

Scilab Textbook Companion for
Optical Fiber Communication System
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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

Ray Theory Transmission in Optical Fiber

Scilab code Exa 2.1 Determine the critical angle and the numerical aperture and ac

```
1 //Ex:2_1
2 clc;
3 clear;
4 close;
5 n1=1.55; // core refractive index
6 n2=1.50; // cladding refractive index
7 x=asin(n2/n1); // Critical angle in radians
8 x1=x*180/(%pi); // Critical angle in degree
9 n_a=sqrt(n1^2-n2^2); // Numerical aperture
10 x_a=asin(n_a)*180/(%pi);
11 x_a1=ceil(x_a); // Acceptance angle in Degree
12 printf(" Critical angle in degree= %f degree",x1);
13 printf("\n Numerical aperture= %f ",n_a);
14 printf("\n Acceptance angle in degree= %f degree",
    x_a1);
```

Scilab code Exa 2.2 Calculate the numerical aperture

```
1 //Ex:2.2
2 clc;
3 clear;
4 close;
5 c=3*10^8; // speed of light in m/s
6 v=2*10^8; // in m/s
7 n1=c/v;
8 x=75; // in degree
9 n2=n1*sin((x*3.14/180));
10 n_2=1.44;
11 n_a=sqrt(n1^2-n_2^2); // numerical aperture
12 printf("Numerical aperture = %f",n_a);
```

Scilab code Exa 2.3 Find the numerical aperture and acceptance angle

```
1 //Ex:2.3
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 n2=1.47; // cladding refractive index
7 dl=(n1-n2)/n1;
8 n_a=n1*(sqrt(2*dl)); // numerical aperture
9 x_a=(asin(n_a))*180/%pi; // acceptance angle in
    degree
10 printf("Numerical aperture = %f",n_a);
11 printf("\n acceptance angle in degree = %f degree",
    x_a);
```

Scilab code Exa 2.4 Determine the numerical aperture and acceptance angle and crit


```

1 //Ex:2.4
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 n2=1.45; // cladding refractive index
7 d1=(n1-n2)/n1;
8 n_a=n1*(sqrt(2*d1)); // numerical aperture
9 x_a=(asin(n_a))*180/%pi; // acceptance angle in
    degree
10 x_c=(asin(n2/n1))*180/3.14; // critical angle in
    degree
11 printf("Numerical aperture = %f",n_a);
12 printf("\n acceptance angle in degree = %f degree",
    x_a);
13 printf("\n critical angle in degree = %f degree",x_c
    );

```

Scilab code Exa 2.5 Determine the refractive indices

```

1 //Ex:2.5
2 clc;
3 clear;
4 close;
5 d1=0.012;
6 n_a=0.22; // numerical aperture
7 n1=n_a/(sqrt(2*d1)); // core refractive ondex
8 n2=n1-(d1*n1); // cladding refractive index
9 printf("core refractive ondex = %f",n1);
10 printf("\n cladding refractive index = %f",n2);

```

Scilab code Exa 2.6 Calculate the refractive indices

```

1 //Ex:2.6
2 clc;
3 clear;
4 close;
5 dl=0.01;
6 n_a=0.35; // numerical aperture
7 n1=n_a/(sqrt(2*dl)); // core refractive index
8 n2=n1-(dl*n1); // cladding refractive index
9 printf("core refractive index = %f",n1);
10 printf("\n cladding refractive index = %f",n2);

```

Scilab code Exa 2.7 Determine the acceptance angle and critical angle and number o

```

1 //Ex:2.7
2 clc;
3 clear;
4 close;
5 n2=1.59; // cladding refractive index
6 n_a=0.2; // numerical aperture
7 n1=sqrt(n2^2+n_a^2); // core refractive index
8 n_1=1.60; // core refractive index
9 n_o=1.33;
10 A=(sqrt(n_1^2-n2^2))/n_o;
11 x_a=(asin(A))*180/%pi; // acceptance angle in degree
12 x_c=(asin(n2/n1))*180/%pi; // critical angle in
    degree
13 y=1300*10^(-9); // in meter
14 a=25*10^(-6); // in meter
15 v=(2*%pi*a*n_a)/y;
16 V=floor(v);
17 M=V^2/2; // number of modes transmitted
18 printf("acceptance angle in degree = %f degree",x_a)
    ;
19 printf("\n critical angle in degree = %f degree",x_c
    );

```

```
20 printf("\n number of modes transmitted = %d",M);
```

Scilab code Exa 2.8 Find the numerical aperture and max angle

```
1 //Ex:2.8
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 n2=1.47; // cladding refractive index
7 d1=(n1-n2)/n1;
8 n_a=n1*(sqrt(2*d1)); // numerical aperture
9 x_e=(asin(n_a))*180/%pi; // the maximum entrance
   angle in degree
10 printf("Numerical aperture = %f",n_a);
11 printf("\n the maximum entrance angle in degree = %f
   degree",x_e);
```

Scilab code Exa 2.9 Calculate the numerical aperture and acceptance angle

```
1 //Ex:2.9
2 clc;
3 clear;
4 close;
5 n1=1.44; // core refractive index
6 d1=0.02;
7 n_a=n1*sqrt(2*d1);
8 n_a=n1*(sqrt(2*d1)); // numerical aperture
9 x_a=(asin(n_a))*180/%pi; // acceptance angle in
   degree
10 printf("Numerical aperture = %f",n_a);
11 printf("\n acceptance angle in degree = %f degree",
   x_a);
```

Scilab code Exa 2.10 Find the refractive index and critical angle and the numerical

```
1 //Ex:2.10
2 clc;
3 clear;
4 close;
5 n1=1.50;// core refractive index
6 n2=(99/100)*1.50;// cladding refractive index
7 x_c=(asin(n2/n1))*180/%pi;// critical angle in
   degree
8 n_m=sqrt(n1^2-n2^2);// numerical aperture
9 printf("critical angle = %f degree",x_c);
10 printf("\n numerical aperture = %f",n_m);
```

Scilab code Exa 2.11 Find the numerical aperture and fractional difference

```
1 //Ex:2.11
2 clc;
3 clear;
4 close;
5 n1=1.50;// core refractive index
6 n2=1.45;// cladding refractive index
7 n_m=sqrt(n1^2-n2^2);// numerical aperture
8 dl=(n1-n2)/n1;// fractional difference
9 printf("numerical aperture = %f",n_m);
10 printf("\n fractional difference = %f",dl);
```

Scilab code Exa 2.12 Find the critical angle and acceptance angle and brewster ang

```

1 //Ex:2.12
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 n2=1.45; // cladding refractive index
7 x_c=(asin(n2/n1))*180/%pi; // critical angle in
    degree
8 n_m=sqrt(n1^2-n2^2); // numerical aperture
9 x_a=(asin(n_m))*180/%pi; // acceptance angle in
    degree
10 printf("critical angle = %f degree",x_c);
11 printf("\n acceptance angle = %f degree",x_a);
12 printf("\n numerical aperture = %f",n_m);

```

Scilab code Exa 2.13 Calculate the refractive indices

```

1 //Ex:2.13
2 clc;
3 clear;
4 close;
5 n_m=0.204; // numerical aperture
6 dl=0.01; // index difference
7 n1=n_m/(sqrt(2*dl)); // core refractive index
8 n2=n1*(1-dl); // cladding refractive index
9 printf("core refractive index = %f",n1);
10 printf("\n cladding refractive index = %f",n2);

```

Scilab code Exa 2.14 calculate the critical angle and numerical aperture

```

1 //Ex:2.14
2 clc;
3 clear;

```

```

4 close;
5 n1=1.46; // core refractive index
6 d1=0.01; // index difference
7 n_2=n1-(n1*d1); // cladding refractive index
8 x_c=(asin(n_2/n1))*180/%pi; // critical angle in
    degree
9 n_m=sqrt(n1^2-n_2^2); // numerical aperture
10 printf("critical angle = %f degree",x_c);
11 printf("\n numerical aperture = %f",n_m);

```

Scilab code Exa 2.15 Calculate the critical angle and acceptance angle and numeric

```

1 //Ex:2.15
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 n2=1.45; // cladding refractive index
7 x_c=(asin(n2/n1))*180/%pi; // critical angle in
    degree
8 n_m=sqrt(n1^2-n2^2); // numerical aperture
9 x_a=(asin(n_m))*180/%pi; // acceptance angle in
    degree
10 n_c=(n_m)^2*100; // percentage of light
11 printf("critical angle=%f degree",x_c);
12 printf("\n acceptance angle=%f degree",x_a);
13 printf("\n numerical aperture=%f",n_m);
14 printf("\n percentage of light=%f%%",n_c);

```

Scilab code Exa 2.16 Estimate the NA and the solid acceptance angle and critical a

```

1 //Ex:2.16
2 clc;

```

```
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 d1=0.01; // index difference
7 n_m=n1*(sqrt(2*d1)); // numerical aperture
8 x_a=%pi*(n_m)^2; // acceptance angle in radian
9 n2_1=1-d1; // the ratio of n2 to n1
10 x_c=(asin(n2_1))*180/%pi; // critical angle in degree
11 printf("numerical aperture=%f",n_m);
12 printf("\n acceptance angle=%f radian",x_a);
13 printf("\n critical angle=%f degree",x_c);
```

Chapter 3

Modes And Rays

Scilab code Exa 3.1 Find the core radius

```
1 //Ex:3.1
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 n2=1.48; // cladding refractive index
7 y=1.3*10^-6;
8 m=1000; // the no. of models
9 v=sqrt(2*m);
10 a=(v*y)/(2*%pi*(sqrt(n1^2-n2^2)))*10^6; // core
    radius in micrometer
11 printf("core radius=%f micrometer",a);
```

Scilab code Exa 3.2 Find the dimension of the core

```
1 //Ex:3.2
2 clc;
3 clear;
```



```

4 close;
5 n1=1.505; // core refractive index
6 n2=1.502; // cladding refractive index
7 n_m=sqrt(n1^2-n2^2); // numerical aperture
8 y=1.3*10^-6;
9 v=2.4;
10 a=(v*y)/(2*pi*(sqrt(n1^2-n2^2)))*10^6; // core
    radius in micrometer
11 printf("numerical aperture=%f",n_m);
12 printf("\n core radius=%f micrometer",a);

```

Scilab code Exa 3.3 Find the propagation constant

```

1 //Ex:3.3
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 dl=0.01; //index difference
7 m=0; // for the dominant mode
8 v=0; // for the dominant mode
9 y=1.3; // in micrometer
10 a=5; // radius in micrometer
11 k=(2*pi)/y;
12 b=k^2*n1^2-(2*k*n1*sqrt(2*dl))/a;
13 B=sqrt(b); // propagation constant in rad/um
14 printf("propagation constant=%f rad/um",B);

```

Scilab code Exa 3.4 Prove that propagation constant of an optical fiber is the pro

```

1 //Ex:3.4
2 clc;
3 clear;

```

```

4 close;
5 b=1/2; // propagation constant
6 printf("normalised propagation constant");
7 printf("\n B=((b/k)^2-n2^2)/(n1^2-n2^2)");
8 printf("\n thus when b=1/2");
9 printf("\n B=k*sqrt(n2^2+b*(n1^2-n2^2))");
10 printf("\n B=k*sqrt((n1^2-n2^2)/2)");
11 printf("\n which gives its rms value");

```

Scilab code Exa 3.5 Find the number of TE modes

```

1 //Ex:3.5
2 clc;
3 clear;
4 close;
5 n1=3.6; // core refractive index
6 n2=3.3; // cladding refractive index
7 d=2.0; // thickness in um
8 y=0.8; // wavelength in um
9 m=(2*d*sqrt(n1^2-n2^2))/y; // total no. of models
   allowed
10 M=ceil(m); // total no. of models allowed
11 printf("total no. of models allowed=%d",M);

```

Scilab code Exa 3.6 Find the normalised frequency and number of guided modess

```

1 //Ex:3.6
2 clc;
3 clear;
4 close;
5 n1=1.48; // core refractive index
6 a=40*(10^-6); // core radius in meter
7 dl=0.015; // index difference

```

```

8 y=0.85*(10^-6); // wavelength in um
9 v=(2*pi*a*n1*sqrt(2*d1))/y; // normalised frequency
10 M=v^2/2;
11 m=ceil(M); // the total no. of guided modes
12 printf("normalised frequency=%f",v);
13 printf("\n the total no. of guided modess =%d",m);

```

Scilab code Exa 3.7 Calculate the refractive index and normalised V number and tot

```

1 //Ex:3.7
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 dl=0.015; // index difference
7 a=30*(10^-6); // core radius in meter
8 y=0.85*(10^-6); // wavelength in um
9 n2=n1-(n1*dl); // cladding refractive index
10 v=(2*pi*a*n1*sqrt(2*d1))/y; // normalised frequency
11 M=v^2/2; // the total no. of guided modes
12 printf("cladding refractive index=%f",n2);
13 printf("\n normalised frequency=%f",v);
14 printf("\n the total no. of guided modess =%d",M);

```

Scilab code Exa 3.8 Calculate the diameter of the fiber

```

1 //Ex:3.8
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 dl=0.01; // index difference
7 M=1100; // the total no. of guided modes

```

```

8 y=1.3*(10^-6); // wavelength in um
9 v=sqrt(2*M); // normalised frequency
10 a=(v*y)/(2*%pi*n1*sqrt(2*d1))*10^6; // core radius in
    meter
11 printf("normalised frequency=%f",v);
12 printf("\n the diameter of the fiber core =%f um",2*
    a);

```

Scilab code Exa 3.9 Determine the normalised frequency for fiber

```

1 //Ex:3.9
2 clc;
3 clear;
4 close;
5 n1=1.45; // core refractive index
6 n_m=0.16; // numerical aperture
7 a=30*10^-6; // core radius in micrometer
8 y=0.5*(10^-6); // wavelength in um
9 v=(2*%pi*a*n_m)/y; // normalised frequency
10 printf("normalised frequency=%f",v);

```

Scilab code Exa 3.10 What should be the max thickness of the guided slab

```

1 //Ex:3.10
2 clc;
3 clear;
4 close;
5 n1=3.6; // core refractive index
6 n2=3.56; // cladding refractive index
7 y=0.85*(10^-6); // wavelength in um
8 m=1;
9 n=0;
10 v_c=2.405; // for planner guide

```

```

11 a=(v_c*y)/(2*%pi*sqrt(n1^2-n2^2)); // core radius in
    micrometer
12 printf("the max thickness=%f um",a*10^6);

```

Scilab code Exa 3.11 Estimate the diameter of the fiber core

```

1 //Ex:3.11
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 y=1.3*(10^-6); // wavelength in um
7 M=1100; // total no. of models
8 dl=0.01; // index difference
9 v=sqrt(2*M);
10 V=ceil(v);
11 a=(V*y)/(2*%pi*n1*sqrt(2*dl))*10^6; // core radius in
    micrometer
12 a1=ceil(a); // core radius in micrometer
13 printf("the core diameter=%d um",2*a1);

```

Scilab code Exa 3.12 Determine the max possible core diameter

```

1 //Ex:3.12
2 clc;
3 clear;
4 close;
5 n1=1.45; // core refractive index
6 dl=0.015; // index difference
7 y=0.85*(10^-6); // wavelength in meter
8 v=2.4*(1+(2/2))^(0.5); // Max normalised frequency
9 a=(v*y)/(2*%pi*n1*(2*dl)^(0.5)); // Max core radius
    in m

```

```

10 d=2*a; // The max core diameter in meter
11 printf("The max core diameter in meter=%f um", d
    *10^6);

