Scilab Textbook Companion for Optical Communication by S. Katiyar[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 2

OPTICAL FIBER WAVEGUIDES

Scilab code Exa 2.1 Thickness

```
// Example 2.1:Thickness
clc;
clear;
close;
pi=3.14;
n1=3.5;//Waveguide Refractive Index
n2=3.0;//Cladding Refractive Index
v=6;// number of modes
h=1.5;// wavelenght in micro meter
Os= asind(n2/n1)// angle in degree
th= round(12*pi*h)/(2*pi*n1*cosd(Os));// Thickness of the film
disp(th,"Thickness of film in mircometers")
disp("Thcikness of the film should be less than 5 micro meter so that only six modes will be guided along the fiber")
```

Scilab code Exa 2.2 ACCEPTANCE AND CRITICAL ANGLE

```
// Example 2.2:Acceptance Angle
clc;
clear;
close;
n1=1.53;//Waveguide Refractive Index
n2=1.48;//Cladding Refractive Index
no=1;// for air
Oa= asind((sqrt(n1^2 - n2^2))/no);//Acceptance Angle
Oc= asind(n2/n1);// Critical Angle
disp(Oa,"Acceptanc Angle in Degree")
disp(Oc,"Critical angle in degree")
```

Scilab code Exa 2.3 numerical aperture

```
// Example 2.3:Numerical Aperture
clc;
clear;
close;
v= 26.6;//normalised frequency
h=1.3;// Wavelenght in micro meters
a=25;//core radius in micro meters
NA=(v*h)/(2*%pi*a);// Numerical Aperture
disp(NA,"Numerical Aperture of the Fiber is")
```

Scilab code Exa 2.4 numerical aperture

```
// Example 2.4:Numerical Aperture
clc;
clear;
close;
n1=1.4675;//Waveguide Refractive Index
```

```
n2=1.4622;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture of the Fiber")
```

Scilab code Exa 2.5 cut off wavelngth

```
// Example 2.5:Cutoff Wavelengt
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
a=4;// core radius in micro meters
NA=sqrt(n1^2-n2^2);// Numerical Aperture
Hc= (2*%pi*a*NA)/(2.405)
disp(Hc,"Cutoff wavelenght in micro meters")
```

Scilab code Exa 2.6 core diameter

```
// Example 2.6:Core Diameter
clc;
clear;
close;
n1=1.55;//Waveguide Refractive Index
n2=1.48;//Cladding Refractive Index
h= 1.55;// Wavelenght in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
a= (2.405*h)/(2*%pi*NA);// Core radius
d=2*a;// Core Diameter
disp(d,"Core Diameter in micro meter")
```

Scilab code Exa 2.7 number of modes

```
// Example 2.7:Number of the modes
clc;
clear;
close;
n1=1.48;//Waveguide Refractive Index
n2=0.01;//Cladding Refractive Index
h= 0.84;// Wavelenght in micrometers
a= 25;// Core radius in micrometers
NA=(n1^2-n2^2);// Numerical Aperture
M=round((((2*%pi)/h)^2*a^2*NA)/100);//
v= round(sqrt(M*2));//
disp(v,"Number of modes")
```

Scilab code Exa 2.8 number of modes

```
// Example 2.8:Number of the modes
clc;
clear;
close;
n1=1.475;//Waveguide Refractive Index
n2=1.472;//Cladding Refractive Index
h1= 0.85;// Wavelenght in micrometers
a= 20;// Core radius in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
v=(2*%pi*a*NA)/h1;
m1= round((v^2)/2);
h2= 1.3;// Wavelenght in micrometers
v1=(2*%pi*a*NA)/h2;
m2= round((v1^2)/2);
disp (m1, "number of modes when wavelngth is 0.85
   micro meters")
disp(m2,"when wavelenght is 1.3 micro meters")
```

Scilab code Exa 2.9 numerical aperture

```
// Example 2.9:Numerical Aperture
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
n2=1.48;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture of the Fiber")
```

Scilab code Exa 2.10.a core radius

```
// Example 2.10.a;Core Readius
clc;
clear;
close;
n1=1.450;//Waveguide Refractive Index
n2=1.447;//Cladding Refractive Index
h= 1.3;// Wavelenght in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
a= (2.405*h)/(2*%pi*NA);// Core radius
disp(a,"Core radius in micro meter")
```

Scilab code Exa 2.10.b numerical aperture

```
// Example 2.10.b;Numerical Aperture
clc;
clear;
```

```
close;
n1=1.450;//Waveguide Refractive Index
n2=1.447;//Cladding Refractive Index
h= 1.3;// Wavelenght in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture is")
```

Scilab code Exa 2.10.c acceptance angle

```
// Example 2.10.c;Acceptance Angle
clc;
clear;
close;
n1=1.450;//Waveguide Refractive Index
n2=1.447;//Cladding Refractive Index
h= 1.3;// Wavelenght in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
Omax=asind(NA);//MAXIMUM ACCEPTANCE ANGLE
disp(Omax,"MAXIMUM ACCEPTANCE ANGLE IN DEGREE")
```

Scilab code Exa 2.11.a critical angle

```
// Example 2.11.a;Critical Angle
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
Oc=asind(n2/n1);//Critical Angle
disp(Oc,"CRITICAL ANGLE IN DEGREE")
```

Scilab code Exa 2.11.b numerical aperture

```
// Example 2.11.b;Numerical Aperture
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture is")
```

Scilab code Exa 2.11.c acceptance angle

```
// Example 2.11.c;Acceptance Angle
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
h= 1.3;// Wavelenght in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
Oa=asind(NA);//ACCEPTANCE ANGLE
disp(Oa," ACCEPTANCE ANGLE IN DEGREE")
```

Scilab code Exa 2.12 acceptance angle

```
// Example 2.12;Acceptance Angle
clc;
clear;
close;
NA=0.4;// Numerical Aperture
r= 50;// Angle at which angle changes for skew rays
   in degreee
```

```
m=cosd(r);
Oas=asind(NA/m)
disp(Oas," ACCEPTANCE ANGLE FOR SKEW RAYS IN DEGREE"
    )
```

Scilab code Exa 2.13.a normalized frequency

```
// Example 2.13.a:Normaised Frequency
clc;
clear;
close;
n1=1.48;//Waveguide Refractive Index
d= 0.015;// Cange in core-cladding refractive index
a=40;// core radius in micro meters
h=0.85;//wavelngth in micro meters
v=(2*%pi*a*n1*sqrt(2*d))/h;//Normalised wavelngth
disp(v,"normalised frequency ")
```

Scilab code Exa 2.13.b number of modes

```
// Example 2.13.b:Number of modes
clc;
clear;
close;
n1=1.48;//Waveguide Refractive Index
d= 0.015;// Cange in core-cladding refractive index
a=40;// core radius in micro meters
h=0.85;//wavelngth in micro meters
v=(2*%pi*a*n1*sqrt(2*d))/h;//Normalised wavelngth
m= round (v^2/2);// number of modes
disp(m,"number of modes")
disp("the fiber have v=76 and it gives nearly 3000
    guided modes")
```

Scilab code Exa 2.14.a cutoff frequency

```
// Example 2.14.a:Cut off wavelength
clc;
clear;
close;
n1=1.48;//Waveguide Refractive Index
d= 0.01;// Cange in core-cladding refractive index
a=2;// parabolic refractive index
h=1.3;//wavelngth in micro meters
v= 2.4*sqrt(1+(2/a));//maximum value of normalised
    frequence
disp(v,"maximum value of normalised frequency")
```

Scilab code Exa 2.14.b core radius

```
// Example 2.14.b:Maximum Core Readius
clc;
clear;
close;
n1=1.48;//Waveguide Refractive Index
d= 0.01;// Cange in core-cladding refractive index
a=2;// parabolic refractive index
h=1.3;//wavelngth in micro meters
v= 2.4*sqrt(1+(2/a));//maximum value of normalised
    frequence
a= (v*h)/(2*%pi*n1*sqrt(2*d));//Core Radius
disp(a,"maximum core radius in micro meters")
```

Scilab code Exa 2.15 cut off wavelength

```
// Example 2.15:Cutoff Wavelengt
clc;
clear;
close;
n1=1.46;//Waveguide Refractive Index
a=4.5;// core radius in micro meters
d= 0.0025;// Cange in core-cladding refractive index
Hc= (2*%pi*a*sqrt(2*d)*n1)/2.405;
disp(Hc,"Cutoff wavelenght in micro meters")
```

Scilab code Exa 2.16 numerical aperture and acceptance angle

```
// Example 2.16;Numerical Aperture & Acceptance Angle
clc;
clear;
close;
n1=1.45;//Waveguide Refractive Index
n2=1.40;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture is")
Om=asind(NA);
disp(Om,"Acceptance angle in degree is")
```

Scilab code Exa 2.17.a CLADDING INDEX

```
// Example 2.17.a:Cladding Index
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
```

```
d= 0.0005;// Cange in core−cladding refractive index
n2= n1-(d*n1);
disp(n2,"Refradctive index of cladding is")
```

Scilab code Exa 2.17.b critical internal reflection angle

```
// Example 2.17.b:Critical Internal Reflection Angle
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
d= 0.0005;// Cange in core−cladding refractive index
n2= n1-(d*n1);
Oc=asind(n2/n1);
disp(Oc,"Critical Internal Reflection angle in
    degree is")
```

Scilab code Exa 2.17.c acceptance angle

```
// Example 2.17.c: External Critical Acceptance
    Angle
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
d= 0.0005;// Cange in core−cladding refractive index
n2= n1-(d*n1);
n0=1;// For air
Om=asind(sqrt(n1^2-n2^2)/n0);
disp(Om,"External Critical Acceptance angle in
    degree is")
```

Scilab code Exa 2.17.d numerical aperture

```
// Example 2.17.d: Numerical Aperture
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
d= 0.0005;// Cange in core-cladding refractive index
NA=n1*sqrt(2*d);
disp(NA,"numerical aperture is")
```

Scilab code Exa 2.18 acceptance angle

```
// Example 2.18:Critical Acceptance Angle
clc;
clear;
close;
n2=1.59;//Cladding Refractive Index
NA=0.20;// NUMERICAL APERTURE IN AIR
n1= sqrt(NA^2+n2^2);// Core refractive index
n0=1.33;//refractive index of water
NA=sqrt(n1^2-n2^2)/n0;// Numerical aperture in water
Om=asind(NA);
disp(Om," Acceptance angle in degree is")
```

