Scilab Textbook Companion for Optoelectronics And Fiber Optics Communication by C. K. Sarkar and D. C. Sarkar¹

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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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Exa 6.3	wavelength and incident optical power
Exa 6.4	critical frequency
$Exa \ 6.5$	Fraction of incident power
$Exa \ 6.6$	Multiplication factor
$Exa \ 6.7$	noise equivalent power and specific directivity
$Exa \ 6.8$	optical gain and current gain
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4.2	optical power coupled
5.1	ratio between stimulated and spontaneous emission rate 36

5.2	Threshold current Density
5.3	minority carrier life time
5.4	number of longitudinal modes
5.5	External Power efficiency
5.6	External Power efficiency
5.7	Threshold current densities
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Chapter 1

Introduction to Fiber Communications

Scilab code Exa 1.1 Critical angle acceptance angle numerical aperture light coupl

```
1
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 1.1
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 n1=1.500;//refractive index of core
12 n2=1.450;//refractive index of cladding
13 thetac=asind(n2/n1);//critical angle for core-
      cladding(in degrees)
14 phim=90-thetac;//corresponding angle of obliqueness(
     in degrees)
```



Figure 1.1: Critical angle acceptance angle numerical aperture light coupled

Scilab code Exa 1.2 Acceptance angle

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Ex2_1sce							
EX2_3.sce							
- Ex2_4.sce							
- 2 EG_1.00							
- 2 Ex3_3.sce							
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EX3_6.sor							
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			help plot				
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			b=log10(VN/VP)				
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Figure 1.2: Acceptance angle

1

```
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 1.2
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 \, \text{clc};
8 clear;
9
10 //given
11 NA=0.3;//numerical aperture of the optical fiber
12 na=1;//refractive index of air
13 Alpham=(asind(NA));//acceptance angle for the
      meridional rays
14 gamma0=45; //in degrees
15 Alphasm=(asind(NA)/cosd(gamma0));//acceptance angle
      for skew rays
16 mprintf("\n Acceptance angle for the meridional rays
       is = \%.2 f degrees", Alpham);
```

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- J	Solid acceptance angle in air for the fiber 18 -0.2/Fadians		n2		1.43	Double	local
Ex1_1.sce			delta		0.02	Double	local
Ext_2.00			n1		1.46	Double	local
Ex2_1.sce							
Ex2_2.soe							
Ex2_4.sce							
Ex3_1.sce							
EX3_2.see							
Ex3_4.sce							
Ex3_5.sce							
- 2 Ex3_6.soe							
Ex3_8.soe							
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Figure 1.3: numerical aperture solid acceptance angle critical angle

```
17 mprintf("\n Acceptance angle for the skew rays is =
%.2f degrees",Alphasm);
18 (/The ensure warm due to rounding
```

```
18\ // The answer vary due to rounding
```

```
Scilab code Exa 1.3 numerical aperture solid acceptance angle critical angle
```

```
1
2 // Optoelectronics and Fiber Optics Communication by
        C.R. Sarkar and D.C. Sarkar
3 //Example 1.3
4 //OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
```

- 10 //given
- 11 n1=1.46;//refractive index of the core of W-step
 index fiber
- 12 delta=0.02;//relative refractive index between the core and the cladding
- 13 n2=n1-(delta*n1);//refractive index of the cladding
- 14 NA=(((n1+n2)*(n1-n2))^0.5);//numerical aperture of the fiber
- 15 thetac=asind(n2/n1);//critical angle at the core cladding interface
- 16 phi=%pi*(NA^2);//solid acceptance angle in air for the fiber
- 17 mprintf("\n Numerical Aperture is %.2 f", NA);
- 19 mprintf("\n Solid acceptance angle in air for the fiber is =%.2 fradians",phi);
- 20 //the answer vary due to rounding

Chapter 2

Electromagnetic Wave Propagation Through Optical Fiber

Scilab code Exa 2.1 Refractive Index normalized frequency guided modes

```
1
2 // Optoelectronics and Fiber Optics Communication by
C.R. Sarkar and D.C. Sarkar
3 //Example 2.1
4 //OS = Windows 7
5 // Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 lamda=85*10^-8; // wavelength of multimode fiber m
12 d=70e-6; // core diameter of the multimode fiber in m
13 n1=1.46; // refractive index of the fiber
14 delta=0.015; // relative refractive index difference
```



Figure 2.1: Refractive Index normalized frequency guided modes

```
15 a=d/2;//radius=d/2 of core in m
```

```
16 n2=n1-(delta*n1);//refractive index of cladding
```

```
17 c=2*%pi*a/lamda;//constant part of the V-Number formula
```

```
18 V=c*((n1^2-n2^2))^0.5; // V-number
```

```
19 M=V^2/2;//total number of guided modes in the
stepindex fiber
```

- 20 mprintf("\n Refractive Index of the cladding is=%.2f
 ",n2);
- 21 mprintf("\n Normalized frequency V-number of the fiber is =%.2f",V);
- 22 mprintf("\n Total number of guided modes in the fiber is= %.0f ",M);
- 23 //The answers vary due to rounding

Scilab code Exa 2.2 core diameter

1

```
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 2.2
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 n1=1.48; //core refractive index of a step-index
     fiber
12 delta=0.015; // relative index difference between the
      core and cladding
13 lamda=85*10^-8;//wavelength of the fiber in m
14 V=2.405; //value of V-number for single mode
15 c=(2*delta)^0.5; // constant value
16 a=(V*lamda)/(2*%pi*n1*c);//value of radius of core
      diameter in m
17 d=2*a;//diameter of core diameter in m
18 mprintf("\n Core diameter of the step index fiber is
      =%.2f um ",d*1e6);
19 delta1=0.0015; // relative index difference between
     the core and the cladding
20 c1=(2*delta1)^0.5; // constant value
21 a1=(V*lamda)/(2*%pi*n1*c1);//value of radius of core
      diameter in m
22 d1=2*a1;//diameter of core diameter in m
23 mprintf("\n Core diameter of the step index fiber is
     = %.2 f um ",d1*1e6);//multiplication by 1e6 to
     convert the unit from m to um
```

24 //the answer vary due to rounding

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In New folder	Minimum value of Beta is= 11.31 rad/um		betamax		12.6	Double	local
<u>*</u>			c Janda		0.8	Double	local
Ex1_1.sce			n2		1.44	Double	local
Ex1_200			n1		1.6	Double	local
Ex2_1.sce							
El2_2so							
EL2, SUE							
Ex3_1.sce							
Ed_2.see							
Ex3_4.sce							
Ex3_5.sce							
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Ex5_6.soe			help antilog				
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			help plot				
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			b				
			alphadB a=10/0.1-0.20				
			b=log10(VN/VF)				
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Figure 2.2: phase constant

Scilab code Exa 2.3 phase constant

```
1
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 2.3
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 n1=1.6; // core and cladding refractive index of first
       fiber
12 n2=1.44;//core and cladding refractive index of
     second fiber
13 lamda=0.8;//wavelength of the electromagnetic wave
     in um
14 c=(2*%pi)/lamda;//constant value propagation
```



Figure 2.3: cutoff wavelength

constant

- 15 betamax=c*n1;//maximum value of maximum value of beta

- 19 //The answer vary due to rounding

Scilab code Exa 2.4 cutoff wavelength

 //Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar

```
3 / Example 2.4
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 \, \text{clc};
8 clear;
9
10 //given
11 a=5*10<sup>-6</sup>;//radius in m
12 Vc=2.405; //cut off value of V-parameter for single
     mode
13 n1=1.46; // refractive index of the core
14 delta=0.0025; // refractive index difference between
      the core and cladding
15 c1=(2*delta)^0.5;//constant value
16 c2=(2*%pi*a)/Vc;//constant value
17 lamdac=c2*n1*c1;//cut off wavelength in m
18 mprintf("\n Cut-off Wavelength is = \%.2 f um ",lamdac
      *1e6); // multiplication by 1e6 to convert the unit
       from m to um
19 //The answer vary due to rounding
```

Scilab code Exa 2.5 number of guided mode and power flow in core cladding

```
1
2 // Optoelectronics and Fiber Optics Communication by
        C.R. Sarkar and D.C. Sarkar
3 //Example 2.5
4 //OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
```



Figure 2.4: number of guided mode and power flow in core cladding

```
9
```

```
10 //given
11 a=30*10^-6; //radius in m
12 n1=1.50; //refractive index of the core
13 n2=1.49; // refractive index of the cladding
14 lamda=0.85e-6//operating wavelength in m
15 V=((2*%pi*a/lamda))*sqrt(n1^2-n2^2)//V number
16 M=(1/2)*V^2//no. of guided modes in fiber
17 mprintf("\n No. of Guided modes is = \%.0 f", M);
18 PcladbyP=(4/3)*M^-0.5//power in cladding to total
     power
19 PcorebyP=1-PcladbyP//power in core to total power
20 PcorebyPclad=PcorebyP/PcladbyP//power in core to
      power in cladding
21 mprintf("\n ratio of power in core to power in
      cladding is = \%.0 \, \text{f} ", PcorebyPclad);
22 //The answer vary due to rounding
```

Chapter 3

Losses and Dispersions in Optical Fiber

Scilab code Exa 3.1 Signal attenuation calculation

```
1
2 //OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 3.1
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \, \text{clc};
7 clear;
8
9 //given
10 Pin=100; // average optical power in microwatts
11 Pout=2.5; // average output power in microwatts
12 L=10;//length of fiber in Km
13 L1=11//Length of fiber in Km
14 Ls=0.8//attenuation per splice in dB
15 ns=3//no of splices
16 u=1/L;
```

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Nerre	Total Attenuation for 11 Km=17.62 dB		0A		20	Double	local
New tolder	The overall attenuation in the link=20.02 dB		TA11		17.6	Double	local
- Py1 Linn	The value of Pin/Pout for 11Rm line with splices=100.52		1A alabad®	-	16	Double	local
Ex1_1.soe			apriado V	-	1.6	Double	local
- Ex1_2.jpg			u		0.1	Double	local
Ex1_2.see			ns		3	Double	local
Ex1_3.pg			Ls		0.8	Double	local
			11	-	11	Double	local
Ex2_1.sce			Pout	-	2.5	Double	local
			Pin		100	Double	local
Ex2_2.sce							
EX2_S100							
Ex2_4.sce							
Ex2_S.sce							
EX3_1SCE							
Ex3 3,sce		Comm	and History				X 5 9
Ex3_4.sce			-Umax3				*
Ex3_5.sce			-Lmax3				
Ed_6.sce			exp(Lmax3)				
EG_Aste			-10^(Lmax3)				
Fv4 1.sce			-Umax3				
Ex4_2.soe			-10^(Lmax3)				
-Ex5_1.sce			-hep toe				
Ex5_2.sce			help xtitle				
EDS_3.500			help legend				
EG_NGE		b-ii	- 09/02/2017 09:	8:43 //			
Ex5_6.sce			a				
Ex6_1.sce			-b				
Ex6_2.sce			a=10/(L1-L2)				
Ex6_3.sce			-b=log10(WN/VF)				
			-a/b				
			-10/1.998				
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Figure 3.1: Signal attenuation calculation

```
17 v=log10(Pin/Pout);
```

```
18 alphadB=u*10*v;//total attenuation per Km
```

```
19 TA=alphadB*L;
```

```
20 mprintf("\ Total Attenuation=%.2 f dB", TA);
```

```
21 TA11=alphadB*L1;//total attenuation for 11 Km
```

```
22 mprintf("\n Total Attenuation for 11 Km=%.2f dB", TA11);
```

```
23 OA=TA11+ns*Ls;//overall attenuation in the link
```

```
24 mprintf("\n The overall attenuation in the link=%.2f dB",OA);
```

```
25 PinbyPout=10<sup>(OA/10)</sup>;//the value of Pin/Pout for 11
Km line with splices
```

```
26 mprintf("\n The value of Pin/Pout for 11Km line with
            splices=%.2 f", PinbyPout);
```

```
27 //the answer vary due to rounding
```

