Scilab Textbook Companion for Engineering Physics (Volume 2) by Dr. K. V. Kumar[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 1

Quantum Mechanics and Quantum Computing

Scilab code Exa 1.1 To calculate the de Broglie wavelength

```
1  clc();
2  clear;
3  // To calculate the de Broglie wavelength
4  c=3*10^8;    //velocity of light in m/s
5  v=c/10;    //velocity of proton in m/s
6  m=1.67*10^(-27);     //mass of proton in kg
7  h=6.626*10^(-34);
8  lamda=h/(m*v);    //de Broglie wavelength
9  printf("The de Broglie wavelength in metres is");
10 disp(lamda);
```

Scilab code Exa 1.2 To calculate the de Broglie wavelength of an electron

```
1  clc();
2  clear;
3  // To calculate the de Broglie wavelength of an
      electron
```

```
4 V=400;   //potential in Volts
5 lamda=12.56/sqrt(V);    //de Broglie wavelength
6 printf("The de Broglie wavelength is %f Armstrong",
     lamda);
7
8 //answer given in the book is wrong
```

Scilab code Exa 1.3 To calculate the de Broglie wavelength of neutron

```
1 clc();
2 clear;
3 // To calculate the de Broglie wavelength of neutron
4 m=1.674*10^(-27);    //mass of neutron in kg
5 h=6.626*10^(-34);
6 E=0.025;   //kinetic energy in eV
7 Ej=E*1.6*10^-19;   //kinetic energy in J
8 lamda=h/sqrt(2*m*Ej);   //de Broglie wavelength
9 printf("The de Broglie wavelength in metres is");
10 disp(lamda);
11 lamdaA=lamda*10^10;   //converting wavelength from m
     to Armstrong
12 printf("The de Broglie wavelength is %f Armstrong",
     lamdaA);
```

Scilab code Exa 1.4 To calculate the wavelength of an electron

```
1
2 clc();
3 clear;
4 // To calculate the wavelength of an electron
5 V=1600;   //potential in Volts
6 lamda=12.26/sqrt(V);    //de Broglie wavelength
```

```
7 printf("The de Broglie wavelength is %3.1f Angstrom"
    ,lamda);
```

Scilab code Exa 1.5 To calculate the uncertainity in momentum

```
1 clc();
2 clear;
3 // To calculate the uncertainity in momentum
4 deltax=0.2;   //distance in armstrong
5 delta_xm=deltax*10^-10;    //distance in m
6 h=6.626*10^(-34);
7 delta_p=h/(2*%pi*delta_xm);
8 printf("The uncertainity in momentum of electron in
    kg m/sec is");
9 disp(delta_p);
```

Scilab code Exa 1.6 To calculate the lowest energy of electron

```
1 clc();
2 clear;
3 // To calculate the lowest energy of electron
4 n1=1;
5 n2=1;
6 n3=1;    //values in lowest energy
7 h=6.62*10^(-34);
8 M=9.1*10^-31;   //mass in kg
9 L=0.1;   //side in nm
10 L=L*10^-9;    //side in m
11 n=(n1^2)+(n2^2)+(n3^2);
12 E1=(n*h^2)/(8*M*L^2);    //energy in j
13 E1eV=E1/(1.6*10^-19);    //energy in eV
14 printf("lowest energy of electron in Joule is");
15 disp(E1);
```

```
16 printf("lowest energy of electron is %f eV",E1eV);
17
18 //answer for lowest energy in eV given in the book
     is wrong
```

Scilab code Exa 1.7 To calculate the wavelength associated with electron

```
1  clc();
2  clear;
3  // To calculate the wavelength associated with
     electron
4  M=9.1*10^-31;     //mass of electron in kg
5  h=6.66*10^(-34);
6  E=2000;    //energy in eV
7  Ej=E*1.6*10^-19;    //energy in J
8  lamda=h/sqrt(2*M*Ej);    //wavelength in m
9  lamda_nm=lamda*10^9;     //converting lamda from m to
     nm
10 printf("The wavelength associated with electron is
     %f nm",lamda_nm);
```

Scilab code Exa 1.8 To calculate the minimum energy of electron

```
1  clc();
2  clear;
3  // To calculate the minimum energy of electron
4  n=1;     //for minimum energy
5  h=6.626*10^(-34);
6  m=9.1*10^-31;    //mass in kg
7  L=4*10^-10;    //size in m
8  E1=(n*h^2)/(8*m*L^2);     //energy in j
9  printf("lowest energy of electron in Joule is");
10 disp(E1);
```

```
11
12 //answer given in the book is wrong
```

Scilab code Exa 1.9 To calculate the velocity and kinetic energy of electron

```
1  clc();
2  clear;
3  // To calculate the velocity and kinetic energy of
       electron
4  h=6.626*10^(-34);
5  m=9.1*10^-31;    //mass in kg
6  lamda=1.66*10^-10;    //wavelength in m
7  v=h/(m*lamda);     //velocity in m/sec
8  printf("velocity of electron in m/sec is");
9  disp(v);
10 v_km=v*10^-3;     //velocity in km/sec
11 printf("velocity of electron is %f km/sec",v_km);
12 E=(1/2)*m*v^2;     //kinetic energy in joule
13 EeV=E/(1.6*10^-19);     //energy in eV
14 printf("kinetic energy of electron in Joule is");
15 disp(E);
16 printf("kinetic energy of electron is %f eV",EeV);
```

Scilab code Exa 1.10 To calculate the wavelength of an electron

```
1  clc();
2  clear;
3  // To calculate the wavelength of an electron
4  V=15;    //potential in kV
5  V=V*10^3;     //potential in V
6  lamda=12.26/sqrt(V);     //de Broglie wavelength
```

```
7 printf("The de Broglie wavelength is %f Armstrong",
    lamda);
```

Scilab code Exa 1.11 To calculate the de Broglie wavelength of neutron

```
1 clc();
2 clear;
3 // To calculate the de Broglie wavelength of neutron
4 m=1.675*10^(-27);    //mass of neutron in kg
5 h=6.626*10^(-34);
6 E=10;   //kinetic energy in keV
7 EeV=E*10^3;    //Energy in eV
8 Ej=EeV*1.6*10^-19;   //kinetic energy in J
9 v=sqrt(2*Ej/m);   //velocity in m/s
10 printf("The velocity in m/sec is");
11 disp(v);
12 lamda=h/(m*v);    //de broglie wavelength in m
13 printf("The de Broglie wavelength in metres is");
14 disp(lamda);
15 lamda_A=lamda*10^10;   //de broglie wavelength in
    armstrong
16 printf("The de Broglie wavelength is %f Armstrong",
    lamda_A);
```

Scilab code Exa 1.12 To calculate the de Broglie wavelength of electron

```
1 clc();
2 clear;
3 // To calculate the de Broglie wavelength of
    electron
4 m=9.1*10^-31;    //mass of electron in kg
5 h=6.6*10^(-34);
6 E=2;   //kinetic energy in keV
```

```
7  EeV=E*10^3;     //Energy in eV
8  Ej=EeV*1.6*10^-19;    //kinetic energy in J
9  p=sqrt(2*m*Ej);     //momentum
10 lamda=h/p;     //de broglie wavelength in m
11 printf("The de Broglie wavelength in metres is");
12 disp(lamda);
13 lamda_A=lamda*10^10;    //de broglie wavelength in
      armstrong
14 printf("The de Broglie wavelength is %f Armstrong",
      lamda_A);
```

Scilab code Exa 1.13 To calculate the wavelength of thermal neutron

```
1  clc();
2  clear;
3  // To calculate the wavelength of thermal neutron
4  m=1.676*10^(-27);     //mass of neutron in kg
5  h=6.62*10^(-34);
6  E=0.025;    //kinetic energy in eV
7  Ej=E*1.6*10^-19;    //kinetic energy in J
8  v=sqrt(2*Ej/m);    //velocity in m/s
9  lamda=h/(m*v);     //wavelength in m
10 printf("The neutrons wavelength in metres is");
11 disp(lamda);
12 lamda_A=lamda*10^10;    //de broglie wavelength in
      armstrong
13 printf("The wavelength is %f Armstrong",lamda_A);
```

Scilab code Exa 1.14 To calculate the wavelength of an electron

```
1  clc();
2  clear;
3  // To calculate the wavelength of an electron
```

```
4 V=10;    //potential in kV
5 V=V*10^3;    //potential in V
6 lamda=12.26/sqrt(V);     //wavelength
7 printf("The wavelength is %f Armstrong",lamda);
```

Scilab code Exa 1.15 To calculate the first three permitted levels of electron

```
1 clc();
2 clear;
3 // To calculate the first three permitted levels of
     electron
4 h=6.626*10^(-34);
5 m=9.1*10^-31;    //mass in kg
6 L=1;     //width in armstrong
7 L=L*10^-10;    //width in m
8 //permitted electron energies En=(n^2*h^2)/(8*m*L^2)
9 //let X = h^2/(8*m*L^2)
10 X = h^2/(8*m*L^2);     //energy in J
11 XeV=X/(1.6*10^-19);    //energy in eV
12 //in the 1st level n1=1
13 n1=1;
14 E1=(n1^2)*XeV;     //energy in eV
15 printf("minimum energy the electron can have is %f
     eV",E1);
16 //in second level n2=2
17 n2=2;
18 E2=(n2^2)*XeV;     //energy in eV
19 //in third level n3=
20 n3=3;
21 E3=(n3^2)*XeV;     //energy in eV
22 printf("other values of energy are %f eV and %f eV",
     E2,E3);
23
24 //answers given in the book are wrong
```