Scilab code Exa 2.19.a numerical aperture

```
// Example 2.19.A:Numerical Aperture
clc;
```

```
clear;
close;
n1=1.55;//cORE Refractive Index
n2=1.51;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture of the Fiber")
```

Scilab code Exa 2.19.b acceptance angle

```
// Example 2.19.b:Acceptance Angle
clc;
clear;
close;
n1=1.55;//cORE Refractive Index
n2=1.51;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
Om= asind(NA);
disp(Om,"Acceptance Angle in degree is")
```

Scilab code Exa 2.20 normalized frequency

```
// Example 2.20:Normaised Frequency
clc;
clear;
close;
n1=1.45;//Core Refractive Index
NA=0.16;//Numerical Aperture
a=30;// core radius in micro meters
h=0.1;//wavelngth in micro meters
v=(2*%pi*a*NA)/h;//Normalised wavelngth
disp(v,"normalised frequency ")
```

Scilab code Exa 2.21.a numerical aperture

```
// Example 2.21.A:Numerical Aperture
clc;
clear;
close;
c=3*10^8 ;// Speed of lignt in m/s
v=2*10^8;//speed of ligh in fiber in m/s
Oc=75;// Critical angle in degree
n1=c/v;//cORE Refractive Index
n2=n1*(sind(Oc));// Cladding Refrative index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture of the Fiber")
```

Scilab code Exa 2.21.b dispersion per unit length

```
// Example 2.21.b:Multipath dispersion per unit
   length
clc;
clear;
close;
c=3*10^8 ;// Speed of lignt in m/s
v=2*10^8;//speed of ligh in fiber in m/s
Oc=75;// Critical angle in degree
n1=c/v;//cORE Refractive Index
n2=n1*(sind(Oc));// Cladding Refrative index
d= n1-n2;// differnce in refractive index
Md1=(n1/n2)*(d/c);//
Md= Md1*10^9;
disp(Md,"Multipath dispersion in microsecond per
   kilometer ")
```

Scilab code Exa 2.22 Thickness

```
// Example 2.22:Thickness
clc;
clear;
close;
n1=3.6;//Core Refractive Index
n2=3.56;//Cladding Refractive Index
h=0.85;// wavelenght in micro meter
m=1;// mode is fundamental TE10
n=0;
Vc=2.405;//Cutoff wavelength
a=(Vc*h)/(2*%pi*sqrt(n1^2-n2^2));// Core radius
disp(a,"Core radius in mircometers")
```

Scilab code Exa 2.23 core diameter

```
// Example 2.23:Daimeter
clc;
clear;
close;
n1=1.5;//Core Refractive Index
d=0.01;//difference in the refrative index
h=1.3;// wavelenght in micro meter
m=1100;// numer of modes
v=round(sqrt(2*m));// Number of guided modes
a=(v*h)/(2*%pi*n1*sqrt(2*d));// Core radius
d= 2*a;// Core Diameter
disp(d,"Core diameter in mircometers")
//answer is calculated wrong in the textbook
```

Scilab code Exa 2.24.a critical angle

```
// Example 2.24.a;Critical Angle
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.46;//Cladding Refractive Index
Oc=asind(n2/n1);//Critical Angle
disp(Oc,"CRITICAL ANGLE IN DEGREE")
```

Scilab code Exa 2.24.b numerical aperture

```
// Example 2.14.b;Numerical Aperture
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.46;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture is")
```

Scilab code Exa 2.25 acceptance angle

```
// Example 2.25;Acceptance Angle
clc;
clear;
close;
NA=0.344;// Numerical Aperture
```

```
r= 50;// Angle at which angle changes for skew rays
   in degreee
m=cosd(r);
Oa=asind(NA);
disp(Oa,"Acceptance angle in degree is")
Oas=asind(NA/m)
disp(Oas," ACCEPTANCE ANGLE FOR SKEW RAYS IN DEGREE"
   )
```

Scilab code Exa 2.26 numer of modes and cutoff frequency

```
// Example 2.26:Number of guided modes
clc;
clear;
close;
n1=1.5;//Core Refractive Index
d= 0.013;// Cange in core-cladding refractive index
alpha=1.90;//  index profile
a=20;//Core radius in micro meters
h=1.55;//wavelngth in micro meters
Mg= round((alpha/(alpha+2))*((n1*2*%pi*a)/h)^2 *d);
Vc=2.405*sqrt(1+2/alpha);
disp(Mg,"Number of guided modes are")
disp(Vc," normalised frequency")
```

Scilab code Exa 2.27.a numerical aperture

```
// Example 2.27.a:Numerical Aperture
clc;
clear;
close;
n1=1.5;//Core Refractive Index
n2=1.48;//Cladding Refractive Index
```

```
a=50;//Core radius in micro meters
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture of the Fiber")
```

Scilab code Exa 2.27.b critical angle

```
// Example 2.27.a:Numerical Aperture
clc;
clear;
close;
n1=1.5;//Core Refractive Index
n2=1.48;//Cladding Refractive Index
a=50;//Core radius in micro meters
NA=sqrt(n1^2-n2^2);// Numerical Aperture
Oc=asind(n2/n1);
disp(Oc,"Critical Angle")
```

Scilab code Exa 2.27.c pulse broadning

```
// Example 2.27.a:Numerical Aperture
clc;
clear;
close;
n1=1.5;//Core Refractive Index
n2=1.48;//Cladding Refractive Index
c=3*10^8;// Speed of ligh in m/s
a=50;//Core radius in micro meters
PB= (n1/n2)*((n1-n2)/c);// Pulse broadning per unit
    length
disp(PB,"Pulse broadning per unit length due to
    multipath dispersion in s/m")
```

Scilab code Exa 2.28 core diameter

```
// Example 2.28:Core diameter
clc;
clear;
close;
n1=1.5;//Core Refractive Index
d= 0.01;// Cange in core-cladding refractive index
alpha=2;//  index profile
h=1.3;//wavelngth in micro meters
Vc=2.405*sqrt(1+2/alpha);
a=(Vc*h)/(2*%pi*n1*sqrt(2*d));
di=2*a;
disp(di,"core diameter in micro meters")
//answer is calculated wrong in the textbook
```

Chapter 4

TRANSMISSION CHARACTERSTICS OF OPTICAL FIBERS

Scilab code Exa 4.1 power loss

```
// Example 4.1:Loss
clc;
clear;
close;
L=0.4;// Length of fiber in km
Pi=1;// Assume input power
Po=0.25//Optical Signal Loss
Loss= round((10/L)*(log10(Pi/Po)));//Loss in dB/Km
disp(Loss,"Loss in dB/Km")
```

Scilab code Exa 4.2 power level

```
// Example 4.2:Outpit Power
clc;
```

```
clear;
close;
h=0.82;// Wavelength in micro meters
alpha = 0.5;//Attenuation loss in dB/Km
L=3;// Length of fiber in km
Pi=1;//Input power in Milli Watt
X= ((alpha*L)/10);
Po=Pi*(10^(- X));//Output power in milli watt
disp(Po,"output power in mili watt")
```

Scilab code Exa 4.3 link length

```
// Example 4.1:Link Length
clc;
clear;
close;
alpha = 0.5;//Attenuation loss in dB/Km
Pi=1.5;//input power in milli watt
Po=2//Output power in micro watt
L=(10/alpha)*(log10((Pi*10^-3)/(Po*10^-6)));// Link
    Length in Km
disp(L,"Length in Km")
```

Scilab code Exa 4.4 pulse dispersion

```
// Example 4.4:Dispersion
clc;
clear;
close;
Pb=1.2;//in nano second
D=30;//in Km
DL=((Pb*10^-3)/30);// Dispersion per unit length
disp(DL,"Dispersion in ns/m")
```

Scilab code Exa 4.5 output optical power

```
// Example 4.5:Outpit Power
clc;
clear;
close;
h=1.3;// Wavelength in micro meters
alpha = 0.8;//Attenuation loss in dB/Km
L=30;// Length of fiber in km
Pi=200;//Input power in micro Watt
X= ((alpha*L)/10);
Po=Pi*(10^(- X));//Output power in micro watt
disp(Po,"output power in micro watt")
```

Scilab code Exa 4.6.a signal loss

```
// Example 4.6.a:Loss
clc;
clear;
close;
L=8;// Length of fiber in km
Pi=120*10^-6;// input power in watt
Po=3*10^-6;//Output power in watt
alpha= round(10*(log10(Pi/Po)));//Loss in dB
disp(alpha,"Loss in dB")
```

Scilab code Exa 4.6.b signal loss per kilometer

```
// Example 4.6.b:Loss in dB/Km
```

```
clc;
clear;
close;
L=8;// Length of fiber in km
Pi=120*10^-6;// input power in watt
Po=3*10^-6;//Output power in watt
alpha= round(10*(log10(Pi/Po)));//Loss in dB
alphadb= alpha/L;//Loss in dB/Km
disp(alphadb,"Loss in dB/Km")
```

Scilab code Exa 4.6.c overall signal attenuation

```
// Example 4.6.c:Loss for 10Km
clc;
clear;
close;
L=8;// Length of fiber in km
Pi=120*10^-6;// input power in watt
Po=3*10^-6;//Output power in watt
alpha= round(10*(log10(Pi/Po)));//Loss in dB
alphadb= alpha/L;//Loss in dB/Km
alphadb2=alphadb*10;// Loss along 10Km fiber length in dB
Ds=alphadb2+9;// Due to splices at 1km Interval
disp(Ds,"Due to splices at 1km Interval in dB")
```

Scilab code Exa 4.6.d ratio of input to output power

```
// Example 4.6.d:Ratio of powers
clc;
clear;
close;
L=8;// Length of fiber in km
```

```
Pi=120*10^-6;// input power in watt
Po=3*10^-6;//Output power in watt
alpha= round(10*(log10(Pi/Po)));//Loss in dB
alphadb= alpha/L;//Loss in dB/Km
alphadb2=alphadb*10;// Loss along 10Km fiber length
    in dB
Ds=alphadb2+9;// Due to splices at 1km Interval
rt= 10^(Ds/10);// Ratio of input to output power
disp(rt,"Ratio of input to output power")
```

