

Scilab Textbook Companion for  
Fiber Optic Communications  
by J. C. Palais<sup>1</sup>

Created by  
Lochan Jolly  
Optical Communication  
Electrical Engineering  
Mumbai, TCET  
College Teacher  
None  
Cross-Checked by  
None

July 31, 2019

<sup>1</sup>Funded by a grant from the National Mission on Education through ICT, <http://spoken-tutorial.org/NMEICT-Intro>. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website <http://scilab.in>

# Book Description

**Title:** Fiber Optic Communications

**Author:** J. C. Palais

**Publisher:** Pearson Education, India

**Edition:** 4

**Year:** 2001

**ISBN:** 81-7808-456-2

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                         | 4   |
| 1 Fiber optic communications systems         | 6   |
| 2 Optics Review                              | 13  |
| 3 Lightwave fundamentals                     | 25  |
| 4 Integrated Optic waveguides                | 45  |
| 5 Optic fiber waveguides                     | 51  |
| 6 Light Sources                              | 64  |
| 7 Light Detectors                            | 70  |
| 8 Couplers and connectors                    | 83  |
| 9 Distribution networks and Fiber components | 97  |
| 10 Modulation                                | 103 |
| 11 Noise and Detection                       | 112 |
| 12 System Design                             | 134 |

# List of Scilab Codes

|          |    |    |
|----------|----|----|
| Exa 1.1  | 1  | 6  |
| Exa 1.2  | 2  | 8  |
| Exa 1.3  | 3  | 9  |
| Exa 1.4  | 4  | 10 |
| Exa 2.1  | 1  | 13 |
| Exa 2.2  | 2  | 14 |
| Exa 2.3  | 3  | 16 |
| Exa 2.4  | 4  | 20 |
| Exa 2.5  | 5  | 22 |
| Exa 2.6  | 6  | 22 |
| Exa 3.1  | 1  | 25 |
| Exa 3.2  | 2  | 27 |
| Exa 3.3  | 3  | 28 |
| Exa 3.4  | 4  | 30 |
| Exa 3.5  | 5  | 31 |
| Exa 3.6  | 6  | 35 |
| Exa 3.7  | 7  | 37 |
| Exa 3.8  | 8  | 39 |
| Exa 3.9  | 9  | 41 |
| Exa 3.10 | 10 | 42 |
| Exa 4.1  | 1  | 45 |
| Exa 4.2  | 2  | 48 |
| Exa 4.3  | 3  | 48 |
| Exa 5.1  | 1  | 51 |
| Exa 5.2  | 2  | 54 |
| Exa 5.3  | 3  | 54 |
| Exa 5.4  | 4  | 56 |
| Exa 5.5  | 5  | 57 |

|          |   |     |
|----------|---|-----|
| Exa 5.6  | 6 | 59  |
| Exa 5.7  | 7 | 60  |
| Exa 5.8  | 8 | 62  |
| Exa 6.1  | 1 | 64  |
| Exa 6.2  | 2 | 67  |
| Exa 6.3  | 3 | 67  |
| Exa 7.1  | 1 | 70  |
| Exa 7.2  | 2 | 70  |
| Exa 7.3  | 3 | 73  |
| Exa 7.4  | 4 | 75  |
| Exa 7.5  | 5 | 76  |
| Exa 7.6  | 6 | 77  |
| Exa 7.7  | 7 | 79  |
| Exa 7.8  | 8 | 81  |
| Exa 8.1  | 1 | 83  |
| Exa 8.2  | 2 | 85  |
| Exa 8.3  | 3 | 87  |
| Exa 8.4  | 4 | 89  |
| Exa 8.5  | 5 | 90  |
| Exa 8.6  | 6 | 92  |
| Exa 8.7  | 7 | 94  |
| Exa 9.1  | 1 | 97  |
| Exa 9.2  | 2 | 99  |
| Exa 9.3  | 3 | 100 |
| Exa 10.1 | 1 | 103 |
| Exa 10.2 | 2 | 106 |
| Exa 10.3 | 3 | 106 |
| Exa 10.4 | 4 | 109 |
| Exa 10.5 | 5 | 109 |
| Exa 11.1 | 1 | 112 |
| Exa 11.2 | 2 | 116 |
| Exa 11.3 | 3 | 117 |
| Exa 11.4 | 4 | 120 |
| Exa 11.5 | 5 | 121 |
| Exa 11.6 | 6 | 124 |
| Exa 11.7 | 7 | 127 |
| Exa 11.8 | 8 | 129 |
| Exa 11.9 | 9 | 130 |

|           |    |       |     |
|-----------|----|-------|-----|
| Exa 11.10 | 10 | ..... | 132 |
| Exa 12.1  | 1  | ..... | 134 |
| Exa 12.2  | 2  | ..... | 135 |