Scilab code Exa 1.16 To calculate the probability of finding the particle

```
clc();
clear;
// To calculate the probability of finding the
   particle
n=1;    //lowest state
L=10;     //width in armstrong
L=L*10^-10;     //width in m
x=L/2;
delta_x=1;     //interval in armstrong
delta_x=delta_x*10^-10;     //interval in m
psi1=(sqrt(2/L))*sin(%pi*x/L);
A=psi1^2;
P=A*delta_x;
printf("probability of finding the particle is %f",P
   );
```

Scilab code Exa 1.17 To calculate the Fermi energy of the metal

```
clc();
clear;
// To calculate the Fermi energy of the metal
d=970;    //density of Na in kg/m^3
n=6.02*10^26;
h=6.62*10^(-34);
m=9.1*10^-31;    //mass in kg
w=23;    //atomic weight
N=(d*n)/w;    //number of atoms per m^3
A=(h^2)/(8*m);
B=(3*N)/%pi;
```

```
Ef=A*B^(2/3);
EfeV=Ef/(1.6*10^-19);
printf("fermi energy of Na is %f eV",EfeV);
```

Scilab code Exa 1.18 To calculate the lowest energy of electron

```
clc();
clear;
// To calculate the lowest energy of electron
n1=1;
n2=1;
n3=1;    //values in lowest energy
h=6.62*10^(-34);
m=9.1*10^-31;   //mass in kg
L=0.1;   //side in nm
L=L*10^-9;    //side in m
n=(n1^2)+(n2^2)+(n3^2);
E1=(n*h^2)/(8*m*L^2);    //energy in j
E1eV=E1/(1.6*10^-19);    //energy in eV
printf("lowest energy of electron in Joule is");
disp(E1);
printf("lowest energy of electron is %f eV",E1eV);
```

Scilab code Exa 1.19 To calculate the de broglie wavelength of neutron

```
clc();
clear;
// To calculate the de broglie wavelength of neutron
mn=1.676*10^-27;   //mass of neutron in kg
me=9.1*10^-31;    //mass of electron in kg
h=6.62*10^(-34);
c=3*10^8;    //velocity of light in m/sec
En=2*me*c^2;
```

```
lamda=h/sqrt(2*mn*En);    //wavelength in m
lamda_A=lamda*10^10;     //converting lamda from m to
    A
printf("The de broglie wavelength is %f Angstrom",
   lamda_A);
```

Scilab code Exa 1.20 To calculate the energies of electron

```
clc();
clear;
// To calculate the energies of electron
n2=2;     //second quantum state
n4=4;     //fourth quantum state
h=6.626*10^-34;
m=9.1*10^-31;    //mass in kg
a=2;    //potential box length in armstrong
a=a*10^-10;     //length in m
A=n2^2*h^2;
B=8*m*a^2;
E2=A/B;     //energy in j
E2eV=E2/(1.6*10^-19);     //energy in eV
C=n4^2*h^2;
E4=C/B;     //energy in j
E4eV=E4/(1.6*10^-19);     //energy in eV
printf("energy corresponding to second quantum state
    in Joule is");
disp(E2);
printf("energy corresponding to second quantum state
    in eV is");
disp(E2eV);
printf("energy corresponding to fourth quantum state
    in Joule is");
disp(E4);
printf("energy corresponding to fourth quantum state
    in eV is");
```

```
24 disp(E4eV);
25
26 //answers given in the book are wrong
```

Scilab code Exa 1.21 To calculate the spacing of the crystal

```
1 clc();
2 clear;
3 // To calculate the spacing of the crystal
4 V=344;    //accelerated voltage in V
5 n=1;     //first reflection
6 theta=60;    //glancing angle in degrees
7 lamda=12.27/sqrt(V);
8 d=(n*lamda)/(2*sind(theta));
9 printf("The spacing of the crystal is %f Angstrom",d
   );
```

Scilab code Exa 1.22 To calculate the energies of electron

```
1 clc();
2 clear;
3 // To calculate the energies of electron
4 n2=2;     //second quantum state
5 n3=3;     //fourth quantum state
6 h=6.626*10^-34;
7 m=9.1*10^-31;    //mass in kg
8 a=1*10^-10;     //width of potential well in m
9 B=8*m*a^2;
10 E1=h^2/B;    //ground state energy
11 E1eV=E1/(1.6*10^-19);     //energy in eV
12 A=n2^2*h^2;
13 E2=A/B;     //energy in j
14 E2eV=E2/(1.6*10^-19);     //energy in eV
```

```
C=n3^2*h^2;
E3=C/B;     //energy in j
E3eV=E3/(1.6*10^-19);     //energy in eV
printf("ground state energy in Joule is");
disp(E1);
printf("ground state energy in eV is");
disp(E1eV);
printf("first energy state in eV is");
disp(E2eV);
printf("second energy state in eV is");
disp(E3eV);

//answers given in the book are wrong by one decimal
```

Scilab code Exa 1.23 To calculate the energy required to jump an electron

```
clc();
clear;
// To calculate the energy required to jump an
   electron
n3=3;     //fourth quantum state
h=6.626*10^-34;
m=9.1*10^-31;    //mass in kg
//ground state energy E1 = h^2/(8*m*a^2)
//second excited state E3 = (9*h^2)/(8*m*a^2)
//required energy E = E3-E1
//E = (9*h^2)/(8*m*a^2) - h^2/(8*m*a^2)
//E = (h^2/(8*m*a^2))*(9-1)
//therefore E = (8*h^2)/(8*m*a^2)
//hence E = (h^2)/(m*a^2)
```

Scilab code Exa 1.24 To calculate the minimum uncertainity in velocity

```
clc();
clear;
// To calculate the minimum uncertainity in velocity
delta_x=10^-8;    //length of box in m
h=6.626*10^-34;
m=9.1*10^-31;    //mass in kg
delta_v=h/(m*delta_x);     //uncertainity in m/sec
delta_vk=delta_v*10^-3;    //uncertainity in km/sec
printf("minimum uncertainity in velocity is %f m/sec
   ",delta_v);
printf("minimum uncertainity in velocity is %f km/
   sec",delta_vk);
```

Scilab code Exa 1.25 To calculate the de broglie wavelength of proton

```
clc();
clear;
// To calculate the de broglie wavelength of proton
mp=1.6*10^-27;    //mass of proton in kg
me=9.1*10^-31;     //mass of electron in kg
h=6.626*10^(-34);
c=3*10^10;     //velocity of light in m/sec
Ep=me*c^2;
lamda=h/sqrt(2*mp*Ep);    //wavelength in m
lamda_A=lamda*10^10;     //converting lamda from m to
    A
printf("The de broglie wavelength in Angstrom is");
disp(lamda_A);
```

Scilab code Exa 1.26 To calculate the glancing angle

```
clc();
clear;
```

```
// To calculate the glancing angle
m=1.675*10^(-27);     //mass of neutron in kg
h=6.626*10^(-34);
n=1;    //diffractive order
d=0.314;    //spacing in nm
d=d*10^-9;    //spacing in m
E=0.04;    //kinetic energy in eV
Ej=E*1.6*10^-19;    //kinetic energy in J
lamda=h/sqrt(2*m*Ej);    //de Broglie wavelength
lamdaA=lamda*10^9;    //converting wavelength from m
   to nm
theta=asind((n*lamda)/(2*d));
printf("The de Broglie wavelength in metres is");
disp(lamda);
printf("The de Broglie wavelength is %f nm",lamdaA);
printf("glancing angle is %f degrees",theta);

//answer given in the book is wrong
```

Chapter 2

Electron Theory of Metals

Scilab code Exa 2.1 To calculate the Fermi function

```
1 clc();
2 clear;
3 // To calculate the Fermi function
4 // given that E-Ef = kT
5 // fermi function FE = 1/(1+exp((E-Ef)/kT)
6 // therefore FE = 1/(1+exp(kT/kT));
7 // FE = 1/(1+exp(1))
8 FE=1/(1+exp(1));
9 printf("fermi function is %f",FE);
```

Scilab code Exa 2.2 To calculate the Fermi function

```
1 clc();
2 clear;
3 // To calculate the Fermi function
4 // given that E-Ef = kT
5 // fermi function FE = 1/(1+exp((E-Ef)/kT)
6 // therefore FE = 1/(1+exp(kT/kT));
```

```
7 // FE = 1/(1+exp(1))
8 FE=1/(1+exp(1));
9 printf("fermi function is %f",FE);
```

Scilab code Exa 2.3 To calculate the temperature

```
1 clc();
2 clear;
3 // To calculate the temperature
4 FE=10/100;     //fermi function is 10%
5 Ef=5.5;    //fermi energy of silver in eV
6 k=1.38*10^-23;
7 E=Ef+(Ef/100);
8 //FE=1/(1+exp((E-Ef)/(k*T)))
9 //therefore 1/FE = 1+exp((E-Ef)/(k*T))
10 //therefore (1/FE)-1 = exp((E-Ef)/(k*T))
11 //therefore log((1/FE)-1) = (E-Ef)/(k*T)
12 //therefore T = (E-Ef)/(k*log((1/FE)-1))
13 //let X=E-Ef;
14 X=E-Ef;      //energy in eV
15 X=X*1.6*10^-19;     //energy in J
16 T = (X/(k*log((1/FE)-1)));
17 printf("temperature is %f K",T);
```

