

Scilab Textbook Companion for
Optical Communiation
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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

Overview of Optical Fiber Communciations

Scilab code Exa 10.q duration

```
1 // Question 10
2 clc;
3 clear;
4 Bit_rate = 2d12; // bit rate of channel
5 // Given sequence is 010111101110
6 Shortest_duration = 1 * (1/Bit_rate); //
   shortest duration is '1'
7 Widest_duration = 4 * (1/Bit_rate); //widest
   duration is '1111'
8 Shortest_duration=Shortest_duration*10^12; //
   Converting into nano seconds
9 Widest_duration=Widest_duration*10^12; //
   Converting into nano seconds
10 printf("\nShortest duration is %.1f nano second.",
   Shortest_duration);
11 printf("\nWidest duration is %d nano second.",
   Widest_duration);
```

Scilab code Exa 1.6.1 duration

```
1 // Example 1.6.1
2 clc;
3 clear;
4 Bit_rate = 2d9; // bit rate of channel
5 // Given sequence is 010111101110
6 Shortest_duration = 1 * (1/Bit_rate); //
   shortest duration is '1'
7 Widest_duration = 4 * (1/Bit_rate); //widest
   duration is '1111'
8 Shortest_duration=Shortest_duration*10^9; //
   Converting into nano seconds
9 Widest_duration=Widest_duration*10^9; //
   Converting into nano seconds
10 printf("\nShortest duration is %.1f nano second.",
   Shortest_duration);
11 printf("\nWidest duration is %d nano second.",
   Widest_duration);
```

Scilab code Exa 1.12.1 capacity

```
1 // Example 1.12.1
2 clc;
3 clear;
4 Bandwidth = 2d6; //Bandwidth of channel
5 Signal_to_Noise_ratio = 1; //Signal to
   Noise ratio of channel
6 Capacity = Bandwidth * log2(1 +
   Signal_to_Noise_ratio); //computing capacity
7 Capacity=Capacity/10^6;
```

```
8 printf("Maximum capacity of channel is %d Mb/sec.",  
Capacity);
```

Chapter 2

optical fibers

Scilab code Exa 4.q birefringence

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

Scilab code Exa 5.q modal birefringence

```
1 // Question 5
2 clc;
3 clear;
4 L_BL=0.6d-3; //beat length
5 lamda=1.4d-6; //wavelength
6 L_BL1=70;
7 Bh=lamda/L_BL; //computing high birefringence
8 Bl=lamda/L_BL1; //computing low birefringence
```

```
9 printf("\nHigh birefringence is %.2e.\nLow
    birefringence is %.1e.",Bh,B1);
```

Scilab code Exa 2.4.1 NA and critical angle

```
1 // Example 2.4.1:Numerical Aperture and critical
    angle
2 clc;
3 clear;
4 close;
5 n1=1.46;//refractive index
6 d=0.01;//difference
7 na=n1*sqrt(2*d);//numerical aperture
8 x=1-d;//
9 oc=asind(x);//in degree
10 disp(na,"numerical aperture is")
11 disp(oc,"critical angle at core cladding interface
    is ,(degree)=")
```

Scilab code Exa 2.5.1 criticle anlge NA nad accerptance angle

```
1 // Example 2.5.1:Numerical Aperture ,critical angle
    and acceptance angle
2 clc;
3 clear;
4 close;
5 n2=1.45;//core refrative index
6 n1=1.49;//cladding refrative index
7 oc=asind(n2/n1);//in degree
8 na=sqrt(n1^2-n2^2);//numerical aperture
9 pc=asind(na);//degree
10 disp(oc,"critical angle is ,(degree)=")
11 disp(na,"numerical aperture is ,=")
```

```
12 disp(pc," acceptance angle is ,(degree)=")
```

Scilab code Exa 2.5.2 refractive index

```
1 // Example 2.5.2
2 clc;
3 clear;
4 delta = 1.2/100; // Relative refractive
  difference index
5 n1=1.45; // Core refractive index
6 NA= n1*sqrt(2*delta); //computing numerical
  aperture
7 Acceptance_angle = asind(NA); //computing
  acceptance angle
8 si = %pi * NA^2; //computing solid acceptance
  angle
9 printf("\nNumerical aperture is %.3f.\nAcceptance
  angle is %.2f degree.\nSolid acceptance angle is
  %.3f radians.",NA,Acceptance_angle,si);
10 //answer in the book for Numerical aperture is
  0.224, deviation of 0.001
11 //answer in the book for solid acceptance angle is
  0.157, deviation of 0.002
```

Scilab code Exa 2.5.3 acceptance angle

```
1 // Example 2.5.3
2 clc;
3 clear;
4 NA = 0.45; // Numerical Aperture
5 Acceptance_angle = asind(NA); //computing
  acceptance angle.
```

```
6 printf("\nAcceptance angle is %.1f degree.",
    Acceptance_angle);
```

Scilab code Exa 2.5.4 full cone angle

```
1 // Example 2.5.4
2 clc;
3 clear;
4 diameter = 1; //Diameter in centimeter
5 Focal_length = 10; //Focal length in centimeter
6 radius=diameter/2; //computing radius
7 Acceptance_angle = atand(radius/Focal_length); //
    computing acceptance angle
8 Conical_full_angle = 2*Acceptance_angle; //
    computing conical angle
9 Solid_acceptance_angle = %pi*Acceptance_angle^2;
    //computing solid acceptance angle
10 NA = sqrt(Solid_acceptance_angle/%pi); //
    computing Numerical aperture
11 printf("\nNumerical aperture is %.2f.\nConical full
    angle is %.2f degree.",NA,Conical_full_angle);
```

