

Scilab Textbook Companion for
Semiconductor Physics And Devices
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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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Chapter 1

Introduction to Quantum Mechanics

Scilab code Exa 1.1 Photon energy

```
1 // Chapter 1_Principles of Quantum Mechanics
2 //Caption_Photon Energy
3 //Ex_1//page 3
4 disp("X-Rays wavelength lambda=0.708*10^-8 cm");
5 lambda=0.708*(10^-10); //Wavelength
6 h=6.625*(10^-34); // Plank's constant
7 c=3*10^8 //speed of light
8
9 E=(h*c)/lambda;
10 printf('The photon energy corresponding to given
    wavelength is %fd J\n',E)
11 Evv=E/(1.6*(10^-19));
12 printf('Energy in the units of ev is %fd eV \n',Evv)
```

Scilab code Exa 1.2 Broglie wavelength

```

1 // Chapter 1_Principles of Quantum Mechanics
2 //Caption_Broglie wavelength
3 //Ex_2//page 5
4 disp("Velocity of electron is 10^7 cm/s");
5 h=6.625*(10^-34); // Plank's constant
6 m=9.11*(10^-31); //Mass of electron
7 v=10^5; //Velocity of electron
8
9 p=m*v; //Momentum
10 printf('Momentum is %fd \n',p)
11 lambda=(h/p)*10^10; //De Broglie's wavelength in
    angstorm
12 printf('The De Broglie wavelength is %fd Angstorm\n',
    ,lambda);

```

Scilab code Exa 1.3 Electron in infinite potential well

```

1 // Chapter 1_Principles of Quantum Mechanics
2 //Caption_Electron in an infinite potential well
3 //Ex_3//page 14
4 disp("Width of electrons infinite potential well is
    5 Angstorm");
5 h=1.054*(10^-34); // Plank's constant
6 m=9.11*(10^-31); //Mass of electron
7 v=10^5; //Velocity of electron
8 a=5*(10^-10);
9 c=1.6*(10^-19);
10 n1=1; // assume
11 En1=((h^2)*(n1^2)*(%pi^2)/(2*m*a^2))/c
12 printf('Energy in first energy level is %fd eV\n',
    En1)
13 n2=2;.....//assume
14 En2=((h^2)*(n2^2)*(%pi^2)/(2*m*a^2))/c
15 printf('Energy in first energy level is %fd eV\n',
    En2)

```

```

16 n3=3;          //assume
17 En3=((h^2)*(n3^2)*(%pi^2)/(2*m*a^2))/c
18 printf('Energy in first energy level is %fd eV\n',
        En3)

```

Scilab code Exa 1.4 Penetration depth of a particle impinging on a potential barrier

```

1 // Chapter 1_Principles of Quantum Mechanics
2 //Caption_Penetration depth of a particle impinging
   on a potential barrier
3 //Ex_4//page 18
4 v=10^5;          // Given velocity of electron
5 m=9.11*(10^-31); // mass of electron
6 c=1.6*(10^-19)
7 E=((1/2)*m*(v^2))/c;
8 V0=2*E;         //Assume that the potential barrier at x
   =0 is twice as large as total energy of the
   incident particle
9 printf('Energy of the particle is %fd eV\n' ,E)
10 h=1.054*(10^-34)
11 d=((h^2)/(2*m*E*c))^(1/2)*10^10;
12 printf('The distance at which the wave function
   magnitude has decayed to e^-1 of its value at x=0
   is %2.1f Angstrom \n',d )

```

Scilab code Exa 1.5 Probability of an electron tunneling through a potential barrier

```

1 // Chapter 1_Principles of Quantum Mechanics
2 //Caption_Probability of an electron tunneling
   through a potential barrier
3 //Ex_5//page 21
4 E=2;           //energy of electron in eV
5 Vo=20;        //potential barrier in eV

```

```
6 w=3; //width of potential barrier in angstrom
7 m=9*(10^-31)
8 h=1.054*(10^-34)
9 c=1.6*(10^-19)
10 K=((2*m)*(Vo-E)*c/(h^2))^(1/2)
11 printf('Factor K is %fd m^-1 \n',K)
12 l=(-2*K*w*(10^-10))
13 a=%e^l
14 x=E/Vo;
15 T=16*x*(1-x)*a;
16 printf('Transmission coefficient i.e. the
    probability of electron to tunnel through the
    potential barrier is %fd \n',T)
```

Chapter 2

Introduction to the quantum theory of solids

Scilab code Exa 2.1 Change in kinetic energy

```
1 // Chapter 2_Introduction to the quantum theory of
  solids
2 //Caption_Change in kinetic energy of electron
3 //Ex_1//page 37
4 v=10^5;
5 delV=0.01;
6 m=9.1*10^-31;
7 c=1.6 *(10^-19)
8 delE=m*v*delV/c;
9 printf('Change in kinetic energy for a very small
  change in velocity of electron is %1.10fd eV \n',
  delE)
```

Scilab code Exa 2.2 Lowest allowed energy bandwidth

```
1 // Chapter 2_Introduction to the quantum theory of
  solids
```

```

2 //Caption_Lowest allowed energy bandwidth
3 //Ex_2//page 46
4
5 m=9.11*(10^-31) //mass of electron
6 h=1.054*(10^-34)
7 a=5*(10^-10)
8 c=1.6*(10^-19) //electron charge
9 E=((%pi^2)*(h^2))/(2*m*(a)^2)
10 E2=E/c;
11 E1= 1.053 // For alpha a=2.628, energy is given
    in eV
12 delE=E2-E1
13 printf('The allowed energy bandwidth is %fd eV\n',
    delE)

```

Scilab code Exa 2.3 Density of States

```

1 // Chapter 2_Introduction to the quantum theory of
    solids
2 //Caption_Density of States
3 //Ex_3//page 63
4 m=9.11*(10^-31) //mass of electron
5 h=6.625*(10^-34)
6 E=1.6*(10^-19)
7 N=((4*%pi*(2*m)^(1.5))/(h^3))*(E^(1.5))*(2/3)
8 printf('Density of states per unit volume with
    energies between 0 and 1 eV is %f states per unit
    vol \n',N)

```

Scilab code Exa 2.4 The Fermi Dirac Probability Function

```

1 // Chapter 2_Introduction to the quantum theory of
    solids

```

```

2 //Caption_The Fermi Dirac Probability Function
3 //Ex_4//page 68
4 Ni=10      //given no. of particles
5 gi=10      //given no. of quantum states
6 P=factorial(gi)/(factorial(Ni)*(factorial(gi-Ni)))
           //Possible no of ways of relizing this
           distribution
7 printf('This distribution can be realized in %i ways
        \n',P)

```

Scilab code Exa 2.5 The Fermi Dirac Probability Function

```

1 // Chapter 2_Introduction to the quantum theory of
  solids
2 //Caption_The Fermi Dirac Probability Function
3 //Ex_5//page 68
4 Ni=9       //given no. of particles
5 gi=10      //given no. of quantum states
6 P=factorial(gi)/(factorial(Ni)*(factorial(gi-Ni)))
           //Possible no of ways of relizing this
           distribution
7 printf('This distribution can be realized in %i ways
        \n',P)

```

Scilab code Exa 2.6 The Distribution function and the Fermi Energy

```

1 // Chapter 2_Introduction to the quantum theory of
  solids
2 //Caption_The Distribution function and the Fermi
  Energy
3 //Ex_6//page 71
4 T=300      // Temperature in kelvin
5 x=3        //x=      (E-Ef)/kT

```

```
6 fE=100/(1+%e^x);
7 printf('Probability that an energy level 3kT above
  the Fermi energy is occupied by an electron is %1
  .2fd%%\n',fE)
```

Scilab code Exa 2.7 The Distribution function and the Fermi Energy

```
1 // Chapter 2_Introduction to the quantum theory of
  solids
2 //Caption_The Distribution function and the Fermi
  Energy
3 //Ex_7//page 72
4 fE=0.01
5 Ef=6.25 //Fermi energy in eV
6 a=1/(1-fE)
7 x=log(a-1)
8 k=1.38*(10^-23)
9 T=(-0.30)*1.6*(10^-19)/(k*x)
10 printf('Temperature at which there is a 1 percent
  probability that an energy state is empty is %3.1
  fd K\n',T)
```

Chapter 3

The Semiconductor in Equilibrium

Scilab code Exa 3.1 Equilibrium Distribution of Electrons and holes

```
1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Equilibrium Distribution of Electrons and
  holes
3 //Ex_1//page 85
4 T=300 // Temperature in kelvin
5 Nc=2.8*(10^19) //Effective density of states
  function in the conduction band in per cm cube
6 delE=0.25 //Fermi energy is 0.25eV below the
  conduction band
7 k=1.389*(10^-23) //Boltzmann constant
8 kT=0.0259
9 fF=%e^(-delE/(kT))
10 no=Nc*fF
11 printf('The thermal equilibrium electron
  concentration in siliconn is %1.2fd per cm^3',no)
```

Scilab code Exa 3.2 Equilibrium Distribution of Electrons and holes

```
1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Equilibrium Distribution of Electrons and
   holes
3 //Ex.2//page 87
4 T=400;
5 N=1.04*(10^19)
6 kT=0.0259*(T/300);
7 Nv=N*(T/300)^(1.5)
8 po=Nv*(%e^(-0.27/kT))
9 printf('The thermal equilibrium hole concentration
   in silicon at T=400K ==%fd per cm^3 \n',po)
```

Scilab code Exa 3.3 Intrinsic carrier concentration

```
1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Intrinsic carrier concentration
3 //Ex.3//page 90
4 T1=300; //Given temperature in kelvin
5 T2=450;
6 Nc1=4.7*(10^17) //effective density of state
   function in cm^-3
7 Nv1=7*(10^18)
8 Eg=1.42 //bandgap energy in eV
9 kT=0.0259*(T2/T1);
10 ni1=(Nc1*Nv1*exp((-Eg)/0.0259))^0.5
11 ni2=(Nc1*Nv1*(T2/T1)^3*exp(-Eg/kT))^0.5
12 printf('The intrinsic carrier concentration in
   gallium arsenide at T=300k is %fd per cm cube and
   at 450k is %fd //cm^3 ', ni1, ni2)
```