# List of Figures

|      |    |    |
|------|----|----|
| 1.1  | 1  | 7  |
| 1.2  | 2  | 8  |
| 1.3  | 3  | 9  |
| 1.4  | 4  | 11 |
| 2.1  | 1  | 14 |
| 2.2  | 2  | 15 |
| 2.3  | 3  | 17 |
| 2.4  | 3  | 18 |
| 2.5  | 4  | 19 |
| 2.6  | 5  | 21 |
| 2.7  | 6  | 23 |
| 3.1  | 1  | 26 |
| 3.2  | 2  | 27 |
| 3.3  | 3  | 29 |
| 3.4  | 4  | 30 |
| 3.5  | 5  | 32 |
| 3.6  | 6  | 35 |
| 3.7  | 7  | 38 |
| 3.8  | 8  | 40 |
| 3.9  | 9  | 41 |
| 3.10 | 10 | 43 |



|      |   |       |     |
|------|---|-------|-----|
| 4.1  | 1 | ..... | 46  |
| 4.2  | 2 | ..... | 47  |
| 4.3  | 3 | ..... | 49  |
| 5.1  | 1 | ..... | 52  |
| 5.2  | 2 | ..... | 53  |
| 5.3  | 3 | ..... | 55  |
| 5.4  | 4 | ..... | 56  |
| 5.5  | 5 | ..... | 58  |
| 5.6  | 6 | ..... | 59  |
| 5.7  | 7 | ..... | 61  |
| 5.8  | 8 | ..... | 62  |
| 6.1  | 1 | ..... | 65  |
| 6.2  | 2 | ..... | 66  |
| 6.3  | 3 | ..... | 68  |
| 7.1  | 1 | ..... | 71  |
| 7.2  | 2 | ..... | 72  |
| 7.3  | 3 | ..... | 74  |
| 7.4  | 4 | ..... | 75  |
| 7.5  | 5 | ..... | 76  |
| 7.6  | 6 | ..... | 78  |
| 7.7  | 7 | ..... | 80  |
| 7.8  | 8 | ..... | 81  |
| 8.1  | 1 | ..... | 84  |
| 8.2  | 2 | ..... | 86  |
| 8.3  | 3 | ..... | 88  |
| 8.4  | 4 | ..... | 89  |
| 8.5  | 5 | ..... | 91  |
| 8.6  | 6 | ..... | 93  |
| 8.7  | 7 | ..... | 94  |
| 9.1  | 1 | ..... | 98  |
| 9.2  | 2 | ..... | 99  |
| 9.3  | 3 | ..... | 101 |
| 10.1 | 1 | ..... | 104 |

|         |   |     |
|---------|---|-----|
| 10.2    | 2 | 105 |
| 10.3    | 3 | 107 |
| 10.4    | 4 | 108 |
| 10.5    | 5 | 110 |
| 11.1    | 1 | 113 |
| 11.2    | 2 | 115 |
| 11.3    | 3 | 118 |
| 11.4    | 4 | 122 |
| 11.5    | 4 | 123 |
| 11.6    | 5 | 125 |
| 11.7    | 6 | 126 |
| 11.8    | 7 | 128 |
| 11.9    | 8 | 129 |
| 11.109  |   | 131 |
| 11.1110 |   | 132 |
| 12.1    | 1 | 135 |
| 12.2    | 2 | 136 |

