Scilab Textbook Companion for Principles of Electrical Engineering Materials by S. O. Kasap[1]

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Book Description

Title: Principles of Electrical Engineering Materials

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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

Elementary Materials Science Concepts

Scilab code Exa 1.1 Bond length and bond energy

```
clc
//Chapter1
//Ex_1.1
//Given
A=8*10^-77 // in J m^6
B=1.12*10^-133 // in J m^12
//lennard-Jones 6-12 potential Energy (PE)curve is E(r)=-A*r^-6+B*r^-12
//For bonding to occur PE should be minimum, hence differentiating the PE equation and setting it to Zero at r=ro we get
ro=(2*B/A)^(1/6)
disp(ro,"Bond length in meters is")
E_bond= -A*ro^-6+(B*ro^-12)//in J
E_bond=abs(E_bond/(1.6*10^-19))
disp(E_bond,"Bond Energy for solid argon in ev is")
```

Scilab code Exa 1.2 rms velocity

```
clc
//Chapter1
//Ex_1.2
//Given
R=8.314 // in J/mol/K
T=27 //in degree celcius
T=T+273 //in Kelvin
M_at=14 //in g/mol
//From Kinetic Theory
V_rms=sqrt((3*R*T)/(2*M_at*10^-3))
disp(V_rms,"rms velocity of Nitrogen molecule in
    atmosphere at 300K in m/s is")
V_rmsx=V_rms/sqrt(3)
disp(V_rmsx,"rms velocity in one direction in m/s is
    ")
```

Scilab code Exa 1.3 heat capacity

```
clc
//Chapter1
//Ex_1.3
//Given
R=8.314 // in J/mol/K
M_at=63.6 //in g/mol
//Acc. to Dulong -Petit rule Cm=3R for NA atoms
C_gram=3*R/M_at
disp(C_gram,"Heat Capacity of copper per unit gram
    in J/g/K is")
```

Scilab code Exa 1.4 speed of gas with non interacting electrons

```
clc
//Chapter1
//Ex_1.4
//Given
k=1.38*10^-23 //in J/K
m=9.1*10^-31 // in Kg
T=300 // in Kelvin
v_av=sqrt(8*k*T/(%pi*m))
disp(v_av*10^-3,"Mean speed for a gas of non
    interacting electrons in Km is ")
v=sqrt(2*k*T/(m))
disp(v*10^-3,"Most probable speed for a gas of non
    interacting electrons in Km is")
v_rms=sqrt(3*k*T/(m))
disp(v_rms*10^-3,"rms velocity for a gas of non
    interacting electrons in Km is")
```

Scilab code Exa 1.5 Minimum rms radio signal

```
clc
//Chapter1
//Ex_1.5
//Given
L=100*10^-6//in Henry
C=100 *10^-12 //in Farad
T=300 // in Kelvin
R=200*10^3 //in ohms
k=1.38*10^-23 //in J/K
fo=1/(2*%pi*sqrt(L*C))//resonant frequency
Q=2*%pi*fo*C*R//quality factor
B=fo/Q //Bandwidth of tuned RLC
//Acc. to Johnson resistor noise equation
Vrms=sqrt(4*k*T*R*B) //in volts
Vrms=Vrms/10^-6 //in micro volts
disp(Vrms," Minimum rms radio signal that can be
```

```
detected in micro volts is")
```

Scilab code Exa 1.7 density of Cu

```
clc
//Chapter1
//Ex_1.7
//Given
n=4
M_at=63.55*10^-3//Kg/mol
NA=6.022*10^23 //mol^-1
R=0.128// in nm
c=8 //no.of cornersof unit cells
f=6 //no.of faces of unit cells
//a
N=c*(1/8)+f*(1/2)
disp(N,"No. of atoms per unit cells is")
//b
//Lattice parameter
a=R*2*2^(1/2)
disp(a,"Lattice Parameter in nm is")
a=a*10^-9 //in m
//c
//APF=(No.of atoms in unit cell)*(Vol. of atom)/(Vol. of unit cell)
APF=4^2*%pi/(3*(2*sqrt(2))^3)
disp(APF,"Atomic Packing Factor is")
//d
p=n*M_at/(a^3*NA) //density
disp(p,"density of Copper in Kg/m3 is")
```

Scilab code Exa 1.8 miller indices

```
clc
//Chapter1
//Ex_1.8
//Given
a=1/%inf
b=-1/1
c=2/1
p = int32([1,1,1])
// 1/%inf = 0  ; (0/1 -1/1 2/1) hence lcm is taken
   for [1 1 1]
LCM = lcm(p)
h=a*double(LCM)
k=b*double(LCM)
l=c*double(LCM)
 mprintf('miller indices = %d %d %d',h,k,l)
```

Scilab code Exa 1.9 fractional concentration of vacancies

```
clc
//Chapter1
//Ex_1.9
//Given
k=1.38*10^-23 //J/K
T=300 //kelvin
Ev=0.75 //eV/atom
Ev=Ev*1.6*10^-19 //in J
T1=660//degree celcius
T1=T1+273 //in kelvin
//at room temperature
//let nv/N=nv_N for convenience
nv_N=exp(-Ev/(k*T))
disp(nv_N,"Fractional concentration of vacancies in
   the aluminium crystal at room temperature is")
//at melting temperature
//let nv/N=nv_N for convenience
```

```
nv_N=exp(-Ev/(k*T1))
disp(nv_N,"Fractional concentration of vacancies in
    the aluminium crystal at melting temperature is")
```

Scilab code Exa 1.10 concentration of vacancies

```
clc
//Chapter1
//Ex_1.10
//Given
NA=6.023*10^23 //mol^-1
d=2.33 //density of Si in g/cm3
Mat=28.09//g/mol
Ev=2.4 //ev/atom
Ev=2.4*1.6*10^-19 //J/atom
k=1.38*10^-23 //J/K
T=300 //kelvin
T1=1000//degree celcius
T1=T1+273 //in kelvin
N= (NA*d)/Mat
//at room temperature
nv=N*exp(-(Ev/(k*T)))
disp(nv,"concentration of vacancies in a Si crystal
    at room temperature in cm^-3 is")
//at 1000 degree celcius
nv=N*exp(-(Ev/(k*T1)))
disp(nv,"concentration of vacancies in a Si crystal
    at 1000 degree celcius in cm^-3 is")
```

Scilab code Exa 1.11 weight fractions

```
clc
//Chapter1
```

```
//Ex_1.11
//Given
//from fig 7.1
//at 210 degree celcius
disp("At 210 degree celcius")
C_L=50 //CL=50% Sn
C_alpha=18 //C_alpha=18% Sn
Co=40 // solidification of alloy
//lever rule
W_alpha=(C_L-Co)/(C_L-C_alpha)
disp(W_alpha*100,"weight fraction of alpha in the alloy is")
W_L=1-W_alpha
disp(W_L*100,"weight fraction of liquid phase in the alloy is")
//at 183.5 degree celcius
disp("At 183.5 degree celcius")
C_L=61.9 //CL=50% Sn
C_alpha=19.2 //C_alpha=18% Sn
Co=40 // solidification of alloy
//lever rule
W_alpha=(C_L-Co)/(C_L-C_alpha)
disp(W_alpha*100,"weight fraction of alpha in the alloy is")
W_L=1-W_alpha
disp(W_L*100,"weight fraction of liquid phase in the alloy is")
//at 182.5 degree celcius
disp("At 182.5 degree celcius")
C_beta=97.5 //CL=50% Sn
C_alpha=19.2 //C_alpha=18% Sn
Co=40 // solidification of alloy
//lever rule
W_alpha=(C_beta-Co)/(C_beta-C_alpha)
disp(W_alpha*100,"weight fraction of alpha in the alloy is")
W_beta=1-W_alpha
disp(W_beta*100,"weight fraction of beta phase in
```

```
the alloy is")
```

Chapter 2

Electrical and thermal conduction in solids

Scilab code Exa 2.2 drift mobility of electrons

```
clc
//Chapter2
//Ex_2.2
//Given
sigma=5.9*10^5 //in ohm^-1*cm^-1
e=1.6*10^-19 //Coulombs
d=8.93 //g/cm^3
Mat=63.5//g/mol
NA=6.02*10^23//mol^-1
n=d*NA/Mat
u_d=sigma/(e*n)//electron drift mobility
disp(u_d,"Drift mobility of electrons in copper at
   room temperature in cm2/V/s is")
```