Scilab code Exa 3.4 Intrinsic fermi level position

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Intrinsic fermi level position
3 //Ex_4//page 92
4 T=300; //temperature in kelvin
5 mnr =1.08 //relative effective mass of negative
   charge carrier
6 mpr=0.56 //relative effective mass of positive
   charge carrier
7 kT=0.0259
8 Efm=(3/4)*kT*log(mpr/mnr) //The intrinsic fermi
   level with respect to the center of bandgap
9 EfmF=-(Efm)*1000
10 printf('The intrinsic fermi level in silicon is %1
   .1fd meV below the midgap energy ',EfmF)

```

Scilab code Exa 3.5 Extrinsic Semiconductor

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Extrinsic Semiconductor
3 //Ex_5//page 101
4 T=300 //temperature in kelvin
5 Nc=2.8*(10^19);
6 Nv=1.04*(10^19); //
7 Fe=0.25 //Fermi energy is FeeV below the
   conduction band
8 Eg=1.12 // Bandgap energy of silicon is Eg in eV
9 no=Nc*exp(-Fe/0.0259);
10 po=Nv*exp(-(Eg-Fe)/0.0259);
11 printf('Thermal equilibrium concentration of
   electrons is %1.2fd cm ^-3 and of holes is %1.2fd
   cm^-3 ',no,po)

```

Scilab code Exa 3.6 Extrinsic Semiconductor

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Extrinsic Semiconductor
3 //Ex_6//page 104
4 nf=2 //nf=(Ef-Ec)/kT
5 Fe=52 //Fermi energy is above the conduction band
    by Fe meV
6 T=300;
7 Nc=2.8*(10^19);
8 F(nf)=2.3 // Value of fermi dirac integral from the
    graph
9 no=(2/((%pi)^0.5))*Nc*F(nf)
10 printf('Electron concentration using fermi dirac
    integral is %fd per cm cube ',no)

```

Scilab code Exa 3.7 Statistics of acceptors and donors

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Statistics of acceptors and donors
3 //Ex_7//page 108
4 T=300;
5 Nd=10^16 // donor concentration per cm cube
6 kT=0.0259
7 Ecd=0.045 //Ec-Ed
8 Nc=2.8*(10^19);
9 x=1/(1+(Nc/(2*Nd))*exp(-(Ecd)/kT))
10 printf('Fraction of total electrons still in the
    donor state is %fd ',x)

```

Scilab code Exa 3.8 Statistics of acceptors and donors

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Statistics of acceptors and donors
3 //Ex_8//page 110

```

```

4 Na=10^16 //Acceptor concentration
5 kT=0.0259
6 Nv=1.04*(10^19);
7 Eav=0.045
8 x=0.1 //90%of acceptor atoms are ionized
9 y=((1/x)-1)*4*Na/Nv);
10 //(T/300)^1.5*exp(-Eav/kT*(T/300))=y
11 //By trial and error
12 printf('Required temperature is 193 K')

```

Scilab code Exa 3.9 Charge Neutrality

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Charge Neutrality
3 //Ex_9//page 112
4 T=300 //temperature in kelvin
5 Nd=10^16 //donor concentration per cm cube
6 Na=0
7 ni=1.5*(10^10) //intrinsic carrier concentration
8 no=((Nd-Na)/2)+(((Nd-Na)/2)^2+ni^2)^0.5
9 po=ni^2/no;
10 printf('The majority carrier electron concentration
is %fd per cm cube while the minority carrier
hole concentration is %fd per cm cube',no,po)

```

Scilab code Exa 3.10 Charge Neutrality

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Charge Neutrality
3 //Ex_10//page 114
4 T=300 //temperature in kelvin
5 Nd=5*(10^13)
6 Na=0

```

```

7 ni=2.4*(10^13)
8 no=((Nd-Na)/2)+(((Nd-Na)/2)^2+ni^2)^0.5
9 po=ni^2/no;
10 printf('The majority carrier electron concentration
    is %fd per cm cube while the minority carrier
    hole concentration is %fd per cm cube',no,po)

```

Scilab code Exa 3.11 Charge Neutrality

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Charge Neutrality
3 //Ex_11//page 115
4 T=300 //temperature in kelvin
5 Na=10^16 //donor concentration per cm cube
6 Nd=3*(10^15)
7 ni=1.5*(10^10) //intrinsic carrier concentration
8 po=((Na-Nd)/2)+(((Na-Nd)/2)^2+ni^2)^0.5
9 no=ni^2/po;
10 printf('The minority carrier electron concentration
    is %fd per cm cube while the majority carrier
    hole concentration is %fd per cm cube',no,po)

```

Scilab code Exa 3.12 Charge Neutrality

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Charge Neutrality
3 //Ex_12//page 116
4 T=550 //temperature in kelvin
5 Nc=2.8*(10^19)
6 Nv=1.04*(10^19)
7 Eg=1.12 // band gap energy in eV
8 ni=(Nc*Nv*(T/300)^3*exp(-Eg/0.0259 *(300/T)))^0.5

```

```

9 //no=1.05*Nd since the intrinsic carrier
   concentration to contribute no more than 5
   percent of the total electron concentration .
10 Nd=(ni^2/(1.05-1))^0.5
11 printf('The required impurity doping concentration
   is %fd per cm cube',Nd)

```

Scilab code Exa 3.13 Position of Fermi Energy level

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Position of Fermi Energy level
3 //Ex_14//page 121
4 T=300 //temperature in kelvin
5 Ef=0.20;
6 kT=0.0259
7 ni=1.5*(10^10) //intrinsic carrier concentration
8 Efa=3*kT //Ef-Ea=3kT
9 Eav=0.045
10 Efif=Ef/2-(Eav)-(Efa) //The position of fermi
   level at the maximum doping
11 Na=exp(Efif/kT)*ni
12 printf('Maximum doping is %3.2f d per cm cube',Na)

```

Scilab code Exa 3.14 Position of Fermi Energy level

```

1 // Chapter 3_The Semiconductor in Equilibrium
2 //Caption_Position of Fermi Energy level
3 //Ex_14//page 121
4 T=300 //temperature in kelvin
5 kT=0.0259
6 ni=1.5*(10^10) //intrinsic carrier concentration
7 Efa=3*kT //Ef-Ea=3kT
8 Eav=0.045

```

```
9 Efif=Eg/2-(Eav)-(Efa) //The position of fermi
   level at the maximum doping
10 Na=exp(Efif/kT)*ni
11 printf('Maximum doping is %fd per cm cube',Na)
```

Chapter 4

Carrier Transport Phenomenon

Scilab code Exa 4.1 Carrier drift

```
1 // Chapter 4_Carrier Transport Phenomenon
2 //Caption_Carrier drift
3 //Ex_1//page 134
4 T=300 //temperature in kelvin
5 Na=0
6 e=1.6*(10^-19)
7 Nd=10^16 //donor concentration in per cm cube
8 E=10 //Applied electric field in V/cm
9 ni=1.8*(10^6)
10 n=(Nd-Na)/2+(((Nd-Na)/2)^2+ni^2)^0.5
11 p=ni^2/n
12 muN=8500 //mobility of electron in gallium
    arsenide in cm^2/V-s
13 mup=400
14 J=e*(muN*n+mup*p)*E
15 printf('The drift current density for this electric
    field is %1.2fd A/cm^2',J )
```

Scilab code Exa 4.2 Carrier drift

```

1 // Chapter 4_Carrier Transport Phenomenon
2 //Caption_Carrier drift
3 //Ex_2//page 143
4 T=300
5 sig=16 //CONDUCTIVITY IN (OHM-CM)^-1
6 Na=10^16 //acceptor doping concentration
7 e=1.6*(10^-19)
8 // sig=e*muN*(Nd-Na)
9 //By trial and error
10 printf('Doping concentration is 3.5*10^17 cm^-3 and
        mobility is 400 cm^2/V-S')

```

Scilab code Exa 4.3 Conductivity

```

1 // Chapter 4_Carrier Transport Phenomenon
2 //Caption_Conductivity
3 //Ex_2//page 144
4 T=300
5 Nd=5*(10^15) //donor concentration
6 R=10 //resistance in kohm
7 J=50 //current density in A/cm^2
8 V=5 //voltage in volts
9 i=V/R //current
10 A=i/J //cross sectional area
11 E=100
12 L=V/E //length of the resistor
13 rho=L/(V*A)
14 // The conductivity of a compensated p-type
    semiconductor is
15 //rho=e*muP*(Na-Nd)
16 //where the mobility is a function of the total
    ionized impurity concentration Na+Nd
17 //Using trial and error , if
18 Na=1.25*(10^16)
19 muP=410

```

```

20 e=1.6*(10^-19)
21 sig=e*muP*(Na-Nd)
22 printf('Conductivity obtained is %1.2fd which is
        very close to the value we need',sig)

```

Scilab code Exa 4.4 Carrier diffusion

```

1 // Chapter 4_Carrier Transport Phenomenon
2 //Caption_Carrier diffusion
3 //Ex_4//page 150
4 T=300
5 d=0.10 //distance in cm over which concentration
        varies
6 Dn=225 //diffusion coefficient
7 e=1.6*(10^-19)
8 delN=1*(10^18)-7*(10^17)
9 J=e*Dn*(delN/d)
10 printf('The diffusion current density is %1.2fd A/cm
        ^3',J)