Scilab code Exa 2.4 To calculate the temperature

```
1 clc();
2 clear;
3 // To calculate the temperature
4 //let X=E-Ef
5 X=0.5;    //E-Ef=0.5 in eV
6 X=X*1.6*10^-19;    //X in J
7 FE=1/100;     //fermi function is 1%
```

```
k=1.38*10^-23;
//FE=1/(1+exp(X/(k*T)))
//therefore 1/FE = 1+exp(X/(k*T))
//therefore (1/FE)-1 = exp(X/(k*T))
//therefore log((1/FE)-1) = X/(k*T)
//but log(x) = 2.303*log10(x)
//therefore T = X/(k*log((1/FE)-1))
//but log(x)=2.303*log10(x)
//therefore T = X/(k*2.303*log10((1/FE)-1))
T = X/(k*2.303*log10((1/FE)-1));
printf("temperature is %f K",T);
```

Scilab code Exa 2.5 To calculate the density and mobility of electrons in silver

```
clc();
clear;
// To calculate the density and mobility of
   electrons in silver
rho_s=10.5*10^3;    //density in kg/m^3
NA=6.02*10^26;     //avagadro number per kmol
MA=107.9;
n=(rho_s*NA)/MA;
sigma=6.8*10^7;
e=1.6*10^-19;    //charge in coulomb
mew=sigma/(n*e);
printf("density of electrons is");
disp(n);
printf("mobility of electrons in silver is %f m^2/Vs
   ",mew);
```

Scilab code Exa 2.6 To calculate the mobility and average time of collision of electrons

```
clc();
clear;
// To calculate the mobility and average time of
   collision of electrons
d=8.92*10^3;    //density in kg/m^3
rho=1.73*10^-8;    //resistivity in ohm-m
m=9.1*10^-31;     //mass in kg
w=63.5;     //atomic weight
e=1.6*10^-19;     //charge in coulomb
A=6.02*10^26;     //avagadro number
n=(d*A)/w;
mew=1/(rho*n*e);
tow=m/(n*(e^2)*rho);
printf("mobility of electrons in Copper is %f m/Vs",
   mew);
printf("average time of collision of electrons in
   copper in sec is");
disp(tow);
```

Scilab code Exa 2.7 To calculate the relaxation time of conduction electrons

```
clc();
clear;
// To calculate the relaxation time of conduction
   electrons
rho=1.54*10^-8;     //resistivity in ohm-m
n=5.8*10^28;    //electron/m^3
m=9.108*10^-31;    //mass in kg
e=1.602*10^-19;    //charge in coulomb
tow=m/(n*(e^2)*rho);
printf("relaxation time of conduction electrons in
   sec is");
disp(tow);
```

Scilab code Exa 2.8 To calculate the temperature

```
clc();
clear;
// To calculate the temperature
FE=10/100;     //fermi function is 10%
Ef=5.5;    //fermi energy of silver in eV
k=1.38*10^-23;
E=Ef+(Ef/100);
//FE=1/(1+exp((E-Ef)/(k*T)))
//therefore 1/FE = 1+exp((E-Ef)/(k*T))
//therefore (1/FE)-1 = exp((E-Ef)/(k*T))
//therefore log((1/FE)-1) = (E-Ef)/(k*T)
//therefore T = (E-Ef)/(k*log((1/FE)-1))
//let X=E-Ef;
X=E-Ef;      //energy in eV
X=X*1.6*10^-19;     //energy in J
T = (X/(k*log((1/FE)-1)));
printf("temperature is %f K",T);
```

Scilab code Exa 2.9 To calculate the Fermi distribution function

```
clc();
clear;
// To calculate the Fermi distribution function
// given that E-Ef = kT
// fermi function FpE = 1/(1+exp((E-Ef)/kT)
// therefore FpE = 1/(1+exp(kT/kT));
// FpE = 1/(1+exp(1))
FpE=1/(1+exp(1));
printf("fermi function is %f",FpE);
```

```
10 //the presence of electron at that energy level is
      not certain
```

Scilab code Exa 2.10 To calculate the number of states per unit volume

```
1  clc();
2  clear;
3  // To calculate the number of states per unit volume
4  m=9.1*10^-31;    //mass in kg
5  h=6.626*10^-34;
6  A=(8*m)^(3/2);
7  B=%pi/(2*h^3);
8  EfeV=3.10;     //fermi energy in eV
9  Ef=EfeV*1.6*10^-19;     //fermi energy in J
10 EFeV=EfeV+0.02;     //energy after interval in eV
11 EF=EFeV*1.6*10^-19;     //energy after interval in J
12 function Q=f(E),Q=A*B*sqrt(E),endfunction
13 I=intg(Ef,EF,f)
14 printf("number of energy states per unit volume is")
      ;
15 disp(I);
```

Scilab code Exa 2.11 To calculate the mean free path of electron

```
1  clc();
2  clear;
3  // To calculate the mean free path of electron
4  T=300;    //temperature in K
5  n=8.5*10^28;    //density per m^3
6  rho=1.69*10^-8;    //resistivity in ohm/m^3
7  me=9.11*10^-31;     //mass of electron in kg
8  e=1.6*10^-19;     //charge in coulomb
9  KB=1.38*10^-23;     //boltzmann constant in J/k
```

```
10 lamda=sqrt(3*KB*me*T)/(n*(e^2)*rho);
11 printf("mean free path of electron in m is");
12 disp(lamda);
13
14 //answer given in the book is wrong
```

Scilab code Exa 2.12 To calculate the relaxation time of conduction electrons

```
1 clc();
2 clear;
3 // To calculate the relaxation time of conduction
     electrons
4 rho=1.43*10^-8;     //resistivity in ohm-m
5 n=6.5*10^28;    //electron/m^3
6 m=9.11*10^-34;    //mass in kg
7 e=1.6*10^-19;    //charge in coulomb
8 tow=m/(n*(e^2)*rho);
9 printf("relaxation time of conduction electrons in
     sec is");
10 disp(tow);
```

Scilab code Exa 2.13 To calculate the mobility and average time of collision of electrons

```
1 clc();
2 clear;
3 // To calculate the mobility and average time of
     collision of electrons
4 d=8.92*10^3;    //density in kg/m^3
5 rho=1.73*10^-8;    //resistivity in ohm-m
6 m=9.1*10^-31;     //mass in kg
7 M=63.5;     //atomic weight
```

```
e=1.6*10^-19;     //charge in coulomb
A=6.02*10^26;     //avagadro number
n=(d*A)/M;
mew=1/(rho*n*e);
tow=m/(n*(e^2)*rho);
printf("mobility of electrons in Copper is %f m/Vs",
   mew);
printf("average time of collision of electrons in
   copper in sec is");
disp(tow);
```

Scilab code Exa 2.14 To calculate the order of magnitude of velocity of molecules

```
clc();
clear;
// To calculate the order of magnitude of velocity
   of molecules
MH=1.008*2*1.67*10^-27;     //mass in kg
T=30;    //temperature in C
T=T+273;     //temperature in K
KB=1.38*10^-23;     //boltzmann constant in J/k
KE=(3/2)*KB*T;    //kinetic energy in J
KEeV=KE*6.24*10^18;    //kinetic energy in eV
cbar=sqrt((3*KB*T)/MH);
printf("average kinetic energy in J is");
disp(KE);
printf("average kinetic energy in eV is");
disp(KEeV);
printf("velocity of molecules is %f m/s",cbar);

//answers for average kinetic energy in eV and
   velocity of electrons given in the book are wrong
```

Scilab code Exa 2.15 To calculate the velocity of an electron and proton

```
clc();
clear;
// To calculate the velocity of an electron and
   proton
Ee=10;   //electron kinetic energy in eV
EeeV=Ee*1.6*10^-19;   //electron kinetic energy in J
Ep=10;   //proton kinetic energy in eV
EpeV=Ep*1.6*10^-19;   //proton kinetic energy in J
me=9.1*10^-31;   //mass of electron in kg
mp=1.67*10^-27;   //mass of proton in kg
cebar=sqrt((2*EeeV)/me);
cpbar=sqrt((2*EpeV)/mp);
printf("velocity of electron in m/s is");
disp(cebar);
printf("velocity of proton in m/s is");
disp(cpbar);

//answers given in the book are wrong
```

Scilab code Exa 2.16 To calculate the drift velocity of free electrons

```
clc();
clear;
// To calculate the drift velocity of free electrons
A=10;   //area of cross section in mm^2
A=A*10^-6;   //area of cross section in m^2
i=100;   //current in amp
n=8.5*10^28;    //number of electrons per mm^3
e=1.6*10^-19;    //electron charge in coulumb
vd=1/(n*A*e);
```

```
10 printf("drift velocity is %f m/s",vd);
11
12 //answer given in the book is wrong
```

