V_SG+V_T;// in V
```

```
disp(V_SDsat,"The value of V_SD(sat) in V is");
if V_SD>V_SDsat then
    disp("The p MOSFET is indeed biased in the
       saturation region")
end
```

Scilab code Exa 5.9 `IDQ and VDSQ`

```
// Exa 5.9
format('v',6)
clc;
clear;
close;
// Given data
V_G= 1.5;// in V
V_P= -3;// in V
R_S= 750;// in
R_D= 1800;// in
I_DSS= 6*10^-3;// in A
V_DD= 18;// in V
// V_GS= V_G-I_D*R_S
// I_D= I_DSS*(1-V_GS/V_P)^2 or I_DSS*(1-(V_G-I_D*
   R_S)/V_P)^2
//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
A= R_S^2;
B=(2*R_S*(V_P-V_G)-V_P^2/I_DSS);
C=(V_P-V_G)^2;
// Evaluating the value of I_D by using polynomial
I_D= [A B C]
I_D= roots(I_D);// in A
I_D= I_D(2);// in A
I_DQ= I_D;// in A
V_DS= V_DD-I_D*(R_D+R_S);// in V
V_DSQ= V_DS;// in V
```

```
disp(I_DQ*10^3,"The value of I_DQ in mA is : ")
disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 5.10 `Necessary value of Rs`

```
// Exa 5.10
format('v',6)
clc;
clear;
close;
// Given data
V_GS = 4;// in V
V_P = 2;// in V
R2 = 10;// in k ohm
R1 = 30;// in k ohm
R_D= 2.5;// in kohm
I_D= 15;// in mA
I_D= I_D*10^-3;// in A
V_DD = 25;// in V
V_G = (V_DD/R_D)*V_DD/(R1+R2);// in V
// The necessary value for R_S
R_S = (V_G-V_GS)/I_D;// in ohm
disp(R_S,"The value of R_S in ohm is");
```

Scilab code Exa 5.11 `ID and VDS`

```
// Exa 5.11
format('v',5)
clc;
clear;
close;
// Given data
k= 0.1;// in mA/V^2
```

```
V_T= 1;// in V
R2= 87*10^3;// in
R1= 110*10^3;// in
R_S=2;// in k
R_D=2;// in k
//R_D=3*10^3;// in
V_DD= 6;// in V
V_SS= 6;// in V
V_G= (V_DD+V_SS)*R2/(R1+R2);// in V
// V_S= I_D*R_S-V_SS
// V_GS= V_G-V_S= V_G+V_SS-(I_D*R_S)
// I_D= k*[V_GS-V_T]^2 = k*[(V_G+V_SS-V_T)-(I_D*R_S)]^2
//(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
A= R_S^2;// assumed
B= -(2*R_S*(V_G+V_SS-V_T)+1/k);// assumed
C= (V_G+V_SS-V_T)^2;// assumed
I_D= [A B C]
I_D= roots(I_D);// in mA
I_D= I_D(2);// in mA
disp(I_D,"The value of I_D in mA is : ")
// Applying KVL to drain source loop, V_DD+V_SS= I_D*R_D+V_DS+I_D*R_S
V_DS=V_DD+V_SS-I_D*R_D-I_D*R_S;// in V
disp(V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 5.12 Designing of NMOS CS circuit

```
// Exa 5.12
format('v',6)
clc;
clear;
close;
// Given data
```

```
k = 0.16;// in mA/V^2
V_T = 2;// in V
I_D = 0.5;// in mA
V_DD = 6;// in V
V_SS = -6;// in V
V_GS = V_T + (sqrt(I_D/k));// in V
R_S = 2;// in k ohm
V_S = (I_D*R_S) - V_DD;// in V
V_G = V_GS+V_S;// in V
I = 0.1*I_D;// in mA
R2 = (V_G+V_DD)/I;// in k ohm
disp(R2,"The value of R2 in k ohm is");
R1 = (V_DD - V_G)/I;// in k ohm
disp(R1,"The value of R1 in k ohm is");
R_D = 10;// in k ohm
V_DS = (V_DD-V_SS) - (I_D*(R_S+R_D));// in V
disp(V_DS,"The value of V_DS in V is");
V_DSsat = V_GS-V_T;// in V
disp(V_DSsat,"The value of V_DS(sat) in V is");
if V_DS>V_DSsat then
    disp("The MOSFET is in saturation region")
end

// Note: The value of R1 is in k ohm but in the book
    it is wrong.
```

Scilab code Exa 5.13 IDQ and VDS

```
// Exa 5.13
format('v',5)
clc;
clear;
close;
// Given data
V_DD = 6;// in V
```

```
V_D = 3;// in V
R_D = 10;// in k ohm
// The value of I_DQ can be find as,
I_DQ = (V_DD-V_D)/R_D;// in mA
disp(I_DQ,"The value of I_DQ in mA is");
V_T = 0.8;// in V
k = 0.12;// in mA/V^2
// The value of Ground to Source voltage,
V_GS = sqrt(I_DQ/k) + V_T;// in V
V_S = -V_GS;// in V
// The value of Drain to Source voltage,
V_DS = V_D-V_S;// in V
disp(V_DS,"The value of V_DS in V is");
```

Scilab code Exa 5.14 The region of operation

```
// Exa 5.14
format('v',5)
clc;
clear;
close;
// Given data
I_D = 0.3;// in mA
k = 0.12;// in mA/V^2
V_T = 1;// in V
V_GS = V_T + (sqrt(I_D/k));// in V
V_S = -V_GS;// in V
V_DD = 6;// in V
V_D = 3;// in V
I_DQ = 0.3;// in mA
R_D = (V_DD-V_D)/I_DQ;// in k ohm
disp(R_D,"The value of R_D in k ohm is");
V_DS = V_D - V_S;// in V
disp(V_DS,"The value of V_DS in V is");
V_DSsat = V_GS - V_T;// in V
```

```
disp(V_DSsat,"The value of V_DS(sat) in V is");
if V_DS>V_DSsat then
    disp("The MOSFET is in saturation region")
end
```

Scilab code Exa 5.15 VDS VGS and ID