```

Scilab code Exa 3.13 Determine the normalised frequency

```

1 //Ex:3.13
2 clc;
3 clear;
4 close;
5 n1=1.48; // core refractive index
6 n2=1.46; // cladding refractive index
7 a=2.5; // radius in um
8 y=0.85; // wavelength in um
9 dl=(n1-n2)/n1; // index difference
10 v=(2*pi*a*n1*(2*dl)^(0.5))/y; // the normaised
    frequency
11 M=(v*v)/2; // number of modes
12 printf("The number of modes=%f", M);

```

Scilab code Exa 3.14 Find the numerical aperture and solid acceptance angle and nu

```

1 //Ex:3.14
2 clc;
3 clear;
4 close;
5 a=25; // radius in um
6 y=1.3; // wavelength in um
7 v=26.6; // the normaised frequency
8 NA=(v*y)/(2*pi*a); // Numerical aperture
9 a_c=%pi*(NA)^2;
10 M=(v*v)/2;
11 printf("The number of modes=%f", NA);

```

```

12 printf("\n The number of modes=%f", a_c);
13 printf("\n answer in textbook is wrong");
14 printf("\n The number of modes=%f", M);

```

Scilab code Exa 3.15 Find the cut off wavelength and min core diameter

```

1 //Ex:3.15
2 clc;
3 clear;
4 close;
5 n1=1.49; // core refractive index
6 n2=1.47; // cladding refractive index
7 a=2; // radius in um
8 dl=(n1-n2)/n1; // index difference
9 v_c=2.405;
10 y_c=(2*3.14*a*n1*(2*dl)^(0.5))/v_c; // cut off
    wavelength in um
11 Y=1.31; // wavelength in um
12 A=(v_c*Y)/(2*3.14*n1*(2*dl)^(0.5)); // min core
    radius in um
13 printf("The cut off wavelength =%f um", y_c);
14 printf("\n The min core radius =%f um", A);

```

Scilab code Exa 3.16 Estimate the total number of guided modes

```

1 //Ex:3.16
2 clc;
3 clear;
4 close;
5 a=25; // radius in um
6 NA=0.3; // Numerical aperture
7 y=1; // wavelength in um
8 v=(2*%pi*a*NA)/y; // the normalised frequency

```

```

9 V=47.1; // the normalised frequency
10 M=(V*V)/4; // The mode volume
11 printf("The normalised frequency =%f", v);
12 printf("\n The mode volume =%d guided modes", M);

```

Scilab code Exa 3.17 Determine the cut off wavelength

```

1 //Ex:3.17
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 a=4.5; // radius in um
7 dl=0.0025; // relative index difference
8 v_c=2.405;
9 y_c=(2*3.14*a*n1*(2*dl)^(0.5))/v_c; // cut off
    wavelength in um
10 printf("The cut off wavelength =%f um", y_c);

```

Scilab code Exa 3.18 Calculate the cut off number and number of modes

```

1 //Ex:3.18
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 n2=1.45; // cladding refractive index
7 a=50; // radius in um
8 y=1.3; // operating wavelength in um
9 NA=sqrt(n1^2-n2^2); // numerical aperture
10 N_A=0.38;
11 v=(2*pi*a*N_A)/y; // cut of numbers
12 M=v^2/2; // number of modes

```



```
13 printf("The cut of numbers =%f", v);
14 printf("\n The number of modes =%f", M);
```

Scilab code Exa 3.19 What will be the max allowable radius

```
1 //Ex:3.19
2 clc;
3 clear;
4 close;
5 n1=1.53; // core refractive index
6 n2=1.5; // cladding refractive index
7 y=1.5; // operating wavelength in um
8 NA=sqrt(n1^2-n2^2); // numerical aperture
9 a=(2.405*y)/(2*3.14*NA); // max radius in um
10 printf("The max core radius =%f um", a);
```

Scilab code Exa 3.20 Find V number and how many modes it will support

```
1 //Ex:3.20
2 clc;
3 clear;
4 close;
5 a=25; // max radius in um
6 y=0.8; // operating wavelength in um
7 NA=0.343; // numerical aperture
8 v=(2*pi*a*NA)/y; // v-number
9 M=v^2/2; // number of modes
10 printf("The v-number =%f", v);
11 printf("\n The number of modes =%f", M);
```

Scilab code Exa 3.21 Determine the core size and cladding index

```
1 //Ex:3.21
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 NA=0.38; // numerical aperture
7 v=75; // v-number
8 y=1.3; // operating wavelength in um
9 a=(v*y)/(2*pi*NA); // core radius in um
10 n2=sqrt(n1^2-NA^2); // cladding refractive index
11 printf("The core radius =%f um", a);
12 printf("\n The cladding refractive index =%f", n2);
13 printf("\n answer in textbook is wrong");
```

Scilab code Exa 3.22 Calculate the corresponding divergence angle

```
1 //Ex:3.22
2 clc;
3 clear;
4 close;
5 y=1.2; // operating wavelength in um
6 w=5; // spot size in um
7 x=(2*y)/(pi*w); // the divergence angle in degree
8 printf("The divergence angle =%f degree", x);
```

Scilab code Exa 3.23 Find the cut off wavelength for a step index fiber

```
1 //Ex:3.23
2 clc;
3 clear;
4 close;
```

```

5 n1=1.46; // core refractive index
6 a=4.5; // core radius in um
7 dl=0.0025; // relative index difference
8 NA=n1*(sqrt(2*dl)); // numerical aperture
9 v=2.405;
10 y=(2*pi*a*NA)/(v); // cut off wavelength in um
11 printf("The cut off wavelength =%f um", y);

```

Scilab code Exa 3.24 Calculate the number of modes

```

1 //Ex:3.24
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 n2=1.47; // cladding refractive index
7 y1=0.87; // operating wavelength in um
8 y2=1.5; // operating wavelength in um
9 a=25; // max radius in um
10 NA=sqrt(n1^2-n2^2); // numerical aperture
11 v1=(2*pi*a*NA)/y1;
12 v2=(2*pi*a*NA)/y2;
13 a1=2; // parabolic index profile for GRIN
14 M1=(a1/(a1+2))*(v1^2/2); // number of modes
15 M2=(a1/(a1+2))*(v2^2/2); // number of modes
16 printf("The number of modes at 870 nm =%f um", M1);
17 printf("\n The number of modes =%f um", M2);

```

Scilab code Exa 3.25 Find the core radius and NA and spot size and also find the d

```

1 //Ex:3.25
2 clc;
3 clear;

```

```

4 close;
5 n1=1.5; // core refractive index
6 n2=1.46; // cladding refractive index
7 v=2.4; // cut off parameter
8 y=0.85; // operating wavelength in um
9 NA=sqrt(n1^2-n2^2); // numerical aperture
10 a=(v*y)/(2*3.14*NA); // max radius in um
11 w=v*a; // spot size
12 x=(2*y)/(3.4*w); // divergence angle in degree
13 d=50; // distance in meter
14 w_s=(y*d)/(%pi*w); // spot size at 50 meter
15 printf("The numerical aperture =%f um", NA);
16 printf("\n The max core radius =%f um", a);
17 printf("\n The spot size =%f um", w);
18 printf("\n The divergence angle =%f degree", x);
19 printf("\n The spot size at 50 meter =%f m", w_s);

```

Scilab code Exa 3.26 Find the max allowable diameter

```

1 //Ex:3.26
2 clc;
3 clear;
4 close;
5 n1=1.53; // core refractive index
6 n2=1.50; // cladding refractive index
7 y=1.2; // wavelength in um
8 v=2.405;
9 a=(v*y)/(2*3.14*(sqrt(n1^2-n2^2))); // core radius in
micrometer
10 printf("The max diameter=%f um", 2*a);

```

Scilab code Exa 3.27 Find the fractional refractive index change and the largest c

```

1 //Ex:3.27
2 clc;
3 clear;
4 close;
5 n1=1.47; // core refractive index
6 n2=1.46; // cladding refractive index
7 y=1.3; // wavelength in um
8 dl=(n1-n2)/n1; // fractional refractive index diff
9 NA=sqrt(n1^2-n2^2);
10 v=2.405;
11 a=(v*y)/(2*3.14*(sqrt(n1^2-n2^2))); // largest core
    radius in micrometer
12 n_eff=n1-(NA/(2*3.14*(a/y))); // fractional
    refractive index
13 printf("The largest core radius =%f um", a);
14 printf("\n The fractional refractive index=%f",n_eff
    );

```

Scilab code Exa 3.28 Calculate the cut off parameter and the of modes

```

1 //Ex:3.28
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 n2=1.48; // cladding refractive index
7 NA=sqrt(n1^2-n2^2); // numerical aperture
8 a=25; // core radius in um
9 y=0.85; // wavelength in um
10 v=(2*3.14*a*NA)/y; // cut off parameter
11 M=v^2/2; // number of modes
12 printf("The cut off parameter =%f", v);
13 printf("\n The number of modes =%d",M);

```

Scilab code Exa 3.29 Calculate the max value of D and also find the acceptance angle

```
1 //Ex:3.29
2 clc;
3 clear;
4 close;
5 n1=1.50; // core refractive index
6 a=25; // core radius in um
7 y=1.5; // wavelength in um
8 v=2.405;
9 NA=(v*y)/(2*3.14*a); // numerical aperture
10 D=(NA/n1)^2/(2); // max value of D
11 n2=n1-(D*n1); // cladding refractive index
12 printf("The max value of D =%f",D);
13 printf("\n The cladding refractive index =%f",n2);
```

Scilab code Exa 3.30 Calculate the relative refractive index difference and acceptance angle

```
1 //Ex:3.30
2 clc;
3 clear;
4 close;
5 n1=1.52; // core refractive index
6 n2=1.48; // cladding refractive index
7 a=45; // core radius in um
8 y=0.85; // wavelength in um
9 dl=(n1-n2)/n1; // relative refractive index
10 x=(asin(n2/n1))*(180/3.14); // critical angle in
    degree
11 NA=sqrt(n1^2-n2^2); // numerical aperture
12 a_c=(asin(NA))*(180/3.14); // acceptance angle in
    degree
```

```

13 a_s=3.14*(n1^2-n2^2); // solid acceptance angle
14 v=(2*3.14*a*0.34)/y; // normalise v-number
15 M=v^2/2; // number of guided modes
16 a1=5; // for single mode step fiber
17 v1=(2*3.14*a1*0.34)/y;
18 M1=v1^2/2;
19 R=M-M1; // reduction in modes
20 printf("The max value of D =%f",d1);
21 printf("\n The critical angle =%f degree",x);
22 printf("\n The acceptance angle =%f degree",2*a_c);
23 printf("\n The solid acceptance angle =%f degree",
    a_s);
24 printf("\n The numerical aperture =%f",NA);
25 printf("\n The normalise v-number =%f",v);
26 printf("\n The number of guided modes =%d",M);
27 printf("\n The reduction in modes =%d",R);

```

Scilab code Exa 3.31 Find the normalised frequency and number of guided modes

```

1 //Ex:3.31
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 a=45/2; // max radius in um
7 y=0.85; // operating wavelength in um
8 NA=0.17; // numerical aperture
9 v=(2*3.14*a*NA)/y; //normalised frequency
10 M=v^2/2; // number of modes
11 printf("The normalised frequency =%f", v);
12 printf("\n The number of modes =%d", M);

```

Chapter 4

Attenuation And Absorption in Optical Fibers

Scilab code Exa 4.1 Find the overall signal attenuation and signal attenuation per

```
1 //Ex:4.1
2 clc;
3 clear;
4 close;
5 Pi=100*10^-6; // mean optical power in watt
6 Po=2*10^-6; // output mean power in watt
7 L=6; // length in km
8 L1=8; // length in km
9 as=10*log(Pi/Po)/log(10); // signal attenuation in dB
10 as1=as/L; // signal attenuation per km
11 Li=as1*L1; // Loss incurred along 8 km
12 Ls=7; // Loss due to splice in dB
13 as2=Li+Ls; // overall signal attenuation in dB
14 As2=29.4; // aprox. overall signal attenuation in dB
15 Pio=10^(As2/10); // i/p o/p power ratio
16 printf("The signal attenuation =%f dB", as);
17 printf("\n The signal attenuation per km =%f dB/km",
    as1);
18 printf("\n The trgth =%f km", Li);
```



```

19 printf("\n The overall signal attenuation =%f dB",
    as2);
20 printf("\n The i/p o/p power ratio =%f ", Pio);

```

Scilab code Exa 4.2 Determine the max possible link length

```

1 //Ex:4.2
2 clc;
3 clear;
4 close;
5 Pi=1.5*10^-3;// mean optical power in watt
6 Po=2*10^-6;// output mean power in watt
7 a=0.5;// dB/km
8 L=(10*log(Pi/Po)/log(10))/a;// max possible link
    Length in km
9 printf("The max possible link Length =%f km", L);

```

Scilab code Exa 4.3 Determine the theoretical attenuation due to fundamental rayle

```

1 //Ex:4.3
2 clc;
3 clear;
4 close;
5 n=1.46;// core refractive index
6 p=0.286;// photoelastic coeff
7 b=7*10^-11;// isothermal compressibility
8 k=1.381*10^-23;// boltzmann's constant
9 tf=1400;// fictive temperature in k
10 y1=0.85*10^-6;// wavelength in m
11 yr=((8*pi^3)*(n^8)*(p^2)*(b*k*tf))/(3*y1^4);
12 e=2.718281828;
13 akm=e^(-yr*10^3);
14 at=10*log(1/akm)/log(10);// attenuation at y=0.85 um

```

```

15 y2=1.55*10^-6; // wavelength in m
16 yr1=((8*pi^3)*(n^8)*(p^2)*(b*k*tf))/(3*y2^4);
17 akm1=e^(-yr1*10^3);
18 at1=10*log(1/akm1)/log(10); // attenuation at y=1.55
    um
19 y3=1.30*10^-6; // wavelength in m
20 yr2=((8*pi^3)*(n^8)*(p^2)*(b*k*tf))/(3*y3^4);
21 akm2=e^(-yr2*10^3);
22 at2=10*log(1/akm2)/log(10); // attenuation at y=1.30
    um
23 printf("The Loss of an optical fiber =%f dB/km", at)
    ;
24 printf("\n The Loss of an optical fiber =%f dB/km",
    at1);
25 printf("\n The Loss of an optical fiber =%f dB/km",
    at2);

```

Scilab code Exa 4.4 calculate the threshold optical power for SBS and SRS

```

1 //Ex:4.4
2 clc;
3 clear;
4 close;
5 d=6; // core diameter in m
6 y=1.55; // wavelength in m
7 a=0.5; // attenuation in dB/km
8 v=0.4;
9 Pb=4.4*10^-3*d^2*y^2*a*v; // threshold power for SBS
10 Pr=5.9*10^-2*d^2*y*a; // threshold power for SRS
11 printf("The threshold power for SBS =%d mw", Pb
    *10^3);
12 printf("\n The threshold power for SRS =%f W", Pr);

```

Scilab code Exa 4.5 Estimate the critical Radius of curvatur at which large Bendin

```
1 //Ex:4.5
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 dl=0.03; // relative refractive index difference
7 y=0.85*10^-6; // operating wavelength in m
8 a=4*10^-6; // core radous in m
9 n2=sqrt(n1^2-2*dl*n1^2); // cladding refractive index
10 Rc=(3*n1^2*y)/(4*pi*(n1^2-n2^2)^1.5); // critical
    radius of curvatur for multimode fiber
11 D1=0.003; // relative refractive index difference
12 N2=sqrt(n1^2-2*D1*n1^2); //
13 yc=(2*pi*a*n1*(2*D1)^0.5)/2.405; // cut off
    wavelength in m
14 y1=1.55*10^-6; // operating wavelength in m
15 Rcs=(20*y1*(2.748-0.996*(y1/yc))^-3)/(0.005)^1.5; //
    critical radius of curvatur for a single mode
    fiber
16 printf("The critical radius of curvatur for
    multimode fiber =%f um", Rc*10^6);;
17 printf("\n The critical radius of curvatur for a
    single mode fiber =%f um", Rcs*10^3);
```