Scilab code Exa 2.6.1 acceptance angle

```
1 // Example 2.6.1
2 clc;
3 clear;
4 NA = 0.45 //Numerical aperture
5 betaB = 45 // Skew ray change direction by 90
    degree at each reflection
6 Meridional_theta = asind(NA); //computing
    acceptacne angle for meridoinal ray
```

```

7 Skew_theta = asind(NA/cosd(betaB)); //computing
  acceptacne angle for skew ray
8 printf("\nAcceptacne angle for Meridoinal ray is %.2
  f degree.\nAcceptance angle for Skew ray %.1f
  degree.",Meridional_theta,Skew_theta);

```

Scilab code Exa 2.8.1 normalized frequency and guided modes

```

1 // Example 2.8.1
2 clc;
3 clear;
4 core_diameter=78d-6; //core diameter
5 delta=1.4/100; //relative index difference
6 lamda=0.8d-6; //operating wavelength
7 n1=1.47; //core refractive index
8 a=core_diameter/2; //computing core radius
9 v= 2*3.14*a*n1*sqrt(2*delta)/lamda; //computing
  normalized frequency
10 M=(v)^2/2; //computing guided modes
11 printf("\nNormalized Frequency is %.3f.\nTotal
  number of guided modes are %.1f",v,M);
12 //answer in the book for normalized frequency is
  given as 75.156(incorrect) and for Guided modes
  is 5648.5(incorrect)

```

Scilab code Exa 2.8.2 cutoff wavelength

```

1 // Example 2.8.2
2 clc;
3 clear;
4 n1=1.47 //refractive index of core
5 a=4.3d-6; //radius of core
6 delta=0.2/100 //relative index difference

```

```

7 lamda= 2*3.14*a*n1*sqrt(2*delta)/2.405;    //
   computing wavelength
8 lamda=lamda*10^9;
9 printf("Wavelength of fiber is %d nm.",lamda);
10 //answer in the book is given as 1230nm which is
   incorrect.

```

Scilab code Exa 2.8.3 solid angle

```

1 // Example 2.8.3
2 clc;
3 clear;
4 n1=1.482;    //refractive index of core
5 n2=1.474;    //refractive index of cladding
6 lamda=820d-9;    //Wavelength
7 NA=sqrt(n1^2 - n2^2);    //computing Numerical
   aperture
8 theta= asind(NA);    //computing acceptance
   angle
9 solid_angle=%pi*(NA)^2;    //computing solid angle
10 a=2.405*lamda/(2*3.14*NA);    //computing core
   radius
11 a=a*10^6;
12 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);
13 //answer in the book for Numerical aperture is
   0.155, deviation of 0.001.
14 //answer in the book for acceptance angle is 8.9,
   deviation of 0.1.
15 //answer in the book for solid acceptance angle is
   0.075, deviation of 0.001.
16 //answer in the book for core radius is 2.02
   micrometer, deviation of 0.02 micrometer.

```

Scilab code Exa 2.8.4 normalized frequency

```
1 // Example 2.8.4
2 clc;
3 clear;
4 NA=0.16 //Numerical aperture
5 n1=1.45 //core refractive index
6 d=60d-6 //core diameter
7 lamda=0.82d-6 //wavelength
8 a=d/2; //core radius
9 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
10 v=round(v);
11 M=v^2/2; //computing guided modes
12 M=floor(M);
13 printf("if normalized frequency is taken as %d, then
    %d guided modes.",v,M);
```

Scilab code Exa 2.8.5 guided modes

```
1 // Example 2.8.5
2 clc;
3 clear;
4 NA=0.2; //Numerical aperture
5 d=50d-6; //Diameter of core
6 lamda=1d-6; //Wavelength
7 a=d/2; //computing radius
8 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
9 Mg=v^2/4; //computing mode volume for
    parabolic profile
```

```

10 Mg=round(Mg);
11 printf("\nNormalized Frequency is %.1f.\nTotal
    number of guided modes are %.d.",v,Mg);
12 //answer in the book for guided modes is 247,
    deviation of 1.

```

Scilab code Exa 2.8.6 core diameter

```

1 // Example 2.8.6
2 clc;
3 clear;
4 delta=0.015; //relative refractive index
5 n1=1.48; //core refractive index
6 lamda=0.85d-6; //wavelength
7 a=(2.4*lamda)/(2*3.14*n1*sqrt(2*delta)); //
    computing radius of core
8 d=2*a; //computing diameter of core
9 a=a*10^7;
10 a=round(a);
11 a=a/10
12 d=d*10^6;
13 printf("\nCore radius is %.1f micrometer.\nCore
    diameter is %.1f micrometer.",a,2*a);
14 printf("\n\nWhen delta is reduced by 10 percent-");
15 delta=0.0015;
16 a=(2.4*lamda)/(2*3.14*n1*sqrt(2*delta)); //
    computing radius of core
17 d=2*a; //computing diameter of core
18 a=a*10^7;
19 a=round(a);
20 a=a/10
21 d=d*10^6;
22 printf("\nCore radius is %.1f micrometer.\nCore
    diameter is %.1f micrometer.",a,2*a);