Scilab code Exa 2.3 Applied electric field

```
clc
//Chapter2
//Ex_2.3
//Given
u_d=3.2*10^-3 //in m^2/V/s
u=1.2*10^6 //m/s
v_dx=0.1*u
// drift velocity of conduction electrons is v_dx=
   u_d*E
E=v_dx/u_d
disp(E,"Applied electric field in V/m is")
```

Scilab code Exa 2.4 percentage change in the resistance

```
clc
//Chapter2
//Ex_2.4
//Given
T_summer=20 //in degree celcius
T_summer=T_summer+273 //in kelvin
T_winter=-30 //in degree celcius
T_winter=T_winter+273 //in kelvin
//we have R is proportional to A*T
//Hence
R=(T_summer-T_winter)/T_summer
R=R*100
disp(R," Percentage change in the resistance of a
   pure metalwire from Saskatchewans summer too
   winter in % is ")
```

Scilab code Exa 2.5 drift mobility and conductivity

```
clc
```

```
//Chapter2
//Ex_2.5
//Given
d=8.96*10^3 //in Kg/m3
NA=6.02*10^23 //mol^-1
Mat=63.56*10^-3 //Kg/mol
k=1.38*10^-23 //J/K
T=300 //kelvin
e=1.6*10^-19 //in couloumbs
m_e= 9.1*10^-31 //in Kg
u=1.25*10^6//m/s
f=4*10^12 //frequency in s^-1
Ns=d*NA/Mat// atomic concentration in m^-3
M=Mat/NA
w=2*%pi*f //angular frequency of the vibration
//by virtue of Equipartition of energy  theorem
a=sqrt((2*k*T)/(M*w^2))
S=%pi*a^2 //cross sectional area
t=1/(S*u*Ns) //mean free time
u_d=e*t/m_e //drift velocity
u_d=u_d*10^4 //change in units
Ns=Ns/10^6 //in cm^-3
sigma=e*Ns*u_d //conductivity
disp(u_d,"drift velocity of electrons in m2/V/s is")
disp(sigma," conductivity of copper in ohm^-1/cm is")
//slight change in the answer is due to the computation method, otherwise answer is matching with textbook
```

Scilab code Exa 2.7 TCR and n

```
clc
//Chapter2
//Ex_2.7
```

```
//Given
n=1.2
To=293 //in kelvin
alpha_o=n/To
printf("Theoretical value of TCR at 293K is %f which
    is in well agreement with exprimental value",
   alpha_o)
alpha_o=0.00393 //experimental value
n=alpha_o*To
disp(n,"Theoretical value of n at 293K is in well
   agreement with exprimental value")
```

Scilab code Exa 2.9 temperature of the filament

```
clc
//Chapter2
//Ex_2.9
//Given
P=40 //in Watt
V=120 //in Volts
D=33*10^-6 //in meter
L=0.381 //in meter
To=293 // in kelvin
P_radiated=40//in watt
epsilon=0.35
sigma_s=5.6*10^-8 //in W/m2/K4
I=P/V
A=%pi*D^2/4
R=V/I // resistance of the filament
p_t=R*A/L // resistivity of tungsten
p_o=5.51*10^-8 // resistivity at room temperature in
    ohm*m
//p_t=p_o*(T/To)^1.2
T=To*(p_t/p_o)^(1/1.2)
disp(T,"Temperature of the bulb when it is operated
```

```
   at the rated voltage in Kelvin is ")
A=L*%pi*D
//Stefans Law
T=(P_radiated/(epsilon*sigma_s*A))^(1/4)
disp(T,"Temperature of the filament in kelvin is")
```

Scilab code Exa 2.10 resistivity

```
clc
//Chapter2
//Ex_2.10
//Given
M_Au=197
w=0.1
M_Cu=63.55
p_exp=108 //n*ohm*m
X=M_Au*w/((1-w)*M_Cu+(w*M_Au))
C=450//n*ohm*m
p_Au=22.8 // resistivity in n*ohm*m
p=p_Au+C*X*(1-X) //Nordheim rule
x=((p-p_exp)/p)*100
disp(p,"resistivity of the alloy in n*ohm*m is")
disp(x,"The difference in the value from
   experimental value in % is")
```

Scilab code Exa 2.11 worst case resistivity

```
clc
//Chapter2
//Ex_2.11
//Given
u=1.58*10^6 //in m/s
N=8.5*10^28 //m^-3
```

```
e=1.6*10^-19 // in coulombs
me=9.1*10^-31 //in Kg
N_I=0.01*N
l_I=N_I^(-1/3)
t_I=l_I/u
p=me/(e^2*N*t_I)
disp(p," worst case resistivity in ohm*m")
//slight change in answer due to computational
   method
```

Scilab code Exa 2.13 effective resistivity

```
clc
//Chapter2
//Ex_2.13
//Given
Xd=0.15
p_c=1*10^-7 //ohm*m
p_eff=p_c*((1+0.5*Xd)/(1-Xd))
disp(p_eff,"Effective resistivity in ohm m is")
//slight change in the answer due to printing the
   answer
```

Scilab code Exa 2.14 Effective Resistivity

```
clc
//Chapter2
//Ex_2.14
//Given
Xd=0.15
p_c=4*10^-8 //ohm*m
p_eff=p_c((1+0.5*Xd)/(1-Xd))
disp(p_eff,"Effective resistivity in ohm m is")
```

```
// change in the answer due to coding
```

Scilab code Exa 2.16 change in dc resistance

```
clc
//Chapter2
//Ex_2.16
//Given
//at f=10MHz
a=10^-3 //in m
f=10*10^6 //in Hz
w=2*%pi*f
sigma_dc=5.9*10^7 // in m^-1
u=1.257*10^-6 //in Wb/A/m
delta=1/sqrt(0.5*w*sigma_dc*u)
//let r=r_ac/r_dc=a/(2*delta)
r=a/(2*delta)
disp(r,"Change in dc resistance of a copper wire at
    10MHz is")
//part(b)
f=1*10^9 //in Hz
w=2*%pi*f
delta=1/sqrt(0.5*w*sigma_dc*u)
//let r=r_ac/r_dc=a/(2*delta)
r=a/(2*delta)
disp(r,"Change in dc resistance of a copper wire at
    1GHz is")
```

Scilab code Exa 2.18 drift mobility

```
clc
//Chapter2
//Ex_2.18
```

```
//Given
sigma=5.9*10^7 //ohm^-1*m^-2
RH=-0.55*10^-10//m^3/A/s
u_d=-RH*sigma
disp(u_d,"drift mobility of electrons in copper in
    m2/V/s")
```

Scilab code Exa 2.19 concentration of conduction electrons

```
clc
//Chapter2
//Ex_2.19
//Given
no=8.5*10^28 // in m3
e=1.6*10^-19 //in coulombs
u_d=3.2*10^-3 //m2/V/s
sigma=5.9*10^7 //in ohm^-1*m^-1
n=sigma/(e*u_d)
disp(n,"concentration of conduction electrons in
    copper in m^-3 is")
A=n/no
disp(A,"Average number of electrons contributed per
    atom is")
```

Scilab code Exa 2.20 Thermal conductivity

```
clc
//Chapter2
//Ex_2.20
//Given
sigma=1*10^7 //ohm^-1*m^-1
T=300// kelvin
C_WFL=2.44*10^-8 //W*ohm/K2
```

```
X_d=0.15
K_c=sigma*T*C_WFL
K_eff=K_c*((1-X_d)/(1+0.5*X_d))
disp(K_eff,"Thermal Conductiity at room temperature
    in W/m/K")
```

Scilab code Exa 2.21 temperature drop

```
clc
//Chapter2
//Ex_2.21
//Given
sigma=50*10^-9//in ohm
T=300 //kelvin
C_WFL=2.45*10^-8 //in W*ohm/K2
L=30*10^-3 //in m
d=20*10^-3 //in m
Q=10 //in W
//Wiedemann-Franz Lorenz Law
k=sigma^-1*T*C_WFL //thermal conductivity
A=%pi*(d^2)/4
theta=L/(k*A) //thermal resistance
delta_T=theta*Q
disp(delta_T,"Temperature drop across the disk in
    degree celcius is")
```

