

Scilab Textbook Companion for
Optical Communication
by S. Katiyar¹

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 2

OPTICAL FIBER WAVEGUIDES

Scilab code Exa 2.1 Thickness

```
1 // Example 2.1: Thickness
2 clc;
3 clear;
4 close;
5 pi=3.14;
6 n1=3.5; // Waveguide Refractive Index
7 n2=3.0; // Cladding Refractive Index
8 v=6; // number of modes
9 h=1.5; // wavelength in micro meter
10 Os= asind(n2/n1) // angle in degree
11 th= round(12*pi*h)/(2*pi*n1*cosd(Os)); // Thickness
    of the film
12 disp(th,"Thickness of film in micrometers")
13 disp("Thickness 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

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

Scilab code Exa 2.3 numerical aperture

```
1 // Example 2.3: Numerical Aperture
2 clc;
3 clear;
4 close;
5 v= 26.6; //normalised frequency
6 h=1.3; // Wavelength in micro meters
7 a=25; //core radius in micro meters
8 NA=(v*h)/(2*%pi*a); // Numerical Aperture
9 disp(NA,"Numerical Aperture of the Fiber is")
```

Scilab code Exa 2.4 numerical aperture

```
1 // Example 2.4: Numerical Aperture
2 clc;
3 clear;
4 close;
5 n1=1.4675; //Waveguide Refractive Index
```

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

Scilab code Exa 2.5 cut off wavelngth

```
1 // Example 2.5: Cutoff Wavelngt
2 clc;
3 clear;
4 close;
5 n1=1.5; //Waveguide Refractive Index
6 n2=1.47; //Cladding Refractive Index
7 a=4; // core radius in micro meters
8 NA=sqrt(n1^2-n2^2); // Numerical Aperture
9 Hc= (2*%pi*a*NA)/(2.405)
10 disp(Hc,"Cutoff wavelngth in micro meters")
```

Scilab code Exa 2.6 core diameter

```
1 // Example 2.6: Core Diameter
2 clc;
3 clear;
4 close;
5 n1=1.55; //Waveguide Refractive Index
6 n2=1.48; //Cladding Refractive Index
7 h= 1.55; // Wavelngth in micrometers
8 NA=sqrt(n1^2-n2^2); // Numerical Aperture
9 a= (2.405*h)/(2*%pi*NA); // Core radius
10 d=2*a; // Core Diameter
11 disp(d,"Core Diameter in micro meter")
```

Scilab code Exa 2.7 number of modes

```
1 // Example 2.7: Number of the modes
2 clc;
3 clear;
4 close;
5 n1=1.48; // Waveguide Refractive Index
6 n2=0.01; // Cladding Refractive Index
7 h= 0.84; // Wavelength in micrometers
8 a= 25; // Core radius in micrometers
9 NA=(n1^2-n2^2); // Numerical Aperture
10 M=round(((2*pi)/h)^2*a^2*NA)/100; //
11 v= round(sqrt(M*2)); //
12 disp(v,"Number of modes")
```

Scilab code Exa 2.8 number of modes

```
1 // Example 2.8: Number of the modes
2 clc;
3 clear;
4 close;
5 n1=1.475; // Waveguide Refractive Index
6 n2=1.472; // Cladding Refractive Index
7 h1= 0.85; // Wavelength in micrometers
8 a= 20; // Core radius in micrometers
9 NA=sqrt(n1^2-n2^2); // Numerical Aperture
10 v=(2*pi*a*NA)/h1;
11 m1= round((v^2)/2);
12 h2= 1.3; // Wavelength in micrometers
13 v1=(2*pi*a*NA)/h2;
14 m2= round((v1^2)/2);
15 disp (m1, "number of modes when wavelngth is 0.85
        micro meters")
16 disp(m2,"when wavelngth is 1.3 micro meters")
```

Scilab code Exa 2.9 numerical aperture

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

Scilab code Exa 2.10.a core radius

