Scilab Textbook Companion for Optical Communication Systems by S. B. Gupta And A. Goel[1]

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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.

Contents

List of Scilab Codes

Chapter 1

Introduction to optical Communication Systems

Scilab code Exa 1.1 Velocity of light in a medium

```
//Exa 1.1
clc;
clear;
close;
//Given data :
//epsilon=2*epsilon_o;
//mu=2*mu_o;
disp("v=1/sqrt(mu*epsilon)");
disp("Putting value of mu and epsilon");
disp("v=1/sqrt(2*mu_o*2*epsilon_o)");
disp("v=1/(2*sqrt(mu_o*epsilon_o))");
disp("v=c/2");
c=3*10^8;//speed of light in m/s
v=c/2;//in m/s
disp(v,"Velocity of light in medium in m/s : ");
```

Scilab code Exa 1.2 Value of Critical Angle

```
//Exa 1.2
clc;
clear;
close;
//Given data :
format('v',5);
n1=1.5;//refractive index
n2=1.47;//refractive index
//Formula : sin(theta_c)=n2/n1;
theta_c=asind(n2/n1);//in Degree
disp(theta_c,"Critical Angle in Degree : ");
//Note : Answer in the book is wrong.
```

Scilab code Exa 1.3 Refractive Index of a medium

```
//Exa 1.3
clc;
clear;
close;
//Given data :
format('v',5);
n1=1.52;//refractive index
//Formula : sin(theta_c)=n2/n1;
theta_c=73.2;//in Degree
n2=n1*sind(theta_c);
disp(n2,"Refractive Index of another medium : ");
```

Scilab code Exa 1.4 Velocity of light in a medium

```
//Exa 1.4
clc;
```

```
clear;
close;
//Given data :
format('v',9);
n=1.33;//refractive index
//Formula : velocity_of_light_in_medium=
    velocity_of_light_in_free_space/Refractive_Index;
c=3*10^8;//in m/s
v=c/n;//in m/s
disp(v,"velocity of light in medium in m/s : ");
```

Scilab code Exa 1.5 Refractive Index of a medium

```
//Exa 1.5
clc;
clear;
close;
//Given data :
format('v',5);
c=3*10^8;//in m/s
v=1.1*10^8;//in m/s
//Formula : velocity_of_light_in_medium=
    velocity_of_light_in_free_space/Refractive_Index;
n=c/v;//in m/s
disp(n,"Refractive Index of medium : ");
```

Chapter 2

Optical Fibres and its types

Scilab code Exa 2.1 Refractive Index of cladding

```
//Exa 2.1
clc;
clear;
close;
//Given data :
n1=1.40;//refractive index
delta=1;//relative refractive index difference in %
//Formula : n2/n1=1-delta
n2=n1*(1-delta/100);//refractive index(unitless)
disp(n2,"Refractive index of cladding : ");
```

Scilab code Exa 2.2 Critical Angle at core cladding interface

```
//Exa 2.2
clc;
clear;
close;
//Given data :
```

```
format('v',5);
n1=1.50;//refractive index
n2=1.47;//refractive index
//Formula : sin(theta_C)=n2/n1;
theta_c=asind((n2/n1));//in degree
disp(theta_c,"Critical Angle at core cladding interface in Degree : ");
```

Scilab code Exa 2.3 Numeriacal aperture of the fibre

```
//Exa 2.3
clc;
clear;
close;
//Given data :
format('v',5);
delta=1;//relative refractive index difference in %
n1=1.50;//refractive index
//Formula : NA=n1*sqrt(2*delta);
NA=n1*sqrt(2*delta/100);
disp(NA,"Numerical Aperture of the fibre : ");
```

Scilab code Exa 2.4 Numeriacal aperture and Acceptance angle

```
//Exa 2.4
clc;
clear;
close;
//Given data :
format('v',5);
delta=1;//relative refractive index difference in %
n1=1.55;//refractive index
n2=1.51;//refractive index
```

```
//Formula : NA=sqrt(n1^2-n2^2);
NA=sqrt(n1^2-n2^2)
disp(NA,"Numerical Aperture of the fibre : ");
//Formula : NA=sin(fi_o).....(max)
fi_o_max=asind(NA);//in Degree
disp(fi_o_max,"Acceptance angle in degree : ");
```

Scilab code Exa 2.5 Acceptance and critical Angle

```
//Exa 2.5
clc;
clear;
close;
//Given data :
format('v',5);
NA=0.40;//Unitless
n1=1.50;//refractive index
delta=1;//relative refractive index difference in %
//Part (a) :
//Formula : NA=sin(fi_o).....(max)
fi_o_max=asind(NA);//in Degree
disp(fi_o_max,"Acceptance angle in degree : ");
//Part (b) :
//Formula : n2/n1=1-delta
n2=n1*(1-delta/100);//refractive index(unitless)
//Formula : sin(theta_C)=n2/n1;
theta_c=asind((n2/n1));//in degree
disp(theta_c,"Critical Angle at core cladding
   interface in Degree : ");
```

Scilab code Exa 2.6 Refractive Index and Numeriacal aperture

```
//Exa 2.6
```

```
clc;
clear;
close;
//Given data :
v=2*10^8;//in m/s
fi_c=60;//in degree
//Part (a)
//Formula : v=c/n;
c=3*10^8;//in m/s
n1=c/v;//unitless
disp(n1,"Refractive index of core : ");
//Formula : sin(fi_c)=n2/n1;
n2=n1*sin(fi_c*%pi/180);//unitless
disp(n2,"Refractive index of cladding :");
//Part (b)
NA=sqrt(n1^2-n2^2);//Unitless
disp(NA,"Numerical Aperture : ");
```

Scilab code Exa 2.7 V number of Fibre

```
//Exa 2.7
clc;
clear;
close;
//Given data :
d=30;//in um
a=d/2;//in um
lambda=0.80;//in um
NA=0.74;//Unitless
V=2*%pi*a*NA/lambda;//V number
disp(V,"V number is : ");
```

Scilab code Exa 2.8 Normalized Frequency and No of modes

```
//Exa 2.8
clc;
clear;
close;
//Given data :
d=60;//in um
a=d/2;//in um
delta=1;//relative refractive index difference in %
lambda=0.80;//in um
n1=1.5;//Unitless
//Part (a)
//Formula : v=2*%pi*a*n1*NA/lambda;
//NA=sqrt(2*delta)
v=2*%pi*a*n1*sqrt(2*delta/100)/lambda;//Normalized
    frequency
disp(v,"Normalized frequency for the fiber : ");
//Part (b)
disp("Only the modes with cut-off v numbers below
    this value will propagate.");
N=v^2/2;//No. of modes supported
disp(round(N),"Number of modes supported : ");
//Note : Answer in the book is wrong.
```

