

Scilab Textbook Companion for  
Optical Fiber Communication  
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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 1

## Introduction to Optical Fiber Communication

Scilab code Exa 1.10.1 Computing maximum capacity of channel

```
1 // Example 1.10.1 page 1.19
2
3 clc;
4 clear;
5
6 Bandwidth = 2d6; //Bandwidth of channel
7 Signal_to_Noise_ratio = 1; //Signal to
   Noise ratio of channel
8
9 Capacity = Bandwidth * log2(1 +
   Signal_to_Noise_ratio); //computing capacity
10 Capacity=Capacity/10^6;
11
12 printf("Maximum capacity of channel is %d Mb/sec.",
   Capacity);
```

---

**Scilab code Exa 1.13.1** Determine duration of shortest and widest optical pulse

```
1 // Example 1.13.1 page 1.30
2
3 clc;
4 clear;
5
6 Bit_rate = 2d9; // bit rate of channel
7 // Given sequence is 010111101110
8
9 Shortest_duration = 1 * (1/Bit_rate); //
   shortest duration is '1'
10 Widest_duration = 4 * (1/Bit_rate); //widest
   duration is '1111'
11
12 Shortest_duration=Shortest_duration*10^9; //
   Converting into nano seconds
13 Widest_duration=Widest_duration*10^9; //
   Converting into nano seconds
14
15 printf("\nShortest duration is %.1f nano second.",
   Shortest_duration);
16 printf("\nWidest duration is %d nano second.",
   Widest_duration);
```

---

# Chapter 2

## Optical Fibers

Scilab code Exa 4.q Find briefringence

```
1 // Question 4 page 2.75
2
3 clc;
4 clear;
5
6 L_BL=8d-2; //beat length
7
8 Br=2*3.14/L_BL; //computing modal briefringence
9 printf("\nModal briefringence is %.1f per meter.",Br
   );
```

---

Scilab code Exa 5.q Determine modal briefringence

```
1 // Question 5 page 2.76
2
3 clc;
4 clear;
5
```

```

6 L_BL=0.6d-3;    //beat length
7 lamda=1.4d-6;  //wavelength
8 L_BL1=70;
9 Bh=lamda/L_BL;    //computing high briefringence
10 B1=lamda/L_BL1;    //computing low briefringence
11
12 printf("\nHigh briefringence is %.2e.\nLow
        briefringence is %.1e.",Bh,B1);

```

---

**Scilab code Exa 2.3.1** Estimate numerical aperture and critical angle

```

1 // Example 2.3.1 page 2.10
2
3 clc;
4 clear;
5
6 delta = 1/100;    // Relative refractive
        difference index
7 n1=1.46;    // Core refractive index (assumption
        )
8
9 NA= n1*sqrt(2*delta);    //computing numerical
        aperture
10 theta = 1 - delta;
11 Critical_angle = asind(theta); //computing critical
        angle
12
13 printf("\nNumerical aperture is %.2f.\nCritical
        angle is %.1f degree.",NA,Critical_angle);

```

---

**Scilab code Exa 2.3.2** Estimate numerical aperture

```

1 // Example 2.3.2 page 2.10

```

```

2
3 clc;
4 clear;
5
6 delta = 1/100;      // Relative refractive
   difference index
7 n1=1.47;           // Core refractive index
8
9 NA= n1*sqrt(2*delta); //computing numerical
   aperture
10
11 printf("\\nNumerical aperture is %.1f.",NA)

```

---

**Scilab code Exa 2.4.1** Determine critical angle numerical aperture and acceptance angle

```

1 // Example 2.4.1 page 2.11
2
3 clc;
4 clear;
5
6 n1=1.49;           //core refractive index
7 n2=1.45;           //cladding refractive index
8
9 phi = asind(n2/n1); //computing critical angle
10 NA = sqrt(n1^2 - n2^2); //computing numerica
   aperture
11 theta= asind(NA); //computing acceptance angle
12
13 printf("\\nCritical angle is %.2f degrees.\\nNumerical
   aperture is %.3f.\\nAcceptance angle is %.2f
   degree.",phi,NA,theta);
14
15 //answer in the book for Numerical aperture is
   0.343, deviation of 0.003

```

```
16 //answer in the book for Acceptance angle is 20.24,  
    deviation of 0.18
```

---

**Scilab code Exa 2.4.2** Determine numerical aperture

```
1 // Example 2.4.2 page 2.12  
2  
3 clc;  
4 clear;  
5  
6 delta = 1/100; // Relative refractive  
    difference index  
7 n1=1.47; // Core refractive index  
8  
9 NA= n1*sqrt(2*delta); //computing numerical  
    aperture  
10 printf("\nNumerical aperture is %.1f.",NA)
```

---

**Scilab code Exa 2.4.3** Find numerical aperture and acceptance angle

```
1 // Example 2.4.3 page 2.12  
2  
3 clc;  
4 clear;  
5  
6 delta = 1.2/100; // Relative refractive  
    difference index  
7 n1=1.45; // Core refractive index  
8  
9 NA= n1*sqrt(2*delta); //computing numerical  
    aperture  
10 Acceptance_angle = asind(NA); //computing  
    acceptance angle
```

```

11 si = %pi * NA^2;           //computing solid acceptance
    angle
12
13 printf("\nNumerical aperture is %.3f.\nAcceptance
    angle is %.2f degree.\nSolid acceptance angle is
    %.3f radians.",NA,Acceptance_angle,si);
14
15 //answer in the book for Numerical aperture is
    0.224, deviation of 0.001
16 //answer in the book for solid acceptance angle is
    0.157, deviation of 0.002

```

---

#### Scilab code Exa 2.4.4 Find acceptance angle

```

1 // Example 2.4.4 page 2.13
2
3 clc;
4 clear;
5
6 NA = 0.45;           // Numerical Aperture
7
8 Acceptance_angle = asind(NA); //computing
    acceptance angle.
9 printf("\nAcceptance angle is %.1f degree.",
    Acceptance_angle);

```

---

#### Scilab code Exa 2.4.5 Compute numerical aperture and full cone angle

```

1 // Example 2.4.5 page 2.13
2
3 clc;
4 clear;
5

```

```

6 diameter = 1;           //Diameter in centimeter
7 Focal_length = 10;      //Focal length in centimeter
8
9 radius=diameter/2;     //computing radius
10 Acceptance_angle = atand(radius/Focal_length); //
    computing acceptance angle
11 Conical_full_angle = 2*Acceptance_angle; //
    computing conical angle
12 Solid_acceptance_angle = %pi*Acceptance_angle^2;
    //computing solid acceptance angle
13 NA = sqrt(Solid_acceptance_angle/%pi); //
    computing Numerical aperture
14
15 printf("\nNumerical aperture is %.2f.\nConical full
    angle is %.2f degree.",NA,Conical_full_angle);

```

---

**Scilab code Exa 2.5.1** Find acceptance angle

```

1 // Example 2.5.1 page 2.17
2
3 clc;
4 clear;
5
6 NA = 0.45           //Numerical aperture
7 betaB = 45         // Skew ray change direction by 90
    degree at each reflection
8
9 Meridional_theta = asind(NA); //computing
    acceptacne angle for meridoinal ray
10 Skew_theta = asind(NA/cosd(betaB)); //computing
    acceptacne angle for skew ray
11
12 printf("\nAcceptacne angle for Meridoinal ray is %.2
    f degree.\nAcceptance angle for Skew ray %.1f
    degree.",Meridional_theta,Skew_theta);

```



---

**Scilab code Exa 2.7.1** Find normalized frequency and number of guided modes

```
1 // Example 2.7.1 page 2.23
2
3 clc;
4 clear;
5
6 core_diameter=78d-6; //core diameter
7 delta=1.4/100; //relative index difference
8 lamda=0.8d-6; //operating wavelength
9 n1=1.47; //core refractive index
10
11 a=core_diameter/2; //computing core radius
12 v= 2*3.14*a*n1*sqrt(2*delta)/lamda; //computing
    normalized frequency
13 M=(v)^2/2; //computing guided modes
14
15 printf("\nNormalized Frequency is %.3f.\nTotal
    number of guided modes are %.1f",v,M);
16 printf("\nNOTE – Calculation error, answer in the
    book for normalized frequency is given as 75.156
    which should be 75.306.");
17
18 //answer in the book for normalized frequency is
    given as 75.156(incorrect) and for Guided modes
    is 5648.5(incorrect)
```

---

**Scilab code Exa 2.7.2** Find wavelength

```
1 // Example 2.7.2 page 2.24
```

```

2
3 clc;
4 clear;
5
6 n1=1.47      //refractive index of core
7 a=4.3d-6;   //radius of core
8 delta=0.2/100 //relative index difference
9
10 lamda= 2*3.14*a*n1*sqrt(2*delta)/2.405; //
    computing wavelength
11 lamda=lamda*10^9;
12 printf("Wavelength of fiber is %d nm.",lamda);
13 printf("\\n\\nNote:Calculation error , answer given in
    the book (1230nm) is incorrect.");
14
15 //answer in the book is given as 1230nm which is
    incorrect.

```

---

**Scilab code Exa 2.7.3** Find core radius NA and acceptance angle

```

1 // Example 2.7.3 page 2.24
2
3 clc;
4 clear;
5
6 n1=1.482;    //refractive index of core
7 n2=1.474;    //refractive index of cladding
8 lamda=820d-9; //Wavelength
9
10 NA=sqrt(n1^2 - n2^2); //computing Numerical
    aperture
11 theta= asind(NA); //computing acceptance
    angle
12 solid_angle=%pi*(NA)^2; //computing solid angle
13 a=2.405*lamda/(2*3.14*NA); //computing core

```

```

    radius
14 a=a*10^6;
15
16 printf("\nNumerical aperture is %.3f.\nAcceptance
    angle is %.1f degrees.\nSolid angle is %.3f
    radians.\nCore radius is %.2f micrometer.",NA,
    theta,solid_angle,a);
17
18 //answer in the book for Numerical aperture is
    0.155, deviation of 0.001.
19 //answer in the book for acceptance angle is 8.9,
    deviation of 0.1.
20 //answer in the book for solid acceptance angle is
    0.075, deviation of 0.001.
21 //answer in the book for core radius is 2.02
    micrometer, deviation of 0.02 micrometer.

```

---

#### Scilab code Exa 2.7.4 Estimate number of guided modes

```

1 // Example 2.7.4 page 2.25
2
3 clc;
4 clear;
5
6 NA=0.16 //Numerical aperture
7 n1=1.45 //core refractive index
8 d=60d-6 //core diameter
9 lamda=0.82d-6 //wavelength
10
11 a=d/2; //core radius
12 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
13 v=round(v);
14 M=v^2/2; //computing guided modes
15 M=floor(M);

```

16

```
17 printf("if normalized frequency is taken as %d, then  
    %d guided modes.",v,M);
```

---

**Scilab code Exa 2.7.5** Determine normalized frequency and number of guided modes

```
1 // Example 2.7.5 page 2.26  
2  
3 clc;  
4 clear;  
5  
6 n1=1.48; //core refractive index  
7 n2=1.46; //cladding refractive index  
8 a=25d-6; //core radius  
9 lamda0=850d-9;  
10 lamda1=1320d-9;  
11 lamda2=1550d-9;  
12  
13 NA=sqrt(n1^2-n2^2); //computing numerical  
    aperture  
14 v0=2*pi*a*NA/lamda0; //computing normalized  
    frequency  
15 M0=v0^2/2; //computing guided modes  
16 M0=floor(M0);  
17 v1=2*pi*a*NA/lamda1;  
18 M1=v1^2/2;  
19 M1=floor(M1);  
20 v2=2*pi*a*NA/lamda2;  
21 M2=v2^2/2;  
22 M2=floor(M2);  
23 lamda0=lamda0*10^9;  
24 lamda1=lamda1*10^9;  
25 lamda2=lamda2*10^9;  
26 printf("\nfor %d nm, normalized frequency = %.2f ,
```

```

    Guided modes = %d.",lamda0,v0,M0);
27 printf("\nfor %d nm, normalized frequency = %.2f,
    Guided modes = %d.",lamda1,v1,M1);
28 printf("\nfor %d nm, normalized frequency = %.2f,
    Guided modes = %d.",lamda2,v2,M2);
29
30 //answers in the book (sligt deviations in each)
31 //for 850 nm, normalized frequency = 45, Guided
    modes = 1012
32 //for 1320 nm, normalized frequency = 28.91, Guided
    modes = 419
33 //for 1550 nm, normalized frequency = 24.67, Guided
    modes = 304

```

---

#### Scilab code Exa 2.7.6 Estimate diameter of core

```

1 // Example 2.7.6 page 2.27
2
3 clc;
4 clear;
5
6 delta=1/100; //relative refractive index
7 n1=1.3; //core refractive index
8 lamda=1100d-9; //wavelength
9
10 a=(2.4*lamda)/(2*3.14*n1*sqrt(2*delta)); //
    computing radius of core
11 d=2*a; //computing diameter of core
12 a=a*10^6;
13 d=d*10^6;
14 printf("\nCore radius is %.1f micrometer\nCore
    diameter is %.1f micrometer",a,d);
15 printf("\nNOTE – In the book they have asked
    diameter of core. However, they have calculated
    only radius.");

```

---

**Scilab code Exa 2.7.7** Calculate NA and maximum angle of entrance

```
1 // Example 2.7.7 page 2.27
2
3 clc;
4 clear;
5
6 n1=1.48; //refractive index of core
7 n2=1.46; //refractive index of cladding
8
9 NA=sqrt(n1^2-n2^2); //computing Numerical
  aperture
10 theta=asind(NA); //computing acceptance angle
11
12 printf("\nNumerical aperture is %.3f.\nAcceptance
  angle is %.2f degrees.",NA,theta);
13
14 //answer in the book for Numerical aperture is
  0.244, deviation of 0.002.
15 //answer in the book for Acceptance angle is 14.12,
  deviation of 0.09.
```

---

**Scilab code Exa 2.7.8** Calculate normalized frequency and number of guided modes

```
1 // Example 2.7.8 page 2.28
2
3 clc;
4 clear;
5
6 core_diameter=80d-6; //core diameter
```

```

7 delta=1.5/100;          //relative index difference
8 lamda=0.85d-6;         //operating wavelength
9 n1=1.48;                //core refractive index
10
11 a=core_diameter/2;     //computing core radius
12 v= 2*pi*a*n1*sqrt(2*delta)/lamda; //computing
    normalized frequency
13 M=(v)^2/2;            //computing guided modes
14 printf("\nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,M);
15
16 //answer in the book for Guided modes is 2873,
    deviation of 1.