```
1 // Example 2.10.a; Core Radius
2 clc;
3 clear;
4 close;
5 n1=1.450; // Waveguide Refractive Index
6 n2=1.447; // Cladding Refractive Index
7 h= 1.3; // Wavelength in micrometers
8 NA=sqrt(n1^2-n2^2); // Numerical Aperture
9 a= (2.405*h)/(2*%pi*NA); // Core radius
10 disp(a, "Core radius in micro meter")
```

Scilab code Exa 2.10.b numerical aperture

```
1 // Example 2.10.b; Numerical Aperture
2 clc;
3 clear;
```

```
4 close;
5 n1=1.450; //Waveguide Refractive Index
6 n2=1.447; //Cladding Refractive Index
7 h= 1.3; // Wavelength in micrometers
8 NA=sqrt(n1^2-n2^2); // Numerical Aperture
9 disp(NA,"Numerical Aperture is")
```

Scilab code Exa 2.10.c acceptance angle

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

Scilab code Exa 2.11.a critical angle

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

Scilab code Exa 2.11.b numerical aperture

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

Scilab code Exa 2.11.c acceptance angle

```
1 // Example 2.11.c; Acceptance Angle
2 clc;
3 clear;
4 close;
5 n1=1.50; //Waveguide Refractive Index
6 n2=1.47; //Cladding Refractive Index
7 h= 1.3; // Wavelength in micrometers
8 NA=sqrt(n1^2-n2^2); // Numerical Aperture
9 Oa=asind(NA); //ACCEPTANCE ANGLE
10 disp(Oa, " ACCEPTANCE ANGLE IN DEGREE")
```

Scilab code Exa 2.12 acceptance angle

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



```

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

```

Scilab code Exa 2.13.a normalized frequency

```

1 // Example 2.13.a:Normalised Frequency
2 clc;
3 clear;
4 close;
5 n1=1.48;//Waveguide Refractive Index
6 d= 0.015;// Cange in core-cladding refractive index
7 a=40;// core radius in micro meters
8 h=0.85;//wavelength in micro meters
9 v=(2*%pi*a*n1*sqrt(2*d))/h;//Normalised wavelength
10 disp(v,"normalised frequency ")

```

Scilab code Exa 2.13.b number of modes

```

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

```

Scilab code Exa 2.14.a cutoff frequency

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

Scilab code Exa 2.14.b core radius

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

Scilab code Exa 2.15 cut off wavelength

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

Scilab code Exa 2.16 numerical aperture and acceptance angle

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

Scilab code Exa 2.17.a CLADDING INDEX

```
1 // Example 2.17.a:Cladding Index
2 clc;
3 clear;
4 close;
5 n1=1.5;//Waveguide Refractive Index
```

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

Scilab code Exa 2.17.b critical internal reflection angle

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

Scilab code Exa 2.17.c acceptance angle

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

Scilab code Exa 2.17.d numerical aperture

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

Scilab code Exa 2.18 acceptance angle

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

Scilab code Exa 2.19.a numerical aperture

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

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

Scilab code Exa 2.19.b acceptance angle

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

Scilab code Exa 2.20 normalized frequency

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

Scilab code Exa 2.21.a numerical aperture

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

Scilab code Exa 2.21.b dispersion per unit length

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

Scilab code Exa 2.22 Thickness

```
1 // Example 2.22: Thickness
2 clc;
3 clear;
4 close;
5 n1=3.6; //Core Refractive Index
6 n2=3.56; //Cladding Refractive Index
7 h=0.85; // wavelength in micro meter
8 m=1; // mode is fundamental TE10
9 n=0;
10 Vc=2.405; //Cutoff wavelength
11 a=(Vc*h)/(2*pi*sqrt(n1^2-n2^2)); // Core radius
12 disp(a,"Core radius in micrometers")
```

Scilab code Exa 2.23 core diameter

```
1 // Example 2.23: Diameter
2 clc;
3 clear;
4 close;
5 n1=1.5; //Core Refractive Index
6 d=0.01; //difference in the refractive index
7 h=1.3; // wavelength in micro meter
8 m=1100; // numer of modes
9 v=round(sqrt(2*m)); // Number of guided modes
10 a=(v*h)/(2*pi*n1*sqrt(2*d)); // Core radius
11 d= 2*a; // Core Diameter
12 disp(d,"Core diameter in micrometers")
13 //answer is calculated wrong in the textbook
```

Scilab code Exa 2.24.a critical angle

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

Scilab code Exa 2.24.b numerical aperture

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

Scilab code Exa 2.25 acceptance angle