Scilab code Exa 2.9 Normalized Frequency

```
//Exa 2.9
clc;
clear;
close;
//Given data :
NA=0.16;//Unitless
d=30;//in um
a=d/2;//in um
n1=1.50;//Unitless
lambda=0.9;//in um
```

```
v=2*%pi*a*NA/lambda;//V number
N=v^2/2;//No. of modes propagate
disp(ceil(N),"Number of guided modes in the fibre :
   ");
```

Scilab code Exa 2.10 Numeriacal aperture and Critical Aangle

```
//Exa 2.10
clc;
clear;
close;
//Given data :
fi_o=22;//in Degree
delta=3;//relative refractive index difference in %
//Part (a) :
//Formula : NA=sin(fi_o).....(max)
NA=sind(fi_o);//Numerical Aperture(Unitless)
disp(NA,"Numerical Aperture : ");
//Part (b) :
//Formula : n2/n1=1-delta
//Let say, n2/n1=n2byn1
n2byn1=(1-delta/100);//refractive index(unitless)
//Formula : sin(fi_C)=n2/n1;
fi_c=asind(n2byn1);//in degree
disp(fi_c,"Critical Angle at core cladding interface
    in Degree : ");
```

Scilab code Exa 2.11 Speed of light in Fibre Core

```
//Exa 2.11
clc;
clear;
close;
```

```
//Given data :
format('v',9)
delta=0.45;//relative refractive index difference in %
fi_o=0.115;//in Radian
c=3*10^8;//speed of light in m/s
//Formula : NA=sin(fi_o).....(max)
NA=sin(fi_o);//Numerical Aperture(Unitless)
//Formula : NA=n1*sqrt(2*delta)
n1=NA/sqrt(2*delta/100);//unitless
//Formula : n1=c/v;
v=c/n1;//in m/s
disp("Speed of light in fibre core is "+string(v)+" m/s");
```

Scilab code Exa 2.12 Diameter of the Fibre Core

```
//Exa 2.12
clc;
clear;
close;
//Given data :
n1=1.5;//Unitless
delta=1;//relative refractive index difference in %
lambda=1.3;//in um
N=1100;//No. of modes
//Formula : v=2*%pi*a*n1*NA/lambda;
//NA=sqrt(2*delta)
//v=sqrt(2*N)
a=(sqrt(2*N)*lambda)/(2*%pi*n1*sqrt(2*delta/100));//Normalized frequency
disp(2*a,"Diameter of the fiber core in micro meter is : ");
```

Scilab code Exa 2.13 Relative Refractive Index Difference

```
//Exa 2.13
clc;
clear;
close;
//Given data :
format('v',5)
n1=1.52;//unitless
fi_o=8;//in Degree
//Formula : sin(fi_o)=n1*sqrt(2*delta)
delta=(sind(fi_o)/n1)^2/2;//Relative refractive
   index
disp("The value of relative refractive index
   difference is "+string(delta*100)+"%");
```

Scilab code Exa 2.14 Wavelength of the Light

```
//Exa 2.14
clc;
clear;
close;
//Given data :
N=700;//No. of modes
d=30;//in um
a=d/2;//in um
NA=0.62;//Numerical Aperture
//Formula : v=2*sqrt(N) and v=2*%pi*a*NA/lambda
lambda=2*%pi*a*NA/(2*sqrt(N));//in um
disp(lambda,"Wavelength of light propagating in
   fibre in micro meter : ");
```

Scilab code Exa 2.15 Normalized Frequency and No of modes

```
//Exa 2.15
clc;
clear;
close;
//Given data :
n1=1.5;//unitless
alfa=2;//characteristic index profile
d=40;//in um
a=d/2;//in um
//Part (a) :
lambda=1.3;//in um
delta=1;
//Formula : v=2*%pi*a*NA/lambda=2*%pi*a*(n1*sqrt(2*
    delta))/lambda
v=2*%pi*a*(n1*sqrt(2*delta/100))/lambda;//Unitless
disp(v,"Normalized Frequency for single mode
    transmission : ");
//Part (b) :
//Formula : N=(alfa/alfa+2)*(v^2/2)
N=(alfa/(alfa+2))*(v^2/2);//No. of guided modes
disp(N,"No. of guided modes propagating in the fibre
     : ");
```

Scilab code Exa 2.16 No of Guided Modes

```
//Exa 2.16
clc;
clear;
close;
//Given data :
```

```
d=60;//in um
a=d/2;//in um
NA=0.25;//Unitless
lambda=1.1;//in um
v=2*%pi*a*NA/lambda;//unitless
N=v^2/4;//No. of modes
disp(N,"Number of supported guided modes :");
```

Scilab code Exa 2.17 Refractive Index Difference and acceptance angle

```
//Exa 2.17
clc;
clear;
close;
//Given data :
format('v',8)
d=10;//in um
a=d/2;//in um
lambda_c=1.3;//in um
n1=1.55;//unitless
//Part (a)
//for single mode transmission cut-off wavelength is lambda_c=2*%pi*a*n1*sqrt(2*delta)/2.405
delta=(lambda_c*2.405/(2*%pi*a*n1))^2/2;//unitless
disp(delta,"Normalized refractive index difference in % : ");
//Part (b)
//Formula : n2/n1=delta
n2=n1*(1-delta);
disp(n2,"Refractive index of cladding glass : ");
//Part (c) :
fi_o=asind(n1*sqrt(2*delta));//in degree
disp(fi_o,"Acceptance angle in degree : ");
```

Scilab code Exa 2.18 Shortest Wavelength and Relative refractive index

```
//Exa 2.18
clc;
clear;
close;
//Given data :
format('v',5);
d=7;//in um
a=d/2;//in um
n1=1.49;//unitless
delta=1;//relative refractive index difference in %
//Part (a)
//Formula : lambda_c=2*%pi*a*n1*sqrt(2*delta)/2.405;
lambda_c=2*%pi*a*n1*sqrt(2*delta/100)/2.405;//in um
disp(lambda_c,"Shortest wavelength of the light in
    micre meter :");
//Part (b)
//Formula : delta=(1/2)*{2.405*lambda_c/(2*%pi*a*n1)
    }^2
d=10;//in um
a=d/2;//in um
delta=(1/2)*{2.405*lambda_c/(2*%pi*a*n1)}^2;//
    unitless
disp(delta*100,"Maximum possible relative refractive
     index difference in % :");
```

Scilab code Exa 2.19 Fibre Core diameter

```
//Exa 2.19
clc;
clear;
```

```
close;
//Given data :
format('v',5);
n1=1.49;//unitless
n2=1.48;//unitless
lambda_c=1.5;//in um
//Formula : a=2.405*lambda_c/(2*%pi*sqrt(n1^2-n2^2))
a=2.405*lambda_c/(2*%pi*sqrt(n1^2-n2^2));//in um
disp(2*a,"Fibre core diameter in micro meter : ");
```