```
// Exa 5.15
format('v',6)
clc;
clear;
close;
// Given data
k= 0.05;// in mA/V^2
V_T= 1;// in V
V_DD= 6;// in V
R_S= 9.1;//in k
//V_GS= V_DD-I_D*R_S
//I_D= k*(V_DD-I_D*R_S)^2
//I_D^2*R_S^2-I_D*(2*V_DD*R_S+1/k)+V_DD^2
A= R_S^2;// assumed
B=-(2*V_DD*R_S+1/k);// assumed
C= V_DD^2;// assumed
I_D= [A B C];
I_D= roots(I_D);// in mA
I_D= I_D(2);// in mA
V_GS= V_DD-I_D*R_S;// in V
V_DS= V_GS;// in V
disp(I_D,"The value of I_D in mA is : ")
disp(V_GS,"The value of V_GS in volts is : ")
disp(V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 5.16 All dc voltages

```
// Exa 5.16
format('v',6)
clc;
clear;
close;
// Given data
k1= 0.01;// in mA/V^2
k2= 0.05;// in mA/V^2
V_DD= 5;// in V
V_T1=1;// in V
V_T2=1;// in V
// Analysis for Vi= 5V
Vi= 5;// in V
//I_D1= k1*(V_GS1-V_T1)^2 and I_D2= k2*(2*(V_GS2-V_T2)*V_DS2-V_DS2^2)
// But V_GS2= Vi, V_DS2= Vo, V_GS1= V_DS1= V_DD-Vo
//Vo^2*(k1+k2)-Vo*[2*k1*(V_DD-V_T1)+2*k2*(Vi-V_T2)]+k1*(V_DD-V_T1)^2
A=(k1+k2);
B=-[2*k1*(V_DD-V_T1)+2*k2*(Vi-V_T2)];
C=k1*(V_DD-V_T1)^2;
Vo= [A B C]
Vo= roots(Vo);// in V
Vo= Vo(2);// in V
V_GS2= Vi;// in V
V_DS2= Vo;// in V
V_GS1= V_DD-Vo;// in V
I_D1= k1*(V_GS1-V_T1)^2;// in mA
I_D2= I_D1;// in mA
disp("Part (i) For Vi = 5 V")
disp(Vo,"The output voltage in volts is : ")
disp(I_D1,"The value of I_D1 in mA is : ")
disp(I_D2,"The value of I_D2 in mA is : ")
// Analysis for Vi= 1.5V
Vi= 1.5;// in V
//I_D2= k2*(V_GS2-V_T2)^2 and I_D1= k1*(V_GS1-V_T1)^2
// But V_GS2= Vi, V_DS2= Vo, V_GS1= V_DS1= V_DD-Vo
```

```
//k2*(Vi-V_T2)^2= k1*(V_DD-Vo-V_T1)^2 or
Vo= V_DD-V_T1-sqrt(k2/k1)*(Vi-V_T2);// in V
I_D2= k2*(Vi-V_T2)^2;//in mA
I_D1= I_D2;// in mA
disp("Part (ii) For Vi = 1.5 V")
disp(Vo,"The output voltage in volts is : ")
disp(I_D1,"The value of I_D1 in mA is : ")
disp(I_D2,"The value of I_D2 in mA is : ")
```

Scilab code Exa 5.17 `ID and VDS`

```
// Exa 5.17
format('v',6)
clc;
clear;
close;
// Given data
k = 0.12;// in mA/V^2
V_T = -2.5;// in V
V_GS = 0;
I_D = k*((V_GS-V_T)^2);// in mA
disp(I_D,"The value of I_D in mA is");
V_DD = 6;// in V
R_S = 4.7;// in k ohm
V_DS = V_DD -(I_D*R_S);// in V
disp(V_DS,"The value of V_DS in V is ");
V_S = 0;// in V
V_DSsat = V_S - V_T;// in V
disp(V_DSsat,"The value of V_DS(sat) in V is");
if V_DS<V_DSsat then
    disp("The device is in the non saturation region ")
end
```

Scilab code Exa 5.18 `Various voltage and current`

```
// Exa 5.18
format('v',6)
clc;
clear;
close;
// Given data
k4 = 0.125;// in mA/V^2
k3 = k4;// in mA/V^2
k2 = k4;// in mA/V^2
k1 = 0.25;// in mA/V^2
V_T1 = 0.8;// in V
V_T2 = V_T1;// in V
V_T3 = V_T1;// in V
V_T4 = V_T1;// in V
V_SS = -5;// in V
V_DD = 5;// in V
R_D = 10;// in k ohm
// Required formula, V_GS3 = ((sqrt(k4/k3) * (-V_SS - V_T4))+V_T3)/(1+sqrt(k4/k3))
V_GS3 = ((sqrt(k4/k3) * (-V_SS - V_T4))+V_T3)/(1+sqrt(k4/k3));// in V
// Calculation to evaluate the value of I_Q,
I_Q = k2*((V_GS3-V_T2)^2);// in mA
I_D1 = I_Q;// in mA
// The value of V_GS1,
V_GS1 = V_T1 + (sqrt(I_D1/k1));// in V
disp(V_GS1,"The value of V_GS1 in V is");
// The value of V_DS2,
V_DS2 = (-V_SS-V_GS1);// in V
disp(V_DS2,"The value of V_DS2 in V is");
// The value of V_DS1,
V_DS1 = V_DD - (I_Q*R_D) - (V_SS + V_DS2);// in V
```

```
disp(V_DS1,"The value of V_DS1 in V is");
```

Scilab code Exa 5.19 Q point

```
// Exa 5.19
format('v',6)
clc;
clear;
close;
// Given data
R2 = 20;// in  k ohm
R1 = 30;// in  k ohm
R_D = 20;// in  k ohm
R_D=R_D*10^3;// in ohm
V_DD = 5;// in V
V_G = (R2/(R1+R2))*V_DD;// in V
V_S = 0;// in V
V_GS = V_G;// in V
k = 100*10^-6;// in A/V^2
V_T = 1;// in V
// The value of I_DQ,
I_DQ = k*((V_GS-V_T)^2);// in A
I_DQ= I_DQ * 10^6;// in  A
disp(I_DQ,"The value of I_DQ in  A  is");
I_DQ= I_DQ * 10^-6;// in A
// The value of V_DSQ,
V_DSQ = V_DD - (I_DQ*R_D);// in V
disp(V_DSQ,"The value of V_DSQ in V is");
```

Scilab code Exa 5.20 IDQ VGSQ and VD

```
// Exa 5.20
format('v',6)
```

```
clc;
clear;
close;
// Given data
V_P= -8;// in V
R_S= 2.4;// in  k
//R_D= 1800;// in
I_DSS= 8;// in mA
V_DD= 20;// in V
R_D= 6.2;// in  k
// V_GS= -I_D*R_S
// I_D= I_DSS*(1-V_GS/V_P)^2 or I_DSS*(1-(-I_D*R_S)/V_P)^2
//I_D^2*R_S^2+I_D*(2*R_S*(V_P-V_G)-V_P^2/I_DSS)+(V_P)^2
A= R_S^2
B=(2*R_S*(V_P)-V_P^2/I_DSS)
C=(V_P)^2
I_D= [A B C]
// Evaluation fo I_D using by polynomial method
I_D= roots(I_D);// in mA
I_D= I_D(2);// in mA
I_DQ= I_D;// in mA
disp(I_DQ,"The value of I_DQ in mA is : ")
// The value of V_GSQ
V_GSQ= -I_D*R_S;// in V
disp(V_GSQ,"The value of V_GSQ in volts ")
// The value of V_D,
V_D= V_DD-I_D*R_D;// in V
disp(V_D,"The value of V_D in volts is : ")
```