```

Scilab code Exa 4.5 Graded impurity distribution

```

1 // Chapter 4_Carrier Transport Phenomenon
2 //Caption_Graded impurity distribution
3 //Ex_5//page 153
4 T=300
5 x=0 //given 0<x<1 micrometer
6 Nd=10^16-10^19*x
7 //Taking the derivative of donor concentration , we
        have d(ND)/dx=-10^19
8 e=1.6*(10^-19)
9 Ex=-(0.0259)*(-10^19)/Nd

```

```
10 printf('The induced electric field is %1.1fd V/cm',  
    Ex)
```

Scilab code Exa 4.6 The Einstein relation

```
1 // Chapter 4_Carrier Transport Phenomenon  
2 //Caption_The Einstein relation  
3 //Ex_6//page 155  
4 T=300  
5 mu=1000 //mobility of a particular carrier  
6 kT=0.0259  
7 e=1.6*(10^-19)  
8 D=(kT)*mu  
9 printf('Diffusion coefficient is %1.2fd cm^2/s ',D)
```

Scilab code Exa 4.7 The hall effect

```
1 // Chapter 4_Carrier Transport Phenomenon  
2 //Caption_The Hall Effect  
3 //Ex_7//page 158  
4 L=10^-3 //LENGTH IN M  
5 W=10^-2 //WIDTH IN CM  
6 d=10^-5  
7 Ix=10^-3 //current in Amp  
8 Vx=12.5  
9 e=1.6*(10^-19)  
10 Bz=500 //magnetic field in gauss  
11 Vh=-6.25*10^-3 //hall voltage  
12  
13 //A negative hall voltage for this geometry implies  
    that we have an n-type semiconductor  
14 BzT=Bz*10^-4 //magnetic field in tesla  
15 n=- (Ix*BzT)/(e*d*Vh*10^6)
```

```
16  $\mu_n = (I_x * L) / (e * n * V_x * W * d)$ 
17 printf('Majority carrier concentration is %1.1fd cm
    ^-3 and mobility is %1.1fd cm^2/V-s ',n, $\mu_n$ )
```

Chapter 5

Non Equilibrium excess carriers in semiconductors

Scilab code Exa 5.5 Relaxation time

```
1 // Chapter 5_Non equilibrium excess carriers in
  semiconductors
2 //Caption_Relaxation time
3 //Ex_5//page 190
4 Nd=10^16 //donor concentration
5 e=1.6*(10^-19) //electronic charge
6 mun=1200 //mobility
7 sig=e*mun*Nd
8 epsR=11.7 //dielectric constant for silicon
9 epso=8.85*(10^-14)
10 eps=epso*epsR //permitivity of silicon
11 taud=eps/sig //dielectric relaxation time
  constant
12 tau=taud*10^12
13 printf('The dielectric relaxation time constant for
  this semiconductor is %1.2f ps',tau)
```

Scilab code Exa 5.6 Quasi Energy Fermi levels

```
1 // Chapter 5_Non equilibrium excess carriers in
  semiconductors
2 //Caption_Quasi Energy Fermi Levels
3 //Ex_6//page 194
4 T=300 //temperature in kelvin
5 no=10^15 //carrier concentration
6 ni=10^10 //intrinsic concentration
7 po=10^5
8 deln=10^13 //excess carrier concentration
9 delp=10^13
10 EfFi=0.0259*log(no/ni) //fermi level for thermal
  equilibrium
11 EfnEfi=0.0259*log((no+deln)/ni)
12 EfiEfp=0.0259*log((po+delp)/ni)
13 printf('Quasi fermi level for electrons in non
  equilibrium is %1.4f eV and for hholes is %1.3 f
  eV ',EfnEfi,EfiEfp)
```

Scilab code Exa 5.10 Surface effects

```
1 // Chapter 5_Non equilibrium excess carriers in
  semiconductors
2 //Caption_Surface effects
3 //Ex_10//page 206
4 gtaupo=10^14
5 Dp=10
6 Lp=31.6*(10^-4)
7 delpo=10^13
8 s=(Dp/Lp)*((gtaupo/delpo)-1)
9 printf('Surface recombination velocity is %1.2fd cm/
  s ',s)
```

Chapter 6

The pn junction

Scilab code Exa 6.1 Zero applied bias

```
1 // Chapter 6_The pn junction
2 //Caption_Zero applied bias
3 //Ex_1//page 220
4 Na=10^18 //acceptor ion concentration
5 T=300 //temperature in kelvin
6 Nd=10^15
7 ni=1.5*(10^10) //intrinsic ion concentration
8 Vbi=(0.0259)*log(Na*Nd/(ni^2))
9 printf('The built in potential barrier is %1.3f V',
    Vbi)
```

Scilab code Exa 6.2 Space charge width

```
1 // Chapter 6_The pn junction
2 //Caption_Space charge width
3 //Ex_2//page 224
4 T=300
5 Na=10^16 //acceptor ion concentration
```

```

6 Nd=10^15 //donor ion concentration
7 eps=11.7*8.85*(10^-14)
8 e=1.6*(10^-19)
9 Vbi=0.635 //built in potential barrier
10 W=(2*eps*Vbi/e*(Na+Nd)/(Na*Nd))^0.5
11 Emax=-e*Nd*W/eps
12 printf('The space charge width is %f cm and the
    electric field is %f V/cm',W,Emax)

```

Scilab code Exa 6.3 Space charge width

```

1 // Chapter 6_The pn junction
2 //Caption_Space charge width
3 //Ex_3//page 227
4 eps=11.7*8.85*(10^-14);
5 e=1.6*(10^-19);
6 Na=10^16 //acceptor ion concentration
7 T=300 //temperature in kelvin
8 Nd=10^15
9 ni=1.5*(10^10) //intrinsic ion concentration
10 Vr=5 //Reverse applied voltage
11 Vbi=0.635
12 V=Vr+Vbi
13 W=(2*eps*V/e*(Na+Nd)/(Na*Nd))^0.5
14 printf('The space charge width is %f cm ',W)

```

Scilab code Exa 6.4 Space charge width

```

1 // Chapter 6_The pn junction
2 //Caption_Space charge width
3 //Ex_4//page 228
4 T=300
5 Na=10^18 //acceptor ion concentration

```

```

6 Emax=3*10^5 //Max electric field
7 Vr=25 //Reverse bias voltage
8 eps=11.7*8.85*(10^-14)
9 e=1.6*(10^-19)
10 x=eps*(Emax^2)/(2*e*Vr);
11 Nd=Na*x/(Na-x)
12 printf('The ntype doping concentration such that the
    maximum electric field is obtained is %f /cm^3',
    Nd)

```

Scilab code Exa 6.5 Junction capacitance

```

1 // Chapter 6_The pn junction
2 //Caption_Junction capacitance
3 //Ex_5//page 230
4 eps=11.7*8.85*(10^-14);
5 e=1.6*(10^-19);
6 Na=10^16 //acceptor ion concentration
7 T=300 //temperature in kelvin
8 Nd=10^15
9 ni=1.5*(10^10) //intrinsic ion concentration
10 Vr=5 //Reverse applied voltage
11 Vbi=0.635
12 V=Vr+Vbi
13 C=(e*eps*Na*Nd/(2*(V)*(Na+Nd)))^0.5
14 A=10^-4 //Area of the pn junction
15 Ca=A*C*10^12
16 printf('The junction capacitance for the given
    semiconductor is %1.3f pF',Ca)

```

Scilab code Exa 6.6 Junction capacitance

```

1 // Chapter 6_The pn junction

```

```

2 //Caption_Junction capacitance
3 //Ex_6//page 232
4 T=300 //temperature in kelvin
5 S=1.32*10^15 //slope of the curve between Vr and
  (1/c)^2
6 ni=1.5*(10^10)
7 Vbi=0.855 //Built in potential barrier
8 eps=11.7*8.85*(10^-14)
9 e=1.6*(10^-19)
10 Nd=2/(e*eps*S)
11 Na=((ni^2)/Nd)*exp(Vbi/0.0259)
12 printf('The impurity doping concentration in p+n
  junction is -acceptor %f cm^-3 and donor %f cm^-3
  ',Na,Nd)

```

Chapter 7

The pn junction diode

Scilab code Exa 7.1 pn junction current

```
1 // Chapter 7_The pn junction Diode
2 //Caption_pn Junction current
3 //Ex_1//page 252
4 T=300 //temperature in kelvin
5 ni=1.5*(10^10) //intrinsic ion concentration
6 Nd=10^16
7 Vf=0.60 //forward bias voltage
8 pno=(ni^2)/Nd
9 e=1.6*10^-19
10 pn=pno*exp(Vf/0.0259)
11 printf('Minority carrier hole concentration is %f cm
    ^-3',pn)
```

Scilab code Exa 7.2 pn junction current

```
1 // Chapter 7_The pn junction Diode
2 //Caption_pn Junction current
3 //Ex_2//page 258
```

```

4 e = 1.6*10^-19;
5 Na=10^16 //acceptor impurity
6 Nd=10^16 // donor impurity
7 ni=1.5*10^10 //intrinsic concentration
8 Dn=25
9 Dp=10
10 tau_po=5*10^-7
11 tau_no=5*10^-7
12 epsr=11.7
13 Js=e*ni^2*((1/Na*(Dn/tau_no)^0.5)+(1/Nd)*(Dp/tau_po)
    ^0.5)*10^9
14 printf('Ideal reverse saturation current density is
    %f nA/cm', Js)

```

Scilab code Exa 7.3 pn junction current

```

1 // Chapter 7_The pn junction Diode
2 //Caption_pn Junction current
3 //Ex_3//page 258
4 Jn=20 //electron current density
5 Jp=5 //hole current density
6 T=300
7 Va=0.65
8 ni=1.5*10^10 //intrinsic concentration
9 Dn=25
10 Dp=10
11 e=1.6*10^-19
12 tau_po=5*10^-7
13 tau_no=5*10^-7
14 epsr=11.7
15 Na=1/(Jn/((e*(Dn/tau_no)^0.5)*(ni^2*(exp(Va/0.0259)
    -1))))
16 Nd=1/(Jp/((e*(Dp/tau_po)^0.5)*(ni^2*(exp(Va/0.0259)
    -1))))
17 printf('The design parameters for this semiconductor