```

Scilab code Exa 2.8.7 guided modes

```
1 // Example 2.8.7
2 clc;
3 clear;
4 NA=0.25; //Numerical aperture
5 d=45d-6; //Diameter of core
6 lamda=1.5d-6; //Wavelength
7 a=d/2; //computing radius
8 v=2*3.14*a*NA/lamda; //computing normalized
  frequency
9 Mg=v^2/4; //computing mode volume for
  parabolic profile
10 Mg=round(Mg);
11 printf(" \nNormalized Frequency is %.1f.\nTotal
  number of guided modes are %.d.",v,Mg);
12 //answer in the book for normalized frequency is
  23.55, deviation 0.05
```

Scilab code Exa 2.8.8 guided modes

```
1 // Example 2.8.8
2 clc;
3 clear;
4 NA=0.25; //Numerical aperture
5 d=45d-6; //Diameter of core
6 lamda=1.2d-6; //Wavelength
7 a=d/2; //computing radius
8 v=2*3.14*a*NA/lamda; //computing normalized
  frequency
9 Mg=v^2/4; //computing mode volume for
  parabolic profile
```

```

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

```

Scilab code Exa 2.8.9 cut off parameter

```

1 // Example 2.8.9
2 clc;
3 clear;
4 n1=1.54; //refractive index of core
5 n2=1.5; //refractive index of cladding
6 a=25d-6; //Radius of core
7 lamda=1.3d-6; //Wavelength
8 NA=sqrt(n1^2-n2^2);
9 v=2*3.14*a*NA/lamda; //computing normalized
    frequency
10 v=round(v);

```

```

11 Mg=v^2/4;           //computing mode volume for
    parabolic profile
12 Mg=round(Mg);
13 lamda_cut_off=v*lamda/2.405;   //computing cut off
    wavelength
14 lamda_cut_off=lamda_cut_off*10^6;
15 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 2.9.1 modal birefringence

```

1 // Example 2.9.1
2 clc;
3 clear;
4 L_BL=8d-2;   //beat length
5 Br=2*3.14/L_BL;   //computing modal birefringence
6 printf("\nModal birefringence is %.1f per meter.",Br
    );

```

Scilab code Exa 2.9.2 output power

```

1 // Example 2.9.2
2 clc;
3 clear;
4 Pin=500d-6;   //input power
5 L=200;       //length of fiber
6 loss=2;     //loss associated with fiber
7 Pin_dbm=10 * log10 (Pin/(10^-3));   //computing
    input power in dBm
8 Pin_dbm=round(Pin_dbm);
9 Pout_dbm=Pin_dbm-L*loss;   //computing output
    power level

```

```
10 Pout= 10^(Pout_dbm/10);
11 printf("Output power is %.2e mW.",Pout);
```

Scilab code Exa 2.12.1 cut off wavelength

```
1 // Example 2.12.1
2 clc;
3 clear;
4 a=4.5d-6; //core diameter
5 delta=0.25/100; //relative index difference
6 lamda=0.85d-6; //operating wavelength
7 n1=1.46; //core refractive index
8 v= 2*pi*a*n1*sqrt(2*delta)/lamda; //computing
   normalized frequency
9 lamda_cut_off=v*lamda/2.405; //computing cut
   off wavelength
10 lamda_cut_off=lamda_cut_off*10^9;
11 printf("\nCut off wavelength is %.d nanometer.",
   lamda_cut_off);
12 printf("\n\nWhen delta is 1.25 percent-");
13 delta=1.25/100;
14 v= 2*pi*a*n1*sqrt(2*delta)/lamda; //computing
   normalized frequency
15 lamda_cut_off=v*lamda/2.405; //computing cut
   off wavelength
16 lamda_cut_off=lamda_cut_off*10^7;
17 lamda_cut_off=round(lamda_cut_off);
18 lamda_cut_off=lamda_cut_off*100;
19 printf("\nCut off wavelength is %.d nanometer.",
   lamda_cut_off);
20
21 //answer in the book for cut off wavelength in the
   book is given as 1214nm, deviation of 1nm.
```

Scilab code Exa 2.12.2 cut off number

```
1 // Example 2.12.2
2 clc;
3 clear;
4 a=50d-6; //core radius
5 lamda=1500d-9; //operating wavelength
6 n1=2.53; //core refractive index
7 n2=1.5; //cladding refractive index
8 delta=(n1-n2)/n1; //computing delta
9 v= 2*3.14*a*n1*sqrt(2*delta)/lamda; //computing
    normalized frequency
10 M=(v)^2/2; //computing guided modes
11 printf("\nNormalized Frequency is %.1f\nTotal number
    of guided modes are %.d",v,M);
12 printf("\nNOTE - Calculation error in book. \n
    Normalized frequency is 477, it is calculated as
    47.66");
13
14 //Calculation error in book. Normalized frequency is
    477, it is calculated as 47.66, hence answers
    after that are erroneous.
15 //answers in the book
16 //normalized frequency = 48.(incorrect)
17 //guided modes = 1152.(incorrect)
```

Scilab code Exa 2.12.3 guided modes

```
1 // Example 2.12.3
2 clc;
3 clear;
4 core_diameter=8d-6; //core diameter
```