Scilab code Exa 2.20 Wavelength of the Light and fibre diameter

```
//Exa 2.20
clc;
clear;
close;
//Given data :
N=742;//No. of guided modes(unitless)
n1=1.5;//unitlessnm
alfa=2;//characteristic index profile
NA=0.3;//unitless
d=70;//in um
a=d/2;//in um
alfa=2;//Graded index profile for parabolic
//Formula : N=(alfa/(alfa+2))/(v^2/2)
v=sqrt(N*((alfa+2)/alfa)*2);//Unitless
//Formula : v=2*%pi*a*NA/lambda
lambda=2*%pi*a*NA/v;//in um
disp(lambda,"Wavelength of light propagating in fibre in micro meter :");
//Formula : lambvda_c=lambda=2*%pi*a*NA/(2.405*(sqrt((alfa+2)/alfa)))
a=lambda*(2.405*(sqrt((alfa+2)/alfa)))/(2*%pi*NA);// in um
disp(2*a,"Diameter of fibre in micro meter : ");
```

```
//Note : Answer in the book is not accurate.
```

Scilab code Exa 2.21 Single Mode Transmission

```
//Exa 2.21
clc;
clear;
close;
//Given data :
format('v',5);
n1=1.447;//unitless
n2=1.442;//unitless
lambda=1.3;//in um
d=7.2;//in um
a=d/2;//in um
//Formula : v=2*%pi*a*sqrt(n1^2-n2^2)/lambda
v=2*%pi*a*sqrt(n1^2-n2^2)/lambda;//unitless
disp(v,"Value of v : ");
disp("To achieve single mode transmission in an
   idealised step index fibre, Value of v must be
   less than 2.405. Hence, the fibre given will
   permit single mode          transmission.")
```

Scilab code Exa 2.23 Cut off normalized frequency

```
//Exa 2.23
clc;
clear;
close;
//Given data :
format('v',5);
alfa=1.9;
//characteristic index profile
```

```
//Formula : v=2.405*sqrt[(alfa+2)/alfa]
v=2.405*sqrt((alfa+2)/alfa);//unitless
disp(v,"Value of v : ");
//Note : Answer in the book is not accurate.
```

Scilab code Exa 2.24 Maximum Diameter of fibre

```
//Exa 2.24
clc;
clear;
close;
//Given data :
delta=1;//relative refractive index difference in %
n1=1.47;//unitless
lambda=1.5;//in um
disp("v=2*%pi*a*n1*sqrt(2*delta)/lambda");
disp("For single mode transmission in graded index fibre , v=2.405*sqrt((alfa+2)/alfa)");
disp("Hence we have :");
alfa=2;//unitless
a=2.405*sqrt((alfa+2)/alfa)*lambda/(2*%pi*n1*sqrt(2*delta/100));
disp(2*a,"Hence the diameter in micro meter : ");
```

Scilab code Exa 2.25 Maximum Diameter for step index fibre

```
//Exa 2.24
clc;
clear;
close;
//Given data :
delta=1;//relative refractive index difference in %
n1=1.47;//unitless
```

```
lambda=1.5;//in um
alfa=2;//unitless
//Formula : v=2*%pi*a*n1*sqrt(2*delta)/lambda
a=2.405*lambda/(2*%pi*n1*sqrt(2*delta/100));
disp(2*a,"Hence the diameter in micro meter : ");
```

Chapter 3

Transmission Characteristics of Fibre

Scilab code Exa 3.1 Maximum Allowed Bit Rate

```
//Exa 3.1
clc;
clear;
close;
//Given data :
lambda=1.5;//im um
deltaTwg=0.5;//in ns
deltaTmat=2.8;//in ns
Tt=2.5;//in ns
//For single mode fibre , deltaTmod=0;//in ns
deltaTmod=0;//in ns
deltaTtotal=sqrt(deltaTmod^2+deltaTmat^2+deltaTwg^2);//in ns
Tr=sqrt(Tt^2+deltaTtotal^2);//in ns
B=1/(2*Tr*10^-9);//in bits/sec
disp(B*10^-6,"Maximum allowed bit rate for the fibre in Mbits/sec : ");
//Note : Answer in the book s not accurate.
```

Scilab code Exa 3.2 Intermodal Dispersion

```
//Exa 3.2
clc;
clear;
close;
//Given data :
n1=1.55;//unitless
n2=1.50;//unitless
l=15;//in Km
delta=(n1-n2)/n1;//unitless
c=3*10^8;//in m/s
deltaT=n1*delta/c;//in ns/m
deltaT=n1*delta*1000/c;//in ns/Km
disp(deltaT,"Intermodal dispersion per Km of length
    in ns/Km : ");
deltaTtotal=deltaT*l*1000;//in ns
disp(deltaTtotal*1000,"Total intermodal dispersion
    in micro second : ");
//Note : Answer in the book is not accurate.
```

Scilab code Exa 3.3 Pulse Broadning per Km

```
//Exa 3.3
clc;
clear;
close;
//Given data :
//Formula Pulse Broadning per Km : deltaTmat(per Km)
    =(deltaTAUs*1000/c)*(lambda*d2n/dlambda^2)
deltaTAUs=45;//in nm
deltaTAUs=45*10^-9;//in m
```

```
lambda=0.9;//in um
lambda=0.9*10^-6;//in m
//let say, d^2n/dlambda^2=a
a=4*10^-2;//in um^-2
a=a*(10^-6)^-2;//in m^-2
c=3*10^8;//in m/s
deltaTmat_Km=(deltaTAUs*1000/c)*(lambda*a);//in sec/Km
disp(deltaTmat_Km*10^9,"Pulse broadning per Km in nano second per Km : ");
```

Scilab code Exa 3.4 Intermodal Dispersion

```
//Exa 3.4
clc;
clear;
close;
//Given data :
n1=1.55;//unitless
n2=1.50;//unitless
l=15;//in Km
delta=(n1-n2)/n1;//unitless
c=3*10^8;//in m/s
//Formula Intermodal_dispersion/m : deltaT_perKm=n1*delta^2/(8*c)
//Formula Intermodal_dispersion/Km : deltaT_perKm=n1*delta^2*1000/(8*c)
deltaT_perKm=n1*delta^2*1000/(8*c);//in sec/km
deltaT_perKm=deltaT_perKm*10^9//in nanosec/km
disp(deltaT_perKm,"Total intermodal dispersion per Km in nano second per Km : ");
disp("Which is very much less than the step index fibre. the total intermodal dispersion for length of 15 Km :");
deltaTtotal=deltaT_perKm*l;//in ns
```

```
disp(deltaTtotal,"Total intermodal dispersion for 15
    Km length in nano second : ");
//Note : Answer in the book is not accurate.
```