Scilab code Exa 5.21 `ID VD VS and VG`

```
// Exa 5.21
format('v',6)
```

```
clc;
clear;
close;
// Given data
k= 75*10^-3;//in mA/V^2
Vth= -0.8;// in V
R2 = 100;// in k ohm
R1 = 100;// in  k ohm
R_S= 6;// in  k
R_D= 3;// in  k
V_SS = 10;// in V
V_G = (R2/(R1+R2))*V_SS;// in V
I_D= poly(0,'I_D');
V_S= V_SS-I_D*R_S;// in V
V_GS= V_G-V_S;//in V
I_D= I_D-k*(V_GS-Vth)^2;
I_D= roots(I_D);// in mA
// For I_D(1), the V_DS will be positive, so
    discarding this
I_D= I_D(2);// in mA
V_DS= -V_SS+I_D*(R_D+R_S);// in V
V_D= I_D*R_D;// in V
V_S= I_D*R_S;// in V
disp(I_D,"The value of I_D in mA is : ")
disp(V_DS,"The value of V_DS in volts is : ")
disp(V_D,"The value of V_D in volts is : ")
disp(V_S,"The value of V_S in volts is : ")
```

Scilab code Exa 5.22 `Value of RD`

```
// Exa 5.22
format('v',6)
clc;
clear;
close;
```

```
// Given data
V_T = 1;// in V
k = 160*10^-6;// in A/V^2
I_DQ = 160*10^-6;// in A
V_GS = V_T + sqrt(I_DQ/k);// in V
V_DD = 5;// in V
V_DSQ = 3;// in V
R_D = (V_DD - V_DSQ)/(I_DQ);// in ohm
R_D = R_D * 10^-3;// in k ohm
disp(R_D,"The value of R_D in k ohm is");
```

Scilab code Exa 5.23 Q point

```
// Exa 5.23
format('v',6)
clc;
clear;
close;
// Given data
V_DD= 12;// in V
V_T= 2;// in V
kn= 0.5;// in mA/V^2
R1 = 2.2;// in M ohm
R2 = 1.8;// in M ohm
R_S= 1.5;// in k
R_D= 3.9;// in k
V_G = (R2/(R1+R2))*V_DD;// in V
I_D= poly(0,'I_D')
V_GS= V_G-I_D*R_S;// V
// Evaluation the value of I_D by using polynomial
   method
I_D= I_D-kn*(V_GS-V_T)^2;// in mA
I_D= roots(I_D);// in mA
I_D= I_D(2);// in mA
I_DQ= I_D;// in mA
```

```
// Evaluation the value of V_DSQ,
V_DSQ= V_DD-I_D*(R_D+R_S);// in V
disp(I_DQ,"The value of I_DQ in mA is : ")
disp(V_DSQ,"The value of V_DSQ in volts is : ")
V_GS= V_G-I_D*R_S;// V
V_DSsat= V_GS-V_T;// in V
disp("The value of V_DS ( "+string(V_DSQ)+" V ) is greater than the value of ")
disp("V_DSsat ( "+string(V_DSsat)+" V ), So the MOSFET is in saturation region")
```

Scilab code Exa 5.24 IDSQ VGSQ and VDSQ

```
// Exa 5.24
format('v',5)
clc;
clear;
close;
// Given data
kn= 0.5;// in mA/V^2
V_T= 1;// in V
R2 = 40;// in k ohm
R1 = 60;// in k ohm
R_S= 1;// in k ohm
R_D= 2;// in k ohm
V_DD = 5;// in V
V_SS = -5;// in V
V_R2 = (R2/(R2+R1))*(V_DD-V_SS);// in V
V_G = V_R2 - V_DD;// in V
I_D= poly(0,'I_D');
V_S= I_D*R_S+V_SS;// in V
V_GS= V_G-V_S;// in V
// Evaluation the value of I_D by using polynomial method,
I_D=I_D-kn*(V_GS-V_T)^2;// in mA
```

```
I_D= roots(I_D);// in mA
// Discarding I_D(1), as it will result in a negative V_DS
I_D= I_D(2);// in mA
I_DQ= I_D;// in mA
V_S= I_D*R_S+V_SS;// in V
V_GS= V_G-V_S;// in V
// The value of V_DSQ,
V_DSQ= V_DD-V_SS-I_D*(R_D+R_S);// in V
disp(I_DQ,"The value of I_DQ in mA is : ")
disp(V_GS,"The value of V_GS in volts is : ")
disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 5.25 `ID VDS VGS and Av`

```
// Exa 5.25
format('v',6)
clc;
clear;
close;
// Given data
R_S1 = 100*10^-3;// in k ohm
R_S2 = 100*10^-3;// in k ohm
R_S = R_S1+R_S2;// in k ohm
R_D= 1.8;// in k ohm
I_DSS= 12;// in mA
Vp= -3.5;// in V
V_DD= 22;// in V
rd= 25;// in k ohm
R_L= 47;// in k ohm
I_D= poly(0,'I_D');
V_GS= -I_D*R_S;// in V
// Evaluation the value of I_D by using polynomial method,
I_D= I_D-I_DSS*(1-V_GS/Vp)^2;// in mA
```

```
I_D= roots(I_D);// in mA
// Discarding I_D(1), as it will give a negative
   result V_DS
I_D= I_D(2);// in mA
disp(I_D,"The value of I_D in mA is : ")
// The value of V_GS,
V_GS= -I_D*R_S;// in V
disp(V_GS,"The value of V_GS in volts is : ")
// The value of V_DS,
V_DS= V_DD-I_D*(R_D+R_S);// in V
disp(V_DS,"The value of V_DS in volts is : ")
gmo= -2*I_DSS/Vp;// in mS
gm= gmo*(1-V_GS/Vp);// in mS
miu= gm*rd;
// The value of Av,
Av= -miu*R_D*R_L/(R_D+R_L)/(rd+R_D*R_L/(R_D+R_L)+(1+
   miu)*R_S1);
disp(Av,"The value of Av is : ")
```

Scilab code Exa 5.26 VGS ID and VDS

```
// Exa 5.26
format('v',6)
clc;
clear;
close;
// Given data
V_T = 1;// in V
k = 0.5;// in mA/V^2
R2 = 40;// in k ohm
R1 = 60;// in k ohm
R_S= 1;// in k ohm
R_D= 2;// in k ohm
V_DD = 5;// in V
V_G = (R2/(R2+R1))*V_DD;// in V
```