```

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

```

Scilab code Exa 2.12.4 delay difference

```

1 // Example 2.12.4
2 clc;
3 clear;
4 delta=1/100;           //relative index difference
5 n1=1.5;                //core refractive index
6 c=3d8;
7 L=6;
8 n2=sqrt(n1^2-2*delta*n1^2);    //computing
    refractive index of cladding
9 delta_T=L*n1^2*delta/(c*n2);    //computing pulse
    broadning
10 delta_T=delta_T*10^11;
11 delta_T=round(delta_T);
12 printf("\nDelay difference between slowest and
    fastest mode is %d ns/km.",delta_T);
13 printf("\nThis means that a pulse broadnes by %d ns
    after travel time a distance of %d km.",delta_T,L
    );

```

Scilab code Exa 2.17.1 entrance angle


```

1 // Example 2.17.1
2 clc;
3 clear;
4 n1=1.48;           //core refractive index
5 n2=1.46;           //cladding refractive index
6 phi = asind(n2/n1); //computing critical angle
7 NA = sqrt(n1^2 - n2^2); //computing numerica
    aperture
8 theta= asind(NA); //computing acceptance angle
9 printf("\\nCritical angle is %.2f degrees.\\nNumerical
    aperture is %.3f.\\nAcceptance angle is %.2f
    degree.",phi,NA,theta);
10 //answers in the book
11 //Critical angle is 80.56 degrees, deviation of
    0.01.
12 //Numerical aperture is 0.244, deviation of 0.002.
13 //Acceptance angle is 14.17 degree, deviation of
    0.14.

```

Chapter 4

Signal degradation in fibers

Scilab code Exa 4.3.1 input output ratio

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

equal to 10^5 , we can say that line is very lossy
.”);

Scilab code Exa 4.6.1 attenuation

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

Scilab code Exa 4.6.2 attenuation

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

```

10 lamda=0.7d-6; //wavelength
11 gamma_r = 8*(3.14^3)*(P^2)*(n^8)*beta_c*k*T/(3*(
    lamda^4)); //computing coefficient
12 attenuation=%e^(-gamma_r*L); //computing
    attenuation
13 gamma_r=gamma_r*1000;
14 printf("\nRaleigh Scattering corfficient is %.3f *
    10^-3 per meter\n",gamma_r);
15 printf("\nNOTE - in quetion they have asked for
    attenuation but in solution they have not
    calcaulted\n");
16 printf("\nAttenuation due to Rayleigh scattering is
    %.3f",attenuation);
17 //answer for Raleigh Scattering corfficient in the
    book is given as 0.804d-3, deviation of 0.003d-3

```

Scilab code Exa 4.7.1 threshold power

```

1 // Example 4.7.1
2 clc;
3 clear;
4 d=5; //core diameter
5 alpha=0.4; //attenuation
6 B=0.5; //Bandwidth
7 lamda=1.4; //wavelength
8 PB=4.4d-3*d^2*lamda^2*alpha*B; //computing
    threshold power for SBS
9 PR=5.9d-2*d^2*lamda*alpha; //computing
    threshold power for SRS
10 PB=PB*10^3;
11 PR=PR*10^3;
12 printf("\nThreshold power for SBS is %.1f mW.\n
    nThreshold power for SRS is %.3f mW.",PB,PR);
13 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.”);
14 // 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
15 //answers in the book
16 //PB=30.8mW
17 //PR=0.413mW

```

Scilab code Exa 4.8.1 critical radius

```

1 // Example 4.8.1
2 clc;
3 clear;
4 n1=1.5; //refractive index of core
5 delta=0.03/100; //relative refractive index
6 lamda=0.82d-6; //wavelength
7 n2=sqrt(n1^2-2*delta*n1^2); //computing
    cladding refractive index
8 Rc=(3*n1^2*lamda)/(4*3.14*(n1^2-n2^2)^1.5); //
    computing critical radius
9 Rc=Rc*10^3;
10 printf(" \nCritical radius is %.1f micrometer.",Rc);
11 //answer in the book is 9 micrometer , deviation of
    0.1 micrometer.

```

Scilab code Exa 4.8.2 singal mode and multi mode

```

1 // Example 4.8.2
2 clc;

```

```

3 clear;
4 n1=1.45; //refractive index of core
5 delta=3/100; //relative refractive index
6 lamda=1.5d-6; //wavelength
7 a=5d-6; //core radius
8 n2=sqrt(n1^2-2*delta*n1^2); //computing
   cladding refractive index
9 Rc=(3*n1^2*lamda)/(4*3.14*(n1^2-n2^2)^0.5); //
   computing critical radius for single mode
10 Rc=Rc*10^6;
11 printf("\nCritical radius is %.2f micrometer",Rc);
12 lamda_cut_off= 2*3.14*a*n1*sqrt(2*delta)/2.405;
13 RcSM= (20*lamda/(n1-n2)^1.5)*(2.748-0.996*lamda/
   lamda_cut_off)^-3; //computing critical
   radius for single mode
14 RcSM=RcSM*10^6;
15 printf("\nCritical radius for single mode fiber is %
   .2f micrometer.",RcSM);
16 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.");
17 //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.
18 //answer in the book is 7.23mm.(incorrect)

```

Scilab code Exa 4.13.1 material dispersion