Scilab code Exa 2.17 To calculate the thermal conductivity of copper

```
1  clc();
2  clear;
3  // To calculate the thermal conductivity of copper
4  tow=3*10^-14;     //relaxation time in sec
5  n=8*10^28;     //density of electrons per m^3
6  KB=1.38*10^-23;    //boltzmann constant in J/k
7  T=0;    //temperature in C
8  T=T+273;    //temperature in K
9  m=9.1*10^-31;    //mass of electron in kg
10 sigma_T=((3*n*tow*(KB^2)*T)/(2*m));
11 printf("thermal conductivity of copper is %f ohm-1",
      sigma_T);
```

Chapter 4

Magnetic Properties

Scilab code Exa 4.1 To calculate the relative permeability of iron

```
1  clc();
2  clear;
3  // To calculate the relative permeability of iron
4  H=6.5*10^-4;     //magnetic field in T
5  M=1.4;      //field with iron
6  chi=M/H;
7  mew_r=1+chi;
8  printf("relative permeability of iron is %f",mew_r);
9
10 //answer given in the book is wrong
```

Scilab code Exa 4.2 To calculate the relative permeability of ferromagnetic material

```
1  clc();
2  clear;
3  // To calculate the relative permeability of
      ferromagnetic material
```

```
4 H=220;      //field in amp/m
5 M=3300;     //magnetisation in amp/m
6 chi=M/H;
7 mew_r=1+chi;
8 printf("relative permeability is %f",mew_r);
```

Scilab code Exa 4.3 To calculate the change in magnetic moment

```
1 clc();
2 clear;
3 // To calculate the change in magnetic moment
4 r=5.29*10^-11;      //radius of orbit in m
5 B=2;     //applied field in Tesla
6 e=1.602*10^-19;    //charge of electron in coulomb
7 m=9.108*10^-31;     //mass of electron in kg
8 mew=(e^2)*(r^2)*B/(4*m);
9 printf("magnetic moment in Am^2 is");
10 disp(mew);
```

Scilab code Exa 4.4 To calculate the intensity of magnetisation and flux density

```
1 clc();
2 clear;
3 // To calculate the intensity of magnetisation and
    flux density
4 chi=0.5*10^-5;     //susceptibility
5 H=10^6;       //field strength in amp/m
6 mew_0=4*%pi*10^-7;
7 I=chi*H;
8 B=mew_0*(I+H);
9 printf("intensity of magnetisation is %f Amp/m",I);
10 printf("flux density is %f Weber/m^2",B);
```

Scilab code Exa 4.5 To calculate the average number of bohr magnetons

```
clc();
clear;
// To calculate the average number of bohr magnetons
e=2.86;     //edge in armstrong
e=e*10^-10;          //edge in m
Is=1.76*10^6;     //magnetisation in amp/m
mewB=9.27*10^-24;    //1 bohr magneton in amp m^2
N=2/(e^3);     //density per m^3
mewbar=Is/N;
mew_bar=mewbar/mewB;
printf("average dipole moment is %f mewB",mew_bar);
```

Scilab code Exa 4.6 To calculate the magnetisation and flux density

```
clc();
clear;
// To calculate the magnetisation and flux density
H=10^6;     //magnetic field in amp/m
chi=1.5*10^-3;      //susceptibility
mew_0=4*%pi*10^-7;
M=chi*H;
B=mew_0*(M+H);
printf("magnetisation is %f Amp/m",M);
printf("flux density is %f Tesla",B);

//answer for flux density given in the book is wrong
```

Scilab code Exa 4.7 To calculate the magnetisation and flux density

```
clc();
clear;
// To calculate the magnetisation and flux density
chi=3.7*10^-3;     //susceptibility
H=10^4;       //field strength in amp/m
mew_0=4*%pi*10^-7;
M=chi*H;
B=mew_0*(M+H);
printf("magnetisation is %f Amp/m",M);
printf("flux density is %f Weber/m^2",B);

//answer for flux density given in the book is wrong
```

Scilab code Exa 4.8 To calculate the change in magnetic moment

```
clc();
clear;
// To calculate the change in magnetic moment
r=0.052*10^-9;      //radius of orbit in m
B=1;     //magnetic field in Wb/m^2
e=1.6*10^-19;    //charge of electron in coulomb
m=9.1*10^-31;     //mass of electron in kg
dmew=(e^2)*(r^2)*B/(4*m);
printf("magnetic moment in Am^2 is");
disp(dmew);

//answer given in the book is wrong
```

Scilab code Exa 4.9 To calculate the intensity of magnetisation and flux density

```
clc();
clear;
// To calculate the intensity of magnetisation and
   flux density
chi=-0.5*10^-5;     //susceptibility
H=9.9*10^4;       //field strength in amp/m
mew_0=4*%pi*10^-7;
I=chi*H;
B=mew_0*H*(1+chi);
printf("intensity of magnetisation is %f Amp/m",I);
printf("flux density in Weber/m^2 is");
disp(B);

//answer for flux density given in the book is wrong
```

Scilab code Exa 4.10 To calculate the flux density at centre and dipole moment

```
clc();
clear;
// To calculate the flux density at centre and
   dipole moment
r=6.1*10^-11;      //radius of H atom in m
new=8.8*10^15;     //frequency in rev/sec
e=1.6*10^-19;
mew0=4*%pi*10^-7;
i=e*new;
B=(mew0*i)/(2*r);
mew=i*%pi*(r^2);
printf("current is %f amp",i);
printf("magnetic induction is %f weber/m^2",B);
printf("dipole moment in amp m^2 is");
disp(mew);
```

Scilab code Exa 4.11 To calculate the average number of Bohr magnetons

```
clc();
clear;
// To calculate the average number of Bohr magnetons
Is=1.96*10^6;      //saturation magnetisation in amp/
   m
a=3;      //cube edge of iron in armstrong
a=a*10^-10;     //cube edge of iron in m
mew_b=9.27*10^-24;      //bohr magneton in amp/m^2
n=2;     //number of atoms per unit cell
N=n/(a^3);
mewbar=Is/N;
mew_ab=mewbar/mew_b;
printf("average number of Bohr magnetons is %f bohr
   magneton per atom",mew_ab);
```

Scilab code Exa 4.12 To calculate the magnetic force and relative permeability

```
clc();
clear;
// To calculate the magnetic force and relative
   permeability
I=3000;     //magnetisation in amp/m
B=0.005;     //flux density in weber/m^2
mew0=4*%pi*10^-7;
H=(B/mew0)-I;
mew_r=(I/H)+1;
printf("magnetic force is %f amp/m",H);
printf("relative permeability is %f",mew_r);

```

```
12 //answer given in the book is wrong
```

Scilab code Exa 4.13 To calculate the permeability

```
1  clc();
2  clear;
3  // To calculate the permeability
4  H=1800;      //magnetising field in amp/m
5  phi=3*10^-5;     //magnetic flux in weber
6  A=0.2;     //cross sectional area in cm^2
7  A=A*10^-4;      //cross sectional area in m^2
8  B=phi/A;
9  mew=B/H;
10 printf("the permeability is %f Henry/m",mew);
11
12 //answer given in the book is wrong
```

Scilab code Exa 4.14 To calculate the magnetic dipole moment and torque

```
1  clc();
2  clear;
3  // To calculate the magnetic dipole moment and
      torque
4  r=0.04;     //radius of circular loop in m
5  i=1000;     //current in mA
6  i=i*10^-3;     //current in amp
7  B=10^-3;     //magnetic flux density in Wb/m^2
8  theta=45;     //angle in degrees
9  A=%pi*(r^2);
10 mew=i*A;
11 tow=i*B*cosd(theta);
12 printf("the magnetic dipole moment is %f amp m^2",
      mew);
```

```
13 printf("the torque is %f Nm",tow);
```

Scilab code Exa 4.15 To calculate the hysterisis loss per cycle

```
1 clc();
2 clear;
3 // To calculate the hysterisis loss per cycle
4 A=100;    //area of hysteris loop in m^2
5 B=0.01;     //flux density in wb/m^2
6 H=40;     //magnetic field in amp/m
7 M=7650;     //atomic weight in kg/m^3
8 hl=A*B*H;
9 printf("the hysterisis loss per cycle is %f J/m^3",
    hl);
```

Scilab code Exa 4.16 To calculate the hysterisis power loss and power loss

```
1 clc();
2 clear;
3 // To calculate the hysterisis power loss and power
    loss
4 hl=200;    //hysterisis loss per cycle in J/m^3
5 M=7650;     //atomic weight in kg/m^3
6 m=100;    //magnetisation cycles per second
7 hpl=hl*m;
8 pl=hpl/M;
9 printf("hysterisis power loss per second is %f watt/
    m^3",hpl);
10 printf("the power loss is %f watt/kg",pl);
```

Chapter 5

Superconductivity

Scilab code Exa 5.1 To calculate the critical field

```
clc();
clear;
// To calculate the critical field
Tc=3.7;          //critical temperature in kelvin
Hc_0=0.0306;     //critical field in T
T=2;
Hc_2k=Hc_0*(1-((T/Tc)^2));
printf("the critical feild at 2K is %f Tesla",Hc_2k)
   ;
```