Chapter 3

Elementary Quantum Physics

Scilab code Exa 3.1 energy

```
clc
//Chapter3
//Ex_1
//Given
lambda=450*10^-9 // in nm
h=6.6*10^-34 //in J s
e=1.6*10^-19 // in coulombs
c=3*10^8 //in m/s
E_ph=h*c/lambda //in J
E_ph=E_ph/e // in eV
disp(E_ph," Energy of blue photon in eV is")
```

Scilab code Exa 3.2 Photoelectric experiment

```
clc
//Chapter3
//Ex_2
//Given
```

```
lambda_o=522*10^-9 // in nm
lambda=250*10^-9 // in nm
h=6.6*10^-34 //in J s
c=3*10^8 //in m/s
e=1.6*10^-19 //in coulombs
I=20*10^-3 //in W/cm2
I=20*10^-3*10^4 //in J/s/m2
//part(a)
phi=h*c/(lambda_o*e) //in eV
disp(phi,"Work function of sodium in eV is")
KE=h*c/(lambda*e)-phi
disp(KE,"Kinetic energy of photoemitted electrons in
    eV is")
J=(e*I*lambda)/(h*c)
disp(J,"Photoelectric current density in A/m2 is")
```

Scilab code Exa 3.4 wavelength of electron

```
clc
//Chapter3
//Ex_4
//Given
theta=15.2 // in degree
d=0.234 // in nm
V=100 //in V
lambda=2*d*sind(theta) //Braggs condition
disp(lambda,"Wavelength of electron in nm is")
lambda=1.226/sqrt(V) //debroglie wavelength in nm
disp(lambda,"de Broglie Wavelength of electron in nm
    is")
disp("de Broglie Wavelength is in excellent
    agreement with that determined from Braggs
    condition")
```

Scilab code Exa 3.5 energy

```
clc
//Chapter3
//Ex_5
//Given
h=6.6*10^-34 //in J s
c=3*10^8 //in m/s
n=1
m=9.1*10^-31 //in Kg
a=0.1*10^-9 //in m
e=1.6*10^-19 //in coulombs
E1=(h^2*n^2)/(8*m*a^2)
E1=E1/e //in eV
disp(E1,"Ground Energy of the electron in J is")
//part(b)
n=3
E3=E1*n^2
disp(E3,"Energy required to put the electrons in third energy level in eV is")
E=E3-E1
disp(E,"Energy required to take the electron from E1 to E3 in eV is ")
lambda=h*c/(E*e)
disp(lambda,"wavelength of the required photon in nm is")
disp( "which is an X-ray photon")
```

Scilab code Exa 3.6 separation of energy levels

```
clc
//Chapter3
```

```
//Ex_6
//Given
h=6.6*10^-34 //in J s
c=3*10^8 //in m/s
n=1
m=0.1 //in Kg
a=1 //in m
E1=(h^2*n^2)/(8*m*a^2)
v=sqrt(2*E1/m)
disp(v,"Minimum speed of the object in m/s")
//calculation of quantum number n
v=1 //in m/s
E_n=m*v^2/2
n=sqrt((8*m*a^2*E_n)/h^2)
disp(n,"Quantum number if the object is moving with
    a minimum speed of 1m/s is")
delta_E=(h^2/(8*m*a^2))*(2*n+1) //delta_E=E_n+1-En
disp(delta_E,"Separation of energy levels of the
    object moving with speed of 1 m/s in Joules is ")
```

Scilab code Exa 3.8 uncertainity principle on Atomic scale

```
clc
//Chapter3
//Ex_8
//Given
h_bar=1.054*10^-34 // in J s
delta_x=0.1*10^-9 //in m
m_e=9.1*10^-31 //in Kg
delta_Px=h_bar/delta_x
disp(delta_Px,"uncertainity in momemtum in Kg m/s is
    ")
delta_v=delta_Px/m_e
KE=delta_Px^2/(2*m_e)
disp(KE,"Uncertainity in Kinetic Energy in J is")
```

Scilab code Exa 3.9 uncertainity principle with macroscopic objects

```
clc
//Chapter3
//Ex_9
//Given
h_bar=1.054*10^-34 // in J s
delta_x=1 //in m
m=0.1 //in Kg
delta_Px=h_bar/delta_x
delta_v=delta_Px/m
disp(delta_v,"minimum uncetainity in the velocity in
    m/s is")
```

Scilab code Exa 3.10 Transmission coefficient

```
clc
//Chapter3
//Ex_10
//Given
h_bar=1.054*10^-34 // in J s
m=9.1*10^-31 //in Kg
e=1.6*10^-19 // in coulombs
Vo=10 //in ev
Vo=Vo*e //in J
E=7 // in eV
E=E*e // in J
a=5*10^-9 // in m
alpha=sqrt(2*m*(Vo-E)/h_bar^2)
To=16*E*(Vo-E)/Vo^2
T=To*exp(-2*alpha*a)
```

```
disp(T,"Transmission coefficient of condution electrons in copper is")
a=1*10^-9 // in m
T=To*exp(-2*alpha*a)
disp(T,"Transmission coefficient if the oxide barrier is 1 nm is")
// slight change in the answer due to approximations in alpha value
```

Scilab code Exa 3.11 significance of small h

```
clc
//Chapter3
//Ex_11
//Given
h_bar=1.054*10^-34 // in J s
m=100// in Kg
g=10 // in m/s2
h=10 // in m
h1=15 // in m
a=10 // in m
E=m*g*h //total energy of carriage
Vo=m*g*h1 // PE required to reach the peak
alpha=sqrt(2*m*(Vo-E)/h_bar^2)
To=16*E*(Vo-E)/Vo^2
T=To*exp(-2*alpha*a)
disp(T, "Transmission probability is")
//clculation using h_bar=10 KJs
h_bar=10*10^3 //Js
alpha=sqrt(2*m*(Vo-E)/h_bar^2)
D=Vo^2/(4*E*(Vo-E))
T=(1+(sinh(alpha*a))^2)^-1
disp(T,"transmission probability in a universe where h_bar is 10KJs is")
```

Scilab code Exa 3.12 number of states with same energy

```
clc
//Chapter3
//Ex_12
//Given
x=9
for n1=1:x
  for n2=1:x
   for n3=1:x
y=n1^2+n2^2+n3^2 //let y=N^2=n1^2+n2^2+n3^2
if (y==41)

    mprintf('%d\t%d\t%d\n',n1    ,n2    ,n3    )

end;
end
end
end
disp("Thus there are nine possible states")
```

Scilab code Exa 3.13 wavelengths of radiation

```
clc
//Chapter3
//Ex_13
//Given
h=6.6*10^-34 //in J s
c=3*10^8 //in m/s
m=9.1*10^-31 //in Kg
e=1.6*10^-19 // in coulombs
v=2.1*10^6 // in m/s
```

```
E=m*v^2/2 //in J
E=E/e // in eV
E1=-13.6 // in eV
//change in the energy is E=En-E1
n=sqrt(-13.6/(E+E1))
printf(" the electron gets excited to %d level",n)
n=3
E3=-13.6/n^2
delta_E31=E3-E1 // in eV
delta_E31=delta_E31*e //in J
lambda_31=h*c/delta_E31
disp(lambda_31*10^9,"wavelength of emmited radiation
    from n=3 to n=1 in nm is")
//Another probability is transition fromm n=3 to n=2
n=2
E2=-13.6/n^2
delta_E32=E3-E2 // in eV
delta_E32=delta_E32*e // in J
lambda_32=h*c/delta_E32
disp(lambda_32*10^9,"wavelength of emmited radiation
    from n=3 to n=2 in nm is")
//Another probability is transition fromm n=2 to n=1
E2=-13.6/n^2
delta_E21=E2-E1 // in eV
delta_E21=delta_E21*e // in J
lambda_21=h*c/delta_E21
disp(lambda_21*10^9,"wavelength of emmited radiation
    from n=2 to n=1 in nm is")
```

Scilab code Exa 3.14 Ionization energy

```
clc
//Chapter3
//Ex_14
//Given
```

```
Z=2
n=1
E1=-Z^2*13.6/n^2
E1=abs(E1)
disp(E1,"Energy required to ionize He+ further in eV
    is")
```