Scilab code Exa 3.5 Bandwidth Distance Product and dispersion limited length

```
//Exa 3.5
clc;
clear;
close;
//Given data :
Tr=6;//in ns/Km
BitRate=10;//in Mbps
//part (a)
BDP=1/(2*Tr*10^-9);//in bps-Km
BDP=BDP/10^6;//in Mbps-Km
disp(BDP,"Bandwidth Distance Product for the fibre
   in Mbps-Km : ");
//Part (b)
lmax=BDP/BitRate;//in Km
disp(lmax,"Dispersion limited length of the fibre in
    Km : ");
```

Scilab code Exa 3.6 Max Bandwidth pulse dispersion

```
//Exa 3.6
clc;
clear;
close;
//Given data :
Tr=0.2;//in us
l=20;//in Km
```

```
//part (a)
B=1/(2*Tr*10^-6);//in Hz
B=B/10^6;//in MHz
disp(B,"Maximum possible assuming no intersymbol
    interference in MHz : ");
//Part (b)
Dispersion=Tr*10^-6/l;//in sec/Km
disp(Dispersion*10^9,"Dispersion in ns/Km : ");
//part (c)
BDP=B*l;//in MHz-Km
disp(BDP,"Band =width Distance product for the fibre
     in MHz-Km : ");
```

Scilab code Exa 3.8 Pulse Broadning due to material dispersion

```
//Exa 3.8
clc;
clear;
close;
//Given data :
deltaTau_s=2;//in nm
L=30;//in Km
Dmat=20;//in ps/nm-km
//formula : deltaT_mat=deltaTau_s*L*[(lambda/c)*(d
    ^2*n/d*lambda^2)]
//formula : deltaT_mat=deltaTau_s*L*Dmat
deltaT_mat=deltaTau_s*L*Dmat;//in ps
deltaT_mat=deltaT_mat*10^-3;//in ns
disp(deltaT_mat,"Pulse broadning due to material
    dispersion in ns : ");
```

Scilab code Exa 3.9 Appropriate Repeater Spcing

```
//Exa 3.9
clc;
clear;
close;
//Given data :
FibreLoss=20;//in dB
//Pat (a)
lambda_a=1.3;///in um
loss_a=1.5;//in dB/Km
//Repeater spacing
la=FibreLoss/loss_a;//in Km
disp(la,"At wavelength of 1.3 micro meter, repeter
    spacing in Km : ");
//Pat (b)
lambda_b=1.5;///in um
loss_b=0.5;//in dB/Km
//Repeater spacing
lb=FibreLoss/loss_b;//in Km
disp(lb,"At wavelength of 1.5 micro meter, repeter
    spacing in Km : ");
```

Scilab code Exa 3.10 Pulse and Material Dispersion

```
//Exa 3.10
clc;
clear;
close;
//Given data :
Dmat=0.15;//in ns/nm-km
lambda=0.9;//in um
deltaTau_s=1.5;//in nm
//part (a)
//formula : deltaTmat/L=deltaTau_s*Dmat
deltaTmatBYL=deltaTau_s*Dmat;//in ns/Km
disp("Pulse dispersion per unit length of fibre is "
```

```
   +string(deltaTmatBYL)+" ns/Km");
//part (b)
L=15;//in Km
//formula : deltaTmat=deltaTau_s*Dmat*L
deltaTmat=deltaTau_s*Dmat*L;//in ns
disp("Material dispersion per in a 15 Km length of
   fibre is "+string(deltaTmat)+" ns");
```

Scilab code Exa 3.11 Material Dispersion coefficient and rms pulse broadning

```
//Exa 3.11
clc;
clear;
close;
//Given data :
//Let Material Dispersion , lambda^2*(d^2n/dlambda^2)
   =a
a=0.03;//in ns
deltaTau_s=15;//in nm
lambda=1.3;//in um
lambda=1.3*10^3;//in nm
c=3*10^8;//speed of light in m/s
c=3*10^5;//speed of light in Km/s
//Part (a)
Dmat=a/(lambda*c);//sec/nm-Km
Dmat=Dmat*10^12;//ps/nm-Km
disp("Material dispersion coefficient at a
   wavelength of 1.3 micro meter is "+string(Dmat)+"
    ps/nm-Km");
//Part (b)
deltaTmat_perKm=deltaTau_s*Dmat;//in ps/km
disp("Rms pulse broadning per Km due to material
   dispersion is "+string(deltaTmat_perKm)+" ps/km
   or "+string(deltaTmat_perKm*10^-3)+" ns/km");
```

```
//Note : Ans is  not accurate in the book.
```

Scilab code Exa 3.12 delay Difference and max Bit Rate

```
//Exa 3.12
clc;
clear;
close;
//Given data :
l=6;//in Km
n1=1.5;//unitless
delta=1//in %
c=3*10^8;//speed of light in m/s
//Part (a)
deltaT=l*10^3*n1*(delta/100)/c;//in sec
deltaT=deltaT*10^9;//in ns
disp(deltaT,"Delay difference between the slowest and fastest modes at output in ns : ");
//Part (b)
B=1/(2*deltaT*10^-9);//in bps
B=B*10^-6;//in Mbps
disp(B,"Assuming no intersymbol interference, maximum bit rate in Mbps : ");
```

Scilab code Exa 3.13 Critical Radius of Curvature

```
//Exa 3.13
clc;
clear;
close;
//Given data :
lambda=1.3;//in um
lambda=1.3*10^-6;//in m
```

```
n1=1.5;//unitless
delta=3//in %
c=3*10^8;//speed of light in m/s
n2=n1*(1-delta/100);//unitless
Rcm=3*n1^2*lambda/(4*%pi*(n1^2-n2^2)^(3/2));//in meter
Rcm=Rcm*10^6;//in um
disp(Rcm," Critical radius of curvature in micro meter : ");
```

Scilab code Exa 3.14 Critical Radius of Curvature

```
//Exa 3.14
clc;
clear;
close;
//Given data :
d=8;//in um
a=d/2;//in um
a=a*10^-6;//in meter
n1=1.5;//unitless
n2=1.46;//unitless
lambda=1.55;//in um
lambda=1.55*10^-6;//in meter
c=3*10^8;//speed of light in m/s
lambda_c=(2*%pi*a*sqrt(n1^2-n2^2))/2.405;//in meter
Rcs=(20*lambda/(n1-n2)^(3/2))*[(2.748*lambda_c-0.996*lambda)/lambda_c]^-3;//in meter
Rcs=Rcs*10^3;//in mm
disp(Rcs," Critical radius of curvature in milli meter : ");
//Note : Answer in the book is wrong.
```