```

---

**Scilab code Exa 2.7.9** Estimate diameter of the core

```

1 // Example 2.7.9 page 2.28
2
3 clc;
4 clear;
5
6 delta=1/100;           //relative refractive index
7 n1=1.5;                //refractive index of core
8 M=1100;                //Guided modes
9 lamda=1.3d-6;          //wavelength
10
11 v=sqrt(2*M);           //computing normalized frequency
12 a=(v*lamda)/(2*3.14*n1*sqrt(2*delta)); //
    computing radius of core
13 d=a*2;
14 a=a*10^6;
15 d=d*10^6;
16
17 printf("\nNormalize frequency is %.1f.\nCore radius
    is %.2f micrometer.\nCore diameter is %.1f

```

```

    micrometer.",v,a,d);
18 printf("\nCalculation error in the book while
    calculating radius and diameter.");
19
20 //calculation error in the book.
21 //answers in the book –
22 //Core radius is 46.18 micrometer.(incorrect)
23 //Core diameter is 92.3 micrometer.(incorrect)

```

---

**Scilab code Exa 2.7.10** Determine normalized frequency and number of guided modes

```

1 // Example 2.7.10 page 2.29
2
3 clc;
4 clear;
5
6 n1=1.48; //refractive index of core
7 n2=1.46; //refractive index of cladding
8 lamda1=1320d-9; //Wavelength
9 lamda2=1550d-9; //Wavelength
10 a=25d-6; //radius of core
11
12 NA=sqrt(n1^2 - n2^2); //computing Numerical
    aperture
13 v1=2*%pi*a*NA/lamda1; //computing normalized
    frequency
14 v1=round(v1);
15 M1=v1^2/2; //computing number of guided modes
16 M1=round(M1);
17 v2=2*%pi*a*NA/lamda2;
18 M2=v2^2/2;
19 M2=round(M2);
20 lamda1=lamda1*10^9;
21 lamda2=lamda2*10^9;

```



```

22
23 printf("\nfor %d nm, normalized frequency = %d,
        Guided modes = %d.",lamda1,v1,M1);
24 printf("\nfor %d nm, normalized frequency = %.2f,
        Guided modes = %d.",lamda2,v2,M2);
25
26 //answer in the book,
27 //for 1550 nm, normalized frequency = 24.69(
        deviation of 0.08), Guided modes = 305(deviation
        of 3)

```

---

**Scilab code Exa 2.7.11** Compute NA and number of guided modes

```

1 // Example 2.7.11 page 2.29
2
3 clc;
4 clear all;
5
6 n1=1.5; //refractive index of core
7 n2=1.38; //refractive index of cladding
8 lamda=1300d-9; //Wavelength
9 a=25d-6; //core radius
10
11 NA=sqrt(n1^2 - n2^2); //computing Numerical
    aperture
12 theta= asind(NA); //computing acceptance
    angle
13 solid_angle=%pi*(NA)^2; //computing solid angle
14 v= 2*pi*a*NA/lamda; //computing normalized
    frequency
15 M=(v)^2/2; //computing guided modes
16 M=round(M);
17 printf("\nNumerical aperture is %.2f.\nNormalized
        frequency is %.2f.\nAcceptance angle is %.2f
        degrees.\nSolid angle is %.3f radians.\nTotal

```

```

        number of modes are %d.",NA,v,theta,solid_angle,M
    );
18 printf("\n\n NOTE – Calculation error in the book.\n
    (2.25 – 1.9) ^0.5=0.59; they have taken 0.35");
19
20
21 //Calculation error in the book.(2.25 – 1.9) ^0.5=0.59;
    they have taken 0.35
22 //answers in the book,
23 //Numerical aperture is 0.35.(incorrect)
24 //Normalized frequency is 42.26.(incorrect)
25 //Acceptance angle is 20.48 degrees.(incorrect)
26 //Solid angle is 0.384 radians.(incorrect)

```

---

**Scilab code Exa 2.7.12** Compute core radius and acceptance angle

```

1 // Example 2.7.12 page 2.30
2
3 clc;
4 clear;
5
6 n1=1.48; //refractive index of core
7 n2=1.478; //refractive index of cladding
8 lamda=820d-9; //Wavelength
9
10 NA=sqrt(n1^2 - n2^2); //computing Numerical
    aperture
11 theta= asind(NA); //computing acceptance
    angle
12 solid_angle=%pi*(NA)^2; //computing solid angle
13
14 printf("\nNumerical aperture is %.3f.\nAcceptance
    angle is %.2f degrees.\nSolid angle is %.4f
    radians.",NA,theta,solid_angle);

```

---

**Scilab code Exa 2.7.13** Estimate range of wavelength for single mode transmission

```
1
2 // Example 2.7.13 page 2.31
3
4 clc;
5 clear;
6
7 n1=1.447; //refractive index of core
8 n2=1.442; //refractive index of cladding
9 lamda=1.3d-6; //Wavelength
10 a=3.6d-6; //core radius
11
12 NA=sqrt(n1^2 - n2^2); //computing Numerical
    aperture
13 v= 2*%pi*a*NA/lamda; //computing normalized
    frequency
14
15 printf("As normalized frequency is %.2f which is
    less than 2.405, this fiber will permit single
    mode transmission",v);
16
17 lamda_cut_off=v*lamda/2.405
18 lamda_cut_off=lamda_cut_off*10^9
19 printf("\n\nSingle mode operation will occur above
    this cut off wavelength of %.2f nm",lamda_cut_off
    );
20 printf("\n\nNOTE - Calculation error in the book.\n
    (1.447^2 - 1.442^2)^0.5=0.121; they have taken
    0.141\nHence calculations after that are
    incorrect in the book");
21
22 //Calculation error in the book.(1.447^2 - 1.442^2)
```

```

    ^0.5=0.121; they have taken 0.141.Hence
    calculations after that are incorrect in the book
23 //They have taken radius as 2.6d-6, whereas in
    question it is given 3.6d-6.
24 //answers in the book
25 //Normalized frequency is 1.77.(incorrect)
26 //cut off wavelength 956nm.(incorrect)

```

---

**Scilab code Exa 2.7.14** Estimate number of guided modes

```

1 // Example 2.7.14 page 2.34
2
3 clc;
4 clear;
5
6 NA=0.2; //Numerical aperture
7 d=50d-6; //Diameter of core
8 lamda=1d-6; //Wavelength
9
10 a=d/2; //computing radius
11 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
12 Mg=v^2/4; //computing mode volume for
    parabolic profile
13 Mg=round(Mg);
14 printf(" \nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,Mg);
15
16 //answer in the book for guided modes is 247,
    deviation of 1.

```

---

**Scilab code Exa 2.7.15** Determine core diameter

```

1 // Example 2.7.15 page 2.34
2
3 clc;
4 clear;
5
6 delta=0.015; //relative refractive index
7 n1=1.48; //core refractive index
8 lamda=0.85d-6; //wavelength
9
10 a=(2.4*lamda)/(2*3.14*n1*sqrt(2*delta)); //
    computing radius of core
11 d=2*a; //computing diameter of core
12 a=a*10^7;
13 a=round(a);
14 a=a/10
15 d=d*10^6;
16 printf("\nCore radius is %.1f micrometer.\nCore
    diameter is %.1f micrometer.",a,2*a);
17
18 printf("\n\nWhen delta is reduced by 10 percent-");
19 delta=0.0015;
20 a=(2.4*lamda)/(2*3.14*n1*sqrt(2*delta)); //
    computing radius of core
21 d=2*a; //computing diameter of core
22 a=a*10^7;
23 a=round(a);
24 a=a/10
25 d=d*10^6;
26 printf("\nCore radius is %.1f micrometer.\nCore
    diameter is %.1f micrometer.",a,2*a);

```

---

**Scilab code Exa 2.7.16** Find number of guided modes

```

1 // Example 2.7.16 page 2.35
2

```

```

3  clc;
4  clear;
5
6  NA=0.25;      //Numerical aperture
7  d=45d-6;     //Diameter of core
8  lamda=1.5d-6; //Wavelength
9
10 a=d/2;      //computing radius
11 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
12 Mg=v^2/4;   //computing mode volume for
    parabolic profile
13 Mg=round(Mg);
14 printf(" \nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,Mg);
15
16 //answer in the book for normalized frequency is
    23.55, deviation 0.05

```

---

**Scilab code Exa 2.7.17** Estimate number of guided modes

```

1  // Example 2.7.17 page 2.35
2
3  clc;
4  clear;
5
6  NA=0.25;      //Numerical aperture
7  d=45d-6;     //Diameter of core
8  lamda=1.2d-6; //Wavelength
9
10 a=d/2;      //computing radius
11 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
12 Mg=v^2/4;   //computing mode volume for
    parabolic profile

```

```

13 Mg=round(Mg);
14 printf("\nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,Mg);
15 printf("\n\nNOTE – In the question NA is given 0.22.
    However while solving it is taken as 0.25");
16
17 // answer in the book for number of guided modes is
    given as 216, deviation of 1.
18
19 printf("\nHence solving for NA = 0.22 also ,");
20 printf("\n\nWhen NA=0.22");
21
22 NA=0.22; //Numerical aperture
23 d=45d-6; //Diameter of core
24 lamda=1.2d-6; //Wavelength
25
26 a=d/2; //computing radius
27 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
28 Mg=v^2/4; //computing mode volume for
    parabolic profile
29 Mg=round(Mg);
30 printf("\nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,Mg);

```

---

**Scilab code Exa 2.7.18** Compute cutoff parameter and number of modes

```

1 // Example 2.7.18 page 2.36
2
3 clc;
4 clear;
5
6 n1=1.54; //refractive index of core
7 n2=1.5; //refractive index of cladding
8 a=25d-6; //Radius of core

```

```

9 lamda=1.3d-6;          //Wavelength
10
11 NA=sqrt(n1^2-n2^2);
12 v=2*3.14*a*NA/lamda;  //computing normalized
    frequency
13 v=round(v);
14 Mg=v^2/4;            //computing mode volume for
    parabolic profile
15 Mg=round(Mg);
16 lamda_cut_off=v*lamda/2.405;  //computing cut off
    wavelength
17 lamda_cut_off=lamda_cut_off*10^6;
18 printf("\nNormalized Frequency is %.d.\nTotal number
    of guided modes are %.d.\nCut off wavelength is
    %.1f micrometer.",v,Mg,lamda_cut_off);

```

---

#### Scilab code Exa 2.10.1 Determine cutoff wavelength

```

1 // Example 2.10.1 page 2.39
2
3 clc;
4 clear;
5
6 a=4.5d-6;            //core diameter
7 delta=0.25/100;     //relative index difference
8 lamda=0.85d-6;      //operating wavelength
9 n1=1.46;            //core refractive index
10
11 v= 2*pi*a*n1*sqrt(2*delta)/lamda;  //computing
    normalized frequency
12 lamda_cut_off=v*lamda/2.405;  //computing cut
    off wavelength
13 lamda_cut_off=lamda_cut_off*10^9;
14 printf("\nCut off wavelength is %.d nanometer.",
    lamda_cut_off);

```



```

15
16 printf("\n\nWhen delta is 1.25 percent-");
17 delta=1.25/100;
18 v= 2*pi*a*n1*sqrt(2*delta)/lamda;           //computing
        normalized frequency
19 lamda_cut_off=v*lamda/2.405;                //computing cut
        off wavelength
20 lamda_cut_off=lamda_cut_off*10^7;
21 lamda_cut_off=round(lamda_cut_off);
22 lamda_cut_off=lamda_cut_off*100;
23 printf("\nCut off wavelength is %.d nanometer.",
        lamda_cut_off);
24
25 //answer in the book for cut off wavelength in the
        book is given as 1214nm, deviation of 1mm.