Scilab 5.5.2 Console	_			_			J X
File Edit Control Applications ?		-					
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File Browser ? * ×	Scalado 5.5.2 Constalle 🛛 🕫 🔻	Varie	able Browser				7 7 X
C:\Users\Admin\Desktop'solabnew\New folder\			Name	Value	Туре	Visit	bility
Name	Rayleigh scattering coefficient=1.888*10^-4 per meter	L.	AdB	0.83		Double	local
R New folder	attenuation in dB=0.02 per km		LKM	0.828		Double	local
- 4			2	1e-24		Double	local
Ex1_1.jpg			v	20.6		Double	local
Ex1_1.sce			u TT	2.74e-25		Double	local
- Ex1_2.sce			KB	1.38e-22		Double	local
			lambda	10-06		Double	local
Ex1_3.sce			Bc	7e-11		Double	local
EX2_1,pg			p	0.286		Double	local
- Di2 2.00		-		1.40		Double	local
Ex2_2.sce							
Ex2_3.jpg							
EX2_Side							
Di2 Asce							
Ex2_5.sce							
Ed_Lipg							
Ex3_2.sce		Corre	mand History				× * *
Ex3_3.sce			help antilog				~
Ex3_4.sce			exp(Lmax3)				
EX3_SKE			- 10^(Lmax3)				
Ex3_7.sce			-Lmax3				
- Ex3_8.sce			-10^(Lmax3)				
Ex4_1.soe			help title				
Ex4_2.sce			help xtitle				
EG_DSC			-help legend				
Ex5_3.sce		6-11	09/02/2017 09:28	:43 //			
-Ex5_4.soe							
EG_S.sce			alphadB				
EG_000E			a=10/().1-L2)				
Ex6_2.sce			b=log10(VN/VF)				
Ex6_3.sce			b*10/1.998				E
			10/1.998				
		11	- 10/02/2017 12:30	06 //			
Preparectory mor		1	- 13/02/2017 17:04	k06 //			
Case sensitive Regular expression			14/02/2017 10:19 14/02/2017 10:19	e32 //			-
						1 40 1	2:41 PM
						2	/14/2017

Figure 3.2: Attenuation

Scilab code Exa 3.2 Attenuation

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 //Example 3.2
4 / OS = Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 n1=1.46;//refractive inde for the silica
11 p=0.286; //photo elastic coefficient for the silica
12 Bc=7e-11;//isothermal compressibility in m^2/N
13 lambda=1e-6; // wavelength in meters
14 KB=1.38e-23;//Boltzman constant in J/K
15 TF=1400//fictive temperature in K
16 u=8*(%pi^3)*KB*Bc*TF*p^2;// partial product
17 v=(n1)^8;//partial product
```

Scilab 5.5.2 Console	_						б <u>ж</u>
File Edit Control Applications ?		-		_			
2 🖹 🕺 G 🗋 🏷 🚔 🚍 🗶 🔍 🔍							
File Browser ? ? ×	Scillab 55.2 Console ? ?	×V	arisble Browser				7 7 X
C:\Users\Admin\Desktop'polabnew\New folder\			Name	Value	Туре		Asblity
	Threshold optical power level for Brillouin scattering is =80.31 mW		Pr Pr		1.38	Double	local
Name	Threshold optical power level for Raman scattering is= 1.38 W		Pb		0.0803	Double	local
New tolder	>		deltatau		0.6	Double	local
E Fri 1 mg			alphado	_	0.5	Double	local
Ex1 1.sce			lamita	-	13	Double	local
- Ex1_2.jpg			and parton	-	110	D D D D D D	
-Ex1_2.sce							
Ex1_3.sce							
Ex2_Lipg							
- Pv2 2.100							
Ex2 2.808							
- Ex2_3.jpg							
-Ex2_3.sce							
- Ex2_4.jpg							
Ex2_4 see							
Pictore							
EX3 1/pg							
Ex3_1.sce							
- Ex3_2.sce		0	ommand History				5 & X
Ex3_3.sce			-10^(-Lmax3)				^
Ex3_4.sce			-Lmax3				
EG_SSC			- 10^(Lmax3)				
EUG_UNE FY3_Z sce			- help title				
Ex3 8.sce			help xtitle				
Ex4_1.sce			help legend				
Ex4_2.sce			- help plot	19-41 //			
Ex5_1.sce		11	a				
Eng Ziste			-b				
EG_SSC			apnade a=10/0.1J 20				
Ex5_5.sce			b=log10(VN/VF)				-
Exd_6.sce			a/b				
Ex6_1.sce			-10/1.998				
Ex6_2.sce			-// 10/02/2017 10:3	9:01 //			
-Ex6_3.sce			// 10/02/2017 12:	0:06 //			
			-// 13/02/2017 17:1 -// 14/02/2017 10:	9-17 //			
		le	// 14/02/2017 10:	9:32 //			
Lucker of the A lines			lambdac				
Case sensitive Regular expression			Rcs=c3*(c2^-3)				-
	·		10 (12 0)				
				_		11 do-	2:08 PM
					-	(D-4/)	2/14/2017

Figure 3.3: Threshold optical power for SBS and SRS

```
18 z=(lambda)^4;//partial product
```

```
20 mprintf("\n Rayleigh scattering coefficient=%.3f
    *10^-4 per meter",taur*10^4);//multiplication by
    1e4 to convert the unit to !0^-4 per Km
```

```
21 LKM=exp(-taur*1e3);//transmission loss factor of fiber per m
```

```
22 AdB=10*log10(1/LKM);//Attenuation in dB
```

```
23 mprintf("\n Attenuation in dB=\%.2 fdB per Km", AdB);
```

```
24 //the answer vary due to rounding
```

Scilab code Exa 3.3 Threshold optical power for SBS and SRS

1

2

```
3
4 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
5 / Example 3.3
6 / OS = Windows 7
7 //Scilab version 5.5.2
8
9 clc;
10 clear;
11
12 //given
13
14 lamda=1.3; //wavelength in mm
15 d=6;//diameter of the fiber in um
16 alphadb=0.5//attenuation in dB
17 deltatau=0.6;//laser source bandwidth in GHz
18 Pb=(4.4*10<sup>-3</sup>)*(d*d)*(lamda*lamda)*(alphadb)*(
      deltatau);//threshold optical power level for
      Brillouin scattering in watts
19 Pr=(5.9*10<sup>-2</sup>)*(d*d)*(lamda)*(alphadb);//threshold
      optical power level for Raman Scattering in watts
20 mprintf("\n Threshold optical power level for
      Brillouin scattering is =\%.2 f mW", Pb*1e3);//
      multiplication by 1e3 to convert unit from w to
     mW
21 mprintf("\n Threshold optical power level for Raman
      scattering is = \%.2 \text{ f W}, Pr);
```

Scilab code Exa 3.4 Critical radius

1

3 // Optoelectronics and Fiber Optics Communication by



Figure 3.4: Critical radius

```
C.R. Sarkar and D.C. Sarkar
4 / Example 3.4
5 / OS = Windows 7
  //Scilab version 5.5.2
6
7
8 clc;
9 clear;
10
11 //given
12 a=4*10^-6; // radius in m
13 n1=1.5; // core refractive index
14 lamda=1.55*10<sup>-6</sup>;//operating wavelength in m
  delta=0.003; // relative refractive index difference
15
      between core and cladding
16 c=(2*delta)^0.5;//constant value
17 lamdac=(c*2*%pi*a*n1)/2.405;//cut off wavelength for
      mono mode
18 Rcs=(20*lamda)/((delta)^1.5)*((2.748-((0.996)*(lamda
     /lamdac)))^-3);//critical radius of curvature
```



Figure 3.5: critical radius

,Rcs*1e3);//multiplication by 1e3 to convert unit to mm//the answer given in textbook is wrong

```
Scilab code Exa 3.5 critical radius
1
2
3
4 // Optoelectronics and Fiber Optics Communication by
        C.R. Sarkar and D.C. Sarkar
5 //Example 3.5
6 //OS = Windows 7
7 // Scilab version 5.5.2
8
9 clc;
10 clear;
```



Figure 3.6: NA acceptance angle and multiple time dispersion

```
11
12 //given
13 a=4*10^-6; //radius in m
14 n1=1.5; //core refractive index
15 delta=0.03; //delta
16 lamda=0.80*10^-6; //wavelength in m
17 c=(2*delta)^0.5; //constant value
18 n2=sqrt((n1^2)-(2*delta*n1^2));
19 c5=((n1^2)-(n2^2))^1.5;
20 Rcs=(3*n1^2*lamda)/(4*%pi*c5); //critical radius
21 mprintf("\n Critical radius is =%.2f um",Rcs*1e6); //
multiplication by 1e6 to convert unit to um//the
answer vary due to rounding
```

Scilab code Exa 3.6 NA acceptance angle and multiple time dispersion

```
1
2
3 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
4 / Example 3.6
5
  //OS = Windows 7
  //Scilab version 5.5.2
6
7
8 clc;
9 clear;
10
11 //given
12
13 n1=1.55; // refractive index of core
14 n2=1.51//refractive index of cladding
15 no=1//refractive index of air
16 C=3e8//velocity of light in m/s
17 deltan=n1-n2;//relative refractive index
18 NA=((n1+n2)*deltan)^0.5; // Numerical aperture
19 alpham=asind(NA)//acceptance angle in degrees
20 deltatbyZ=(n1/n2)*deltan/C//multiple time
      dispersionin s/m
21 mprintf("Numerical Aperture is=%.2 f",NA);
22 mprintf("\nAcceptance angle is=%.2f degree",alpham)
23 mprintf("\nMultiple time dispersion is=\%.2 f ns/Km",
     deltatbyZ*1e12) // multiplication by 1e12 to
      convert unit from s/m to ns/Km
24 //the answer vary slightly due to rounding
```

```
Scilab code Exa 3.7 Bandwidth distance product
```

1

2



Figure 3.7: Bandwidth distance product

```
3
  //Optoelectronics and Fiber Optics Communication by
4
     C.R. Sarkar and D.C. Sarkar
  //Example 3.7
5
6 / OS = Windows 7
  //Scilab version 5.5.2
7
8
9 clc;
10 clear;
11
12 //given
13 C=3*10^8; //speed of light in m/s
14 lamda=0.85*10^-6;//wavelength in m
15 SW=0.003*10^-6; //spectrum width in m
16 Ym=0.021;//material dispersion parameter (ps/Km.nm)
17 Gamma=SW/lamda;
18 taubyZ=(Gamma/C)*(Ym)//in ns/Km
19 deltafZ=(C)/(4*Gamma*Ym);//Bandwidth distance
     product in GHz.Km
20 mprintf("\n Bandwidth distance product is =%.0fGHz.
```



Figure 3.8: Waveguide dispersion

```
Km",deltafZ/1e12);//division by 1e9 to convert
unit to GHz.Km from Hz.m
```

```
Scilab code Exa 3.8 Waveguide dispersion
```

```
1
2
3 //Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
4 //Example 3.8
5 //OS = Windows 7
6 //Scilab version 5.5.2
7
8 clc;
9 clear;
10
```



Figure 3.9: Pulse width and approximate bit rate

```
11 //given
12 n1=1.48; // refractive index of core
13 delta=0.0022; // relative refractive index difference
14 a=4.5*10^-6;//core radius
15 lamda=1.3*10^-6;//wavelength in m
16 \operatorname{cod}=9*10^{-3};//\operatorname{core} diameter
17 cad=125*10<sup>-3</sup>; // cladding diameter
18 C=3e8;//velocity of light in m/s
19 Vd2VbbydV2=0.48//waveguide dispersion constant at V
      =2.14
20 V=((2*%pi*a)/lamda)*n1*((2*delta)^0.5);//V-number
21 n2=n1*(1-delta);
22 DelGbyZdelL=(-n2*delta)*Vd2VbbydV2/(C*lamda);//
      waveguide dispersion in ps/Km?nm
23 mprintf("waveguide dispersion =%.2 f ps/Km/nm",
      DelGbyZdelL*1e6) // multiplication by 1e6 to
      convert unit ps/Km/nm
```

Scilab code Exa 3.9 Pulse width and approximate bit rate