Scilab code Exa 4.7.a signal attenuation

```
// Example 4.8.a:Attenuation
clc;
clear;
close;
L=1;// dISTANCE IN kM
h=0.63;//in micro meter
Tf=1400;//Temperature in kelvin
p=0.286;//photoelastic coefficient of silica
n=1.46;//Refractive index of silica
Bc=7*10^-11;//isothermal compersebility in in Metere
     square per N
K=1.38*10^-23;// bOLTZMAN CONSTT. IN JULIAN PER
    KELVIN
x= (h*10^-6);
Yr=(8*%pi^3*n^8*p^2*Bc*K*Tf)/(3*(x)^4);//ray leigh
    scattering coefficient
Ekm= exp(-Yr*L*10^3)
alpha=10*(log10(1/Ekm));//Attenuation in dB/Km
disp(alpha,"Attenuation in dB/Km")
disp("solutions of example 4.8 and 4.7 are
    interchanged in the book")
```

Scilab code Exa 4.7.b signal attenuation

```
// Example 4.7.b:Attenuation
clc;
clear;
close;
L=1;//distance in Km
h=1.30;//in micro meter
Tf=1400;//Temperature in kelvin
p=0.286;//photoelastic coefficient of silica
n=1.46;//Refractive index of silica
Bc=7*10^-11;//isothermal compersebility in in Metere square per N
K=1.38*10^-23;// bOLTZMAN CONSTT. IN JULIAN PER KELVIN
x= (h*10^-6);
Yr=(8*%pi^3*n^8*p^2*Bc*K*Tf)/(3*(x)^4);//ray leigh scattering coefficient
Ekm= exp(-Yr*L*10^3);//Transmission loss factor
alpha=10*(log10(1/Ekm));//Attenuation in dB/Km
disp(alpha,"Attenuation in dB/Km")
disp("solutions of example 4.8 and 4.7 are interchanged in the book")
```

Scilab code Exa 4.8 refractive index

```
// Example 4.8:refrative index
clc;
clear;
close;
alpha=0.46;//attenuation in Db/Km
L=1;// dISTANCE IN kM
```

```
h=1;//in micro meter
Tf=758;//Temperature in kelvin
p=0.245;//photoelastic coefficient of silica
Bc=8.4*10^-11;//isothermal compersebility in in
    Metere square per N
K=1.38*10^-23;// bOLTZMAN CONSTT. IN JULIAN PER
    KELVIN
x= h
Yr=((8*%pi^3*p^2*Bc*K*Tf)/(3*(x)^4))*10^24;//ray
    leigh scattering coefficient
n=((alpha)/(4.34*Yr*10^3))^(1/8);//Refractive index
disp(n,"Refractive index is")
```

Scilab code Exa 4.9 operating wavelength and attenuation

```
// Example 4.9:Attenuation
clc;
clear;
close;
Pb=150;//Threshold optical power for brillouin
    scattering in milli watt
Pr=1.5;//Threshold optical power for Raman
    scattering in watt
d=8;//Core diameter in micro meter
v=1;//frequency in Giga Hertz
h=(5.9*10^-2*d^2*Pb*10^-3)/((4.4*10^-3*d^2*Pr));
alpha=(Pb*10^-3)/((4.4*10^-3*d^2*h^2));//
    Attenuation in db/Km
disp(alpha,"Loss in dB/Km")
```

Scilab code Exa 4.10 optical power

```
// Example 4.10:Optical Powers
```

```
clc;
clear;
close;
h=1.5;//Wavelength in micro meters
d=6;//Core diameter in micro meter
v=0.8;//frequency in Giga Hertz
alpha=0.5;//Attenuation in dB/Km
Pb=(4.4*10^-3*d^2*h^2*alpha*v)*10^3;//Threshold optical power for brillouin scattering in milli watt
Pr=(5.9*10^-2*d^2*alpha*h);//Threshold optical power for Raman scattering in watt
disp(Pb,"Threshold optical power for brillouin scattering in milli watt")
disp(Pr,"Threshold optical power for Raman scattering in watt")
```

Scilab code Exa 4.11 critical radius

```
// Example 4.11:Critical Radius
clc;
clear;
close;
d=0.03;//Refractive index difference
n1=1.5;//Core refractive index
h= 0.82*10^-6;//Wavelength in meters
n2=sqrt(n1^2-(2*d*n1^2));// Cladding refractive index
Rc=(3*n1^2*h)/(4*%pi*sqrt(n1^2-n2^2))*10^6;// Critical Radius in micro meters
disp(Rc,"Critical Radius in micro meters")
//answer is calculated wrong in the textbook
```

Scilab code Exa 4.12 critical radius

```
// Example 4.11:Critical Radius
clc;
clear;
close;
d=0.003;//Refractive index difference
a=4;// core radius in micro meters
n1=2;//Core refractive index
h= 1.55*10^-6;//Wavelength in meters
n2=sqrt(n1^2-(2*d*n1^2));// Cladding refractive index
hc= ((2*%pi*a*10^-6*sqrt(2*d)*n1)/2.405)*10^6;//cut off wavelength in micro meters;
x=(20*h)/(sqrt(n1-1.75));
y=((2.748-0.996*(h*10^6/hc))^-3;
Rcs=x*y*10^6;
disp(Rcs,"Critical Radius in micro meters")
```

Scilab code Exa 4.13.a bandwidth

```
// Example 4.13.a:Maximum possible optical bandwidth
clc;
clear;
close;
t=0.1*10^-6;//Time in second
L=10;//Distance in Km
Bt=(1/(2*t))*10^-6;//Maximum possible optical bandwidth in Mega Hertz
disp(Bt,"Maximum possible optical bandwidth in Mega Hertz")
```

Scilab code Exa 4.13.b pulse dispersion

```
// Example 4.13.b:Despersion per unit length
clc;
clear;
close;
t=0.1*10^-6;//Time in second
L=10;//Distance in Km
dp=(t/L)*10^6;//Despersion per unit length in micro
    second per Km
disp(dp,"Despersion per unit length in micro second
    per Km")
```

Scilab code Exa 4.13.c bandwidth length product

```
// Example 4.13.b:Bandwidth legth product
clc;
clear;
close;
t=0.1*10^-6;//Time in second
L=10;//Distance in Km
Bt=(1/(2*t))*10^-6;//Maximum possible optical
    bandwidth in Mega Hertz
BL=Bt*L;// bANDWIDTH LENGTH PRODUCT IN kM
disp(BL,"BANDWIDTH LENGTH PRODUCT IN Km")
```

Scilab code Exa 4.14 wavelength

```
// Example 4.14:Wavelength
clc;
clear;
close;
Rc=84;// Critical Radius in micro meters
n2=1.45;//Cladding refrative index
n1=1.46;//Core refractive index
```

```
h=(Rc*10^-6*4*%pi*sqrt(n1^2-n2^2))/(3*n1^2)*10^6;//
   Wavelength in micro meters
disp(h,"Wavelength in micro meters")
//answer is calculated wrong in the textbook
```

Scilab code Exa 4.15 pulse broadning

```
// Example 4.15;//Pulse broadning
clc;
clear;
close;
M=20;//dispersion parametr picosecond per nano meter
    per kilometer
L=30;//distance in Km
h=1.5;//WAVELENGTH IN MICRO METERS
Sh=2;// Spectral width in nano meter
Sm=Sh*L*M;//Pulse broadning due to material
   dispersion in pico second
disp(Sm,"Pulse broadning due to material dispersion
   in pico second")
```

Scilab code Exa 4.16.a material dispersion parameter

```
// Example 4.16.a;/Material Dispersion Parameter
clc;
clear;
close;
c=2.998*10^5;// speed of light in km/s
Dh=0.025;//Material dispersion
L=30;//distance in Km
h=850;//WAVELENGTH IN Nano METERS
Sh=20;// Spectral width in nano meter
```

```
M=((Dh)/(c*h))*10^12;//dispersion parametr
    picosecond per nano meter per kilometer
disp(M,"dispersion parametr picosecond per nano
    meter per kilometer")
```

Scilab code Exa 4.16.b pulse broadning

```
// Example 4.16.b;/Pulse broadning due to material
    dispersion
clc;
clear;
close;
c=2.998*10^5;// speed of light in km/s
Dh=0.025;//Material dispersion
L=30;//distance in Km
h=850;//WAVELENGTH IN Nano METERS
Sh=20;// Spectral width in nano meter
M=((Dh)/(c*h))*10^12;//dispersion parametr
    picosecond per nano meter per kilometer
Sm=(Sh*1*M)*10^-3;//Pulse broadning due to material
    dispersion in nanp second per kilometer
disp(Sm,"Pulse broadning due to material dispersion
    in nanp second per kilometer")
```

Scilab code Exa 4.17 pulse broadning

```
// Example 4.17;/Pulse broadning due to material
    dispersion
clc;
clear;
close;
c=3*10^8;// speed of light in m/s
Dh=4*10^-2;//Material dispersion
```

```
L=30;//distance in Km
h=0.9;//WAVELENGTH IN micro METERS
Sh=45;// Spectral width in nano meter
Sm=(Sh*1*900*10^6*4*10^-2)/c;//Pulse broadning due
   to material dispersion in nano second per
   kilometer
disp(Sm,"Pulse broadning due to material dispersion
   in nano second per kilometer")
```

Scilab code Exa 4.18 pulse broadning

```
// Example 4.18;//Pulse broadning
clc;
clear;
close;
M=95;//dispersion parametr picosecond per nano meter
    per kilometer
L=1;//distance in Km
h=0.85;//WAVELENGTH IN MICRO METERS
Sh=0.0012*h*10^-6;// Spectral width in nano meter
Sm=(Sh*L*M)*10^6;//Pulse broadning due to material
   dispersion in nano second
disp(Sm,"Pulse broadning due to material dispersion
   in nano second per kilo meter")
```

Scilab code Exa 4.19 pulse broadning

```
// Example 4.19;//LIGHT PULSE SPREAD IN NS
clc;
clear;
close;
NA=0.275;//Numerical Aperture
n1=1.48;//Core refrctive index
```

```
L=5;//Length in Km
C=3*10^5;//Speed of light in km/s
dts=((L*(NA)^2)/(2*n1*C))*10^9;//LIGHT PULSE SPREAD IN NS
disp(dts,"LIGHT PULSE SPREAD IN NS")
```

Scilab code Exa 4.20.a delay

```
// Example 4.20.a;//delay
clc;
clear;
close;
d=0.02;// Change in refractive index
n1=1.5;//Core refrctive index
L=3*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
dts=round(((L*n1*d)/C)*10^9);//DELAY IN NS
disp(dts,"DELAY IN NS")
```