```

---

**Scilab code Exa 2.10.2** Calculate cutoff number and number of modes

```

1 // Example 2.10.2 page 2.40
2
3 clc;
4 clear;
5
6 a=50d-6;           //core radius
7 lamda=1500d-9;    //operating wavelength
8 n1=2.53;          //core refractive index
9 n2=1.5;           //cladding refractive index
10
11 delta=(n1-n2)/n1; //computing delta
12 v= 2*3.14*a*n1*sqrt(2*delta)/lamda; //computing
        normalized frequency
13 M=(v)^2/2;        //computing guided modes
14 printf("\nNormalized Frequency is %.1f\nTotal number
        of guided modes are %.d",v,M);
15 printf("\nNOTE - Calculation error in book. \n

```

```

    Normalized frequency is 477, it is calculated as
    47.66");
16
17 // Calculation error in book. Normalized frequency is
    477, it is calculated as 47.66, hence answers
    after that are erroneous.
18 //answers in the book
19 //normalized frequency = 48.(incorrect)
20 //guided modes = 1152.(incorrect)

```

---

### Scilab code Exa 2.10.3 Compute number of modes

```

1 // Example 2.10.3 page 2.41
2
3 clc;
4 clear;
5
6 core_diameter=8d-6; //core diameter
7 delta=0.92/100; //relative index difference
8 lamda=1550d-9; //operating wavelength
9 n1=1.45; //core refractive index
10
11 a=core_diameter/2; //computing core radius
12 v= 2*%pi*a*n1*sqrt(2*delta)/lamda; //computing
    normalized frequency
13 M=(v)^2/2; //computing guided modes
14 printf("\nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,M);

```

---

### Scilab code Exa 2.10.4 Calculate delay difference

```

1 // Example 2.10.4 page 2.41
2

```

```

3  clc;
4  clear;
5
6  delta=1/100;          //relative index difference
7  n1=1.5;              //core refractive index
8  c=3d8;
9  L=6;
10
11 n2=sqrt(n1^2-2*delta*n1^2);    //computing
    refractive index of cladding
12 delta_T=L*n1^2*delta/(c*n2);    //computing pulse
    broadning
13 delta_T=delta_T*10^11;
14 delta_T=round(delta_T);
15 printf("\nDelay difference between slowest and
    fastest mode is %d ns/km.",delta_T);
16 printf("\nThis means that a pulse broadnes by %d ns
    after travel time a distance of %d km.",delta_T,L
    );

```

---

### Scilab code Exa 2.13.1 Find modal briefringence

```

1  // Example 2.13.1  page 2.54
2
3  clc;
4  clear;
5
6  L_BL=8d-2;    //beat length
7
8  Br=2*3.14/L_BL;    //computing modal briefringence
9  printf("\nModal briefringence is %.1f per meter.",Br
    );

```

---

### Scilab code Exa 2.13.2 Find output power

```
1 // Example 2.13.2 page 2.57
2
3 clc;
4 clear;
5
6 Pin=500d-6; //input power
7 L=200; //length of fiber
8 loss=2; //loss associated with fiber
9
10 Pin_dbm=10 * log10 (Pin/(10^-3)); //computing
    input power in dBm
11 Pin_dbm=round(Pin_dbm);
12 Pout_dbm=Pin_dbm-L*loss; //computing output
    power level
13 Pout= 10^(Pout_dbm/10);
14 printf("Output power is %.2e mW.",Pout);
```

---

### Scilab code Exa 2.16.1 Calculate NA and maximum acceptance angle

```
1 // Example 2.16.1 page 2.67
2
3 clc;
4 clear;
5
6 n1=1.48; //core refractive index
7 n2=1.46; //cladding refractive index
8
9 phi = asind(n2/n1); //computing critical angle
10 NA = sqrt(n1^2 - n2^2); //computing numerica
    aperture
11 theta= asind(NA); //computing acceptance angle
12 printf("\nCritical angle is %.2f degrees.\nNumerical
    aperture is %.3f.\nAcceptance angle is %.2f
```

```
    degree.",phi,NA,theta);
13
14 //answers in the book
15 //Critical angle is 80.56 degrees, deviation of
    0.01.
16 //Numerical aperture is 0.244, deviation of 0.002.
17 //Acceptance angle is 14.17 degree, deviation of
    0.14.
```

---

# Chapter 4

## Signal Degradation in Fibers

Scilab code Exa 4.3.1 Find signal attenuation and InputOutput ratio

```
1
2
3 // Example 4.3.1 page 4.4
4
5 clc;
6 clear;
7
8 L=10; //fiber length in km
9 Pin=150d-6; //input power
10 Pout=5d-6; //output power
11 len=20; //length of optical link
12 interval=1; //splices after interval of 1 km
13 l=1.2; //loss due to 1 splice
14
15 attenuation=10*log10(Pin/Pout);
16 alpha=attenuation/L;
17 attenuation_loss=alpha*20;
18 splices_loss=(len-interval)*l;
19 total_loss=attenuation_loss+splices_loss;
20 power_ratio=10^(total_loss/10);
21
```

```

22 printf("\nSignal attenuation is %.2f dBs.\nSignal
    attenuation is %.3f dB/Km.\nTotal loss in 20 Km
    fiber is %.2f dbs.\nTotal attenuation is %.2f dBs
    .\ninput/output ratio is %e.",attenuation,alpha,
    attenuation_loss,total_loss,power_ratio);
23 printf("\nAs signal attenuation is approximately
    equal to 10^5, we can say that line is very lossy
    .");

```

---

#### Scilab code Exa 4.4.1 Find output power

```

1 // Example 4.4.1 page 4.8
2
3 clc;
4 clear;
5
6 L=30; //fiber length
7 Pin=200d-6; //input power
8 alpha=0.8; //signal attenuation per km
9
10 Pout=Pin/(10^(alpha*L/10)); //computing output
    power
11 Pout=Pout*10^6;
12 printf("\nOutput power is %.3f microwatt.",Pout);
13 printf("\nNOTE – calculation error in the book.\n
    nThey have taken 0.8*30=2.4 which actually is 24.
    ");
14
15 //calculation error in the book.They have taken
    0.8*30=2.4 which actually is 24.
16 //answer in the book is 115.14 microwatt.(incorrect)

```

---

#### Scilab code Exa 4.6.1 Find attenuation due to Rayleigh scattering

```

1 // Example 4.6.1 page 4.12
2
3 clc;
4 clear;
5
6 beta_c=8d-11; //isothermal compressibility
7 n=1.46; //refractive index
8 P=0.286; //photoelastic constat
9 k=1.38d-23; //Boltzmn constant
10 T=1500; //temperature
11 L=1000; //length
12 lamda=1000d-9; //wavelength
13
14 gamma_r = 8*(3.14^3)*(P^2)*(n^8)*beta_c*k*T/(3*(
    lamda^4)); //computing coefficient
15 attenuation=%e^(-gamma_r*L); //computing
    attenuation
16 printf("\nAttenuation due to Rayleigh scattering is
    %.3f.",attenuation);

```

---

**Scilab code Exa 4.6.2** Determine attenuation due to Rayleigh scattering

```

1 // Example 4.6.2 page 4.13
2
3 clc;
4 clear;
5
6 beta_c=7d-11; //isothermal compressibility
7 n=1.46; //refractive index
8 P=0.29; //photoelastic constat
9 k=1.38d-23; //Boltzmn constant
10 T=1400; //temperature
11 L=1000; //length
12 lamda=0.7d-6; //wavelength
13

```



```

14 gamma_r = 8*(3.14^3)*(P^2)*(n^8)*beta_c*k*T/(3*(
    lamda^4)); //computing coefficient
15 attenuation=%e^(-gamma_r*L); //computing
    attenuation
16 gamma_r=gamma_r*1000;
17 printf("\nRaleigh Scattering corfficient is %.3f *
    10^-3 per meter\n",gamma_r);
18 printf("\nNOTE - in quetion they have asked for
    attenuation but in solution they have not
    calcaulted\n");
19 printf("\nAttenuation due to Rayleigh scattering is
    %.3f",attenuation);
20
21 //answer for Raleigh Scattering corfficient in the
    book is given as 0.804d-3, deviation of 0.003d-3

```

---

#### Scilab code Exa 4.8.1 Compare SRS and SBS threshold powers

```

1 // Example 4.8.1 page 4.17
2
3 clc;
4 clear;
5
6 d=5; //core diameter
7 alpha=0.4; //attenuation
8 B=0.5; //Bandwidth
9 lamda=1.4; //wavelength
10 PB=4.4d-3*d^2*lamda^2*alpha*B; //computing
    threshold power for SBS
11 PR=5.9d-2*d^2*lamda*alpha; //computing
    threshold power for SRS
12 PB=PB*10^3;
13 PR=PR*10^3;
14 printf("\nThreshold power for SBS is %.1f mW.\
    nThreshold power for SRS is %.3f mW.",PB,PR);

```

```

15 printf("\nNOTE - Calculation error in the book while
    calculating threshold for SBS.\nAlso, while
    calculating SRS, formula is taken incorrectly,
    Bandwidth is multiplied in second step, which is
    not in the formula.");
16
17 //Calculation error in the book while calculating
    threshold for SBS. Also, while calculating SRS,
    formula is taken incorrectly, Bandwidth is
    multiplied in second step, which is not in the
    formula
18 //answers in the book
19 //PB=30.8mW
20 //PR=0.413mW

```

---

**Scilab code Exa 4.9.1** Find critical radius of curvature

```

1 // Example 4.9.1 page 4.19
2
3 clc;
4 clear;
5
6 n1=1.5; //refractive index of core
7 delta=0.03/100; //relative refractive index
8 lamda=0.82d-6; //wavelength
9
10 n2=sqrt(n1^2-2*delta*n1^2); //computing
    cladding refractive index
11 Rc=(3*n1^2*lamda)/(4*3.14*(n1^2-n2^2)^1.5); //
    computing critical radius
12 Rc=Rc*10^3;
13 printf("\nCritical radius is %.1f micrometer.",Rc);
14
15 //answer in the book is 9 micrometer, deviation of
    0.1 micrometer.

```

---

**Scilab code Exa 4.9.2** Find critical radius for both single mode and multi mode fiber

```
1 // Example 4.9.2 page 4.20
2
3 clc;
4 clear;
5
6 n1=1.45; //refractive index of core
7 delta=3/100; //relative refractive index
8 lamda=1.5d-6; //wavelength
9 a=5d-6; //core radius
10
11 n2=sqrt(n1^2-2*delta*n1^2); //computing
    cladding refractive index
12 Rc=(3*n1^2*lamda)/(4*3.14*(n1^2-n2^2)^0.5); //
    computing critical radius for single mode
13 Rc=Rc*10^6;
14 printf("\nCritical radius is %.2f micrometer",Rc);
15
16 lamda_cut_off= 2*3.14*a*n1*sqrt(2*delta)/2.405;
17
18 RcSM= (20*lamda/(n1-n2)^1.5)*(2.748-0.996*lamda/
    lamda_cut_off)^-3; //computing critical
    radius for single mode
19 RcSM=RcSM*10^6;
20 printf("\nCritical radius for single mode fiber is %
    .2f micrometer.",RcSM);
21 printf("\nNOTE - Calculation error in the book.\n
    (2.748-0.996*lamda/lamda_cut_off)^-3; in this
    term raised to -3 is not taken in the book.");
22
23 //Calculation error in the book.(2.748-0.996*lamda/
    lamda_cut_off)^-3; in this term raised to -3 is
```

not taken in the book.  
24 //answer in the book is 7.23mm.(incorrect)

---

**Scilab code Exa 4.14.1** Compute material dispersion

```
1 // Example 4.14.1 page 4.31
2
3 clc;
4 clear;
5
6 lamda=1550d-9;
7 lamda0=1.3d-6;
8 s0=0.095;
9
10 Dt=lamda*s0/4*(1-(lamda0/lamda)^4); //computing
    material dispersion
11 Dt=Dt*10^9;
12 printf("\nMaterial dispersion at 1550 nm is %.1f ps/
    nm/km",Dt);
13 printf("\n\nNOTE – Slight deviation in the answer
    because of printig mistake\nIn problem they have
    given lamda0 as 1300 nanometer \nbut while
    solving they have taken it as 1330 nanometer");
14
15 //answer in the book 15.6 ps/nm/km, deviaton due to
    printing mistake.
```