Scilab code Exa 5.2 To calculate the critical current

```
clc();
clear;
// To calculate the critical current
T=4.2;           //temp in kelvin
Tc=7.18;         //critical temp in kelvin
Hc_0=6.5*10^4;          //in amp/m
```

```
7 d=1;      //diameter in mm
8 d=d*10^-3;     //diameter in m
9 r=d/2;
10 Hc_T=Hc_0*(1-((T/Tc)^2));
11 Ic=2*%pi*r*Hc_T;
12 printf("the critical current is %f Amp",Ic);
13
14 //answer given in the book is wrong
```

Scilab code Exa 5.3 To calculate the penetration depth

```
1 clc();
2 clear;
3 // To calculate the penetration depth
4 lamda_T=75;        // penetration depth in nm
5 T=3.5;         //temperature in K
6 HgTc=4.12;        //in K
7 lamda_0=lamda_T*sqrt(1-((T/HgTc)^4));
8 printf("the pentration depth at 0k is %f nm",lamda_0
   );
```

Scilab code Exa 5.4 To calculate the critical temperature

```
1 clc();
2 clear;
3 // To calculate the critical temperature
4 lamda_T1=396;            //pentration depth in
   armstrong
5 lamda_T2=1730;           //pentration depth in
   armstrong
6 T1=3;                      //temperature in K
7 T2=7.1;                    //temperature in K
8 //lamda_T2^2=lamda_0^2*(((Tc^4-T2^4)/Tc^4)^-1)
```

```
9  //lamda_T12^=lamda_0^2*(((Tc^4-T1^4)/Tc^4)^-1)
10 //dividing lamda_T2^2 by lamda_T1^2 = (Tc^4-T1^4)/(
       Tc^4-T2^4)
11 //let A=lamda_T2^2 and B=lamda_T1^2
12 A=lamda_T2^2;
13 B=lamda_T1^2;
14 C=A/B;
15 X=T1^4;
16 Y=T2^4;
17 //C*((TC^4)-Y)=(Tc^4)-X
18 //C*(Tc^4)-(Tc^4)=C*Y-X
19 //(Tc^4)*(C-1)=(C*Y)-X
20 //let Tc^4 be D
21 //D*(C-1)=(C*Y)-X
22 D=((C*Y)-X)/(C-1);
23 Tc=D^(1/4);
24 printf("the critical temperature is %f K",Tc);
```

Scilab code Exa 5.5 To calculate the critical field

```
1  clc();
2  clear;
3  // To calculate the critical field
4  Tc=7.2;          //critical temp in K
5  Ho=6.5*10^3;      //critical magnetic field in amp/m
6  T=5;          //temp in K
7  Hc=Ho*(1-((T/Tc)^2));
8  printf("the critical magnetic field at 5K is %f amp/
       m",Hc);
9
10 //answer given in the book is wrong
```

Scilab code Exa 5.6 To calculate the critical feild

```
clc();
clear;
// To calculate the critical feild at 2.5K
Tc=3.5;          //in K
Ho=3.2*10^3;     //in amp per m
T=2.5;          //in K
Hc=Ho*(1-((T/Tc)^2));
printf("critical field is %f amp/m is",Hc);
```

Scilab code Exa 5.7 To calculate the transition temperature

```
clc();
clear;
// To calculate the transition temperature
Hc=5*10^3        //critical magnetic field in amp/m
Ho=2*10^4;       //critical field in amp/m
T=6;          //temp in K
Tc=T/sqrt(1-(Hc/Ho));
printf("the transition temperature is %f K",Tc)

//answer in the book is wrong
```

Scilab code Exa 5.8 To calculate the critical current

```
clc();
clear;
// To calculate the critical current
Hc=2*10^3;        //critical magnetic field in amp/m
R=0.02;        //radius in m
p=3.14;
Ic=2*p*R*Hc;
printf("the critical current is %f amp",Ic);
```

Scilab code Exa 5.9 To calculate the isotopic mass

```
clc();
clear;
// To calculate the isotopic mass
M1=199.5;       //isotopic mass in in a.m.u
T1=5;          //1st critical temp in K
T2=5.1;        //2nd critical temp in K
M2=((T1/T2)^2)*M1;
printf("the isotopic mass of M2 is %f a.m.u",M2);
```

Scilab code Exa 5.10 To calculate the critical current

```
clc();
clear;
// To calculate the critical current
d=3;      //diameter in mm
d=d*10^-3;      //diameter in m
Tc=8;         //critical temp in K
T=5;        //temp in K
Ho=5*10^4;     //magnetic field in A/m
r=d/2;
Hc=Ho*(1-((T/Tc)^2));
Ic=2*%pi*r*Hc;
printf("critical current is %f amp",Ic);

//answer in the book is wrong
```

Scilab code Exa 5.11 To calculate the critical temperature

```
clc();
clear;
// To calculate the critical temperature
M1=199.5;     //isotopic mass
M2=203.4;
Tc1=4.185;       //1st critical temp in K
Tc2=Tc1*sqrt(M1/M2);
printf("the critical temperature is %f K",Tc2);
```

Scilab code Exa 5.12 To calculate the EM wave frequency

```
clc();
clear;
// To calculate the EM wave frequency
V=8.50;     //voltage in micro Volts
V=V*10^-6;      //in volts
e=1.6*10^-19;        //electron charge in coulomb
h=6.626*10^-24;
new=2*e*V/h;
printf("EM wave frequency in Hz is");
disp(new);

//answer given in the book is wrong
```

Scilab code Exa 5.13 To calculate the critical temperature

```
clc();
clear;
// To calculate the critical temperature
p1=1;      //1st pressure in mm
p2=6;      //2nd pressure in mm
Tc1=5;     //1st critical temp in K
Tc2=Tc1*(p2/p1);
```

```
8 printf("the critical temperature is %f K",Tc2);
```

Scilab code Exa 5.14 To calculate maximum critical temperature

```
1  clc();
2  clear;
3  // To calculate maximum critical temperature
4  Tc=8.7;       //1st critical temp in K
5  Hc=6*10^5;       //critical magnetic field in Amp/m
6  Ho=3*10^6;       //critical magnetic field in Amp/m
7  T=Tc*sqrt(1-(Hc/Ho));
8  printf("maximum critical temperature is %f K",T);
9
10 //answer given in the book is wrong
```

Chapter 6

Dielectric Properties

Scilab code Exa 6.1 To calculate the energy stored in the condenser and polarizing the dielectric

```
1  clc();
2  clear;
3  // To calculate the energy stored in the condenser
     and polarizing the dielectric
4  C=2;     //capacitance in micro farad
5  C=C*10^-6;     //capacitance in farad
6  V=1000;    //voltage in Volts
7  epsilon_r=100;
8  W=(C*(V^2))/2;
9  C0=C/epsilon_r;
10 W0=(C0*(V^2))/2;
11 W_0=1-W0;
12 printf("energy stored in the condenser is %f Joule",
     W);
13 printf("energy stored in the dielectric is %f Joule"
     ,W_0);
```

Scilab code Exa 6.2 To calculate the ratio between electronic and ionic polarizability

```
clc();
clear;
// To calculate the ratio between electronic and
   ionic polarizability
epsilon_r=4.94;
N=2.69;      //let n^2 be N
//(epsilon_r-1)/(epsilon_r+2) = (N*alpha)/(3*
   epsilon_0)
//alpha = alpha_e+alpha_i
//therefore (epsilon_r-1)/(epsilon_r+2) = (N*(
   alpha_e+alpha_i))/(3*epsilon_0)
//let (N*(alpha_e+alpha_i))/(3*epsilon_0) be X
X=(epsilon_r-1)/(epsilon_r+2);
//Ez=n^2
//therefore (N-1)/(N+2) = (N*alpha_e)/(3*epsilon_0)
//let (N*alpha_e)/(3*epsilon_0) be Y
Y=(N-1)/(N+2);
//dividing X/Y = (N*(alpha_e+alpha_i))/(N*alpha_e)
//therefore X/Y = 1+(alpha_i/alpha_e)
//let alpha_i/alpha_e be A
R=(X/Y)-1;
printf("ratio between electronic and ionic
   polarizability is %f",R);

//answer given in the book is wrong in the second
   part
```

Scilab code Exa 6.3 To calculate the dielectric constant of the material

```
clc();
clear;
// To calculate the dielectric constant of the
```

```
    material
4 N=3*10^28;    //atoms per m^3
5 alpha_e=10^-40;    //farad m^2
6 epsilon_0=8.854*10^-12;     //f/m
7 epsilon_r=1+(N*alpha_e/epsilon_0);
8 printf("dielectric constant of the material is %f",
    epsilon_r);
```

Scilab code Exa 6.4 To calculate the electronic polarizability of He atoms

```
1 clc();
2 clear;
3 // To calculate the electronic polarizability of He
    atoms
4 epsilon_0=8.854*10^-12;     //f/m
5 epsilon_r=1.0000684;
6 N=2.7*10^25;    //atoms per m^3
7 alpha_e=(epsilon_0*(epsilon_r-1))/N;
8 printf("electronic polarizability of He atoms in Fm
    ^2 is");
9 disp(alpha_e);
```

Scilab code Exa 6.5 To calculate the capacitance and charge

```
1 clc();
2 clear;
3 // To calculate the capacitance and charge
4 epsilon_0=8.854*10^-12;     //f/m
5 A=100;     //area in cm^2
6 A=A*10^-4;    //area in m^2
7 V=100;    //potential in V
8 d=1;    //plate seperation in cm
9 d=d*10^-2;     //plate seperation in m
```

```
10 C=(epsilon_0*A)/d;
11 Q=C*V;
12 printf("charge on the plates in F is");
13 disp(C);
14 printf("charge on the capacitor in coulomb is");
15 disp(Q);
```