```

are $N_a = \text{\%f cm}^{-3}$ and $N_d = \text{\%f cm}^{-3}$ ', N_a, N_d)

Scilab code Exa 7.4 pn junction current

```
1 // Chapter 7_The pn junction Diode
2 //Caption_pn Junction current
3 //Ex_4//page 261
4 T=300
5 Va=0.65
6 Js=4.15*10^-11
7 e=1.6*10^-19
8 J=Js*(exp(Va/0.0259)-1)
9 mun=1350
10 Nd=10^16
11
12 E=J/(e*mun*Nd)
13 printf('The electric field required to produce a
    given majority carrier drift is %f V/cm',E)
```

Scilab code Exa 7.5 Temperature effects on pn junction

```
1 // Chapter 7_The pn junction Diode
2 //Caption_Temperature effects on pn Junction current
3 //Ex_5//page 262
4 T2=310
5 T1=300
6 Eg=1.12 //energy band gap
7 Va1=0.60 //forward bias voltage at 300k
8 Va2=Eg-((T2/T1)*(Eg-Va1))
9 delV=Va2-Va1
10 printf('Change in fprward bias voltage on a pn
    junction with the change in temperature is %f V',
    delV)
```

Scilab code Exa 7.6 small signal admittance

```
1 // Chapter 7_The pn junction Diode
2 //Caption_Small signal admittance
3 //Ex_6//page 272
4 T=300
5 tau_po=10^-7
6 Ipo=0.001
7 Idq=0.001
8 Cd=10^9*(1/(2*0.0259))*(Ipo*tau_po)
9 rd=0.0259/(Idq) //diffusion resistance
10 printf('Diffusion capacitance is %1.2f nF and
    diffusion resistance is %1.2f ohm',Cd,rd)
```

Scilab code Exa 7.7 Generation recombination currents

```
1 // Chapter 7_The pn junction Diode
2 //Caption_Generation Recombination currents
3 //Ex_7//page 277
4 T=300
5 tau_o=5*10^-7
6 tau_po=5*10^-7
7 tau_no=5*10^-7
8 Na=10^16 //acceptor impurity
9 Nd=10^16 // donor impurity
10 ni=1.5*10^10 //intrinsic concentration
11 epsr=11.7
12 eps=epsr*8.85*10^-14
13 V=5 //V=Vbi+VR
14 e=1.6*10^-19
15 W=((2*eps/e)*((Na+Nd)/(Na*Nd))*(V))^0.5
```

```
16 Jgen=e*ni*10^9*W/(2*tau_o)
17 printf('The ideal reverse saturation current density
    was calculated in example 2 and it was
    4.15810^-11 A/cm^2 and the generation current
    density calculated here is %f nA/cm^2',Jgen)
```

Chapter 8

Metal semiconductors and semiconductor heterojunctions

Scilab code Exa 8.1 Shottky barrier diode

```
1 // Chapter 8_Metal Semiconductor and Semiconductor
  heterojunctions
2 //Caption_Shottky barrier diode
3 //Ex_1//page 308
4 eps=13.1*8.85*10^-14;
5 e = 1.6*10^-19;
6 T=300 //temperature in kelvin
7 Nd=10^16 //donor impurity
8 phi_m=4.55 //metal work function for tungsten
9 xi=4.01 //electron affinity for silicon
10 phi_bo=phi_m-xi
11 phi_n=0.0259*log(2.8*10^19/Nd)
12 Vbi=phi_bo-phi_n
13 xn=(2*eps*Vbi/(e*Nd))^0.5 //space charge width
  at zero bias
14 Emax=e*Nd*xn/eps //maximum electric field
15 printf('Theoretical barrier height is %f V, built-in
  potential barrier is %f V and maximum electric
  field is %f V/cm', phi_bo,phi_n,Emax)
```

Scilab code Exa 8.2 Non ideal effects on barrier height

```
1 // Chapter 8_Metal Semiconductor and Semiconductor
  heterojunctions
2 //Caption_Non ideal effects on the barrier height
3 //Ex_3//page 312
4 E=6.8*10^4
5 T=300
6 e=1.6*10^-19
7 eps=13.1*8.85*10^-14
8 delphi=(e*E/(4*pi*eps))^0.5
9 xm=(e/(16*pi*eps*E))^0.5*10^8
10 printf('Position of the maximum barrier height is %1
    .0f Angstorm ',xm)
```

Scilab code Exa 8.3 Non ideal effects on barrier height

```
1 // Chapter 8_Metal Semiconductor and Semiconductor
  heterojunctions
2 //Caption_Non ideal effects on the barrier height
3 //Ex_3//page 312
4 E=6.8*10^4
5 T=300
6 e=1.6*10^-19
7 eps=13.1*8.85*10^-14
8 delphi=(e*E/(4*pi*eps))^0.5
9 xm=(e/(16*pi*eps*E))^0.5*(10^8)
10 printf('Position of maximum barrier height is %fA',
    xm)
```

Scilab code Exa 8.4 Current voltage relationship

```
1 // Chapter 8_Metal Semiconductor and Semiconductor
  heterojunctions
2 //Caption_Current voltage relationship
3 //Ex_4/page 318
4 phi_bn=0.67 //barrier height
5 Jst=6*10^-5 //reverse saturation current density
6 T=300
7 e=1.6*10^-19
8 A=Jst/(T^2)*exp(phi_bn/0.0259)
9 printf('The effective Richardson constant is %1.0f A
  /K^2-cm^2 ',A)
```

Scilab code Exa 8.5 Comparison of the schottky barrier diode and the pn junction d

```
1 // Chapter 8_Metal Semiconductor and Semiconductor
  heterojunctions
2 //Caption_Comparison of the schottky barrier diode
  and the pn junction diode
3 //Ex_5/page 319
4 e = 1.6*10^-19;
5 e_phi_bn=0.67
6 A=114 //effective richardson constant
7 T=300
8 Jst=A*T^2*exp(-e_phi_bn/0.0259)
9 //if we neglect the barrier lowering effect , we have
  for the schottky barrier diode
10 //for a pn junction
11 Na=10^18
12 Nd=10^16
13 Dp=10
14 Dn=25
15 tau_po=10^-7
16 tau_no=10^-7
```

```

17 Lp=(Dp*tau_po)^0.5
18 Ln=(Dn*tau_no)^0.5
19 pno=2.25*10^4
20 npo=2.25*10^2
21 //the ideal reverse saturation current density of
    the pn junction diode can be determined as
22 Js=e*Dn*np0/Ln+(e*Dp*pno/Lp)
23 J=10^9*(Js+5.7*10^-13)
24 printf('Reverse saturation current density for
    schottky baarier diode is %f A/cm^2 and for pn
    junction is %f nA/cm^2',Jst,J)

```

Scilab code Exa 8.6 Shottky barrier diode and pn junction

```

1 // Chapter 8_Metal Semiconductor and Semiconductor
    heterojunctions
2 //Caption_Shottky barrier diode and pn junction
3 //Ex_6//page 308
4 Jf=10 //forward biased current density
5 Jst=5.98*10^-5
6 Va=(0.0259*log(Jf/Jst))
7 //for pn junction diode
8 Js=3.66*10^-11 //reverse saturation current
    density
9 Va_pn=0.0259*log(Jf/Js)
10 printf('Forward bised voltage required for schottky
    is %1.3f V and for pn junction is %1.3fV',Va,
    Va_pn)

```

Scilab code Exa 8.7 Tunnelling barrier

```

1 // Chapter 8_Metal Semiconductor and Semiconductor
    heterojunctions

```

```

2 //Caption_Tunnelling barrier
3 //Ex_7//page 325
4 T=300 //temperature in kelvin
5 Nd=7*10^18 //donor impurity
6 e=1.6*10^-19
7 phi_bn=0.67 //schottky barrier
8 Vbi=phi_bn //assumption with neglect of
   barrier lowering effect
9 eps=11.7*8.85*10^-14
10 xn=(2*eps*Vbi/(e*Nd))^0.5
11 x=10^8*xn
12 printf('The space charge width is %1.0f Angstrom',x)

```

Scilab code Exa 8.8 Equilibrium electrostatics

```

1 // Chapter 8_Metal Semiconductor and Semiconductor
   heterojunctions
2 //Caption_Equilibrium electrostatics
3 //Ex_8//page 333
4 Nd=10^16 //donor impurity
5 Na=10^16 //acceptor impurity
6 ni=2.4*10^13 //intrinsic ion concentration
7 T=300
8 e=1.6*10^-19
9 xi_n=4.13 //electron affinity
10 xi_p=4.07
11 del_Ec=(xi_n-xi_p) //difference between two
   conduction band energies
12 del_Eg=1.43-0.67
13
14 del_Ev=del_Eg-del_Ec //difference between two
   valence band energies
15 pno=ni^2/Nd
16 Ncp=6*10^18
17 Ncn=7*10^18

```

```
18 Vbi=del_Ev+(0.0259*log(Na*Ncp/(pno*Ncn)))
19 printf('Difference between two conduction band
    energies is %1.2f eV ,difference between two
    valence band energies is %f eV and Vbi=%fV',
    del_Ec,del_Ev,Vbi)
```

Chapter 9

The Bipolar transistor

Scilab code Exa 9.1 Gain factors

```
1 // Chapter 9_The bipolar transistor
2 //Caption_Gain factors
3 //Ex_1//page 371
4 gamma=0.9967 //emitter injection efficiency
   factor
5 Nbe=(1/gamma)-1 //base to emitter doping
   concentration ratio
6 NEB=1/Nbe
7 printf('The emitter doping concentration must be
   much larger i.e.%1.0ftimes that of base',NEB)
```