Scilab code Exa 3.15 Fraunhofer lines

```
clc
//Chapter3
//Ex_15
//Given
Z=1
n1=2
n2=3
R_inf=1.0974*10^7 // in m^-1
//Let x=1/lambda
x=R_inf*Z^2*((1/n1^2)-(1/n2^2))
lambda=1/x
disp(lambda*10^10, "Wavelength of first spectral
   line in Angstroms is")
n1=2
n2=4
x=R_inf*Z^2*((1/n1^2)-(1/n2^2))
lambda=1/x
disp(lambda*10^10, "Wavelength of second spectral
   line in Angstroms is")
disp("These spectral lines correspond to H_alpha and
    H_beta lines of Hydrogen")
```

Scilab code Exa 3.16 Giant atoms in space

```
clc
//Chapter3
//Ex_16
//Given
h=6.6*10^-34 //in J s
e=1.6*10^-19 // in coulombs
E1=13.6 //in eV
E1=E1*e //in J
Z=1
n1=109
n2=110
ao=52.918*10^-12 // in m
v=Z^2*E1*((1/n1^2)-(1/n2^2))/h
disp(v*10^-6,"Frequency of radiation in MHz is")
disp("The frequency of radiation in the transition
    from n1=109 to n2=110 is same as that of the
    detected frequency .Hence, the radiation comes
    from excited hydrogen atoms in the give
    transition")
x=2*n2^2*ao
disp(x*10^6,"The sie of the atom in micro meter is")
//slight difference in the answer is due to
    approximations
```

Scilab code Exa 3.20 efficiency of HeNe laser

```
clc
//Chapter3
//Ex_20
//Given
P_out=2.5*10^-3 // in Watt
I=5*10^-3 // in Amp
V=2000 // in volts
P_in=V*I
E=(P_out/P_in)*100
```

```
disp(E,"Efficiency of the laser in % is")
```

Scilab code Exa 3.21 Doppler Broadened Linewidth

```
clc
//Chapter3
//Ex_21
//Given
lambda_o=632.8*10^-9 //in m
c=3*10^8 //in m/s
T=127 //in degree celcius
T=T+273 // in Kelvin
m_A=20.2*10^-3 // in Kg/mol
NA=6.023*10^23 //mol^-1
k=1.38*10^-23 //in J/K
m=m_A/NA //in Kg
vx=sqrt(k*T/m)
vo=c/lambda_o
delta_v=2*vo*vx/c
disp(delta_v*10^-9,"delta_v in GHz is")
delta_lambda=delta_v*(-lambda_o/vo)
disp(abs(delta_lambda),"delta_lambda in meters is")
```

Chapter 4

Bonding the Band Theory of Solids and Statistics

Scilab code Exa 4.5 Fermi speed

```
clc
//Chapter4
//Ex_5
//Given
E_F0=7 //in eV
e=1.6*10^-19 // in coulombs
E_F0=E_F0*e //in Joules
me=9.1*10^-31 //in Kg
v_f=sqrt(2*E_F0/me)
disp(v_f,"Speed of the conduction electrons in m/s
    is")
```

Scilab code Exa 4.6 Cutt Off wavelength

```
clc
//Chapter4
```

```
//Ex_6
//Given
e=1.6*10^-19 // in coulombs
Eg=1.1 //in eV
Eg=Eg*e // in Joules
h=6.6*10^-34 //in Js
c=3*10^8 // in m/s
lambda=h*c/Eg
disp(lambda*10^6,"Wavelength of light that can be absorbed by an Si photodetector at Eg=1.1 eV in micro meter is")
disp("Hence the light of wavelength 1.31 micro meter and 1.55 micro meter will not be absorbed by Si and thus cannot be detected by detector")
```

Scilab code Exa 4.7 Density of states in a band

```
clc
//Chapter4
//Ex_7
//Given
e=1.6*10^-19 // in coulombs
h=6.626*10^-34 //in Js
me=9.1*10^-31 //in Kg
//let x=k*T
x=0.026 // in eV
E=5 //in ev
E=E*e // in Joules
g_E=(8*%pi*sqrt(2))*(me/h^2)^(3/2)*sqrt(E)// in J^-1*m^-3
//convesion of units
g_E=g_E*10^-6*e //in eV^-1 cm^-3
disp(g_E,"density of states at the center of the band in cm^-3*J^-1 is")
//part(b)
```

```
n_E=g_E*x // in cm^-3
disp(n_E," No.of states per unit volume within kT
    about the center in cm^-3 is")
//part(c)
E=0.026 //in eV
E=E*e // in joules
g_E=(8*%pi*sqrt(2))*(me/h^2)^(3/2)*sqrt(E)// in J
    ^-1*m^-3
//convesion of units
g_E=g_E*10^-6*e //in eV^-1 cm^-3
disp(g_E,"density of states at at kT above the band
    in cm^-3*J^-1 is")
//part(d)
n_E=g_E*x // in cm^-3
disp(n_E," No.of states per unit volume within kT
    about the center in cm^-3 is")
//solved using the values taken from the solution of
     textbook
```

Scilab code Exa 4.8 Total number of states in a band

```
clc
//Chapter4
//Ex_8
//Given
e=1.6*10^-19 // in coulombs
h=6.626*10^-34 //in Js
me=9.1*10^-31 //in Kg
d=10.5 // in g/cm
Mat=107.9 //g/mol
NA=6.023*10^23 // mol^-1
E_ctr=5 //in ev
E_ctr=E_ctr*e // in Joules
S_band=2*(16*%pi*sqrt(2)/3)*(me/h^2)^(3/2)*(E_ctr)
    ^(3/2)// in states m^-3
```

```
//convesion of units
S_band=S_band*10^-6 //in states cm^-3
disp(S_band,"No. of states in the band in states cm
   ^-3 is")
n_Ag=d*NA/Mat
disp(n_Ag,"No.of atoms per unit volume in silver in
   atoms per cm3 is")
```

Scilab code Exa 4.9 Mean speed of conduction electrons

```
clc
//Chapter4
//Ex_9
//Given
e=1.6*10^-19 // in coulombs
h=6.626*10^-34 //in Js
me=9.1*10^-31 //in Kg
d=8.96 // in g/cm
Mat=63.5 // g/ mol
NA=6.023*10^23 // mol^-1
n=d*NA/Mat //in cm^-3
n=n*10^6 //in m^-3
E_F0=(h^2/(8*me))*(3*n/%pi)^(2/3) //in J
E_F0=E_F0/e //in eV
disp(E_F0,"Fermi energy at 0 Kelvin in eV is")
E_F0=(h^2/(8*me))*(3*n/%pi)^(2/3) //in J
v_e=sqrt(6*E_F0/(5*me))
disp(v_e,"Average speed of conduction electrons in m
   /s is")
```

Scilab code Exa 4.10 Mean free path of electrons in a metal

```
clc
```

```
//Chapter4
//Ex_10
//Given
e=1.6*10^-19 // in coulombs
me=9.1*10^-31 //in Kg
u_d=43*10^-4 // in cm2/V/s
v_e=1.22*10^6 // in m/s
T=u_d*me/e
l_e=v_e*T
disp(l_e,"Mean free path of electrons in meters is")
```

Scilab code Exa 4.11 Thermocouple EMF

```
clc
//Chapter4
//Ex_11
//Given
e=1.6*10^-19 // in coulombs
T=373 // in kelvin
To=273 // in kelvin
k=1.38*10^-23 //in m2 kg /k/s2
//from table 4.3
E_FA0= 11.6 //in eV
E_FA0=E_FA0*e //in J
x_A=2.78
E_FB0= 7.01 //in eV
E_FB0=E_FB0*e //in J
x_B=-1.79
//Mott jones Equation
V_AB=(-%pi^2*k^2/(6*e))*((x_A/E_FA0)-(x_B/E_FB0))*(T
   ^2-To^2)
disp(V_AB*10^6,"EMF in micro volts available from Al
    and Cu thermocouple with the given respective
   temperatures at the junctions is")
```