Scilab code Exa 4.6 Compute The material loss of a graded index fiber

```
1 //Ex:4.6
2 clc;
3 clear;
4 close;
5 x=2; // index profile
6 dl=0.0126; // index difference
7 a=(85/2)*10^-6; // core radius
```

```

8 R=2*10^-3; // curve of radius
9 n1=1.45; // core refractive index
10 k=6.28;
11 y=850*10^-9; // wavelength in m
12 A=(x+2)/(2*x*d1);
13 B=(2*a/R);
14 C=(3*y/(2*k*R*n1))^(2/3);
15 D=B+C;
16 E=A*D;
17 F=1-E;
18 Lm=-10*log(1-A*(B+C))/log(10); // macrobend loss in
    dB
19 printf("The macrobend loss =%f dB", Lm);
20 printf("\n The answer is wrong in the textbook");

```

Scilab code Exa 4.7 Calculate the Loss Of An Optical fiber

```

1 //Ex:4.7
2 clc;
3 clear;
4 close;
5 Pi=15; // optical power in uw
6 Po=7; // ouput power in uw
7 L=0.15; // length in km
8 Ls=(10*log(Pi/Po)/log(10))/L; // Loss of an optical
    fiber in dB
9 printf("The Loss of an optical fiber =%d dB", Ls);

```

Scilab code Exa 4.8 Calculate the signal attenuation per km and overall signal att

```

1 //Ex:4.8
2 clc;
3 clear;

```

```

4 close;
5 Pi=200*10^-6; // average optical power in watt
6 Po=5*10^-6; // average output power in watt
7 L=20; // in km
8 L1=12; // in km
9 ns=5; // number of attenuation
10 a=0.9; // attenuation in dB
11 sa=10*log(Pi/Po)/log(10); // signal attenuation
12 sp=sa/L; // signal attenuation per km
13 sn=sp*L1; // signal attenuation for 12 km
14 sn1=ns*a; // attenuation in dB
15 sn2=sn+sn1; // overall signal attenuation in dB
16 printf("The signal attenuation per km =%f dB/km", sp
);
17 printf("\n The overall signal attenuation=%f dB ",
sn2);

```

Scilab code Exa 4.9 Find the overall signal attenuation and the signal attenuation

```

1 //Ex:4.9
2 clc;
3 clear;
4 close;
5 Pi=100*10^-6; // average optical power in watt
6 Po=4*10^-6; // average output power in watt
7 L=6; // in km
8 L1=10; // in km
9 sa=10*log(Pi/Po)/log(10); // signal attenuation
10 sp=sa/L; // signal attenuation per km
11 sn=sp*L1; // signal attenuation for 12 km
12 sn1=sn+9; // overall signal attenuation in dB
13 printf("The signal attenuation=%f dB", sa);
14 printf("\n The signal attenuation per km =%f dB/km",
sp);
15 printf("\n The overall signal attenuation=%f dB ",

```

```
sn1);
```

Scilab code Exa 4.10 Find the overall loss and the overall loss in dB per km and a

```
1 //Ex:4.10
2 clc;
3 clear;
4 close;
5 Pi=20*10^-6; // average optical power in watt
6 Po=7.5*10^-6; // average output power in watt
7 sl=10*log(Pi/Po)/log(10); // signal Loss in dB
8 L=15; // in km
9 L1=30; // in km
10 ns=29; // number of attenuation
11 sp=sl/L; // signal Loss per km
12 sn=sp*L1; // signal attenuation for 30 km
13 sn1=sn+ns; // overall signal attenuation in dB
14 i_o=10^(sn1/20); // input output power ratio
15 printf("The signal Loss =%f dB", sl);
16 printf("\n The signal Loss per km=%f dB/km", sp);
17 printf("\n The overall signal attenuation=%f dB",
    sn1);
18 printf("\n The input output power ratio=%f", i_o);
```

Scilab code Exa 4.11 Dtermine the attenuation in db per km due to rayleigh scatter

```
1 //Ex:4.11
2 clc;
3 clear;
4 close;
5 Tf=1400; // temperature in k
6 Bc=7*10^-11; // in m^2/N
7 n=1.38; //
```

```

8 P=0.29; // Photoelastic coefficient
9 y=0.9*10^-6; // wavelength in m
10 K=1.38*10^-23; // boltzman's constant
11 Rrs=((8*%pi^3)*(n^8)*(P^2)*(Bc*Tf*K))/(3*y^4);
12 Rrs1=Rrs/10^-3; // per km
13 e=2.718281828; // Exponential term
14 Lkm=e^(-Rrs1); // transmission loss facter
15 At=10*log(1/Lkm)/log(10); // Attenuation in dB/km
16 printf("The Attenuation=%f dB/km", At);

```

Scilab code Exa 4.12 Calculat the threshold optical powers of SBS and SRS

```

1 //Ex:4.12
2 clc;
3 clear;
4 close;
5 y=1.35; // wavelength in um
6 d=5; // core diamater in um
7 a=0.75; // attenuation in dB/km
8 v=0.45; // bandwidth in GHz
9 Pb=4.4*10^-3*(d^2)*(y^2)*(a*v); // threshold optical
   power for sbs
10 Pr=5.9*10^-2*(d^2)*(y)*(a); // threshold optical
   power for sbr
11 Pbr=Pb/Pr; // the ratio of threshold power level
12 printf("The ratio of threshold power level=%f %%",
   Pbr*100);

```

Scilab code Exa 4.13 Calculate the critical radius of curvature at which large ben

```

1 //Ex:4.13
2 clc;
3 clear;

```

```

4 close;
5 n1=1.5; // core refractive index
6 y=0.85*10^-6; // wavelength in m
7 d1=0.024; // relative refractive index difference
8 N2=sqrt(n1^2-2*d1*n1^2); // cladding refractive index
9 n2=1.46;
10 Rcs=(3*n1^2*y)/((4*pi)*(n1^2-n2^2)^1.5); // critical
    radius of curvature for multimode fiber
11 printf("The critical radius of curvature =%f um",
    Rcs*10^6);

```

Scilab code Exa 4.14 Find the critical radius of both single mode and multimode fi

```

1 //Ex:4.14
2 clc;
3 clear;
4 close;
5 n1=1.45; // core refractive index
6 y=1.5*10^-6; // wavelength in m
7 d1=0.03; // relative refractive index difference
8 a=5*10^-6; // core radius
9 n2=sqrt(n1^2-2*d1*n1^2); // cladding refractive index
10 yc=(2*pi*a*n1*sqrt(2*d1))/(2.405);
11 Rcs=(20*y*(2.748-0.996*(y/yc))^-3)/(n1^2-n2^2)^1.5;
    // critical radius of curvature for single mode
    fiber
12 Rcs1=(3*n1^2*y)/((4*pi)*(n1^2-n2^2)^1.5); //
    critical radius of curvature for multimode fiber
13 printf("The critical radius of curvature for single
    mode fiber =%f um", Rcs*10^6);
14 printf("\n The answer is wrong in the textbook");
15 printf("\n The critical radius of curvature for
    multimode fiber =%f um", Rcs1*10^6);

```

Scilab code Exa 4.15 Find the loss in db per km of the fiber

```
1 //Ex:4.15
2 clc;
3 clear;
4 close;
5 L=500/1000; // distance in km
6 Pio=(1/(1-0.75));
7 Ls=10*log(Pio)/log(10)/L; // Loss in dB/km
8 printf("The Loss =%f dB/km", Ls);
```

Scilab code Exa 4.16 Calculate the power level in mW after travelling a distance o

```
1 //Ex:4.16
2 clc;
3 clear;
4 close;
5 L=5; // length in km
6 a=0.5; // attenuaion loss in dB/km
7 Po=10^-3*10^(-(a*L)/10); // power level in mW
8 printf("The power level =%f mW", Po*10^3);
```

Scilab code Exa 4.17 Calculate the fiber loss in dB

```
1 //Ex:4.17
2 clc;
3 clear;
4 close;
5 L=1; // distance in km
```

```

6  Pio=(1/(1-0.40));
7  Ls=10*log(Pio)/log(10)/L; // Loss in dB/km
8  printf("The Loss =%f dB/km", Ls);

```

Scilab code Exa 4.18 What will be the transmission length caused by the fiber

```

1  //Ex:4.18
2  clc;
3  clear;
4  close;
5  Pi=1*10^-3; // input power in watt
6  Po=0.75*10^-3; // output power in watt
7  a=0.5; // in dB/km
8  L=(10*log(Pi/Po)/log(10))/a; // transmission length
   in km
9  printf("The transmission length =%f km", L);

```

Scilab code Exa 4.19 Find the macrobend loss of a single mode fiber and also calcu

```

1  //Ex:4.19
2  clc;
3  clear;
4  close;
5  y=1300*10^-9; // wavelength in m
6  yc=1200*10^-9; // cut off wavelength in m
7  rc=5*10^-6; // core diameter in m
8  n=1.5; // refractive index
9  R=1.2/100; // curve of radius in m
10 dmf=2*rc*((0.65)+0.434*(y/yc)^1.5+0.0149*(y/yc)^6);
   // mode field diameter
11 K=(2*%pi)/y;
12 Lm=-10*log(1-(K^4)*(n^4)*((3.95*10^-6)/(8*R^2))^6)/
   log(10); // macrobend loss

```

```
13 printf("The mode field diameter =%f um", dmf*10^6);
14 printf("\n The macrobend loss =%f dB", Lm);
15 printf("\n The answer is wrong in the textbook");
```

Scilab code Exa 4.20 Find the loss in dB per km for a fiber

```
1 //Ex:4.20
2 clc;
3 clear;
4 close;
5 Pi=10*10^-3; // input power in watt
6 Po=8*10^-3; // output power in watt
7 L=0.150; // length in km
8 Ls=(10*log(Po/Pi)/log(10))/L;
9 printf("The transmission length =%f km", Ls);
```

Chapter 5

Dispersion in Optical Fibers

Scilab code Exa 5.1 Find out the max bandwidth and pulse dispersion per unit length

```
1 //Ex:5.1
2 clc;
3 clear;
4 close;
5 t=0.1*10^-6; // pulse broadening in sec
6 d=12; // distance in km
7 B=1/(2*t); // max bandwidth MHz
8 ds=t/d; // dispersion in ns/km
9 bl=B*d; // bandwidth length product
10 printf("The max bandwidth =%d MHz", B/10^6);
11 printf("\n The dispersion =%f ns/km", ds*10^9);
12 printf("\n bandwidth length product =%d MHz km", bl
    /10^6);
```

Scilab code Exa 5.2 Find out the max bandwidth and pulse dispersion per unit length

```
1 //Ex:5.2
2 clc;
```

```

3 clear;
4 close;
5 t=0.1*10^-6; // pulse broadening in sec
6 d=15; // disance in km
7 B=1/(2*t); // max bandwidth MHz
8 ds=t/d; // dispersion in ns/km
9 bl=B*d; // bandwidth length product
10 printf("The max bandwidth =%d MHz", B/10^6);
11 printf("\n The dispersion =%f ns/km", ds*10^9);
12 printf("\n bandwidth length product =%d MHz km", bl
    /10^6);

```

Scilab code Exa 5.3 Calculate the Na and multipass pulse brodening and bandwidth l

```

1 //Ex:5.3
2 clc;
3 clear;
4 close;
5 n1=1.465; // core refractive index
6 n2=1.45; // cladding refractive index
7 c=3*10^8; // the speed of light in m/s
8 NA=sqrt(n1^2-n2^2); // numerical aperture
9 Mp=(NA^2)/(2*n1*c); // multipath pulse broadening in
    ns/km
10 bl=(1/NA^2)*(2*n1*c); // bandwidth length product in
    GHz km
11 printf("The numerical aperture =%f", NA);
12 printf("\n The multipath pulse broadening =%f ns/km"
    , Mp*10^9);
13 printf("\n The bandwidth length product =%d GHz km",
    bl/10^9);

```

Scilab code Exa 5.4 find the material dispersion and estimate also the rms pulse b

```

1 //Ex:5.4
2 clc;
3 clear;
4 close;
5 ds=0.020; // material dispersion
6 c=3*10^8; // the speed of light m/s
7 y=1.3; // wavelength in um
8 M=ds/(c*y); // material dispersion parameter in ps/nm/
   /km
9 w=6; // spectral width in nm
10 l=1; // length in km
11 rm=w*l*M; // rms pulse broadening in ns/km
12 printf("The material dispersion parameter =%f ps/nm/
   km", M*10^12);
13 printf("\n The rms pulse broadening =%f ns/km", rm
   *10^9);

```

Scilab code Exa 5.5 Estimate the rms pulse broadening per km of the fibers

```

1 //Ex:5.5
2 clc;
3 clear;
4 close;
5 wr=0.0014; // relative spectral width in nm
6 y=1.3*10^-6; // wavelength in m
7 w=wr*y; // spectral width in nm
8 ds=0.020; // material dispersion
9 c=3*10^8; // the speed of light in m/s
10 M=ds/(c*y); // material dispersion parameter in ps/nm/
   /km
11 l=1; // length in km
12 rm=w*l*M; // rms pulse broadening in ns/km
13 printf("The rms pulse broadening =%f ns/km", rm
   *10^9*10^3);

```

Scilab code Exa 5.6 Find the delay difference and rms pulse broadening and max bit

```
1 //Ex:5.6
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 d1=0.01; // relative index difference
7 L=10*10^3; // optical length in meter
8 c=3*10^8; // the speed of light in m/s
9 dt=(L*n1*d1)/c; // delay difference in s
10 dT=dt*10^9; // delay difference in ns
11 rm=(L*n1*d1)/(2*sqrt(3)*c); // rms pulse broadening s
12 rM=rm*10^9; // rms pulse broadening ns
13 bt=0.2/rm; // max bit rate in bit/sec
14 bT=bt/10^6; // max bit rate in M bits/sec
15 bl=bt*L; // bandwidth length product in Hz meter
16 bL=(bt*L)/(10^6*10^3); // bandwidth length product in
    MHz km
17 printf("The delay difference =%d ns", dT);
18 printf("\n The rms pulse broadening =%f ns", rM);
19 printf("\n The max bit rate =%f M bits/sec", bT);
20 printf("\n The bandwidth length product =%f MHz km",
    bL);
```

Scilab code Exa 5.7 Estimate the max bit rate assuming only intermodel dispersion

```
1 //Ex:5.7
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
```

```

6 d1=0.01; // relative index difference
7 L=6*10^3; // optical length in meter
8 c=3*10^8; // the speed of light in m/s
9 rm=(L*n1*d1)/(2*sqrt(3)*c); // rms pulse broadening s
10 rM=rm*10^9; // rms pulse broadening ns
11 bt=0.2/rm; // max bit rate in bit/sec
12 bT=bt/10^6; // max bit rate in M bits/sec
13 printf("The rms pulse broadening =%f ns", rM);
14 printf("\n The max bit rate =%f M bits/sec", bT);