```
1 // Example 2.25; Acceptance Angle
2 clc;
3 clear;
4 close;
5 NA=0.344; // Numerical Aperture
```

```

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

```

Scilab code Exa 2.26 numer of modes and cutoff frequency

```

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

```

Scilab code Exa 2.27.a numerical aperture

```

1 // Example 2.27.a: Numerical Aperture
2 clc;
3 clear;
4 close;
5 n1=1.5;//Core Refractive Index
6 n2=1.48;//Cladding Refractive Index

```

```

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

```

Scilab code Exa 2.27.b critical angle

```

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

```

Scilab code Exa 2.27.c pulse broadning

```

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

```

Scilab code Exa 2.28 core diameter

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

Chapter 4

TRANSMISSION CHARACTERISTICS OF OPTICAL FIBERS

Scilab code Exa 4.1 power loss

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

Scilab code Exa 4.2 power level

```
1 // Example 4.2: Output Power
2 clc;
```

```

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

```

Scilab code Exa 4.3 link length

```

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

```

Scilab code Exa 4.4 pulse dispersion

```

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

```

Scilab code Exa 4.5 output optical power

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

Scilab code Exa 4.6.a signal loss

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

Scilab code Exa 4.6.b signal loss per kilometer

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

```

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

```

Scilab code Exa 4.6.c overall signal attenuation

```

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

```

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

```

1  // Example 4.6.d: Ratio of powers
2  clc;
3  clear;
4  close;
5  L=8; // Length of fiber in km

```



```

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

```

Scilab code Exa 4.7.a signal attenuation

```

1 // Example 4.8.a: Attenuation
2 clc;
3 clear;
4 close;
5 L=1; // DISTANCE IN km
6 h=0.63; // in micro meter
7 Tf=1400; // Temperature in kelvin
8 p=0.286; // photoelastic coefficient of silica
9 n=1.46; // Refractive index of silica
10 Bc=7*10^-11; // isothermal compressibility in in Metere
    square per N
11 K=1.38*10^-23; // BOLTZMAN CONSTT. IN JULIAN PER
    KELVIN
12 x= (h*10^-6);
13 Yr=(8*pi^3*n^8*p^2*Bc*K*Tf)/(3*(x)^4); // rayleigh
    scattering coefficient
14 Ekm= exp(-Yr*L*10^3)
15 alpha=10*(log10(1/Ekm)); // Attenuation in dB/Km
16 disp(alpha,"Attenuation in dB/Km")
17 disp("solutions of example 4.8 and 4.7 are
    interchanged in the book")

```

Scilab code Exa 4.7.b signal attenuation

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

Scilab code Exa 4.8 refractive index

```
1 // Example 4.8: refrative index
2 clc;
3 clear;
4 close;
5 alpha=0.46; //attenuation in Db/Km
6 L=1; // DISTANCE IN KM
```

```

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

```

Scilab code Exa 4.9 operating wavelength and attenuation

```

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

```

Scilab code Exa 4.10 optical power

```

1 // Example 4.10: Optical Powers

```

```

2  clc;
3  clear;
4  close;
5  h=1.5; //Wavelength in micro meters
6  d=6; //Core diameter in micro meter
7  v=0.8; //frequency in Giga Hertz
8  alpha=0.5; //Attenuation in dB/Km
9  Pb=(4.4*10-3*d2*h2*alpha*v)*103; //Threshold
    optical power for brillouin scattering in milli
    watt
10 Pr=(5.9*10-2*d2*alpha*h); //Threshold optical power
    for Raman scattering in watt
11 disp(Pb,"Threshold optical power for brillouin
    scattering in milli watt")
12 disp(Pr,"Threshold optical power for Raman
    scattering in watt")

```

Scilab code Exa 4.11 critical radius