Scilab code Exa 4.13 Vacuum tubes

```
clc
//Chapter4
//Ex_13
//Given
phi=2.6 //in eV
e=1.6*10^-19 //in coulombs
phi=phi*e //in Joules
Be=3*10^4 //schottky coefficient in A/m2/K2
T=1600 //in degree celcius
T=T+273 //in Kelvin
k=1.38*10^-23 //m2 kg s-2 K-1
d=2*10^-3 //in m
l=4*10^-2 //in in m
//Richardson-Dushman Equation
J=Be*T^2*exp(-phi/(k*T))
A=%pi*d*l
I=J*A
disp(I,"Saturation current in Amperes if the tube is
    operated at 1873 kelvin is")
```

Scilab code Exa 4.14 Field Assisted Thermionic Emission

```
clc
//Chapter4
//Ex_14
//Given
phi=2.6 //in eV
e=1.6*10^-19 //in coulombs
phi=phi*e //in Joules
x=1*10^-3 // distance in m
```

```
V=4*10^3 // in Volts
Be=3*10^4 //schottky coefficient in A/m2/K2
T=1600 //in degree celcius
T=T+273 //in Kelvin
k=1.38*10^-23 //m2 kg s-2 K-1
d=2*10^-3 //in m
l=4*10^-2 //in in m
A=2.5*10^-4 //in m2 //from example 12
E=V/x
beta_s=3.79*10^-5 //in eV/sqrt(V/m)
phi_eff=phi-beta_s*sqrt(E)
Io=A*Be*T^2
I1=Io*exp(-phi/(k*T))
I2=I1*exp((phi-phi_eff)*e/(k*T)) //converting phi
    value from joules to eV
disp(I2,"Theoretical saturation current in Amperes
    is")
```

Chapter 5

Semiconductors

Scilab code Exa 5.1 Intrinsic concentration and conduction of Si

```
clc
//Chapter5
//Ex_1
//Given
e=1.6*10^-19 // in coulombs
h=6.6*10^-34 //in J s
m=9.1*10^-31 //in Kg
me=1.08*m
mh=0.56*m
T=300 //in Kelvin
Eg=1.10 // in eV
ue=1350//in cm2/V/s
uh=450//in cm2/V/s
k=1.38*10^-23 //m2 kg s-2 K-1
Nc=2*((2*%pi*me*k*T)/h^2)^(3/2) //in m^-3
Nc=Nc*10^-6 //in cm^-3
Nv=2*((2*%pi*mh*k*T)/h^2)^(3/2) //in m^-3
Nv=Nv*10^-6 //in cm^-3
ni=sqrt(Nc*Nv)*exp(-Eg*e/(2*k*T))
disp(ni,"Intrinsic concentration of Si in cm^-3 is")
sigma=e*ni*(ue+uh)
```

```
p=1/sigma
disp(p,"Intrinsic resistivity of Si in ohm cm is")
```

Scilab code Exa 5.2 Mean speed of electrons in conduction band

```
clc
//Chapter5
//Ex_2
//Given
T=300//in kelvin
k=1.38*10^-23 // in m2 kg s-2 K-1
me=9.1*10^-31 // in Kg
m=0.26*me
Ve=sqrt(3*k*T/m)
disp(Ve,"Mean speed of electrons in conduction band
   in m/s is")
```

Scilab code Exa 5.3 Resistivity of intrinsic and doped Si

```
clc
//Chapter5
//Ex_3
//Given
e=1.6*10^-19 // in coulombs
ue=1350//in cm2/V/s
uh=450//in cm2/V/s
ni=1.45*10^10 //in cm^-3
L=1 //in cm
A=1 //in cm2
N_Si=5*10^22 //in cm^-3
sigma=e*ni*(ue+uh)
R=L/(sigma*A)
```

```
disp(R,"Resistance of a pure Silicon crystal in ohms
    is")
Nd=N_Si/10^9
n=Nd //at room temperature
p=ni^2/Nd
sigma=e*n*ue
R=L/(sigma*A)
disp(R,"Resistance in ohms of Silicon crystal when
   dopped with Arsenic with 1 in 10^9 is")
```

Scilab code Exa 5.4 compensation doping

```
clc
//Chapter5
//Ex_4
//Given
Na=10^17 //acceptor atoms /cm3
Nd=10^16 //donor atoms /cm3
p=Na-Nd // in cm^-3
ni=1.45*10^10 //in cm^-3
n=ni^2/p
disp(n,"Electron concentration in cm^-3")
```

Scilab code Exa 5.5 fermi level

```
clc
//Chapter5
//Ex_5
//Given
Na=2*10^17 //acceptor atoms /cm3
Nd=10^16 //acceptor atoms /cm3
ni=1.45*10^10 //in cm^-3
K=0.0259 //  in eV
```

```
//since Nd>>ni
n=Nd
//let EFn−EFi=E
E=K*log(Nd/ni)
disp(E,"Position of the fermi energy w.r.t fermi
   energy in intrinsic Si in eV is")
//for intrinsic Si
//ni=Nc*exp(−(Ec−E_Fi)/(k*T))
//for doped Si
//Nd=Nc*exp(−(Ec−E_Fn)/(k*T))
//let x=Nd/ni
//let K=k*T
p=Na-Nd
//let E=EFp−EFi
//let n=p/ni
E=-K*log(p/ni)
disp(E,"Position of the fermi energy w.r.t fermi
   energy in n−type case in eV is")
```

Scilab code Exa 5.7 Saturation and Intrinsic temperatures

```
clc
//Chapter5
//Ex_7
//Given
Nd=10^15 //in cm^−3
Nc=2.8*10^19 //in cm^−3
Ti=556 // in Kelvin
k=8.62*10^-5 //in eV/K
delta_E=0.045 //in eV
T=300 //in kelvin
//part(a)
disp("From fig 5.16 the estimated temperature above
   which the si sample behaves as if intrinsic is
   556 Kelvin")
```

```
//part(b)
Ts=delta_E/(k*log(Nc/(2*Nd)))
Nc_Ts=Nc*(Ts/T)^(3/2)
disp(Ts,"Lowest temperature in kelvin is")
//the improved temperature
Ts=delta_E/(k*log(Nc_Ts/(2*Nd)))
printf("Extrinsic range of Si is %f K to 556 K",Ts)
```

Scilab code Exa 5.9 Compensation Doped Si

```
clc
//Chapter5
//Ex_9
//Given
e=1.6*10^-19 // in coulombs
Nd=10^17 //in cm^-3
Na=9*10^16 //in cm^-3
//part(a)
ue1=800 // at 300 kelvin ue in cm2/V/s
sigma1=e*Nd*ue1
ue2=420 // at 400 kelvin ue in cm2/V/s
sigma2=e*Nd*ue2
disp(sigma2,sigma1,"when Si sample is doped with
    10^17 arsenic atoms/cm3, the conductivity of the
    sample at 300K and 400K in ohm^-1*cm^-1 is")
//part(b)
ue1=600 // at 300 kelvin ue in cm2/V/s
sigma1=e*(Nd-Na)*ue1
ue2=400 // at 400 kelvin ue in cm2/V/s
sigma2=e*(Nd-Na)*ue2
disp(sigma2,sigma1,"when n-type Si is further doped
    with 9*10^16 boron atoms /cm3, the conductivity
    of the sample at 300K and 400K in ohm^-1*cm^-1 is
    ")
```

Scilab code Exa 5.11 Photoconductivity

```
clc
//Chapter5
//Ex_11
//Given
//part(a)
h=6.63*10^-34 //in Js
c=3*10^8 // in m/s
e=1.6*10^-19 // in coulombs
ue=0.034 //in m2/V/s
uh=0.0018 //in m2/V/s
t=1*10^-3 // in seconds
L=1*10^-3 //in m
D=0.1*10^-3 //in m
W=1*10^-3 //in m
I=1// mW/cm^2
I=I*10^-3*10^4 // conversion of units to W/m^2
n=1 //quantum efficiency
lambda=450*10^-9 // in m
V=50 // in volts
//part(a)
A=L*W //in m3
EHP_ph=(A*n*I*lambda)/(h*c)
disp(EHP_ph,"No.of EHP/s generated per second is")
//part(b)
delta_sigma=e*n*I*lambda*t*(ue+uh)/(h*c*D)
disp(delta_sigma,"Photo conductivity of the sample
    in ohm^-1 m^-1 is")
//part(c)
A=0.1*10^-6 //m2
E=V/W
delta_J=E*delta_sigma
delta_I=A*delta_J
```

```
disp(delta_I*10^3,"Photocurrent produced in mA is")
```