---

**Scilab code Exa 4.15.1** Find maximum possible bandwidth pulse disper-  
sion and bandwidth length product

```
1 // Example 4.15.1 page 4.35
2
3 clc;
```

```

4 clear;
5
6 tau=0.1d-6;      //pulse broadning
7 dist=20d3;      //distance
8
9 Bopt=1/(2*tau);  //computing optical bandwidth
10 Bopt=Bopt*10^-6;
11 dispertion=tau/dist;      //computing dispersion
12 dispertion=dispertion*10^12;
13 BLP=Bopt*dist;      //computing Bandwidth length
   product
14 BLP=BLP*10^-3;
15 printf("\noptical bandwidth is %d MHz.\nDispersion
   per unit length is %d ns/km.\nBandwidth length
   product is %d MHz.km.",Bopt,dispertion,BLP);

```

---

**Scilab code Exa 4.15.2** Calculate overall signal attenuation

```

1 // Example 4.15.2 page 4.36
2
3 clc;
4 clear;
5
6 L=10;      //fiber length in km
7 Pin=100d-6;      //input power
8 Pout=5d-6;      //output power
9 len=12;      //length of optical link
10 interval=1;      //splices after interval of 1 km
11 l=0.5;      //loss due to 1 splice
12
13 attenuation=-10*log10(Pin/Pout);      //computing
   attenuation
14 alpha=attenuation/L;
15 signal_attenuation=-alpha*L;      //computing
   signal attenuation

```

```

16 splices_loss=(len-interval)*1;           //computing
    splices loss
17 attenuation_loss=-len*alpha             //computing
    attenuation loss
18 total_attenuation=attenuation_loss+splices_loss;
    //computing total attenuation
19
20 printf("\nSignal attenuation is %.1f dB/Km.\nOverall
    attenuation is %d dB for 10 km.\nTotal
    attenuation is %.1f dBs for 12km.",alpha,
    signal_attenuation,total_attenuation);

```

---

**Scilab code Exa 4.15.3** Calculate bandwidth dispersion and bandwidth length product

```

1 // Example 4.15.3 page 4.37
2
3 clc;
4 clear;
5
6 tau=0.1d-6;           //pulse broadning
7 dist=12d3;           //distance
8
9 Bopt=1/(2*tau);       //computing optical bandwidth
10 Bopt=Bopt*10^-6;
11 dispertion=tau/dist; //computing dispersion
12 dispertion=dispertion*10^12;
13 BLP=Bopt*dist;       //computing Bandwidth length
    product
14 BLP=BLP*10^-3;
15 printf("\noptical bandwidth is %d MHz.\nDispersion
    per unit length is %.1f ns/km.\nBandwidth length
    product is %d MHz.km",Bopt,dispertion,BLP);

```

---

#### Scilab code Exa 4.15.4 Determine maximum bit rate

```
1 // Example 4.15.4 page 4.38
2
3 clc;
4 clear;
5
6 tau01=10; //pulse broadning ns/mm
7 L1=0.1; //length in kilometer
8 tau02=20; //pulse broadning ns/m
9 L2=1; //length in kilometer
10 tau03=2000; //pulse broadning ns/m
11 L3=2; //length in kilometer
12
13 tau1=10d-9/1d-6;
14 tau1=tau1*L1;
15 Bopt1=1/(2*tau1); //computing optical bandwidth
16 tau2=20d-9/1d-3;
17 tau2=tau2*L2;
18 Bopt2=1/(2*tau2); //computing optical bandwidth
19 Bopt2=Bopt2*10^-3;
20 tau3=2000d-9/1d-3;
21 tau3=tau3*L3;
22 Bopt3=1/(2*tau3); //computing optical bandwidth
23
24
25 printf("\nWhen tau is %d ns/mm, over length %.1f km,
    optical bandwidth for RZ is %d MHz and for NRZ
    is %d MHz.",tau01,L1,Bopt1,Bopt1/2 );
26 printf("\nWhen tau is %d ns/m, over length %d km,
    optical bandwidth for RZ is %.1f KHz and for NRZ
    is %.1f KHz.",tau02,L2,Bopt2,Bopt2/2 );
27 printf("\nWhen tau is %d ns/m, over length %d km,
    optical bandwidth for RZ is %d Mz and for NRZ is
```

```

    %.1f Hz.",tau03,L3,Bopt3,Bopt3/2 );
28
29 printf("\n NOTE – printing errors in the book.\nIn
    first two cases tau is not multiplied by 2");
30
31 //Calculation error because, In first two cases tau
    is not multiplied by 2
32 //answers–
33 //When tau is 10 ns/mm, over length 0.1 km, optical
    bandwidth for RZ is 1000 MHz and for NRZ is 500
    MHz.
34 //When tau is 20 ns/m, over length 1 km, optical
    bandwidth for RZ is 50 KHz and for NRZ is 25 KHz.

```

---

**Scilab code Exa 4.15.5** Calculate maximum possible bandwidth and dispersion

```

1 // Example 4.15.5 page 4.39
2
3 clc;
4 clear;
5
6 tau=0.1d-6; //pulse broadning
7 dist=15d3; //distance
8
9 Bopt=1/(2*tau); //computing optical bandwidth
10 Bopt=Bopt*10^-6;
11 dispertion=tau/dist; //computing dispersion
12 dispertion=dispertion*10^12;
13 printf("\noptical bandwidth is %d MHz.\nDispersion
    per unit length is %.2f ns/km.",Bopt,dispertion);

```

---



**Scilab code Exa 4.15.6** Compute delay difference rms pulse broadening and maximum bit rate

```
1 // Example 4.15.6 page 4.39
2
3 clc;
4 clear;
5
6 L=5; //length of optical link
7 n1=1.5 //refractive index
8 c=3d8; //speed of light
9 delta=1/100; //relative refractive index
10
11 delTS=L*n1*delta/c; //computing delay difference
12 delTS=delTS*10^12;
13 sigmaS=L*n1*delta/(2*sqrt(3)*c); //computing rms
    pulse broadning
14 sigmaS=sigmaS*10^12;
15 B=1/(2*delTS); //computing maximum bit rate
16 B=B*10^3;
17 B_acc=0.2/(sigmaS); //computing accurate bit
    rate
18 B_acc=B_acc*10^3;
19 BLP=B_acc*L; //computing Bandwidth length
    product
20
21 printf("\nDelay difference is %d ns.\nRMS pulse
    broadning is %.2f ns.\nBit rate is %.1f Mbit/s.\n
    Accurate bit rate is %.2f Mbits/s.\nBandwidth
    length product is %.2f MHz.km.",delTS,sigmaS,B,
    B_acc, BLP);
22
23 //answer in the book for RMS pulse broadning is
    72.25 ns, deviation of 0.08ns.
24 //answer in the book for Bandwidth length product is
    13.85 MHz.km, deviation of 0.01MHz.km.
```

---

**Scilab code Exa 4.15.7** Estimate rms pulse broadening and bandwidth length product

```
1 // Example 4.15.7 page 4.40
2
3 clc;
4 clear;
5
6 NA=0.3; //numerical aperture
7 n1=1.45; //refractive index
8 M=250; //material dispersion parameter in ps/nm
   /km
9 L=1; //length
10 BW=50; //Bandwidth in nm
11 c=3d8; //speed of light
12
13 sigmaLamda=BW*L;
14 sigmaM=sigmaLamda*L*M*10^-12;
15 sigmaS=10^3*L*(NA)^2/(4*sqrt(3)*n1*c);
16 sigmaT=sqrt(sigmaM^2+sigmaS^2); //computing
   total RMS pulse broadning
17 BLP=0.2/sigmaT; //computing bandwidth length
   product
18 sigmaT=sigmaT*10^9;
19 sigmaM=sigmaM*10^9;
20 sigmaS=sigmaS*10^9;
21 BLP=BLP/10^6;
22 printf("\nTotal RMS pulse broadning is %.1f ns/km.\n
   nBandwidth length product is %.1f MHz.km",sigmaT,
   BLP);
```

---

**Scilab code Exa 4.15.8** Estimate Bandwidth dispersion and bandwidth length product

```
1 // Example 4.15.8 page 4.41
2
3 clc;
4 clear;
5
6 tau=0.1d-6; //pulse broadning
7 dist=10d3; //distance
8
9 Bopt=1/(2*tau); //computing optical bandwidth
10 Bopt=Bopt*10^-6;
11 dispertion=tau/dist; //computing dispersion
12 dispertion=dispertion*10^12;
13 BLP=Bopt*dist; //computing Bandwidth length
    product
14 BLP=BLP*10^-3;
15 printf("\noptical bandwidth is %d MHz.\nDispersion
    per unit length is %.1f ns/km.\nBandwidth length
    product is %d MHz.km.",Bopt,dispertion,BLP);
```

---

**Scilab code Exa 4.15.9** Estimate rms pulse broadening

```
1 // Example 4.15.9 page 4.41
2
3 clc;
4 clear;
5
6 RSW=0.0012; //relative spectral width
7 lamda=0.85d-6; //wavelength
8 L=1; //distance in km (assumed)
9 M=100; //material dispersion parameter in ps/nm
    /km (assumed)
10
```

```

11 sigma_lamda=RSW*lamda;
12 sigmaM=sigma_lamda*L*M*10^6;    //computing rms
    pulse broadning.
13 printf("\nRMS pulse broadning is %.3f ns/km.",sigmaM
    );

```

---

**Scilab code Exa 4.15.10** Estimate bandwidth pulse broadening and bandwidth length product

```

1 // Example 4.15.10 page 4.42
2
3 clc;
4 clear;
5
6 tau=0.1d-6;    //pulse broadning
7 dist=18d3;    //distance
8
9 Bopt=1/(2*tau);    //computing optical bandwidth
10 Bopt=Bopt*10^-6;
11 dispertion=tau/dist;    //computing dispersion
12 dispertion=dispertion*10^12;
13 BLP=Bopt*dist;    //computing Bandwidth length
    product
14 BLP=BLP*10^-3;
15 printf("\noptical bandwidth is %d MHz.\nDispersion
    per unit length is %.1f ns/km.\nBandwidth length
    product is %d MHz.km",Bopt,dispertion,BLP);
16 printf("\nNOTE – printing mistake in the book at
    dispersion per unit length.\nThey have printed ps
    /km; it should be ns/km");
17
18 //printing mistake in the book at dispersion per
    unit length.They have printed ps/km; it should be
    ns/km.
19 //answer in the book 5.55 ps/km (incorrect)

```

---

**Scilab code Exa 4.16.1** Estimate rms pulse broadening

```
1 // Example 4.16.1 page 4.43
2
3 clc;
4 clear;
5
6 RSW=0.0012; //relative spectral width
7 lamda=0.90d-6; //wavelength
8 L=1; //distance in km (assumed)
9 P=0.025; //material dispersion parameter
10 c=3d5; //speed of light in km/s
11
12 M=10^3*P/(c*lamda); //computing material
    dispersion
13 sigma_lamda=RSW*lamda;
14 sigmaM=sigma_lamda*L*M*10^7; //computing RMS
    pulse broadning
15 sigmaB=25*L*M*10^-3;
16
17 printf("\nMaterial dispersion parameter is %.2f ps/
    nm/km.\nRMS pulsr broadning when sigma_lamda is
    25 is %.1f ns/km.\nRMS pulse broadning is %.1f ns
    /km.",M,sigmaB,sigmaM);
18
19 //answer in the book for RMS pulse broadning is 0.99
    ns/km, deviation of 0.01ns/km.
```

---

**Scilab code Exa 4.18.1** Find delay difference and rms pulse broadening

```
1 // Example 4.18.1 page 4.45
```

```

2
3 clc;
4 clear;
5
6 L=10;           //length of optical link
7 n1=1.49        //refractive index
8 c=3d8;         //speed of light
9 delta=1/100;   //relative refractive index
10
11 delTS=L*n1*delta/c; //computing delay difference
12 delTS=delTS*10^12;
13 sigmaS=L*n1*delta/(2*sqrt(3)*c); //computing rms
    pulse broadning
14 sigmaS=sigmaS*10^12;
15 B=1/(2*delTS); //computing maximum bit rate
16 B=B*10^3;
17 B_acc=0.2/(sigmaS); //computing accurate bit
    rate
18 B_acc=B_acc*10^3;
19 BLP=B_acc*L; //computing Bandwidth length
    product
20
21 printf("\\nDelay difference is %d ns.\\nRMS pulse
    broadning is %.1f ns.\\nBit rate is %.1f Mbit/s.\\
    nAccurate bit rate is %.3f Mbits/s.\\nBandwidth
    length product is %.1f MHz.km",delTS,sigmaS,B,
    B_acc,BLP);
22
23 //answer for maximum bit rate is given as 1.008 Mb/s
    , deviation of 0.008 Mb/s.