Scilab code Exa 4.20.b pulse broadning

```
// Example 4.20.b;//Pulse broadning due to intermodal dispersion
clc;
clear;
close;
d=0.02;// Change in refractive index
n1=1.5;//Core refrctive index
L=3*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
Ss=(L*n1*d)/(2*sqrt(3)*C)*10^9;//Pulse broadning due to intermodal dispersion in ns
disp(Ss,"DELAY IN NS")
```

Scilab code Exa 4.20.c bit rate

```
// Example 4.20.c;//Bit Rate
clc;
clear;
close;
d=0.02;// Change in refractive index
n1=1.5;//Core refrctive index
L=3*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
dts=round(((L*n1*d)/C)*10^9);//DELAY IN NS
Bt=(1/(2*dts*10^9))*10^12;//Bit rate in Mbits/sec
disp(Bt,"Bit rate in Mbits/sec")
```

Scilab code Exa 4.20.d bandwidth length product

```
// Example 4.20.d;/bANDWIDTH LENGTH PRODUCT
clc;
clear;
close;
d=0.02;// Change in refractive index
n1=1.5;//Core refrctive index
L=3*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
dts=round(((L*n1*d)/C)*10^9);//DELAY IN NS
Bt=(1/(2*dts*10^9))*10^12;//Bit rate in Mbits/sec
BL=Bt*L*10^-3;// bANDWIDTH LENGTH PRODUCT IN kM
disp(BL,"bANDWIDTH LENGTH PRODUCT IN Mega Hertz kM")
```

Scilab code Exa 4.21 pulse broadning

```
// Example 4.21;//Pulse broadning due to intermodal
   dispersion
clc;
clear;
close;
d=0.01;// Change in refractive index
n1=1.5;//Core refrctive index
L=6;//Length in Km
C=2.998*10^8;//Speed of light in m/s
Pb=86.7;// rms pulse broadning in ns
PbL=Pb/L;//rms pulse broadning in ns/Km
Sg=(1*10^3*n1*d^2)/(20*sqrt(3)*C)*10^12;//Pulse
   broadning due to intermodal dispersion in Ps
disp(Sg,"Pulse broadning due to intermodal
   dispersion in Ps")
```

Scilab code Exa 4.22 pulse broadning

```
// Example 4.22;//TOTAL RMS Pulse broadning
clc;
clear;
close;
M=30;//dispersion parametr picosecond per nano meter
    per kilometer
Sa=25;//spectral width in nm
NA=0.4;//nUMERICAL aPERTURE
n1=1.48;// Core refractibve index
n2=1.47;//cleadding refrative index
C=2.998*10^8;//Speed of light in m/s
d=n1-n2;
L=1;//length in Km
Sm=M*L*Sa;//rms pulse broadning due to material
   dispersion
```

```
Sg=(L*10^3*n1*d^2)/(20*sqrt(3)*C)*10^12;//Pulse
    broadning due to intermodal dispersion in Ps/Km
St=sqrt(Sm^2+Sg^2);// Total broadning
disp(St,"Total broadning Ps per Km is")
```

Scilab code Exa 4.23.a pulse broadning

```
// Example 4.23.a;//TOTAL RMS Pulse broadning
clc;
clear;
close;
M=250;//dispersion parametr picosecond per nano
    meter per kilometer
Sa=50;//spectral width in nm
NA=0.3;//nUMERICAL aPERTURE
n1=1.45;// Core refractibve index
C=2.998*10^8;//Speed of light in m/s
L=1;//length in Km
Sm=M*L*Sa*10^-3;//rms pulse broadning due to
    material dispersion
Ss=(L*10^3*NA^2)/(4*sqrt(3)*C*n1)*10^9;//Pulse
    broadning due to intermodal dispersion in ns/Km
St=sqrt(Sm^2+Ss^2);// Total broadning
disp(Ss,Sm,St,"Total broadning ns per Km is")
```

Scilab code Exa 4.23.b bandwidth length product

```
// Example 4.23.b;//bandwidth length product
clc;
clear;
close;
M=250;//dispersion parametr picosecond per nano
    meter per kilometer
```

```
Sa=50;//spectral width in nm
NA=0.3;//nUMERICAL aPERTURE
n1=1.45;// Core refractibve index
C=2.998*10^8;//Speed of light in m/s
L=1;//length in Km
Sm=M*L*Sa*10^-3;//rms pulse broadning due to
    material dispersion
Ss=(L*10^3*NA^2)/(4*sqrt(3)*C*n1)*10^9;//Pulse
    broadning due to intermodal dispersion in ns/Km
St=sqrt(Sm^2+Ss^2);// Total broadning
BL= (0.2/(St*10^-9))*10^-6;// Bandwidth length
    product in Mega hertz Km
disp(BL,"Bandwidth length product in Mega hertz Km")
```

Scilab code Exa 4.24 beat length

```
// Example 4.23.b;//bandwidth length product
clc;
clear;
close;
Lbc=100;//Birefringent Coherence over length in Km
h=1.32;//wavelength in micro meter
df=1.5;//spectral width
Bf=((h*10^-6)^2)/(Lbc*10^3*df*10^-9);
Lb=(h*10^-6)/Bf;//Beat Length in Km
disp(Lb,"Beat Length in Km")
```

Scilab code Exa 4.25 modal birefringence

```
// Example 4.25;//birefringence
clc;
clear;
close;
```

```
Lbc1=0.5;//beat length mm
h=1.3;//wavelength in micro meter
Bf1=((h*10^-6)/(Lbc1*10^-3));// birefringence when
    beat length = 0.5mm
Lbc2=60;//beat length meter
Bf2=((h*10^-6)/(Lbc2));// birefringence when beat
    length = 60 meter
disp(Bf1,"birefringence when beat length = 0.5mm")
disp(Bf2,"birefringence when beat length = 60 meter"
    )
```

Scilab code Exa 4.26 modal birefringence cohrence length and prop diif

```
// Example 4.26;// Bifringence and differnce between
    the propogation constt.
clc;
clear;
close;
Lb=0.05;//Birefringent Coherence over length in
    meter
h=0.5;//wavelength in micro meter
df=1;//spectral width in nano meter
Bf=((h*10^-6)/(Lb));//modal bifringence
Lbc= (((h*10^-6)^2)/(Bf*df*10^-9));//COHERENCE
    LENGTHnin meter
Bxy=(2*%pi)/(Lb);//Diff in the propogation constant
disp(Bf,"modal bifringence  is")
disp(Bxy,"Diff in the propgation constt. is")
```

Scilab code Exa 4.27 bit rate

```
// Example 4.27;//Maximum bit rate
clc;
```

```
clear;
close;
L=10;//Length in Km
Dt2=600*10^-12;//Birefringent in second per
    kilometer
B=(0.9)/(Dt2*L*10^3);//
Btm= round((B/0.55)*10^-3);// maximum bit rate in
    kilo bit per second
disp(Btm,"maximum bit rate in kilo bit per second")
```

Scilab code Exa 4.28 pulse broadning

```
// Example 4.28;//Pulse Spreadning
clc;
clear;
close;
L=100;// Length in Km
Tpmd=0.5*sqrt(L);// pulse broadning in pico second
disp(Tpmd,"pulse broadning in pico second is ")
```

Chapter 6

OPTICAL SOURCES THE LASER

Scilab code Exa 6.1 ratio of stimulated emission rate to spontaneous emission rate

```
// Example 6.1;//Ratio of stimulated emision to
   spontaneous emission
clc;
clear;
close;
hw=0.5;//wavelength in micro meetr
h=6.626*10^-34;//
T=1000;// temeperature in kelvin
C=3*10^8;// speed of light in m/s
f=C/(hw*10^-6);//frequency in hertz
K=1.38*10^-23;//bOltzman constt.
x=(h*f)/(K*T);
Rtp= 1/(exp(x)-1);
disp(Rtp,"Ratio of stimulated emisssion rate to
   spontaneous rate is")
```

Scilab code Exa 6.2 optical spacing

```
// Example 6.2;//optical spacing
clc;
clear;
close;
h=0.5*10^-6;//Wavelength in meter
n=1.38;//refractive index
T=1000;//tEMPERTURE IN KELVIN
q=1.3*10^4;//logitudinal modes
L=(h*q)/(2*n);// optical spacing in meter
disp(L,"optical spacing in meter")
```

Scilab code Exa 6.3 emission wavelength

```
// Example 6.3;//number of longitudinal modes and
   frequency spacing
clc;
clear;
close;
h=0.55*10^-6;//Wavelength in meter
n=1.78;//refractive index
L=4*10^-2;//LENGTH IN METER
C=3*10^8;//Speed of light in m/s
q=(2*n*L)/(h);//Number of logitudinal modes
df=((C)/(2*n*L))*10^-9;//frequency sepration in Gega
    Hertz
disp(df,"frequency spacing in Gega Hertz is ")
disp(q,"Number of longitudinal modes are ")
```

Scilab code Exa 6.4 optical gain

```
// Example 6.4;//optical gain
```

```
clc;
clear;
close;
R1=0.32;
R2=0.32;
alpha=10;// in cm
L=500;//in micro meter
gth=alpha+(1/(2*L*10^-4)*log(1/(R1*R2)));
disp(gth,"Optical gain in per centimeter is ")
```

Scilab code Exa 6.5 FREQUENCY AND WAVELNEGTH SPACING

```
// Example 6.5;//wavelength spacing and frequency spacing
clc;
clear;
close;
h=850*10^-9;//Wavelength in meter
n=3.7;//refractive index
L=500*10^-6;//LENGTH IN METER
C=3*10^8;//Speed of light in m/s
df=((C)/(2*n*L))*10^-9;//frequency sepration in Gega Hertz
dh=((h^2)/(2*n*L))*10^9;//wavelength spacing in mm
disp(df,"frequency spacing in Gega Hertz is ")
disp(dh," wavelength spacing in mm is")
```

Scilab code Exa 6.6 CARRIER LIFETIME

```
// Example 6.3;//wavelength spacing and frequency spacing
clc;
clear;
```

```
close;
Br1=7.21*10^-10;//Bit rate
n=10^18;//hole concentration
Trg=((Br1*n)^-1)*10^9;//radiative minority carrier lifetime in GaAs in ns
Br2=1.79*10^-15;//Bit rate
Trs=((Br2*n)^-1)*10^3;//radiative minority carrier lifetime in Si in ms
disp(Trg,"radiative minority carrier lifetime in GaAs in ns")
disp(Trs,"radiative minority carrier lifetime in Si in ms")
```