Scilab code Exa 6.6 To calculate the resultant voltage across the capacitors

```
1 clc();
2 clear;
3 // To calculate the resultant voltage across the
     capacitors
4 Q=2*10^-10;    //charge in coulomb
5 d=4;    //plate seperation in mm
6 d=d*10^-3;     //plate seperation in m
7 epsilon_r=3.5;
8 epsilon_0=8.85*10^-12;     //f/m
9 A=650;     //area in mm^2
10 A=A*10^-6;     //area in m^2
11 V=(Q*d)/(epsilon_0*epsilon_r*A);
12 printf("voltage across the capacitor is %f Volts",V)
     ;
```

Scilab code Exa 6.7 To calculate the dielectric displacement

```
1 clc();
2 clear;
3 // To calculate the dielectric displacement
4 V=10;    //potential in volts
5 d=2*10^-3;     //plate seperation in m
6 epsilon_r=6;     //dielectric constant
```

```
epsilon_0=8.85*10^-12;      //f/m
E=V/d;
D=epsilon_0*epsilon_r*E;
printf("dielectric displacement in cm^-2 is");
disp(D);

//answer given in the book is wrong in the 7th
   decimal point
```

Scilab code Exa 6.8 To calculate the polarizability and relative permittivity of He

```
clc();
clear;
// To calculate the polarizability and relative
   permittivity of He
R=0.55;     //radius of He atom in angstrom
R=R*10^-10;     //radius of He atom in m
epsilon_0=8.84*10^-12;     //f/m
N=2.7*10^25;
alpha_e=4*%pi*epsilon_0*R^3;
epsilon_r=(N*alpha_e/epsilon_0)+1;
printf("polarizability in farad m^2 is");
disp(alpha_e);
printf("relative permitivity is");
disp(epsilon_r);
```

Scilab code Exa 6.9 To calculate the field strength and total dipole moment

```
clc();
clear;
```

```
// To calculate the field strength and total dipole
   moment
V=15;     //potential difference in volts
C=6;     //capacity in micro farad
C=C*10^-6;     //capacity in farad
epsilon_0=8.84*10^-12;     //f/m
epsilon_r=8;
A=360;      //surface area in cm^2
A=A*10^-4;     //surface area in m^2
E=(V*C)/(epsilon_0*epsilon_r*A);
d=epsilon_0*(epsilon_r-1)*V*A;
printf("field strength in V/m is");
disp(E);
printf("total dipole moment in cm is");
disp(d);

//answer for field strength E given in the book is
   wrong
```

Scilab code Exa 6.10 To calculate the complex polarisability of material

```
clc();
clear;
// To calculate the complex polarisability of
   material
epsilonr=4.36;       //dielectric constant
t=2.8*10^-2;
N=4*10^28;
epsilon0=8.84*10^-12;
epsilon_r=epsilonr*t;
//epsilonstar=epsilonr-(j*epsilon_r)
//by substituting values epsilonstar = 4.36-(j
   *0.12208)
//by taking out 4.36 common we get epsilonstar =
   4.36(1-(j*0.028))
```

```
12 //(epsilonstar-1)/(epsilonstar+2) = (N*alphastar/(3*
   epsilon0))
13 // (4.36(1-(j*0.028))-1)/(4.36(1-(j*0.028))+2) = (N*
   alphastar/(3*epsilon0))
14 //consider real part in numerator of LHS be A and in
    denominator be B
15 A=4.36-1;
16 B=4.36+2;
17 C=N/(3*epsilon0);
18 //therefore alpastar = (1/C)*((3.36-0.12208j)
   /(6.36-0.12208j))
19 //by rationalising the denominatore we get
20 //((3.36-0.12208j)/(6.36-0.12208j))*((6.36+0.12208j)
   /(6.36+0.12208j))
21 //after simplifuing let real part ne X and imaginary
    part be Y
22 X=((3.36*6.36)+(0.12208*0.12208))/((6.36^2)
   +(0.12208^2));
23 Y=((3.36*0.12208)-(6.36*0.12208))/((6.36^2)
   +(0.12208^2));
24 //alphastar=(1/C)*(X+jY) = ((1/C)*X)+((1/C)*jY)
25 R=(1/C)*X;
26 I=(1/C)*Y;
27 printf("the complex polarizability in F-m^2 is");
28 disp('j',I,R);
29 //by taking 10^-40 common we get alphastar = (3.5-j0
   .06)*10^-40 F-m^2
```

Chapter 7

Semiconductors

Scilab code Exa 7.1 To calculate the number of electron hole pairs

```
clc();
clear;
// To calculate the number of electron hole pairs
T1=300;     //temp in K
T2=310;     //temp in K
ni1=2.5*10^19;    //per cubic metre
EgeV1=0.72;     //value of Eg in eV
EgeV2=1.12;     //value of Eg in eV
Eg1=EgeV1*1.6*10^-19;     //Eg in J
Eg2=EgeV2*1.6*10^-19;     //Eg in J
KB=1.38*10^-23;      //boltzmann constant in J/k
//density of electron hole pair is ni = A*(T^(3/2))*
   exp(-Eg/(2*KB*T))
// let (T^(3/2))*exp(-Eg/(2*KB*T)) be X
X1=(T1^(3/2))*exp(-Eg1/(2*KB*T1));
X2=(T2^(3/2))*exp(-Eg2/(2*KB*T2));
//therefore ni1=A*X1 and ni2=A*X2. dividing ni2/ni1
   we get X2/X1
ni2=ni1*(X2/X1);
printf("the number of electron hole pairs per cubic
   metre is");
```

```
19 disp(ni2);
20
21 //answer given in the book is wrong
```

Scilab code Exa 7.2 To calculate the charge carrier density and electron mobility

```
1 clc();
2 clear;
3 // To calculate the charge carrier density and
     electron mobility
4 RH=3.66*10^-4;    //hall coefficient in m^3/coulomb
5 sigma=112;     //conductivity in ohm-1 m-1
6 e=1.6*10^-19;
7 ne=1/(RH*e);
8 //sigma = e*ne*(mew_e+mew_h)
9 //assuming mew_h = 0
10 mew_e=sigma/(e*ne);
11 printf("the charge carrier density per m^3 is");
12 disp(ne);
13 printf("electron mobility is %f m^2/Vs",mew_e);
14
15 //answer given in the book is wrong
```

Scilab code Exa 7.3 To calculate the conductivity of intrinsic silicon and resultant conductivity

```
1 clc();
2 clear;
3 // To calculate the conductivity of intrinsic
     silicon and resultant conductivity
4 ni=1.5*10^16;    //intrinsic concentration per m^3
5 e=1.6*10^-19;
```

```
mew_e=0.13;     //mobility of electrons in m^2/Vs
mew_h=0.05;     //mobility of holes in m^2/Vs
ND=5*10^20;     //conductivity in atoms/m^3
sigma1=ni*e*(mew_e+mew_h);
nd=(ni^2)/ND;
sigma2=ND*e*mew_e;
NA=5*10^20;
na=(ni^2)/NA;
sigma3=NA*e*mew_h;
printf("intrinsic conductivity of Si is %f ohm-1 m-1
   ",sigma1);
printf("conductivity of Si during donor impurity is
   %f ohm-1 m-1",sigma2);
printf("conductivity of Si during acceptor impurity
   is %f ohm-1 m-1",sigma3);
```

Scilab code Exa 7.4 To calculate the conductivity

```
clc();
clear;
// To calculate the conductivity
sigma1=2;     //conductivity in ohm-1 m-1
EgeV=0.72;     //band gap in eV
Eg=EgeV*1.6*10^-19;     //in J
KB=1.38*10^-23;     //boltzmann constant
T1=20;     //temp in C
T1=T1+273;     //temp in K
T2=40;     //temp in C
T2=T2+273;     //temp in K
//sigma2/sigma1 = exp((-Eg/(2*KB))*((1/T2)-(1/T1)))
//by taking log on both sides we get 2.303*log10(
   sigma2/sigma1) = (Eg/(2*KB))*((1/T1)-(1/T2))
//let (Eg/(2*KB))*((1/T1)-(1/T2)) be X
X=(Eg/(2*KB))*((1/T1)-(1/T2));
//let log10(sigma2/sigma1) be Y
```

```
Y=X/2.303;
//log10(sigma2/sigma1) = log10(sigma2)-log10(sigma1)
//let log10(sigma2) be A
A=Y+log10(sigma1);
sigma2=10^A;
printf("the conductivity is %f ohm-1 m-1",sigma2);
```

Scilab code Exa 7.5 To calculate the concentration of holes and electrons

```
clc();
clear;
// To calculate the concentration of holes and
   electrons
mew_n=1300*10^-4;    //in m^2/Vs
mew_p=500*10^-4;    //in m^2/Vs
sigma=3*10^4;    //conductivity in ohm-1 m-1
e=1.6*10^-19;
N=sigma/(e*mew_n);
ni=1.5*10^16;     //per m^3
p=(ni^2)/N;
P=sigma/(e*mew_p);
n=(ni^2)/P;
printf("concentration of electrons in n-type per
   cubic metre are");
disp(N);
printf("concentration of holes in n-type per cubic
   metre are");
disp(p);
printf("concentration of electrons in p-type per
   cubic metre are");
disp(n);
printf("concentration of holes in p-type per cubic
   metre are");
disp(P);
```