# Chapter 1

## Fiber optic communications systems

Scilab code Exa 1.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 1.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 LP1=-11// Loss in element 1 in dB
9 LP2=-6// Loss in element 2 in dB
10 LP3=-3// Loss in element 3 in dB
11 //to find
12 total_Loss=LP1+LP2+LP3//total Loss in dB
13 mprintf(" total Loss=%fdB",total_Loss)
14 input_power=5e-3// input power in Watt
15 output_power=input_power*10^(total_Loss/10)//output
    power in Watt
16 mprintf("\nOutput power=%fmW",output_power*1e3)
```

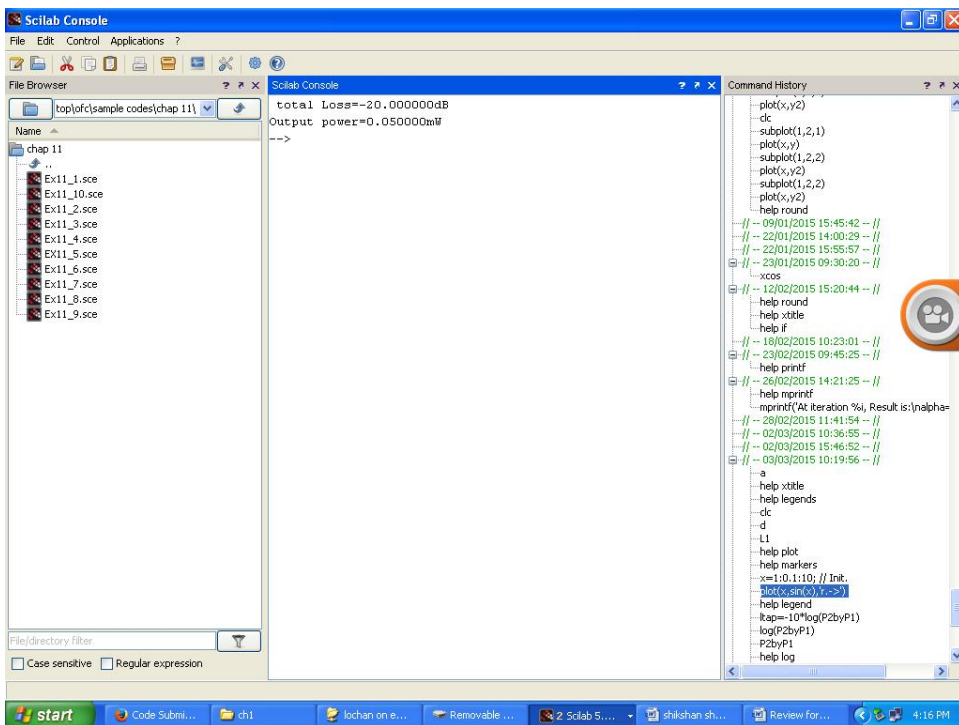


Figure 1.1: 1

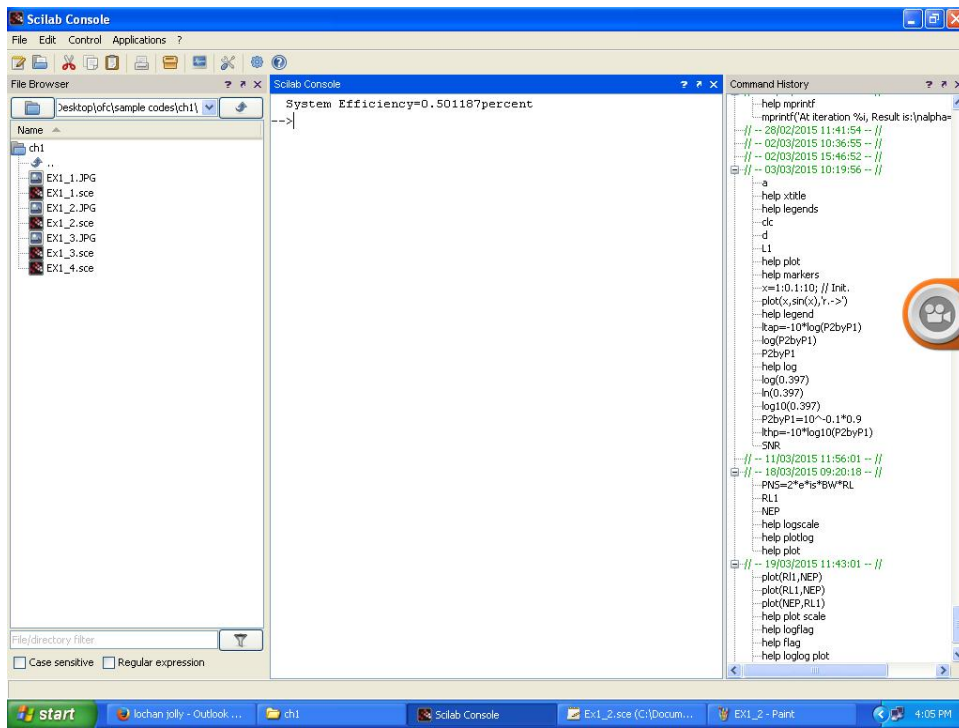


Figure 1.2: 2

### Scilab code Exa 1.2 2