```
I_D= poly(0,'I_D');
V_GS= V_G-I_D*R_S;// in V
// Evaluation the value of I_D by using polynomial
   method,
I_D= I_D-k*(V_GS-V_T)^2;
I_D= roots(I_D);// in mA
// For I_D(1), V_DS will be negative , so discarding
   it
I_D= I_D(2);// in mA
// The value of V_GS,
V_GS= V_G-I_D*R_S;// in V
// The value of V_DS,
V_DS= V_DD-I_D*(R_D+R_S);// in V
disp(I_D,"The value of I_D in mA is : ")
disp(V_GS,"The value of V_GS in volts is : ")
disp(V_DS,"The value of V_DS in volts is : ")
```

Scilab code Exa 5.27 Drain current and source to drain voltage

```
// Exa 5.27
format('v',6)
clc;
clear;
close;
// Given data
R_D = 7.5;// in k ohm
V_T = -0.8;// in V
k = 0.2;// in mA/V^2
R2 = 50;// in ohm
R1 = 50;// in  ohm
V_DD = 5;// in V
V_S = 5;// in V
V_G = (R2/(R2+R1))*V_DD;// in V
V_GS = V_G - V_S;// in V
I_D = k*((V_GS-V_T)^2);// in mA
```

```
disp(I_D,"Drain current in mA is");
V_SD = V_DD - (I_D*R_D);// in V
disp(V_SD,"Source to drain voltage in V is");
```

Scilab code Exa 5.28 IDQ VGSQ VD and VS

```
// Exa 5.28
format('v',6)
clc;
clear;
close;
// Given data
I_Don = 5*10^-3;// in A
V_GSon = 6;// in V
V_GSth = 3;// in V
k = I_Don/(V_GSon-V_GSth)^2;// in A/V^2
R2 = 6.8;// in M ohm
R1 = 10;// in M ohm
R_S= 750;// in ohm
R_D= 2.2*10^3;// in ohm
V_DD = 24;// in V
R_S = 750;// in  ohm
// Applying KVL for input circuit
V_G= R2*V_DD/(R1+R2);// in V
I_D= poly(0,'I_D');
V_GS= V_G-I_D*R_S;// in V
I_D= I_D-k*(V_GS-V_GSth)^2;
I_D= roots(I_D);// in A
I_D= I_D(2);// in A
I_DQ= I_D;// in A
V_GS= V_G-I_D*R_S;// in V
V_GSQ= V_GS;// in V
V_DSQ= V_DD-I_DQ*(R_D+R_S);// in V
I_D= I_D*10^3;// in mA
disp(I_D,"The value of I_D in mA is : ")
```

```
disp(V_GSQ,"The value of V_GSQ in volts is : ")
disp(V_DSQ,"The value of V_DSQ in volts is : ")
```

Scilab code Exa 5.29 VDD RD and VGS

```
// Exa 5.29
format('v',6)
clc;
clear;
close;
// Given data
I_Don = 4*10^-3;// in A
V_GSon = 6;// in V
V_GSth = 3;// in V
V_DS= 6;// in V
I_D= I_Don;// in A
k = I_Don/((V_GSon-V_GSth)^2);// in A/V^2
V_GS= poly(0,'V_GS')
// Evaluation the value of V_GS by using polynomial
   method,
V_GS= I_D-k*(V_GS-V_GSth)^2;
V_GS= roots(V_GS);// in V
V_GS= V_GS(1);// in V
V_DD= 2*V_DS;// in V
// V_GS= V_DD-I_D*R_D
// Drain resistance,
R_D= (V_DD-V_GS)/I_D;// in ohm
R_D=R_D*10^-3;// in k ohm
disp(V_GS,"The value of V_GS in volts is : ")
disp(V_DD,"The value of V_DD in volts is : ")
disp(R_D,"The value of R_D in k   is : ")
```

Scilab code Exa 5.30 Value of ID

```
// Exa 5.30
format('v',6)
clc;
clear;
close;
// Given data
I_DD= 20;// in mA
R2 = 10;// in k ohm
R1 = 30;// in k ohm
R_S= 1.2;// in k ohm
R_D= 500*10^-3;// in k ohm
V_DD = 12;// in V
Vp= -6;// in V
V_G = (R2/(R2+R1))*V_DD;// in V
I_D= poly(0,'I_D')
V_GS= V_G-I_D*R_S;// in V
// Evaluation the value of I_D by using polynomial method,
I_D=I_D-I_DD*(1-V_GS/Vp)^2;
I_D= roots(I_D);// in mA
// For I_D(1), V_DS will be negative, so discarding it
I_D= I_D(2);// in mA
// The value of V_DS,
V_DS= V_DD-I_D*(R_D+R_S);// in V
// The value of V_D,
V_D= V_DD-I_D*R_D;// in V
// The value of V_S,
V_S= V_D-V_DS;// in V
disp(I_D,"The value of I_D in mA is : ")
disp(V_DS,"The value of V_DS in volts is : ")
disp(V_D,"The value of V_D in volts is : ")
disp(V_S,"The value of V_S in volts is : ")
```

Scilab code Exa 5.31 `Voltages at all nodes`

```
// Exa 5.31
format('v',5)
clc;
clear;
close;
// Given data
V_DD = 5;// in V
V_T= 1;// in V
k= 1;// in mA/V^2
R1 = 1;// in M ohm
R2 = 1;// in M ohm
R_S= 2;// in k ohm
R_D= 2;// in k ohm
// Calculation of I1
I1 = V_DD/(R1+R2);// in A
disp(I1,"The value of I1 in  A  is : ")
// The value of V_A,
V_A = (R2/(R2+R1))*V_DD;// in V
disp(V_A,"The value of V_A and V_G in volts is : ")
I_D= poly(0,'I_D');
V_C= I_D*R_S;// in V
V_GS= V_A-V_C;// in V
// Evaluation the value of I_D by using polynomial method,
I_D= I_D-k*(V_GS-V_T)^2;
I_D= roots(I_D);// in mA
// For I_D(1),  V_DS will be negative, so discarding it
I_D= I_D(2);// in mA
disp(I_D,"The value of I_D in mA is : ")
// The value of V_B,
V_B= V_DD-I_D*R_D;// in V
// The value of V_C,
V_C= I_D*R_S;// in V
// The value of V_DS,
V_DS= V_B-V_C;// in V
disp(V_B,"The value of V_B in volts is : ")
disp(V_C,"The value of V_C in volts is : ")
```

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

// Note: In the book, the calculated values are not
   accurate, this is why the answer in the book is
   wrong.
```