```

Scilab code Exa 5.8 Find the delay difference and rms pulse broadening and max bit

```

1 //Ex:5.8
2 clc;
3 clear;
4 close;
5 n1=1.4; // core refractive index
6 d1=0.012; // relative index difference
7 L=6*10^3; // optical length in meter
8 c=3*10^8; // the speed of light in m/s
9 dt=(L*n1*d1)/c; // delay difference in s
10 dT=dt*10^9; // delay difference in ns
11 rm=(L*n1*d1)/(2*sqrt(3)*c); // rms pulse broadening s
12 rM=rm*10^9; // rms pulse broadening ns
13 bt=0.2/rm; // max bit rate in bit/sec
14 bT=bt/10^6; // max bit rate in M bits/sec
15 printf("The delay difference =%d ns", dT);
16 printf("\n The rms pulse broadening =%f ns", rM);
17 printf("\n The max bit rate =%f M bits/sec", bT);

```

Scilab code Exa 5.9 Find the rms pulse broadening and Bandwidth length product for

```

1 //Ex:5.9

```



```

2  clc;
3  clear;
4  close;
5  n1=1.5; // core refractive index
6  c=3*10^8; // the speed of light m/s
7  w=6*10^-6; // rms spectral width in m
8  M=200; // material dispersion parameter in ps/nm/km
9  NA=0.25; // numerical aperture
10 w=50; // spectral width in nm
11 L=1; // length in m
12 rm=w*L*M; // rms pulse broadening in s/km
13 rM=rm/10^3; // rms pulse broadening in ns/km due to
    material dispersion
14 rm1=(L*1000*(NA)^2)/(4*sqrt(3)*n1*c); //rms pulse
    broadening in ns/km due to material dispersion in
    sec/m
15 rM1=rm1*10^9; // rms pulse broadening in ns/km due to
    intermodel dispersion in ns/km
16 rmt=sqrt(rM^2+rM1^2); // total rms pulse broadening
    in ns/km
17 bl=0.2/(rmt*10^-9); // bandwidth length product in Hz
    km
18 bL=b1/10^6; // bandwidth length product in MHz km
19 printf("The total rms pulse broadening =%f ns/km",
    rmt);
20 printf("\\n The bandwidth length product =%f MHz km",
    bL);

```

Scilab code Exa 5.10 Determine the total first order dispersion and also find the

```

1  //Ex:5.10
2  clc;
3  clear;
4  close;
5  yo=1320; // zero dispersion wavelength in nm

```

```

6 y=1290; // dispersion wavelength in nm
7 so=0.092; // dispersion slop
8 dt=(y*so/4)*(1-(yo/y)^4); // toal first order
    dispersion at 1290 nm in ps/nm/km
9 yo1=1310; // zero dispersion wavelength in um
10 y1=1550; // dispersion wavelength in nm
11 so=0.092; // dispersion slop
12 dt1=(y1*so/4)*(1-(yo1/y1)^4); // toal first order
    dispersion at 1550 nm in ps/nm/km
13 DM=13.5; // profile dispersion in ps/nm/km
14 DP=0.4; // profile dispersion in ps/nm/km
15 DW=dt1-(DM+DP); // wavelength dispersion in ps/nm/km
16 printf("The toal first order dispersion at 1290 nm =
    %f ps/nm/km", dt);
17 printf("\n The toal first order dispersion at 1550
    nm =%f ps/nm/km", dt1);
18 printf("\n The wavelength dispersion at 1550 nm =%f
    ps/nm/km", DW);

```

Scilab code Exa 5.11 Find the model birefringence and coherence length and also the

```

1 //Ex:5.11
2 clc;
3 clear;
4 close;
5 L=6*10^-2; // beat length in m
6 dy=6*10^-9; // spectral width in m
7 y=1.3*10^-6; // operating wavelength in m
8 BF=y/(L); //model birefringence in um
9 Lc=y^2/(BF*dy); // coherence length in m
10 db=2*3.14/(L); // difference between two propagation
    constants
11 dB=(2*3.14*BF)/y;
12 printf("The model birefringence =%f um", BF*10^6);
13 printf("\n The coherence length=%f m", Lc);

```

```

14 printf("\n The difference beween two propagation
    constants=%f", db);
15 printf("\n The difference between two propagation
    constants=%f", dB);

```

Scilab code Exa 5.12 Find the model birefringence and interpret the length

```

1 //Ex:5.12
2 clc;
3 clear;
4 close;
5 y=0.85*10^-6; // operating wavelength in m
6 L=0.5*10^-3; // beat length in m
7 BF=y/(L); //model birefringence in um
8 L1=75; // beat length in m
9 BF1=y/(L1); //model birefringence in um
10 printf("The model birefringenceat 0.5 nm =%f*10^-3",
    BF);
11 printf("\n The model birefringence at 75 m =%f*10^-8
    ", BF1*10^8);

```

Scilab code Exa 5.13 Find the beat length within the fiber

```

1 //Ex:5.13
2 clc;
3 clear;
4 close;
5 Lc=100000; // coherence length in m
6 y=1.32*10^-6; // operating wavelength in m
7 dy=1.5*10^-9; // spectral width in m
8 BF=y^2/(Lc*dy); //model birefringence in um
9 L=y/BF; // beat length in m
10 printf("The beat length=%f m", L);

```

Scilab code Exa 5.14 Find the rms intermodel pulse broadening

```
1 //Ex:5.14
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 NA=0.25; // numerical aperture
7 c=3*10^5; // the speed of light km/s
8 L=7; // length in km
9 si=NA^2/(4*sqrt(3)*n1*c); //intermodel pulse
    broadening ns/km
10 st=si*L; //total intermodel pulse broadening
11 BW=0.187/st; // bandwidth in MHz
12 printf("The intermodel pulse broadening =%f ns/km",
    st*10^9);
13 printf("\n The bandwidth =%f MHz", BW/10^6);
```

Scilab code Exa 5.15 Compute the max dispersion

```
1 //Ex:5.15
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 df=0.025;
7 L=500; // length in m
8 c=3*10^8; // the speed of light in m/s
9 dt=(n1*L*df^2)/(8*c); // max dispersion in ns/m
10 printf("The max dispersion =%f ns/m", dt*10^9);
11 printf("\n The answer in the textbook is wrong");
```

Scilab code Exa 5.16 Calculate the amount of material dispersion

```
1 //Ex:5.16
2 clc;
3 clear;
4 close;
5 dy=15; // spectral width in nm
6 L=25; // optical length in km
7 ps=1.60; // pulse spreads in ns/km
8 pS=1.6; // pulse spreads in ns/km
9 d=pS/(dy*L); // material dispersion in ns/km^2/nm
10 printf("The max dispersion =%f ns/km^2/nm", d);
```

Scilab code Exa 5.17 Calculate the intermodel dispersion of a step index fiber

```
1 //Ex:5.17
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 NA=0.2; // numerical aperture
7 L=1.5*10^3; // length in m
8 c=3*10^8; // the spee of light in m/s
9 dt=(L*NA^2)/(2*c*n1); //intermodel dispersion in ns/
   km
10 printf("The intermodel dispersion =%f ns/km", dt
   *10^9);
```

Scilab code Exa 5.18 Compute the pulse broadening due to modal and combined pulse

```

1 //Ex:3.18
2 clc;
3 clear;
4 close;
5 BLP=250*10^6; // bandwidth length product in Hz
6 tr=0.32/BLP; // intermodel pulse width broadening
7 md=75; // material dispersion in ps/nm.km
8 tm=2.25; //pulse broadening due to material
    dispersion in ns/km
9 tc=sqrt((tr*10^9)^2+tm^2); // combine pulse
    broadening in ns/km
10 Ba=0.32/tm*10^9; // actual BLP in Hz.km
11 Bac=Ba/10^6; // actual BLP in MHz.km
12 printf("The intermodel pulse width broadening =%f ns
    /km", tr*10^9);
13 printf("\n pulse broadening due to material
    dispersion =%f ns/km", tm);
14 printf("\n The combine pulse broadening =%f ns/km",
    tc);
15 printf("\n The actual BLP =%f MHz.km", Bac);

```

Scilab code Exa 5.19 Compute the material dispersion

```

1 //Ex:5.19
2 clc;
3 clear;
4 close;
5 L=40; // length in m
6 Ny=.75; // in ps/nm
7 dy=8; // spectral width in nm
8 t_mat=L*Ny*dy; // chromatic/material dispersion in ps
9 t_mat1=t_mat/1000; // chromatic/material dispersion
    in ns
10 printf("The chromatic/material dispersion =%f ns",
    t_mat1);

```

Scilab code Exa 5.20 Calculate the pulse width of the received signal and approxi

```
1 //Ex:5.20
2 clc;
3 clear;
4 close;
5 y=1.3; // operating wavelength in um
6 md=2.80; // material dispersion in ns
7 wd=0.50; // waveguide dispersion in ns
8 wt=0.60; // width of transmitted pulse in ns
9 td=sqrt(md^2+wd^2); // total dispersion in ns
10 dt=wt+td; // received pulse width in ns
11 br=1/(5*dt*10^-9); // max bit rate bit/sec
12 Br=br/10^6; // max bit rate in mbps
13 printf("The received pulse width =%f ns", dt);
14 printf("\n The max bit rate =%f mbps", Br);
```

Scilab code Exa 5.21 Calculate the pulse width of the received signal and approxi

```
1 //Ex:5.21
2 clc;
3 clear;
4 close;
5 y=0.85; // operating wavelength in um
6 md=2.75; // material dispersion in ns
7 wd=0.45; // waveguide dispersion in ns
8 wt=0.50; // width of transmitted pulse in ns
9 td=sqrt(md^2+wd^2); // total dispersion in ns
10 dt=wt+td; // received pulse width in ns
11 br=1/(5*dt*10^-9); // max bit rate bit/sec
12 Br=br/10^6; // max bit rate in mbps
```

```
13 printf("The received pulse width =%f ns", dt);
14 printf("\n The max bit rate =%f mbps", Br);
```

Scilab code Exa 5.22 find the total dispersion

```
1 //Ex:5.22
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 df=0.025;
7 L=1500; // length in meter
8 c=3*10^8; // the speed of lighth in m/s
9 md=(n1*L*df)/(c*(1-df)); // max dispersion in sec
10 Md=md*10^9; // max dispersion in ns
11 printf("The max dispersion =%d ns", Md);
```

Scilab code Exa 5.23 Find the intermodel dispersion

```
1 //Ex:5.23
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 L=1000; // length in meter
7 NA=0.22; // numerical aperture
8 dl=(NA/n1)^2/2;
9 c=3*10^8; // the speed of lighth in m/s
10 dt=(L*n1*dl)/c; //intermodel dispersion in sec
11 dT=dt*10^9; //intermodel dispersion in ns
12 printf("The max dispersion =%d ns", dT);
```

Scilab code Exa 5.24 Find the total intermodal and intramodal and total dispersion

```
1 //Ex:5.24
2 clc;
3 clear;
4 close;
5 w=30; // line width in nm
6 L=1.5; // length in km
7 d1=6; // in ns/km
8 d2=85; // in ps/km/nm
9 d3=d2/1000; // in ns/km/nm
10 dt=d1*L; // intermodel dispersion in ns
11 dt1=w*d3*L; // intramodal dispersion in ns
12 dT=sqrt(dt^2+dt1^2); // total dispersion in ns
13 printf("The max dispersion =%d ns", dt);
14 printf("\n The max dispersion =%f ns", dt1);
15 printf("\n The max dispersion =%f ns", dT);
16 printf("\n answer in the textbook is wrong");
```

Scilab code Exa 5.25 Find the intermodal dispersion

```
1 //Ex:5.25
2 clc;
3 clear;
4 close;
5 n1=1.55; // core refractive index
6 n2=1.48; // cladding refractive index
7 l=150; // fiber length in m
8 c=3*10^8; // the speed of light in m/s
9 dl=(n1^2-n2^2)/(2*n1);
10 dL=0.068;
11 dt=(l*n1*dL)/(c); // intermodel dispersion in s
```

```

12 dT=dt*10^9; // intermodel dispersion in ns
13 printf("The intermodel dispersion =%f ns", dT);

```

Scilab code Exa 5.26 Find the intermodal dispersion per km

```

1 //Ex:5.29
2 clc;
3 clear;
4 close;
5 n1=1.42; // core refractive index
6 dl=0.02;
7 c=3*10^8; //the speed of light in m/s
8 dt=(n1*dl)/c; // intermodel dispersion in sec/m
9 dt1=dt*1000; // intermodel dispersion in sec/km
10 dt2=dt1*10^9; // intermodel dispersion in ns/km
11 printf("The intermodel dispersion per km =%f ns/km",
        dt2);

```

Scilab code Exa 5.27 Find the waveguide dispersion parameter DW

```

1 //Exa:5.27
2 clc;
3 clear;
4 close;
5 printf("Dwg=n2*(dl/cy)*V(d^2(Vb)/dV^2)");
6 printf("\n Dwg=n2*(dl/cy)*V(d^2(V(1-exp(-V))))/dv^2");
7 printf("\n =CV(Z-V)exp(-V)");
8 printf("\n where C=n2(dl/cy)");
9 printf("\n waveguide dispersion will be zero , when
        V=2");

```

Scilab code Exa 5.28 Find the pulse spreading due to material dispersion

```
1 //Ex:5.28
2 clc;
3 clear;
4 close;
5 y=900; // operating wavelength in nm
6 yo=1343; // wavelength in nm
7 so=0.095; // in ps/nm2-km
8 L=150; // in km
9 dy=50; //in nm
10 Dy=(so*y/4)*(1-(yo/y)4); // inps/nm-km
11 Dy1=Dy*(-1); // do not consider -ve sign
12 dt=Dy1*L*dy; // pulse spreading in ps
13 dt1=dt/1000; // pulse spreading in ns
14 printf("The pulse spreading =%f ns", dt1);
```

Scilab code Exa 5.29 Find the pulse spread due to material and waveguide dispersio

```
1 //Ex:5.29
2 clc;
3 clear;
4 close;
5 n1=1.48; // core refractive index
6 y=900; // operating wavelength in nm
7 yo=1343; // wavelength in nm
8 so=0.095; // in ps/nm2-km
9 L=1.5; // in km
10 dy=50; //in nm
11 dl=0.002;
12 c=3*108; // the speed of lighth in m/s
13 Dm=(so*y/4)*(1-(yo/y)4); // inps/nm-km
```

```

14 Dm1=Dm*(-1); // do not consider -ve sign
15 Vd=0.26;
16 Dw=((n1*d1)/(c*y*10^-9))*(Vd);
17 DW=Dw*10^6; // in ps/nm-km
18 dt=DW*L*dy; // pulse spreading in ps
19 dt1=dt/100; // pulse spreading in ns
20 printf("The pulse spreading =%f ps", dt1);

```

Scilab code Exa 5.30 calculate w_0 and w_p for operation at wavelength is 1310 nm and

```

1 //Ex:5.30
2 clc;
3 clear;
4 close;
5 a=4.1*10^-6; // core radius in um
6 d1=0.0036;
7 y1=1.310*10^-6; // operating wavelength in um
8 y2=1.550*10^-6; // operating wavelength in um
9 n1=1.4677; // core refractive index at y=1.310
10 n2=1.4682; // core refractive index at y=1.550
11 v1=(2*3.14*a*n1*sqrt(2*d1))/y1; // normalised
    frequency at y=1.310
12 v2=(2*3.14*a*n2*sqrt(2*d1))/y2; // normalised
    frequency at y=1.550
13 wo=a*(0.65+(1.619/v1^1.5)+2.879/v1^3);
14 wp=wo-a*(0.016+1.567/v1^7);
15 wo1=a*(0.65+(1.619/v2^1.5)+2.879/v2^3);
16 wp1=wo-a*(0.016+1.567/v2^7);
17 printf("The value of wo =%f um", wo*10^6);
18 printf("\n The value of wp =%f um", wp*10^6);
19 printf("\n The value of wo1 =%f um", wo1*10^6);
20 printf("\n The value of wp1 =%f um", wp1*10^6);