```

1 //fiber optic communications by joseph c. palais
2 //example 1.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8

```

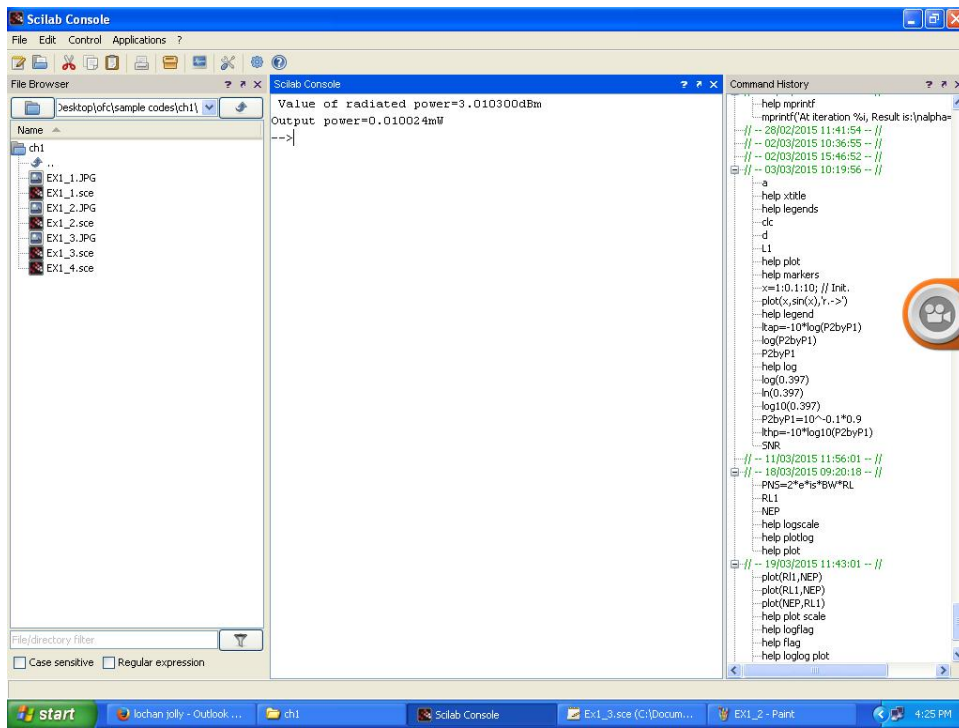


Figure 1.3: 3

```

9 Loss=-23// total loss in dB
10 //to find
11 P2byP1=10^(Loss/10)//P2/P1 gives efficiency
12 mprintf(" System Efficiency=%fpercent",P2byP1*100)

```

---

### Scilab code Exa 1.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 1.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1

```

```

5  clc
6  clear all
7  //given
8  total_Loss=23// total loss in components in dB
9  input_power=2e-3// Input power in W
10 //to find
11 Input_power_dBm=10*log10(input_power/10^-3)//
    expressing input power in dBm
12 output_power_dBm=Input_power_dBm-total_Loss //output
    power in dBm
13 output_power=10^(output_power_dBm/10)//output power
    in mW
14 mprintf(" Value of radiated power=%fdBm",
    Input_power_dBm)
15 mprintf("\nOutput power=%fmW",output_power)

```

---

#### Scilab code Exa 1.4 4

```

1  //fiber optic communications by joseph c. palais
2  //example 1.4
3  //OS=Windows XP sp3
4  //Scilab version 5.4.1
5  clc
6  clear all
7  //given
8  h=6.626e-34// plancks constant
9  c=3e8// velocity of light in m/s
10 lambda=0.8e-6//wavelength in m
11 P=1e-6//input power in W
12 t=1// time in sec
13 //to find
14 Wp=h*c/lambda// energy of one photon
15 W=P*t//energy in J