```

1 // Example 4.13.1
2 clc;
3 clear;
4 lamda=1550d-9;
5 lamda0=1.3d-6;
6 s0=0.095;
7 Dt=lamda*s0/4*(1-(lamda0/lamda)^4); //computing

```

```

    material dispersion
8 Dt=Dt*10^9;
9 printf("\nMaterial dispersion at 1550 nm is %.1f ps/
    nm/km",Dt);
10 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");
11 //answer in the book 15.6 ps/nm/km, deviaton due to
    printing mistake.

```

Scilab code Exa 4.14.1 bandwidth

```

1 // Example 4.14.1
2 clc;
3 clear;
4 tau=0.1d-6; //pulse broadning
5 dist=20d3; //distance
6 Bopt=1/(2*tau); //computing optical bandwidth
7 Bopt=Bopt*10^-6;
8 dispertion=tau/dist; //computing dispersion
9 dispertion=dispertion*10^12;
10 BLP=Bopt*dist; //computing Bandwidth length
    product
11 BLP=BLP*10^-3;
12 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 4.15.1 rms pulse

```

1 // Example 4.15.1
2 clc;

```

```

3 clear;
4 RSW=0.0012; //relative spectral width
5 lamda=0.90d-6; //wavelength
6 L=1; //distance in km (assumed)
7 P=0.025; //material dispersion parameter
8 c=3d5; //speed of light in km/s
9 M=10^3*P/(c*lamda); //computing material
    dispersion
10 sigma_lamda=RSW*lamda;
11 sigmaM=sigma_lamda*L*M*10^7; //computing RMS
    pulse broadning
12 sigmaB=25*L*M*10^-3;
13 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);
14 //answer in the book for RMS pulse broadning is 0.99
    ns/km, deviation of 0.01ns/km.

```

Scilab code Exa 4.17.1 maximum bit rate

```

1 // Example 4.17.1
2 clc;
3 clear;
4 L=10; //length of optical link
5 n1=1.49 //refractive index
6 c=3d8; //speed of light
7 delta=1/100; //relative refractive index
8 delTS=L*n1*delta/c; //computing delay difference
9 delTS=delTS*10^12;
10 sigmaS=L*n1*delta/(2*sqrt(3)*c); //computing rms
    pulse broadning
11 sigmaS=sigmaS*10^12;
12 B=1/(2*delTS); //computing maximum bit rate
13 B=B*10^3;

```



```
14 B_acc=0.2/(sigmaS);      //computing accurate bit
    rate
15 B_acc=B_acc*10^3;
16 BLP=B_acc*L;           //computing Bandwidth length
    product
17 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);
18 //answer for maximum bit rate is given as 1.008 Mb/s
    , deviation of 0.008 Mb/s.
```

Chapter 5

optical fiber connection splicing

Scilab code Exa 5.2.1 loss

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

Scilab code Exa 5.2.2 loss

```

1 // Example 5.2.2
2 clc;
3 clear;
4 n1=1.47;           //refractive index of fiber
5 n=1;              //refractive index of air
6 d=40d-6;         //core diameter
7 y=4d-6;          //lateral displacement
8 a=d/2;           //computing core radius
9 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
10 loss=-10*log10(eta_lateral);           //computing loss
    when air gap is present
11 eta_lateral1=(2*acos(y/(2*a))-(y/a)*(1-(y/(2*a))^2)
    ^0.5)/%pi;           //computing eta_lateral without
    air gap
12 loss1=-10*log10(eta_lateral1);        //computing loss
    when air gap is not present
13 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);
14 //answer in the book for loss with air gap is 0.91dB
    , deviation of 0.01dB.

```

Scilab code Exa 5.2.3 loss

```

1 // Example 5.2.3
2 clc;
3 clear;
4 n1=1.48;           //refractive index of fiber
5 n=1;              //refractive index of air
6 theta=10;        //angle in degree
7 NA1=0.3;
8 NA2=0.6

```

```

9 eta_angular1= (16*(n1/n)^2)/((1+(n1/n))^4)*(1-((n*
    theta*pi/180)/(%pi*NA1))); //computing eta
    angular
10 eta_angular2= (16*(n1/n)^2)/((1+(n1/n))^4)*(1-((n*
    theta*pi/180)/(%pi*NA2))); //computing eta
    angular
11 loss1=-10*log10(eta_angular1); //computing loss
12 loss2=-10*log10(eta_angular2); //computing loss
13 printf("\nLoss when NA is %.1f is %.2f dB.\nLoss
    when NA is %.1f is %.2f dB.",NA1,loss1,NA2,loss2)
    ;
14 printf("\nThus we can say that insertion loss is
    considerably reduced with higher NA.");

```

Scilab code Exa 5.4.1 loss

```

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

```

Scilab code Exa 5.4.2 angular misalignment loss

```

1 // Example 5.4.2
2 clc;
3 clear;
4 lamda=1.3d-6; //wavelength
5 theta=1; //angle in degree
6 n2=1.465; //cladding refractive index

```

```

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

```

Scilab code Exa 5.6.1 split ratio

```

1 // Example 5.6.1
2 clc;
3 clear;
4 p1=50d-6;
5 p2=0.003d-6;
6 p3=25d-6;
7 p4=26.5d-6
8 EL=10*log10(p1/(p3+p4));           //computing excess
    loss
9 IL13=10*log10(p1/p3);             //computing insertion loss
10 IL14=10*log10(p1/p4);            //computing insertion loss
11 ct=10*log10(p2/p1);              //computing cross talk
12 sr=(p3/(p3+p4))*100;            //computing split ratio
13 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 );
14 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.");
15 //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.
16 //answers in the book with slight deviations
17 //Excess loss is 0.12 dB.(printing error)
18 //Insertion loss from port 1 to port 4 is 2.75 dB.