Scilab code Exa 9.2 Gain factors

```
1 // Chapter 9_The bipolar transistor
2 //Caption_Gain factors
3 //Ex_2//page 372
4 alpha_T=0.9967
5 Db=10
```

```

6 tau_bo=10^-7
7 xBLb=abs(acosh(alpha_T)) //xB/Lb where LB is the
    length
8 Lb=(Db*tau_bo)^0.5
9 xb=xBLb*Lb*10^4
10 printf('Base width required to achieve the given
    base transport factor is %1.3f micrometer',xb)

```

Scilab code Exa 9.3 Gain factors

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Gain factors
3 //Ex_3//page 373
4 delta=0.9967 //recombination factor
5 T=300
6 Jro=10^-8
7 Jso=10^-11
8 del=1/delta-1
9 x=del*Jso/Jro
10 Vbe=-2*0.0259*log(x)
11 printf('Forward biased BE voltage required to
    achieve the given delta is %1.3f V',Vbe)

```

Scilab code Exa 9.4 Gain factors

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Gain factors
3 //Ex_4//page 373
4 DE=10
5 DB=25
6 XB=0.70*10^-4 //width of base
7 XE=0.50*10^-4 //width of emitter
8 NE=10^18 //doping concentration in emitter

```

```

 9 NB=10^16    //doping concentration in base
10 VBE=0.65
11 e=1.6*10^-19
12 tau_eo=10^-7 //minority carrier lifetime in
    emitter
13 tau_bo=5*10^-7 //minority carrier lifetime in base
14 Jro=5*10^-8
15 T=300
16 peo=(1.5*10^10)^2/NE
17 nbo=(1.5*10^10)^2/NB
18 Le=(DE*tau_eo)^0.5
19 Lb=(DB*tau_bo)^0.5
20 gamma_i=1/(1+((peo*DE*Lb*tanh(0.0198))/(nbo*DB*Le*
    tanh(0.050))))
21 alpha_T=1/(cosh(XB/Lb))
22 Jso=e*DB*nbo/(Lb*tanh(XB/Lb))
23 delta=1/1+(Jro*exp(-VBE/(2*0.0259)/Jso))
24 delta=0.99986
25 alpha=gamma_i*alpha_T*delta
26 beta_i=alpha/(1-alpha)
27 printf('Common emitter current gain is %1.0f',beta_i
    )

```

Scilab code Exa 9.5 Non ideal effects

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Non ideal effects
3 //Ex_5//page 376
4 T=300
5 e=1.6*10^-19
6 NB=5*10^16    //doping concentration in base
7 NC=2*10^15    //doping concentration in collector
8 XB=0.70*10^-4 //metturgical base width
9 ni=1.5*10^10 //intrinsic ion concentration
10 Vbi=0.718    //built-in potential

```

```

11 Vcb1=2
12 eps=11.7*8.85*10^-14
13 xdb1=(2*eps*(Vbi+Vcb1)*NC/(e*Nb*(NC+Nb)))^0.5
14 Vcb2=10
15 xdb2=(2*eps*(Vbi+Vcb2)*NC/(e*Nb*(NC+Nb)))^0.5
16 xb1=XB-xdb1 //neutral base width
17 xb2=XB-xdb2
18 del_xb=((xb1-xb2)/xb1)*100
19 printf('The neutral base width changes by %1.0f
    percent as the C-B voltage changes from 2 to 10 V
    ',del_xb)

```

Scilab code Exa 9.6 Non ideal effects

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Non ideal effects
3 //Ex_6//page 377
4 DB=25
5 VBE=0.60
6 T=300
7 e=1.6*10^-19
8 NB=5*10^16 //doping concentration in base
9 NC=2*10^15 //doping concentration in collector
10 XB=0.70*10^-4 //metturgical base width
11 ni=1.5*10^10 //intrinsic ion concentration
12 nB0=ni^2/NB
13 xb1=0.648*10^-4
14 Jc1=e*DB*nB0*exp(VBE/0.0259)/xb1
15 xb2=0.597*10^-4
16 Jc2=e*DB*nB0*exp(VBE/0.0259)/xb2
17 VCE1=2.6
18 VCE2=10.6
19 del_JC_VCE=(Jc2-Jc1)/(VCE2-VCE1)
20 Va=3.20/del_JC_VCE-2.6
21 printf('The early voltage is %1.0f V',Va)

```

Scilab code Exa 9.7 Non ideal effects

```
1 // Chapter 9_The bipolar transistor
2 //Caption_Non ideal effects
3 //Ex_7//page 382
4 T=300
5 NE1=10^18 //emitter doping
6 NE2=10^19
7 ni=1.5*10^10 //intrinsic ion concentration
8 pE01=ni^2/NE1
9 pE02=ni^2/NE2
10 //This we did by neglecting bandgap narrowing , if
    we consider it , we get
11 pE011=pE01*exp(0.030/0.0259)
12 pE021=pE02*exp(0.1/0.0259)
13 printf('The thermal equilibrium minority carrier
    concentration increases by a factor of 1.5
    instead of decreasing by a factor of 9.This
    effect is due to bandgap narrowing')
```

Scilab code Exa 9.8 Breakdown voltage

```
1 // Chapter 9_The bipolar transistor
2 //Caption_Breakdown voltage
3 //Ex_8//page 387
4 Wb=0.5*10^-4 //metallurgical base width
5 NB=10^16
6 eps=11.7*8.85*10^-14
7 e=1.6*10^-19
8 Vpt=25 //punch through voltage
9 x=Vpt*2*eps/(e*Wb^2*NB)
```

```

10 y=x-1
11 NC=NB/y
12 xn=(2*eps*(Vpt)*NB/(e*NC*(NB+NC)))^0.5*10000
13 printf('The collector doping is %1.2f per cm^3 and
        collector width is %1.2f micrometer',NC,xn)

```

Scilab code Exa 9.9 Breakdown voltage

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Breakdown voltage
3 //Ex_9//page 390
4 bet=100 //common emitter current gain
5 NB=10^17 //base doping concentration
6 vmin=15 //minimum open base breakdown voltage
7 BVcbo=(bet)^(1/3)*vmin
8 printf('To achieve this breakdown voltage, the
        maximum collector doping concentration should be
        7*10^15 cm^-3 from the figure')

```

Scilab code Exa 9.10 Ebers moll model

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Ebers Moll model
3 //Ex_10//page 394
4 T=300
5 alpha_f=0.99
6 alpha_r=0.20
7 Ic=.001
8 Ib=50*10^-6
9 Vt=0.0259
10 x=Ic*(1-alpha_r)+Ib
11 y=alpha_f*Ib-((1-alpha_f)*Ic)
12 z=alpha_f/alpha_r

```

```

13 VCEsat=Vt*log(x*z/y)
14 printf('The collector emitter saturation voltage is
    %1.3 f V',VCEsat)

```

Scilab code Exa 9.12 Transistor cut off frequency

```

1 // Chapter 9_The bipolar transistor
2 //Caption_Transistor cut off frequency
3 //Ex_12//page 403
4 Ie=0.001 //emitter current
5 Cje=10^-12
6 xb=0.5*10^-4
7 vs=10^7
8 Dn=25
9 xdc=2.4*10^-4
10 rc=20
11 Cu=0.1*10^-12 //B-C junction capacitance
12 Cs=0.1*10^-12 //collector to substrate
    capacitance
13 re=0.0259/Ie
14 tau_e=re*Cje*10^12 //emitter base junction
    charging time
15 tau_b=(xb^2)/(2*Dn) *10^12 //base transit time
16 tau=xdc/vs*10^12
17 tau_c=rc*(Cu+Cs)*10^12
18 tau_ec=(tau_e+tau_b+tau+tau_c) //total emitter to
    collector time delay
19 fT=(10^3)/(2*pi*tau_ec)
20 bet=100
21 fB=fT/bet //beta cutoff frrequency
22 printf('Emitter to collector transit time is %1.1f
    psec and cut off frequency is %1.2f GHz',tau_ec,
    fT)

```

Chapter 10

Fundamentals of the Metal Oxide semiconductor Field Effect Transistor

Scilab code Exa 10.1 The two terminal MOS structure

```
1 // Chapter 10_Fundamentals of the Metal Oxide
  Semiconductor Field Effect Transistor
2 //Caption_The two terminal MOS structure
3 //Ex_1//page 434
4 Na=10^16
5 T=300
6 eps=11.7*8.85*10^-14
7 e=1.6*10^-19
8 ni=1.5*10^10 //intrinsic carrier concentration
9 phi_fp=0.0259*log(Na/ni)
10 xdT=10^4*(4*eps*phi_fp/(e*Na))^0.5
11 printf('The maximum space charge width is %1.2 f
  micrometer ',xdT)
```

Scilab code Exa 10.2 Work function

```
1 // Chapter 10_Fundamentals of the Metal Oxide
   Semiconductor Field Effect Transistor
2 //Caption_Work function
3 //Ex.2//page 437
4 phi_m=3.2 //work function for Al-Si junction
5 xi=3.25 //oxide electron affinity
6 Eg=1.11
7 ni=1.5*10^10 //intrinsic carrier concentration
8 Na=10^14
9 phi_fp=0.0259*log(Na/ni)
10 phi_ms=phi_m-(xi+Eg/(2)+phi_fp)
11 printf('Metal semiconductor work function difference
   is %1.2f V',phi_ms)
```

Scilab code Exa 10.3 Flat band voltage

```
1 // Chapter 10_Fundamentals of the Metal Oxide
   Semiconductor Field Effect Transistor
2 //Caption_Flat band voltage
3 //Ex.3//page 442
4 Na=10^16
5 tox=500*10^-8 //oxide thickness
6 Qss=10^11 //trapped charge per unit area
7 e=1.6*10^-19
8 eps_ox=3.9*8.85*10^-14
9 Cox=eps_ox/tox
10 QSS=Qss*e
11 phi_ms=-1.1
12 Vfb=phi_ms-(QSS/Cox)
13 printf('Flat band voltage for this MOS capacitor is
   %1.2f V',Vfb)
```