```

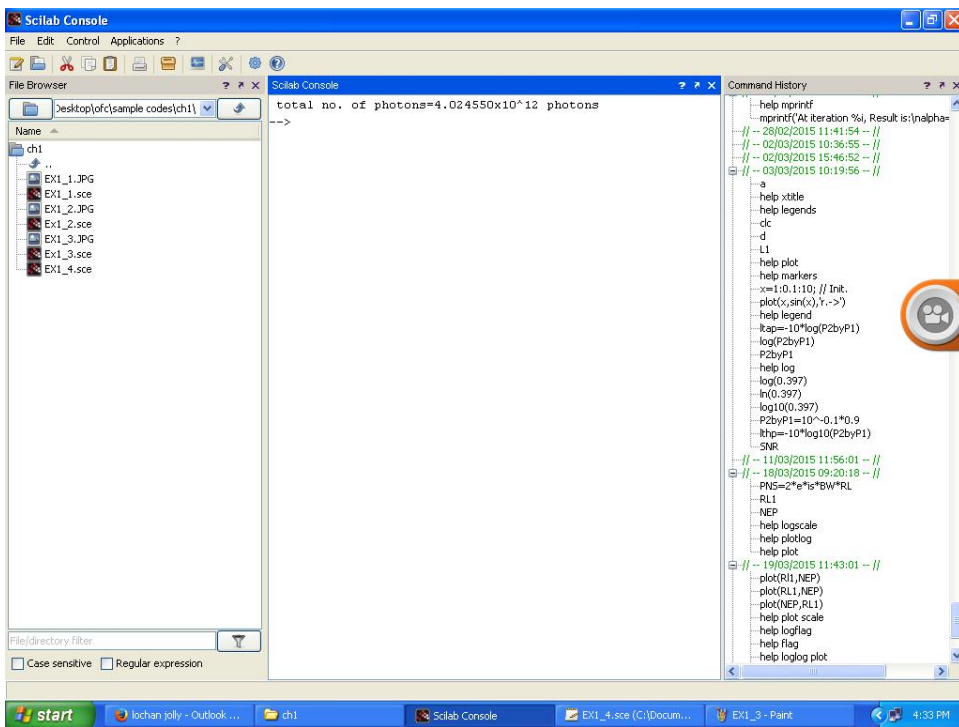


Figure 1.4: 4



```
16 n=W/Wp//no of photons
17 mprintf("total no. of photons=%fx10^12 photons",n
    /10^12)
```