Scilab code Exa 7.6 To calculate the resistivity

```
clc();
clear;
// To calculate the resistivity
ni=2.37*10^19;    //intrinsic carrier density per m^3
mew_e=0.38;     //in m^2/Vs
mew_n=0.18;     //in m^2/Vs
e=1.6*10^-19;
sigmai=ni*e*(mew_e+mew_n);
rho=1/sigmai;
printf("resistivity is %f ohm m",rho);
```

Scilab code Exa 7.7 To calculate the position of fermi level

```
clc();
clear;
// To calculate the position of fermi level
Eg=1.12;    //band gap in eV
K=1.38*10^-23;
T=300;    //temp in K
//EF = (Eg/2)+(3*K*T/4)*log(mh/me)
//given me=0.12m0 and mh=0.28m0. therefore mh/me =
    0.28/0.12
//let mh/me be X. therefore X=0.28/0.12
X=0.28/0.12;
EF=(Eg/2)+((3*K*T/4)*log(X));
printf("the position of fermi level is %f eV",EF);

//answer given in the book is wrong
```

Scilab code Exa 7.8 To calculate the concentration of intrinsic charge carriers

```
clc();
clear;
// To calculate the concentration of intrinsic
   charge carriers
KB=1.38*10^-23;
T=300;    //temp in K
h=6.626*10^-34;
m0=9.11*10^-31;
mh=m0;
me=m0;
EgeV=0.7;     //energy gap in eV
Eg=EgeV*1.6*10^-19;     //in J
A=((2*%pi*KB/(h^2))^(3/2))*(me*mh)^(3/4);
B=T^(3/2);
C=exp(-Eg/(2*KB*T));
ni=2*A*B*C;
printf("concentration of intrinsic charge carriers
   per cubic metre is");
disp(ni);
```

Scilab code Exa 7.9 To calculate the resistivity

```
clc();
clear;
// To calculate the resistivity
ni=2.4*10^19;
mew_e=0.39;
mew_h=0.19;
e=1.6*10^-19;
```

```
sigmai=ni*e*(mew_e+mew_h);
rhoi=1/sigmai;
printf("resistivity is %f ohm m",rhoi);
```

Scilab code Exa 7.10 To calculate the resistance

```
clc();
clear;
// To calculate the resistance
l=1;     //length in cm
l=l*10^-2;     //length in m
e=1.6*10^-19;
w=1;     //width in mm
w=w*10^-3;     //width in m
t=1;      //thickness in mm
t=t*10^-3;       //thickness in m
A=w*t;
ni=2.5*10^19;
mew_e=0.39;
mew_p=0.19;
sigma=ni*e*(mew_p+mew_e);
R=l/(sigma*A);
printf("resistance of intrinsic Ge rod is %f ohm",R)
   ;
```

Scilab code Exa 7.11 To calculate the conductivity

```
clc();
clear;
// To calculate the conductivity
Eg=1.1;    //energy gap in eV
m=9.109*10^-31;
k=1.38*10^-23;
```

```
T=300;
e=1.6*10^-19;
h=6.626*10^-34;
mew_e=0.48;      //electron mobility
mew_h=0.013;     //hole mobility
C=2*(2*%pi*m*k/(h^2))^(3/2);
X=2*k*T/e;
Y=-Eg/X;
A=exp(Y);
ni=C*(T^(3/2))*A;
sigma=ni*e*(mew_e+mew_h);
printf("conductivity in ohm-1 m-1 is");
disp(sigma);

//answer given in the book is wrong
```

Scilab code Exa 7.12 To calculate the intrinsic carrier density and conductivity

```
clc();
clear;
// To calculate the intrinsic carrier density and
   conductivity
m=9.109*10^-31;
k=1.38*10^-23;
T=300;
e=1.6*10^-19;
h=6.626*10^-34;
Eg=0.7;
mew_e=0.4;      //electron mobility
mew_h=0.2;     //hole mobility
C=2*(2*%pi*m*k/((h^2)))^(3/2);
X=2*k*T/e;
ni=C*(T^(3/2))*exp(-Eg/X);
sigma=ni*e*(mew_e+mew_h);
```

```
16 printf("conductivity is %f ohm-1 m-1",sigma);
17
18 //answer given in the book is wrong
```

Scilab code Exa 7.13 To calculate the energy band gap

```
1  clc();
2  clear;
3  // To calculate the energy band gap
4  k=8.616*10^-5;
5  T1=20;     //temp in C
6  T1=T1+273;     //temp in K
7  T2=32;      //temp in C
8  T2=T2+273;     //temp in K
9  rho2=4.5;     //resistivity in ohm m
10 rho1=2;     //resistivity in ohm m
11 dy=log10(rho2)-log10(rho1);
12 dx=(1/T1)-(1/T2);
13 Eg=2*k*dy/dx;
14 printf("energy band gap is %f eV",Eg);
```

Scilab code Exa 7.14 To calculate the temperature

```
1  clc();
2  clear;
3  // To calculate the temperature
4  EgeV=1;    //energy in eV
5  k=1.38*10^-23;
6  Eg=EgeV*1.602*10^-19;     //in J
7  //EF can be taken as (Ev+0.5)eV
8  //therefore (Ev+0.5)eV = (Ec+Ev)/2--------(1)
9  //let fermi level shift by 10% then (Ev+0.6)eV = ((
      Ec+Ev)/2)+((3*k*T/4)*log(4))-----(2)
```

```
10 //subtracting (1) from (2)
11 //0.1 eV = (3*k*T/4)*log(4)
12 E=0.1;     //energy in eV
13 E=E*1.602*10^-19;     //energy in J
14 T=(4*E)/(3*k*log(4));
15 printf("temperature is %f K",T);
```

Scilab code Exa 7.15 To calculate the conductivity of intrinsic silicon

```
1  clc();
2  clear;
3  // To calculate the conductivity of intrinsic
      silicon
4  ni=1.5*10^16;
5  e=1.6*10^-19;
6  mew_e=0.13;
7  mew_h=0.05;
8  sigma=ni*e*(mew_e+mew_h);
9  printf("conductivity is %f ohm-1 m-1",sigma);
10 M=28.1;     //atomic weight of Si
11 d=2.33*10^3;    //density in kg/m^3
12 v=M/d;
13 N=6.02*10^26;
14 N1=N/v;
15 printf("number of Si atoms per m^3 is");
16 disp(N1);
17 //1 donor type impurity is added to 1 impurity atom
18 ND=N1/(10^8);
19 p=(ni^2)/ND;
20 sigma_exd=ND*e*mew_e;
21 printf("conductivity for donor type impurity is %f
      ohm-1 m-1",sigma_exd);
22 //1 acceptor type impurity is added to 1 impurity
      atom
23 Na=N1/(10^8);
```

```
24 n=(ni^2)/Na;
25 sigma_exa=Na*e*mew_h;
26 printf("conductivity for acceptor type impurity is
      %f ohm-1 m-1",sigma_exa);
```

Scilab code Exa 7.16 To calculate the diffusion coefficient of electrons

```
1 clc();
2 clear;
3 // To calculate the diffusion coefficient of
      electrons
4 T=300;    //temperature in K
5 KB=1.38*10^-23;
6 e=1.6*10^-19;
7 mew_e=0.19;     //mobility of electrons in m^2/Vs
8 Dn=mew_e*KB*T/e;
9 printf("diffusion coefficient of electrons is %f m
      ^2/s",Dn);
```

Scilab code Exa 7.17 To calculate the Hall voltage

```
1 clc();
2 clear;
3 // To calculate the Hall voltage
4 RH=3.66*10^-4;      //hall coefficient in m^3/coulomb
5 I=10^-2;     //current in amp
6 B=0.5;     //magnetic field in wb/m^2
7 t=1;     //thickness in mm
8 t=t*10^-3;     //thickness in m
9 VH=(RH*I*B)/t;
10 VH=VH*10^3;     //converting from Volts to mV
11 printf("Hall voltage is %f mV",VH);
```

Scilab code Exa 7.18 To calculate the density and mobility of charge carrier

```
clc();
clear;
// To calculate the density and mobility of charge
   carrier
RH=-7.35*10^-5;     //hall coefficient
e=1.6*10^-19;
n=(-1/(RH*e));
sigma=200;
mew=sigma/(n*e);
printf("density of charge carriers in m^3 is");
disp(n);
printf("mobility of charge carriers is %f m^2/Vs",
   mew);
```

Scilab code Exa 7.19 To calculate the magnitude of Hall voltage

```
clc();
clear;
// To calculate the magnitude of Hall voltage
I=50;     //current in amp
B=1.5;    //magnetic field in T
n=8.4*10^28;      //free electron concentration in
   electron/m^3
t=0.5;     //thickness in cm
e=1.6*10^-19;
t=t*10^-2;     //thickness in m
VH=(I*B)/(n*e*t);
VH=VH*10^6;    //converting VH from V to micro V
```

```
12 printf("magnitude of Hall voltage is %f microVolt",
      VH);
```