```
1
\mathbf{2}
  //Optoelectronics and Fiber Optics Communication by
3
     C.R. Sarkar and D.C. Sarkar
4 //Example 3.9
5 / OS = Windows 7
6 //Scilab version 5.5.2
7
8 \, \text{clc};
9 clear;
10
11 //given
12 Gama0=0.5; //transmitted pulse width in ns
13 delta_timd=0;//total intermodulation dispersion in
      ns
14 delta_tmd=2.81; // total material dispersion in ns
15 delta_twgd=0.495; //total waveguide dispersion in ns
16 delta_ttotal=((delta_timd^2)+(delta_tmd^2)+(
      delta_twgd^2))^0.5; // Total dispersion in ns
17 Gama=GamaO+delta_ttotal;// width of received pulse
      in ns
18 Bmax=1/(5*Gama*1e-9);//bitrate in Hz
19 mprintf ("Total dispersion is = \%.2 f ns", delta_ttotal)
20 mprintf("\n Width of the received pulse is = \%.2 f ns"
      ,Gama);
21 mprintf("\n Approximate Bit rate is=%.2f MHz",Bmax/1
      e6);//division by 1e6 to convert unit into MHz
```

```
from Hz
```

Chapter 4

Light Emitting Diode LED

Scilab code Exa 4.1 total carrier life time and optical power

```
1
2 // Optoelectronics and Fiber Optics Communication by
      C.R. Sarkar and D.C. Sarkar
3 / Example 4.1
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 h=6.62*10<sup>-34</sup>;//Plank's constant in SI units
12 c=3*10^8; //speed of the light in m/s
13 e=1.9*10<sup>-19</sup>; // electric charge in columb
14 I=50*10<sup>-3</sup>;//drive current in A
15 lamda=0.85*10<sup>-6</sup>;//peak emission wavelength in m
16 taur=50*10<sup>-9</sup>;//radiative carrier life time in s
17 taunr=100*10^-9; // nonradiative carrier life time in
      \mathbf{S}
```
Scilab 5.5.2 Console		_			-	C - X
File Edit Control Applications ?						
2 🖹 🗶 🗊 🏷 📇 🚍 🗶 🔍 🛛						
File Browser	7 7 X Scieb 5.5.2 Console		Variable Browse	r		7 7 X
C-V Isers Admin Desktro (sciabnew/New Frider)	* *		Name	Value Tur	r 1	Vshilty
	Total carrier life time is =33.33ns		H Pint	0.041	Double	local
Name	Optical power generated internally i	s= 40.99 mW	c1	0.0615	Double	local
hew folder	^>		etaint	0.667	Double	local
- <u>*</u>			Тр	3.33e-08	Double	local
Ex1_1.jpg			Lnr	1e-07	Double	local
Ex1_1.soe			u u	5e-08	Double	local
Ext_2.pg			landa	8.5e-07	Double	local
Ext 3.00				1.00-10	Double	local
Ex1_3.sce				3e+08	Double	local
			h	6.628-34	Double	local
-Ex2_1.sce						
Ex2_2.sce						
Ex2_3.pg						
EX2_MOR						
EV2_Npg						
- Ex2 Sim						
Ex2 5.sce	E					
Ex3_1.pg						
- Ex3_2.jpg			Command History	(5 5 X
- Ex3_2.soe			-Lmax3	•		^
- Ex3_3.jpg			exp(Lmax	3)		
EX3_3.sce			- 10^(Lma:	3)		
CO_3130			-10^(-Lma	×3)		
Etc. top			-10^1.mat	3)		
EV3 S INC			help title			
EX EX3 5.sce			-help mytil	le .		
- Ex3_51.jpg			help xtitle	4		
Ex3_51.sce			help plot			
Ex3_6.sce			B-// 09/02/20	17 09:28:43 //		
Ex3_7.soe			-8			
Ex3_76.jpg			-D alahadR			
Ex3_78.jpg			a=10/0.1	12)		
EKS_0.sce			- b=log10(N/IF)		
Frd 2 pro			-a/b			
Ex5 1.sce			10/1 998	18		-
Exd_2.sce	*		// 10/02/20	17 10:29:01 //		
The Pleastory filter	T		-// 10/02/20	17 12:30:06 //		
	4			17 17:04:06 //		
Case sensitive I Regular expression			etaint	11.00140105 1]		-
					 . †⊓ €0 	9:54 AM
					2 1	2/15/2017

Figure 4.1: total carrier life time and optical power

```
18 Tp=(taur*taunr)/(taur+taunr);///total carrier life
	time in s
19 etaint=Tp/taur;//equation of internal efficiency
20 c1=(I*h*c)/(e*lamda);//constant value
21 Pint=(etaint)*c1;//internal optical power generated
	in W
22 mprintf("\n Total carrier life time is =%.2fns ",Tp
	*1e9);//multiplication by 1e9 for conversion of
	unit from s to ns
23 mprintf("\n Optical power generated internally is= %
	.2f mW ",Pint*1e3);//multiplication by 1e3 for
	conversion of unit from W to mW//the answer vary
	due to rounding
```

Scilab code Exa 4.2 optical power coupled

Scilab 5.5.2 Console				_			6 ×
File Edit Control Applications ?							
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File Browser ?	* X Schlub 552 Console ? *	Variat	sie Browser				7 7 X
C:\Users\Admin\Desktop\sciebnew\New folder\			Name	Value	Type		Asblity
	Optical power coupled to the fiber is =59 uW	H	Pc	5.9	4e-05	Double	local
Name	>		A	1.9	5e-05	Double	local
New folder			a	0	.0025	Double	local
The second secon			R		0.01	Double	local
EX1_1pg			d	_	0.005	Double	local
- Ex1 2.100			NA	_	0.19	Double	local
Ex1_2.soe			100		0.20	COUDE	1000A
Ex1_3.sce							
EV2_1.sce							
Ev2 2.sce							
Ex2_3.jpg							
Ex2_3.sce							
Ex2_4.sce							
EX2,550							
Ex3_Lpg							
Ex3_2.jpg		Commi	and History				× 5 9
Ex3_2.soe			LHAX3				*
			-10^(Lmax3)				
Ed_lste			-10^(-Lmax3)				
EG_31.see			Lmax3				
Els_t.pg			-belo title				
Ex3 5.jpg			help myttle				
Ex3_5.sce			help xtitle				
		110	help plot				
Ex3_51.sce			- 09/02/2017 09:	28:43 //			
Ed_6.soe			a				
EG_7.808			alphadB				
			a=10/(L1-L2)				
Ex3_8.sce		-	b=log10(VN/VP)				
Ex4_1.sce			b*10/1.998				
Ex4_2.soe			10/1.998				
Ex5_1.sce		-11-	- 10/02/2017 10:	29:01 //			
Ex5_2.sce		1	10/02/2017 12: 13/02/2017 17:	30:06 //			
Fle/drectory filter	Z	e	- 15/02/2017 09:	48:02 - //			
Case sensitive 🔄 Regular expression		t	etaint A				-
🚳 💪 🚺 🚞 🚳					*	₩	10:03 AM 2/15/2017

Figure 4.2: optical power coupled

1

```
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 4.2
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 NA=0.18; // numerical aperture
12 RD=30;//radiance of the source in W/Sr/cm<sup>2</sup>
13 d=50*10^{-4}; // core diameter in cm
14 R=0.01;//Fresnel reflection coefficient
15 a=d/2; //radius of the core in cm
16 A=%pi*((a)^2);//emission area of the source in cm<sup>2</sup>
17 Pc=%pi*(1-R)*A*RD*((NA)^2);//optical power coupled
      to the fiber in W
18 mprintf("\n Optical power coupled to the fiber is =\%
```

.0f uW", Pc*1e6);//multiplication by 1e6 for conversion of unit from W to uW//the answer given in textbook is wrong

Chapter 5

Semiconductor Lasers

Scilab code Exa 5.1 ratio between stimulated and spontaneous emission rate

```
1
\mathbf{2}
3 //OptoElectronics and Fibre Optics Communication, by
       C.K Sarkar and B.C Sarkar
4 / Example 5.1
5 / OS = Windows 10
6 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
7 clc;
8 clear;
9
10 //given
11 Tc=727; //temperature in celcius
12 lamda=0.5*10^-6;//wavength of emitting radiation in
     Μ
13 h=6.626*10<sup>-34</sup>;//Plank's constant in SI units
14 KB=1.38*10<sup>-23</sup>;//boltzman constant in SI units
15 c=3*10^8; //speed of light in m/s
16 f=c/lamda;//frequency in Hz
17 T=Tc+273; //temperature in kelvin
```



Figure 5.1: ratio between stimulated and spontaneous emission rate

```
18 c1=(h*f)/(KB*T);//constant value
```

```
19 B21byA21Pf=1/(exp(c1)-1);//ratio of stimulated and spontaneous emission rate
```

```
20 mprintf("\n Ratio between stimulated and spontaneous
emission is =%.1fx10^-13",B21byA21Pf*1e13); //
multiplication by 1e13 to convert the ratio to
10^{-13}
```

Scilab code Exa 5.2 Threshold current Density

```
1
2
3 //OptoElectronics and Fibre Optics Communication, by
C.K Sarkar and B.C Sarkar
4 //Example 5.2
```

```
5 / OS = Windows 10
```

Scilab 5.5.2 Console			- 0
le Edit Control Applications ?			
2 🖬 👗 🖸 🜔 🛎 🚍 🛤 🗶 🔍 🔍			
			7 1
	Name	Value Type 1	Visibility
hreshold current density is= 3.19 x10^3 A/cm^2	Eth .	0.639 Double	
preshold current is =639.00 mA	Jth	3.19e+03 Double	
	c1	63.9 Double	
	N.1	10 Double	
	Beta	0.02 Double	
	W	0.01 Double	
	L L	0.02 Double	
	p p	3.8 Double	
	Conneed Hotory Rep aged		
	 (a) //0872202 0758-0- // (b) // - 0872202 0758-0- // (c) // - 084361 (c) // - 084362 (c) //		
			4. 3:29 5

Figure 5.2: Threshold current Density

```
6 ////Scilab version Scilab 6.0.0 - beta - 2(64 bit)
7 clc;
8 clear;
9
10 //given
11 n=3.8; //refractive index
12 L=200*10^-4; //length in cm
13 W=100*10^-4; //width in cm
14 Beta=20*10^-3; //gain factor in A/cm^3
15 alpha=10;//loss coefficient per cm
16 R1=((n-1)/(n+1))^2; // reflectivity
17 c1=((alpha+((1/L)*(log(1/R1)))))/(constant value)))
  Jth=(1/Beta)*c1;//threshold current density in A/cm
18
      ^{2}
19 mprintf("\n Threshold current density is = \%.2 \text{ f } x10^{3}
      A/cm^2", Jth*1e-3); // multiplication by 1e-3 to
      convert the ratio to 10^{-3}
20 Ith=Jth*L*W; //threshold current in A
21 mprintf("\n Threshold current is =%.2f mA", Ith*1e3);
      //the answer vary due to rouding
```



Figure 5.3: minority carrier life time

```
Scilab code Exa 5.3 minority carrier life time
1
\mathbf{2}
   //OptoElectronics and Fibre Optics Communication, by
       C.K Sarkar and B.C Sarkar
3 //Example 5.3
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \quad clc;
7
  clear;
8
9 //given
10 Br=7.21*10<sup>-10</sup>; //injected electron density
11 Pn=10<sup>18</sup>;//majority carrier hole density in/cm<sup>3</sup>
12 Gamar=1/(Br*Pn);//minority carrier life time
```



Figure 5.4: number of longitudinal modes

```
13 mprintf("\n Minority carrier life time is =%.2f ns "
    ,Gamar*1e9);// the answer vary due to roundingoff
14 // multiplication by 1e9 to convert the unit to nm
```

Scilab code Exa 5.4 number of longitudinal modes

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 5.5
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
```



Figure 5.5: External Power efficiency

```
10 lamda=0.85*1e-6;//wavelength of GaAs in m
```

- 11 n1=3.6;//refractive index
- 12 L=200e-6//length of the cavity in m
- 13 K=L*(2*n1)/lamda;//number of modes
- 14 mprintf("\n Number of modes=%.0f",K);//the answer vary due to rounding//multiplication by 1e6 to convert the unit to um

```
15 u=2*n1*L;//partial product
```

- 16 v=(lamda)^2;//partial product
- 17 dellamda=v/u;//separation wavelength between the two mode in m
- 18 mprintf("\nThe separation wavelength between the two mode=%.2f nm",dellamda*1e9);//multiplication by 1e9 to convert the unit to nm// the answer given in textbook is wrong the unit is nm but the textbook gives it as um