```

---

## Chapter 5

# Fiber Optic Splices Connectors and Couplers

Scilab code Exa 5.2.1 Calculate loss due to Fresnel reflection

```
1 // Example 5.2.1 page 5.2
2
3 clc;
4 clear;
5
6 n1=1.47; //refractive index of fiber
7 n=1; //refractive index of air
8
9 r=((n1-n)/(n1+n))^2; //computing fraction of
   light reflected
10 loss=-10*log10(1-r); //loss
11 total_loss=2*loss;
12 printf("r = %.3f, which means %.1f percent of the
   transmitted light is reflected at one interface"
   ,r,r*100);
13 printf("\nTotal loss is %.3f dB",total_loss);
14
15 //answer in the book for total loss of fiber is
   0.318 dB, deviation of 0.002
```

---

**Scilab code Exa 5.2.2** Estimate insertion loss due to lateral misalignment

```
1 // Example 5.2.2 page 5.4
2
3 clc;
4 clear;
5
6 n1=1.47; //refractive index of fiber
7 n=1; //refractive index of air
8 d=40d-6; //core diameter
9 y=4d-6; //lateral displacement
10
11 a=d/2; //computing core radius
12 eta_lateral = (16*(n1/n)^2)/(%pi*(1+(n1/n))^4)*(2*
    acos(y/(2*a))-(y/a)*(1-(y/(2*a))^2)^0.5); //
    computing eta_lateral with air gap
13 loss=-10*log10(eta_lateral); //computing loss
    when air gap is present
14 eta_lateral1=(2*acos(y/(2*a))-(y/a)*(1-(y/(2*a))^2)
    ^0.5)/%pi; //computing eta_lateral without
    air gap
15 loss1=-10*log10(eta_lateral1); //computing loss
    when air gap is not present
16
17 printf("\nloss with air gap is %.2f dB.\nloss with
    no air gap is %.2f dB.\n Thus we can say that
    loss reduces considerably if there is no air gap.
    ",loss,loss1);
18
19 //answer in the book for loss with air gap is 0.91dB
    , deviation of 0.01dB.
```

---



### Scilab code Exa 5.2.3 Estimate angular misalignment insertion loss

```
1 // Example 5.2.3 page 5.5
2
3 clc;
4 clear;
5
6 n1=1.48; //refractive index of fiber
7 n=1; //refractive index of air
8 theta=10; //angle in degree
9 NA1=0.3;
10 NA2=0.6
11 eta_angular1= (16*(n1/n)^2)/((1+(n1/n))^4)*(1-((n*
    theta*%pi/180)/(%pi*NA1))); //computing eta
    angular
12 eta_angular2= (16*(n1/n)^2)/((1+(n1/n))^4)*(1-((n*
    theta*%pi/180)/(%pi*NA2))); //computing eta
    angular
13 loss1=-10*log10(eta_angular1); //computing loss
14 loss2=-10*log10(eta_angular2); //computing loss
15 printf("\nLoss when NA is %.1f is %.2f dB.\nLoss
    when NA is %.1f is %.2f dB.",NA1,loss1,NA2,loss2)
    ;
16 printf("\nThus we can say that insertion loss is
    considerably reduced with higher NA.");
```

---

### Scilab code Exa 5.2.4 Loss due to Fresnel reflection

```
1 // Example 5.2.4 page 5.7
2
3 clc;
4 clear;
5
6 n1=1.5; //refractive index of fiber
7 n=1; //refractive index of air
```

```

8
9 r=((n1-n)/(n1+n))^2; //computing fraction of
    light reflected
10 loss=-10*log10(1-r); //loss
11 total_loss=2*loss;
12 printf("r = %.2f, which means %.1f percent of the
    transimitted light is reflected at one interface"
    ,r,r*100);
13 printf("\nTotal loss is %.2f dB",total_loss);
14
15 //answer in the book for total loss of fiber is 0.36
    dB, deviation of 0.01

```

---

**Scilab code Exa 5.2.5** Estimate insertion loss due to lateral misalignment

```

1 // Example 5.2.5 page 5.7
2
3 clc;
4 clear;
5
6 n1=1.5; //refractive index of fiber
7 n=1; //refractive index of air
8 d=50d-6; //core diameter
9 y=5d-6; //lateral displacement
10
11 a=d/2; //computing core radius
12 eta_lateral = (16*(n1/n)^2)/(%pi*(1+(n1/n))^4)*(2*
    acos(y/(2*a))-(y/a)*(1-(y/(2*a))^2)^0.5); //
    computing eta_lateral with air gap
13 loss=-10*log10(eta_lateral); //computing loss
    when air gap is present
14 eta_lateral1=(2*acos(y/(2*a))-(y/a)*(1-(y/(2*a))^2)
    ^0.5)/%pi; //computing eta_lateral without
    air gap
15 loss1=-10*log10(eta_lateral1); //computing loss

```

```

        when air gap is not present
16
17 printf("\\nloss with air gap is %.2f dB.\\nloss with
        no air gap is %.2f dB.",loss,loss1);
18
19 //answer in the book for loss with air gap is 0.95dB
        , deviation of 0.01dB.

```

---

### Scilab code Exa 5.2.6 Total insertion loss

```

1 // Example 5.2.6 page 5.8
2
3 clc;
4 clear;
5
6 n1=1.47; //refractive index of fiber
7 n=1; //refractive index of air
8 theta=3; //angle in degree
9 d=80d-6; //core diameter
10 y=2d-6; //lateral displacement
11 delta=2/100; //relative refractive index
12
13 a=d/2; //computing core radius
14 eta_lateral = (16*(n1/n)^2)/(%pi*(1+(n1/n))^4)*(2*
        acos(y/(2*a))-(y/a)*(1-(y/(2*a))^2)^0.5); //
        computing eta lateral
15 loss_lateral=-10*log10(eta_lateral); //computing
        loss due to lateral misalignment
16 eta_angular= (16*(n1/n)^2)/((1+(n1/n))^4)*(1-((n*
        theta*%pi/180)/(%pi*n1*(sqrt(2*delta))))); //
        computing eta angular
17 loss_angular=-10*log10(eta_angular); //computing
        loss due to angular misalignment
18 total_loss=loss_lateral+loss_angular; //computing
        total loss due to misalignment

```

```

19 printf("\nloss due to lateral misalignment is %.2f
    dB.\nloss due to angular misalignment is %.2f dB
    .\nTotal loss is %.2f dB",loss_lateral,
    loss_angular,total_loss);
20
21 //answer in the book for loss due to lateral
    misalignment is 0.48 dB, deviation of 0.02.
22 //answer in the book for total loss due is 1.05 dB,
    deviation of 0.02.

```

---

#### Scilab code Exa 5.4.1 Find insertion loss

```

1 // Example 5.4.1 page 5.17
2
3 clc;
4 clear;
5
6 d=1d-6; //lateral displacement
7 W=4.95d-6; //MFD
8
9 Lsm_lat= -10*log10(%e^(-(d/W)^2)); //computing
    loss
10 printf("\nInsertion loss is %.2f dB.",Lsm_lat);

```

---

#### Scilab code Exa 5.4.2 Find angular misalignment loss

```

1 // Example 5.4.2 page 5.18
2
3 clc;
4 clear;
5
6 lamda=1.3d-6; //wavelength
7 theta=1; //angle in degree

```

```

8 n2=1.465;           //cladding refractive index
9 W=4.95d-6;         //MFD
10
11 Lsm_ang= -10*log10(%e^(-(%pi*n2*W*(theta*%pi/180)/
    lamda)^2));      //computing loss
12 printf("\nInsertion loss is %.2f dB.",Lsm_ang);

```

---

**Scilab code Exa 5.6.1** Determine excess loss insertion loss cross talk and split ratio

```

1 // Example 5.6.1 page 5.30
2
3 clc;
4 clear;
5
6 p1=50d-6;
7 p2=0.003d-6;
8 p3=25d-6;
9 p4=26.5d-6
10
11 EL=10*log10(p1/(p3+p4));           //computing excess
    loss
12 IL13=10*log10(p1/p3);             //computing insertion loss
13 IL14=10*log10(p1/p4);             //computing insertion loss
14 ct=10*log10(p2/p1);               //computing cross talk
15 sr=(p3/(p3+p4))*100;             //computing split ratio
16
17 printf("\nExcess loss is %.2f dB.\nInsertion loss
    from port 1 to port 3 is %.2f dB.\nInsertion loss
    from port 1 to port 4 is %.2f dB.\ncross talk is
    %.2f dB.\nSplit ratio is %.2f percent",EL,IL13,
    IL14,ct,sr );
18 printf("\nNOTE - calculation error in the book.\n
    Minus sign is not printed in the answer of excess
    loss.\nP1 is taken 25 instead of 50 while

```

```

        calculating cross talk.");
19
20 //calculation error in the book.Minus sign is not
    printed in the answer of excess loss.P1 is taken
    25 instead of 50 while calculating cross talk.
21 //answers in the book with slight deviations
22 //Excess loss is 0.12 dB.(printing error)
23 //Insertion loss from port 1 to port 4 is 2.75 dB.
24 //cross talk is -39.2 dB. (calculation error)

```

---

**Scilab code Exa 5.6.2** Find total loss and average insertion loss

```

1 // Example 5.6.2 page 5.32
2
3 clc;
4 clear;
5
6 N=16; //Number of ports
7 Pin=1d-3; //input power
8 Pout=12d-6; //output power
9
10 split_loss=10*log10(N); //computing split loss
11 excess_loss=10*log10(Pin/(Pout*N)); //computing
    excess loss
12 total_loss=split_loss+excess_loss; //computing
    total loss
13 insertion_loss= 10*log10(Pin/Pout); //computing
    insertion loss
14
15 printf("\\nTotal loss is %.2f dB.\\nInsertion loss is
    %.2f dB.",total_loss,insertion_loss);
16
17 //answer in the book for Total loss is 19.14,
    deviation of 0.06dB.
18 //answer in the book for insertion loss is 19.20,

```

deviation of 0.01dB.

---

# Chapter 6

## Optical Sources

Scilab code Exa 6.3.1 Find operating wavelength

```
1 // Example 6.3.1 page 6.7
2
3 clc;
4 clear;
5
6 x=0.07;
7 Eg=1.424+1.266*x+0.266*x^2;
8 lamda=1.24/Eg; //computing wavelength
9 printf("\nWavelength is %.3f micrometer.",lamda);
```

---

Scilab code Exa 6.3.2 Find out number of longitudinal modes and frequency separation

```
1 // Example 6.3.2 page 6.12
2
3 clc;
4 clear;
5
```



```

6 n=1.7;          //refractive index
7 L=5d-2;        //distance between mirror
8 c=3d8;         //speed of light
9 lamda=0.45d-6; //wavelength
10
11 k=2*n*L/lamda; //computing number of modes
12 delf=c/(2*n*L); //computing mode separation
13 delf=delf*10^-9;
14
15 printf("\nNumber of modes are %.2e.\nFrequency
      separation is %.2f GHz.",k,delf);

```

---

#### Scilab code Exa 6.14.1 Single longitudinal mode

```

1 // Example 6.14.1 page 6.42
2
3 clc;
4 clear;
5
6 // This is example does not consist of any numerical
   computation
7
8 printf("\nQuestion – What do you understand by
   single longitudinal mode laser or SLM? ")
9 printf("\nAnswer – \nIn laser operation optical gain
   alone is not sufficient for laser operation but
   a minimum amount of gain is also necessary.\nThis
   gain can be achieved when laser is pumped above
   threshold level.\nIn simplest laser structure we
   have p–n junction.Active layer is sandwiched
   between p and n type layers of higher bandgap
   material. Such broad area semiconductor laser
   need high threshold current and light confinement
   becomes difficult.\nGain guided semiconductor
   laser limit the current injection over a narrow

```

stripe thus overcome the problem of light confinement. They are also called stripe geometry lasers. In index guided laser an index step is introduced to form waveguide. In buried heterostructure laser the active region is buried by layers of lower refractive indices. When width and thickness of the active layer is controlled, light can be made to emerge in a single spatial mode, but the problem arises when such lasers oscillate in many longitudinal modes in Fabry Perot cavity. The spectral width obtained is about 2–4 nm which can be tolerated for 1.3 micrometer operation, but for systems operating near 1.55 micrometer at higher bit rates such multimode lasers can not be used. At such times laser which emit light in a single longitudinal mode are required to give higher bit rates than 1 Gb/s. They are called Single Longitudinal Mode (SLM) lasers.”);

---

**Scilab code Exa 6.21.1** Determine total recombination lifetime and internally generated power emission

```
1 // Example 6.21.1 page 6.59
2
3 clc;
4 clear;
5
6 tr=50; //radiative recombination lifetime
7 tnr=85; //non-radiative recombination lifetime
8 h=6.624d-34; //plank's constant
9 c=3d8; //speed of light
10 q=1.6d-19; //charge of electron
11 i=35d-3; //current
12 lamda=0.85d-6; //wavelength
```

```

13
14 t=tr*tnr/(tr+tnr);           //computing total
    recombination time
15 eta=t/tr;                     //computing internal
    quantum efficiency
16 Pint=eta*h*c*i/(q*lamda);    //computing internally
    generated power
17 Pint=Pint*10^3
18
19 printf("\nTotal recombinaiton time is %.2f ns.\n
    nInternal quantum efficiency is %.3f.\nInternally
    generated power is %.1f mW.",t,eta,Pint);
20
21 //answer in the book for Internal quantum efficiency
    is 0.629, deviation of 0.001.
22 //answer in the book for Internally generated power
    is 32.16 mW, deviation of 0.04 mW.