Scilab code Exa 6.7 threshold density

```
// Example 6.6;//threshold density
clc;
clear;
close;
B=21*10^-3;//Gain factor in ampere per centimeter cube
alpha=10;// in per cm
L=250*10^-6;//length in meter
r=0.32
Jth=(1/B)*(alpha+(1/L)*log(1/r));//Threshold current in ampere per centimeter cube
disp(Jth,"threshold density in amper per centimeter cube")
```

Scilab code Exa 6.8 external power efficiency

```
// Example 6.8;//external power efficiency
clc;
```

```
clear;
close;
nt=0.18;//total efficiency of injection laser
Eg=1.43;//Energy gap in elecron volt
V=2.5;//votls
next=round(nt*(Eg/V)*100);//EXTERNAL EFEICIENCY
disp(next,"external efficiency percentage is")
```

Scilab code Exa 6.9 ratio of threshold current densities

```
// Example 6.9;//ratio of threshold current at differnt temperatures
clc;
close;
clear;
To=160;//Absolute temperature in Kelovin
T1=293;//T=20 in kelvin
T2=353;//T=80 in kelvin
J1=exp(T2/To);//threshold current at T=80 degree celsius
J2=exp(T1/To);//threshold current at T=20 degree celsius
Jr=(J1/J2);//ratio of threshold current
disp(Jr,"ratio of threshold current is")
```

Scilab code Exa 6.10 wavelngth and line width

```
// Example 6.10;//wavelength
clc;
close;
clear;
Eg=1.43;//Energy gap in electron-volt
hC=1.24;//cONSTANT
```

```
h=hC/Eg;//wavelength in micro meter
disp(h,"wavelength in micro meter is")
```

Scilab code Exa 6.11 threshold coefficient gain

```
// Example 6.4;//threshold coefficient gain
clc;
clear;
close;
R1=0.35;
R2=0.35;
alpha=1.5;// in per meter
L=0.5;//in mm
t=0.8;//confinement factor
gth=alpha+(1/(2*L)*log(1/(R1*R2)));
Tc= gth/t;// threshold coefficient gain in per mm
disp(Tc,"threshold coefficient gain in per mm ")
```

Scilab code Exa 6.12 cavity length and number of logitudinal modes

```
// Example 6.12;//Cavity length and longitudinal
   modes
clc;
close;
clear;
h=0.87*10^-6;//Wavelength in meter
n=3.6;//refractive index
df=278;//frequency sepration in Gega Hertz
C=3*10^8;//Speed of light in m/s
L=(C/(2*n*df*10^9))*10^4;//Length of cavity in cm
q=(2*n*L*10^-2)/(h);//Number of logitudinal modes
disp(L,"Length of cavity in cm")
disp(q,"Number of longitudinal modes are ")
```

Scilab code Exa 6.13 internal quantum efficiency

```
// Example 6.13;//internal quantum efficiency
clc;
clear;
close;
n=3.6;//refractive index
nd=0.45;//differntilal quantum efficiency
alpha=20;// in per cm
L=500;//in micro meter
r1= ((n-1)/(n+1))^2;
r2=r1;
ni=(nd*(1+((2*alpha*L*10^-4)/(log(1/(r1*r2))))))
    *100;
disp(ni,"Internal quantum efficiency is")
```

Scilab code Exa 6.14 number of longitudinal modes and frequency sepra-tion

```
// Example 6.14;//number of longitudinal modes and
    frequency spacing
clc;
clear;
close;
h=0.5*10^-6;//Wavelength in meter
n=1.5;//refractive index
L=7*10^-2;//LENGTH IN METER
C=3*10^8;//Speed of light in m/s
q=(2*n*L)/(h);//Number of logitudinal modes
df=((C)/(2*n*L))*10^-9;//frequency sepration in Gega
     Hertz
```

```
disp(df,"frequency spacing in Gega Hertz is ")
disp(q,"Number of longitudinal modes are ")
```

Scilab code Exa 6.15 cavity length and number of logitudinal modes

```
// Example 6.15;//Cavity length and longitudinal
    modes
clc;
close;
clear;
h=0.87*10^-6;//Wavelength in meter
n=3.6;//refractive index
df=278;//frequency sepration in Gega Hertz
C=3*10^8;//Speed of light in m/s
L=round((C/(2*n*df*10^9))*10^6);//Length of cavity
    in micro meter
q=round(((2*n*L*10^-2)/(h))*10^-4);//Number of
    logitudinal modes
disp(L,"Length of cavity in micro meter")
disp(q,"Number of longitudinal modes are ")
```

Scilab code Exa 6.16 hole concentration

```
// Example 6.16;//Hole concentration
clear;
close;
clc;
Br=2.39*10^-10;//Bit rate
Tr=1;//Time in nano second
n=1/(Br*Tr*10^-9)//hole concentration
disp(n,"hole concentration in per cubic centimeter")
```

Scilab code Exa 6.17 gain factor

```
// Example 6.17;//Gain factor
clc;
clear;
close;
W=15;//width in per centimeter
Ith=50;//Current in mili ampere
r1=0.3;
r2=0.3;
alpha=10;// in per cm
L=50;//length in MICRO meter
Jth=(Ith/(L*10^-6*W));//Current density
B=(1/Jth)*(alpha+((1/(2*L*10^-04))*log(1/(r1*r2))));
    //gain factor in centimeter per ampere is
disp(B,"gain factor in centimeter per ampere is")
```

Scilab code Exa 6.18 internal quantum efficiency

```
// Example 6.18;//internal quantum efficiency
clc;
clear;
close;
n=3.6;//refractive index
nd=0.225;//differntilal quantum efficiency
alpha=20;// in per cm
L=500;//in micro meter
r1= ((n-1)/(n+1))^2;
r2=r1;
ni=(nd*(1+((2*alpha*L*10^-4)/(log(1/(r1*r2))))))
    *100;
disp(ni,"Internal quantum efficiency is")
```

Chapter 7

OPTICAL SOURCES THE LIGHT EMITTING DIODE

Scilab code Exa 7.1.a bulk recombination life time

```
// Example 7.1.a;//Bulk recombination life time
clc;
clear;
close;
h=1310*10^-9;//wavelength in meter
tr=30;//radiative recombination time in nano second
tnr=100;//non radiative recombination time in nano
   second
i=40;//injected current in milli ampere
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time
   in nano second
disp(t,"Bulk recombination life time in nano second"
   )
```

Scilab code Exa 7.1.b internal quantum efficiency

```
// Example 7.1.b;//inernal quantum efficiency
clc;
clear;
close;
h=1310*10^-9;//wavelength in meter
tr=30;//radiative recombination time in nano second
tnr=100;//non radiative recombination time in nano
    second
i=40;//injected current in milli ampere
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time
    in nano second
nint= (t/tr)
disp(nint,"inernal quantum efficiency is ")
```

Scilab code Exa 7.1.c power level

```
// Example 7.1.c;//inernal power level
clc;
clear;
close;
e=1.6*10^-19;//Electronic charge
ht=6.62*10^-34;//Constt
C=3*10^8;//sPPED OF LIGHT IN M/S
h=1310*10^-9;//wavelength in meter
tr=30;//radiative recombination time in nano second
tnr=100;//non radiative recombination time in nano
    second
i=40;//injected current in milli ampere
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time
    in nano second
nint= (t/tr)
Pint= (nint*((ht*C*i*10^-3)/(e*h)))*10^2;//internal
    power level in milli watt
disp(Pint,"internal power level in milli watt")
```

Scilab code Exa 7.2 power radiated

```
// Example 7.2;//power radiated by LED
clc;
clear;
close;
e=1.6*10^-19;//Electronic charge
ht=6.62*10^-34;//plank Constt
C=3*10^8;//sPPED OF LIGHT IN M/S
h=670*10^-9;//wavelength in meter
i=50;//injected current in milli ampere
nint=0.03;//inernal quantume efficiency
Pint= (nint*((ht*C*i*10^-3)/(e*h)))*10^2;//internal
    power level in milli watt
disp(Pint,"internal power level in milli watt")
```

Scilab code Exa 7.3 non radiative recombination lifetime

```
// Example 7.3;//non radiative recombination time
clc;
clear;
close;
h=890*10^-9;//wavelength in meter
tr=100;//radiative recombination time in nano second
t=130;//Bulk recombination life time in nano second
i=14;//injected current in milli ampere
tnr=round((t*tr)/(t-tr));//non radiative
    recombination time in nano second
disp(tnr,"non radiative recombination time in nano
    second")
```

Scilab code Exa 7.4 internal quantum efficiency

```
// Example 7.4;//inernal power level
clc;
clear;
close;
e=1.6*10^-19;//Electronic charge
ht=6.62*10^-34;//Constt
C=3*10^8;//sPPED OF LIGHT IN M/S
h=0.87*10^-9;//wavelength in meter
i=40;//injected current in milli ampere
nint= 0.625;//inernal quantum efficieny
Pint= (nint*((ht*C*i*10^-3)/(e*h)));//internal power
    level in milli watt
disp(Pint,"internal power level in milli watt")
```

Scilab code Exa 7.5 optical power emitted

```
// Example 7.5;//optical power emitted
clc;
clear;
close;
F=0.68;//transmission factore
nx=3.6;//refractive index
n=1;//refractive index of air
Px=((F*n^2)/(4*nx^2))*100;//optical power emitter
disp(Px,"percentage of emiiter power in terms of
   power generated internally")
```

Scilab code Exa 7.6.a coupling efficiency

```
// Example 7.6.a;//coupling efficiency
clc;
clear;
close;
NA=0.2;//numerical aperture
n=1.4;//refractive index
nc=(NA)^2;//coupling efficiency
disp(nc,"coupling efficiency is")
```

Scilab code Exa 7.6.b optical loss

```
// Example 7.6.b;//optical power loss
clc;
clear;
close;
NA=0.2;//numerical aperture
n=1.4;//refractive index
nc=(NA)^2;//coupling efficiency
Loss=round(-(10*log10(nc)));//optical loss in dB
disp(Loss,"optical loss in dB is")
```

Scilab code Exa 7.7 optical power

```
// Example 7.7;//optical power
clc;
clear;
close;
r=0.01;//fresenel reflection coefficient
NA=0.15;//numeical apertrure
Rd=30;//radiance in W sr-1 cm-2
i=40;//currenct in milli ampere
```

```
R=25*10^-4;//radis in centi meter
A=(%pi*R^2);//area
Pc=(%pi*(1-r)*A*Rd*NA^2)*10^6;//optical power
    coupled in mincro watt
disp(Pc,"optical power coupled in mincro watt is")
```