```

19 //cross talk is -39.2 dB. (calculation error)

Scilab code Exa 5.6.2 average insertion loss

```
1 // Example 5.6.2
2 clc;
3 clear;
4 N=16; //Number of ports
5 Pin=1d-3; //input power
6 Pout=12d-6; //output power
7 split_loss=10*log10(N); //computing split loss
8 excess_loss=10*log10(Pin/(Pout*N)); //computing
   excess loss
9 total_loss=split_loss+excess_loss; //computing
   total loss
10 insertion_loss= 10*log10(Pin/Pout); //computing
   insertion loss
11 printf("\nTotal loss is %.2f dB.\nInsertion loss is
   %.2f dB.",total_loss,insertion_loss);
12
13 //answer in the book for Total loss is 19.14,
   deviation of 0.06dB.
14 //answer in the book for insertion loss is 19.20,
   deviation of 0.01dB.
```

Chapter 6

optical sources

Scilab code Exa 6.3.1 operating wavelength

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

Scilab code Exa 6.3.2 longitudinal modes

```
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 6.7.1 power

```

1 // Example 6.7.1
2 clc;
3 clear;
4 tr=50; //radiative recombination lifetime
5 tnr=85; //non-radiative recombination lifetime
6 h=6.624d-34; //plank's constant
7 c=3d8; //speed of light
8 q=1.6d-19; //charge of electron
9 i=35d-3; //current
10 lamda=0.85d-6; //wavelength
11 t=tr*tnr/(tr+tnr); //computing total
recombination time
12 eta=t/tr; //computing internal
quantum efficiency
13 Pint=eta*h*c*i/(q*lamda); //computing internally
generated power
14 Pint=Pint*10^3
15 printf("\nTotal recombinaiton time is %.2f ns.\n
Internal quantum efficiency is %.3f.\nInternally
generated power is %.1f mW.",t,eta,Pint);
16 //answer in the book for Internal quantum efficiency
is 0.629, deviation of 0.001.
17 //answer in the book for Internally generated power
is 32.16 mW, deviation of 0.04 mW.

```

Scilab code Exa 6.8.1 bandwidth

```
1 // Example 6.8.1
2 clc;
3 clear;
4 f1=10d6; //frequency
5 f2=100d6
6 t=4d-9;
7 Pdc=280d-6; //optincal output power
8 w1=2*%pi*f1; //computing omega
9 Pout1=Pdc*10^6/(sqrt(1+(w1*t)^2)); //computing
    output power
10 w2=2*%pi*f2; //computing omega
11 Pout2=Pdc*10^6/(sqrt(1+(w2*t)^2)); //computing
    output power
12 printf("Ouput power at 10 MHz is %.2f microwatt.\n
    nOuput power at 100 MHz is %.2f microwatt.\n
    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);
13 BWopt = sqrt(3)/(2*%pi*t);
14 BWelec = BWopt/sqrt(2);
15 BWopt=BWopt*10^-6;
16 BWelec=BWelec*10^-6;
17 printf("\n3 dB optical power is %.2f MHz.\n3 dB
    electrical power is %.2f MHz.",BWopt,BWelec);
18 //calculation error. In the book square term in the
    denominater is not taken.
19 //answers in the book -
20 //Ouput power at 10 MHz is 228.7 microwatt.(
    incorrect)
21 //Ouput power at 100 MHz is 175 microwatt.(incorrect
    )
```

```
22 //3 dB optical power is 68.8 MHz, deviation of 0.12
23 //3 dB electrical power is 48.79 MHz, deviation of
    0.06
```

Scilab code Exa 6.8.2 power

```
1 // Example 6.8.2
2 clc;
3 clear;
4 n1=3.5; //refractive index
5 n=1; //refractive index of air
6 F=0.69; //transmission factor
7 eta = 100*(n1*(n1+1)^2)^-1; //computing eta
8 printf("\neta external is %.1f percent i.e. small
    fraction of intrnally generated opticalpower is
    emitted from the device.",eta);
9 printf("\n\n OR we can also arrive at solution ,\n");
10 r= 100*F*n^2/(4*n1^2); //computing ratio of
    Popt/Pint
11 printf("\n Popt/Pint is %.1f percent",r);
12 printf("\nNOTE – printing mistake at final answer.\n
    nThey have printed 40 percent it should be 1.4
    percent");
```

Scilab code Exa 6.8.3 operating lifetime

```
1 // Example 6.8.3
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, devaiiton of 0.1e1
```

Chapter 7

Source to Fiber Power Launching and Photodetectors

Scilab code Exa 7.2.1 Fresnel Reflection and Power loss

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

Scilab code Exa 7.2.2 optical power

```
1 // Example 7.2.2
2 clc;
3 clear;
```

```

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

```

Scilab code Exa 7.2.3 optical power