```

---

**Scilab code Exa 6.21.2** Determine total recombination life time internal quantum efficiency internal power level

```

1 // Example 6.21.2 page 6.59
2
3 clc;
4 clear;
5
6 tr=30;           //radiative recombination lifetime
7 tnr=100;        //non-radiative recombination lifetime
8 h=6.624d-34;    //plank's constant
9 c=3d8;          //speed of light
10 q=1.6d-19;     //charge of electron
11 i=40d-3;       //current
12 lamda=1310d-9; //wavelength
13
14 t=tr*tnr/(tr+tnr);           //computing total

```

```

    recombination time
15 eta=t/tr;           //computing internal
    quantum efficiency
16 Pint=eta*h*c*i/(q*lamda); //computing internally
    generated power
17 Pint=Pint*10^3
18
19 printf("\nTotal recombinaiton time is %.2f ns.\
    nInternal quantum efficiency is %.3f.\nInternally
    generated power is %.2f mW.",t,eta,Pint);
20
21 //answer in the book for Total recombinaiton time is
    23.07 ns, deviation of 0.01ns.

```

---

**Scilab code Exa 6.21.3** Determine total recombination lifetime and internally generated power

```

1 // Example 6.21.3 page 6.60
2
3 clc;
4 clear;
5
6 tr=50; //radiative recombination lifetime
7 tnr=110; //non-radiative recombination lifetime
8 h=6.624d-34; //plank's constant
9 c=3d8; //speed of light
10 q=1.6d-19; //charge of electron
11 i=40d-3; //current
12 lamda=0.87d-6; //wavelength
13
14 t=tr*tnr/(tr+tnr); //computing total
    recombination time
15 eta=t/tr; //computing internal
    quantum efficiency
16 Pint=eta*h*c*i/(q*lamda); //computing internally

```

```

    generated power
17 Pint=Pint*10^3
18
19 printf("\nTotal recombinaiton time is %.2f ns.\
    nInternal quantum efficiency is %.4f.\nInternally
    generated power is %.2f mW.",t,eta,Pint);
20
21 //answers in the book with slight devaiitons
22 //Total recombinaiton time is 34.37 ns, deviation of
    0.01ns.
23 //Internal quantum efficiency is 0.6874, devaiiton
    of 0.0001.
24 //Internally generated power is 39.24 mW, deviation
    of 0.02mW.

```

---

#### Scilab code Exa 6.22.1 Determine optical power

```

1 // Example 6.22.1 page 6.68
2
3 clc;
4 clear;
5
6 f1=10d6; //frequency
7 f2=100d6
8 t=4d-9;
9 Pdc=280d-6; //optincal output power
10
11 w1=2*pi*f1; //computing omega
12 Pout1=Pdc*10^6/(sqrt(1+(w1*t)^2)); //computing
    output power
13
14 w2=2*pi*f2; //computing omega
15 Pout2=Pdc*10^6/(sqrt(1+(w2*t)^2)); //computing
    output power
16

```

```

17 printf("Ouput power at 10 MHz is %.2f microwatt.\
    nOuput power at 100 MHz is %.2f microwatt.\
    nConclusion when device is drive at higher
    frequency the optical power reduces.\nNOTE –
    calculation error. In the book square term in the
    denominater is not taken.",Pout1,Pout2);
18
19 BWopt = sqrt(3)/(2*pi*t);
20 BWelec = BWopt/sqrt(2);
21 BWopt=BWopt*10^-6;
22 BWelec=BWelec*10^-6;
23
24 printf("\n3 dB optical power is %.2f MHz.\n3 dB
    electrical power is %.2f MHz.",BWopt,BWelec);
25
26
27 //calculation error. In the book square term in the
    denominater is not taken.
28 //answers in the book –
29 //Ouput power at 10 MHz is 228.7 microwatt.(
    incorrect)
30 //Ouput power at 100 MHz is 175 microwatt.(incorrect
    )
31 //3 dB optical power is 68.8 MHz, deviation of 0.12
32 //3 dB electrical power is 48.79 MHz, deviation of
    0.06

```

---

**Scilab code Exa 6.22.2** To calculate emitted optical power as percent of internal optical power

```

1 // Example 6.22.2 page 6.69
2
3 clc;
4 clear;
5

```

```

6 n1=3.5; //refractive index
7 n=1; //refractive index of air
8 F=0.69; //transmission factor
9
10 eta = 100*(n1*(n1+1)^2)^-1; //computing eta
11
12 printf("\neta external is %.1f percent i.e. small
fraction of intrnally generated opticalpower is
emitted from the device.",eta);
13 printf("\n\n OR we can also arrive at solution ,\n");
14
15 r= 100*F*n^2/(4*n1^2); //computing ratio of
Popt/Pint
16
17 printf("\n Popt/Pint is %.1f percent",r);
18
19 printf("\nNOTE – printing mistake at final answer.\
nThey have printed 40 percent it should be 1.4
percent");

```

---

### Scilab code Exa 6.22.3 Find operating lifetime

```

1 // Example 6.22.3 page 6.73
2
3 clc;
4 clear;
5
6 beta0=1.85d7;
7 T=293; //temperature
8 k=1.38d-23; //Boltzman constant
9 Ea=0.9*1.6d-19;
10 theta=0.65; //thershold
11
12 betar=beta0*%e^(-Ea/(k*T));
13 t=-log(theta)/betar;

```

```
14
15 printf("\nDegradation rate is %.2e per hour.\n
    nOperating lifetime is %.1e hour.",betar,t);
16
17 //answer in the book for Degradation rate is 6.4e-09
    per hour, deviation of 0.08e-9
18 //answer in the book for Operating lifetime is 6.7e
    +07 hour, deviaiton of 0.1e1
```

---



# Chapter 7

## Source to Fiber Power Launching and Photodetectors

Scilab code Exa 7.2.1 Find Fresnel reflection and power loss

```
1 // Example 7.2.1 page 7.11
2
3 clc;
4 clear;
5
6 n1=3.4; //refractive index of optical source
7 n=1.46; //refractive index of silica fiber
8
9 r=((n1-n)/(n1+n))^2; //computing Frensel
    reflection
10 L=-10*log10(1-r); //computing loss
11
12 printf("\nFrensel reflection is %.3f.\nPower loss is
    %.2f dB.",r,L);
```

---

Scilab code Exa 7.2.2 Compute optical power coupled

```

1 // Example 7.2.2 page 7.11
2
3 clc;
4 clear;
5
6 r=35d-6; //radius
7 R=150; //Lambertian emission pattern
8 NA=0.2; //Numerical aperture
9 Pled= %pi^2*r^2*R*NA^2;
10 Pled=Pled*10^7;
11 printf("\nOptical power for larger core of 35
    micrometer is %.3f mW.",Pled);
12 r1=25d-6;
13 Pled1=(r1/r)^2*Pled;
14 printf("\nOptical power for smaller core of 25
    micrometer is %.2f mW.",Pled1);

```

---

### Scilab code Exa 7.2.3 Calculate coupled power

```

1 // Example 7.2.3 page 7.12
2
3 clc;
4 clear;
5
6 r=25d-6; //radius
7 R=39; //Lambertian emission pattern
8 NA=0.25; //numerical aperture
9 a=35d-6; //area
10 Pc1= %pi^2*a^2*R*NA^2; //computing coupled power
    when r<a
11 Pc1=Pc1*10^7;
12 Pc= %pi^2*r^2*R*NA^2; //computing coupled power
    when r>a
13 Pc=Pc*10^7;
14

```

```
15 printf("\nOptical power when r>a is %.2f mW.\n\nOptical power when r<a is %.3f mW.",Pc,Pc1);
```

---

#### Scilab code Exa 7.2.4 Estimate external power efficiency

```
1 // Example 7.2.4 page 7.12
2
3 clc;
4 clear;
5
6 n1=3.6; //refractive index
7 n=1; //refractive index of air
8 F=0.68; //transmission factor
9 Pin=30/100; //percent power supplied
10
11 eta =(n1*(n1+1)^2)^-1; //computing eta
12 P=Pin*eta; //computing optical power emitted
13 eta=eta*100;
14 P=P*1000;
15 Pt=P*Pin; //computing internal power
16
17 printf("\neta external is %.1f percent.\nOptical\npower emitted is %.1f mW.\nInternal power is %.2f\nmW.",eta,P,Pt);
18 printf("\nNote – Printing error in the book they\nhave printed 1.5 instead of 1.3 as the answer of\neta.");
19
20 //Printing error in the book they have printed 1.5\ninstead of 1.3 as the answer of eta
```

---

#### Scilab code Exa 7.5.1 Estimate upper wavelength cutoff

```

1 // Example 7.5.1 page 7.24
2
3 clc;
4 clear;
5
6 h=6.626d-34; //plank's constant
7 c=3d8; //speed of light
8 e=1.6d-19; //charge of electron
9 q=1.43; //Bandgap energy
10
11 lamda=h*c/(q*e)*10^9; //computing wavelength
12 printf("\nWavelength is %d nm",lamda);
13 printf("\nThis proves that photodiode will not
    operate for photon of wavelength greater than %d
    nm.",lamda);
14
15 //answer in the book 868nm; deviation of 1nm

```

---

#### Scilab code Exa 7.5.2 Find photocurrent

```

1 // Example 7.5.2 page 7.24
2
3 clc;
4 clear;
5
6 R=0.6; //responsivity
7 Pin=15; //optical power in microwatt
8
9 Ip=R*Pin; //computing photocurrent
10 printf("\nPhotocurrent generated is %d microAmpere."
    ,Ip);

```

---

#### Scilab code Exa 7.5.3 Find cut off wavelength

```

1 // Example 7.5.3 page 7.24
2
3 clc;
4 clear;
5
6 lamda1=1300d-9;
7 lamda2=1600d-9;
8 h=6.625d-34; //plank's constant
9 c=3d8; //speed of light
10 q=1.6d-19; //charge of electron
11 eta=90/100; //quantum efficiency
12 E=0.73; //energy gap in eV
13 R1=eta*q*lamda1/(h*c);
14 R2=eta*q*lamda2/(h*c);
15 lamdac=1.24/E;
16
17 printf("\nResponsivity at 1300nm is %.2f A/W.\n
    nResponsivity at 1600nm is %.2f A/W.\nCutoff
    wavelength is %.1f micrometer.",R1,R2,lamdac);
18
19 //R1 is calculated as 0.92 in the book, deviation of
    0.02.

```

---

**Scilab code Exa 7.5.4** Determine quantum efficiency and responsivity

```

1 // Example 7.5.4 page 7.25
2
3 clc;
4 clear;
5
6 lamda=0.8d-6;
7 h=6.625d-34; //plank's constant
8 c=3d8; //speed of light
9 q=1.6d-19; //charge of electron
10 ne=1.8d11; //electrons collected

```

```

11 np=4d11;    //photons incident
12
13 eta=ne/np;    //computing quantum efficiency
14 R=eta*q*lamda/(h*c);    //computing responsivity
15
16 printf("\nResponsivity of photodiode at 0.8
    micrometer is %.3f A/W.",R);
17
18 //answer in the book is 0.289. deviation of 0.001 A/
    W

```

---

**Scilab code Exa 7.5.5** Find wavelength and incident power

```

1
2 // Example 7.5.5 page 7.25
3
4 clc;
5 clear;
6
7 h=6.626d-34;    //plank's constant
8 c=3d8;    //speed of light
9 eta=70/100; //quantum efficiency
10 I=3d-6;    //photocurrent
11 E=1.8d-19; //energy of photns
12 q=1.6d-19; //charge of electron
13
14 lamda=h*c/E;    //computing wavelength
15 R=eta*q*lamda/(h*c);    //computing responsivity
16 Popt=I/R;    //computing optical power
17 lamda=lamda*10^6;
18 Popt=Popt*10^6;
19
20 printf("\nWavelength is %.2f micrometer.\n
    nResponsivity is %.3f A/W.\nIncident optical
    power required is %.3f microWatt.",lamda,R,Popt);

```

```
21
22 //answer of Popt in the book is calculated as 4.823,
    deviation of 0.002
```

---

### Scilab code Exa 7.5.6 Determine wavelength

```
1 // Example 7.5.6 page 7.26
2
3 clc;
4 clear;
5
6 h=6.626d-34; //plank's constant
7 c=3d8; //speed of light
8 q=1.6d-19; //charge of electron
9 E=1.35; //energy gap in eV
10
11 lamda=h*c/(q*E); //computing wavelength
12 lamda=lamda*10^6;
13
14 printf("\nThe InP photodetector will stop operation
    above %.2f micrometer.",lamda);
15 printf("\nNOTE - calculation error in the book");
16
17 //calculation error in the book
18 //answer in the book 1.47 micrometer.(incorrect)
```

---

### Scilab code Exa 7.5.7 Calculate wavelength and incident optical power

```
1
2 // Example 7.5.7 page 7.27
3
4 clc;
5 clear;
```

```

6
7 h=6.626d-34; //plank's constant
8 c=3d8; //speed of light
9 eta=65/100; //quantum efficiency
10 I=2.5d-6; //photocurrent
11 E=1.5d-19; //energy of photns
12 q=1.6d-19; //charge of electron
13
14 lamda=h*c/E; //computing wavelength
15 R=eta*q*lamda/(h*c); //computing responsivity
16 Popt=I/R; //computing optical power
17 lamda=lamda*10^6;
18 Popt=Popt*10^6;
19
20 printf("\nWavelength is %.3f micrometer.\n
    nResponsivity is %.3f A/W.\nIncident optical
    power required is %.1f microWatt.",lamda,R,Popt);
21
22 //answer of R(responsivity) in the book is
    calculated as 0.694 A/W, deviation of 0.001.