Scilab code Exa 5.5.A External Power efficiency

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 5.5(A)
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 etaT=0.20//total efficiency
11 Eg=1.43//bandgap energy in eV
12 V=2.5//applied voltage in V
13 etae=etaT*Eg*100/V//external power efficiency
14 mprintf("\n External power efficiency =%.2f percent
     ",etae);
```

Scilab code Exa 5.5 External Power efficiency

```
1
2 //OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 5.5
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
```



Figure 5.6: External Power efficiency

```
9 //given
10 etaT=0.18//total efficiency
11 Eg=1.43//bandgap energy in eV
12 V=2.5//applied voltage in V
13 etae=etaT*Eg*100/V//external power efficiency
14 mprintf("\n External power efficiency =%.0f percent
",etae);
```

Scilab code Exa 5.6 Threshold current densities

```
1
2 //OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 5.6
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
```



Figure 5.7: Threshold current densities

```
6 \, \operatorname{clc};
7 clear;
8
9 //given
10 T1=273+20; // first temperature for an AlGaAs
      injection laser diode in kelvin
11 T2=273+80; //second temperature for an AlGaAs
      injection laser diode in kelvin
12 T01=160; // first thershold temperature in kelvin
13 T02=55; // second thershold temperature in kelvin;
14
15 // case 1:
16 Jth120C=exp(T1/T01);
17 Jth180C=exp(T2/T01);
18 Jth1=Jth180C/Jth120C;
19 mprintf("\n The ratio of threshold current densities
       for AlGaAs=%.2f", Jth1);//the answer vary due to
      rounding
20
21 \ // case \ 2:
```



Figure 5.8: length of cavity in laser and wavelength separation

```
22 Jth220C=exp(T1/T02);
23 Jth280C=exp(T2/T02);
24 Jth2=Jth280C/Jth220C;
25 mprintf("\n The ratio threshold current densities
    for InGaAs=%.2 f", Jth2);
```

```
Scilab code Exa 5.7 length of cavity in laser and wavelength separation
```

```
1
2 //OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 5.7
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
```

8

```
9 //given
```

- 10 lamda=0.85*1e-6;//wavelength of GaAs in m
- 11 n1=3.6; //refractive index
- 12 K=1700//number of modes
- 13 L=K*lamda/(2*n1);//length of the cavity in m
- 14 mprintf("\n Length of cavity in the laser=%.0f um",L
 *1e6);//the answer vary due to rounding//
 multiplication by 1e6 to convert the unit to um
- 15 u=2*n1*L;//partial product
- 16 v=(lamda)^2;//partial product
- 17 dellamda=v/u;//separation wavelength between the two mode in m
- 18 mprintf("\nThe separation wavelength between the two mode=%.2f nm",dellamda*1e9);//multiplication by 1e9 to convert the unit to nm// the answer given in textbook is wrong the unit is nm but the textbook gives it as um

Chapter 6

Photo Detectors

Scilab code Exa 6.1 opearting wavelength and incident power

```
1
2 // Optoelectronics and Fiber Optics Communication by
      C.R. Sarkar and D.C. Sarkar
3 / Example 6.1
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 eta=0.70;//quantum efficiency
12 E=2.2*10<sup>-19</sup>;//energy of the photons in Joule
13 Ip=2*10<sup>-6</sup>;//photocurrent in A //the value in
      question is different from that used in solution
      in question it is mA and in solution it is uA
14 h=6.62*10<sup>-34</sup>;//Planck's constant in SI units
15 c=3*10^8; //speed of the light in m/s
16 e=1.9*10<sup>-19</sup>;//electric charge in coulomb
```

Scilab 5.5.2 Console				_	a.,	- 0 - × -
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A	Operating wavelength of the photodiode is= 0.90 um	H	Po	3.31e-06	Double	local
Pane Citie	Incident power is =3.31 uW		R	0.605	Double	local
New folder	▲>		lands.	3.32e+14	Double	local
- Ex1 1.100			landa	9.032-07	Double	local
Ex1_1.soe			E C	3e+08	Double	local
			h	6.62e-34	Double	local
Ex1_2.soe			lo lo	2e-06	Double	local
			E	2.2e-19	Double	local
EX1_3.508			eta	0.7	Double	local
Ex2_3.sce						
Ex2_4.jpg						
EN2_HSUE						
Ev2 5.sce	E					
-Ex3_1.sce						
		Corr	mand History			5 5 X
EX3_2 see			exp(Lmax3)			^
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Ex3 31.sce			- 10*(-Lmax3)			
Ex3_4.jpg			-10^(Lmax3)			
Ex3_Asce			help title			
			help myste			
EX3_5.sce			help legend			
			help plot			
Ex3 6.sce			1/ 09/02/2017 09:	28043 //		
Ex3_7.soe			-b			
			alphadB			
			a=10/(L1-L2)			
Ex3_8.sce			a/b			
EX4_1.sce			-b*10/1.998			
EVE Lose				20-01 11		
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Figure 6.1: opearting wavelength and incident power

Scilab code Exa 6.2 quantum efficiency and reponsivity

1

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11mm	Quantum efficiency is= 0.50		R		0.407	Double	local
The second	Responsivity of the photodiode is= 0.41 A/W		c1		0.813	Double	local
New Youes	>	-	eta	-	0.5	Double	local
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-Ex1_1.see			h	6.	62e-34	Double	local
Ex1_2.jpg			landa	8	8.5e-07	Double	local
Ex1_2.soe			re	1	5e+11	Double	local
Ex1 3 sce			//P		38+11	Double	local
Ex2_1.sce							
- Ex2_2.jpg							
EX2_clice							
En2 3 see							
- Ex2_4.jpg							
- Ex2_4.sce							
- Ex2_5.jpg							
EX2_5.60							
- Eng 1 app							
Ex3_2.pp		Corre	nand History				× 5 9
			exp(max3)				^
			-10^(Lmax3)				
EX3_ASCE			-10^(-Lmax3)				
- Bi3 4.00							
Ex3_4.sce			help title				
			help myttle				
Ek3_5.sce			help legend				
EG_SL(p)			help plot				
End 6.sce		P -11	09/02/2017 09:2	5:43 //			
-Ex3_7.soe			b				
Ex3_76.jpg			alphadB				
- Ex3_78.jpg			b=log10(VN/VF)				
EG_6.50			a/b				
Evel 2.sce			-b*10/1.998				-
Ex5_1.sce		-11	10/02/2017 10:2	01-//			1
- Ex5_2.sce *		H	10/02/2017 12:3	0:06 //			
File/directory filter		12	13/02/2017 17:0 15/02/2017 09:4	ecue // e-02 //			
Case sensitive Regular expression		37	etaint				
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Figure 6.2: quantum efficiency and reponsivity

```
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 6.2
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 rp=3*10^11;//number of incident photon
12 re=1.5*10^11; //number of hole-pairs generated
13 lamda=0.85*10<sup>-6</sup>;//wavength in m
14 h=6.62*10<sup>-34</sup>;//Plank's constant in SI Unit
15 c=3*10^8;//speed of the light in m/s
16 e=1.9*10<sup>-19</sup>;//electric charge in Coulomb
17 eta=re/rp;//quantum efficiency
18 c1=(e*lamda)/(h*c);//constant value
19 R=eta*c1;//responsivity of the photodiode inA/W
20 mprintf("\n Quantum efficiency is = \%.2 f", eta);
```



Figure 6.3: wavelength and incident optical power

21 mprintf("\n Responsivity of the photodiode is= $\%.2\,{\rm f}$ A/W",R);

```
Scilab \ code \ Exa \ 6.3 wavelength and incident optical power
```

```
1
2 // Optoelectronics and Fiber Optics Communication by
        C.R. Sarkar and D.C. Sarkar
3 // Example 6.3
4 //OS = Windows 7
5 // Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 // given
```

- 11 eta=0.65; //quantum efficiency
- 12 $E=1.5*10^{-19}$; //energy of the photons in V
- 13 Ip=3*10⁻⁶;//diode current in A
- 14 h=6.62*10⁻³⁴;//Plank's constant in SI unit
- 15 $c=3*10^8$; //speed of the light in m/s
- 16 e=1.9*10⁻¹⁹;//electric charge in coulomb
- 17 lamda=(h*c)/E;//wavelength of the operating diode in m
- 18 f=c/lamda;//frequency in Hz
- 19 R=(eta*e)/(h*f);//responsivity in A/W
- 20 Po=Ip/R; //incident optical power in W
- 21 mprintf("\n Operating wavelength is =%.2f um",lamda
 *1e6);//multiplication by 1e6 for conversion of
 unit from m to um
- 22 mprintf("\n Incident optical power is =%.2f uW ",Po
 *1e6);//multiplication by 1e6 for conversion of
 unit from W to uW//the answer vary due to
 rounding

Scilab code Exa 6.4 critical frequency

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 6.4
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
10 Eg1=1.43;//Band Gap Energy of photodetector in eV
```

11 Eg2=[(1.43*1.6*10⁻¹⁹)];//Band Gap Energy in joule



Figure 6.4: critical frequency

12

```
14 mprintf("\n cut-off wave length is=%.2fum",lamdac
 *10^6);//multiplication by 10^6 to convert unit
 into um//the error is due to roundingoff
```

Scilab code Exa 6.5 Fraction of incident power

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 6.5
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
```



Figure 6.5: Fraction of incident power

```
clear;
7
8
9 //given
10 //case (1):
11 n1=3.5; //refractive index of layer 1
12 alpha=1e5; // it is in m<sup>-1</sup>
13 d=3e-6//depth of planar layer in m
14 W=1e-6//width of depletion layer in m
15 // case (2):
16 alpha2=1e6; //it is in 1/m
17
18 Rf=[(n1-1)/(n1+1)]^2; // reflection coefficient
19 //case (1):
20 PW1byP1=exp(-alpha*(d))*[1-exp(-alpha*W)]*(1-Rf);//
      fraction of incident power absorbed
21 / case (2):
22 PW2byP1=[exp(-alpha2*(d))]*[1-exp(-alpha2*W)]*(1-Rf)
      ;//fraction of incident power absorbed
23 mprintf("Fraction of energy absorbed for case 1 is=
     %0.2f percentage", PW1byP1*100);
```

	a a v Variable Determore			
2 Conce	A Revisition Processor			
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	Name	Value	Type	Wshilty
nsivity is=0.45 A/W	HE M	36.9	Double	
current is=0.27 uA	E Lo	2,71e-07	Double	
plication factor is=36.94	R	0.451	Double	
	- c	3e+08	Double	
	i h	6.62e-34	Double	
		1.6e-19	Double	
	1 I	1e-05	Double	
	ta ita	0.7	Double	-
	P P	6e-07	Double	-
	landa	8e-07	Double	
	Command History			
	-// 11/07/2017 10:17:13 /			

Figure 6.6: Multiplication factor

24 mprintf("\nFraction of energy absorbed for case 2 is =%0.2f percentage",PW2byP1*100);

```
Scilab code Exa 6.6 Multiplication factor
```

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 6.6
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
```

```
10 lamda=0.8e-6;//wave length of radiation in
micrometer
11 P=0.60e-6;//optical power in microwatts
12 ita=0.7;//quantum efficiency of a silicon RAPD is 70
%
```

13 I=10e-6;//Output of device after avalanche gain in microampere

```
14 e=1.6e-19;//
```

```
15 h=6.62e-34;//plank's constant in S.I units
```

```
16 c=3e8;//velocity of light in m/s
```

```
17
```

```
18 R=[(ita*e*lamda)]/[h*c];//Responsivity in A/W
```

```
19 Ip=P*R; //diode current in microampere
```

```
20 M=I/Ip;//multiplication factor
```

- 21 mprintf("\n Responsivity is=%.2 f A/W, R);
- 22 mprintf("\n Diode current is=%.2f uA", Ip*1e6);// multiplication by 1e6 to convert the unit from ampers to uA
- 23 mprintf("\n Multiplication factor is=%.2 f",M);