Scilab code Exa 7.8 power conversion efficiency

```
// Example 7.8;//overall power conversion efficiency
clc;
clear;
close;
Pc=150*10^-6;//Optical power in watt
If=25;//forward current in milli ampere
Vf=2.5;//forward voltage in volts
P=If*10^-3*If;//power in watt
npc=((Pc/P)*10^3);//overall power conversion
    efficiency
disp(npc,"overall power conversion efficiency in
    percentage")
```

Scilab code Exa 7.9 optical power

```
// Example 7.9;//overall power
clc;
clear;
close;
Pdc=300*10^-6;//d.c. power in watt
f=20*10^6;//frequency in hertz
Ti=5*10^-9;//recombination life time in nano second
Pe=(Pdc*sqrt(1+(2*%pi*f*Ti)^2))*10^6;
disp(Pe,"overall power in micro watt")
```

Scilab code Exa 7.10.a internal quantum efficiency and internal power level

```
// Example 7.10.a;//inernal quantum efficiency and
   internal power level
clc;
clear;
close;
e=1.6*10^-19;//Electronic charge
ht=6.62*10^-34;//Constt
C=3*10^8;//sPPED OF LIGHT IN M/S
h=1310*10^-9;//wavelength in meter
tr=25;//radiative recombination time in nano second
tnr=90;//non radiative recombination time in nano
   second
i=35;//injected current in milli ampere
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time
   in nano second
nint= (t/tr)
Pint= (nint*((ht*C*i*10^-3)/(e*h)))*10^2;//internal
   power level in milli watt
disp(nint,"inernal quantum efficiency is ")
disp(Pint,"internal power level in milli watt")
```

Scilab code Exa 7.10.b power emitted

```
// Example 7.10.b;//power emitted
clc;
clear;
close;
n=3.5;//refractive index
e=1.6*10^-19;//Electronic charge
```

```
ht=6.62*10^-34;//Consttt
C=3*10^8;//sPPED OF LIGHT IN M/S
h=1310*10^-9;//wavelength in meter
tr=25;//radiative recombination time in nano second
tnr=90;//non radiative recombination time in nano second
i=35;//injected current in milli ampere
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time in nano second
nint= (t/tr)
Pint= (nint*((ht*C*i*10^-3)/(e*h)))*10^2;//internal power level in milli watt
P=(Pint)/(n*(n+1)^2)*10;//Power emitted
disp(P,"power emitted in milli watt is")
```

Scilab code Exa 7.11 transmission factor

```
// Example 7.11;//transmission factor
clc;
clear;
close;
n=1;//refratcive index of air
i=37;//current in milli ampere
V=1.6;//Voltage in volts
nep=0.75;//external power efficiency
Pint=30;//power in milli watt
nx=3.46;//refrative index
P=i*V*10^-3;//POWER IN WATT
Pe=(nep*P)/100;//
F=(Pe*4*nx^2)/(Pint*10^-3*n^2);//Transmission factor
disp(F,"Transmission factor is")
```

Scilab code Exa 7.12 optical power and external power efficiency

```
// Example 7.12;//OPTICAL POWER EMITTED & EXTERNAL
    POWER EFFICIENCY
clc;
clear;
close;
e=1.6*10^-19;//Electronic charge
ht=6.62*10^-34;//Constt
C=3*10^8;//sPPED OF LIGHT IN M/S
h=0.85*10^-5;//wavelength in meter
V=1;//VOLTAGE
F=0.68;//transmiison factor
nx=3.6;//refractive index
n=1;;//refrative index of air
nint=0.6;//inernal efficiency
i=20*10^-3;//injected current in milli ampere
Pint= (nint*((ht*C*i*10^-3)/(e*h)))*10^7;//internal
    power level in milli watt
Pe=round((Pint*F)/(4*nx^2)*10^3);//optical power
    emitted
nep=(Pe*10^-6/(V*i))*100;//EXTERNAL POWER EFFICIENCY
disp(Pe,"optical power emitted in micro watt")
disp(nep,"external power efficiency is")
```

Chapter 8

POWER LAUNCHING AND COUPLING

Scilab code Exa 8.1.a optical power coupled

```
// Example 8.1.a;//OPTICAL POWER coupled
clc;
clear;
close;
B0=100;//in W per cm2 sr
rs=0.002;// radiating radius in cm
a=0.0015;//core radius in cm
NA=0.3;//numerical aperture
Pc=(B0*rs^2*%pi^2*NA^2)*10^3;//POWER COUPLED IN STEP
    INDEX FIBER in mili watt
disp(Pc,"POWER COUPLED IN STEP INDEX FIBER in mili
    watt")
```

Scilab code Exa 8.1.b core radius

```
// Example 8.1.b;//OPTICAL POWER coupled in fiber
```

```
clc;
clear;
close;
B0=100;//in W per cm2 sr
rs=0.002;// radiating radius in cm
a=0.0015;//core radius in cm
NA=0.3;//numerical aperture
Pc=(B0*a^2*%pi^2*NA^2)*10^3;//POWER COUPLED IN FIBER
    in mili watt
disp(Pc,"POWER COUPLED IN FIBER in mili watt")
```

Scilab code Exa 8.2 power distribution coefficients

```
// Example 8.2;//lateral power distribution
   coefficient
clc;
clear;
close;
th=5;//power beam width angle in degree
ph=0;//lateral angle in degree
L=round((log10(1/2))/(log10(cosd(th))));
disp(L,"lateral power distribution coefficient")
```

Scilab code Exa 8.3 power coupled

```
// Example 8.3;//power coupled
clc;
clear;
close;
n1=1.48;//core refractive index
n2=1.46;//cladiing refractive index
Po=150;//output power in micro watt
NA=sqrt(n1^2-n2^2);//numerical aperture
```

```
Pin=Po*NA^2;
disp(Pin,"Power couled in micro watt")
```

Scilab code Exa 8.4 fresnel reflection coefficient

```
// Example 8.4;//fresenel reflection coefficient
clc;
clear;
close;
n1=1.45;//Core refrative index
n2=1;//refractive index of air
R=((n1-n2)/(n1+n2))^2;//Fresenel Coefficient
disp(R,"fresenel reflection coefficient is")
```

Scilab code Exa 8.5 compare optical powers

```
// Example 8.5;//Compare OPTICAL POWER
clc;
clear;
close;
a=20;//core radius in micro meter
Bo=100;//in W per cm2 sr
rs=35;// radiating radius in micro meter
rs1=50;//
NA=0.2;//numerical aperture
Ps1= (%pi^2*(rs*10^-6)^2*Bo*NA^2)*10^7;
Ps2= (((rs/rs1)^2)*Ps1);//
disp(Ps1,"POWER when area is large in micro watt")
disp(Ps2,"power wHEN AREA IS SMALL in milli watt")
```

Chapter 9

OPTICAL DETECTORS

Scilab code Exa 9.1 quantum efficiency

```
// Example 9.1;//quantum efficiency
clc;
clear;
close;
re=4.2*10^6;// Average no. of electron hole pair
   generated
rp=6*10^6;//no. of photons
h=1200;//wavelength in nano meter
n=round((re/rp)*100);//quantum efficiency
disp(n,"quantum efficiency is")
```

Scilab code Exa 9.2 photocurrent

```
// Example 9.2;//photocurrent
clc;
clear;
close;
R=0.85;//responsivity in ampere per watt
```

```
Po=1;//output power in milli watt
Ip= R*Po;//photocurrent in milli ampere
disp(Ip,"photocurrent in milli ampere is ")
```

Scilab code Exa 9.3 responsivity

```
// Example 9.3;//responsivity
clc;
clear;
close;
E=0.75;//energy gap in electron volt
C=3*10^8;//SPEED of light in meter per second
n=0.60;//quantum efficiency
ht=6.62*10^-34;//plank constt.
h=((ht*C)/(E*1.6*10^-19))*10^9;//wavelength in nano
    meter
R=((n*h)/1248);//responsivity
disp(R,"Responsivity is in ampere per watt")
```

Scilab code Exa 9.4 quantum efficiency and responsivity

```
// Example 9.3;//quantum efficiency and responsivity
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
re=1.5*10^12;// Average no. of electron hole pair
    generated
rp=3*10^12;//no. of photons
h=0.65;//wavelength in micro meter
E=0.75;//energy gap in electron volt
C=3*10^8;//SPEED of light in meter per second
n=round((re/rp)*100);//quantum efficiency
```

```
ht=6.62*10^-34;//plank constt.
R=((n/100)*e*h*10^-6)/(ht*C);
disp(n,"quantum efficiency is")
disp(R,"Responsivity is in ampere per watt")
```

Scilab code Exa 9.5.a operating wavelngth

```
// Example 9.5.a;//WAVELENGTH
clc;
clear;
close;
E=1.5*10^-19;//energy in joule
e=1.6*10^-19;//elecronic charge
If=1.5*10^-6;//forward current in ampere
C=3*10^8;//SPEED of light in meter per second
n=0.65;//quantum efficiency
ht=6.62*10^-34;//plank constt.
h=((ht*C)/E)*10^6;//Wavelength
disp(h,"wavelength in micro meter")
```

Scilab code Exa 9.5.b incident optical power

```
// Example 9.5.b;//Incident optical power
clc;
clear;
close;
E=1.5*10^-19;//energy in joule
e=1.6*10^-19;//elecronic charge
If=1.5*10^-6;//forward current in ampere
C=3*10^8;//SPEED of light in meter per second
n=0.65;//quantum efficiency
ht=6.62*10^-34;//plank constt.
h=((ht*C)/E)*10^6;//Wavelength
```

```
R=(n*e)/(E);//Responsivity in ampere per watt
Po=(If/R)*10^6;//Output power in micro watt
disp(Po,"Output power in micro watt")
```

Scilab code Exa 9.6 WAVELENGTH

```
// Example 9.6;//WAVELENGTH
clc;
clear;
close;
E=1.43//energy gap in electron-volt
e=1.6*10^-19;//elecronic charge
C=3*10^8;//SPEED of light in meter per second
ht=6.62*10^-34;//plank constt.
h=((ht*C)/(E*e))*10^6;//Wavelength
disp(h,"wavelength in micro meter")
```