Scilab code Exa 5.13 Diffusion coefficient of electrons in Si

```
clc
//Chapter5
//Ex_13
//Given
e=1.6*10^-19 // in coulombs
T=300//in kelvin
ue=1300 //in cm2/V/s
//V=k*T/e
V=0.0259 //thermal voltage in Volts
//D=ue*k*T/e
D=ue*V
disp(D,"Diffusion coefficient of electrons at room temperature in cm2/s is")
```

Scilab code Exa 5.17 Photogeneration in GaAs

```
clc
//Chapter5
//Ex_17
//Given
Eg=1.42 //in eV
//letE=hc/lambda=hf
E=1.96 //in eV
P_L=50 //in mW
kT=0.0259 // in eV
delta_E=E-(Eg+(3/2)*kT)
P_H=(P_L/(E))*delta_E
disp(P_H,"Amount of power dissipated as heat in mW is")
```

Scilab code Exa 5.18 Schottky diode

```
clc
//Chapter5
//Ex_18
//Given
phi_m=4.28 //in eV
e=1.6*10^-19 // in coulombs
X=4.01 //in eV
kT=0.026 // in eV
Vf=0.1// in V
T=300//in kelvin
Be=30 //A/K2/cm2
A=0.01 //cm2
//part(a)
phi_B=phi_m-X
disp(phi_B,"Theoretical barrier height in eV")
//part(b)
phi_B=0.5 //in eV
Io=A*Be*T^2*exp(-phi_B/kT)
disp(Io*10^6,"Saturation current in micro amperes is
    ")
//let/E=e*Vf //in eV
E=0.1 //in eV
If=Io*(exp((E/kT))-1)
disp(If*10^3,"Forward current in milli amperes is")
```

Chapter 6

Semiconductor devices

Scilab code Exa 6.1 Built in potential

```
clc
//Chapter6
//Ex_1
//Given
//let K=kT/e
K=0.0259 //in V
Nd=10^17 //in cm^-3
Na=10^16 //in cm^-3
ni_Si=1.45*10^10 //in cm^-3
ni_Ge=2.40*10^13 //in cm^-3
ni_GaAs=1.79*10^6 //in cm^-3
//Vo=(k*T/e)*log(Nd*Na/ni^2)
Vo_Si=(K)*log(Nd*Na/ni_Si^2)
disp(Vo_Si,"Built in potential for Si in Volts is")
Vo_Ge=(K)*log(Nd*Na/ni_Ge^2)
disp(Vo_Ge,"Built in potential for Ge in Volts is")
Vo_GaAs=(K)*log(Nd*Na/ni_GaAs^2)
disp(Vo_GaAs,"Built in potential for GaAs in Volts
    is")
```

Scilab code Exa 6.2 depletion width

```
clc
//Chapter6
//Ex_2
//Given
//let K=kT/e
K=0.0259 //in V
Na=10^18 //in cm^-3
Nd=10^16 //in cm^-3
e=1.6*10^-19 // in coulombs
Eo=8.85*10^-12 //in m-3 kg-1 s4 A2
Er=11.9
E=Eo*Er
ni=1.45*10^10 //in cm^-3
//Vo=(k*T/e)*log(Nd*Na/ni^2)
Vo=(K)*log(Nd*Na/ni^2)
disp(Vo)
Nd=Nd*10^6 //in m^-3
Wo=sqrt(2*E*Vo/(e*Nd))
disp(Wo*10^6,"Depletion width in micro meters is")
```

Scilab code Exa 6.3 Forward and Reverse biased

```
clc
//Chapter6
//Ex_3
//Given
//part(a)
//let K=k*T/e
K=0.0259 // in V
Te=5*10^-9 // in s
```

```
Th=417*10^-9 // in s
ue=120 //in cm2/V/s
uh=440 //in cm2/V/s
Na=5*10^18 // in cm^-3
Nd=10^16 //in cm^-3
T1=300 //in kelvin
T2=373 //in kelvin
Tg=10^-6 //in seconds
Vr=5 //in volts
ni_300=1.45*10^10 //in cm^-3 at 300K
ni_373=1.2*10^12 //in cm^-3 at 373K
A=0.01 //in cm2
e=1.6*10^-19 // in coulombs
epsilon_o=8.85*10^-12 //in F/m
epsilon_r=11.9
V=0.6 //in v
//De=k*T*ue/e
De=K*ue
Dh=K*uh
Le=sqrt(De*Te)
Lh=sqrt(Dh*Th)
disp(Le,"Diffusion length of electrons in cm is")
disp(Lh,"Diffusion length of holes in cm is")
//part(b)
//Vo=(k*T/e)*log(Nd*Na/ni^2)
Vo=K*log(Nd*Na/ni_300^2)
disp(Vo,"Built-in potential in volts is")
//part(C)
Iso_300=A*e*ni_300^2*Dh/(Lh*Nd)
//I=Iso*exp(eV/kT)
I=Iso_300*exp(V/K)
disp(I,"Current when there is a forward bias of 0.6
    V at 300K in Amperes is")
//part(d)
Iso_373=Iso_300*(ni_373/ni_300)^2
I=Iso_373*exp((V/K)*(T1/T2))
disp(I,"Current when there is a forward bias of 0.6
    V at 373K in Amperes is")
```

```
//part(e)
Nd=Nd*10^6 //in m^-3
epsilon=epsilon_o*epsilon_r
W=sqrt(2*epsilon*(Vo+Vr)/(e*Nd))
W=W*10^2 //in cm
ni=1.45*10^10 //in cm^-3
I_gen=e*A*W*ni/Tg
disp(I_gen,"Thermal generation current in Amperes is
   ")
```

Scilab code Exa 6.5 resistance and capacitance

```
clc
//Chapter6
//Ex_5
//Given
A=10^-6 //in m2
Vo=0.856 //in V
I=5*10^-3 // in Amperes
Iso=0.176*10^-12 //in Amperes
e=1.6*10^-19 // in coulombs
Eo=8.85*10^-12 //in m-3 kg-1 s4 A2
Er=11.9
Th=417*10^-9 //in seconds
Nd=10^22 //in m^-3
//let K=kT/e
K=0.0259 //in V
//Vo=(k*T/e)*log(I/Iso)
V=(K)*log(I/Iso)
I=5 // in mA
rd=25/I
disp(rd,"Incremental diode resistance in ohms is")
E=Eo*Er
C_dep=A*sqrt((e*E*Nd)/(2*(Vo-V)))
disp(C_dep,"Depletion capacitance of the diode in
```

```
   Farads")
C_diff=Th*I/25
disp(C_diff,"Incremental difusion coefficient in
   Farads is")
```

Scilab code Exa 6.6 Avalanche breakdown

```
clc
//Chapter6
//Ex_6
//Given
e=1.6*10^-19 // in coulombs
Nd=10^16 //in cm^-3
Ebr=4*10^5//in V/cm
epsilono=8.85*10^-12*10^-2 //in F/cm
epsilonr=11.9
epsilon=epsilono*epsilonr
Vbr=epsilon*Ebr^2/(2*e*Nd)
disp(Vbr,"Reverse break down voltage of the Si diode
    in Volts is")
//part(b)
Nd=10^17 //in cm^-3
Ebr=6*10^5//in V/cm
Vbr=epsilon*Ebr^2/(2*e*Nd)
disp(Vbr,"Reverse break down voltage in Volts when
   phosphorous doping is incresed to 10^17 cm^-3 is"
   )
```