Scilab code Exa 6.7 noise equivalent power and specific directivity

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 6.7
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
10 A=(100)*(50);//area in u-meter^2
```

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sclabnew			c .	9.75e	-14	Double	local
- #			h	6.62e	-34	Double	local
6_4.jpg			e	1.6e	-19	Double	local
			landa	1.2e	-06	Double	local
- 4 6,9,00			eta Id	10	-08	Double	local
			A	Set	03	Double	local
- III 9_3.jpg							
- 9_4.jpg							
9_6.00							
Exil Lice							
Ex11_3.sce							
Ex6_10.sce							
Etb_4.pg							
Ex6 5.sce							
Ex6_6.sce		Comma	nd History				× 5 9
Ex6_7.sce			25/01/2017 11 27/01/2017 09	46:20 // 53:36 //			
Pif 9.sce		TH	Rf				
Ex7_2.soe			Pf1 Pf2				
- Ex8_1.sce			PW tbyP1=exp(-alpha*(d))*[1-exp	(-alpha*W)]*	1-R.f)	
Ex6_2 see			e^(-1)*(1-e^-1	(1-0.309)			
Englishe			exp(-1)*(1-exp	-1))*(1-0.309)			
- Ex8_5.sce		1.4	exp(-3)*(1-exp	-3))*(1-0.309)			
Ex9_1.sce			06/02/2017 11	38:40 // 48:47 //			
El9_2.soe		∈-#	05/02/2017 13	48:47 //			
EN9 4.sce		-	NEP				
Ex9_5.sce							
Ex9_6.sce							
Eta_/.soe							
Fle/drectory filter							
Case sensitive Regular expression							
		_			_		
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Figure 6.7: noise equivalent power and specific directivity

```
11 Id=10e-9;//Measured dark current in nanoampere
12 eta=0.6; //Quantum efficiency is 60%
13 lamda=1.2e-6;//operating wave length in micrometer
14 e=1.6e-19; //charge of an electron in columb
15 h=6.62e-34;//plank's constant in S.I units
16 c=3e8;//velocity of light in m/s
17
18 NEP=[h*c*sqrt(2*e*Id)]/(eta*e*lamda);//noise
      equivalent power in watts
19 D=sqrt(A*10^-12)/(NEP);//Specific directivity of the
       device
20 mprintf("\n Noise equivalent power is=\%.2 \text{ f }*10^{-14} \text{ W}
     ",NEP*10^14);//multiplication by10^-14 to change
      the unit 10^{-14} W
21 mprintf("\n Specific directivity is=%2.f *10^8m Hz
      (1/2)/W',D/10^8)//multiplication by10^8 to
     change the unit 10^8 \text{ m Hz}(1/2)/W
```

Scilab 5.5.2 Console						- 0 - ×
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a solabnew	>		v v	2.6e-2	2 Dou 9 Dou	ble local
			u	3.18e-2	7 Dou	ble local
- G 6 (pg			c h	6.626-3	5 DOL 4 DOL	ble local
- G_8.jpg			landa	1.25e-0	6 Dou	ble local
- G_9.00			p	0.0001	3 Dou	ble local
			pc	0.03	6 Dou	ble local
9_3.jpg						
9 6.00						
- 9_7.jpg						
Ex11_1.sce						
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Exb_6.500			25/01/2017 11:4	6:20 //		
Ex6 8.sce		©-//2	27/01/2017 09:5	3:36 //		
Ex6_9.sce		R	Lf HF1			
Ex7_2.sce		P	f2			
Full 2.sce		P	W1byP1=exp(-e	(pha*(d))*[1-exp(- *(1-0_309)	alpha*W)]*(1-RI)
Ex8_3.sce		-9	Ne^(-1)*(1-%e-	-1)*(1-0.309)		
Ex8_4.sce		- 0	sp(-1)*(1-exp(-	1))*(1-0.309)		
Ex8_5.sce		-11-5	04/02/2017 11:3	8:46 //		
ENG_LISCE		-//0	06/02/2017 13:4	8:47 //		
		-N	EP	004711		
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Figure 6.8: optical gain and current gain

```
Scilab code Exa 6.8 optical gain and current gain
1
2 //OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 6.8
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 Ic=16e-3;//collector current in mA
11 P=130e-6;//incident power in microwatts
12 lamda=1.25e-6;//wavelength in micrometer
13 h=6.62e-34;//plank's constant in S.I units
14 c=3e8;//velocity of light in m/s
```

	Scilab 5.5.2 Console					_		. D 🛛 🗙
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	File Browser	7 7 X	Schub 552 Console ? * ×	Variab	le Browser			7 7 X
	C:\Users\Admin\Desktop'sclabnew\	* ÷	The 3dB bandwidth is=331.57 MHz		Name	Value	Туре	Visibility
	l trans		>	-	Bm	3.32e+08	Double	local
	Pile edabrase				G	60	Double	local
					lt.	8e-12	Double	local
	- G_4.jpg							
	6_6.jpg							
2 3260 2 3260 3 328 3 328	6,8,100							
	2 7.2.jpg							
• 1.5.30 • 1.5.30	8_2.jpg							
	- B_3.jpg							
	9-5.100							
13.56 13.56								
************************************	9_6.jpg							
Contrast filter 1 + x Contrast filter	- 9_7.jpg							
	Ex11_1.sce							
Control files *** Control files **** Control files ***** Control files ************************************	Ext 10.sce							
	Ex6_4.jpg							
Image: Section 2013 Image: Section 2013<	Ex6_4.sce							
Image: Sector Sector 11 - 400 - 11 Image: Sector 11 - 400 - 11 Image: Sector 11 - 40	Ex6_5.sce			Contra	and History			2 7 X
Image: State in the state	Fut 7.sce			-11-	- 25/01/2017 11	46:20 //		
Image: State in the state	Ex6_8.sce			₽ <i>1</i> /-	- 27/01/2017 09:	53:36 //		
	Ex6_9.sce				Pf1			
Image: Section of the section of th	Ex7_2.sce				Pf2			
	Fig. 2.sce				PW1byP1=exp(-alpha*(d))*[1-exp(-al *(1-0_309)	oha*W)]*(1-Rf)	
	Ex8 3.sce				-%e^(-1)*(1-%	^-1)*(1-0.309)		
	Ex8_4.sce				exp(-1)*(1-expl	-1))*(1-0.309)		
	Ex8_5.sce			11-	exp(-3)*(1-exp) 04/02/2017 11	-3))*(1-0.309) 38:46 //		
	Ex9_1.sce			-11-	- 06/02/2017 13	48:47 //		
	- Ex9 3.ace			€-//	- 05/02/2017 13:	48:47 //		
	Ex9_4.sce			0	Bm			
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Figure 6.9: Bandwidth

```
15
16 // case 1:
17 u=h*c*Ic;
18 v=lamda*P*1.6e-19;
19 Go=u/v;//optical gain of the photo transistor
20 // case 2:
21 hFE=Go/0.45;//common emitter current gain
22 mprintf("\n optical gain of phototransistor Go is=%
.2 f",Go);
23 mprintf("\n common emitter current gain hFE is=%.2 f"
,hFE);
```

```
24 //Answers are different due to roundingoff error
```

Scilab code Exa 6.9 Bandwidth

1

Scilab 5.5.2 Console	_		-	_		- C -×-
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- *			Ē	1.84	2-19 Dou	ble local
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6.8.jpg						
- G_9.jpg						
- B_3.pp						
9-5.jpg						
9 4.tm						
9_6.pg						
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Ex6_4.jpg						
Ex6_5.sce						
Ex6_6.sce		Corr	nmand History	20 11		× * ?
Ex6_7.sce		6	// 27/01/2017 09:53	c20 // c36 //		
Ex6_9.sce			-Rf			
			Pf2			
Ex8_1.sce			PW1byP1=exp(-a)	pha*(d))*[1-ex '1-0.309)	p(-alpha*W)]*(1-RI)
Ex8_3.sce			-%e^(-1)*(1-%e^	1)*(1-0.309)		
Ex8_4.sce			exp(-1)*(1-exp(-1 exp(-3)*(1-exp(-3))*(1-0.309)))*(1-0.309)		
Exe_store		1	// 04/02/2017 11:38	-46 //		
Ex9_2.sce		6	// 06/02/2017 13:48 // 06/02/2017 13:48	≥47 ≥47		
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Case sensitive Regular expression						
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Figure 6.10: critical wavelength

```
2 // OptoElectronics and Fibre Optics Communication, by
       C.K Sarkar and B.C Sarkar
3 //Example 6.9
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0 - beta - 2(64 bit)
6 \, \operatorname{clc};
7 clear;
8
9 //given
10 tf=8e-12;//electron transit time in second
11 G=60//photoconductive gain of the device
12
13 Bm=1/(2*%pi*tf*G);//the maximum 3dB bandwidth in Hz
14 mprintf("The 3dB bandwidth is=%.2f MHz", Bm/1e6);//
      division by 1e6 to covert unit from Hz to MHz
15 //The answer in textbook is wrong
```

Scilab code Exa 6.10 critical wavelength

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 6.10
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 E=1.15*(1.6e-19);//band gap energy in V
11 h=6.62e-34;//plank's constant in S.I units
12 c=3e8;//velocity of light in m/s
13
14
15 lamda_c=(h*c)/(E);//critical wavelength in meter
16 mprintf("The critical wavelength is=%.2f um",lamda_c
     *1e6);//multiplication by 1e6 to convert unit
     from m to um
17 //the answer vary due to roundingoff
```

Scilab code Exa 6.11 conversion efficiency

```
    //Optoelectronics and Fiber Optics Communication by
C.R. Sarkar and D.C. Sarkar
    //Example 6.11
```

4 / OS = Windows 7



Figure 6.11: conversion efficiency

```
5 // Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 // given
11 Pin=900*10^-3; // Input Power in W
12 Voc=600*10^-3; // Open circuit voltage in V
13 Isc=240*10^-3; // Short circuit current in A
14 FF=0.75; // Fill factor
15 Pmax=(Voc*Isc*FF); // Maximum Power in W
16 eta=(Pmax/Pin); // Conversion Efficiency
17 mprintf("\n Conversion Efficiency is =%.2f Percent",
eta*100); // multiplication by 100 to convert into
percentage
```



Figure 6.12: number of cells total area of panel and current capacity of each cell

Scilab code Exa 6.12 number of cells total area of panel and current capacity of e

```
1
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 6.12
4 / OS = Windows 7
  //Scilab version 5.5.2
5
6
7 clc;
8
  clear;
9
10 //given
11 Area_Cell=4;// Area of each cell in cm^2
12 eta=0.12;// Conversion Efficiency
13 V=0.5;// Voltage generated in V
14 Pt=12;// Total output Power in W
15 IR=100*10^-3;// Solar Constant or Input Radiation in
      mW/cm^2
```

- 18 I=(eta*IR*Area_Cell/V);// Current capacity in A
- 19 mprintf("\n Number of Cells are =%.2f", Number_Cells)
 ;
- 20 mprintf("\n Active area of the Panel is= $\%.2 \text{ fcm}^2$ ", Active_area_Panel);
- 21 mprintf("\n Current capacity of each cell is =%.2fmA
 ",I*1e3);//Multiplication by 1e3 to convert unit
 to mA from A

Chapter 7

Manufacture of fibers and cables

Scilab code Exa 7.1 value of n

```
1
2 // Optoelectronics and Fiber Optics Communication by
     C.R. Sarkar and D.C. Sarkar
3 / Example 7.1
4 / OS = Windows 7
5 //Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 //given
11 theta=30;//value of angle of deliverence in degrees
12 b=cosd(theta);// cosine value of the theta
13 a=log10(b); // constant
14 c = \log 10 (1/2); // constant
15 n=c/a;// refractive index
16 mprintf("The value of refractive index is = \%.2 f",n);
```



Figure 7.1: value of n

//the answer vary due to rounding

 $Scilab \ code \ Exa \ 7.2$ Lateral power distribution coefficient

```
1
2 // Optoelectronics and Fiber Optics Communication by
        C.R. Sarkar and D.C. Sarkar
3 // Example 7.2
4 //OS = Windows 7
5 // Scilab version 5.5.2
6
7 clc;
8 clear;
9
10 // given
11 theta=10; // value of theta in degrees
```



Figure 7.2: Lateral power distribution coefficient

```
12 phi=0;// value of phi in degrees
13 a=log10(1/2);// value of constant
14 c=log10(cosd(theta));// constant
15 L=a/c;// lateral power distribution
16 mprintf(" The Lateral Power Distribution is= %.2f",L
);//the answer vary due to rounding
```