Scilab code Exa 3.15 Refractive Index of cladding refractive index difference

```
//Exa 3.15
clc;
clear;
close;
//Given data :
format('v',6);
n1=1.49;//unitless
Rcs=10.4;//in mm
Rcs=Rcs*10^-3;//in meter
lambda=1.3;//in um
lambda=1.3*10^-6;//in meter
c=3*10^8;//speed of light in m/s
lambda_c=1.15;//in um
lambda_c=lambda_c*10^-6;//in meter
//part (a) :
//formula : (n1-n2)^(3/2)=(20*lambda/Rcs)*[(2.748*
   lambda_c -0.996*lambda)/lambda_c]^-3
n2=n1-(20*lambda/Rcs)^(2/3)*[(2.748*lambda_c-0.996*
   lambda)/lambda_c]^(-3*2/3);//unitless
disp(n2,"Refractive index of cladding : ");
//Part (b) :
delta=(n1-n2)/n1;//unitless
disp(delta*100,"Relative refractive index diference
   in % : ");
```

Scilab code Exa 3.16 Wavelength of the transmitted Light

```
//Exa 3.16
clc;
clear;
close;
//Given data :
```

```
n1=1.46;//unitless
n2=1.45;//unitless
Rcm=84;//in um
Rcm=Rcm*10^-6;//in meter
lambda=Rcm*4*%pi*(n1^2-n2^2)^(3/2)/(3*n1^2);//in
   meter
disp(lambda*10^6,"Wavelength of transmitted light in
    micro meter : ");
```

Chapter 5

Optical Fibre Connection

Scilab code Exa 5.1 Fraction of Reflected and Transmitted Power

```
//Exa 5.1
clc;
clear;
close;
//Given data :
format('v',6)
n=1.5;//refractive index
R=[(1-n)/(1+n)]^2;//unitless
disp(R*100,"Reflected light in % ");
disp(100-R*100,"The remainder transmitted light in %
    ");
loss=-10*log10(1-R);//in dB
disp(loss,"Transmission loss in dB : ");
```

Scilab code Exa 5.2 Loss in dB due to Fresnels reflection

```
//Exa 5.2
clc;
```

```
clear;
close;
//Given data :
format('v',5);
n1=3.6;//refractive index
n2=1.48;//refractive index
R=[(n1-n2)/(n1+n2)]^2;//unitless
loss=-10*log10(1-R);//in dB
disp(loss,"Transmission loss in dB : ");
```

Chapter 6

LED light source

Scilab code Exa 6.1 Bulk recombination life time and efficiency

```
//Exa 6.1
clc;
clear;
close;
//given data :
format('v',5);
Tr=40;//in ns
Tnr=90;//in ns
T=Tr*Tnr/(Tr+Tnr);//in ns
disp(T,"Bulk recombination life-time in nano second
    : ");
ETAint=(T/Tr)*100;//in %
disp(ETAint,"Internal Quantum Efficiency in % : ") ;
```

Scilab code Exa 6.2 Internally Generated Optical Power

```
//Exa 6.2
clc;
```

```
clear;
close;
//given data :
format('v',5);
lambda=1310;//in nm
lambda=lambda*10^-9;//in meter
ETAint=70;//in %
I=50;//in mA
I=I*10^-3;//in A
h=6.63*10^-34;//constant
c=3*10^8;//speed of light in m/s
q=1.6*10^-19;//in coulamb
Pint=(ETAint/100)*I*h*c/(q*lambda);//in Watts
disp(Pint*10^3,"Internally generated optical power
    in mWatt : ");
```

Scilab code Exa 6.3 Peak Emission wavelength

```
//Exa 6.3
clc;
clear;
close;
//given data :
format('v',6);
Pint=28.4;//in mw
Pint=Pint*10^-3;//in Watts
I=60;//in mA
I=I*10^-3;//in A
h=6.63*10^-34;//constant
c=3*10^8;//speed of light in m/s
q=1.6*10^-19;//in coulamb
//Tr=Tnr
//Formula : Pint=(Tnr/(Tr+Tnr))*(I*h*c/(q*lambda))
//as Tr=Tnr : (Tnr/(Tr+Tnr))=1/2
lambda=(1/2)*(I*h*c/(q*Pint));//in m
```

```
disp(lambda*10^6,"Peak emission waelength from the
    device in micro meter : ");
```

Scilab code Exa 6.4 Diffusion Coefficient of LED

```
//Exa 6.4
clc;
clear;
close;
//given data :
format('v',7);
L=20;//in um
L=L*10^-6;//in meter
Tr=80;//in ns
Tnr=80;//in ns
tau=Tr*Tnr/(Tr+Tnr);//in ns
//Formula : L=(D*tau)^(1/2)
D=(L^2)/(tau*10^-9);//in m^2-s^-1
disp(D,"Diffusion Coefficient of LED in m^2-s^-1 : "
    );
```

Scilab code Exa 6.5 3 dB optical Bandwidth

```
//Exa 6.5
clc;
clear;
close;
//given data :
format('v',5);
EBW=50;//MHz in 3dB
//Formula : EBW(3dB)=OpticalBW(3dB)/sqrt(2)
OpticalBW=sqrt(2)*EBW;//in 3dB
disp(OpticalBW,"3dB Optical Bandwidth in MHz : ");
```

Scilab code Exa 6.6 Optical Modulation Bandwidth

```
//Exa 6.6
clc;
clear;
close;
//given data :
format('v',4);
tau=5;//in ns
disp("For determining the optical 3-dB bandwidth we
    consider high frequency 3-dB point which occur
    when : P(w)/P(o)=1/2");
disp("It gives : 1/((1+omega*tau)^2)^(1/2) = 1/2");
//Formula :omega=2*%pi*F;
F=sqrt(3)/(2*%pi*tau*10^-9);//in Hz
disp(F*10^-6,"Optical Modulation Bandwidth in MHz :
    ") ;
```

Scilab code Exa 6.7 Electrical Modulation Bandwidth

```
//Exa 6.7
clc;
clear;
close;
//given data :
format('v',6);
tau=10;//in ns
disp("To find out electrical modulation bandwidth,
    first we will find out optical modulation
    bandwidth, which is determined by putting : P(w)/
    P(o)=1/2");
```

```
disp("It gives : 1/((1+omega*tau)^2)^(1/2) = 1/2");
//Formula :omega=2*%pi*F;
F=sqrt(3)/(2*%pi*tau*10^-9);//in Hz
F=F*10^-6;//in MHz
EMB=F/sqrt(2);//in MHz
disp(EMB,"Electrical Modulation Bandwidth in MHz : ");
```

Scilab code Exa 6.8 Optical Output power

```
//Exa 6.8
clc;
clear;
close;
//given data :
format('v',7);
Po=200;//in uwatts
tau=10;//in ns
F=10;//in MHz
disp("We have : P(w)/P(o)=Po/((1+2*%pi*F*tau)^2)^(1/2)");
Pw=(Po*10^-6)/(1+(2*%pi*F*10^6*tau*10^-9)^2)^(1/2);//in Watts
disp(Pw*10^6,"Optical output power in micro watts : ");
```