Scilab code Exa 7.20 To calculate mew and n

```
1  clc();
2  clear;
3  // To calculate mew and n
4  RH=3.66*10^-4;
5  e=1.6*10^-19;
6  rho_n=8.93*10^-3;
7  n=1/(RH*e);
8  mew_e=RH/rho_n;
9  printf("n per m^3 is");
10 disp(n);
11 printf("mew_e is %f m^2/V",mew_e);
```

Scilab code Exa 7.21 To calculate the conductivity and equilibrium hole concentration

```
1  clc();
2  clear;
3  // To calculate the conductivity and equilibrium
      hole concentration
4  mew_e=0.13;     //electron mobility in m^2/Vs
5  mew_h=0.048;    //hole mobility in m^2/Vs
6  ni=1.5*10^16;
7  e=1.6*10^-19;
8  T=300;    //temp in K
9  ND=10^23;     //density per m^3
10 sigmai=ni*e*(mew_e+mew_h);
11 sigma=ND*mew_e*e;
12 p=(ni^2)/ND;
```

```
13 printf("conductivity of intrinsic Si is %f s",sigmai
   );
14 printf("conductivity is %f s",sigma);
15 printf("equilibrium hole concentration per m^3 is");
16 disp(p);
17
18 //answers for sigmai and sigma given in the book are
    wrong
```

Scilab code Exa 7.22 To calculate the forbidden energy gap

```
1  clc();
2  clear;
3  // To calculate the forbidden energy gap
4  T=300;   //temp in K
5  kB=1.38*10^-23;
6  mew_e=0.36;    //mobility of electrons in m^2/Vs
7  e=1.6*10^-19;
8  mew_h=0.7;    //mobility of electrons in m^2/Vs
9  sigma=2.12;    //conductivity in ohm-1 m-1
10 C=4.83*10^21;    //proportional constant
11 ni=sigma/(e*(mew_e+mew_h));
12 //exp(-Eg/(2*kB*T)) = (C*(T^(3/2)))/ni
13 //let X be (C*(T^(3/2)))/ni
14 X=(C*(T^(3/2)))/ni;
15 //exp(-Eg/(2*kB*T)) = X
16 //applyinf log on both sides
17 //Eg/(2*kB*T) = log(X)
18 Eg=2*kB*T*log(X);
19 printf("forbidden energy gap in eV is");
20 disp(Eg);
21
22 //answer given in the book is wrong
```

Scilab code Exa 7.23 To calculate the probability of occupation

```
clc();
clear;
// To calculate the probability of occupation
Eg=0.4;     //energy gap in eV
Eg=Eg*1.6*10^-19;     //Eg in J
KB=1.38*10^-23;
T1=0;    //temp 1 in C
T1k=T1+273;     //temp 1 in K
T2=50;    //temp 2 in C
T2k=T2+273;     //temp 2 in K
T3=100;    //temp 3 in C
T3k=T3+273;     //temp 3 in K
//F(E) = 1/(1+(exp((E-Ep)/(KB*T))))
//but E-Ep = (1/2)*Eg
//therefore F(E) = 1/(1+(exp(Eg/(2*KB*T))))
FE1=1/(1+(exp(Eg/(2*KB*T1k))));
FE2=1/(1+(exp(Eg/(2*KB*T2k))));
FE3=1/(1+(exp(Eg/(2*KB*T3k))));
printf("probability of occupation at 0 C is %f eV",
   FE1);
printf("probability of occupation at 50 C is %f eV",
   FE2);
printf("probability of occupation at 100 C is %f eV"
   ,FE3);

//answers given in the book are wrong
```

Scilab code Exa 7.24 To calculate the ratio between conductivity

```
clc();
```

```
clear;
// To calculate the ratio between conductivity
Eg=1.2;    //energy in eV
Eg=Eg*1.6*10^-19;     //in J
KB=1.38*10^-23;
T1=600;    //temp in K
T2=300;    //temp in K
//sigma is proportional to exp(-Eg/(2*KB*T))
//let sigma1/sigma2 be R
R=exp((Eg/(2*KB))*((1/T2)-(1/T1)));
disp(R);

//answer given in the book is wrong
```

Scilab code Exa 7.25 To calculate the resistivity of doped Ge

```
clc();
clear;
// To calculate the resistivity of doped Ge
ni=2.5*10^19;    //density of charge carriers in m^3
r=1/(10^6);     //ratio
e=1.6*10^-19;
mew_e=0.36;    //mobility of electrons in m^2/Vs
mew_h=0.18;    //mobility of holes in m^2/Vs
N=4.2*10^28;     //number of Si atoms per m^3
Ne=r*N;
printf("number of impurity atoms per m^3 is");
disp(Ne);
Nh=(ni^2)/Ne;
sigma=(Ne*e*mew_e)+(Nh*e*mew_h);
rho=1/sigma;
printf("the resistivity of doped Ge is %f ohm m",rho
   );
```

Scilab code Exa 7.26 To calculate the conductivity of material

```
clc();
clear;
// To calculate the conductivity of material
n=5*10^17;    //concentration in m^3
vd=350;    //drift velocity in m/s
E=1000;    //electric field in V/m
e=1.6*10^-19;
mew=vd/E;
sigma=n*e*mew;
printf("the conductivity of material is %f ohm m",
   sigma);
```

Scilab code Exa 7.27 To calculate the concentration

```
clc();
clear;
// To calculate the concentration
sigma_e=2.2*10^-4;    //conductivity
mew_e=125*10^-3;     //mobility of electrons in m^2/
   Vs
e=1.602*10^-19;
ne=sigma_e/(e*mew_e);
printf("concentration in m^3 is");
disp(ne);
```

Scilab code Exa 7.28 To calculate the mobility and density of charge carrier

```
clc();
clear;
// To calculate the mobility and density of charge
   carrier
RH=3.66*10^-4;     //hall coefficient in m^3/c
rho_i=8.93*10^-3;     //resistivity in ohm m
e=1.6*10^-19;
nh=1/(RH*e);
mew_h=1/(rho_i*nh*e);
printf("density of charge carriers in m^3 is");
disp(nh);
printf("mobility of charge carriers is %f m^2/Vs",
   mew_h);
```

Scilab code Exa 7.29 To calculate the Hall voltage and charge carrier concentration

```
clc();
clear;
// To calculate the Hall voltage and charge carrier
   concentration
I=3;     //current in mA
I=I*10^-3;     //current in amp
e=1.6*10^-19;
RH=3.66*10^-4;     //hall coefficient in m^3/C
B=1;     //flux density in w/m^2
d=2;    //dimension along Y in cm
d=d*10^-2;    //dimension along Y in m
z=1;    //dimension along z in mm
z=z*10^-3;     //dimension along z in m
A=d*z;    //area in m^2
EH=RH*I*B/A;
VH=EH*d;
VH=VH*10^3;     //converting from V to mV
n=1/(RH*e);
```

```
18 printf("Hall voltage is %f mV",VH);
19 printf("charge carrier concentration in m^3 is");
20 disp(n);
```

Chapter 8

Physics of Nano Materials

Scilab code Exa 8.1 To calculate the surface area to volume ratio

```
clc();
clear;
// To calculate the surface area to volume ratio
r=5;    //radius in m
SA=4*%pi*r^2;    //surface area of sphere in m^2
V=(4/3)*%pi*r^3;    //volume of sphere in m^3
R=SA/V;    //ratio
//surface area to volume ratio can also be given by 3/radius
printf("surface area to volume ratio of sphere is %f m-1",R);
```

Scilab code Exa 8.2 To calculate the surface area to volume ratio

```
clc();
clear;
// To calculate the surface area to volume ratio
d=26;    //distance in m
```

```
r=d/2;     //radius in m
SA=4*%pi*r^2;     //surface area of sphere in m^2
V=(4/3)*%pi*r^3;    //volume of sphere in m^3
R=SA/V;     //ratio
//surface area to volume ratio can also be given by
   3/radius
printf("surface area to volume ratio of sphere is %f
    m-1",R);
```

Scilab code Exa 8.3 To calculate the volume of cone

```
clc();
clear;
// To calculate the volume of cone
r=1;    //radius in m
h=1;    //height in m
V=(1/3)*%pi*(r^2)*h;
printf("volume of cone is %f m^3",V);
```

Scilab code Exa 8.4 To calculate the total surface area of cone

```
clc();
clear;
// To calculate the total surface area of cone
r=3;    //radius in m
h=4;    //height in m
SA=%pi*r*sqrt((r^2)+(h^2));
TSA=SA+(%pi*r^2);
printf("total surface area of cone is %f m^2",TSA);

//answer given in the book is wrong
```

Scilab code Exa 8.5 To calculate the height of cone

```
1  clc();
2  clear;
3  // To calculate the height of cone
4  V=100;    //volume of cone in cubic inches
5  r=5;    //radius of cone in inches
6  r_m=r*0.0254;     //radius of cone in m
7  //volume V=(1/3)*%pi*(r^2)*h
8  //therefore h = (3*V)/(%pi*r^2)
9  h=(3*V)/(%pi*r^2);    //height in inches
10 R=3/r_m;
11 printf("height of the cone is %f inches",h);
12 printf("surface area to volume ratio is %f m-1",R);
13
14 //answer for the surface area to volume ratio given
      in the book is wrong
```