Scilab code Exa 7.3 maximum magnification factor and coupling efficiency

```
1
2 // Optoelectronics and Fiber Optics Communication by
        C.R. Sarkar and D.C. Sarkar
3 //Example 7.3
4 //OS = Windows 7
5 //Scilab version 5.5.2
6
```



Figure 7.3: maximum magnification factor and coupling efficiency

```
7 clc;
8 clear;
9
10 //given
11 Df=80*10^{-6};// diameter of the fiber in m
12 Ds=45*10<sup>-6</sup>;// diameter of the source in m
13 NA=0.15; // numerical aperture of the fiber
14 Mmax=(Df/Ds);// maximum magnification
15 eta_d=((NA)^2)*100;// coupling efficiency
      considering direct coupling
16 eta_l=((Mmax)*(NA^2))*100;// coupling efficiency
      considering lens coupling
  mprintf("\nThe Maximum Magnification factor is = %.2 f
17
     ",Mmax);
18 mprintf("\nThe coupling efficiency considering
      direct coupling is = \%.2 fpercent", eta_d);
19 mprintf("\nThe coupling efficiency considering lens
      coupling is = \%.3 fpercent", eta_1); // the answer
      vary due to rounding
```

Chapter 8

Optical Fiber receiver

Scilab code Exa 8.1 photocurrent shot noise and thermal noise

```
1
2 //OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 8.1
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \quad clc;
7 clear;
8
9 //given
10 eta=0.50;//quantum efficiency of optical fibre
11 e=1.6e-19; //energy of electron in 1 joules
12 Po=250e-9; //incident optical power in watts
13 B=8e6;//bandwidth of receiver in Hz
14 lamda=0.85e-6;//wavelenth in meter
15 Id=4e-9;//dark current in ampere
16 t=300; //temperature in kelvin
17 c=3e8;// velocity in m/s
18 K=1.38e-23; //bolt 'zman constant in S.I units
```
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File Browser ? * ×	Schlub 55.2 Console 7 • ×	Varial	ale Browser				7 7 X
C:\Users\Admin\Desktop\sclabnew\			Name	Value	Type		sblity
-	Photo current in diode 1s=85.60 nA	H	jith	4.7e-0	9	Double	local
Name	Total shot noise generated in photo diode is=0.48 nA		13	2.21e-1	7	Double	local
in sciabnew	The total thermal noise generated in load resistance is=4.70 nA		R	6e+0	3	Double	local
- G 6 6 m	>		x	1.328-1	3	Double	local
- 🖬 6_6.jpg			1	2.298-1	9	Double	local
- G_8.jpg			1p	8.56e-0	8	Double	local
			v	1.99e-2	5	Double	local
- 2.jpg			u	1.7e-3	2	Double	local
			h	6.62e-3	4	Double	local
9-5.00			6	1.308-4	0	Double	local
9_3.jpg				34	0	Double	local
			bd	4e-0	9	Double	local
			landa	8.5e-0	7	Double	local
			8	8e+0	6	Double	local
Ex11_1.400			Po	2.5e-0	7	Double	local
Exil_3.sce			e	1.6e-1	9	Double	local
			pera.	0	2	DOTON	local
Ex6_4.sce							
- Ex6_5.sce		Cum	and Materia				
Ex6_6.sce			25/01/2017 11	46-20 - 11			1.6.4
Ext_Aste		e''	- 27/01/2017 09	153:36 //			
Pub Size			Rf				
Ex7 2.sce			Pf1				
Ex8_1.sce			PW thyP1 mexce	-alpha*(d))*[1-exp(-	alpha "W)]	5(1-80	
Ex8_2.sce			e^(-1)*(1-e^-1	l)*(1-0.309)			
Ex8_3.sce			-%e^(-1)*(1-%	e^-1)*(1-0.309)			
Ex8_4.sce			exp(-1)*(1-exp	(-1))*(1-0.309) (-3))*(1-0.309)			
Exa 1 cm		-11-	- 04/02/2017 11	:38:46 //			
EV9 2.sze		-11-	- 06/02/2017 13	:48:47 //			
Ex9 3.sce		1 m	06/02/2017 13	c40c47 //			
Ex9_4.sce			Bm				
Et9_5.sce			alpha_m				
Ex9_6.sce							
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Figure 8.1: photocurrent shot noise and thermal noise

```
19 h=6.62e-34//planck's constant in S.I.Units
20 / / case 1:
21 u=[eta*e*Po*lamda];
22 v=[h]*[c];
23 Ip=u/v;//photo current in diode in nA
24 mprintf("\n Photo current in diode is=%.2f nA", Ip*1
      e9);
25
26 \ // case \ 2:
27 i1=2*e*B*(Ip+Id);
28 ish=sqrt(i1);//total shot noise generated in photo
      diode
29 mprintf("\n Total shot noise generated in photo
      diode is=\%.2 \text{ f nA}", ish*1e9);
30
31 \ // case \ 3:
32 x = 4 * K * t * B;
33 R=6e3;//load resistance in ohms
34 i 3=x/R;
35 ith=sqrt(i3);//total thermal noise generated in load
```

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liene	The load resistance is=3.18 *10^3ohms	B1	5e+06 Double	e local
Name P g schwarz g g schwarz <td>Bandwidth when system is connected to load resistance 1=-5.00 HHz </td> <td>Operand History </td> <td>3x - 0 Deck 3.18 + 63) Deck 0.00214 Deck Deck Deck <td>1 600 1 601 2 601 2 601 1 601</td></td>	Bandwidth when system is connected to load resistance 1=-5.00 HHz 	Operand History	3x - 0 Deck 3.18 + 63) Deck 0.00214 Deck Deck Deck <td>1 600 1 601 2 601 2 601 1 601</td>	1 600 1 601 2 601 2 601 1 601
-rejorectory nor				
Case sensitive E Regular expression				
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Figure 8.2: maximum load resistance

Scilab code Exa 8.2 maximum load resistance

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 8.2
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
```

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C:\Users\Admin\Desktop\sclabnew\ • +			Name	Value T)	pe Vis	bility
	Load resistance is=663.48 ohms	TH	SbyN	4.87e+03	Double	local .
Name	Signal to noise ratio is=40.07		NI	7.65e-15	Double	local
i sciebnew	Signal to noise ratio is=4871.84		\$1	3.73e-11	Double	local
The stars	>		Mopt	30.5	Double	local
			M1	2.6e+03	Double	local
			D	6.3/e-24	Double	local
6 9.100			2	1.000-20	Double	local
7_2.jpg			2	40.1	Double	local
			N	9,98e-16	Double	local E
			s	4e-14	Double	local
9-5.jpg			12th	9.98e-16	Double	local
			N.	6.62e-13	Double	local
9_4,00			i2sh	2.56e-18	Double	local
9_6.00			RL	663	Double	local
EVII 1 see			v	0.00151	Double	loca
- Englisher			e ve	1.66-19	Double	loca
Ex6 10.sce			Fn	1.000-2.0	Double	local.
Ex6_4.jpg			T	300	Double	local
Ex6_4.sce			1	2e-07	Double	local +
- Ex6_5.sce						
Ex6_6.sce		Com	mano mistory	1.47.70 //		
Ex6_7.sce		1.57	25/01/2017 1	1:40:20 // 9:53:36 //		
ENG S.S.C.		11"	Rf			
ENG_NEC			-Pf1			
Ex8 1.sce			Pf2	alaha Mathatta anal ala	-BADING 00	
Ex8 2.sce			-eo(-1)*(1-eo-	1)*(1-0.309)	(18 W)] (196))	
- Ex8_3.sce			-%e^(-1)*(1-9	Ge^-1)*(1-0.309)		
Ex8_4.sce			-exp(-1)*(1-exp	p(-1))*(1-0.309)		
Ex8_5.sce			exp(-3)*(1-exp	p(+3))*(1+0.309)		
Ex9_1.sce			05/02/2017 1	3:48:47 //		
El9_2.sce		01	05/02/2017 1	3:48:47 //		
EU9_3408			NEP			
ENG Street			alpha m			
Ex9 6.sce			Mopt			
Ex9_7.sce			-rti			
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Figure 8.3: Signal to noise ratio and Multiplication factor

```
8
9 //given
10 Cd=5e-12; // capacitance in Farad
11 B=10e6;//Bandwidth in Hz
12
13 u=2*3.14*B*Cd;
14 RL=1/u;//Load resistance in ohms
15 mprintf("\n The load resistance is=%.2f *10^3ohms",
      RL/10<sup>3</sup>);//multiplication factor to change unit
      from ohms to 10<sup>3</sup> ohms
16 v=2*3.14*RL*(10e-12);
17 B1=1/v;//bandwidth when the system is connected to
      load resistance
18 mprintf("\n Bandwidth when system is connected to
      load resistance is=%.2f MHz",B1/1e6);
19 //multiplcation factor to change unit to MHz from Hz
```

Scilab code Exa 8.3 Signal to noise ratio and Multiplication factor

```
1
2 // OptoElectronics and Fibre Optics Communication, by
       C.K Sarkar and B.C Sarkar
3 / Example 8.3
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 Cd=6e-12; // capacitance in farad
11 Id=0;//dark current in photodiode
12 B=40e6; //bandwidth in Hz
13 I=2e-7;//photo current before gain in Ampere
14 T=300;//temperature in kelvin
15 Fn=1;
16 KB=1.38*1e-23//boltzman constant in SI units
17 e=1.6*10<sup>-19</sup>//charge of an electron in columb
18 \ // case \ 1:
19 u=2*3.14*Cd*B;
20 RL=1/u;//load resistance in ohms
21 mprintf("\n Load resistance is=%.2f ohms", RL);
22
23 \ // case \ 2:
24 i2sh=2*(e)*B*I;// shot noise in A^2
25 v = 4 * (KB) * T * B;
26 i2th=v/RL;//thermal noise in A<sup>2</sup>
27 //if i2 > i1 then
28 S=I^2;
29 N=i2th;
30 z=S/N;
31 mprintf("\n Signal to noise ratio is=%.2f",z);
```

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Name	Thermal energy noise current per bandwidth is=6.62 *10^-27 A^2/Hz		×	3.14e-06	Double	local
The address	Maximum bandwidth without equalization for transimpedance is=1.27*10^8Hz)2th	1.66e-25	Double	local
suburew	For RI< <rt1 *10~-25="" a*2hz<="" bandwidth="" current="" energy="" is="1.66" noise="" per="" td="" the="" thermal=""><td></td><td></td><td>1.668-20</td><td>Double</td><td>local</td></rt1>			1.668-20	Double	local
6 4.00	>			7.85e-05	Double	local
- G 6.jpg			Rt	2.5e+06	Double	local
- G_8.jpg			18	1.38e-23	Double	local
- B 6_9.0pg			A	400	Double	local
			Rf	5e+05	Double	local
			T CON	300	Double	local
9-5.jpg			B	58-12	Double	local
- B 9_3.jpg				36.100		10000
9_6.jpg						
Exil_lace						
Enf 10.sce						
Ex6_4.jpg						
Ex6_4.sce						
-Ex6_5.sce			A			
Ex6_6.sce			UL_2501/2017.11	46-20 - 11		
Ext 2 cm			E-// 27/01/2017 05	53:36 //		
Puis 9 som			Rf			
Ex7 2.sce			-Pf1			
Ex8_1.sce			PW 1byP1=exp	-alpha*(d))*[1-exp(-alpha*	W)]*(1-Rf)	
Ex8_2.sce			-e^(-1)*(1-e^-)*(1-0.309)		
Ex8_3.sce			-%e^(-1)*(1-%	E^-1)*(1-0.309)		
EX3_4.500			exp(-3)*(1-exp	(-3))*(1-0.309)		
EV9_1 see			-// 04/02/2017 11	38:46 //		
Ex9 2.sce			-// 06/02/2017 13	:48:47 //		
Ex9_3.sce			-NEP	040047 //		
Ex9_4.sce			Bm			
Ex9_5.sce			alpha_m			
Ex9_6.sce			-rti			
E Logrado			Rd			
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Case sensitive Regular expression						
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Figure 8.4: Maximum bandwidth mean square thermal noise per unit bandwidth