```

1 // Example 7.2.3
2 clc;
3 clear;
4 r=25d-6;           //radius
5 R=39;           //Lambertian emission pattern
6 NA=0.25;         //numerical aperture
7 a=35d-6;         //area
8 Pc1= %pi^2*a^2*R*NA^2; //computing coupled power
   when r<a
9 Pc1=Pc1*10^7;
10 Pc= %pi^2*r^2*R*NA^2; //computing coupled power
   when r>a
11 Pc=Pc*10^7;
12 printf("\nOptical power when r>a is %.2f mW.\
   nOptical power when r<a is %.3f mW.",Pc,Pc1);

```

Scilab code Exa 7.5.1 wavelength

```

1 // Example 7.5.1

```

```

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

```

Scilab code Exa 7.5.2 photocurrent

```

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

```

Scilab code Exa 7.5.3 responsivity

```

1 // Example 7.5.3
2 clc;
3 clear;
4 lamda1=1300d-9;
5 lamda2=1600d-9;
6 h=6.625d-34;    //plank's constant

```

```

7 c=3d8;           //speed of light
8 q=1.6d-19;      //charge of electron
9 eta=90/100;     //quantum efficiency
10 E=0.73;        //energy gap in eV
11 R1=eta*q*lamda1/(h*c);
12 R2=eta*q*lamda2/(h*c);
13 lamdac=1.24/E;
14 printf("\nResponsivity at 1300nm is %.2f A/W.\n
    nResponsivity at 1600nm is %.2f A/W.\nCut-off
    wavelength is %.1f micrometer.",R1,R2,lamdac);
15
16 //R1 is calculated as 0.92 in the book, deviation of
    0.02.

```

Scilab code Exa 7.5.4 responsivity

```

1 // Example 7.5.4
2 clc;
3 clear;
4 lamda=0.8d-6;
5 h=6.625d-34;    //plank's constant
6 c=3d8;         //speed of light
7 q=1.6d-19;     //charge of electron
8 ne=1.8d11;     //electrons collected
9 np=4d11;       //photons incident
10 eta=ne/np;    //computing quantum efficiency
11 R=eta*q*lamda/(h*c); //computing responsivity
12 printf("\nResponsivity of photodiode at 0.8
    micrometer is %.3f A/W.",R);
13
14 //answer in the book is 0.289. deviation of 0.001 A/
    W

```

Scilab code Exa 7.5.6 wavelength

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

Scilab code Exa 7.5.7 wavelength responsivity and optical power

```
1 // Example 7.5.7
2 clc;
3 clear;
4 h=6.626d-34; //plank's constant
5 c=3d8; //speed of light
6 eta=65/100; //quantum efficiency
7 I=2.5d-6; //photocurrent
8 E=1.5d-19; //energy of photns
9 q=1.6d-19; //charge of electron
10 lamda=h*c/E; //computing wavelength
11 R=eta*q*lamda/(h*c); //computing responsivity
12 Popt=I/R; //computing optical power
13 lamda=lamda*10^6;
14 Popt=Popt*10^6;
15 printf("\nWavelength is %.3f micrometer.\n
    nResponsivity is %.3f A/W.\nIncident optical
```



```

    power required is %.1f microWatt.",lamda,R,Popt);
16 //answer of R(responsivity) in the book is
    calculated as 0.694 A/W, deviation of 0.001.

```

Scilab code Exa 7.5.8 quantum efficiency

```

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

```

Scilab code Exa 7.8.1 drift time and capacitance

```

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

```

```
14 //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 response time

```
1 // Example 7.8.2
2 clc;
3 clear;
4 w=20d-6; //width
5 v=4d4; //velocity
6 t=w/v; //computing drift time
7 BW=(2*%pi*t)-1; //computing bandwidth
8 rt=1/BW; //computing response time
9 rt=rt*109;
10 printf("\nMaximum response time is %.1f ns.",rt);
11 printf("\nNOTE - Calculation error in the book.");
12 //Calculation error in the book, answer given is 6.2
    ns
```

Scilab code Exa 7.9.1 noise equivalent power and specific directivity

```
1 // Example 7.9.1
2 clc;
3 clear;
4 lamda=1.4d-6;
5 h=6.626d-34; //plank's constant
6 c=3d8; //speed of light
7 q=1.6d-19; //charge of electron
8 eta=65/100; //quantum efficiency
9 I=10d-9; //current
10 NEP= h*c*sqrt(2*q*I)/(eta*q*lamda);
11 D=NEP-1;
```

```

12 printf("\nNoise equivalent power is %.3e W.\n
    nSpecific directivity is %.2e.",NEP,D);
13
14 //answers in the book for NEP is 7.683*10^-14,
    deviation of 0.04*10^-14.
15 //answers in the book for D is 13.01 *10^12,
    deviation of 0.11*10^12.

```

Scilab code Exa 7.9.2 shot noise and thermal noise

```

1 // Example 7.9.2
2 clc;
3 clear;
4 lamda=1300d-9;
5 h=6.626d-34; //plank's constant
6 c=3d8; //speed of light
7 q=1.6d-19; //charge of electron
8 eta=90/100; //quantum efficiency
9 P0=300d-9; //optical power
10 Id=4; //dark current
11 B=20d6; //bandwidth
12 K=1.39d-23; //Boltzman constant
13 T=298; //temperature
14 R=1000; //load resister
15 Ip= 10^9*eta*P0*q*lamda/(h*c);
16 Its=10^9*(2*q*B*(Ip+Id));
17 Its=sqrt(Its);
18 printf("\nrms shot noise current is %.2f nA.",Its);
19 It= 4*K*T*B/R;
20 It=sqrt(It);
21 printf("\nThermal noise is %.2e A.",It);
22 //answer given in book for shot noise is 1.34nA,
    deviation of 0.01nA.
23 //answer given in book for Thermal noise it is
    1.81*10^-8 A, deviation of 0.01*10^-8.