Scilab code Exa 5.32 Av Ri Ro and Rodesh

```
// Exa 5.32
format('v',6)
clc;
clear;
close;
// Given data
I_DSS = 12;// in mA
I_DSS= I_DSS*10^-3;// in A
V_P = -3;// in V
r_d = 45;// in k ohm
r_d= r_d*10^3;// in ohm
g_m = I_DSS/abs(V_P);// in S
// Part (i)
R1 = 91;// in M ohm
R1=R1*10^6;//in ohm
R2 = 10;// in M ohm
R2= R2*10^6;// in ohm
// Calculation to find the value of Ri
Ri= R1*R2/(R1+R2);// in ohm
Ri=Ri*10^-6;// in M ohm
disp(Ri,"The value of Ri in Mohm is : ")
// Part (ii)
R_S = 1.1;// in k ohm
R_S = R_S * 10^3;// in ohm
// The value of R_o,
R_o= (R_S*1/g_m)/(R_S+1/g_m);// in ohm
disp(R_o,"The value of R_C in ohm is : ")
```

```
// Part (iii)
// The value of R_desh_o
R_desh_o= R_o*r_d/(R_o+r_d);// in ohm
disp(R_desh_o,"The value of R''o in ohm is : ");
// Part (iv)
// The voltage gain can be find as,
Av= g_m*(R_S*r_d/(R_S+r_d))/(1+g_m*(R_S*r_d/(R_S+r_d)));
disp(Av,"The value of Av is : ")
```

Scilab code Exa 5.34 `Current flow through M1 MOSFET`

```
// Exa 5.34
format('v',6)
clc;
clear;
close;
// Given data
V_S2 = -2;// in V
V_GS2 = -V_S2;// in V
I_DS2 = (V_GS2-1)^2;// in mA
I = 2;// in mA
// The current flow through M1 MOSFET,
I_DS1 = I-I_DS2;// in mA
disp(I_DS1,"The current flow through M1 MOSFET in mA is");
```

Scilab code Exa 5.35 `Value of R and VD`

```
// Exa 5.35
format('v',6)
clc;
clear;
```

```
close;
// Given data
V_DD= 10;// in V
I_D= 0.4*10^3;// in A
W= 100;// in  m
L= 10;// in  m
uACox= 20;// in A/V^2
Vt= 2;// in V
R= poly(0,'R')
V_GS= V_DD-I_D*R;// in V
// Evaluation the value of R by using polynomial method,
R= I_D-1/2*uACox*W/L*(V_GS-Vt)^2;
R= roots(R);// in Mohm
// For R(1), V_DS will be zero, so discarding it
R= R(2);// in Mohm
R=R*10^3;// in k ohm
disp(R,"The value of R in k  is : ")
R=R*10^-3;// in ohm
// The value of V_D,
V_D= V_DD-I_D*R;// in V
disp(V_D,"The value of V_D in volts is : ")
```

Scilab code Exa 5.36 ID and VDS

```
// Exa 5.36
format('v',5)
clc;
clear;
close;
// Given data
V_GSth= 2;// in V
k= 2*10^-4;// in A/V^2
V_DD= 12;// in V
R_D= 5*10^3;// in ohm
```

```
I_D= poly(0,'I_D');
V_DS= V_DD-I_D*R_D;// in V
// Evaluation the value of I_D by using polynomial method,
I_D= I_D-k*(V_DS-V_GSth)^2;
I_D= roots(I_D);// in A
// For I_D(1), V_DS will be negative, so discarding it
I_D= I_D(2);// in A
// The value of V_DS,
V_DS= V_DD-I_D*R_D;// in V
I_D= I_D*10^3;// in mA
disp(I_D,"The value of I_D in mA is : ")
disp(V_DS,"The value of V_DS in volts is : ")
```

Chapter 6

Bipolar Junction Transistor

Scilab code Exa 6.1 `Common base dc current gain`

```
// Exa 6.1
format('v',6)
clc;
clear;
close;
// Given data
I_C= 5.10;// in mA
I_E= 5.18;// in mA
alpha= I_C/I_E;
alpha_dc= alpha;
disp(alpha_dc,"The common-base d.c. current gain is
    : ")
```

Scilab code Exa 6.2 `Base current`

```
// Exa 6.2
format('v',6)
clc;
```

```
clear;
close;
// Given data
alpha= 0.987;
I_E= 10;// in mA
// Formula alpha= I_C/I_E;
I_C= alpha*I_E;// in mA
I_B= I_E-I_C;// in mA
disp(I_B,"The base current in mA is : ")
```

Scilab code Exa 6.3 Value of IC and IB

```
// Exa 6.3
format('v',6)
clc;
clear;
close;
// Given data
alpha= 0.987;
I_E= 10;// in mA
// Formula alpha= I_C/I_E;
I_C= alpha*I_E;// in mA
I_B= I_E-I_C;// in mA
disp(I_C,"The collector current in mA is : ")
disp(I_B,"The base current in mA is : ")
```

Scilab code Exa 6.4 Collector and base current

```
// Exa 6.4
format('v',6)
clc;
clear;
close;
```

```
// Given data
Beta= 100;
I_E= 10;// in mA
alpha= Beta/(1+Beta);
disp(alpha,"The value of alpha is : ")
// Formula alpha= I_C/I_E;
I_C= alpha*I_E;// in mA
I_B= I_E-I_C;// in mA
disp(I_C,"The collector current in mA is : ")
disp(I_B,"The base current in mA is : ")

// Note: The calculated value of alpha in the book
   is wrong, due to this the answer in the book is
   wrong.
```

Scilab code Exa 6.5 `Value of alpha and bita`

```
// Exa 6.5
format('v',6)
clc;
clear;
close;
// Given data
alpha= 0.950;
Beta= alpha/(1-alpha);
disp(Beta,"For alpha = 0.950, the value of beta is :
    ")
Beta= 100;
alpha= Beta/(1+Beta);
disp(alpha,"For beta = 100, the value of alpha is :
   ")
```

Scilab code Exa 6.6 `Collector and base current`

```
// Exa 6.6
format('v',6)
clc;
clear;
close;
// Given data
I_E= 10;// in mA
Beta= 100;
alpha= Beta/(1+Beta);
// Formula alpha= I_C/I_E;
I_C= alpha*I_E;// in mA
I_B= I_E-I_C;// in mA
disp(I_B,"The base current in mA is : ")
disp(I_C,"The collector current in mA is : ")

// Note: In the book the calculated value of I_B is not correct, so the answer in the book is not accurate
```

Scilab code Exa 6.7 `DC load line`

```
// Exa 6.7
format('v',6)
clc;
clear;
close;
// Given data
V_CC= 12;// in V
R_C= 3;// in k
V_CE= 0:0.1:12;// in V
I_C= (V_CC-V_CE)/R_C;// in mA
plot(V_CE,I_C);
xlabel("V_CE in volts")
ylabel("I_C in mA")
title("DC load line")
```

```
disp("DC load line shown in figure.")
```

Scilab code Exa 6.8 Operating point and stability factor

```
// Exa 6.8
format('v',6)
clc;
clear;
close;
// Given data
bita= 100;
V_CC= 6;// in V
V_BE= 0.7;// in V
R_B= 530*10^3;// in
R_C= 2*10^3;// in
// Applying KVL for input side, V_CC= I_B*R_B+V_BE
   or
I_B= (V_CC-V_BE)/R_B;// in A
I_C= bita*I_B;// in A
// Applying KVL to output side,
V_CE= V_CC-I_C*R_C;// in V
S= 1+bita;
disp("The operating point is : "+string(V_CE)+" V, "
   +string(I_C*10^3)+" mA")
disp(S,"The stability factor is : ")
```