```
32 //when M=Mopt and x=0.3
33 x=0.3;//lies between 0.3 to 0.5 for silicon and 0.7
        to 1 for Ge
34 a=4*(KB)*T;
35 b=(e)*x*RL*I;
36 M1=a/b;
37 Mopt=M1^(1/2.3)
38 S1=[(Mopt)*I]^2;//signal strength in W
39 N1=[2*(e)*B*I*((Mopt)^2.3)]+[(4*(KB)*T*B)/(RL)];//
        noise power in W
40 SbyN=S1/N1;//signal to noise ratio
41 mprintf("\n Signal to noise ratio is=%.2f",SbyN);
42 //the answer in book is wrong
```

Scilab code Exa 8.4 Maximum bandwidth mean square thermal noise per unit bandwidth

```
1
2 // OptoElectronics and Fibre Optics Communication, by
       C.K Sarkar and B.C Sarkar
3 / Example 6.4
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
10 R=5e6;//effective resistance in ohms
11 CT=5e-12; // capacitance in Farads
12 T=300; //temperature in kelvin
13 Rf=1e5;//resistance in ohms
14 A=400; //open loop gain
15 KB=1.38e-23//boltzman constant in S.I. unit
16 //case 1:
17 Rtl=[(R)*(R)]/[(R)+(R)];//total effective load
      resistance
18 u=2*3.14*Rtl*CT;
19 B=1/u;//maximum bandwidth in Hz
20 mprintf("The maximum bandwidt obtained equalization
      is=%.2f *10^4Hz", B/1e4); // multiplication factor
      to change unit
21
22 / case 2:
23 v = 4 * (KB) * T;
24 i2th=v/Rtl;//thermal energy noise current per
      bandwidth in A^2/Hz
25 mprintf("\nThermal energy noise current per
      bandwidth is=\%.2 \text{ f } *10^{-}-27 \text{ A}^{2}/\text{Hz}", i2th*1e27);
26
27 \ // case \ 3:
28 x=2*%pi*Rf*CT;
29 B=A/x; //maximum bandwidth without equalization for
      transimpedance
30 mprintf("\nMaximum bandwidth without equalization
```

```
77
```

for transimpedance is= $\%.2 \text{ f} * 10^8 \text{Hz}$, B/1e8);

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Comparison C				III U 2.21e-13 III B 24:67 III N 0.26 IIII N 0.9 IIII P 400 IIII IIII 400	Double local Double local Double local Double local Double local Double local Double local Double local
1 1.5 1.5 1 1.1 3.6 1 1.5 3.6 1 1.5 5.6 1 5.5 5.6 5 5.5 5.6 5 5.6 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6 5 5.5 5.6				Command Helsony -fil 359(2/00) 11:46:20 − // ⊕ if 279(2/00) 70:955:26 − // ±87	X 5 5
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Figure 8.5: repeatno 8point4 to calculate minimum power

```
31 //Assuming Rf<<Rtl then the thermal energy noise
      current per bandwidth is given by
32 i2th=v/Rf;
33 mprintf("\nFor Rf<<Rtl the thermal energy noise
      current per bandwidth is=%.2f *10^-25 A^2Hz",i2th
      *1e25);
34 // the answer in book is wrong
```

Scilab code Exa 8.5 repeatno 8point4 to calculate minimum power

```
1
2 //OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 6.4
4 //OS=Windows 10
```

5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)

```
6 \, \text{clc};
7 clear;
8
9 //given
10 BER=1e-6;// a bit error
11 T=400; //temperature in kelvin
12 R1=50;//load resistance in ohms
13 R=0.4//responsivity in A/W
14 K=1.38*1e-23//boltzman constant in SI units
15 B=1e7//bandwidth in Hz
16 u=4*(K)*T*B;
17 is=9.56*sqrt(u/Rl);//current in Ampere
18 Pmin=is/R;//minimum power required to maintain a bit
       error
19 mprintf("The minimum power required to maintain a
      bit error=\%.3 f uW", Pmin*1e6);
20 //The answer vary due to rounding
21 // the question no. in book is wrong there is repeat
      of 8.4
```

Chapter 9

Optical Fiber Measurements

Scilab code Exa 9.1 Attenuation

1 2 // OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar 3 / Example 914 / OS=Windows 105 ////Scilab version Scilab 6.0.0-beta-2(64 bit) $6 \quad clc;$ 7 clear; 8 9 //given 10 L1=2;//length of fiber in m 11 L2=0.002; //length of fiber cutback in Km for testing 12 VF=2.1;//output voltage of photodetector in volts at lambda = 0.85um13 lamda=0.85e-6//wavelength in m 14 VN=10.5; //output voltage for 2m cutback fiber length at wavelength 0.85um in volts 1516 a=10/(L1-L2);

Scilab 5.5.2 Console			_	_			C - X
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C:\Users\Admin\Desktop\sclabnew\ • +	The attenuation per Kilometer at wavelength 0.85um is=3.50 dB/Km		Name	Value	Type	v	isblity
	>	H	alphadB		3.5	Double	local
Nare Dr. d L			b		0.699	Double	local
sciaonew A		-	a		5.01	Double	local
- G_4.jpg			landa	8	Se-07	Double	local
			VF		2.1	Double	local
6_8.jpg			1.2		0.002	Double	local
7.2 inc			11		2	Double	local
8 3.00							
9-5.jpg							
9_6.00							
E PUTI 1 Im							
Exil isce							
Exi1_2.sce							
Exil_3jpg							
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Exit_spy			BR				
- Ex11_5.jpg			Lmax1				
Ex11_5.sce			-Lmax3				
			help antilog				
Ex6_10.sce			-Lmax3				
Ext_hpg			-10^(Lmax3)				
			-10^(-Lmax3)				
Ext Sisce			-Lmax3				
			help title				
Ex6_6.sce			help myttle				
- Ex6_7.jpg			help xtitle				
Elle_7.ste			help plot				
Ette State		-11	09/02/2017 09:28	:43 //			
Ex6_9.jpg		91	09/02/2017 09:28	:43 //			
Ex6_9.sce			-b				
Ex7_2.jpg			alphadB				
Ex7_2.sce *			a=10/(L1-L2)				
File/directory filter			-a/b				
Case sensitive Regular expression			-b*10/1.998 -10/1.998				-
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Figure 9.1: Attenuation

```
17 b = log 10 (VN/VF);
```

```
18 alphadB=a*b;//attenuation per Kilometer in dB/km at wavelength 0.85um
```

Scilab code Exa 9.2 Attenuation

```
1
2 //OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 9.2
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
```

Scilab 5.5.2 Console				_		-	o x
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C:\Users\Admin\Desktop'solabnew\	The attenuation per Kilometer at wavelength 1.1um is=5.92 dB/Km		Name	Value	Туре		Asblity
Name	>	H	alphadB		5.92	Double	local
Ph sciebnew a			b		0.886	Double	local
			Pf		385	Double	local
			Pn		50.1	Double	local
			1.2		0.002	Double	local
			1.1		1.5	Double	local
- 7 2.00							
- B 2.100							
9_7.pg							
- Ex11_1.jpg E							
Ex11_1.sce							
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- Exit 3 ace							
- Ex11_4.jpg		Comme	ind History				× 5 9
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			Lmax2				
Ex11_5.sce			Lmax3				
Enc_10.pg			help antilog I max3				
- Ex6 4.pg			exp(Lmax3)				
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			10^(-Lmax3)				
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Ex6_7.sce			help legend				
		1.4	help plot				
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Case sensitive Dendar everyession			a/b b*10/1.998				
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Figure 9.2: Attenuation

8

- 9 //given
- 10 L1=1.5; //length of optical fiber in Km
- 11 L2=0.002;//length of fiber cutback in Km
- 12 Pn=50.1;//output power in microwatts for the full link length

```
14
```

```
15 a=10/(L1-L2);
```

- 16 b=log10(Pf/Pn);
- 17 alphadB=a*b;//attenuation per Kilometer in dB/km at wavelength 1.1um
- 18 mprintf("The attenuation per Kilometer at wavelength 1.1um is=%.2f dB/Km",alphadB);

Scilab 5.5.2 Console			_			© <u>×</u>
File Edit Control Applications ?						
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C:\Users\Admin'Desktop'sclabnew\			Name	Value T	ype 1	Visibility
	The 3dB pulse dispersion for the fibre is=10.58 ns/Km	H	Bopt	4.16e+07	Double	local
Name	The fibre bandwidth length product is=41.60 MHzKm		Gama_3dB	10.6	Double	local
sciabnew A	>		v	1.2	Double	local
			u	12.7	Double	local
			e	101	Double	local
G 8.jpg			0	161	Double	local
- 🔛 6_9.pg			12	0.4	Double	local
- 2.jpg			L1	12.7	Double	local
- B_2,pg			L	1.2	Double	local
- 3,300 - 5,500						
9-5.00						
10 9 4 m						
9 6.00						
9_7.jpg						
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Ex11_1.sce						
Ex11_2.jpg						
Exi1_2.sce						
Ex11_3.00						
- Pril 4m		Comm	and History			× 5 9
Ex11 4.sce		TF	BR			
- Ex11_5.jpg			-Lmax1			
Ex11_5.sce			Lmax3			
Ex6_10.jpg			help antilog			
Ex6_10.sce			Lmax3			
			-10^() max3)			
Dug Stop			10^(-Lmax3)			
End Same			Lmax3			
Ex6_6.jpg			-son(Lmaxs)			
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			help xtitle			
Ex6_7.sce			help legend			
- 2 Ex6_8.jpg		-11-	- 09/02/2017 09:28:4	3-11		
Ext_0.sce		011-	- 09/02/2017 09:28:4	3 //		
End Sace			8			=
Ex7_2.jpg			alphadB			
- Ex7_2.sce *			a=10/(L1-L2)			
Fieldrectory fiter			b-log10(VN/VF)			
Case sensitive Regular expression			b*10/1.998 10/1.998			
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Figure 9.3: pulse dispersion and fiber bandwidth length product

 ${
m Scilab\ code\ Exa\ 9.3}$ pulse dispersion and fiber bandwidth length product

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 9.3
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0 - beta - 2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 L=1.2//link length in Km
11 Gama_o=12.7; //optical output pulse of 3dB width in
      nanoseconds
12 Gama_i=0.4; //optical input pulse of 3dB width in
      nanosseconds
13
14 q=(Gama_o)^2;
15 w=(Gama_i)^2;
```

Scilab 5.5.2 Console			_	_			
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File Browser ? *	X Sciulo 55.2 Consule 7 7 1	Varie	ble Browser				7 7 X
C:\Users\Admin'Desktop'polabnew\	The numerical appertur is=0.44		Name	Value	Type	Vsblit	ty
New	The distance from the screen is=17.04 cm	H	AB		17	Double	local
mane III analysis			L		16.7	Double	local
sudurew *		-	NA		0.44	Double	local
- G_4.jpg		-	age sets		40.4	Louis	
6.8.90							
7.2.00							
8_2.jpg							
9-5.00							
9.4.00							
9_6.jpg							
- 9_7.jpg	-						
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		Corre	nand History				* * *
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			-Lmax1 Imax2				
Ex11_5.sce			Lmax3				
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- Die Sipo			exp(Lmax3)				
Ex6_4.sce			-10^(Lmax3)				
Ex6_5.jpg			-Lmax3				
Ext_Size			- 10^(Lmax3)				
Ex6_6.sce			help myttle				
			help xtitle				100
Ex6_7.sce			help legend				
Ext_app			09/02/2017 09:28	43 //			
Ex6_9.jpg		B -11	09/02/2017 09:28	43 //			
Ex6_9.sce			b				
EX/_2.00			alphad8				
The following films			-b=log10(VN/VF)				
Prevarectory niter			a/b				
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Figure 9.4: NA and distance of fiber output end face from screen

```
16 e=q-w;
17 u=sqrt(e);
18 v=1.2;
19 Gama_3dB=u/v;//3dB pulse dispersion for the fibre in
ns/Km
20 mprintf("\n The 3dB pulse dispersion for the fibre
is=%.2f ns/Km",Gama_3dB);
21 Bopt=0.44/(Gama_3dB*1e-9);//fibre bandwidth length
productmultiplication by 1e-9 as gama is in nsKm
22 mprintf("\n The fibre bandwidth length product is=%
.2f MHzKm",Bopt/1e6); //multiplication by 1e6 to
convert unit from Hz to MHz
```

```
23 //the answer vary due to rounding
```