Scilab code Exa 10.4 Flat band voltage

```
1 // Chapter 10_Fundamentals of the Metal Oxide
   Semiconductor Field Effect Transistor
2 //Caption_Flat band voltage
3 //Ex_4//page 445
4 Na=3*10^16
5 eps=11.7*8.85*10^-14
6 eps_ox=3.9*8.85*10^-14
7 e=1.6*10^-19
8 Qss=10^11
9 Vtn=0.65
10 ni=1.5*10^10 //intrinsic carrier concentration
11 phi_ms=-1.13
12 phi_fp=0.0259*log(Na/ni)
13 xdt=(4*eps*phi_fp/(e*Na))^0.5
14 QSD=e*Na*xdt
15 x=Vtn-phi_ms-2*phi_fp
16 y=(QSD-Qss*e)/eps_ox
17 z=x/y*10^8
18 printf('The oxide thickness of this MOS system is %1
   .0f angstorm ',z)
```

Scilab code Exa 10.5 Threshold voltage

```
1 // Chapter 10_Fundamentals of the Metal Oxide
   Semiconductor Field Effect Transistor
2 //Caption_Threshold voltage voltage
3 //Ex_5//page 446
4 T=300
5 eps=11.7*8.85*10^-14
6 eps_ox=3.9*8.85*10^-14
```

```

7 e=1.6*10^-19
8 ni=1.5*10^10 //intrinsic carrier concentration
9 Na=10^14 //acceptor impurity concentration
10 Qss=10^10
11 tox=500*10^-8 //oxide thickness
12 phi_ms=-0.83
13 phi_fp=0.0259*log(Na/ni)
14 xdt=(4*eps*phi_fp/(e*Na))^0.5
15 QSD_MAX=e*Na*xdt;
16 Vtn=(QSD_MAX-Qss*e)*(tox/eps_ox)+phi_ms+2*phi_fp
17 printf('The threshold voltage of this MOS system is
    %1.3 f V',Vtn)

```

Scilab code Exa 10.6 Threshold voltage

```

1 // Chapter 10_Fundamentals of the Metal Oxide
   Semiconductor Field Effect Transistor
2 //Caption_Threshold voltage voltage
3 //Ex_6//page 448
4 e = 1.6*10^-19;
5 tox=650*10^-8
6 eps=11.7*8.85*10^-14
7 eps_ox=3.9*8.85*10^-14
8 Qss=10^10
9 Vtp=-1
10 Nd=2.5*10^14
11 ni=1.5*10^10 //intrinsic carrier concentration
12 phi_tn=0.0259*log(Nd/ni)
13 xdt=(4*eps*phi_tn/(e*Nd))^0.5
14 QSD_MAX=e*Nd*xdt;
15 phi_ms=-0.35
16 Vtp2=(-QSD_MAX-Qss*e)*(tox/eps_ox)+phi_ms-2*phi_tn
17 q=abs(Vtp2)==Vtp
18 printf('Since Vtp2=Vtp, it is essentially equal to
    the desired result')

```

Scilab code Exa 10.7 Capacitance Voltage characteristics

```
1 // Chapter 10_Fundamentals of the Metal Oxide
  Semiconductor Field Effect Transistor
2 //Caption_Capacitance Voltage characteristics
3 //Ex_7//page 455
4 e = 1.6*10^-19;
5 Na=10^16
6 tox=550*10^-8 //oxide thickness
7 eps=11.7*8.85*10^-14
8 eps_ox=3.9*8.85*10^-14
9 Cox=eps_ox/tox*10^9
10 ni=1.5*10^10 //intrinsic carrier concentration
11 phi_fp=0.0259*log(Na/ni)
12 xdt=(4*eps*phi_fp/(e*Na))^0.5
13 Cmin=eps_ox/(tox+(eps_ox/eps)*xdt)*10^9
14 r=Cmin/Cox
15 CFB=eps_ox/(tox+(eps_ox/eps)*(0.0259*eps/(e*Na))
  ^0.5) *10^9 //flat band capacitance
16 r2=CFB/Cox
17 printf('The value of oxide capacitance , minimum
  capacitance and flat band capacitance are %1.2 f
  nF, %1.2 f nF and %1.2 f nF respectively ',Cox,Cmin,
  CFB)
```

Scilab code Exa 10.8 Current voltage relationship

```
1 // Chapter 10_Fundamentals of the Metal Oxide
  Semiconductor Field Effect Transistor
2 //Caption_Current voltage relationship
3 //Ex_8//page 473
```

```

4 L=1.25*10^-4 //channel length
5 mun=650 //mobility of electrons
6 Cox=6.9*10^-8 //oxide capacitance
7 Vt=0.65 //thermal voltage
8 Idsat=4*10^-3 //saturated current
9 VGS=5
10 W=2*L*Idsat/(mun*Cox*(VGS-Vt)^2)*10^4
11 printf('The width of MOSFET such that the specified
current is induced is %1.1f micrometer',W)

```

Scilab code Exa 10.9 Threshold voltage

```

1 // Chapter 10_Fundamentals of the Metal Oxide
Semiconductor Field Effect Transistor
2 //Caption_Current voltage relationship
3 //Ex_9//page 474
4 W=15*10^-4 //Width of MosFET
5 L=2*10^-4 //length of MOSFET
6 COX=6.9*10^-8 //oxide capacitance
7 VDS=0.10
8 ID1=35*10^-6 //DRAIN CURRENT
9 VGS1=1.5
10 ID2=75*10^-6
11 VGS2=2.5
12 mun=L*(ID2-ID1)/(W*COX*(VGS2-VGS1)*VDS)
13 printf('The inversion carrier mobility is %1.0f cm
^2/V-s',mun)

```

Scilab code Exa 10.10 Substrate bias effects

```

1 // Chapter 10_Fundamentals of the Metal Oxide
Semiconductor Field Effect Transistor
2 //Caption_Substrate bias effects

```

```

3 //Ex_10//page 478
4 e = 1.6*10^-19;
5 T=300
6 Na=3*10^16
7 tox=500*10^-8
8 VSB=1
9 ni=1.5*10^10 //intrinsic carrier concentration
10 phi_fp=0.0259*log(Na/ni)
11 eps_ox=3.9*8.85*10^-14
12 Cox=eps_ox/tox
13 delVT=(2*e*eps_ox*Na)^0.5*((2*phi_fp+VSB)^0.5-(2*
    phi_fp)^0.5)/Cox
14 printf('The change in threshold voltage is %1.2fV',
    delVT)

```

Scilab code Exa 10.11 Cut off frequency

```

1 // Chapter 10_Fundamentals of the Metal Oxide
    Semiconductor Field Effect Transistor
2 //Caption_Cut off frequency
3 //Ex_11//page 484
4 mun=400 //mobility
5 L=4*10^-4
6 VT=1
7 VGS=3
8 fT=mun*(VGS-VT)/(2*pi*L^2)*10^-6
9 printf('The cut off frequency of this MOSFET with
    constant mobility is %1.0f MHz',fT)

```

Chapter 11

Metal semiconductors and semiconductor heterojunctions Additional concepts

Scilab code Exa 11.1 Mobility variation

```
1 // Chapter 11_ Metal-Oxide-Semiconductor Field
   Effect Transistor: Additional Concepts
2 //Caption_Mobility variation
3 //Ex_1//page 509
4 eps=11.7*8.85*10^-14
5 e=1.6*10^-19
6 T=300
7 Na=3*10^16
8 ni=1.5*10^10 //intrinsic carrier concentration
9 phi_fp=0.0259*log(Na/ni)
10 xdt=(4*eps*phi_fp/(e*Na))^0.5
11 QSD_MAX=e*Na*xdt;
12 Eeff=1/eps*QSD_MAX
13 printf('Effective electric field at threshold is %1
   .2f V/cm',Eeff)
```

Scilab code Exa 11.2 Mobility variation

```
1 // Chapter 11. Metal–Oxide–Semiconductor Field
  Effect Transistor: Additional Concepts
2 //Caption_Mobility variation
3 //Ex_2//page 517
4 Na=3*10^16
5 tox=450*10^-8
6 eps=11.7*8.85*10^-14
7 e=1.6*10^-19
8 eps_ox=3.9*8.85*10^-14
9 ni=1.5*10^10 //intrinsic carrier concentration
10 L=1.25*10^-4
11 rj=0.5*10^-4
12 Cox=eps_ox/tox //oxide capacitance
13 phi_fp=0.0259*log(Na/ni)
14 xdt=(4*eps*phi_fp/(e*Na))^0.5
15 x=e*Na*xdt/Cox
16 y=(1+(2*xdt/rj))^0.5-1
17 delVt=-x*(rj*y/L) //voltage shift
18
19 printf('Threshold voltage shift due to short channel
  effects is %1.3f V',delVt)
```

Scilab code Exa 11.3 narrow channel effects

```
1 // Chapter 11. Metal–Oxide–Semiconductor Field
  Effect Transistor: Additional Concepts
2 //Caption_Narrow channel effects
3 //Ex_3//page 520
4 e = 1.6*10^-19;
5 Na=3*10^16
```

```

6  tox=450*10^-8    //oxide thickness
7  fi=%pi/2        //fitting parameter
8  delVt=0.2
9  Cox=7.67*10^-8   //oxide capacitance
10 xdt=0.18*10^-4
11 W=10^4*e*Na*(fi*xdt^2)/(Cox*delVt)
12 printf('The channel width that will limit the
    threshold voltage is %1.2f micrometer',W)