```

Scilab code Exa 7.10.1 multiplication factor

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

Scilab code Exa 7.10.2 multiplication factor

```
1 // Example 7.10.3
2 clc;
3 clear;
4 lamda=900d-9;
5 h=6.626d-34; //plank's constant
6 c=3d8; //speed of light
7 q=1.6d-19; //charge of electron
8 eta=65/100; //quantum efficiency
9 P0=0.5d-6; //incident optical power
10 Im=10d2; //avalanche gain
11 R= eta*q*lamda/(h*c); //computing responsivity
```

```

12 Ip=10^8*P0*R;           //computing photocurrent
13 M=Im/Ip;               //computing multiplication factor
14 printf("\nMultiplication factor is %d.",M);
15
16 //answer in the book is 41.7 deviation 0.3.

```

Scilab code Exa 7.10.3 multiplication factor

```

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

```

Chapter 8

optical receiver operation

Scilab code Exa 7.q maximum response time

```
1 // Question 7 page 8.44
2 clc;
3 clear;
4 w=25d-6; //width
5 v=3d4; //velocity
6 t=w/v; //computing drift time
7 BW=(2*%pi*t)^-1; //computing bandwidth
8 rt=1/BW; //response time
9 rt=rt*10^9;
10
11 printf("\\nMaximum response time is %.2f ns.",rt);
12
13 //Answer in the book is given as 5.24ns deviation of
    0.01ns
```

Scilab code Exa 8.2.1 quantum limit

```
1 // Example 8.2.1
```

```

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

```

Scilab code Exa 8.2.2 optical power

```

1  // Example 8.2.2
2  clc;
3  clear;
4  SN_dB=60;    //signal to noise ratio
5  h=6.626d-34 //plank's constant
6  c=3d8;    //speed of light
7  lamda=1.3d-6; //wavelength
8  eta=1;
9  B=6.5d6;    //Bandwidth
10 SN=10^(SN_dB/10);

```

```

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

```

Scilab code Exa 8.3.1 shot noise

```

1 // Example 8.3.1
2 clc;
3 clear;
4 lamda=0.85d-6;
5 h=6.626d-34; //plank's constant
6 c=3d8; //speed of light
7 q=1.6d-19; //charge of electron
8 eta=65/100; //quantum efficiency
9 P0=300d-9; //optical power
10 Id=3.5; //dark current
11 B=6.5d6; //bandwidth
12 K=1.39d-23; //Boltzman constant
13 T=293; //temperature
14 R=5d3; //load resister
15 Ip= 10^9*eta*P0*q*lamda/(h*c);
16 Its=10^9*(2*q*B*(Ip+Id));

```



```

17 Its=sqrt(Its);
18 printf("\nrms shot noise current is %.2f nA.",Its);
19 It= 4*K*T*B/R;
20 It=sqrt(It);
21 It=It*10^9;
22 printf("\nThermal noise is %.2f nA.",It);
23
24 //answer given in book for Thermal noise it is 4.58
    nA, deviation is 0.02nA.

```

Scilab code Exa 8.3.2 S N ratio

```

1 // Example 8.3.2
2 clc;
3 clear;
4 lamda=0.85d-6;
5 h=6.626d-34; //plank's constant
6 c=3d8; //speed of light
7 q=1.6d-19; //charge of electron
8 eta=65/100; //quantum efficiency
9 P0=300d-9; //optical power
10 Id=3.5; //dark current
11 B=6.5d6; //bandwidth
12 K=1.39d-23; //Boltzman constant
13 T=293; //temperature
14 R=5d3; //load resistor
15 F_dB=3; //noise figure
16 F=10^(F_dB/10);
17 Ip=10^9*eta*P0*q*lamda/(h*c);
18 Its=10^9*(2*q*B*(Ip+Id));
19 It1= 4*K*T*B*F/R;
20 SN= Ip^2/(Its+It1);
21 SN_dB=10*log10(SN);
22 SN=SN/10^4;
23 printf("\nSNR is %.2f*10^4 or %.2f dB.",SN,SN_dB);

```

24

```
25 //answer given in the book is  $6.16 \times 10^4$  (deviation  
of 0.9) and 47.8dB (deviation of 0.16dB)
```

Scilab code Exa 8.4.1 bandwidth

```
1 // Example 8.4.1
2 clc;
3 clear;
4 Cd=7d-12;
5 B=9d6;
6 Ca=7d-12;
7 R=(2*3.14*Cd*B)^-1;
8 B1=(2*3.14*R*(Cd+Ca))^-1;
9 R=R/1000;
10 B1=B1/10^6;
11 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);
12
13 //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 design

Scilab code Exa 9.4.1 power margin

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

Scilab code Exa 9.6.1 maximum bit rate

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

Chapter 10

performance measurement and monitoring

Scilab code Exa 10.5.1 pulse broadning and optical bandwidth

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

Scilab code Exa 10.6.1 attenuation

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