Scilab code Exa 6.7 A pnp transistor

```
clc
//Chapter6
//Ex_7
```

```
//Given
//part(a)
Th=250*10^-9 //in seconds
A=0.02*10^-2 //in cm2
Av=10 //voltage gain
ni=1.45*10^10 //in cm^-3
Nd=2*10^16 //in cm^-3
W_B=2*10^-4 //in cm
uh=410 //in cm2/V/s
I_E=2.5*10^-3 //in Amperes
//let K=kT/e
K=0.0259 //in V
//Dh=(kT/e)*uh
Dh=K*uh
Tt=W_B^2/(2*Dh)
e=1.6*10^-19 // in coulombs
alpha=1-(Tt/Th)
disp(alpha,"CB current transfer ratio is")
funcprot(0)
beta=alpha/(1-alpha)
disp(beta,"current gain is")
//part(c)
I_EO=e*A*Dh*ni^2/(Nd*W_B)
//V_EB=(k*T/e)*log(I_E/I_EO)
V_EB=(K)*log(I_E/I_EO)
disp(V_EB,"V_EB in volts is")
//re=(k*T/e)/IE=25/IE(mA)
I_E=2.5 //in mA
re=25/I_E
disp(re,"small signal input resistance in ohms is")
//part(d)
R_C=Av*re
disp(R_C,"R_C in ohms is")
//part(e)
I_E=2.5*10^-3 //in Amperes
I_B=I_E*(1-alpha)
disp(I_B*10^6,"base current in micro amperes is")
//part(f)
```

```
f=1/Tt
disp(f*10^-6,"upper frequency range limit in MHz is")
```

Scilab code Exa 6.8 Emitter Injection Efficiency

```
clc
//Chapter6
//Ex_8
//Given
//part(c)
Nd=2*10^16 //in cm^-3
Na=10^19 //in cm^-3
W_B=2*10^-4 //in cm
W_E=2*10^-4 //in cm
ue=110 //in cm2/V/s
uh=410 //in cm2/V/s
Th=250*10^-9 //in seconds
//let K=kT/e
K=0.0259 //in V
//Dh=(kT/e)*uh
Dh=K*uh
Tt=W_B^2/(2*Dh)
gamma=1/(1+((Nd*W_B*ue)/(Na*W_E*uh)))
disp(gamma,"Injection frequency is")
alpha=gamma*(1-(Tt/Th))
disp(alpha,"Modified alpha is")
beta=alpha/(1-alpha)
disp(beta,"modified current gain is")
```

Scilab code Exa 6.9 power and voltage

```
clc
```

```
//Chapter6
//Ex_9
//Given
//rms output voltage
Ic=2.5 // in mA
Rc=1000 //in ohms
beta=100
vs=1//in mV
Rs=50 // in ohms
r_be=beta*25/Ic //Ic in mA
gm=Ic/25 //Ic in mA
//Av=v_ce/v_be=gm*Rc
Av=gm*Rc
v_be=vs*(r_be)/(r_be+Rs)//in mV
v_ce=Av*v_be
disp(v_ce,"rms output voltage in mV is")
v_be=v_be*10^-3 //in volts
Ap=beta*Av
P_in=v_be^2/r_be
disp(P_in*10^9,"Input power in watts is")
P_out=P_in*Ap
disp(P_out*10^6,"output power in watts is")
```

Scilab code Exa 6.10 jet amplifier

```
clc
//Chapter6
//Ex_10
//Given
V_GS=-1.5 //in Volts
V_GS_off=-5 //in Volts
I_DSS=10*10^-3 // in A
R_D=2000 // in ohms
I_DS=I_DSS*(1-(V_GS/V_GS_off))^2 // in A
gm=-2*sqrt(I_DSS*I_DS)/V_GS_off
```

```
Av=-gm*R_D
disp(Av,"voltage amplification for small signal is")
```

Scilab code Exa 6.11 drain current

```
clc
//Chapter6
//Ex_11
//Given
Z=50*10^-6 //in m
L=10*10^-6 //in m
t_ox=450*10^-10 //in m
V_GS=8//in V
V_th=4//in V
V_DS=20//in V
lambda=0.01
ue=750*10^-4 //in m2/V/s
epsilon_r=3.9
epsilon_o=8.85*10^-12//F/m2
epsilon=epsilon_r*epsilon_o
K=(Z*ue*epsilon)/(2*L*t_ox)
I_DS=K*(V_GS-V_th)^2*(1+lambda*V_DS)
disp(I_DS*10^3,"drain current in mA is")
```

Scilab code Exa 6.13 shot noise

```
clc
//Chapter6
//Ex_13
//Given
e=1.6*10^-19 // in coulombs
I=10^-3 //in A
Th=10^-6 //in s
```

```
B=1/Th //in Hz
i_sn=sqrt(2*e*I*B)
disp(i_sn,"shot noise current in amperes is")
```

Chapter 7

Dielectric Materials and Insulation

Scilab code Exa 7.1 dielectric constant

```
clc
//Chapter7
//Ex_1
//Given
NA=6.023*10^23 // in mol^-1
d=1.8 //g/cm3
Mat=39.95 //in mol^-1
epsilon_o=8.85*10^-12//F/m2
alpha_e=1.7*10^-40 //F*m2
N=NA*d/Mat //in cm^-3
N=N*10^6 // in m^-3
epsilon_r=1+(N*alpha_e/epsilon_o)
disp(epsilon_r,"Dielectric constant of solid Ar is")
//using clausius-mossotti equation
epsilon_r=(1+(2*N*alpha_e/(3*epsilon_o)))/(1-(N*
    alpha_e/(3*epsilon_o)))
disp(epsilon_r,"using clausius-mossotti equation,
    Dielectric constant of solid Ar is")
```

Scilab code Exa 7.2 Electronic Polarizability of covalent solids

```
clc
//Chapter7
//Ex_2
//Given
N=5*10^28 //in m^-3
e=1.6*10^-19 // in coulombs
Z=4
me=9.1*10^-31 //in Kg
epsilon_o=8.85*10^-12//F/m2
epsilon_r=11.9
//part(a)
alpha_e=(3*epsilon_o/N)*((epsilon_r-1)/(epsilon_r+2))
disp(alpha_e,"Electronic polarizability in F/m2")
//part(b)
//let x=E_loc/E
x=(epsilon_r+2)/3
printf("Local field is a factor of %f greater than applied field",x)
//part(c)
wo=sqrt(Z*e^2/(me*alpha_e))
fo=wo/(2*%pi)
disp(fo,"resonant frequency in Hz is")
```

Scilab code Exa 7.3 dielectric constant

```
clc
//Chapter7
//Ex_3
//Given
```

```
//let epsilon=E
Eo=8.85*10^-12 //in F/m
Ni=1.43*10^28//in m^-3
alpha_e_Cs=3.35*10^-40 //F m2
alpha_e_Cl=3.40*10^-40 //F m2
alpha_i=6*10^-40 //F m2
//(Er-1)/(Er+2)=(1/(3*E0))*(Ni*alpha_e(Cs+)+Ni*
    alpha_e(Cl-)+Ni*alpha_i)
//let x=(1/(3*E0))*(Ni*alpha_e(Cs+)+Ni*alpha_e(Cl-)+
    Ni*alpha_i)
//after few mathematical steps we get
//Er=(2*x+1)/(1-x)
x=(1/(3*Eo))*(Ni*alpha_e_Cs+Ni*alpha_e_Cl+Ni*alpha_i
    )
Er=(2*x+1)/(1-x)
disp(Er,"Dielectric constant at low frequency is")
//similarly
//let y=(1/(3*E0))*(Ni*alpha_e(Cs+)+Ni*alpha_e(Cl-))
//after few mathematical steps we get
//Erop=(2*x+1)/(1-x)
y=(1/(3*Eo))*(Ni*alpha_e_Cs+Ni*alpha_e_Cl)
Erop=(2*y+1)/(1-y)
disp(Erop,"Dielectric constant at optical frequency
    is")
```

Scilab code Exa 7.6 Dielectric loss per unit capacitance

```
clc
//Chapter7
//Ex_6
//Given
//power dissipated at a given voltage per unit
    capacitance depends only on w*tan(delta)
//at f=60 //in Hz.
f=60 //in Hz.
```

```
w=2*%pi*f
//let x=tan(delta)
x_PC=9*10^-4 //Ploycarbonate
x_SR=2.25*10^-2 //Silicone rubber
x_E=4.7*10^-2 //Epoxy with mineral filler
p_PC=w*x_PC
p_SR=w*x_SR
p_E=w*x_E
a=min(p_PC,p_SR,p_E)
printf("The minimum w*tan(delta) is %f which
    corresponds to polycarbonate",a)
disp("Hence the lowest power dissipation per unit
    capacitance at a given voltage corresponds to
    polycarbonate at 60Hz")
//at f=1 //in MHz.
f=10^6 //in Hz.
w=2*%pi*f
//let x=tan(delta)
x_PC=1*10^-2 //Ploycarbonate
x_SR=4*10^-3 //Silicone rubber
x_E=3*10^-2 //Epoxy with mineral filler
p_PC=w*x_PC
p_SR=w*x_SR
p_E=w*x_E
a=min(p_PC,p_SR,p_E)
printf("The minimum w*tan(delta) is %f which
    corresponds to Silicone rubber",a)
disp("Hence, the lowest power dissipation per unit
    capacitance at a given voltage corresponds to
    Silicone rubber at 1MHz")
```