```

Scilab code Exa 11.4 Breakdown voltage

```

1  // Chapter 11. Metal-Oxide-Semiconductor Field
    Effect Transistor: Additional Concepts
2  //Caption_Breakdown voltage
3  //Ex_4//page 527
4  eps=11.7*8.85*10^-14
5  e=1.6*10^-19;
6  Nd=10^19        //donor concentration
7  Na=10^16        //acceptor concentration
8  L=1.2*10^-4     //channel length
9  ni=1.5*10^10    //intrinsic carrier concentration
10 Vbi=0.0259*log(Na*Nd/ni^2)
11 xdo=(2*eps*Vbi/(e*Na))^0.5 //zero biased source-
    substrate pn junction width
12 //xd=(2*eps*(VbiVDS)/(e*Na))^0.5 //reverse biased
    drain substrate pn junction width
13 xd=L-xdo //at punch through
14 VbiVDS=xd^2*e*Na/(2*eps) //Vbi+VDS
15 VDS=VbiVDS-Vbi
16 printf('The punch through voltage is %1.1f V',VDS)

```

Scilab code Exa 11.5 Lightly doped drain transistor

```

1 // Chapter 11. Metal–Oxide–Semiconductor Field
  Effect Transistor:Additional Concepts
2 //Caption_Lightly doped drain transistor
3 //Ex_5//page 531
4 tox=500*10^-8
5 VFB0=-1.25 //initial flat band voltage
6 e=1.6*10^-19
7 eps_ox=3.9*8.85*10^-14
8 ni=1.5*10^10 //intrinsic carrier concentration
9 VT=0.70
10 Na=5*10^15
11 phi_fpo=0.0259*log(Na/ni)
12 xdto=(4*eps_ox*phi_fpo/(e*Na))^0.5
13 Cox=eps_ox/tox
14 VT0=VFB0+2*phi_fpo+(e*Na*xdto)/Cox
15 x=VT-VT0
16 Dt=Cox*x/e //implant dose
17 xt=0.15*10^-4 //depth to which uniform implant
  extends
18 Nsa=Dt/xt
19 Ns=Nsa+Na
20 printf('The required implant dose to achieve the
  desired threshold voltage is %1.2f per cm^2',Dt)

```

Scilab code Exa 11.6 Radiation and hot electron effect

```

1 // Chapter 11. Metal–Oxide–Semiconductor Field
  Effect Transistor:Additional Concepts
2 //Caption_Radition and hot electron effect
3 //Ex_6//page 535
4 tox=500*10^-8 //oxide thickness
5 p=0.2 //20% are trapped at oxide semiconductor
  surface
6 N=10^18 //electron hole pair
7 e=1.6*10^-19

```

```
8 eps_ox=3.9*8.85*10^-14
9 ni=1.5*10^10 //intrinsic carrier concentration
10 Nh=N*tox //areal density of holes
11 Qss=Nh*p //trapped surface charge density
12 Cox=eps_ox/tox
13 delVt=-Qss*e/Cox
14 printf('The threshold voltage shift due to radiation
induced oxide charge trapping is %1.2f V',delVt)
```

Chapter 12

The junction field effect transistor

Scilab code Exa 12.1 Device characteristics

```
1 // Chapter 12_The junction field effect transistor
2 //Caption_Device characteristics
3 //Ex_1//page 557
4 T=300
5 Na=10^18
6 e=1.6*10^-19
7 eps=8.85*10^-14*11.7
8 ni=1.5*10^10
9 Nd=10^16 //donor concentration
10 a=0.75*10^-4 //metallurgical channel thickness
11 Vpo=e*a^2*Nd/(2*eps) //internal pinch off
    voltage
12 Vbi=0.0259*log(Na*Nd/ni^2) //built in potential
    barrier
13 Vp=Vbi-Vpo //pinch off voltage
14 printf('The pinch off voltage of this n-channel JFET
    is %1.2fV',Vp)
```

Scilab code Exa 12.2 Device characteristics

```
1 // Chapter 12_The junction field effect transistor
2 //Caption_Device characteristics
3 //Ex_2//page 558
4 T=300
5 Nd=10^18
6 Na=2*10^16
7 e=1.6*10^-19
8 eps=8.85*10^-14*11.7
9 ni=1.5*10^10
10 Vp=2.25 //pinchoff voltage
11 Vbi=0.0259*log(Na*Nd/ni^2)
12 Vpo=Vp+Vbi
13 a=(2*eps*Vpo/(e*Na))^0.5*10^4
14 printf('Metallurgical channel thickness is %1.3f
micrometer ',a)
```

Scilab code Exa 12.3 Depletion mode JFET

```
1 // Chapter 12_The junction field effect transistor
2 //Caption_Depletion mode JFET
3 //Ex_3//page 558
4 T=300
5 Na=10^18
6 e=1.6*10^-19
7 eps=8.85*10^-14*11.7
8 Vbi=0.814
9 Vpo=4.35
10 ni=1.5*10^10
11 Nd=10^16
12 a=0.75*10^-4 //metallurgical channel thickness
```

```

13 L=10*10^-4 //channel length
14 W=30*10^-4 //channel width
15 mun=1000
16 Ipi=10^3*mun*(e*Nd)^2*W*a^3/(6*eps*L)
17 IDmax=Ipi*(1-3*(Vbi/Vpo)*(1-(2/3)*(Vbi/Vpo)^0.5))
18 printf('The maximum current is %1.3f mA while pinch
off current is %1.3f mA',IDmax,Ipi)

```

Scilab code Exa 12.4 Transconductance

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_Transconductance
3 //Ex_4//page 566
4 Ipi=0.522*10^-3
5 Vbi=0.814 //built in potential barrier
6 Vpo=4.35 //pinch off
7 VGS=0
8 gms_max=10^3*3*Ipi*(1-(Vbi/Vpo)^0.5)/Vpo
9 printf('The maximum transconductance is %1.3f mA/V',
gms_max)

```

Scilab code Exa 12.5 The MESFET

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_The MESFET
3 //Ex_5//page 567
4 Nc=4.7*10^17
5 e=1.6*10^-19
6 eps=8.85*10^-14*13.1
7 T=300
8 phi_bn=0.89 //barrier height
9 Nd=2*10^15
10 Vt=0.25

```

```

11 phi_n=0.0259*log(Nc/Nd)
12 Vbi=phi_bn-phi_n //built in potential barrier
13 Vpo=Vbi-Vt
14 a=10^4*(Vpo*2*eps/(e*Nd))^0.5
15 printf('The channel thickness of GaAs is %1.3 f
micrometer ',a)

```

Scilab code Exa 12.6 The MESFET

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_The MESFET
3 //Ex_6//page 568
4 e=1.6*10^-19
5 eps=8.85*10^-14*13.1
6 T=300
7 ni=1.8*10^6
8 Na=10^18
9 Nd=3*10^15
10 a=0.70*10^-4
11 Vbi=0.0259*log(Na*Nd/ni^2)
12 Vpo=e*a^2*Nd/(2*eps) //internal pinch off
voltage
13 Vt=Vbi-Vpo //threshold voltage
14 h=0.6*10^-4
15 VGS=Vbi-(e*h^2*Nd/(2*eps))
16 printf('The forward bias voltage required in an n
channel GaAs enhancement mode pn jfet to open up
a channel is %1.2 f V',VGS)

```

Scilab code Exa 12.7 The MESFET

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_The MESFET

```

```

3 //Ex_7//page 570
4 e=1.6*10^-19
5 eps=8.85*10^-14*13.1
6 T=300
7 ni=1.8*10^6
8 L=1.2*10^-4
9 mun=8000
10 a=0.70*10^-4
11 Idi=75*10^-6
12 VGS=0.5
13 Vt=0.24
14 kn=Idi/(VGS-Vt)^2 //conduction parameter
15 W=10^4*kn*2*a*L/(mun*eps)
16 printf('The required channel width is %1.2f
micrometer ',W)

```

Scilab code Exa 12.8 The MESFET channel length modulation

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_The MESFET-Channel length modulation
3 //Ex_8//page 573
4 Nd=3*10^15
5 eps=8.85*10^-14*11.7
6 L=10;
7 e = 1.6*10^-19;
8 ID1=4
9 VDSsat=0 //assume
10 VDS1=VDSsat+2
11 VDS2=VDSsat+2.5
12
13 delL2=10^4*(2*eps*(VDS2-VDSsat)/(e*Nd))^0.5 //
change in length
14 delL1=10^4*(2*eps*(VDS1-VDSsat)/(e*Nd))^0.5 //
change in length
15 //drain currents are

```

```

16 ID22=ID1*(L/(L-0.5*delL2))
17 ID11=ID1*(L/(L-0.5*delL1))
18 rds=(VDS2-VDS1)/(ID22-ID11)
19 printf('The small signal output resistance at the
    drain terminal due to channel length modulation
    effects is %1.1f kohm',rds)

```

Scilab code Exa 12.9 cut off frequency

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_Cutoff frequency
3 //Ex_9//page 579
4 e=1.6*10^-19
5 mun=1000
6 L=5*10^-4
7 eps=8.85*10^-14*11.7
8 a=0.60*10^-4
9 Nd=10^16
10 fT=(e*mun*Nd*a^2)/(2*pi*eps*L^2)*10^-9
11 printf('The cutoff frequency of silicon JFET with
    given parameters is %1.2f GHz',fT)

```

Scilab code Exa 12.10 High electron mobility transistor

```

1 // Chapter 12_The junction field effect transistor
2 //Caption_High electron mobility transistor
3 //Ex_10//page 585
4 Nd=10^18
5 d=20*10^-8
6 dd=500*10^-8 //thickness
7 phi_B=0.85
8 q=1.6*10^-19
9 VG=0