```

---

#### Scilab code Exa 7.5.8 Find quantum efficiency

```

1 // Example 7.5.8 page 7.27
2
3 clc;
4 clear;
5
6 ne=3.9d6; //electrons collected
7 np=6d6; //photons incident
8
9 eta=100*ne/np; //computing efficiency
10 printf("\nQuantum efficiency is %d percent.",eta);

```

---



**Scilab code Exa 7.8.1** Determine drift time and junction temperature

```
1 // Example 7.8.1 page 7.39
2
3 clc;
4 clear;
5
6 w=25d-6; //width
7 v=1d5; //velocity
8 r=40d-6; //radius
9 eps=12.5d-13;
10
11 t=w/v; //computing drift time
12 c=eps*3.14*(r)^2/w; //computing junction
    capacitance
13 c=c*10^16;
14 printf("\nDrift time %.1e sec.\nJunction capacitance
    %.1f pf.",t,c);
15 printf("\nCalculation error in the book at the
    answer of drift time.");
16
17 //calculation error in drift time answer in the book
    is 25*10^-10. it should be 2.5*10^-10.
```

---

**Scilab code Exa 7.8.2** Find maximum response time

```
1 // Example 7.8.2 page 7.39
2
3 clc;
4 clear;
5
6 w=20d-6; //width
```

```

7 v=4d4;          //velocity
8
9 t=w/v;          //computing drift time
10 BW=(2*%pi*t)^-1;      //computing bandwidth
11 rt=1/BW;       //computing response time
12 rt=rt*10^9;
13
14 printf("\nMaximum response time is %.1f ns.",rt);
15 printf("\nNOTE - Calculation error in the book.");
16
17 //Calculation error in the book, answer given is 6.2
   ns

```

---

**Scilab code Exa 7.9.1** Calculate noise equivalent power and specific directivity

```

1 // Example 7.9.1 page 7.45
2
3 clc;
4 clear;
5
6 lamda=1.4d-6;
7 h=6.626d-34;    //plank's constant
8 c=3d8;          //speed of light
9 q=1.6d-19;     //charge of electron
10 eta=65/100;   //quantum efficiency
11 I=10d-9;      //current
12
13 NEP= h*c*sqrt(2*q*I)/(eta*q*lamda);
14 D=NEP^-1;
15
16 printf("\nNoise equivalent power is %.3e W.\n
   nSpecific directivity is %.2e.",NEP,D);
17
18 //answers in the book for NEP is 7.683*10^-14,

```

```

    deviation of  $0.04 \times 10^{-14}$ .
19 //answers in the book for D is  $13.01 \times 10^{12}$ ,
    deviation of  $0.11 \times 10^{12}$ .

```

---

**Scilab code Exa 7.9.2** Find mean square quantum noise current and mean square dark current

```

1 // Example 7.9.2 page 7.46
2
3 clc;
4 clear;
5
6 lamda=1300d-9;
7 h=6.626d-34; //plank's constant
8 c=3d8; //speed of light
9 q=1.6d-19; //charge of electron
10 eta=90/100; //quantum efficiency
11 P0=300d-9; //optical power
12 Id=4; //dark current
13 B=20d6; //bandwidth
14 K=1.39d-23; //Boltzman constant
15 T=298; //temperature
16 R=1000; //load resister
17 Ip= 10^9*eta*P0*q*lamda/(h*c);
18 Its=10^9*(2*q*B*(Ip+Id));
19 Its=sqrt(Its);
20 printf(" \nrms shot noise current is %.2f nA.",Its);
21
22 It= 4*K*T*B/R;
23 It=sqrt(It);
24 printf(" \nThermal noise is %.2e A.",It);
25
26 //answer given in book for shot noise is 1.34nA,
    deviation of 0.01nA.
27 //answer given in book for Thermal noise it is

```

$1.81 \times 10^{-8}$  A, deviation of  $0.01 \times 10^{-8}$ .

---

**Scilab code Exa 7.10.1** Find multiplication factor

```
1 // Example 7.10.1 page 7.53
2
3 clc;
4 clear;
5
6 lamda=0.85d-6;
7 h=6.626d-34; //plank's constant
8 c=3d8; //speed of light
9 q=1.6d-19; //charge of electron
10 eta=75/100; //quantum efficiency
11 P0=0.6d-6; //incident optical power
12 Im=15d2; //avalanche gain
13
14 R= eta*q*lamda/(h*c); //computing responsivity
15 Ip=10^8*P0*R; //computing photocurrent
16 Ip=floor(Ip);
17 M=Im/Ip; //computing multiplication factor
18 printf("\nMultiplication factor is %d.",M);
```

---

**Scilab code Exa 7.10.2** Find avalanche gain

```
1 // Example 7.10.3 page 7.54
2
3 clc;
4 clear;
5
6 lamda=900d-9;
7 h=6.626d-34; //plank's constant
8 c=3d8; //speed of light
```

```

9 q=1.6d-19; //charge of electron
10 eta=65/100; //quantum efficiency
11 P0=0.5d-6; //incident optical power
12 Im=10d2; //avalanche gain
13
14 R= eta*q*lamda/(h*c); //computing responsivity
15 Ip=10^8*P0*R; //computing photocurrent
16 M=Im/Ip; //computing multiplication factor
17 printf("\nMultiplication factor is %d.",M);
18
19 //answer in the book is 41.7 deviation 0.3.

```

---

### Scilab code Exa 7.10.3 Find multiplication factor

```

1 // Example 7.10.3 page 7.54
2
3 clc;
4 clear;
5
6 lamda=900d-9;
7 h=6.626d-34; //plank's constant
8 c=3d8; //speed of light
9 q=1.6d-19; //charge of electron
10 eta=65/100; //quantum efficiency
11 P0=0.5d-6; //incident optical power
12 Im=10d2; //avalanche gain
13
14 R= eta*q*lamda/(h*c); //computong responsivity
15 Ip=10^8*P0*R; //computing photocurrent
16 Ip=floor(Ip);
17 M=Im/Ip; //computing multiplication factor
18 printf("\nMultiplication factor is %d.",M);

```

---

**Scilab code Exa 7.10.4** Find wavelength incident optical power and responsivity

```
1 // Example 7.10.4 page 7.54
2
3 clc;
4 clear;
5
6 h=6.626d-34; //plank's constant
7 c=3d8; //speed of light
8 q=1.602d-19; //charge of electron
9 eta=70/100; //quantum efficiency
10 P0=0.5d-6; //incident optical power
11 Ip=4d-6; //avalanche gain
12 E=1.5d-19;
13
14 lamda=h*c/(E); //computing wavelength
15 R= eta*q*lamda/(h*c); //computing responsivity
16 P0=Ip/R; //computing optical power
17
18 lamda=lamda*10^6;
19 P0=P0*10^6;
20 printf("\nWavelength is %.3f micrometer.\n
    nResponsivity is %.4f A/W.\nOptical power is %.2f
    microWatt.", lamda, R, P0);
21
22 //answer of optical power in the book is 5.53
    microWatt, deviation of 0.17 microWatt.
```

---

**Scilab code Exa 7.10.5** Find multiplication factor

```
1 // Example 7.10.5 page 7.55
2
3 clc;
4 clear;
```

```

5
6 lamda=900d-9;
7 h=6.626d-34;    //plank's constant
8 c=3d8;         //speed of light
9 q=1.6d-19;     //charge of electron
10 eta=65/100;   //quantum efficiency
11 P0=0.5d-6;    //incident optical power
12 Im=10d2;      //avalanche gain
13
14 R= eta*q*lamda/(h*c);    //computing responsivity
15 Ip=10^8*P0*R;           //computing photocurrent
16 Ip=floor(Ip);
17 M=Im/Ip;                //computing multiplication factor
18 printf("\nMultiplication factor is %d.",M);
19
20 //answer in the book is 42.55 deviation 0.45

```

---

**Scilab code Exa 7.10.6** Calculate quantum efficiency and output photocurrent

```

1 // Example 7.10.6 page 7.55
2
3 clc;
4 clear;
5
6 h=6.626d-34;    //plank's constant
7 c=3d8;         //speed of light
8 q=1.602d-19;   //charge of electron
9 P0=0.5d-6;     //incident optical power(assumption)
10 lamda=1.5d-6;  //wavelength
11 M=20;          //Multiplication factor
12 R=0.6;         //Responsivity
13
14 eta=(R*h*c)/(q*lamda); //computing quantum
    efficiency

```

```
15 Ip=P0*R;          //computing photocurrent
16 I=M*Ip*10^6;     //computing output current
17
18 printf("\nQuantum efficiency is %.3f micrometer.\n
        nOutput current %d microAmpere.",eta,I);
19
20 //answer of quantum efficiency in the book is given
    as 0.495, deviation of 0.001.
```

---



## Chapter 8

# Optical Receiver Operation

Scilab code Exa 7.q Determine maximum response time

```
1 // Question 7 page 8.55
2
3 clc;
4 clear;
5
6 w=25d-6; //width
7 v=3d4; //velocity
8
9 t=w/v; //computing drift time
10 BW=(2*%pi*t)^-1; //computing bandwidth
11 rt=1/BW; //response time
12 rt=rt*10^9;
13
14 printf("\nMaximum response time is %.2f ns.",rt);
15
16 //Answer in the book is given as 5.24ns deviation of
    0.01ns
```

---

Scilab code Exa 8.3.1 Find quantum efficiency and minimum incident power

```

1 // Example 8.3.1 page 8.9
2
3 clc;
4 clear;
5
6 P=10^-9; //probability of error
7 eta=1; //ideal detector
8 h=6.626d-34 //plank's constant
9 c=3d8; //speed of light
10 lamda=1d-6; //wavelength
11 B=10^7; //bit rate
12
13 Mn= - log(P);
14 printf("\n The quantum limit at the receiver to
    maintain bit error rate 10^-9 is (%.1f*h*f)/eta."
    ,Mn);
15 f=c/lamda
16 Popt= 0.5*Mn*h*f*B/eta; //computing optical
    power
17 Popt_dB = 10 * log10(Popt) + 30; //optical power
    in dbm
18 Popt=Popt*10^12;
19
20 printf("\nMinimum incident optical power is %.1f W
    or %.1f dBm." ,Popt ,Popt_dB);

```

---

**Scilab code Exa 8.3.2** Calculate incident optical power

```

1 // Example 8.3.2 page 8.11
2
3 clc;
4 clear;
5
6 SN_dB=60; //signal to noise ratio
7 h=6.626d-34 //plank's constant

```

```

8 c=3d8;          //speed of light
9 lamda=1.3d-6;  //wavelength
10 eta=1;
11 B=6.5d6;      //Bandwidth
12
13 SN=10^(SN_dB/10);
14 f=c/lamda
15 Popt= 2*SN*h*f*B/eta;    //computing optical power
16 Popt_dB = 10 * log10(Popt) + 30;    //optical power
    in dbm
17 Popt=Popt*10^6;
18 printf("\nIncident power required to get an SNR of
    60 dB at the receiver is %.4f microWatt or %.3f
    dBm",Popt,Popt_dB);
19 printf("\nNOTE – Calculation error in the book.\n
    They have take SN as 10^5 while calculating ,
    which has lead to an error in final answer");
20
21 //Calculation error in the book.They have take SN as
    10^5 while calculating , which has lead to an
    error in final answer
22 //answer in the book 198.1nW and -37.71 dBm

```

---

### Scilab code Exa 8.10.1 Find signal to noise ratio

```

1 // Example 8.10.1 page 8.25
2
3 clc;
4 clear;
5
6 //erfc 4.24 is given to be 2d-9
7
8 SN=(2*sqrt(2)*4.24)^2; //computing optical SNR
9 SN=round(SN);
10 SN1=sqrt(SN); //computing electrical SNR

```

```
11 printf("\nOptical SNR is %d.\nElectrical SNR is %d."
        ,SN ,SN1);
```

---

#### Scilab code Exa 8.11.1 Find photon energy

```
1 // Example 8.11.1 page 8.26
2
3 clc;
4 clear;
5
6 P=1d-9; //probability of error
7 eta=1;
8 N= -log(P);
9 N1=round(N);
10 printf("Thus %.1f or %d photons are required for
        maintaining 10^-9 BER.\nAssuming eta=1;\nE=%.1f*
        hv." ,N,N1,N);
```

---

#### Scilab code Exa 8.17.1 Calculate shot noise and thermal noise

```
1 // Example 8.17.1 page 8.46
2
3 clc;
4 clear;
5
6 lamda=0.85d-6;
7 h=6.626d-34; //plank's constant
8 c=3d8; //speed of light
9 q=1.6d-19; //charge of electron
10 eta=65/100; //quantum efficiency
11 P0=300d-9; //optical power
12 Id=3.5; //dark current
13 B=6.5d6; //bandwidth
```

```

14 K=1.39d-23; //Boltzman constant
15 T=293;      //temperature
16 R=5d3;      //load resister
17 Ip= 10^9*eta*P0*q*lamda/(h*c);
18 Its=10^9*(2*q*B*(Ip+Id));
19 Its=sqrt(Its);
20 printf("\nrms shot noise current is %.2f nA.",Its);
21
22 It= 4*K*T*B/R;
23 It=sqrt(It);
24 It=It*10^9;
25 printf("\nThermal noise is %.2f nA.",It);
26
27 //answer given in book for Thermal noise it is 4.58
   nA, deviation is 0.02nA.