Scilab code Exa 9.4 NA and distance of fiber output end face from screen

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 9.4
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 alpham=26.1;//angular limit of far field pattern in
     degrees
11 NA=sind(alpham);//numerical aperture
12 L=16.7; //length of picture in cm
13
14 AB=(L/2)/[tand(alpham)];//distance from the screen
     in cm
15 mprintf("The numerical appertur is=%.2f",NA);
16 mprintf("\nThe distance from the screen is=%.2f cm",
     AB);
17 //th answer vary due to rounding
```

Scilab code Exa 9.5 NA

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 9.5
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
```



Figure 9.5: NA

```
9 //given
10 A=6.0;//measured output pattern size in cm
11 D=10.0;//distance between the screen and fibre face
in cm
12
13 q=(A)^2;
14 w=4*D^2;
15 u=sqrt(q+w);
16 NA=A/u;//numerical aperture
17 mprintf("The numerical aperture is=%.2f",NA);
```

Scilab code Exa 9.6 repeatno9point4 determine outer diameter of fiber

```
1
2 //OptoElectronics and Fibre Optics Communication, by
C.K Sarkar and B.C Sarkar
```

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C:\Users\Admin\Desktop'scilabnew\ • 🔹	The outer diameter of the fiber is=100.00 um	Name	Value	Туре	Visibi	lity
Name	>	d0		100	Double	local
En sciebnew		dsbydt		0.4	Double	local
- ÷				0.1	Double	local
- B 6_4.jpg		dphibyd	t .	4	Double	local
- G 6.jpg						
- C 6 9.00						
- III 7_2.jpg						
- B_2.jpg						
9-5.jpg						
9.6.00						
- E 9_7.pg						
Ex11_1.jpg						
Exil_i.sce						
Exil_2.pg						
Ex11 3.00						
Ex11_3.sce		L				
- Ex11_4.jpg		Command Histor	r			5 & X
Ex11_4.sce		-Lmax1				^
Exil_5.jpg		-Lmax2				
- Etf 10.ing		-Lmax3				
Ex6_10.sce		-Lmax3	~			
		exp(Lmax	3)			
Ex6_4.sce		- 10**(Lmas	(3)			
EX6_5.00		-Lmax3				
Ex6 6.00		- 10^(Lmas	<3)			
Ex6_6.sce		help myth	ie .			
		-help xtitle				100
Ex6_7.sce		help leger	hd			
Ext_stpg		-// 09/02/20	17 09:28:43 //			
		⊕ -// 09/02/20	17 09:28:43 //			
Ext 9.sce		-b				
- Ex7_2.jpg		alphadB				
- Ex7_2.sce *		a=10/0.1	+L2)			
Fle/drectory fiter		a-log su(ingit')			
Case sensitive Regular expression		b*10/1.9 -10/1.998	98			-
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Figure 9.6: repeatno9point4 determine outer diameter of fiber

```
3 / Example 9.6
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \, \text{clc};
7 clear;
8
9 //given
10 dphibydt=4;//angula velocity of roatng mirror in rad
     /sec
11 L=0.1;//distance between mirror and the detector in
     meter
12 We=250; //shadow pulse width in micrometer;
13
14 dsbydt=L*dphibydt;
15 d0=We*[dsbydt];//outer diameter of the fiber in
      micrometer
16 mprintf("The outer diameter of the fiber is=%.2f um"
      ,d0);
```



Figure 9.7: repeatno9point5 calculate excess loss of the connector

Scilab code Exa 9.7 repeatno9point5 calculate excess loss of the connector

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 9.7
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
10 P1=100; //power at the input in microwatts
11 P2=83.2; //power at the output in microwatts
12 P3=35.5; //power at the ouput after connector in
```

```
microwatts
13 L=1.8;//length of the added fibre in Km
14 alpha=1.5;//fiber attenuation in dB/L;
15
16 //case 1:
17 Ls=-10*log10(P2/P1);//insertion loss of connector in
      dB
18 mprintf("\n The insertion loss of connector is=%.2f
      dB",Ls);
19
20 //case 2:
21 deltaLs=-10*log10(P3/P1)-Ls-alpha*L;//excess loss of
      the connector
22 mprintf("\n The excess loss of connector is=%.2f dB", deltaLs);
```

Chapter 11

Optical Fiber Links and Wavelength Division Multiplexers

Scilab code Exa 11.1 material dispersion delay

```
1
2 // OptoElectronics and Fibre Optics Communication, by
C.K Sarkar and B.C Sarkar
3 //Example 11.1
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
10 L=1.25e3;//length of the link in m
11 delta_lamda=45;//change in wavelength in nanometers
12 lamda=850;//perating wavelength of fibre in
nanometer
13 C=3e8;//velocity of light in m/s
```

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C:\Users\Admin\Desktop'pclabnew\ • 🔹	The dispersion delay when length is 1.25 km=5.07 ns		Name	Value	Туре		Visibility
Nome	1		delta_t_mat	5.0	7e-09	Double	local
aslabnew			u v	4.1	7e-06	Double	local
- 3			м		0.023	Double	local
- C 6 6 ing			C	3	e+08	Double	local
- 6.8.pg			delta landa	-	45	Double	local
			1	1.25	e+03	Double	local
9-5.jpg							
9_4,00							
9 7.100							
Ex11_1.sce							
Ex11_3.sce							
Ex6_10.sce							
Ext Asce							
Ex6_5.sce							
Ex6_6.sce		Comm	and mistory	6-20 - 11			* * ×
Etto_/.sce		011-	- 27/01/2017 09:5	3:36 //			
Ex6_9.sce			Rf				
Ex7_2.soe			Pf2				
Ex8_1.sce			PW1byP1=exp(-	slpha*(d))*[1-e	xp(-alpha*W)]*(1-Rf)	
Exa_2.see			e^(-1)*(1-e^-1) %e^(-1)*(1-%e	*(1-0.309) (_1)*(1.0.309)			
Ex8_4.sce			exp(-1)*(1-exp(-	1))*(1-0.309)			
Ex8_5.sce		1	exp(-3)*(1-exp(-	3))*(1-0.309)			
Ex9_1.sce			- 05/02/2017 13:4	8:47 //			
EN9_2.500		⊜#,-	- 05/02/2017 13:4	k8:47 //			
Ex9_4.sce			Bm				
Ex9_5.sce			alpha_m				
Ex9_6.sce			-Mopt -rtl				
- El9_/.sce			Rđ				
			6				
File/directory filter							
Case sensitive Regular expression							
		_					
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Figure 11.1: material dispersion delay

```
14 M=0.023;//value of material dispersion parameter
15
16 u=L/C;
17 v=delta_lamda/lamda;
18 delta_t_mat=u*v*0.023;//dispersion delay when length
is 1.25 km
19 mprintf("The dispersion delay when length is 1.25 km
=%.2f ns",delta_t_mat*1e9);
```

Scilab code Exa 11.2 material dispersion limited transmission distance

```
1
2 //OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 11.1
```

4 //OS=Windows 10

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Figure 11.2: material dispersion limited transmission distance

```
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \, \text{clc};
7 clear;
8
9 //given
10 L=1.25e3;//length of the link in m
11 delta_lamda=45;//change in wavelength in nanometers
12 lamda=850; // perating wavelength of fibre in
     nanometer
13 C=3e8;//velocity of light in m/s
14 M=0.023; //value of material dispersion parameter
15 BR=1e7//bitate in bps
16 TB=1/BR//bit period in s
17 v=delta_lamda/lamda;
18 Lmax=0.35*TB*C/(M*v)//The material dispersion
      limited transmission distance
19
20 mprintf("The material dispersion limited
      transmission distance=%.2 f Km",Lmax/1e3);
```



Figure 11.3: modal dispersion limited transmission distance

Scilab code Exa 11.3 modal dispersion limited transmission distance

```
1
2 // OptoElectronics and Fibre Optics Communication, by
        C.K Sarkar and B.C Sarkar
3 //Example 11.3
4 //OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 clc;
7 clear;
8
9 //given
10 n1=1.45//refractive index of core
11 delta=0.01;//relative refractive index difference
12 Br=50e6;//data rate in bps
```



Figure 11.4: material dispersion modal and attenuation limited distance and length versus data rate

```
13 C=3e8// velocity of light in m/s
14 //for step index fibre
15 Lmaxs1=0.35*C/(delta*n1*Br);//modal dispersion
     limited transmission distance in meter for step
     index fiber
16 mprintf("\n The modal dispersion limited
     transmission distance for step index fiber is=%.2
     f m",Lmaxs1);
17 //for graded index fibre
18
19 Lmaxc1=1.4*C*n1/(delta*n1*Br);;//modal dispersion
     limited transmission distance in meter for graded
      index fiber
20 mprintf("\n The modal dispersion limited
     transmission distance for graded index fiber is=%
     .2 f m",Lmaxc1);
```

Scilab code Exa 11.4 material dispersion modal and attenuation limited distance an

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 / Example 11.4
4 / OS=Windows 10
5 ////Scilab version Scilab 6.0.0-beta-2(64 bit)
6 \, \text{clc};
7 clear;
8
9 //given
10
11 BR=[0.5e6 10e6 100e6 1000e6]//data rate in bps
12
13 for i=1:4
14 Lmax1(i)=6.757e10/BR(i)//Material dispersion limited
       distance in m
15 Lmax2(i)=4.2e10./BR(i)//modal limited distance in m
16 Lmax3(i)=(55-20*log10(BR(i)))//attenuation limited
      distance in m
17 \text{ end}
18 BR=[0 1 2 3]
19 plot((BR)/1e6,Lmax1/1e4,'---')
20 plot((BR)/1e6,Lmax2/1e4)
21 // plot (\log 10 (BR)), (10^{(Lmax3)}/1e6)^{(-.-.)}
22 xtitle( 'Link Length Versus Data Rate', 'Data Rate (
     Mb/s)', 'Link Length (Km)', boxed = %t );
23 hl=legend(['Lmax1'; 'Lmax2']);
```

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Name	Max bit rate for NRZ format is=17.42x10^6 bps		dalta trur	2.01e-02	Double	local
a solabnew			delta tmat	-9.648-09	Double	local
- <u>*</u>			delta_tmodal	8.75e-09	Double	2 local
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0_0.00			м	0.024	Double	r local
			delta_tr	1e-08	Double	local
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- B 2.00			delta ts	Se-09	Double	- local
- 🔛 8_3.jpg			c	3e+08	Double	e local
			Br	1e+08	Double	2 local
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- Ex6_6.jpg			-%e^(-1)*(1-%e^	-1)*(1-0.309)		
Elle Side			-exp(-3)*(1-exp(-3))*(1-0.309)		
Ev6 7 sce			04/02/2017 11:38	-46 //		
Ex6 8.100		<i>⊜-</i> //	05/02/2017 13:48	:47 //		
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- Ex6_9.jpg			alpha_m			
- Ex6_9.sce			Mopt			
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Figure 11.5: maximum bit rate

Scilab code Exa 11.5 maximum bit rate

```
1
2 // OptoElectronics and Fibre Optics Communication, by
      C.K Sarkar and B.C Sarkar
3 //Example 11.5
4 / OS = Windows 10
5 ////Scilab version Scilab 6.0.0 - beta - 2(64 bit)
6 \text{ clc};
7 clear;
8
9 //given
10 n1=1.45//refractive index of core
11 delta=0.01;//relative refractive index difference
12 Br=100e6;//data rate in bps
13 C=3e8// velocity of light in m/s
14 delta_ts=8e-9//silica fiber link rise time in s
15 lambda=830e-9//wavelength in m
16 delta_lambda=40e-9//spectral width in m
17 delta_tr=10e-9//rise time in 10 \, \text{ns}
```

- 18 M=0.024//silica fiber parameter
- 19 L=2.5e3//length of link in m
- 20 delta_tmodal=3.5e-9*L/1e3//intermodal dispersion delay in s
- 21 delta_tmat=(-L/C)*(delta_lambda/lambda)*(M)// material dispersion in s
- 23 BT=0.7/delta_tsys//Max bit rate for RZformat
- 25 BT=0.35/delta_tsys//Max bit rate for NRZformat
- 27 // the answer differ because of roundoff