```

Scilab code Exa 5.31 calculate the range of the propagation constant and length of

```
1 //Ex:5.31
2 clc;
3 clear;
4 close;
5 y=1.30*10^-6; // operating wavelength in m
6 dn1=10^-6;
7 dn2=10^-5;
8 db1=(dn1*2*3.14)/y; // in per m
9 db2=(dn2*2*3.14)/y; // in per m
10 Lp1=(2*3.14)/(db1); // beat length in m
11 Lp2=(2*3.14)/(db2); // beat length in m
12 printf("The max core radius =%f um", db1);
13 printf("\n The max core radius =%f um", db2);
14 printf("\n The beat length =%f m", Lp1);
15 printf("\n The beat length =%f cm", Lp2*100);
16 printf("\n Hence, range of beat length; 13cm-1.3m");
```

Scilab code Exa 5.32 Estimate the waveguide dispersion for the given fiber

```
1 //Ex:5.32
2 clc;
3 clear;
4 close;
5 n1=1.48; // core refractive index
6 d1=0.0027;
7 a=4.4*10^-6; // radius in m
8 y=1.32*10^-6; // operating wavelength in m
9 n2=n1*(1-d1);
10 c=3*10^8; // the speed of light in m/s
11 v=(2*3.14*a*n1*sqrt(2*d1))/y;
12 VD=0.080+0.549*(2.834-v)^2;
13 DW=(-1)*(n2*d1*VD)/(c*y); // wavelength dispersion in
    s /um/m
```

```

14 Dw=DW*10^6; // wavelength dispersion in ps /nm/km
15 printf("The wavelength dispersion =%f ps n/m/km", Dw
);

```

Scilab code Exa 5.33 What should be the radius of the core so that the total dispe

```

1 //Exa:5.33
2 clc;
3 clear;
4 close;
5 n1=1.48; // core refractive index
6 dl=0.01; // refractive index difference
7 c=3*10^8; // the speed of light in m/s
8 y=1.55; // wavelength in um
9 DM=7; // in ps/nm-km
10 DW=(-1)*DM; // in ps/nm-km
11 X=-10^12*(n1*dl)/(c*y); // in ps/nm/km
12 Z=(DW/X)-0.08; //
13 V=2.834-sqrt(Z/0.549);
14 a=(V*y)/(2*pi*n1*sqrt(2*dl)); // core radius in um
15 printf("The core radius =%f um", a);

```

Chapter 6

Preparation of Optical Fibers And Cables

Scilab code Exa 6.1 Compute the stain on the fiber and what will happen if this co

```
1 //Ex:6.1
2 clc;
3 clear;
4 close;
5 r=125*10^-6; // cladding radius in meter
6 R=8*10^-2; // curve of radius in meter
7 s=((R+2*r)/(R+r))-1;
8 s_p=s*100; // percentage of strain
9 printf("The percentage of strain =%f %%", s_p);
10 printf("\n If this condition is maintained the fiber
    will maintain without any break");
```

Scilab code Exa 6.2 Find the pulling tension

```
1 //Ex:6.2
2 clc;
```

```
3 clear;
4 close;
5 w=40*10^-3; // cable weighing in kg/m
6 R=20*10^-2; // radius of curvature in meter
7 n=0.19; // co-efficient of friction
8 x=(3.14/4); // angle in rad
9 si=42.36; // pulling tension at the entrance in kg
10 X=(si/(w*R)); //
11 Y=asinh(si/(w*R));
12 Z=w*R*sinh(n*x+Y); //puttling tension at the exit of
    an optical cable
13 printf("The puttling tension at the exit of an
    optical cable =%f kg", Z);
```

Chapter 7

Optical Fiber Connection Connectors Joints And Couplers

Scilab code Exa 7.1 Calculate the fiber loss in db

```
1 //Ex:7.1
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 n=1; // refractive index due to air
7 r=((n1-n)/(n1+n))^2;
8 r1=0.03; // r take upto two decimal place
9 l_s=-10*log(1-r1)/log(10); // fiber loss in db
10 l_t=2*l_s; // total loss in db
11 printf("The fiber loss =%f db", l_s);
12 printf("\n there is a similar loss at the other
    interface");
13 printf("\n The total fiber loss =%f db", l_t);
```

Scilab code Exa 7.2 Find the insertion loss due to lateral misalignment

```
1 //Ex:7.2
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 n=1; // refractive index due to air
7 a=25*10^-6; // core radius in m
8 y=3*10^-6; // in m
9 A=(y/a)*(1-(y/(2*a))^2)^0.5;
10 B=acos(y/(2*a));
11 C=n1/n;
12 M=(16*C^2)/(pi*(1+C)^4);
13 n_lat=M*(2*B-A); // coupling efficiency for multimode
    step index fiber
14 L_lat=-10*log(n_lat)/log(10); // insertion loss for
    lateral misalignment
15 n_lat1=(1/pi)*(2*B-A); // coupling efficiency when
    there is no air gap
16 L_lat1=-10*log(n_lat1)/log(10); // insertion loss for
    lateral misalignment when there is no air gap
17 printf("The coupling efficiency for multimode step
    index fiber =%f", n_lat);
18 printf("\n The insertion loss for lateral
    misalignment =%f dB", L_lat);
19 printf("\n The coupling efficiency when there is no
    air gap =%f", n_lat1);
20 printf("\n The insertion loss for lateral
    misalignment when there is no air gap =%f dB",
    L_lat1);
```

Scilab code Exa 7.3 Calculate the total insertion loss at the joint

```
1 //Ex:7.3
```

```

2  clc;
3  clear;
4  close;
5  n1=1.50; // core refractive index
6  n=1; // refractive index due to air
7  a=25*10^-6; // core radius in m
8  y=4*10^-6; // in m
9  A=(y/a)*(1-(y/(2*a))^2)^0.5;
10 B=acos(y/(2*a));
11 C=n1/n;
12 M=(16*C^2)/(pi*(1+C)^4);
13 n_lat=M*(2*B-A); // coupling efficiency for multimode
    step index fiber
14 L_lat=-10*log(n_lat)/log(10); // insertion loss for
    lateral misalignment
15 dx=4*(3.14/180); // angular misalignment in radian
16 dl=0.02; // relative index difference
17 NA=n1*sqrt(2*dl); // numerical aperture
18 n_ang=1-(0.069/(3.14*NA)); // coupling efficiency due
    to angular misalignment
19 L_ang=-10*log(n_ang)/log(10); // loss due to angular
    misalignment
20 Lt=L_lat+L_ang; // total insertion loss in dB
21 printf("The total insertion loss =%f dB", Lt);
22 printf("\n the answer is wrong in the textbook");

```

Scilab code Exa 7.4 Estimate the insertion loss at the joint when there is a small

```

1  //Ex:7.4
2  clc;
3  clear;
4  close;
5  n1=1.46; // core refractive index
6  n=1; // refractive index due to air
7  a=1; // core radius in m

```

```

8 y=0.12; // lateral offset
9 A=(y/a)*(1-(y/(2*a))^2)^0.5;
10 B=acos(y/(2*a));
11 C=n1/n;
12 M=(16*C^2)/(pi*(1+C)^4);
13 n_lat=M*(2*B-A); // coupling efficiency when there is
    a small air gap
14 L_lat=-10*log(n_lat)/log(10); // insertion loss when
    there is a small air gap
15 n_lat1=(1/pi)*(2*B-A); // coupling efficiency when
    the joint is indexed matched
16 L_lat1=-10*log(n_lat1)/log(10); // insertion loss
    when the joint is indexed matched
17 printf("The insertion loss when there is a small air
    gap =%f dB", L_lat);
18 printf("\n The insertion loss when the joint is
    indexed matched =%f dB", L_lat1);

```

Scilab code Exa 7.5 Find the insertion loss of a signal in the fwd and backward di

```

1 //Ex:7.5
2 clc;
3 clear;
4 close;
5 d1=60*10^-6; // core diameter of fiber 1 in m
6 d2=50*10^-6; // core diameter of fiber 1 in m
7 NA1=0.25; // numerical aerture of fiber 1
8 NA2=0.22; // numerical aerture of fiber 2
9 a1=2.0; // for fiber 1
10 a2=1.9; // for fiber 2
11 n_cd=(d2/d1)^2;
12 n_NA=(NA2/NA1)^2;
13 n_a=(1+(2/a1))/(1+(2/a2));
14 n_t=n_cd*n_NA*n_a; // total coupling efficiency
15 Lt=-10*log(n_t)/log(10); // total loss at the joint

```

```

    in dB
16 printf("The total coupling efficiency in the frw
    direction =%f", n_t);
17 printf("\n The total loss at the joint in the frw
    direction =%f dB", Lt);
18 printf("\n In the backward direction n_cd & n_a are
    all unity therefore there will be no loss in the
    backward direction of transmission of the signal
    ");

```

Scilab code Exa 7.6 Calculate the insertion loss at the joint in the fwd and backward

```

1 //Ex:7.6
2 clc;
3 clear;
4 close;
5 d1=80*10^-6; // core diameter of fiber 1 in m
6 d2=60*10^-6; // core diameter of fiber 1 in m
7 NA1=0.25; // numerical aerture of fiber 1
8 NA2=0.20; // numerical aerture of fiber 2
9 a1=1.9; // for fiber 1
10 a2=2.1; // for fiber 2
11 n_cd=(d2/d1)^2;
12 n_NA=(NA2/NA1)^2;
13 n_a=(1+(2/a1))/(1+(2/a2));
14 n_t=n_cd*n_NA*n_a; // total coupling efficiency in
    the frw direction
15 Lt=-10*log(n_t)/log(10); // total loss at the joint
    in the frw direction in dB
16 n_cd1=1;
17 n_NA1=1;
18 n_a1=(1+(2/a2))/(1+(2/a1));
19 n_t1=n_cd1*n_NA1*n_a1; // total coupling efficiency
    in the backward direction
20 Lt1=-10*log(n_t1)/log(10); // total loss at the joint

```

```

    in the backward direction in dB
21 printf("The total loss at the joint in the frw
    direction =%f dB", Lt);
22 printf("\n The total loss at the joint in the
    backward direction =%f dB", Lt1);

```

Scilab code Exa 7.7 Determine the insertion loss of the splices

```

1 //Ex:7.7
2 clc;
3 clear;
4 close;
5 n1=1.5; // core refractive index
6 n=1.47; // refractive index due to air
7 a=1; // core radius in m
8 y=0.12; // lateral offset
9 A=(y/a)*(1-(y/(2*a))^2)^0.5;
10 B=acos(y/(2*a));
11 C=n1/n;
12 M=(16*C^2)/(%pi*(1+C)^4);
13 n_lat=M*(2*B-A); // coupling efficiency of the splice
14 L_lat=-10*log(n_lat)/log(10); // insertion loss of
    the splice
15 printf("The insertion loss of the splice =%f dB",
    L_lat);

```

Scilab code Exa 7.8 Determine the refractive index of the fiber core

```

1 //Ex:7.8
2 clc;
3 clear;
4 close;
5 L_f=0.036;

```

```

6 n_f=10^(-0.036);
7 // here we get a quadratic equation in n1 and on
  solving we get
8 n1=(2.17+sqrt((-2.17)^2-4*1*1))/2; // refractive
  index of the fiber core
9 printf("The refractive index of the fiber core =%f",
  n1);

```

Scilab code Exa 7.9 Find the numerical aperture of the fiber

```

1 //Ex:7.9
2 clc;
3 clear;
4 close;
5 n1=1.46; // core refractive index
6 n=4; // refractive index due to air
7 x=%pi/180;
8 A=(16*n1^2)/((1+n1)^4);
9 B=n*x;
10 n_ang=10^(-0.06); // angular coupling efficiency
11 NA=B/((%pi)*(1-(n_ang/A))); // numerical aperture
12 printf("The numerical aperture =%f", NA);

```

Scilab code Exa 7.10 Find the insertion loss due to misalignment assuming index ma

```

1 //Ex:7.10
2 clc;
3 clear;
4 close;
5 y=5*10^-6; // lateral misalignment in m
6 a=25*10^-6; // core diameter in m
7 Lt=0.85*(y/a); // misalignment loss
8 n_c=1-Lt; // coupling efficiency

```

```

 9 L_i=-10*log(n_c)/log(10);// insertion loss in dB
10 Lt1=0.75*(y/a);// misalignment loss if we have both
   guided and leaky modes
11 n_c1=1-Lt1;// coupling efficiency
12 L_i1=-10*log(n_c1)/log(10);// insertion loss in dB
   if we have both guided and leaky modes
13 printf("The insertion loss =%f dB", L_i);
14 printf("\n The insertion loss ,if we have both guided
   and leaky modes =%f dB", L_i1);

```

Scilab code Exa 7.11 Find the insertion loss due to misalignment

```

1 //Ex:7.11
2 clc;
3 clear;
4 close;
5 n1=1.5;// core refractive index
6 n=1;// refractive index due to air
7 x=5*%pi/180;
8 C=n1/n;
9 A=(16*C^2)/((1+C)^4);
10 B=n*x;
11 NA=0.22;// numerical aperture
12 n_ang=A*(1-(B/(%pi*NA)));// angular coupling
   efficiency
13 L_ang=-10*log(n_ang)/log(10);// inserion loss when
   NA=0.22
14 NA1=0.32;// numerical aperture
15 n_ang1=A*(1-(B/(%pi*NA1)));// angular coupling
   efficiency
16 L_ang1=-10*log(n_ang1)/log(10);// inserion loss when
   NA=0.32
17 printf("The inserion loss when NA=0.22 =%f dB",
   L_ang);
18 printf("\n The inserion loss when NA=0.32 =%f dB",

```



```
L_ang1);
```

Scilab code Exa 7.12 Find the insertion loss of a fiber joint

```
1 //Ex:7.12
2 clc;
3 clear;
4 close;
5 V=2.50; // normalised frequency
6 n1=1.5; // core refractive index
7 a=4.5*10^-6; // core radius in m
8 NA=0.2; // numerical aperture
9 y=3*10^-6; // lateral misalignment in m
10 w=a*((0.65+1.62*(V)^-1.5+2.88*(V)^-6)/2^0.5); //
    normalised spot size in m
11 T1=2.17*(y/w)^2; // Loss due to lateral offset in dB
12 x=(%pi/180)*w;
13 Ta=2.17*((x*n1*V)/(a*NA))^2; // loss due to angular
    misalignment in dB
14 T=T1+Ta; // total insertion loss in dB
15 printf("The total insertion loss =%f dB", T);
16 printf("\n The answer is wrong in the textbook");
```

Scilab code Exa 7.13 Find the insertion losses between the input and output ports

```
1 //Ex:7.13
2 clc;
3 clear;
4 close;
5 P1=65; // optical power in uW
6 P2=0.005; // output power at port 2 in uW
7 P3=24; // output power at port 3 in uW
8 P4=26.5; // output power at port 4 in uW
```

```

 9 Le=10*log(P1/(P3+P4))/log(10);// Excess loss in dB
10 Le1=10*log(P1/P3)/log(10);// insertion loss port 1
    to 3 in dB
11 Le2=10*log(P1/P4)/log(10);// insertion loss port 1
    to 4 in dB
12 ct=10*log(P2/P1)/log(10);// cross talk in dB
13 sr=(P3/(P3+P4))*100;// split ratio
14 printf("The Excess loss =%f dB", Le);
15 printf("\n The insertion loss port 1 to 3  =%f dB",
    Le1);
16 printf("\n The insertion loss port 1 to 4  =%f dB",
    Le2);
17 printf("\n The cross talk =%f dB", ct);
18 printf("\n The split ratio =%f %%", sr);