```

---

#### Scilab code Exa 8.17.2 Find signal to noise ratio

```

1 // Example 8.17.2 page 8.47
2
3 clc;
4 clear;
5
6 lamda=0.85d-6;
7 h=6.626d-34; //plank's constant
8 c=3d8;      //speed of light
9 q=1.6d-19; //charge of electron
10 eta=65/100; //quantum efficiency
11 P0=300d-9; //optical power
12 Id=3.5;    //dark current
13 B=6.5d6;   //bandwidth
14 K=1.39d-23; //Boltzman constant
15 T=293;    //temperature
16 R=5d3;    //load resister
17 F_dB=3;   //noise figure

```

```

18 F=10^(F_dB/10);
19 Ip=10^9*eta*P0*q*lamda/(h*c);
20 Its=10^9*(2*q*B*(Ip+Id));
21 It1= 4*K*T*B*F/R;
22
23 SN= Ip^2/(Its+It1);
24 SN_dB=10*log10(SN);
25 SN=SN/10^4;
26
27 printf("\nSNR is %.2f*10^4 or %.2f dB.",SN,SN_dB);
28
29 //answer given in the book is 6.16*10^4 (deviation
    of 0.9) and 47.8dB (deviation of 0.16dB)

```

---

#### Scilab code Exa 8.18.1 Calculate maximum load resistance

```

1 // Example 8.18.1 page 8.48
2
3 clc;
4 clear;
5
6 Cd=7d-12;
7 B=9d6;
8 Ca=7d-12;
9
10 R=(2*3.14*Cd*B)^-1;
11 B1=(2*3.14*R*(Cd+Ca))^-1;
12 R=R/1000;
13 B1=B1/10^6;
14 printf("\nThus for 9MHz bandwidth maximum load
    resistance is %.2f Kohm\nNow if we consider input
    capacitance of following amplifier Ca then
    Bandwidth is %.2fMHz\nMaximum post detection
    bandwidth is half.",R,B1);
15

```

16 //answer for resistance in the book is 4.51Kohm,  
deviation of 0.01Kohm, while for bandwidth it is  
4.51 MHz, deviation of 0.01MHz

---

# Chapter 9

## Link Designs and Optical Amplifiers

Scilab code Exa 9.4.1 Find safty margin

```
1 // Example 9.4.1 page 9.11
2
3 clc;
4 clear;
5
6 output=13; //laser output
7 sensitivity=-31; //APD sensitivity
8 coupling_loss=0.5;
9 L=80; //length in km
10 sl=0.1; //loss correspond to one splice in dB
11 fl=0.35; //fiber loss in dB/km
12 noise=1.5;
13
14 allowed_loss=output-sensitivity;
15 splices_loss=(L-1)*sl;
16 fiber_loss=L*fl;
17 margin=allowed_loss-(splices_loss+fiber_loss+
    coupling_loss+noise);
18
```



```
19 printf("\nFinal margin is %.1f dB.",margin);
```

---

#### Scilab code Exa 9.4.2 Determine safety margin

```
1 // Example 9.4.2 page 9.12
2
3 clc;
4 clear;
5
6 output=3; //laser output
7 sensitivity=-54; //APD sensitivity
8 coupling_loss=17.5;
9 L=6; //length in km
10 sl=1.1; //loss correspond to one splice in dB
11 n=3; //number of splices
12 fl=5; //fiber loss in dB/km
13 connector_loss=0.8;
14
15 allowed_loss=output-sensitivity;
16 splices_loss=n*sl;
17 fiber_loss=L*fl;
18 margin=allowed_loss-(splices_loss+fiber_loss+
19     coupling_loss+connector_loss);
20 printf("\nFinal margin is %.1f dB.",margin);
```

---

#### Scilab code Exa 9.4.3 Determine safety margin

```
1 // Example 9.4.3 page 9.13
2
3 clc;
4 clear;
5
```

```

6 output=-10;      //laser output
7 sensitivity=-41; //APD sensitivity
8 L=7;    //length in km
9 sl=0.5; //loss correspond to one splice in dB
10 fl=2.6; //fiber loss in dB/km
11 connector_loss=1.5;
12 saftey_margin=6;
13
14 allowed_loss=output-sensitivity;
15 splices_loss=(L-1)*sl;
16 fiber_loss=L*fl;
17 margin=allowed_loss-(splices_loss+fiber_loss+
    connector_loss+saftey_margin);
18
19 printf("\nFinal margin is %.1f dB.",margin);

```

---

**Scilab code Exa 9.4.4** Determine safety margin and link length

```

1 // Example 9.4.4 page 9.14
2
3 clc;
4 clear;
5
6 output=-10;      //laser output
7 sensitivity=-25; //APD sensitivity
8 L=2;    //length in km
9 sl=0.7; //loss correspond to one splice in dB
10 fl=3.5; //fiber loss in dB/km
11 connector_loss=1.6;
12 saftey_margin=4;
13
14 allowed_loss=output-sensitivity;
15 splices_loss=L*sl;
16 fiber_loss=L*fl;
17 margin=allowed_loss-(splices_loss+fiber_loss+

```

```

        connector_loss+saftey_margin);
18
19 printf("\nFinal margin is %.1f dB.",margin);
20
21 printf("\n\nIf laser launches a optical power of 0
        dBm then,\n");
22
23 output=0;          //laser output
24 sensitivity=-25;   //APD sensitivity
25 saftey_margin=7;
26 allowed_loss=output-sensitivity;
27 length_fiber= (allowed_loss-(splices_loss+
        connector_loss+saftey_margin))/fl;
28 increase=length_fiber-L;
29 printf("\nIncrease in the fiber length is %.2f km.",
        increase);
30
31 //answer in the book is 2.28, deviation of 0.01

```

---

#### Scilab code Exa 9.4.5 Determine link length

```

1 // Example 9.4.5 page 9.16
2
3 clc;
4 clear;
5
6 output=22;          //laser output
7 sensitivity=-35;    //APD sensitivity
8 sl=0.05; //loss correspond to one splice in dB
9 fl=0.4; //fiber loss in dB/km
10 connector_loss=2;
11 saftey_margin=6;
12 penalties=1.5
13 allowed_loss=output-sensitivity;
14 Length = (allowed_loss-(connector_loss+penalties+

```

```

    saftey_margin))/(sl+fl);
15 Length=floor(Length);
16 printf("\nLink length is %d km.",Length);

```

---

### Scilab code Exa 9.6.1 Find maximum bit rate

```

1 // Example 9.6.1 page 9.19
2
3 clc;
4 clear;
5
6 L=10;
7 ts=10;
8 tD=8;
9 tmod=L*6;
10 tt=L*2;
11
12 Tsys=1.1*sqrt(ts^2+tmod^2+tt^2+tD^2);
13 Bt=0.7/Tsys;
14 Bt=Bt*10^3;
15 printf("Maximum bit rate for link using NRZ data
    format is %.2f Mbits/sec.",Bt);
16 printf("\nNOTE - calculation error in the book");
17
18 //calculation error in the book
19 //answer given in the book is 10.3mbits/sec.(
    incorrect)

```

---

### Scilab code Exa 9.6.2 Estimate maximum bit rate

```

1 // Example 9.6.2 page 9.20
2
3 clc;

```

```

4  clear;
5
6  L=8;
7  ts=8;
8  tD=6;
9  tmod=L*1;
10 tt=L*5;
11
12 Tsys=sqrt(ts^2+tmod^2+tt^2+tD^2);
13 Bt=0.7/Tsys;
14 Bt=Bt*10^3;
15 printf("\nMaximum bit rate for link using NRZ data
    format is %.2f Mbits/sec.\nMaximum bit rate for
    link using RZ data format is %.2f Mbits/sec.",Bt,
    Bt/2);

```

---

**Scilab code Exa 9.6.3** Determine whether or not combination of component gives an adequate response

```

1  // Example 9.6.3 page 9.21
2
3  clc;
4  clear;
5
6  L=5;
7  ts=10;
8  tD=3;
9  tmod=L*2;
10 tt=L*9;
11
12 Tsys=sqrt(ts^2+tmod^2+tt^2+tD^2);
13 Bt=0.7/Tsys;
14 Bt=Bt*10^3;
15 printf("\nMaximum bit rate for link using NRZ data
    format is %.1f Mbits/sec.",Bt);

```

```
16 printf("\nThis is equivalent to a 3 dB optical
    bandwidth of %.1f MHz, hence the desired required
    bandwidth 6 MHz which will be supported",Bt/2);
```

---

**Scilab code Exa 9.16.1** Find amplifier gain and minimum pump power required

```
1 // Example 9.16.1 page 9.53
2
3 clc;
4 clear;
5
6 Pin=2;
7 Pout=27;
8
9 gain_db= Pout-Pin;
10 gain= 10^(Pout/10)/10^(Pin/10);
11 min_pow = 10^(Pout/10) - 10^(Pin/10);
12
13 printf("\nGain in dB is %d dB.\nGain is %.2f.\n
    nMinimum pump power is %.1f mW.",gain_db,gain,
    min_pow);
14
15 //answer in the book for gain is 317, deviation of
    0.77 and for minimum pump power it is 499.4,
    deviation of 0.2
```

---

**Scilab code Exa 9.20.1** Maximum input and output power

```
1 // Example 9.20.1 page 9.65
2
3 clc;
4 clear;
```

```

5
6 gain_db=25;
7 lamdaP=980d-9;
8 lamdaS=1550d-9;
9 Pp=40d-3;
10
11 gain=10^(gain_db/10);           //computing gain
12 Pin=(lamdaP/lamdaS)*Pp/(gain-1); //computing
    maximum input power
13 Pout=Pin+(lamdaP/lamdaS)*Pp;    //computing
    maximum output power
14 Pout_db=10*log10(Pout/10^-3);   //computing
    maximum output power in dB
15 Pin=Pin*10^6;
16 printf("\nGain is %.2f.\nMaximum input power is %.2f
    microWatt.\nMaximum output power is %.2f dbm.",
    gain,Pin,Pout_db);
17 printf("\n\nNOTE - calculation error in max input
    power instead of G-1, G-100 is taken.");
18
19 //answer in the book for Max output power is 14.03
    dBm, deviation of 0.01
20 //calculation error in max input power instead of G
    -1, G-100 is taken, answer given is 116 microWatt

```

---

# Chapter 10

## Fiber Measurements

**Scilab code Exa 10.5.1** Calculate 3 dB pulse broadening and bandwidth length product

```
1 // Example 10.5.1 page 10.24
2
3 clc;
4 clear;
5
6 To=12.6; //width of output pulse
7 Ti=0.3; //width of input pulse
8 l=1.2; //length of measurement
9
10 Pulse_dispersion = sqrt(To^2 - Ti^2); //computing
    pulse dispersion
11 PDKM=Pulse_dispersion/l; //computing pulse
    dispersion per Kilometer
12 BW=0.44/PDKM; //computing optical bandwidth
13 BW=BW*1000;
14 printf("\nPulse broadning is %.1f ns/km.\nOptical
    bandwidth is %.1f MHz.Km.",PDKM,BW);
```

---



**Scilab code Exa 10.6.1** Determine attenuation and estimate accuracy

```
1 // Example 10.6.1 page 10.28
2
3 clc;
4 clear;
5
6 V2=12;
7 V1=2.5;
8 L2=3;
9 L1=0.004;
10
11 alpha_dB = 10* log10(V2/V1)/(L2-L1);
12 un = 0.2/(L2-L1);
13
14 printf("\nAttenuation is %.2f dB/km\nUncertainty
    +/- %.3f dB.", alpha_dB, un);
15
16 //answer for attenuation in the book is 2.26
    deviation of 0.01 and for uncertainty is 0.066
    deviation of 0.001
```

---