Scilab code Exa 6.9 Optical Output power

```
//Exa 6.9
clc;
clear;
close;
//given data :
```

```
format('v',5);
Po=200;//in uwatts
tau=10;//in ns
F=50;//in MHz
disp("We have : P(w)/P(o)=Po/((1+2*%pi*F*tau)^2)^(1/2)");
Pw=(Po*10^-6)/(1+(2*%pi*F*10^6*tau*10^-9)^2)^(1/2); //in Watts
disp(Pw*10^6,"Optical output power in micro watts : ") ;
```

Scilab code Exa 6.10 optical emitted Power and External efficiency

```
//Exa 6.10
clc;
clear;
close;
//given data :
format('v',6);
nm=3.5;//refractive index of InP;unitless
n=1;//refractive index of air ;unitless
F=0.6;//Transmission factor at crystal-air interface
//Part (a)
disp("Pe=Pint*F*n^2/(4*nm^2)");
//Let F*n^2/(4*nm^2)=x
x=F*n^2/(4*nm^2);
disp(string(x)+"Pint");
disp("Hence the power emitted into air is only 1.2% of the internal optical power.");
//Part (b)
disp("ETAext=(Pe/P)*100");
disp("ETAext=(0.012*Pint/P)*100")
//Given : Pint=0.5P
disp("ETAext=(0.012*0.5*P/P)*100")
disp("ETAext : "+string((0.012*0.5)*100)+"%");
```

Scilab code Exa 6.11 External Power Eficiency

```
//Exa 6.11
clc;
clear;
close;
//given data :
format('v',5);
//Given : Pint=0.3*P
nm=3.6;//refractive index of InP;unitless
n=1;//refractive index of air ;unitless
F=0.68;//Transmission factor at crystal-air
    interface
disp("ETAext=Pint*100*F*n^2/(4*P*nm^2)");
//Let F*n^2/(4*nm^2)=x
//Pint/P=0.3
//ETAext=0.3*x
x=100*F*n^2/(4*nm^2);
ETAext=0.3*x;
disp(ETAext,"External Power Efficiency in % : ");
```

Scilab code Exa 6.12 External Power Eficiency

```
//Exa 6.12
clc;
clear;
close;
//given data :
format('v',5);
ETAext=1.5;//in %
I=25;//in mA
```

```
V=4;//in Volt
F=0.8;//Transmission factor at crystal-air interface
nm=3.6;//refractive index of GaAs;unitless
n=1;//refractive index of air ;unitless
disp("ETAext=Pint*100*F*n^2/(4*P*nm^2)");
//P=V*I
Pint=(ETAext*4*V*I*10^-3*nm^2)/(F*100);//in watts
disp(Pint*1000,"Optical power generated in the device in mWatts : ");
```

Chapter 7

LASER light source

Scilab code Exa 7.1 Ratio of stimulated to spontaneous emission Rate

```
//Exa 7.1
clc;
clear;
close;
//Given data :
format('v',10);
lambda=1.5;//in um
T=900;//in kelvin
h=6.63*10^-34;//Planks contant
c=3*10^8;//speed of light in m/s
K=1.38*10^-23;//Boltzman Constant
//Formula : StiEmissionRate/SponEmissionRate=1/(exp(
    h*F/(K*T))-1)=1/(exp(h*c/(K*T*lambda))-1)
StiEmRateBySponEmRate=1/(exp(h*c/(K*T*lambda*10^-6))
    -1);
disp(StiEmRateBySponEmRate,"Stimulated Emission Rate
    /Spontanious Emission Rate is : ");
```

Scilab code Exa 7.2 Length of Optical Cavity and no of modes

```
//Exa 7.2
clc;
clear;
close;
//Given data :
lambda=0.8;//in um
lambda=lambda*10^-6;//in meter
deltaNEU=300;//in GHz
deltaNEU=deltaNEU*10^9;//in Hz
c=3*10^8;//speed of light in m/s
n=3.6;//Refractive index(unitless)
//Part (a) :
//Formula : deltaNEU=c/(2*n*L)
L=c/(2*n*deltaNEU);//in meter
disp(L*10^6,"Length of optical cavity in micro meter
    :")
//Part(b) :
K=2*n*L/lambda;//No. of longitudinal modes
disp(K,"No. of longitudinal modes : ");
```

Scilab code Exa 7.3 Length of crystal and Frequency separation

```
//Exa 7.3
clc;
clear;
close;
//Given data :
lambda=0.55;//in um
lambda=lambda*10^-6;//in meter
c=3*10^8;//speed of light in m/s
n=1.78;//Refractive index(unitless)
K=260000;//No. of longitudinal modes
//Part (a) :
L=K*lambda/(2*n);//in meter
disp(L,"Length of the crystal in  meter : ");
```

```
//Part (b) :
deltaNEU=c/(2*n*L);//in Hz
disp(deltaNEU*10^-9,"Frequency separation of
    longitudinal modes in GHz : ");
```

Scilab code Exa 7.4 wavelength and Linewidth

```
//Exa 7.4
clc;
clear;
close;
//Given data :
Eg=1.43;//in eV
deltaLambda=0.1;//in nm
deltaLambda=deltaLambda*10^-9//in meter
c=3*10^8;//speed of light in m/s
h=6.63*10^-34;//Planks contant
//Part (a) :
//Fomula : Eg=h*c/lambda
lambda=h*c/(Eg*1.6*10^-19);//in meter
disp(lambda*10^6,"Wavelength of optical emission in
    micro meter : ");
//Part (b) :
//Formula : deltaNEU=c*deltaLambda/lambda^2;//in Hz
deltaNEU=c*deltaLambda/lambda^2;//in Hz
disp(deltaNEU*10^-9,"Frequency separation of
    longitudinal modes in GHz : ");
```

Scilab code Exa 7.5 Ratio of threshold current densities

```
//Exa 7.5
clc;
clear;
```

```
close;
//Given data :
format('v',4)
To=150;//in kelvin
T1=20;//in degree C
T1=T1+273;//in kelvin
T2=70;//in degree C
T2=T2+273;//in kelvin
//Formula ; Jth=exp(T/To)
Jth20=exp(T1/To);
Jth70=exp(T2/To)
ratio=Jth70/Jth20;//unitless
disp(ratio,"Ratio of current densities for AlGaAs injection laser : ");
```

Scilab code Exa 7.6 Grating Period

```
//Exa 7.6
clc;
clear;
close;
//Given data :
lambda=1.55;//in um
m=1;//for first order
n=3.5;//Refractive Index(unitless)
//Formula : GratingPeriod=m*lambda/(2*n)
GratingPeriod=m*lambda/(2*n);//in um
disp(GratingPeriod,"grating Period for an InGaAsP DFB Laser diode : ");
```