```

Scilab code Exa 7.14 Calculate the fresnel loss at each glass air boundary

```

1 //Ex:7.14
2 clc;
3 clear;
4 close;
5 n=1;
6 n1=1.48;
7 r=((n1-n)/(n1+n))^2;// fresnel's reflection
8 Ls=-10*log(1-r)/log(10);// optical loss in dB
9 Lt=2*Ls;// total fresnel loss
10 printf("The total fresnel loss =%f dB", Lt);

```

Scilab code Exa 7.15 Find the numerical aperture

```

1 //Ex:7.15
2 clc;
3 clear;

```

```

4 close;
5 NA1=0.32; // numerical aperture for fiber1
6 NA2=0.22; // numerical aperture for fiber2
7 Lc=20*log(NA1/NA2)/log(10); // NA mismatch coupling
  loss
8 printf("The NA mismatch coupling loss =%f dB", Lc);

```

Scilab code Exa 7.16 Find the coupling ratio and excess loss and insertion loss and

```

1 //Ex:7.16
2 clc;
3 clear;
4 close;
5 P0=250; // optical power in uW
6 P1=80; // output power at port 1 in uW
7 P2=70; // output power at port 2 in uW
8 P3=5*10^-3; // output power at port 3 in uW
9 cr=(P2/(P1+P2))*100; // coupling ratio
10 Le=10*log(P0/(P1+P2))/log(10); // Excess loss in dB
11 Le1=10*log(P0/P1)/log(10); // insertion loss port 0
  to 1 in dB
12 Le2=10*log(P0/P2)/log(10); // insertion loss port 0
  to 2 in dB
13 ct=10*log(P3/P0)/log(10); // cross talk in dB
14 printf("The coupling ratio =%f %%", cr);
15 printf("\n The Excess loss =%f dB", Le);
16 printf("\n The insertion loss port 0 to 1 =%f dB",
  Le1);
17 printf("\n The insertion loss port 0 to 2 =%f dB",
  Le2);
18 printf("\n The cross talk =%f dB", ct);

```

Scilab code Exa 7.17 What fraction of the input power goes to each port and comput

```

1 //Ex:7.17
2 clc;
3 clear;
4 close;
5 P_21=4/5; // ratio of the input available at port2
6 P_31=1/5; // ratio of the input available at port3
7 Lt=-10*log(P_21)/log(10); // throughput loss
8 Lp=-10*log(P_31)/log(10); // tap loss
9 Le=-10*log(P_21+P_31)/log(10); // excess loss
10 printf("The throughput loss =%f dB", Lt);
11 printf("\n The tap loss =%f dB", Lp);
12 printf("\n Directionality=-10*log(0/Pi=infinity)");
13 printf("\n The excess loss =%d dB", Le);

```

Scilab code Exa 7.18 What fraction of the input power goes to each port and compute

```

1 //Ex:7.18
2 clc;
3 clear;
4 close;
5 Le=4; // excess loss in dB
6 D=60; // Directionality in dB
7 P_41=10^-6; // the ratio of P4 to P1
8 P_31=0.670/5; // the ratio of P3 to P1
9 P_21=P_31*4; // the ratio of P2 to P1
10 Lt=-10*log(P_21)/log(10); // throughput loss
11 Lp=-10*log(P_31)/log(10); // tap loss
12 Ls=-10*log(0.670)/log(10); // loss due to radiation
    scattering in dB
13 printf("The fraction of the input power goes to each
    of the ports =%f dB", P_21);
14 printf("\n The throughput loss =%f dB", Lt);
15 printf("\n The tap loss =%f dB", Lp);
16 printf("\n The loss due to radiation scattering =%f
    dB", Ls);

```

Scilab code Exa 7.19 Determine the attenuation per km for the fiber

```
1 //Ex:7.19
2 clc;
3 clear;
4 close;
5 L1=1.5; // length in km
6 L2=2/1000; // length in km
7 Pi=50.1*10^-6; // optical power in W
8 Po=385.4*10^-6; // output power in W
9 a=(10/(L1-L2))*log(Po/Pi)/log(10); // attenuation per
   km
10 printf("The attenuation per km =%f dB/km", a);
```

Scilab code Exa 7.20 Determine the optical loss due to scattering for a fiber

```
1 //Ex:7.20
2 clc;
3 clear;
4 close;
5 Psc=5.31*10^-9; //
6 Popt=98.45*10^-6; //
7 L=5.99; // length in km
8 asc=(4.343*10^5/L)*(Psc/Popt); // scattering loss in
   the fiber in dB
9 printf("The scattering loss in the fiber =%f dB/km",
   asc);
```

Chapter 8

Optical Sources

Scilab code Exa 8.1 Find the total carrier recombination life time and power inter

```
1 //Ex:8.1
2 clc;
3 clear;
4 close;
5 tr=40;// radiative life time in ns
6 tnr=60;// nonradiative life time in ns
7 i=35*10^-3;// drive current in amp
8 y=0.85*10^-6;// wavelength in m
9 h=6.626*10^-34;// plank constant
10 c=3*10^8;// the speed of light in m/s
11 e=1.602*10^-19;// charge
12 t=tr*tnr/(tr+tnr);// total carrier recombination
    lifetime ns
13 ni=t/tr;// internal quantam efficiency
14 pi=(ni*h*c*i)/(e*y);// internal power in watt
15 p_int=pi*10^3;// internal power in mW
16 printf("The total carrier recombination lifetime =%d
    ns", t);
17 printf("\n The internal power =%f mW", p_int);
18 printf("\n the answer is wrong in textbook");
```

Scilab code Exa 8.2 Find the peak emissionwavelength from the device

```
1 //Ex:8.2
2 clc;
3 clear;
4 close;
5 tr=30; // radiative life time in ns
6 tnr=50; // nonradiative life time in ns
7 i=40*10^-3; // drive current in amp
8 pi=28.4*10^-3; // internal power in watt
9 h=6.626*10^-34; // plank constant
10 c=3*10^8; // the speed of light in m/s
11 e=1.602*10^-19; // charge
12 t=tr*tnr/(tr+tnr); // total carrier recombination
    lifetime ns
13 ni=t/tr; // internal quantam efficiency
14 y=(ni*h*c*i)/(e*pi); // peak emission wavelength in m
15 printf("The total carrier recombination lifetime =%f
    ns", t);
16 printf("\n The peak emission wavelength =%f um", y
    *10^6);
```

Scilab code Exa 8.3 Find the external power efficiency of a GaAs planar LED

```
1 //Ex:8.3
2 clc;
3 clear;
4 close;
5 nx=3.6; // refractive index
6 Fn=0.68; // transmission factor
7 pe_pi=(Fn)/(4*nx^2);
8 pi_p=0.3;
```

```

9 nep=pe_pi*pi_p;// external power efficiency
10 printf("The external power efficiency =%f %%", nep
    *100);

```

Scilab code Exa 8.4 Find the coupling efficiency and the optical loss in decibels

```

1 //Ex:8.4
2 clc;
3 clear;
4 close;
5 n=3.6;// core refractive index
6 NA=0.15;// numerical aperture
7 nc=NA^2;// coupling efficiency
8 l_s=-10*log(nc)/log(10);// loss in db
9 pe_pi=0.023*0.0013;// from ex 8.3
10 pc=-10*log(pe_pi)/log(10);// loss in decibels
    relative to Pint
11 printf("The coupling efficiency =%f %%", nc*100);
12 printf("\n The loss =%f db", l_s);
13 printf("\n The loss in decibels relative to Pint=%f
    db", pc);

```

Scilab code Exa 8.5 Calculate the optical power coupled into a 200 um diameter

```

1 //Ex:8.5
2 clc;
3 clear;
4 close;
5 r=45*10^-6;// radius in m
6 NA=0.3;// numerical aperture
7 rd=40;// radiance
8 A=3.14*(r*100)^2;// area in cm^2

```



```

9 pe=3.14*(1-r)*A*rd*NA^2; // optical power coupled
  into the fiber
10 Pe=pe*10^4; // optical power coupled into the fiber
  uW
11 printf("The optical power coupled into the fiber =%f
  uW" , Pe);

```

Scilab code Exa 8.6 What will be the overall efficiency when the frwd voltage across

```

1 //Ex:8.6
2 clc;
3 clear;
4 close;
5 pc=150*10^-6; // coupling power W
6 p=20*10^-3*2; // optical power W
7 npc=pc/p; // overall efficiency
8 Npc=npc*100; // percentage of overall efficiency
9 printf("The percentage of overall efficiency =%f %%"
  , Npc);

```

Scilab code Exa 8.7 Find the number of longitudinal modes of a ruby laser

```

1 //Ex:8.7
2 clc;
3 clear;
4 close;
5 n=1.5; // refractive index
6 L=0.05; // crystal length in m
7 y=0.5*10^-6; // wavelength in m
8 c=3*10^8; // speed of light in m/s
9 q=2*n*L/y; // the number of longitudinal modes
10 df=c/(2*n*L); // frequency separation of the modes in
  Hz

```

```

11 Df=df/10^9; // frequency separation of the modes in
    GHz
12 printf("The number of longitudinal modes =%f", q);
13 printf("\n The frequency separation of the modes =%f
    GHz", Df);

```

Scilab code Exa 8.8 Find the wavelength of optical emission from the device

```

1 //Ex:8.8
2 clc;
3 clear;
4 close;
5 Eg=1.43; // bandgap energy in eV
6 dy=0.15*10^-9;
7 c=3*10^8; // speed of light in m/s
8 y=1.24/Eg; // in um
9 y1=y*10^-6; // wavelength of optical emission in m
10 df=(c*dy)/(y1^2); // the line width in Hz
11 Df=df/10^9; // the line width in GHz
12 printf("The wavelength of optical emission =%f um",
    y);
13 printf("\n The frequency separation of the modes =%d
    GHz", Df);

```

Scilab code Exa 8.9 Find the length of the optical cavity and the number of longit

```

1 //Ex:8.9
2 clc;
3 clear;
4 close;
5 n=3.6; // refractive index
6 c=3*10^8; // speed of light in m/s
7 y=0.85*10^-6; // wavelength in m

```

```

8 df=275*10^9; // frequency separation of the modes in
  Hz
9 L=c/(2*n*df); // crystal length in m
10 L1=L*10^6; // crystal length in um
11 q=2*n*L/y; // the number of longitudinal modes
12 printf("The crystal length =%f um", L1);
13 printf("\n The the number of longitudinal modes =%d"
  , q);
14 printf("\n answer is wrong in textbook");

```

Scilab code Exa 8.10 Find the external power efficiency of the device

```

1 //Ex:8.10
2 clc;
3 clear;
4 close;
5 nt=0.20; // total efficiency
6 Eg=1.43; // bandgap energy in eV
7 V=2.2; // applied voltage in volts
8 nep=(nt*Eg)/V; // external power efficiency
9 Nep=nep*100; // percentage of external power
  efficiency
10 printf("The external power efficiency =%f %%", Nep);

```

Scilab code Exa 8.11 Calculate the divergence angle of LED

```

1 //Ex:8.11
2 clc;
3 clear;
4 close;
5 h=0.35*10^-3; // irradiance W/cm^2
6 po=0.45*10^-3; // power output in watt
7 d=1.5; // separation distance in cm

```

```

8 x=sqrt((4*po)/(3.14*d^2*h)); // divergence angle in
   radians
9 X=(x*180)/3.14; // divergence angle in degree
10 printf("The divergence angle =%f degree ", X);

```

Scilab code Exa 8.12 Calculate the irradiance at the detector

```

1 //Ex:8.12
2 clc;
3 clear;
4 close;
5 ni=0.09; // normal efficiency
6 d=2*2.54; // separation distance in cm
7 x=0.2; // divergence angle in radians
8 vf=2.0; // forward voltage in volts
9 i_f=65*10^-3; // forward current in amp
10 pi=vf*i_f; // input power in Watt
11 po=ni*pi; // output power in Watt
12 H=4*po/(3.14*d^2*x^2); // irradiance in watt/cm^2
13 H1=H*1000; // irradiance in mwatt/cm^2
14 printf("The irradiance =%f mwatt/cm^2 ", H1);

```

Scilab code Exa 8.13 Calculate the internal quantum efficiency for an LED

```

1 //Ex:8.13
2 clc;
3 clear;
4 close;
5 tr=3.5; // relative life time in ms
6 tnr=50; // nonrelative life time in ms
7 ni=tnr/(tr+tnr); // internal quantum efficiency
8 printf("The internal quantum efficiency =%f %%", ni
   *100);

```

Scilab code Exa 8.14 Calculate the optical power complete into the fiber generated

```
1 //Ex:8.14
2 clc;
3 clear;
4 close;
5 ni=0.15; // internal quantum efficiency
6 vf=2.0; // forward voltage in volts
7 i_f=15*10^-3; // forward current in amp
8 x=25; // acceptance angle in degree
9 pi=vf*i_f; // input power in Watt
10 po=ni*pi; // output power in Watt
11 NA=(sin(x*3.14/180));
12 nc=NA^2; // numerical aperture
13 pf=nc*po; // optical power coupled into optical fiber
    in w
14 printf("The optical power coupled into optical fiber
    =%f mW ", pf*1000);
```

Scilab code Exa 8.15 Calculate the radiative life time

```
1 //Ex:8.15
2 clc;
3 clear;
4 close;
5 tnr=10; // nonradiative life time in ns
6 n_inj=0.80; // injection efficiency
7 n_ex=0.60; // extraction efficiency
8 nt=0.025; // total efficiency
9 nr=nt/(n_inj*n_ex); // non radiative life time in ns
10 tr=((1/nr)-1)*tnr; // radiative life time in ns
11 printf("The radiative life time =%d ns", tr);
```

Scilab code Exa 8.16 Calculate the bandwidth of the LED with a rise time of 30 ns

```
1 //Ex:8.16
2 clc;
3 clear;
4 close;
5 tr=30*10^-9; // rise time in s
6 Bw=0.35/tr; // bandwidth in Hz
7 printf("The bandwidth =%f MHz", Bw/10^6);
```

Scilab code Exa 8.17 Compute the divergence angle

```
1 //Ex:8.17
2 clc;
3 clear;
4 close;
5 y=630*10^-9; // operating wavelength in m
6 w=25*10^-6; // spot size in m
7 x=2*y/(3.14*w); // divergence angle in radians
8 x1=x*180/3.14; // divergence angle in degree
9 printf("The divergence angle =%f radians", x);
10 printf("\n The divergence angle =%f degree", x1);
```

Scilab code Exa 8.18 calculate the energy in electron volts associated with light

```
1 //Ex:8.18
2 clc;
3 clear;
4 close;
```

```

5 y1=550*10^-3; // peak of eyes response in um
6 y2=10.6; // standard wavelength in um
7 y3=2.39; // predominant IR line of He-Ne laser in um
8 E1=1.24/y1; // energy in electron volts
9 E2=1.24/y2; // energy in electron volts
10 E3=1.24/y3; // energy in electron volts
11 printf("The energy =%f electron volts", E1);
12 printf("\n The energy =%f electron volts", E2);
13 printf("\n The energy =%f electron volts", E3);

```

Scilab code Exa 8.19 Calculate the cut off wavelength of GaAs material

```

1 //Ex:8.19
2 clc;
3 clear;
4 close;
5 Eg=1.4; // energy in electron volts
6 y=1.24/Eg; // cut off wavelength in um
7 y1=y*1000; // cut off wavelength in nm
8 printf("The cut off wavelength =%d nm", y1);