```

1  // Example 4.11: Critical Radius
2  clc;
3  clear;
4  close;
5  d=0.03; //Refractive index difference
6  n1=1.5; //Core refractive index
7  h= 0.82*10-6; //Wavelength in meters
8  n2=sqrt(n12-(2*d*n12)); // Cladding refractive
    index
9  Rc=(3*n12*h)/(4*%pi*sqrt(n12-n22))*106; //
    Critical Radius in micro meters
10 disp(Rc," Critical Radius in micro meters")
11 //answer is calculated wrong in the textbook

```

Scilab code Exa 4.12 critical radius

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

Scilab code Exa 4.13.a bandwidth

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

Scilab code Exa 4.13.b pulse dispersion

```

1 // Example 4.13.b:Dispersion per unit length
2 clc;
3 clear;
4 close;
5 t=0.1*10^-6;//Time in second
6 L=10;//Distance in Km
7 dp=(t/L)*10^6;//Dispersion per unit length in micro
    second per Km
8 disp(dp,"Dispersion per unit length in micro second
    per Km")

```

Scilab code Exa 4.13.c bandwidth length product

```

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

```

Scilab code Exa 4.14 wavelength

```

1 // Example 4.14:Wavelength
2 clc;
3 clear;
4 close;
5 Rc=84;// Critical Radius in micro meters
6 n2=1.45;//Cladding refractive index
7 n1=1.46;//Core refractive index

```

```

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

```

Scilab code Exa 4.15 pulse broadning

```

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

```

Scilab code Exa 4.16.a material dispersion parameter

```

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

```

```

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

```

Scilab code Exa 4.16.b pulse broadning

```

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

```

Scilab code Exa 4.17 pulse broadning

```

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

```



```

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

```

Scilab code Exa 4.18 pulse broadning

```

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

```

Scilab code Exa 4.19 pulse broadning

```

1 // Example 4.19; //LIGHT PULSE SPREAD IN NS
2 clc;
3 clear;
4 close;
5 NA=0.275; //Numerical Aperture
6 n1=1.48; //Core refrctive index

```

```

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

```

Scilab code Exa 4.20.a delay

```

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

```

Scilab code Exa 4.20.b pulse broadning

```

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

```

Scilab code Exa 4.20.c bit rate

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

Scilab code Exa 4.20.d bandwidth length product

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

Scilab code Exa 4.21 pulse broadning

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

Scilab code Exa 4.22 pulse broadning

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

```

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

```

Scilab code Exa 4.23.a pulse broadning

```

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

```

Scilab code Exa 4.23.b bandwidth length product

```

1 // Example 4.23.b; //bandwidth length product
2 clc;
3 clear;
4 close;
5 M=250; //dispersion parametr picosecond per nano
    meter per kilometer

```

```

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

```

Scilab code Exa 4.24 beat length

```

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

```

Scilab code Exa 4.25 modal birefringence

```

1 // Example 4.25; // birefringence
2 clc;
3 clear;
4 close;

```

```

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

```

Scilab code Exa 4.26 modal birefringence coherence length and prop diif

```

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

```

Scilab code Exa 4.27 bit rate

```

1 // Example 4.27; //Maximum bit rate
2 clc;

```

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

Scilab code Exa 4.28 pulse broadning

```
1 // Example 4.28; //Pulse Spreadning
2 clc;
3 clear;
4 close;
5 L=100; // Length in Km
6 Tpm�=0.5*sqrt(L); // pulse broadning in pico second
7 disp(Tpm�,"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

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

Scilab code Exa 6.2 optical spacing

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

Scilab code Exa 6.3 emission wavelength

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

Scilab code Exa 6.4 optical gain

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

```

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

```

Scilab code Exa 6.5 FREQUENCY AND WAVELNEGTH SPACING

```

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

```

Scilab code Exa 6.6 CARRIER LIFETIME

```

1  // Example 6.3; // wavelength spacing and frequency
   spacing
2  clc;
3  clear;

```

```

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

```

Scilab code Exa 6.7 threshold density

```

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

```

Scilab code Exa 6.8 external power efficiency

```

1 // Example 6.8;//external power efficiency
2 clc;