Scilab code Exa 9.7.a responsivity

```
// Example 9.7.a;//responsivity
clc;
clear;
close;
C=3*10^8;//SPEED of light in meter per second
n=0.50;//quantum efficiency
h=900;//wavelength in nano meter
ht=6.62*10^-34;//plank constt.
R=((n*h)/1248);//responsivity
disp(R,"Responsivity is in ampere per watt")
```

Scilab code Exa 9.7.b received optical power

```
// Example 9.7.b;//optical POWER
clc;
clear;
close;
Ip=10^-6;//optical current in ampere
C=3*10^8;//SPEED of light in meter per second
n=0.50;//quantum efficiency
h=900;//wavelength in nano meter
ht=6.62*10^-34;//plank constt.
R=((n*h)/1248);//responsivity
Po=(Ip/R);//Output power in  watt
disp(Po,"Output power in  watt")
```

Scilab code Exa 9.7.c number of received photons

```
// Example 9.7.b;//optical current
clc;
clear;
close;
Ip=10^-6;//optical current in ampere
C=3*10^8;//SPEED of light in meter per second
n=0.50;//quantum efficiency
h=900;//wavelength in nano meter
ht=6.62*10^-34;//plank constt.
R=((n*h)/1248);//responsivity
Po=(Ip/R);//Output power in  watt
n=(Po*h*10^-9)/(ht*C);//no. of received phontons
disp(n,"no. of received phontons is")
```

Scilab code Exa 9.8 multiplication factor

```
// Example 9.8;//multiplication factor
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=0.9;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.80;//efficiency
ht=6.62*10^-34;//plank constt.
I=12;//CURRENT IN MICRO AMPERE
Po=0.5;//output power in micro watt
R=((n*e*h*10^-6)/(ht*C));
Ip=Po*R;//photocurrent in micro ampere
M=I/Ip;//Multilplication factor
disp(M,"Multilplication factor IS")
```

Scilab code Exa 9.9 responsivity and multiplication factor

```
// Example 9.9;//multiplication factor
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=850;//wavelength in NANO meter
C=3*10^8;//SPEED of light in meter per second
n=0.65;//efficiency
ht=6.62*10^-34;//plank constt.
I=10;//CURRENT IN MICRO AMPERE
Po=0.5;//output power in micro watt
R=((n*e*h*10^-9)/(ht*C));
Ip=Po*R;//photocurrent in micro ampere
M=I/Ip;//Multilplication factor
disp(M,"Multilplication factor IS")
```

Scilab code Exa 9.10.a noise equivalent power

```
// Example 9.10.a;//noise equivalent power
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=1.3;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.55;//efficiency
ht=6.62*10^-34;//plank constt.
Id=8;//CURRENT IN nano AMPERE
NEP=((ht*C)*sqrt(2*e*Id*10^-9))/(n*e*h*10^-6);//
    noise equivalent power in watt
disp(NEP,"noise equivalent power in watt is")
```

Scilab code Exa 9.10.b specific detectivity

```
// Example 9.10.a;//specific detectivity
clc;
clear;
close;
A=75*50*10^-12;//
e=1.6*10^-19;//elecronic charge
h=1.3;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.55;//efficiency
ht=6.62*10^-34;//plank constt.
Id=8;//CURRENT IN nano AMPERE
NEP=((ht*C)*sqrt(2*e*Id*10^-9))/(n*e*h*10^-6);//
    noise equivalent power in watt
D=(sqrt(A)/NEP);//specific detectivity
```

```
disp(D,"specific detectivity is")
```

Scilab code Exa 9.11.a optical gain

```
// Example 9.11.a;//Optical gain
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=1.26;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.60;//efficiency
ht=6.62*10^-34;//plank constt.
Ic=15;//CURRENT IN milli ampere
Po=125;//output power in micro watt
Gc=(ht*C*Ic*10^-3)/(h*10^-6*e*Po*10^-6);//Gain
disp(Gc,"optical gain is")
```

Scilab code Exa 9.11.b common emitter current gain

```
// Example 9.11.b;//Common emitter current gain
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=1.26;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.60;//efficiency
ht=6.62*10^-34;//plank constt.
Ic=15;//CURRENT IN milli ampere
Po=125;//output power in micro watt
Gc=(ht*C*Ic*10^-3)/(h*10^-6*e*Po*10^-6);//Gain
nfc=Gc/n;//Common emitter current gain
```

```
disp(nfc,"common emittergain is")
```

Scilab code Exa 9.12 bandwidth

```
// Example 9.12;//Maximuum bandwidth
clc;
clear;
close;
tr=5*10^-12;//electron transit time in pico second
G=70;//photo conductive gain
Bm=(1/(2*%pi*tr*G))*10^-6;//Maximum bandwidth
disp(Bm,"Maximum bandwidth in mega hertz is")
```

Scilab code Exa 9.13 photocurrent

```
// Example 9.13;//output photo current
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
rp=10^11;//photons per second
hf=1.28*10^19;// energy in joule
n=1;//efficency
C=3*10^8;//SPEED of light in meter per second
ht=6.62*10^-34;//plank constt.
Po=(rp/hf)*10^9;//incident optical power in micro
    watt
Ip=(n*Po*10^-6*e)/(hf);//output photo current
disp(Ip,"output photo current in ampere is")
```

Scilab code Exa 9.14 photocurrent

```
// Example 9.14;//output photo current
clc;
clear;
close;
R=0.40;//RESPONSIVITY IN AMPERE PER WATT
If=100;//incident flus in micro watt per milli meter
    square
Ae=2;//active area in mili mtere square
Po=If*Ae;//incident optical power in micro watt
Ip=Po*R*10^-3;//output photo current IN MIILI AMPERE
disp(Ip,"output photo current in milli ampere is")
```

Scilab code Exa 9.15 multiplication factor

```
// Example 9.15;//multiplication factor
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=1.3;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.5;//efficiency
ht=6.62*10^-34;//plank constt.
I=8;//CURRENT IN MICRO AMPERE
Po=0.4;//output power in micro watt
R=((n*e*h*10^-6)/(ht*C));
Ip=Po*R;//photocurrent in micro ampere
M=I/Ip;//Multilplication factor
disp(M,"Multilplication factor IS")
```

Scilab code Exa 9.16 bandwidth

```
// Example 9.16;//Maximuum bandwidth
clc;
clear;
close;
tr=4.5*10^-12;//electron transit time in  second
G=80;//photo conductive gain
Bm=(1/(2*%pi*tr*G))*10^-9;//Maximum bandwidth
disp(Bm,"Maximum bandwidth in giga hertz is")
```

Scilab code Exa 9.17 responsivity and optical power

```
// Example 9.17;//responsivity and recieved optical power
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
h=0.9;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
n=0.50;//efficiency
ht=6.62*10^-34;//plank constt.
I=1;//CURRENT IN MICRO AMPERE
R=((n*e*h*10^-6)/(ht*C));
Po=(I*10^-6)/R;//
disp(R,"Responsivity is in ampere per watt")
disp(Po,"Output power in m watt")
```

Scilab code Exa 9.18 EFFICIENCY

```
// Example 9.18;//efficiency
clc;
clear;
close;
```

```
e=1.6*10^-19;//elecronic charge
h=1300;//wavelength in nano meter
C=3*10^8;//SPEED of light in meter per second
R=0.374;//Responsivity is in ampere per watt
ht=6.62*10^-34;//plank constt.
n=((R*ht*C)/(e*h*10^-9))*100;
disp(n,"Efficiency is")
```

Scilab code Exa 9.19.a responsivity

```
// Example 9.19.a;//responsivity
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
C=3*10^8;//SPEED of light in meter per second
n=0.50;//quantum efficiency
h=0.9;//wavelength in nano meter
ht=6.62*10^-34;//plank constt.
R=((n*e*h*10^-6)/(ht*C));//responsivity
disp(R,"Responsivity is in ampere per watt")
```

Scilab code Exa 9.19.b optical power

```
// Example 9.19.a;//OPTICAL POWER
clc;
clear;
close;
Ip=10^-6;//optical current in ampere
e=1.6*10^-19;//elecronic charge
C=3*10^8;//SPEED of light in meter per second
n=0.50;//quantum efficiency
h=0.9;//wavelength in nano meter
```

```
ht=6.62*10^-34;//plank constt.
R=((n*e*h*10^-6)/(ht*C));//responsivity
Po=(Ip/R)*10^6;//Output power in micro watt
disp(Po,"Output power in  micro watt")
```

Scilab code Exa 9.20 Thickness

```
// Example 9.20;//thickness
clc;
clear;
close;
A=1.5;//area in mili meter square
R=100;//resistance in ohms
Eo=1.04*10^-10;//F/m
Vd=10^7;//DRIFT VELOCITY IN m/s
w=round((sqrt(R*Eo*A*10^-6*Vd))*10^6);//thickness in
    micro meters
disp(w,"thickness in micro meters is")
```

Scilab code Exa 9.21 dark current

```
// Example 9.21;//dark current
clc;
clear;
close;
C=2.998*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
h=0.85;//wavelength in micro meters
n=0.64;//efficiency
B=1;//bandwidth in hertz
D=7*10^10;//SPECIFIC DETECTIVITY
a=10;//active dimension in micro meter
```

```
Id=((n*sqrt(e*a*10^-6)*h*10^-6)/(ht*C*sqrt(2)*D))^2;
    //
disp(Id,"Dark current in ampere is")
```

Chapter 10

OPTICAL RECEIVER

Scilab code Exa 10.1 quantum noise dark and thermal noise current

```
// Example 10.1;//QUANTUM NOISE , DARK CURRENT & THERMAL NOISE
clc;
clear;
close;
T=300;//TEMPRATURE IN KELVIN
K=1.38*10^-23;//boltzman constt
C=3*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
Id=4;//dark current in nano ampere
n=0.90;//efficiency
Rl=1000;//load resistance in ohms
h=1100;//wavelength in nano meter
Po=300;// ouput power in nano watt
B=20;// bandwidth in mega hertz
Ip= (n*h*10^-9*Po*10^-9*e)/(ht*C);//PHOTO CURRENT IN AMPERE
Iq=(sqrt(2*e*Ip*B*10^6))*10^9;//QUANTUM NOISE IN NANO AMPERE
id=(sqrt(2*e*B*10^6*Id*10^-9))*10^9;//dark current
```

```
   in nano ampere
it=(sqrt((4*K*T*B*10^6)/Rl))*10^9;//thermal noise
disp(Iq,"QUANTUM NOISE IN NANO AMPERE")
disp(id,"dark current in nano ampere")
disp(it,"THERMAL NOISE in nano ampere")
```