```

Scilab code Exa 8.20 calculate the corresponding divergence angle

```

1 //Ex:8.20
2 clc;
3 clear;
4 close;
5 y=1200*10^-9; // operating wavelength in m
6 w=5*10^-6; // spot size in m
7 x=2*y/(3.14*w); // divergence angle in radians
8 x1=x*180/3.14; // divergence angle in degree
9 printf("The divergence angle =%f radians", x);
10 printf("\n The divergence angle =%f degree", x1);

```

Scilab code Exa 8.21 Calculate the max angle of acceptance and the coupling effici

```
1 //Ex:8.21
2 clc;
3 clear;
4 close;
5 n1=1.48; // core refractive index
6 n2=1.46; // cladding refractive index
7 NA=sqrt(n1^2-n2^2); // numerical aperture
8 xa=(asin(NA))*(180/%pi); // acceptance angle in
   degree
9 nc=NA^2; // coupling efficiency
10 printf("The acceptance angle =%f degree", xa);
11 printf("\n The coupling efficiency =%f %%", nc*100);
```

Scilab code Exa 8.22 Calculate the frequency separation of the resonant modes of a

```
1 //Ex:8.22
2 clc;
3 clear;
4 close;
5 c=3*10^8; // speed of light in m/s
6 n=3.66; // for GaAs
7 L=150*10^-6; // cavity length in m
8 dv=c/(2*n*L); //frequency separation in Hz
9 dv1=dv/10^12; // frequency separation in GHz
10 h=6.64*10^-34; // plank constant
11 q=1.6*10^-19; // charge of an electron
12 dE=(h*dv)/q; // energy separation eV
13 printf("The frequency separation =%f GHz", dv1);
14 printf("\n The energy separation =%f meV", dE*1000);
```

Scilab code Exa 8.23 Find the LED conversion efficiency from electrical to optical

```
1 //Ex:8.23
2 clc;
3 clear;
4 close;
5 po=2*10^-3; // optical power in watts
6 I=100*10^-3; // current in amp
7 V=2; // applied voltage in volt
8 pe=I*V; // electrical power in watts
9 n=(po/pe)*100; // conversion efficiency
10 printf("The conversion efficiency =%d %%", n);
```

Scilab code Exa 8.24 Find the wavelength of optical emission and determine its liv

```
1 //Ex:8.24
2 clc;
3 clear;
4 close;
5 c=3*10^8; // speed of light in m/s
6 h=6.64*10^-34; // plank constant
7 Eg=1.43; // gap energy in eV
8 y=(1.24*10^-6)/Eg; // wavelength in m
9 dy=0.1*10^-9; // in m
10 df=(dy*c)/y^2; // width in Hz
11 printf("The wavelength =%f um", y*10^6);
12 printf("\n The width =%d GHz", df/10^9);
```

Scilab code Exa 8.25 Find the internal quantum efficiency and internal power level

```

1 //Ex:8.25
2 clc;
3 clear;
4 close;
5 tr=25; // radiative life time in ns
6 tnr=90; // nonradiative life time in ns
7 i=3.5*10^-3; // drive current in amp
8 y=1.31*10^-6; // wavelength in m
9 h=6.625*10^-34; // plank constant
10 c=3*10^8; // the speed of light in m/s
11 e=1.6*10^-19; // charge
12 t=tr*tnr/(tr+tnr); // total carrier recombination
    lifetime ns
13 ni=t/tr; // internal quantum efficiency
14 pi=(ni*h*c*i)/(e*y); // internal power in watt
15 p_int=pi*10^3; // internal power in mW
16 P=p_int/(ni*(ni+1)); // power emitted in mW
17 printf("The total carrier recombination lifetime =%f
    ns", t);
18 printf("\n The internal quantum efficiency =%f ", ni
    );
19 printf("\n The internal power =%f mW", p_int);
20 printf("\n The power emitted =%f mW", P);

```

Scilab code Exa 8.26 calculate the external power efficiency of the device

```

1 //Ex:8.26
2 clc;
3 clear;
4 close;
5 nt=0.18; // total efficiency
6 Eg=1.43; // band gap energy eV
7 V=2.5; // applied voltage in volt
8 n_ex=(nt*(Eg/V))*100; // external efficiency
9 printf("The external efficiency =%f %%", n_ex);

```

Scilab code Exa 8.27 Determine the length of the optical cavity and the longitudinal

```
1 //Ex:8.27
2 clc;
3 clear;
4 close;
5 c=3*10^8; // speed of light in m/s
6 n=3.6; // for GaAs
7 df=278*10^9; // separation in Hz
8 y=0.87*10^-6; // wavelength in m
9 L=c/(2*n*df); // cavity length in m
10 l=L*10^6; // cavity length in um
11 L1=floor(l)*10^-6; // cavity length in m
12 q=(2*n*L1)/y; // number of longitudinal modes
13 printf("The cavity length =%d um", l);
14 printf("\n The number of longitudinal modes =%d", q)
    ;
```

Scilab code Exa 8.28 find the optical loss in dB

```
1 //Ex:8.28
2 clc;
3 clear;
4 close;
5 ac=14; // acceptance angle in degree
6 nc=(sin(ac*3.14/180))^2; // coupling efficiency
7 l_s=-10*log(nc)/log(10); // loss in decibels
8 printf("The coupling efficiency =%f", nc);
9 printf("\n The loss =%f decibels", l_s);
```

Scilab code Exa 8.29 What are the frequency and wavelength spacings

```
1 //Ex:8.29
2 clc;
3 clear;
4 close;
5 c=3*10^8; // speed of light in m/s
6 n=3.7; // for GaAs
7 L=500*10^-6; // cavity length in m
8 y=850*10^-9; //
9 df=c/(2*n*L); //frequency separation in Hz
10 df1=df/10^9; // frequency separation in GHz
11 dy=(y*y)/(2*L*n); // wavelength in m
12 dy1=dy*10^9; // wavelength in nm
13 printf("The frequency separation =%d GHz", df1);
14 printf("\n The wavelength separation =%f nm", dy1);
```

Chapter 9

Optical Detectors

Scilab code Exa 9.1 Calculate the responsivity of the device

```
1 //Ex:9.1
2 clc;
3 clear;
4 close;
5 e_c=550; // number of electron collected
6 p=800; // number of photon incident
7 n=e_c/p; // quantum efficiency
8 e=1.602*10^-19; // charge
9 h=6.626*10^-34; // plank constant
10 c=3*10^8; // speed of light in m/s
11 y=1.3*10^-6 // wavelength in m
12 R=(n*e*y)/(h*c); // responsivity in A/W
13 printf("The responsivity =%f Amp/Watt", R);
```

Scilab code Exa 9.2 Calculate the efficiency of a PIN silicon photodiode

```
1 //Ex:9.2
2 clc;
```

```

3 clear;
4 close;
5 e=1.602*10^-19; // charge
6 h=6.626*10^-34; // plank constant
7 c=3*10^8; // speed of light in m/s
8 y=0.85*10^-6 // wavelength in m
9 R=0.274; // responsivity in A/W
10 n=(R*h*c)/(e*y); // quantum efficiency
11 n1=n*100; // % of quantum efficiency
12 printf("The quantum efficiency =%f %%", n1);

```

Scilab code Exa 9.3 calculate the quantum efficiency and max possible band gap ene

```

1 //Ex:9.3
2 clc;
3 clear;
4 close;
5 e_c=1; // number of electron collected
6 p=3; // number of photon incident
7 n=e_c/p; // quantum efficiency
8 e=1.602*10^-19; // charge
9 h=6.626*10^-34; // plank constant
10 c=3*10^8; // speed of light in m/s
11 y=0.8*10^-6 // wavelength in m
12 Eg=(h*c)/y; // band gap energy in J
13 R=(n*e*y)/(h*c); // responsivity in A/W
14 Po=10^-7; // in W
15 Ip=R*Po; // output photo current
16 printf("The quantum efficiency =%f %%", n*100);
17 printf("\n band gap energy =%f*10^-20 J", Eg*10^20);
18 printf("\n The output photo current =%f nA", Ip
    *10^9);

```

Scilab code Exa 9.4 calculate the responsivity and received optical power and

```
1 //Ex:9.4
2 clc;
3 clear;
4 close;
5 n=0.50; // quantum efficiency
6 e=1.602*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=0.85*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Ip=10^-6; // mean photo current
12 Po=Ip/R; // received optical power in W
13 f=c/y;
14 re=(n*Po)/(h*f);
15 rp=re/n; // number of received photons
16 printf("The responsivity =%f A/W", R);
17 printf("\n The received optical power =%f uW", Po
    *10^6);
18 printf("\n The number of received photons =%f*10^13
    photons/sec", rp/10^13);
```

Scilab code Exa 9.5 Show that a GaAs photodetector will cease to operate above 087

```
1 //Ex:9.5
2 clc;
3 clear;
4 close;
5 h=6.626*10^-34; // plank constant
6 c=3*10^8; // speed of light in m/s
7 Eg=1.43; // in eV
8 Eg1=Eg*1.602*10^-19; // in J
9 y=(h*c)/Eg1; // cut off wavelength in m
10 printf("The cut off wavelength =%f um", y*10^6);
```

Scilab code Exa 9.6 What will be the max response time for the device

```
1 //Ex:9.6
2 clc;
3 clear;
4 close;
5 vd=2.5*10^4; // carrier velocity in m/s
6 w=30*10^-6; // width in m
7 Bm=vd/(2*pi*w);
8 Tm=1/Bm; // max response time in sec
9 Tm1=Tm*10^9; // max response time in ns
10 printf("The max response time =%f ns", Tm1);
```

Scilab code Exa 9.7 Find the multiplication factor under these conditions

```
1 //Ex:9.7
2 clc;
3 clear;
4 close;
5 n=0.65; // quantum efficiency
6 e=1.602*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=0.85*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Po=0.35*10^-6; // in W
12 Ip=R*Po; // output photo current
13 I=9*10^-6; // output current in A
14 M=I/Ip; // multiplication factor
15 M1=ceil(M);
16 printf("The multiplication factor =%d", M1);
```

Scilab code Exa 9.8 Find wavelength at which photodiode operating and what will be

```
1 //Ex:9.8
2 clc;
3 clear;
4 close;
5 n=0.50; // quantum efficiency
6 e=1.602*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 Eg=1.5*10^-19; // in J
10 y=(h*c)/Eg; // cut off wavelength in m
11 f=c/y;
12 R=(n*e)/(h*f); // responsivity in A/W
13 Ip=2.7*10^-6; // photo current in A
14 Po=Ip/R; // incident optical power in W
15 Po1=Po*10^6; // incident optical power in uW
16 printf("The cut off wavelength =%f um", y*10^6);
17 printf("\n The responsivity =%f A/W ", R);
18 printf("\n The incident optical power =%f uW", Po1);
```

Scilab code Exa 9.9 Calculate the responsivity of a detector

```
1 //Ex:9.9
2 clc;
3 clear;
4 close;
5 n=0.15; // quantum efficiency
6 e=1.6*10^-19; // charge
7 h=6.63*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=0.85*10^-6; // cut off wavelength in m
```

```

10 f=c/y; // frequency in Hz
11 R=(n*e)/(h*f); // responsivity in A/W
12 printf("The responsivity =%f A/W ", R);

```

Scilab code Exa 9.10 Calculate the quantum efficiency and responsivity of the detector

```

1 //Ex:9.10
2 clc;
3 clear;
4 close;
5 Iph=75*10^-6; // output photocurrent in A
6 y=0.85; // operating wavelength in um
7 Pi=750*10^-6; // incident optical power in uW
8 R=Iph/Pi; // responsivity in A/W
9 n=1.24*R/y; // external quantum efficiency
10 n1=n*100; // percentage of external quantum
    efficiency
11 printf("The responsivity =%f A/W ", R);
12 printf("\n The external quantum efficiency =%f%% ",
    n1);

```

Scilab code Exa 9.11 Calculate the transit time for silicon photodiode

```

1 //Ex:9.11
2 clc;
3 clear;
4 close;
5 Vs=10^5; // saturation in m/s
6 W=7*10^-6; // depletion layer width in m
7 tr=W/Vs; // transit time in sec
8 printf("The transit time =%f ps", tr*10^12);

```

Scilab code Exa 9.12 Calculate the max 3dB bandwidth for a silicon

```
1 //Ex:9.12
2 clc;
3 clear;
4 close;
5 Vs=3*10^4; // saturation in m/s
6 W=25*10^-6; // depletion layer width in m
7 tr=W/Vs; // transit time in sec
8 f=0.35/tr; // max 3 dB bandwidth Hz
9 f1=f/10^6; // max 3 dB bandwidth Hz
10 printf("The max 3 dB bandwidth =%d MHz", f1);
11 printf("\n The answer is wrong in the textbook");
```

Scilab code Exa 9.13 Find the transit time and junction capacitance and time constant

```
1 //Ex:9.13
2 clc;
3 clear;
4 close;
5 Vs=3*10^4; // saturation in m/s
6 W=25*10^-6; // depletion layer width in m
7 E=10.5*10^-11; // in F/m
8 RL=15*10^6; // load resistor in ohm
9 A=0.25*10^-6; // area in m^2
10 tr=W/Vs; // transit time in sec
11 Cj=E*A/W; // junction capacitance in F
12 t=RL*Cj; // time constant in sec
13 printf("The transit time =%f ns", tr*10^9);
14 printf("\n The junction capacitance =%f pF", Cj
    *10^12);
15 printf("\n The time constant =%f us", t*10^6);
```

Scilab code Exa 9.14 calculate the cut off wavelength for silicon and germanium PI

```
1 //Ex:9.14
2 clc;
3 clear;
4 close;
5 Eg1=1.12; // band gap for Si in eV
6 Eg2=0.667; // band gap for Ge in eV
7 y_si=1.24/Eg1; // cut off wavelength for Si in um
8 y_he=1.24/Eg2; // cut off wavelength for Ge in um
9 printf("The cut off wavelength for Si =%f um", y_si
   );
10 printf("\n The cut off wavelength for Ge =%f um",
   y_he);
```

Scilab code Exa 9.15 Calculate the responsivity and received optical power and cor

```
1 //Ex:9.15
2 clc;
3 clear;
4 close;
5 n=0.50; // quantum efficiency
6 e=1.6*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=0.9*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Ip=10^-6; // mean photo current
12 Po=Ip/R; // received optical power in W
13 f=c/y;
14 re=(n*Po)/(h*f);
```

```

15 rp=re/n; // number of received photons
16 printf("The responsivity =%f A/W", R);
17 printf("\n The received optical power =%f uW", Po
    *10^6);
18 printf("\n The number of received photons =%f*10^13
    photons/sec", rp/10^13);

```

Scilab code Exa 9.16 What will be the output photocurrent

```

1 //Ex:9.16
2 clc;
3 clear;
4 close;
5 R=0.40; // Responsivity in A/W
6 m=100*10^-6; // incident flux in W/m-m
7 A=2; // area in m-m
8 Po=m*A; // incident power in W
9 Ip=R*Po; // photon current in A
10 printf("The photon current =%d uA", Ip*10^6);

```

Scilab code Exa 9.17 Determine the operating wavelength of the device and Calculate

```

1 //Ex:9.17
2 clc;
3 clear;
4 close;
5 n=0.65; // quantum efficiency
6 e=1.602*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 Eg=1.5*10^-19; // in J
10 y=(h*c)/Eg; // cut off wavelength in m
11 f=c/y;

```

```

12 R=(n*e)/(h*f); // responsivity in A/W
13 Ip=2.5*10^-6; // photo current in A
14 Po=Ip/R; // incident optical power in W
15 Po1=Po*10^6; // incident optical power in uW
16 printf("The cut off wavelength =%f um", y*10^6);
17 printf("\n The responsivity =%f A/W ", R);
18 printf("\n The incident optical power =%f uW", Po1);