Scilab code Exa 6.9 Collector and base current

```
// Exa 6.9
format('v',6)
clc;
clear;
close;
```

```
// Given data
Beta= 75;
V_CC= 20;// in V
V_BE= 0;// in V
R_B= 200*10^3;// in
R_C= 800;// in
// Applying KVL for input side, V_CC= I_B*R_B+V_BE or
I_B= (V_CC-V_BE)/R_B;// in A
I_B=I_B*10^6;// in  A
disp(I_B,"The base current in  A  is : ")
I_B=I_B*10^-6;// in A
// The collector current,
I_C= Beta*I_B;// in A
I_C=I_C*10^3;// in mA
disp(I_C,"The collector current in mA is : ")
I_C=I_C*10^-3;// in A
// Applying KVL to output side, the collector to emitter voltage
V_CE= V_CC-I_C*R_C;// in V
disp(V_CE,"The collector to emitter voltage in V is : ")
// The stability factor,
S= 1+Beta;
disp(S,"The stability factor is : ")
```

Scilab code Exa 6.10 Base resistor and stability factor

```
// Exa 6.10
format('v',6)
clc;
clear;
close;
// Given data
Beta= 100;
```

```
V_CC= 12;// in V
V_BE= 0;// in V
I_B= 0.3*10^-3;// in A
R_C= 300;// in
// Applying KVL for input side, V_CC= I_B*R_B+V_BE or
R_B= (V_CC-V_BE)/I_B;// in
R_B= R_B*10^-3;// in k ohm
disp(R_B,"The value of base resistor in k  is : ")
I_C= Beta*I_B;// in A
// The collector to emitter voltage
V_CE= V_CC-I_C*R_C;// in V
disp(V_CE,"The collector to emitter voltage in V is : ")
// The stability factor,
S= 1+Beta;
disp(S,"The stability factor is : ")
```

Scilab code Exa 6.11 DC bias voltage

```
// Exa 6.11
format('v',6)
clc;
clear;
close;
// Given data
R_B= 400*10^3;// in
R_C= 2*10^3;// in
R_E= 1*10^3;// in
V_CC= 20;// in V
Beta= 100;
// Base current can be evaluated as,
I_B= V_CC/(R_B+Beta*R_E);// in A
// Collector current
I_C= Beta*I_B;// in A
```

```
// The collector to emitter voltage
V_CE= V_CC-I_C*(R_C+R_E);// in V
I_B= I_B*10^3;// in mA
I_C= I_C*10^3;// in mA
disp(I_B,"The value of base current in mA is : ")
disp(I_C,"The value of collector current in mA is : ")
disp(V_CE,"The collector to emitter voltage in V is : ")
```

Scilab code Exa 6.12 Collector current collector to emitter voltage and stability

```
// Exa 6.12
format('v',6)
clc;
clear;
close;
// Given data
R_B= 180*10^3;// in
R_C= 820;// in
R_E= 200;// in
V_CC= 25;// in V
V_BE= 0.7;// in V
Beta= 80;
// Collector current can be find as,
I_C= (V_CC-V_BE)/(R_E+R_B/Beta);// in A
// The collector to emitter voltage
V_CE= V_CC-I_C*(R_C+R_E);// in V
I_C=I_C*10^3;// in mA
disp(I_C,"The value of collector current in mA is : ")
disp(V_CE,"The collector to emitter voltage in V is : ")

// Note: The calculated value of V_CE in the book is
```

```
wrong.
```

Scilab code Exa 6.13 collector current and stability factor

```
// Exa 6.13
format('v',6)
clc;
clear;
close;
// Given data
R_B= 200*10^3;// in
R_C= 20*10^3;// in
V_CC= 20;// in V
V_BE= 0.7;// in V
Beta= 100;
// The value of collector current
I_C= (V_CC-V_BE)/(R_C+R_B/Beta);// in A
// The collector to emitter voltage
V_CE= V_CC-I_C*R_C;// in V
// The stability factor
S= (1+Beta)/(1+Beta*(R_C/(R_C+R_B)));
I_C=I_C*10^3;// in mA
disp(I_C,"The value of collector current in mA is : ")
disp(V_CE,"The collector to emitter voltage in V is : ")
disp(S,"The stability factor is : ")
```

Scilab code Exa 6.14 IB IC VCE and stability

```
// Exa 6.14
format('v',6)
clc;
```

```
clear;
close;
// Given data
R_B= 100*10^3;// in
R_C= 10*10^3;// in
V_CC= 10;// in V
V_BE= 0;// in V
Beta= 100;
// Base current can be evaluated as,
I_B= (V_CC-V_BE)/(R_B+R_C*Beta);// in A
// The value of collector current
I_C= Beta*I_B;// in A
// The collector to emitter voltage
V_CE= V_CC-I_C*R_C;// in V
// The stability factor,
S= (1+Beta)/(1+Beta*(R_C/(R_C+R_B)));
I_C=I_C*10^3;// in mA
disp(I_C,"The value of collector current in mA is :
   ")
disp(V_CE,"The collector to emitter voltage in V is
   : ")
disp(S,"The stability factor is : ")

// Note: The calculated value of S in the book is
   wrong.
```

Scilab code Exa 6.15 Emitter and collector current and VCE

```
// Exa 6.15
format('v',6)
clc;
clear;
close;
// Given data
R_B= 50*10^3;// in
```

```
R_C= 1*10^3;// in
R_E= 5*10^3;// in
V_CC= 10;// in V
V_EE= 10;// in V
V_BE= 0.7;// in V
V_E= -V_BE;// in V
// The value of emitter current
I_E= (V_EE-V_BE)/R_E;// in A
// The collector current will be equal to emitter current
I_C= I_E;// in A
// The collector to emitter voltage
V_CE= V_CC-I_C*R_C;// in V
V_CE= V_CE-V_E;// in V
I_C=I_C*10^3;// in mA
I_E=I_E*10^3;// in mA
disp(I_E,"The value of emitter current in mA is : ")
disp(I_C,"The value of collector current in mA is : ")
disp(V_CE,"The collector to emitter voltage in V is : ")
```