```

```
10 epsn=12.2 //relative dielectric constant
11 Vp2=q*Nd*dd^2/(2*epsn*8.85*10^-14) //a parameter
12 x=0.22 //x=del Ec/q
13 Voff=phi_B-x-Vp2 //threshold voltage
14 ns=(VG-Voff)*epsn*8.85*10^-14/(q*(dd+d+80*10^-8))
15 printf('The two dimensional electron concentration
is %1.2f cm^-2',ns)
```

Chapter 13

Optical devices

Scilab code Exa 13.1 Optical absorption

```
1 // Chapter 13_Optical Devices
2 //Caption_Optical absorption
3 //Ex_1//page 598
4 lambda1=1*10^-4 //incident wavelength
5 lambda2=0.5*10^-4
6 alpha1=100 //absorption coefficient
7 d1=1*log(1/0.1)/alpha1 //If 90percent of the
    incident flux is to be absorbed in a distance d ,
    then the flux emerging at x=d will be 10% of the
    incident flux
8 alpha2=10000
9 d2=1*log(1/0.1)/alpha2*10^4
10 printf('As the incident photon energy increases , the
    absorption coefficient increases rapidly since
    d1=%1.4 f cm and d2=%1.2 f micrometer ',d1,d2)
```

Scilab code Exa 13.2 Electron hole pair generation rate

```

1 // Chapter 13_Optical Devices
2 //Caption_Electron hole pair generation rate
3 //Ex_2//page 600
4 T=300
5 Ivx=0.05 //photon intensity
6 lambda=0.75 //wavelength
7 alpha=0.7*10^4 //absorption coefficient
8 h=1.24
9 v=1/lambda // v is the frequency
10 E=h*v //energy in eV,
11 g=alpha*Ivx/(1.6*10^-19*h*v) //generation rate of
    electron hole pair
12 tau=10^-7 //lifetime of minority carrier
13 deln=g*tau //excess carrier concentration
14 printf('The generation rate of electron hole pair is
    %1.2f cm^-3 s^-1',g)

```

Scilab code Exa 13.3 Solar cells

```

1 // Chapter 13_Optical Devices
2 //Caption_Solar cells
3 //Ex_3//page 602
4 Na=5*10^18
5 Nd=10^16
6 Dn=25
7 e=1.6*10^-19
8 ni=1.5*10^10
9 Dp=10
10 tau_no=5*10^-7
11 tau_po=10^-7
12 JL=15*10^-3 //photocurrent density
13 Ln=(Dn*tau_no)^0.5
14 Lp=(Dp*tau_po)^0.5
15 Js=e*(ni^2)*((Dn/(Ln*Na))+(Dp/(Lp*Nd)))
16 Voc=0.0259*log(1+JL/Js)

```

```
17 printf('Open circuit voltage of SI pn junction solar
    cell is %1.3f V',Voc)
```

Scilab code Exa 13.4 Solar concentration

```
1 // Chapter 13_Optical Devices
2 //Caption_Solar concentration
3 //Ex_4//page 605
4 JL=150*10^-3 //PHOTOCURRENT DENSITY
5 Js=3.6*10^-11 //reverse saturation current density
6 Voc=0.0259*log(1+JL/Js)
7 printf('Open circuit voltage when solar
    concentration is used is %1.3f V',Voc)
```

Scilab code Exa 14.4 Heat sinks and junction temperature

```
1 // Chapter 14_Semiconductor Power Devices
2 //Caption_Heat sinks and junction temperature
3 //Ex_4//page-663
4 P=20 //Rated power
5 Tj_max=175 //Junction temperature
6 TOC=25
7 Tamb=25 //ambient temperature
8 Theta_case_snk=1
9 Theta_snk_amb=5
10 Theta_dev_case=(Tj_max-TOC)/P
11 PD_MAX=(Tj_max-Tamb)/(Theta_dev_case+Theta_case_snk+
    Theta_snk_amb)
12 printf('Maximum power dissipated is %1.1f W',PD_MAX)
```

Scilab code Exa 13.5 Photo conductor

```
1 // Chapter 13_Optical Devices
2 //Caption_Photo conductor
3 //Ex_5//page 611
4 mup=480
5 mun=1350
6 L=100*10^-4 //length of photoconductor
7 A=10^-7 //cross sectional area
8 tau_p=10^-6 //minority carrier lifetime
9 V=10 //applied voltage
10 tn=L^2/(mun*V)
11 //photoconductor gain is
12 G=(tau_p/tn)*(1+(mup/mun))
13 printf('The photoconductor gain is %1.2f',G)
```

Scilab code Exa 13.6 Photo diode

```
1 // Chapter 13_Optical Devices
2 //Caption_Photodiode
3 //Ex_6//page 616
4 Na=10^16
5 eps=8.85*10^-14;
6 Nd=10^16
7 Dn=25
8 Dp=10
9 tau_no=5*10^-7
10 e=1.6*10^-19
11 ni=1.5*10^10
12 tau_po=10^-7
13 VR=5 //reverse bias voltage
14 GL=10^21 //generation rate of excess carriers
15 Ln=(Dn*tau_no)^0.5
16 Lp=(Dp*tau_po)^0.5
17 Vbi=0.0259*log(Na*Nd/ni^2)
```

```

18 W=((2*eps/e)*((Na+Nd)/(Na*Nd))*(Vbi+VR))^0.5
19 JL=e*(W+Ln+Lp)*GL
20 printf('The steady state photocurrent density is %1
    .2 f A/cm^2 ', JL)

```

Scilab code Exa 13.7 PIN Photodiode

```

1 // Chapter 13_Optical Devices
2 //Caption_PIN Photodiode
3 //Ex_7//page 618
4 e = 1.6*10^-19;
5 W=20*10^-4 //intrinsic region width
6 phio=10^17 //photon flux
7 alpha=10^3 //absorption coefficient
8 GL1=alpha*phio //generation rate of electron hole
    pair at the front region
9 GL2=GL1*exp(-alpha*W)
10 JL=1000*e*phio*(1-exp(-alpha*W)) //photocurrent
    density
11 printf('The photocurrent density in PIN photodiode
    is %1.1 f mA/cm^2 ', JL)

```

Scilab code Exa 13.8 Materials

```

1 // Chapter 13_Optical Devices
2 //Caption_Materials
3 //Ex_8//page 625
4 Eg=1.42
5 lambda=1.24/Eg //output wavelength of photon
6 lam=0.653 //desired wavelength
7 E=1.24/lam //bandgap energy

```

```
8 printf('The band gap energy corresponding to visible
    given wavelength is %1.2f eV and it would
    correspond to a mole fraction of x=4',E)
```

Scilab code Exa 13.9 Quantum efficiency

```
1 // Chapter 13_Optical Devices
2 //Caption_Quantum efficiency
3 //Ex_9//page 628
4 n2=3.666 //index of refraction in GaAs
5 n1=1 //index of refraction in air
6 T=((n2-n1)/(n2+n1))^2 //reflection coefficient
7 printf('The reflection coefficient at semiconductor-
    air interface is %1.2f',T)
```

Scilab code Exa 13.10 Quantum efficiency

```
1 // Chapter 13_Optical Devices
2 //Caption_Quantum efficiency
3 //Ex_10//page 629
4 n2=3.66 //index of refraction in GaAs
5 n1=1 //index of refraction in air
6 theta=asind(n1/n2)
7 printf('The critical angle at semiconductor-air
    interface is %1.1f degree',theta)
```

Chapter 14

Semiconductor Power Devices

Scilab code Exa 14.1 Power transistor characteristics

```
1 // Chapter 14_Semiconductor Power Devices
2 //Caption_Power transistor characteristics
3 //Ex_1//page-651
4 RL=10
5 Vcc=35
6 Ic_max=Vcc/RL
7 Ic=Vcc/(2*RL)
8 VCE=Vcc-Ic*RL //Collector emitter voltage at
   maximum power point
9 PT=VCE*Ic //Maximum transistor power dissipation
10 printf('The maximum power dissipation in transistor
   occurs at centre of the load line. The maximum
   power dissipation is therefore %1.1f W',PT)
```

Scilab code Exa 14.2 Power MOSFET characteristics

```
1 // Chapter 14_Semiconductor Power Devices
2 //Caption_Power MOSFET characteristics
```

```

3 //Ex_2//page-658
4 VDD=24
5 PT=30 //Maximum rated power
6 ID1max=5 //Maximum rated current
7 ID2max=4
8 RD1=VDD/ID1max //Drain resistance
9 RD2=VDD/ID2max
10 ID1=VDD/(2*RD1) //Current at the maximum power
    point
11 ID2=VDD/(2*RD2)
12 VDS1=VDD-ID1*RD1 //Drain to source voltage
13 VDS2=VDD-ID2*RD2
14 P1=VDS1*ID1 //Maximum power that may be dissipated
    in transistor
15 P2=VDS2*ID2
16 printf('The maximum dissipated power in first case
    is %1.0f W which corresponds to the maximum rated
    power while in second case is %1.0f W which is
    less than the maximum rated power',P1,P2)

```

Scilab code Exa 14.3 Heat sinks and junction temperature

```

1 // Chapter 14_Semiconductor Power Devices
2 //Caption_Heat sinks and junction temperature
3 //Ex_3//page-662
4 Theta_dev_case=1.75
5 Theta_case_snk=1
6 Theta_snk_amb=5
7 Theta_case_amb=50
8 Tamb=30 //Ambient temperature
9 Tdev=150 //maximum junction or device temperature
10 PD_max=(Tdev-Tamb)/(Theta_dev_case+Theta_case_amb)
    //when no heat sink is used
11 PD_MAX2=(Tdev-Tamb)/(Theta_dev_case+Theta_case_snk+
    Theta_snk_amb)

```

```
12 printf('Maximum power dissipated when no sink was  
    used is %1.2f W while with the sink is %1.2f W  
    which is more than the previous case. Thus use of  
    heat sink allows more power to be dissipated in  
    the device.', PD_max, PD_MAX2)
```