```

```

3 clear;
4 close;
5 nt=0.18; //total efficiency of injection laser
6 Eg=1.43; //Energy gap in electron volt
7 V=2.5; //votls
8 next=round(nt*(Eg/V)*100); //EXTERNAL EFEICIENCY
9 disp(next, "external efficiency percentage is")

```

Scilab code Exa 6.9 ratio of threshold current densities

```

1 // Example 6.9; //ratio of threshold current at
  differnt temperatures
2 clc;
3 close;
4 clear;
5 To=160; //Absolute temperature in Kelovin
6 T1=293; //T=20 in kelvin
7 T2=353; //T=80 in kelvin
8 J1=exp(T2/To); //threshold current at T=80 degree
  celsius
9 J2=exp(T1/To); //threshold current at T=20 degree
  celsius
10 Jr=(J1/J2); //ratio of threshold current
11 disp(Jr, "ratio of threshold current is")

```

Scilab code Exa 6.10 wavelngth and line width

```

1 // Example 6.10; // wavelength
2 clc;
3 close;
4 clear;
5 Eg=1.43; //Energy gap in electron-volt
6 hC=1.24; //cONSTANT

```

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

Scilab code Exa 6.11 threshold coefficient gain

```
1 // Example 6.4; //threshold coefficient gain
2 clc;
3 clear;
4 close;
5 R1=0.35;
6 R2=0.35;
7 alpha=1.5; // in per meter
8 L=0.5; //in mm
9 t=0.8; //confinement factor
10 gth=alpha+(1/(2*L)*log(1/(R1*R2)));
11 Tc= gth/t; // threshold coefficient gain in per mm
12 disp(Tc,"threshold coefficient gain in per mm ")
```

Scilab code Exa 6.12 cavity length and number of logitudinal modes

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

Scilab code Exa 6.13 internal quantum efficiency

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

Scilab code Exa 6.14 number of longitudinal modes and frequency separation

```
1 // Example 6.14; // number of longitudinal modes and
    frequency spacing
2 clc;
3 clear;
4 close;
5 h=0.5*10^-6; // Wavelength in meter
6 n=1.5; // refractive index
7 L=7*10^-2; // LENGTH IN METER
8 C=3*10^8; // Speed of light in m/s
9 q=(2*n*L)/(h); // Number of longitudinal modes
10 df=((C)/(2*n*L))*10^-9; // frequency separation in Gega
    Hertz
11 disp(df,"frequency spacing in Gega Hertz is ")
12 disp(q,"Number of longitudinal modes are ")
```

Scilab code Exa 6.15 cavity length and number of longitudinal modes

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

Scilab code Exa 6.16 hole concentration

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

Scilab code Exa 6.17 gain factor

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

Scilab code Exa 6.18 internal quantum efficiency

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

Chapter 7

OPTICAL SOURCES THE LIGHT EMITTING DIODE

Scilab code Exa 7.1.a bulk recombination life time

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

Scilab code Exa 7.1.b internal quantum efficiency

```

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

```

Scilab code Exa 7.1.c power level

```

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

```

Scilab code Exa 7.2 power radiated

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

Scilab code Exa 7.3 non radiative recombination lifetime

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

Scilab code Exa 7.4 internal quantum efficiency

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

Scilab code Exa 7.5 optical power emitted

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

Scilab code Exa 7.6.a coupling efficiency

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

Scilab code Exa 7.6.b optical loss

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

Scilab code Exa 7.7 optical power

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

```

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

```

Scilab code Exa 7.8 power conversion efficiency

```

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

```

Scilab code Exa 7.9 optical power

```

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

```

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

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

Scilab code Exa 7.10.b power emitted

```
1 // Example 7.10.b; // power emitted
2 clc;
3 clear;
4 close;
5 n=3.5; // refractive index
6 e=1.6*10^-19; // Electronic charge
7 ht=6.62*10^-34; // Constt
```



```

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

```

Scilab code Exa 7.11 transmission factor

```

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