Scilab code Exa 6.16 Change in Q point

```
// Exa 6.16
format('v',5)
clc;
clear;
close;
// Given data
R_B= 10*10^3;// in
R_C= 5*10^3;// in
R_E= 10*10^3;// in
Beta=50;
V_CC= 20;// in V
```

```
V_EE= 20;// in V
V_BE= 0.7;// in V
V_E= -V_BE;// in V
// The value of I_E1,
I_E1= (V_EE-V_BE)/(R_E+R_B/Beta);// in A
I_C1= I_E1;// in A
V_C= V_CC-I_C1*R_C;// in V
V_CE1= V_C-V_E;// in V
Beta= 100;
V_BE= 0.6;// in V
V_E= -V_BE;// in V
// The value of I_E2,
I_E2= (V_EE-V_BE)/(R_E+R_B/Beta);// in A
I_C2= I_E2;// in A
V_C= V_CC-I_C2*R_C;// in V
V_CE2= V_C-V_E;// in V
// The change in collector current
delta_IC= (I_C2-I_C1)/I_C1*100;// in %
// The change in collector to emitter voltage
delta_V_CE= (V_CE1-V_CE2)/V_CE1*100;// in %
disp(delta_IC,"The change in collector current in %
    is : ")
disp(delta_V_CE,"The change in collector to emitter
    voltage in % is : ")
```

Scilab code Exa 6.18 Value of alphaDC and emitter current

```
// Exa 6.18
format('v',6)
clc;
clear;
close;
// Given data
I_CBO = 3;//in  A
I_CBO= I_CBO*10^-3;// in mA
```

```
I_C= 15;// in mA
// But it is given that I_C= 99.5% of I_E, SO
I_E= I_C/99.5*100;// in mA
alpha_dc= I_C/I_E;
disp(alpha_dc,"The value of alpha_dc is : ")
disp(I_E,"The value of I_E in mA is : ")
```

Scilab code Exa 6.19 IC and IB

```
//Exa 6.19
format('v',6)
clc;
clear;
close;
//Given data
alpha_dc = 0.99;
I_CBO = 10;// in  A
I_CBO= I_CBO*10^-6;// in A
I_E = 10;// in mA
I_E= I_E*10^-3;// in A
// The collector current can be find as,
I_C = (alpha_dc * I_E) + I_CBO;// in A
I_C=I_C*10^3;// in mA
disp(I_C,"The value of I_C in mA is");
I_C=I_C*10^-3;// in A
// Calculation to find the value of base current
I_B = I_E - I_C;// in A
I_B = I_B * 10^6;// in  A
disp(I_B,"The value of I_B in  A is");
```

Scilab code Exa 6.20 Base current

```
// Exa 6.20
```

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

Scilab code Exa 6.22 Emitter current

```
//Exa 6.22
format('v',6)
clc;
clear;
close;
// Given data
alpha_dc = 0.98;
I_CBO = 12;// in  A
I_CBO = I_CBO * 10^-6;// in A
I_B = 120;// in  A
I_B = I_B * 10^-6;// in A
beta_dc = alpha_dc/(1-alpha_dc);
I_E = ((1 + beta_dc) * I_B) + ((1 + beta_dc) * I_CBO
   );//in A
I_E = I_E * 10^3;// in mA
disp(I_E,"The value of I_E in mA is");
```

Scilab code Exa 6.23 Region of operation

```
//Exa 6.23
format('v',6)
clc;
clear;
close;
// Given data
bita= 100;
V_BEsat= 0.8;// in V
V_CEsat= 0.2;// in V
V_BEact= 0.7;// in V
V_CC = 10;// in V
V_BB=5;// in V
R_E = 2;// in k
R_C = 3;// in k
R_B= 50;// in k
// Applying KVL to collector loop
// V_CC= I_Csat*R_C +V_CEsat +I_E*R_E and I_E=
    I_Csat+I_B , So
//I_B= ((V_CC-V_CEsat)-(R_C+R_E)*I_Csat)/R_E;
                (i)
// Applying KVL to base loop
// V_BB-I_B*R_B -V_BEsat-I_E*R_E =0 and I_E= I_Csat+
    I_B , So
//V_BB-V_BEsat= R_E*I_Csat + (R_B+R_E)*I_B
                     (ii)
// From eq (i) and (ii)
I_B = ((V_BB-V_BEsat)*5- (V_CC-V_CEsat)*2) / ((R_B+
    R_E)*5 - R_E*2) ;// in mA
I_Csat= ((V_CC-V_CEsat)-R_E*I_B)/(R_C+R_E);// in mA
I_Bmin= I_Csat/bita;// in mA
if I_B<I_Bmin then
    disp("Since the value of I_B ("+string(I_B*10^3)
```

```
        +" A ) is less than the value of I_Bmin ("+
        string(I_Bmin*10^3)+"  A )");
    disp("So the transistor is not in the saturation
         region. But it is conducting hence it can
        not be in cutoff.")
    disp("Therefore the transistor is in the active
        region")
end
```

Scilab code Exa 6.24 IB IC and VCE

```
//Exa 6.24
format('v',6)
clc;
clear;
close;
// Given data
Beta= 100;
V_BEsat= 0.8;// in V
V_CEsat= 0.2;// in V
V_BEact= 0.7;// in V
V_CC = 10;// in V
V_BB=5;// in V
R_E = 2;// in k
R_C = 3;// in k
R_B= 50;// in k
// Applying KVL to input loop
// V_BB= I_B*R_B+(1+Beta)*I_B*R_E+V_BEact or
I_B= (V_BB-V_BEact)/(R_B+(1+Beta)*R_E);// in mA
// The collector current,
I_C= Beta*I_B;// in mA
// Applying KVL to collector circuit
// V_CC= I_Csat*R_C +V_CEsat +(I_C+I_B)*R_E
V_CEact= V_CC-I_B*R_E-I_C*(R_C+R_E);// in V
// The base current,
```

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

Scilab code Exa 6.25 Region of operation

```
//Exa 6.25
format('v',6)
clc;
clear;
close;
//Given data
Beta = 100;
V_CEsat = 0.2;// in V
R_B = 150;// in k ohm
R_C = 2;// in k ohm
V_CC  = 10;// in V
V_BEsat = 0.8;// in V
I_B = (V_CC - V_BEsat)/R_B;// in mA
I_C = (V_CC - V_CEsat)/R_C;// in mA
I_Bmin = I_C/Beta;// in mA
I_B=I_B*10^3;// in  A
I_Bmin=I_Bmin*10^3;// in  A
if I_B>I_Bmin then
    disp("Since the value of I_B ("+string(I_B)+" A
       ) is greater than the value of I_Bmin ("+
       string(I_Bmin)+" A )");
    disp("So the transistor is in the saturation
       region.")
end
```

Scilab code Exa 6.26 Value of VBB

```
//Exa 6.26
format('v',6)
clc;
clear;
close;
//Given data
Beta = 100;
V_CE = 0.2;//in V
V_BE = 0.8;// in V
R_C= 500;// in
R_B= 44*10^3;// in
R_E= 1*10^3;// in
V_CC= 15;// in V
V_GE= -15;// in V
// Applying KVL to collector circuit , V_CC-V_GE - I_Csat*R_C-V_CE-I_E*R_E=0, but I_Csat= Beta* I_Bmin and I_E= 1+Beta
// Minimum value of base current ,
I_Bmin= (V_CC-V_GE-V_CE)/(R_C*Beta+(1+Beta)*R_E);// in A
// Applying KVL to the base emitter circuit , V_BB- I_Bmin*R_B-V_BE-I_E*R_E + V_CC=0
// The value of V_BB,
V_BB= I_Bmin*R_B + V_BE + (1+Beta)*I_Bmin*R_E-V_CC; // in V
I_Bmin= I_Bmin*10^3;//in mA
disp(I_Bmin,"The value of I_B(min) in mA is : ")
disp(V_BB,"The value of V_BB in volts is : ")
```