Scilab code Exa 7.7 Dielectric loss

```
clc
//Chapter7
```

```
//Ex_7
//Given
//at 60 Hz
f=60 //Hz
E=100*10^3*10^2 //in V/m
//values taken from table 7.3
epsilon_o=8.85*10^-12 //in F/m
epsilon_r_HLPE=2.3
epsilon_r_Alumina=8.5
//let x=tan(delta)
x_HLPE=3*10^-4
x_Alumina=1*10^-3
W_vol_HLPE=2*%pi*f*E^2*epsilon_o*epsilon_r_HLPE*x_HLPE //in W/m3
W_vol_HLPE=W_vol_HLPE/10^3 //in mW/cm3
disp(W_vol_HLPE,"Heat dissipated per unit volume of HLPE at 60 Hz in mW/cm3 is")
W_vol_Alumina=2*%pi*f*E^2*epsilon_o*epsilon_r_Alumina*x_Alumina
W_vol_Alumina=W_vol_Alumina/10^3 //in mW/cm3
disp(W_vol_Alumina, "Heat dissipated per unit volume of Alumina at 60 Hz in mW/cm3 is")
//at 1 MHz
f=10^6 //Hz
x_HLPE=4*10^-4
x_Alumina=1*10^-3
W_vol_HLPE=2*%pi*f*E^2*epsilon_o*epsilon_r_HLPE*x_HLPE //in W/m3
W_vol_HLPE=W_vol_HLPE/10^6 //in W/cm3
disp(W_vol_HLPE,"Heat dissipated per unit volume of HLPE at 1 MHz in mW/cm3 is")
W_vol_Alumina=2*%pi*f*E^2*epsilon_o*epsilon_r_Alumina*x_Alumina
W_vol_Alumina=W_vol_Alumina/10^6 //in W/cm3
disp(W_vol_Alumina, "Heat dissipated per unit volume of Alumina at 1 MHz in mW/cm3 is")
disp("The heats at 60Hz are small comparing to heats at 1MHz")
```

Scilab code Exa 7.10 Dielectric Breakdown in a coaxial cable

```
clc
//Chapter7
//Ex_10
//Given
//part(C)
d=0.5 // cm
a=d/2 //in cm
t=0.5 // in cm
Ebr_X=217 // in kV/cm from table 7.5
Ebr_S=158 // in kV/cm from table 7.5
b=a+t
Vbr_X=Ebr_X*a*log(b/a)
disp(Vbr_X,"breakdown voltage of XLPE in kV is")
Vbr_S=Ebr_S*a*log(b/a)
disp(Vbr_S,"breakdown voltage of Silicone rubber in
    kV is")
//part(d)
//letE=epsiolon
Er_X=2.3 // for XLPE
Er_S=3.7 // for Silicone rubber
//Eair_br=Ebr
Eair_br_X=100 //in kV/cm
Eair_br_S=100 //in kV/cm
//Vair_br=Eair_br*a*log(b/a)/Er
Vair_br_X=Eair_br_X*a*log(b/a)/Er_X
disp(Vair_br_X,"Voltage for partial discharge in a
    microvoid for XLPE in  kV is")
Vair_br_S=Eair_br_S*a*log(b/a)/Er_S
disp(Vair_br_S, "Voltage for partial discharge in a
    microvoid for Silicone rubber in  kV is")
```

Scilab code Exa 7.11 conductance

```
clc
//Chapter7
//Ex_11
//Given
//letE=epsiolon
Er_100c=2.69
Er_25c=2.60
f=1*10^3 // in Hz
w=2*%pi*f
C_25c=560*10^-12 // in Farads
//Gp=w*C*tan(delta)
//let x=tan(delta)=0.002
x=0.002
Gp=w*C_25c*x
disp(Gp,"Equivalent parallel conductance at 25
    degree celcius in ohm^-1 is")
//at 100 c
x=0.01
C_100c=C_25c*Er_100c/Er_25c
Gp=w*C_100c*x
disp(Gp,"Equivalent parallel conductance at 100
    degree celcius in ohm^-1 is")
```

Scilab code Exa 7.12 Force

```
clc
//Chapter7
//Ex_12
//Given
Eo=8.85*10^-12//F/m2
```

```
Er=1000
D=3*10^-3 //in m
V=5000 // in V
d=200*10^-12 //in m/V
L=10*10^-3 //in mm
A=%pi*(D/2)^2
F=Eo*Er*A*V/(d*L)
disp(F,"Force required to spark the gap in Newton is
    ")
```

Scilab code Exa 7.13 frequency

```
clc
//Chapter7
//Ex_13
//Given
fs=1 //in MHz
k=0.1
fa=fs/(sqrt(1-k^2))
disp(fa,"fa value in MHz for given fs is")
printf("thus fa-fs is only %f kHz, which means they
    are very close ",(fa-fs)*10^3)
```

Scilab code Exa 7.14 Quality factor of the crystal

```
clc
//Chapter7
//Ex_14
//Given
Co=5 //in pF
fa=1.0025 //in MHz
fs=1 //in MHz
R=20 //in ohms
```

```
C=Co*((fa/fs)^2-1)
disp(C,"Capacitance value in the equivalent circuit
   of the crystal in pF is")
L=1/(C*(2*%pi*fs)^2)
disp(L,"Inductance value in the equivalent circuit
   of the crystal in Henry is")
fs=fs*10^6 //in Hz
C=C*10^-12 //in F
Q=1/(2*%pi*fs*R*C)
disp(Q,"Quality factor of the crystal is")
```

Scilab code Exa 7.15 Minimum radiation intensity

```
clc
//Chapter7
//Ex_15
//Given
P=380*10^-6 //in C/m2/K
c=380//in J/Kg/K
//let epsilon=E
Eo=8.85*10^-12 //in F/m
Er=290
rho=7000//in Kg/m3
delta_V=0.001 //in V
delta_t=0.2 //in seconds
I=(P/(rho*c*Eo*Er))^-1*delta_V/delta_t
disp(I,"Minimum radiation intensity that can be
   measured in W/m2 is")
```

Chapter 8

Magnetic properties and conductivity

Scilab code Exa 8.3 Saturation magnetization in iron

```
clc
//Chapter8
//Ex_3
//Given
Mat=55.85*10^-3 //in Kg/mol
NA=6.022*10^23 // in mol^-1
p=7.86*10^3 //in kg/m3
Msat=1.75*10^6 //in A/m
funcprot(0)
beta=9.27*10^-24 //in J/tesla
n_at=p*NA/(Mat)
x=Msat/(n_at*beta)
printf("In the solid each Fe atom contributes only
   %f bohr magneton",x)
```

Scilab code Exa 8.5 Inductance

```
clc
//Chapter8
//Ex_5
//Given
u_o=4*%pi*10^-7 //in H/m
u_ri=2*10^3 //
N=200 //no. of turns
d=0.005 //in m
D=2.5*10^-2 //in m
A=%pi*(d^2)/4
l=%pi*D
L=u_ri*u_o*N^2*A/l
disp(L,"Approximate inductance of the coil in Henry
    is")
```

Scilab code Exa 8.7 Energy stored in the solenoid

```
clc
//Chapter8
//Ex_7
//Given
N=500 //no.of turns
B=5 //in Tesla
l=1 //in m
r=10^-3 //in m
uo=4*%pi*10^-7 //in H/m
d=10*10^-2 //in m
I=(B*l)/(uo*N)
disp(I,"current in Amperes is")
E_vol=B^2/(2*uo)
v=%pi*l*d^2/4
E=E_vol*v
disp(E,"Energy stored in the solenoid in joules is")
```