```

Scilab code Exa 7.12 optical power and external power efficiency

```

1 // Example 7.12; //OPTICAL POWER EMITTED & EXTERNAL
  POWER EFFICIENCY
2 clc;
3 clear;
4 close;
5 e=1.6*10-19; //Electronic charge
6 ht=6.62*10-34; //Constt
7 C=3*108; //sPPED OF LIGHT IN M/S
8 h=0.85*10-5; //wavelength in meter
9 V=1; //VOLTAGE
10 F=0.68; //transmission factor
11 nx=3.6; //refractive index
12 n=1; //refractive index of air
13 nint=0.6; //internal efficiency
14 i=20*10-3; //injected current in milli ampere
15 Pint= (nint*((ht*C*i*10-3)/(e*h)))*107; //internal
  power level in milli watt
16 Pe=round((Pint*F)/(4*nx2)*103); //optical power
  emitted
17 nep=(Pe*10-6/(V*i))*100; //EXTERNAL POWER EFFICIENCY
18 disp(Pe, "optical power emitted in micro watt")
19 disp(nep, "external power efficiency is")

```

Chapter 8

POWER LAUNCHING AND COUPLING

Scilab code Exa 8.1.a optical power coupled

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

Scilab code Exa 8.1.b core radius

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

```

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

```

Scilab code Exa 8.2 power distribution coefficients

```

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

```

Scilab code Exa 8.3 power coupled

```

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

```

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

Scilab code Exa 8.4 fresnel reflection coefficient

```
1 // Example 8.4;//fresnel reflection coefficient
2 clc;
3 clear;
4 close;
5 n1=1.45;//Core refrative index
6 n2=1;//refractive index of air
7 R=((n1-n2)/(n1+n2))^2;//Fresnel Coefficient
8 disp(R,"fresnel reflection coefficient is")
```

Scilab code Exa 8.5 compare optical powers

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

Chapter 9

OPTICAL DETECTORS

Scilab code Exa 9.1 quantum efficiency

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

Scilab code Exa 9.2 photocurrent

```
1 // Example 9.2;//photocurrent
2 clc;
3 clear;
4 close;
5 R=0.85;//responsivity in ampere per watt
```

```

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

```

Scilab code Exa 9.3 responsivity

```

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

```

Scilab code Exa 9.4 quantum efficiency and responsivity

```

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

```

```

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

```

Scilab code Exa 9.5.a operating wavelength

```

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

```

Scilab code Exa 9.5.b incident optical power

```

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

```



```

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

```

Scilab code Exa 9.6 WAVELENGTH

```

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

```

Scilab code Exa 9.7.a responsivity

```

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

```

Scilab code Exa 9.7.b received optical power

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

Scilab code Exa 9.7.c number of received photons

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

Scilab code Exa 9.8 multiplication factor

```

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

```

Scilab code Exa 9.9 responsivity and multiplication factor

```

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

```

Scilab code Exa 9.10.a noise equivalent power

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

Scilab code Exa 9.10.b specific detectivity

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

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

Scilab code Exa 9.11.a optical gain

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

Scilab code Exa 9.11.b common emitter current gain

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

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

Scilab code Exa 9.12 bandwidth

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

Scilab code Exa 9.13 photocurrent

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

Scilab code Exa 9.14 photocurrent

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

Scilab code Exa 9.15 multiplication factor

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

Scilab code Exa 9.16 bandwidth

```

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

```

Scilab code Exa 9.17 responsivity and optical power

```

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

```

Scilab code Exa 9.18 EFFICIENCY

```

1 // Example 9.18;// efficiency
2 clc;
3 clear;
4 close;

```



```

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

```

Scilab code Exa 9.19.a responsivity

```

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

```

Scilab code Exa 9.19.b optical power

```

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

```

```

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

```

Scilab code Exa 9.20 Thickness

```

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

```

Scilab code Exa 9.21 dark current

```

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

```

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

Chapter 10

OPTICAL RECEIVER

Scilab code Exa 10.1 quantum noise dark and thermal noise current

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

```

        in nano ampere
19 it=(sqrt((4*K*T*B*10^6)/R1))*10^9; //thermal noise
20 disp(Iq,"QUANTUM NOISE IN NANO AMPERE")
21 disp(id,"dark current in nano ampere")
22 disp(it,"THERMAL NOISE in nano ampere")