Scilab code Exa 6.27 `Minimum value of RC required`

```
// Exa 6.27
format('v',6)
clc;
clear;
```

```
close;
// Given data
V_ECsat= 0.2;// in V
V_CC= 10;// in V
V_EBsat= 0.8;// in V

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

Scilab code Exa 6.28 `Value of RE`

```
//Exa 6.28
format('v',6)
clc;
clear;
close;
// Given data
```

```
Beta= 100;
V_BEsat= 0.8;// in V
V_CEsat= 0.2;// in V
V_BEact= 0.7;// in V
V_CC = 10;// in V
R_E = 1;// in k
R_C = 2;// in k
R_B= 100;// in k
Beta=100;
alpha= Beta/(1+Beta);
// Applying KVL to collector circuit
// V_CC= I_Csat*R_C +V_CE +R_E*I_E
// but I_E= alpha*I_Csat
I_Csat= (V_CC-V_CEsat)/(R_C+R_E*alpha);// in mA
I_Bmin= I_Csat/Beta;// in mA
// Applying KVL to base loop
// V_CC= I_B*R_B +V_BEsat +I_E*R_E
// but I_E= I_Csat+I_B
I_B= (V_CC-V_BEsat-I_Csat*R_E)/(R_B+R_E);// in mA
I_B=I_B*10^3;// in  A
disp(I_B,"The value of I_B in  A  is : ")
I_B=I_B*10^-3;// in mA
I_Bmin= I_Bmin*10^3;// in  A
disp(I_Bmin,"The minimum value of I_B in  A  is : ")
I_Bmin= I_Bmin*10^-3;// in mA
if I_B>I_Bmin then
    disp("Since the value of I_B is greater than the
        value of I_Bmin, ")
    disp("Hence the transistor is in saturation.")
end
// The emitter current,
I_E= (1+Beta)*I_Bmin;// in mA
// The value of R_E
R_E= (V_CC-V_BEact-I_Bmin*R_B)/I_E;// in k
disp(R_E,"The value of R_E in k  is : ")
disp("So R_E should be greater than this value in
   order to bring the transistor just out of
   saturation")
```

Scilab code Exa 6.29 `Collector voltage`

```
// Exa 6.29
format('v',6)
clc;
clear;
close;
// Given data
V_CC = 9;// in V
V_BE = 0.8;// in V
V_CE = 0.2;// in V
R_B = 50;// in k
R_C=2;// in k
R_E = 1;// in k
Beta=70;
// Applying KVL to input loop, V_CC= I_B*R_B +V_BE + I_E*R_E
// V_CC- V_BE= (R_B+R_E)*I_B + R_E*I_C            (i)
// Applying KVL to output loop, V_CC= R_C*I_C +V_CE +I_C*R_E +I_B*R_E
//I_B = ((V_CC- V_CE)-(R_C+R_E)*I_C)/R_E          (ii)
// From eq (i) and (ii)
I_C= ( (V_CC- V_BE)-(R_B+R_E)* (V_CC- V_CE)/R_E) /(1-(R_B+R_E)*(R_C+R_E));// in mA
I_B = ((V_CC- V_CE)-(R_C+R_E)*I_C)/R_E// in mA
I_Bmin= I_C/Beta;// in mA
if I_B>I_Bmin then
    disp("Since the value of I_B ("+string(I_B)+" mA) is greater than the value of I_Bmin ("+string(I_Bmin)+" mA)")
    disp("So the transistor is in saturation ")
end
V_C= V_CC-I_C*R_C;// in V
```

```
disp(V_C,"The value of collector voltage in volts is
    : ")
Beta= I_C/I_B;
disp(Beta,"The minimum value of beta that will
   change the state of the trasistor is : ")
```

Chapter 7

Optoelectonic Devices

Scilab code Exa 7.1 `Component value`

```
// Exa 7.1
format('v',6)
clc;
clear;
close;
// Given data
O_V = 5;// output voltage in V
V_D = 1.5;//voltage drop in V
R = (O_V - V_D)/O_V;
R = R * 10^3;// in ohm
disp(R,"The resistance value in   is");
disp("As this is not standard value, use R=680 which is a standard value")
```

Scilab code Exa 7.2 `Open circuit voltage`

```
// Exa 7.2
format('v',6)
```

```
clc;
clear;
close;
// Given data
N_A = 7.5*10^24;// in atoms/m^3
N_D = 1.5*10^22;// in atoms/m^3
D_e = 25*10^-4;// in m^2/s
D_h = 1*10^-3;// in m^2/s
Torque_eo = 500;// in ns
Torque_ho = 100;// in ns
n_i = 1.5*10^16;// in /m^3
e = 1.6*10^-19;// in C
P_C = 12.5;// in mA/cm^2
// Electron diffusion length
L_e = sqrt(D_e*Torque_ho*10^-9);// in m
L_e = L_e * 10^6;// in  m
// hole diffusion length
L_h = sqrt(D_h*Torque_ho*10^-9);// in m
L_h = L_h * 10^6;// in  m
// The value of J_s can be calculated as,
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
J_s = J_s * 10^3;// in A/cm^2
V_T = 26;// in mV
I_lembda = 12.5*10^-3;
I_s = 2.4*10^-4;
// Open circuit voltage
V_OC = V_T*log( 1+(I_lembda/J_s) );// in mV
V_OC = V_OC * 10^-3;// in V
disp(V_OC,"Open circuit voltage in V is");

// Note: There is calculation error to evaluate the value of VOC since 26*10^-3*log(1+12.5*10^-3/2.4*10^-4) calculated as 0.10318 not 0.522 V
```

Scilab code Exa 7.3 Photocurrent density

```
// Exa 7.3
format('v',6)
clc;
clear;
close;
// Given data
Phi_o = 1*10^21;// in m^-2s^-1
Alpha = 1*10^5;// in m^-1
W = 25;// in  m
W =W * 10^-6;// in m
e = 1.6*10^-19;// in C
// At the front edge of intrinsic region, the
    generation rate of EHP
G_L1 = Alpha*Phi_o;// in m^-3s^-1
// At the back edge of intrinsic region, the
    generation rate of EHP
G_L2 = Alpha*Phi_o*%e^( (-Alpha*W) );// in m^-3s^-1
// Photo current density,
J_L = e*Phi_o*(1-%e^(-Alpha*W));// in A/m^2
J_L = J_L * 10^-1;// in mA/cm^2
disp(J_L,"Photo current density in mA/cm^2 is");
```