Scilab code Exa 10.2.a quantum limit

```
// Example 10.2.a;//threshold quantum limit
clc;
clear;
close;
n=1;//efficiency for idea case
ht=6.62*10^-34;//plank constt.
f=3*10^14;//frequency in hertz
B=10^7;//NO. OF BITS
h=10^-6;//wavelength in metr
BER=10^-9;//bit error rate
Zm=-(log(BER));//probality of error
Emin=(20.7*h*f)/n;
disp(Emin , "this is the quantum limit")
```

Scilab code Exa 10.2.b incident optical power

```
// Example 10.2.a;//threshold quantum limit
clc;
clear;
close;
n=1;//efficiency for idea case
ht=6.62*10^-34;//plank constt.
f=3*10^14;//frequency in hertz
B=10^7;//NO. OF BITS
h=10^-6;//wavelength in metr
```

```
BER=10^-9;//bit error rate
Zm=-(log(BER));//probality of error
Po=((20.7*ht*f*B)/(2*n))*10^12;//pulse energy in
    pico watt
Podb=10*(log10(Po*10^-12));//pulse energy in dB when
     refrence level is one watt
Podb1=10*(log10(Po*10^-9));//pulse energy in dB when
     refrence level is one miili watt
disp(Podb , "pulse energy in dB when refrence level
    is one watt in dBW")
disp(Podb1 , "pulse energy in dB when refrence level
     is one miiliwatt in dBm")
```

Scilab code Exa 10.3 incident optical power

```
// Example 10.3;//incident optical power
clc;
clear;
close;
ht=6.62*10^-34;//plank constt.
f=3*10^14;//frequency in hertz
n=1;//efficiency for ideal case
SNR=50;//signal to noise ration in dB
h=1;//wavelength in micro meter
B=5;//bandwidth in mega hertz
SN=10^5;//Signal too noise ratio
Po=((2*ht*f*B*10^6*SN)/n)*10^9;//output power in
    nano watt
Podb=10*(log10(Po*10^-6));//output power in dB
disp(Podb,"output power in dB")
```

Scilab code Exa 10.4.a shot noise

```
// Example 10.4.a;//TOTAL SHOT NOISE
clc;
clear;
close;
T=293;//TEMPRATURE IN KELVIN
K=1.38*10^-23;//boltzman constt
C=3*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
Id=3;//dark current in nano ampere
n=0.60;//efficiency
Rl=4;//load resistance in killo ohms
h=0.9;//wavelength in micro meter
Po=200;// ouput power in nano wat
B=5;// bandwidth in mega hertz
Ip= ((n*h*10^-6*Po*10^-9*e)/(ht*C))*10^9;//PHOTO CURRENT IN AMPERE
its=(2*e*B*10^6*(Id+Ip)*10^-9);//total shot noise
itsr=sqrt(its);//RMS shot noise
disp(its,"total shot noise is")
disp(itsr,"RMS shot noise current in ampere is")
```

Scilab code Exa 10.4.b thermal noise

```
// Example 10.4.b;//Thermal noise
clc;
clear;
close;
T=293;//TEMPRATURE IN KELVIN
K=1.38*10^-23;//boltzman constt
C=3*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
Id=3;//dark current in nano ampere
n=0.60;//efficiency
```

```
Rl=4;//load resistance in killo ohms
h=0.9;//wavelength in micro meter
Po=200;// ouput power in nano wat
B=5;// bandwidth in mega hertz
it=(((4*K*T*B*10^6)/(Rl*10^3)));//thermal noise
itr=sqrt(it);//rms thermal noise
disp(it,"total thermal noise is")
disp(itr,"RMS thermal noise current in ampere is")
```

Scilab code Exa 10.5.a load resistance

```
// Example 10.5.a;//maximum load resistance
clc;
clear;
close;
B=6;//bandwidth in mega hertz
Cd=8;//Photodiode capacitance in pico farad
Ca=4;//amplifier capacitance in pico farad
Rlm=(1/(2*%pi*B*10^6*Cd*10^-12))*10^-3;//Maximum lod
    resistance in Kilo ohm
disp(Rlm,"Maximum lod resistance in Kilo ohm")
```

Scilab code Exa 10.5.b bandwidth

```
// Example 10.5.b;//maximum bandwidth
clc;
clear;
close;
B=6;//bandwidth in mega hertz
Cd=8;//Photodiode capacitance in pico farad
Ca=4;//amplifier capacitance in pico farad
Rlm=(1/(2*%pi*B*10^6*Cd*10^-12))*10^-3;//Maximum lod
    resistance in Kilo ohm
```

```
B=(1/(2*%pi*Rlm*10^3*(Cd+Ca)*10^-12))*10^-6;//
    Maximum bandwidth in mega hertz
disp(B,"Maximum bandwidth in mega hertz")
```

Scilab code Exa 10.6 SNR

```
// Example 10.6;//maximum bandwidth
clc;
clear;
close;
Ip=87.1*10^-9;//Photo current in ampere
its=1.44*10^-19;
it=2.02*10^-17;
Fn=2;//noise figure
SN=(Ip^2)/(its+(it*Fn));//Signal to noise ratio
SNdb=10*(log10(SN));//SIGNAL TO NOISE RATIO IN dB
disp(SNdb,"signal to noise raion in dB")
```

Scilab code Exa 10.7 SNR IMPROVEMENT

```
// Example 10.7;//max SNR improvment
clc;
clear;
close;
K=1.38*10^-23;//boltzman constt
C=3*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
B=50;//bandwidth in mega hertz
Cd=5;//Photodiode capacitance in pico  farad
T=291;//tEMPERATURE IN KELVIN
Ip=10^-7;//photo current in ampere
```

```
Rlm=(1/(2*%pi*B*10^6*Cd*10^-12));//Maximum lod resistance in ohm
//Case 1 when M=1
SNR1=(Ip^2)/((2*e*B*10^6*Ip)+((4*K*T*B*10^6)/(Rlm)));
SNR1dB=10*(log10(SNR1));//signal to noise ration when M=1 in dB
//CASE2 M=Mop & x=0.3
x=0.3;
Mop=(((4*K*T)/(x*e*Rlm*Ip))^(1/2.3))
SNR2=(Mop^2*Ip^2)/((2*e*B*10^6*Ip*Mop^2.3)+((4*K*T*B*10^6)/(Rlm)));//signal to noise ratio M=Mop & x=0.3
SNR2dB=10*(log10(SNR2));//signal to noise ratio M=Mop & x=0.3 in dB
disp(SNR1dB,"signal to noise ration when M=1 in dB")
disp(SNR2dB,"signal to noise ratio M=Mop & x=0.3 in dB")
```

Scilab code Exa 10.8.a photocurrent

```
// Example 10.8.a;//MIMIMUM PHOTO CURRENT
clc;
clear;
close;
x=1;
SNR=3.16*10^3;//SIGNAL TO NOISE RATIO
Fn=1,26;//Noise figure
K=1.38*10^-23;//boltzman constt
C=3*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
B=10;//bandwidth in mega hertz
T=120;//tEMPERATURE IN KELVIN
Rl=10//Maximum lod resistance in killo ohm
```

```
Ip=(((SNR*((12*K*T*B*10^6*Fn)/(Rl*10^3))))/(((4*K*T*Fn)/(1.1*e*Rl*10^3)))^(2/3))^(3/4);//
disp(Ip,"Photo current in ampere")
```

Scilab code Exa 10.8.b avalanche multiplication factor

```
// Example 10.8.b;//optimum avalanche multiplication factor
clc;
clear;
close;
x=1;
SNR=3.16*10^3;//SIGNAL TO NOISE RATIO
Fn=1,26;//Noise figure
K=1.38*10^-23;//boltzman constt
C=3*10^8;//SPEED of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
B=10;//bandwidth in mega hertz
T=120;//tEMPERATURE IN KELVIN
Rl=10//Maximum lod resistance in killo ohm
Ip=(((SNR*((12*K*T*B*10^6*Fn)/(Rl*10^3))))/(((4*K*T*Fn)/(1.1*e*Rl*10^3)))^(2/3))^(3/4);//
Mop=(((4*K*T*Fn)/(1.1*e*Ip*10^3)))^(1/3);//optimum avalanche multiplication factor
disp(Mop,"optimum avalanche multiplication factor is ")
```

Scilab code Exa 10.9.a bandwidth

```
// Example 10.9.a;//maximum bandwidth
clc;
clear;
```

```
close;
Ra=4*10^6;//input resistane in ohms
Rb=4*10^6;//matched bias resistane in ohms
Ct=6*10^-12;//total capicatance in farad
T=300;//TEMPERATURE IN KELVIN
Rtl=(Ra*Rb)/(Ra+Rb);//total resistance
B=(1/(2*%pi*Rtl*Ct));//Maximum bandwidth inhertz
disp(B,"Maximum bandwidth in  hertz")
```

Scilab code Exa 10.9.b thermal noise current

```
// Example 10.9.b;//thermal noise
clc;
clear;
close;
K=1.38*10^-23;//boltzman constt
Ra=4*10^6;//input resistane in ohms
Rb=4*10^6;//matched bias resistane in ohms
Ct=6*10^-12;//total capicatance in farad
T=300;//TEMPERATURE IN KELVIN
Rtl=(Ra*Rb)/(Ra+Rb);//total resistance
B=(1/(2*%pi*Rtl*Ct));//Maximum bandwidth inhertz
it=(((4*K*T)/(Rtl)));//thermal noise
disp(it,"thermal noise in ampere square per hertz")
```

Scilab code Exa 10.10 optical power

```
// Example 10.10;//threshold quantum limit
clc;
clear;
close;
e=1.6*10^-19;
R=0.5;//responsivity in amper per watt
```

```
n=1;//efficiency for idea case
ht=6.62*10^-34;//plank constt.
f=3*10^14;//frequency in hertz
R=35;//mega bits per second
h=0.50^-6;//wavelength in metr
BER=10^-7;//bit error rate
Zm=-(log(BER));//probality of error
Po=(Zm*2*e*R*10^6)/2;
Podb=10*(log10(Po*10^3));//pulse energy in dB when refrence level is one milli watt
disp(Podb ,"pulse energy in dB when refrence level is one miiliwatt in dBm")
```