```

Scilab code Exa 10.2.a quantum limit

```

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

```

Scilab code Exa 10.2.b incident optical power

```

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

```

```

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

```

Scilab code Exa 10.3 incident optical power

```

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

```

Scilab code Exa 10.4.a shot noise

```

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

```

Scilab code Exa 10.4.b thermal noise

```

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

```

```

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

```

Scilab code Exa 10.5.a load resistance

```

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

```

Scilab code Exa 10.5.b bandwidth

```

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

```



```

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

```

Scilab code Exa 10.6 SNR

```

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

```

Scilab code Exa 10.7 SNR IMPROVEMENT

```

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

```

```

13 R1m=(1/(2*%pi*B*10^6*Cd*10^-12)); //Maximum lod
    resistance in ohm
14 //Case 1 when M=1
15 SNR1=(Ip^2)/((2*e*B*10^6*Ip)+((4*K*T*B*10^6)/(R1m)))
    ;
16 SNR1dB=10*(log10(SNR1)); //signal to noise ration
    when M=1 in dB
17 //CASE2 M=Mop & x=0.3
18 x=0.3;
19 Mop=((4*K*T)/(x*e*R1m*Ip))^(1/2.3)
20 SNR2=(Mop^2*Ip^2)/((2*e*B*10^6*Ip*Mop^2.3)+((4*K*T*B
    *10^6)/(R1m))); //signal to noise ratio M=Mop & x
    =0.3
21 SNR2dB=10*(log10(SNR2)); //signal to noise ratio M=
    Mop & x=0.3 in dB
22 disp(SNR1dB,"signal to noise ration when M=1 in dB")
23 disp(SNR2dB,"signal to noise ratio M=Mop & x=0.3 in
    dB")

```

Scilab code Exa 10.8.a photocurrent

```

1 // Example 10.8.a; //MINIMUM PHOTO CURRENT
2 clc;
3 clear;
4 close;
5 x=1;
6 SNR=3.16*10^3; //SIGNAL TO NOISE RATIO
7 Fn=1,26; //Noise figure
8 K=1.38*10^-23; //boltzman constt
9 C=3*10^8; //SPEED of light in meter per second
10 e=1.6*10^-19; //electronic charge
11 ht=6.62*10^-34; //plank constt.
12 B=10; //bandwidth in mega hertz
13 T=120; //TEMPERATURE IN KELVIN
14 R1=10 //Maximum lod resistance in killo ohm

```

```

15 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);//
16 disp(Ip,"Photo current in ampere")

```

Scilab code Exa 10.8.b avalanche multiplication factor

```

1 // Example 10.8.b;//optimum avalanche multiplication
    factor
2 clc;
3 clear;
4 close;
5 x=1;
6 SNR=3.16*10^3;//SIGNAL TO NOISE RATIO
7 Fn=1,26;//Noise figure
8 K=1.38*10^-23;//boltzman constt
9 C=3*10^8;//SPEED of light in meter per second
10 e=1.6*10^-19;//electronic charge
11 ht=6.62*10^-34;//plank constt.
12 B=10;//bandwidth in mega hertz
13 T=120;//TEMPERATURE IN KELVIN
14 Rl=10//Maximum lod resistance in killo ohm
15 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);//
16 Mop=(((4*K*T*Fn)/(1.1*e*Ip*10^3)))^(1/3);//optimum
    avalanche multiplication factor
17 disp(Mop,"optimum avalanche multiplication factor is
    ")

```

Scilab code Exa 10.9.a bandwidth

```

1 // Example 10.9.a;//maximum bandwidth
2 clc;
3 clear;

```

```

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

```

Scilab code Exa 10.9.b thermal noise current

```

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

```

Scilab code Exa 10.10 optical power

```

1  // Example 10.10; //threshold quantum limit
2  clc;
3  clear;
4  close;
5  e=1.6*10^-19;
6  R=0.5; //responsivity in amper per watt

```

```

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

```