Scilab code Exa 7.7 Frequency spread and wavelength spread

```
//Exa 7.8
```

```
clc;
clear;
close;
//Given data :
format('v',5)
L=0.3;//in mm
L=L*10^-3;//in meter
n=3.6;//Refractive Index(unitless)
c=3*10^8;//speed of light in m/s
lambda=0.82;//in um
lambda=lambda*10^-6;//in meter
deltaNEU=c/(2*n*L);//in Hz
disp(deltaNEU*10^-9,"Frequency spread between
    longitudinal modes in GHz");
deltaLambda=lambda^2/(c/deltaNEU)//in meter
disp(deltaLambda*10^9,"Wavelength spread between
    longitudinal modes in nano meter : ");
```

Chapter 8

Photodetectors

Scilab code Exa 8.1 Longest Wavelength cut off

```
//Exa 8.1
clc;
clear;
close;
//Given data :
Eg=1.43;//in eV
T=300;//in kelvin
h=6.63*10^-34;//Planks constant
c=3*10^8;//speed of light in m/s
lambda_c=h*c/(Eg*1.6*10^-19);//in meter
disp(lambda_c*10^9,"Longest Wavelength cut-off in nm
    : ")
```

Scilab code Exa 8.2 Quantum Efficieny of photodiode

```
//Exa 8.2
clc;
clear;
```

```
close;
//Given data :
photons=6*10^12;//no. of incident photons
lambda=1330;//in nm
pairs=4.8*10^12;//no. of electron hole pairs generated
ETA=pairs/photons;//Quantum efficiency (unitless)
ETA=ETA*100;//Quantum efficiency in %
disp(ETA,"Quantum efficiency in % : ");
```

Scilab code Exa 8.3 Responsivity of InGaAs photodiode

```
//Exa 8.3
clc;
clear;
close;
//Given data :
lambda=1300;//in nm
lambda=lambda*10^-9;//in meter
ETA=90;//quantum efficiency in %
h=6.63*10^-34;//Planks constant
q=1.6*10^-19;//in coulamb
c=3*10^8;//in m/s
R=(ETA/100)*q*lambda/(h*c);//in A/W
disp(R,"Responsivity of InGaAs in A/W : ");
```

Scilab code Exa 8.4 value of generated photocurrent

```
//Exa 8.4
clc;
clear;
close;
//Given data :
```

```
E=4.5*10^-21;//in Joule
R=0.9;//in A/W
P=20;//in uWatt
Ip=R*P;//in uA
disp(Ip,"Photocurrent generated in micro Ampere : ")
    ;
```

Scilab code Exa 8.5 Multiplication Factor

```
//Exa 8.5
clc;
clear;
close;
//Given data :
ETA=65;//Quantum efficiency in %
lambda=900;//in nm
lambda=lambda*10^-9;//in meter
q=1.6*10^-19;//in coulamb
h=6.63*10^-34;//Planks constant
c=3*10^8;//in m/s
P=0.5;//in uWatt
Im=20;//in uA
Ip=(ETA/100)*q*P*lambda/(h*c);//in micro Ampere
M=Im/Ip;//unitless
disp(M,"Multiplication Factor : ");
//Note : Ans in the book is not accurate.
```

Scilab code Exa 8.6 Circuit Bandwidth of pin phoodiode

```
//Exa 8.6
clc;
clear;
close;
```

```
//Given data :
C_A=2;//in pF
C_D=5;//in pF
RL=50;//in Ohm
RA=1;//in KOhm
RA=1*10^3;//in Ohm
C=C_A+C_D;//in pF
R=RA*RL/(RA+RL);//in Ohm
B=1/(2*%pi*R*C*10^-12);//in Hz
disp(B*10^-6,"Circuit Bandwidth of p-i-n photodiode
    in MHz : ");
//Note : Ans in the book is not accurate.
```

Scilab code Exa 8.7 Wavelength and incident optical power

```
//Exa 8.7
clc;
clear;
close;
//Given data :
ETA=40;//quantum efficiency in %
E=1.5;//in eV
Ip=3;//in uA
h=6.63*10^-34;//Planks constant
c=3*10^8;//in m/s
q=1.6*10^-19;//in coulamb
lambda=h*c/(E*1.6*10^-19);//in meter
disp(lambda*10^9,"Wavelength of photodiode in nm : "
    );
P=Ip*10^-6*(E*1.6*10^-19)/(ETA*q/100);
disp(P*10^6,"Power required in micro Watts ; ");
//Note : Ans in the book is not accurate.
```

Scilab code Exa 8.8 Responsivity of the device

```
//Exa 8.8
clc;
clear;
close;
//Given data :
format('v',5);
photons=1600;//incident photons/sec
lambda=1.3;//in um
electrons=1100;//generated/sec
ETA=electrons/photons;//unitless
q=1.6*10^-19;//in coulamb
h=6.63*10^-34;//Planks constant
c=3*10^8;//in m/s
R=ETA*q*lambda*10^-6/(h*c);//in A/W
disp(R,"Responsivity in A/W : ");
```

Scilab code Exa 8.9 Maximum Load Resistance

```
//Exa 8.9
clc;
clear;
close;
//Given data :
C=1;//in pF
//Part (a) :
FH=1;//in MHz
R=1/((2*%pi*FH*10^6*C)*10^-12);//in ohm
disp(R*10^-3,"For 1 MHz, Maximum Load Resistnce in
    Kohm : ");

//Part (b) :
FH=1;//in GHz
R=1/((2*%pi*FH*10^9*C)*10^-12);//in ohm
```

```
disp(R,"For 1 GHz, Maximum Load Resistnce in Ohm : "
   );
```

Scilab code Exa 8.10 NEP for Si pin photodiode

```
//Exa 8.10
clc;
clear;
close;
//Given data :
format('v',10);
lambda=1.3;//in um
lambda=lambda*10^-6;//in meter
Id=8;//in nA
ETA=55;//in %
h=6.63*10^-34;//Planks constant
c=3*10^8;//in m/s
q=1.6*10^-19;//in coulamb
NEP=(h*c)*sqrt(2*q*Id*10^-9)/((ETA/100)*q*lambda);//
   in Ohm
disp(NEP,"NEP for Si p-i-n photodiode in Ohm : ");
```

Scilab code Exa 8.11 Smallest Detactable signal power

```
//Exa 8.11
clc;
clear;
close;
//Given data :
A=2.5;//in mm^2
A=A*10^-6;//in m^2
B=1;//in KHz
B=B*10^3;//in Hz
```

```
Dstar=10^11;//mHz^1/2W^-1
NEP=sqrt(A*B)/Dstar;//in Watts
disp(NEP*10^12,"Smallest detectable signal power in pW : ");
```