```

Scilab code Exa 9.18 Determine the wavelength

```

1 //Ex:9.18
2 clc;
3 clear;
4 close;
5 h=6.626*10^-34; // plank constant
6 c=3*10^8; // speed of light in m/s
7 Eg=1.43; // in eV
8 Eg1=Eg*1.602*10^-19; // in J
9 y=(h*c)/Eg1; // cut off wavelength in m
10 printf("The cut off wavelength =%f um", y*10^6);

```

Scilab code Exa 9.19 Find the optical gain and common emitter gain

```

1 //Ex:9.19
2 clc;
3 clear;
4 close;
5 n=0.45; // quantum efficiency
6 h=6.62*10^-34; // plank constant
7 c=3*10^8; // speed of light in m/s
8 y=1.2*10^-6; // cut off wavelength in m
9 Ic=20*10^-6; // collector current in A
10 Po=120*10^-6; // incident optical power in W

```

```

11 e=1.602*10^-19; // charge
12 Go=(h*c*Ic)/(y*Po*e); // optical gain
13 h_e=Go/n; // common emitter gain
14 printf("The optical gain =%f", Go);
15 printf("\n The common emitter gain =%f", h_e);

```

Scilab code Exa 9.20 Calculate the multiplication factor of diode

```

1 //Ex:9.20
2 clc;
3 clear;
4 close;
5 n=0.5; // quantum efficiency
6 e=1.602*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=1.3*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Po=0.4*10^-6; // in W
12 Ip=R*Po; // output photo current
13 I=8*10^-6; // output current in A
14 M=I/Ip; // multiplication factor
15 printf("The multiplication factor =%d", M);

```

Scilab code Exa 9.21 Calculate the multiplication factor of APD

```

1 //Ex:9.21
2 clc;
3 clear;
4 close;
5 n=0.85; // quantum efficiency
6 e=1.6*10^-19; // charge
7 h=6.625*10^-34; // plank constant

```

```

8 c=3*10^8; // speed of light in m/s
9 y=0.9*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Po=0.6*10^-6; // in W
12 Ip=R*Po; // output photo current
13 I=10*10^-6; // output current in A
14 M=I/Ip; // multiplication factor
15 printf("The multiplication factor =%d", M);

```

Scilab code Exa 9.22 Calculate the quantum efficiency and wavelength of operation

```

1 //Ex:9.22
2 clc;
3 clear;
4 close;
5 e_c=1.2*10^11; // number of electron collected
6 p=2*10^11; // number of photon incident
7 n=e_c/p; // quantum efficiency
8 e=1.602*10^-19; // charge
9 h=6.626*10^-34; // plank constant
10 c=3*10^8; // speed of light in m/s
11 E=1.5*10^-19; // energy in J
12 y=(h*c)/E // wavelength in m
13 R=(n*e*y)/(h*c); // responsivity in A/W
14 Ip=2.6*10^-6; // photocurrent in A
15 Po=Ip/R; // incident optical power in W
16 printf("The quantum efficiency =%d %%", n*100);
17 printf("\n The wavelength =%f um", y*10^6);
18 printf("\n The responsivity =%f Amp/Watt", R);
19 printf("\n The incident optical power =%f uW", Po
    *10^6);

```

Scilab code Exa 9.23 Calculate the multiplication factor of an APD


```

1 //Ex:9.23
2 clc;
3 clear;
4 close;
5 n=0.40; // quantum efficiency
6 e=1.602*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=1.35*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Po=0.2*10^-6; // in W
12 Ip=R*Po; // output photo current
13 I=4.9*10^-6; // output current in A
14 M=I/Ip; // multiplication factor
15 printf("The multiplication factor =%d", M);

```

Scilab code Exa 9.24 Find the responsivity and optical power and corresponding num

```

1 //Ex:9.24
2 clc;
3 clear;
4 close;
5 n=0.55; // quantum efficiency
6 e=1.6*10^-19; // charge
7 h=6.626*10^-34; // plank constant
8 c=3*10^8; // speed of light in m/s
9 y=0.85*10^-6 // wavelength in m
10 R=(n*e*y)/(h*c); // responsivity in A/W
11 Ip=2*10^-6; // mean photo current
12 Po=Ip/R; // received optical power in W
13 re=(n*Po*y)/(h*c); // number of received photons
14 printf("The responsivity =%f A/W", R);
15 printf("\n The received optical power =%f uW", Po
    *10^6);
16 printf("\n The number of received photons =%f*10^13

```

```
photons/sec", re/10^13);
```

Scilab code Exa 9.25 Find the wavelength of incident radiation and output photocur

```
1 //Ex:9.25
2 clc;
3 clear;
4 close;
5 h=6.625*10^-34; // plank constant
6 c=3*10^8; // speed of light in m/s
7 n=1; // quantum efficiency
8 e=1.602*10^-19; // charge
9 E=1.3*10^-19; // energy in J
10 y=(h*c)/E; // wavelength in m
11 M=18; // multiplication factor
12 rp=10^13; // no. of photon per sec
13 Po=rp*E; // output power in w
14 Ip=(n*Po*e)/E; // output photocurrent in A
15 I=M*Ip; // photocurrent in A
16 printf("The wavelength =%f um", y*10^6);
17 printf("\n The output power =%f uW", Po*10^6);
18 printf("\n The photocurrent =%f uA", I*10^6);
```

Scilab code Exa 9.26 calculate the quantum efficiency and max possible band gap en

```
1 //Ex:9.26
2 clc;
3 clear;
4 close;
5 e_c=2*10^10; // number of electron collected
6 p=5*10^10; // number of photon incident
7 n=e_c/p; // quantum efficiency
8 e=1.602*10^-19; // charge
```

```

 9 h=6.626*10^-34; // plank constant
10 c=3*10^8; // speed of light in m/s
11 y=0.85*10^-6; // wavelength in m
12 y1=0.85; // wavelength in um
13 Eg=(h*c)/y; // bandgap energy in J
14 Eg1=1.24/y1; // bandgap energy in terms of eV
15 Po=10*10^-6; // incident power in W
16 Ip=(n*e*Po)/Eg; // mean output photocurrent in A
17 printf("The quantum efficiency =%d %%", n*100);
18 printf("\n The bandgap energy =%f*10^-19 J", Eg
    *10^19);
19 printf("\n The bandgap energy =%f eV", Eg1);
20 printf("\n The mean output photocurrent =%f uA", Ip
    *10^6);

```

Chapter 10

Optical Fiber Systems

Scilab code Exa 10.1 Determine the voltage needed to effect a phase change of pi r

```
1 //Ex:10.1
2 clc;
3 clear;
4 close;
5 r=30.8*10^-12; // electro optice coefficient in m/V
6 L=3*10^-2; // length in m
7 y=1.3*10^-6; // wavelength in m
8 n=2.1;
9 d=30*10^-6; // distance between the electrodes in m
10 V=(y*d)/((n)^3*r*L); // voltage required to have a pi
    radian phase change in volt
11 printf("The voltage required to have a pi radian
    phase change =%f volt", V);
```

Scilab code Exa 10.2 Calculate the total channel loss

```
1 //Ex:10.2
2 clc;
```

```

3 clear;
4 close;
5 a_fc=4; // fider cable loss in dB/km
6 aj=0.7; // splice loss in db/km
7 L=5; // length in km
8 a_cr1=4; // connector losses
9 a_cr2=3.5; // connector losses
10 CL=(a_fc+aj)*L+(a_cr1+a_cr2); // total channel loss
    in dB
11 printf("The total channel loss =%d dB", CL);

```

Scilab code Exa 10.3 Determine the dispersion equalisation penalty and estimate pe

```

1 //Ex:10.3
2 clc;
3 clear;
4 close;
5 p=0.5*10^-9; // pulse broadening in s/km
6 L=12; // length in km
7 Pt=p*sqrt(L); // with mode coupling, the total rms
    broadening in s
8 BT=20*10^6; //
9 DL=2*(2*Pt*BT*sqrt(2))^4; // dispersion equalization
    penalty in dB
10 Pt1=p*L; // without mode coupling, the total rms
    broadening in s
11 DL1=2*(2*Pt1*BT*sqrt(2))^4; // without mode coupling,
    equalization penalty in dB
12 DL2=2*(2*Pt1*150*10^6*sqrt(2))^4; // without mode
    coupling, dispersion equalization penalty with 125
    Mb/s
13 DL3=2*(2*Pt*125*10^6*sqrt(2))^4; // with mode
    coupling, dispersion equalization penalty with 125
    Mb/s
14 printf("with mode coupling, the total rms broadening

```

```

    =%f ns", Pt*10^9);
15 printf("\n The dispersion equalization penalty =%f
    dB", DL*10^4);
16 printf("\n without mode coupling, the total rms
    broadening =%f dB", Pt1*10^9);
17 printf("\n without mode coupling, equalization
    penalty =%f dB", DL1);
18 printf("\n without mode coupling, dispersion
    equalization penalty with 125 Mb/s =%f dB", DL2);
19 printf("\n with mode coupling, dispersion
    equalization penalty with 125 Mb/s =%f dB", DL3);
20 printf("\n The answer is wrong in the textbook");

```

Scilab code Exa 10.4 Find the possible link length without employing repeaters and

```

1 //Ex:10.4
2 clc;
3 clear;
4 close;
5 Pi=-2.5;// mean optical power launched into the
    fiber in dBm
6 Po=-45;// mean output optical power available at the
    receiver in dBm
7 a_fc=0.35;// fider cable loss in dB/km
8 aj=0.1;// splice loss in db/km
9 a_cr=1;// connector losses
10 Ma=6;// safety margin in dB
11 L=(Pi-Po-a_cr-Ma)/(a_fc+aj);// length in km when
    system operating at 25 Mbps
12 Po1=-35;// mean output optical power available at
    the receiver in dBm
13 L1=(Pi-Po1-a_cr-Ma)/(a_fc+aj);// length in km when
    system operating at 350 Mbps
14 printf("The length when system operating at 25 Mbps
    =%f km", L);

```

```
15 printf("\n The length when system operating at 350
    Mbps =%f km", L1);
```

Scilab code Exa 10.5 Find the optical power budget for an optical link

```
1 //Ex:10.5
2 clc;
3 clear;
4 close;
5 Tx=-80; // transmitter output in dBm
6 Rx=-40; // receiver sensitivity in dBm
7 sm=32; // system margin in dB
8 L=10; // in km
9 fl=2*L; // fider loss in dB
10 cl=1; // detector coupling loss in dB
11 t1=0.4*8; // total splicing loss in dB
12 ae=5; // angle effects & future splice in dB
13 ta=29.2; // total attenuation in dB
14 Ep=2.8; // excess power margin in dB
15 printf("The fider loss =%f dB", fl);
16 printf("\n The total splicing loss =%f dB", t1);
17 printf("\n The fangle effects & future splice =%f dB
    ", ae);
18 printf("\n The total attenuation =%f dB", ta);
19 printf("\n The excess power margin =%f dB", Ep);
20 printf("\n hence the system can operate with small
    excess power margin")
```

Scilab code Exa 10.6 What is the max transmission distance and if transmission is

```
1 //Ex:10.6
2 clc;
3 clear;
```

```

4  close;
5  Lc=1; // connector loss in db
6  Ls=5; // star coupler insertion loss in dB
7  af=2; // fider loss in dB
8  Ps=-14; // transmitted power in dBm
9  Pr=-49; // receiver sensitivity in dBm
10 sm=6; // system margin in dB
11 N=16;
12 L=(Ps-Pr-Ls-4*Lc-(10*log(N))/log(10)-sm)/(2*af); //
    max transmission length in km when transmission
    star coupler is used
13 N1=32;
14 L1=(Ps-Pr-Ls-4*Lc-(10*log(N1))/log(10)-sm)/(2*af); //
    max transmission length in km when reflection
    star coupler is used
15 printf("The max transmission length when
    transmission star coupler is used =%f km", L);
16 printf("\n The max transmission length when
    reflection star coupler is used =%f km", L1);

```

Scilab code Exa 10.7 Find the rise time and the data rate for a system supporting

```

1  //Ex:10.7
2  clc;
3  clear;
4  close;
5  y=860*10^-9; // wavelength in m
6  L=5000; // length in m
7  X=0.024;
8  dy=20*10^-9; // spectral width in m
9  dts=6*10^-9; // silica optical link rise time in s
10 dtr=8*10^-9; // detector rise in s
11 c=3*10^8; // speed of light in m/s
12 dtm=-(L*dy*X)/(c*y); // material dispersion delay
    time in s

```



```

13 id=2.5*10^-12; // intermodel dispersion in s/m
14 dti=id*L; // intermodel dispersion delay time
15 dtsy=sqrt((dts^2)+(dtr^2)+(dtm^2)+(dti^2)); // system
    rise time in s
16 Br_max=0.7/dtsy; // max bit rate for NRZ coding in
    bit/s
17 Br_max1=0.35/dtsy; // max bit rate for RZ coding in
    bit/s
18 printf("The system rise time =%f ns", dtsy*10^9);
19 printf("\n The max bit rate for NRZ coding =%f Mbit/
    s", Br_max/10^6);
20 printf("\n The max bit rate for RZ coding =%f Mbit/s
    ", Br_max1/10^6);

```

Scilab code Exa 10.8 Find the modal dispersion limited transmission distance

```

1 //Ex:10.8
2 clc;
3 clear;
4 close;
5 Br=50*10^6; // data rate in b/s
6 c=3*10^8; // speed of light in m/s
7 n1=1.47; //
8 dl=0.02; //
9 n12=n1*dl; // the difference b/w n1 and n2
10 L_si=(0.35*c)/(n12*Br); // transmission distance for
    Si fiber
11 L_GI=(2.8*c*n1^2)/(2*n1*n12*Br); // transmission
    distance for GRIN fiber
12 printf("The transmission distance for Si fiber =%f m
    ", L_si);
13 printf("\n The transmission distance for GRIN fiber
    =%f m", L_GI);

```

Scilab code Exa 10.9 Find the material dispersion limited transmission distance

```
1 //Ex:10.9
2 clc;
3 clear;
4 close;
5 Br=20*10^6; // data rate in b/s
6 c=3*10^8; // speed of light in m/s
7 y=86*10^-9; // wavelength in m
8 dy=30*10^-9; // spectral width in m
9 X=0.024;
10 Tb=1/Br;
11 Lmax=(0.35*Tb*c*y)/(dy*X); // material dispersion
    limited transmission distance for RZ coding in m
12 printf("The material dispersion limited transmission
    distance =%d m", Lmax);
```

Scilab code Exa 10.10 Find the material dispersion limited distance and modal disp

```
1 //Ex:10.10
2 clc;
3 clear;
4 close;
5 y=860*10^-9; // wavelength in m
6 c=3*10^8; // speed of light in m/s
7 n1=1.47; //
8 d1=0.02; //
9 n12=n1*d1; // the difference b/w n1 and n2
10 La=1/1000; // loss a in dB/m
11 Pr=-65; // receiver power in dB
12 Pt=-5; // transmitted power in dB
13 dy=30*10^-9; // line width in m
```

```
14 X=0.024;
15 Lmax=(0.35*c*y)/(dy*X); // material dispersion
    limited distance for RZ coding in m
16 L_GI=(1.4*c*n1)/(n12); // model dispersion limited
    distance for RZ coding in m
17 L_At=(Pt-Pr)/(La); // attenuation limited distance
    for RZ coding in m
18 printf("The material dispersion limited distance =%f
    *10^10*1/Br m", Lmax/10^10);
19 printf("\n The model dispersion limited distance =%f
    *10^10*1/Br m", L_GI/10^10);
20 printf("\n The attenuation limited distance =%d-20
    log(Br) km", L_At/10^3);
```