Scilab code Exa 8.12 NEP and detectivity of Ge pin photodiode

```
//Exa 8.12
clc;
clear;
close;
//Given data :
A=200*25;//in um^2
A=A*10^-12;//in m^2
ETA=55;//Quantum Efficiency in %
lambda=1.3;//in um
lambda=lambda*10^-6;//in meter
Id=8;//in nA
Id=Id*10^-9;//i Ampere
h=6.63*10^-34;//Planks constant
q=1.6*10^-19;//in coulamb
c=3*10^8;//in m/s
NEP=h*c*sqrt(2*q*Id)/((ETA/100)*q*lambda);//in Watts
disp(NEP,"Noise equivalent power in Watts : ");
Dstar=sqrt(A)/NEP;//in m-Hz^2/W^-1
disp(Dstar,"Specific detectivity of Ge p-i-n photodiode in m-Hz^2/W : ");
//Note : Answer in the bok is not accurate.
```

Scilab code Exa 8.13 Maximum Load Resistance

```
//Exa 8.13
clc;
```

```
clear;
close;
//Given data :
C=6;//in pF
C=C*10^-12;//in F
FH=8;//in MHz
FH=FH*10^6;//in Hz
//Formula : FH=1/(2*%pi*R*C)
R=1/(2*%pi*FH*C);//in Ohm
disp(R*10^-3,"Maximum load resistance in Kohm");
```

Scilab code Exa 8.14 Generated shot noise in Ge pin photodiode

```
//Exa 8.14
clc;
clear;
close;
//Given data :
format('v',5);
lambda=0.9;//in um
lambda=lambda*10^-6;//in meter
ETA=60;//Quantum Efficiency in %
Id=3;//in nA
Id=Id*10^-9;//in Ampere
B=5;//in MHz
P=200;//in nW
P=P*10^-9;//in Watts
h=6.63*10^-34;//Planks constant
q=1.6*10^-19;//in coulamb
c=3*10^8;//in m/s
Ip=P*(ETA/100)*q*lambda/(h*c);//in Ampere
//Formula : Is^2=2*q*(Ip+Id)*B
Is=sqrt(2*q*(Ip+Id)*B*10^6);//in Ampere
disp(Is*10^9,"Total shot noise current in nA : ");
```

Scilab code Exa 8.15 Multiplication Factor for an APD

```
//Exa 8.15
clc;
clear;
close;
//Given data :
lambda=1.35;//in um
lambda=lambda*10^-6;//in meter
ETA=40;//Quantum Efficiency in %
Im=4.9;//in uA
Im=Im*10^-6;//in Ampere
P=0.2;///in uW
P=P*10^-6;//in watts
h=6.63*10^-34;//Planks constant
q=1.6*10^-19;//in coulamb
c=3*10^8;//in m/s
M=Im*h*c/((ETA/100)*q*P*lambda);//unitless
disp(floor(M),"Multiplication factor : ");
```

Scilab code Exa 8.16 Wavelength and output photocurrent

```
//Exa 8.16
clc;
clear;
close;
//Given data :
format('v',5);
photons=10^13;//incident photons/sec
E=1.28*10^-19;//in Joule
h=6.63*10^-34;//Planks constant
q=1.6*10^-19;//in coulamb
```

```
c=3*10^8;//in m/s
//Part (a) :
lambda=h*c/(E);//in meter
disp(lambda*10^6,"Wavelength of incident radiation in micro meter : ");
//Part (b) :
Ip=q*photons;//in Ampere
disp(Ip*10^6,"Output photocurrent in micro Ampere : ");
//Part (c) :
M=18;//unitless
Im=M*Ip;//in Ampere
disp(Im*10^6,"If device is an APD, Output photocurrent in micro Ampere : ");
```

Scilab code Exa 8.17 Quantum Efficieny and output photocurrent

```
//Exa 8.17
clc;
clear;
close;
//Given data :
M=20;//unitless
lambda=1.5;//in um
lambda=lambda*10^-6;//in meter
R=0.6;//in A/W
h=6.63*10^-34;//Planks constant
q=1.6*10^-19;//in coulamb
c=3*10^8;//in m/s
photons=10^10;//incident photons/sec
Im=M*R*photons*h*c/lambda;//in Ampere
disp(Im*10^9,"Output Photo current in nA : ");
ETA=R*h*c/(q*lambda);//unitless
disp(round(ETA*100),"Quantum Efficiency in % : ");
```

Scilab code Exa 8.18 Maximum SNR

```
//Exa 8.18
clc;
clear;
close;
//Given data :
format('v',5);
RL=630;//in Ohm
B=50;//in MHz
B=B*10^6;//in Hz
Ip=10^-7;//in Ampere
T=18;//in degree C
T=T+273;//in kelvin
q=1.6*10^-19;//in coulamb
K=1.38*10^-23;//Boltzman Constant
SbyN=Ip^2/(2*q*B*Ip+4*K*T*B/RL);//unitless
SbyNdB=10*log10(SbyN);//in dB
disp(round(SbyNdB),"Maximum SNR in dB : ");
```

Scilab code Exa 8.19 Mean square value of noise current

```
//Exa 8.19
clc;
clear;
close;
//Given data :
lambda=1.3;//in um
lambda=lambda*10^-6;//in meter
Id=16;//in nA
Id=Id*10^-9;//in Ampere
ETA=90;//Quantum Efficiency in %
```

```
RL=1000;//in Ohm
P=1.2;//in uW
P=P*10^-6;//in Watts
B=80;//in Mhz
B=B*10^6;//in Hz
T=20;//in degree C
T=T+273;//in kelvin
q=1.6*10^-19;//in c
K=1.38*10^-23;//Boltzman Constant
h=6.63*10^-34;//Planks constant
c=3*10^8;//in m/s
Ip=(ETA/100)*q*lambda*P/(h*c);//in Ampere
Iq=sqrt(2*q*Ip*B);//in Ampere
disp(Iq*10^9,"Mean square quantum nooise in nA : ");
I_dark=sqrt(2*q*Id*B);//in Ampere
disp(I_dark*10^9,"Mean square dark current noise in
    nA :");
It=sqrt(4*K*T*B/RL);//in Ampere
disp(round(It*10^9),"Mean square thermal current
    noise in nA :");
```

Scilab code Exa 8.20 Determine the SNR

```
//Exa 8.20
clc;
clear;
close;
//Given data :
F=3;//in dB
F=10^(F/10);//unitless
M=1;//unitless
lambda=1.3;//in um
lambda=lambda*10^-6;//in meter
Id=16;//in nA
Id=Id*10^-9;//in Ampere
```

```
ETA=90;//Quantum Efficiency in %
RL=1000;//in Ohm
P=1.2;//in uW
P=P*10^-6;//in Watts
B=80;//in Mhz
B=B*10^6;//in Hz
T=20;//in degree C
T=T+273;//in kelvin
q=1.6*10^-19;//in c
K=1.38*10^-23;//Boltzman Constant
h=6.63*10^-34;//Planks constant
c=3*10^8;//in m/s
Ip=(ETA/100)*q*lambda*P/(h*c);//in Ampere
SbyN=Ip^2*M^2/(2*q*B*(Ip+Id)*M^2+(4*K*T*B*F/RL));
disp(SbyN,"SNR at the output : ");
```