---

# Chapter 2

## Optics Review

Scilab code Exa 2.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 2.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n1=1//refractive index of air
9 n2=1.5//refractive index of glass medium
10 theta_i_1=0//angle of incidence case 1 in degrees
11 theta_i_2=15//angle of incidence case 2 in degrees
12 //to find
13 theta_t_1=(asind(n1/n2*sind(theta_i_1)))//
    Transmission angle in degrees
14 mprintf("Transmission angle for %f degree incident
    angle=%fdegree",theta_i_1,theta_t_1)
15 theta_t_2=(asind(n1/n2*sind(theta_i_2)))
16 mprintf("\\nTransmission angle for %f degree incident
    angle=%fdegree",theta_i_2,theta_t_2)
```

---

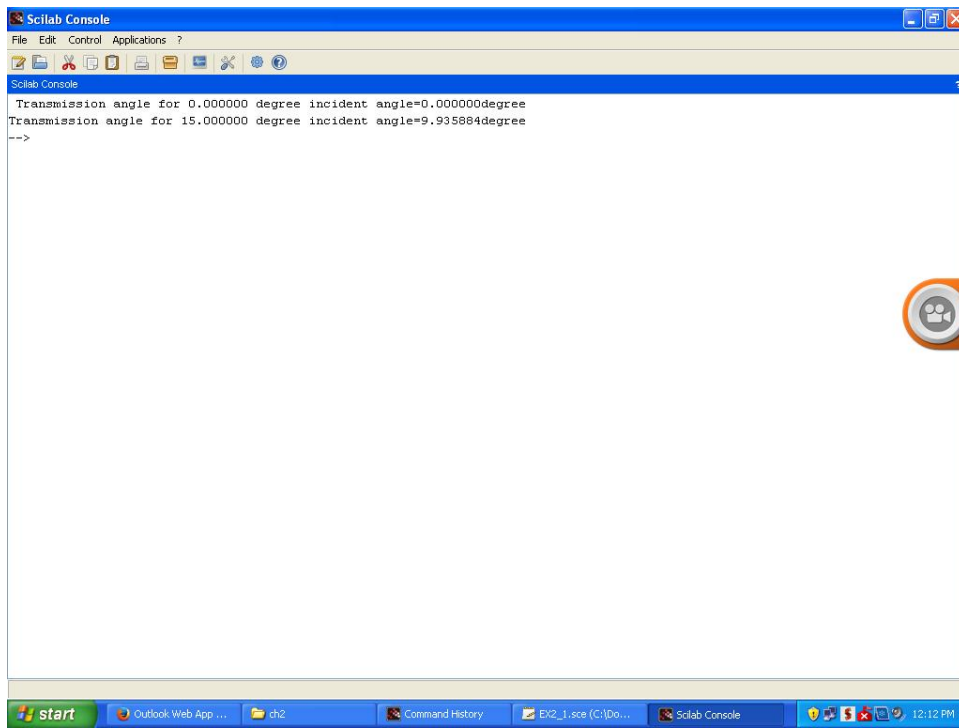


Figure 2.1: 1

### Scilab code Exa 2.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 2.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
```

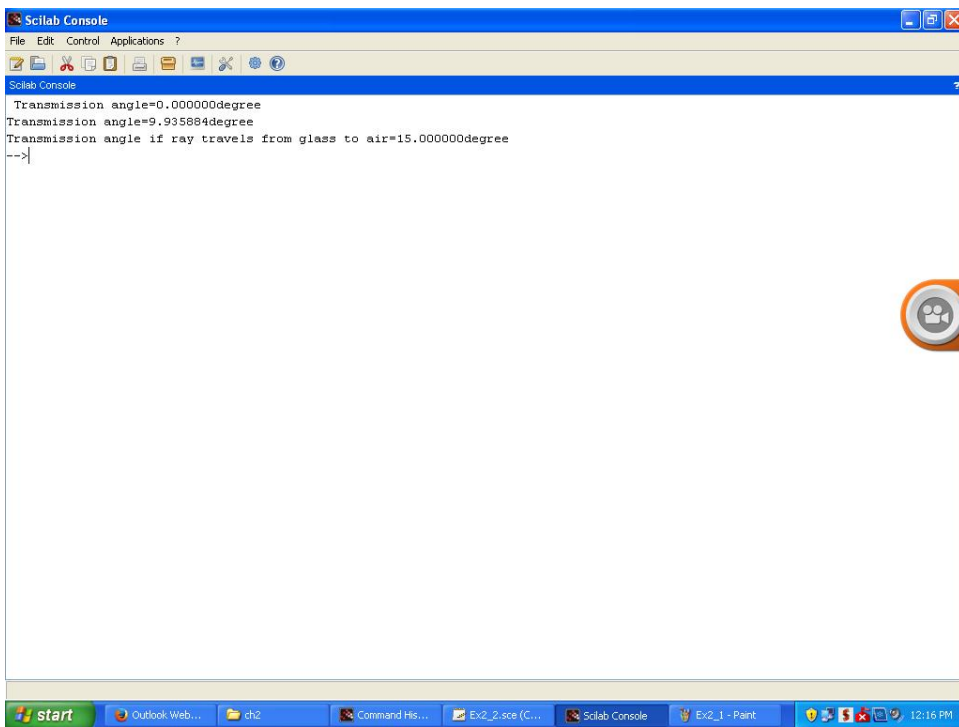


Figure 2.2: 2

```

7 //given
8 n1=-1//refractive index of air
9 n2=1.5//refractive index of glass medium
10 theta_i_1=0//angle of incidence case 1 in degree
11 theta_i_2=15//angle of incidence case 2 in degree
12 //to find
13 theta_t_1=abs(asind(n1/n2*sind(theta_i_1)))//
    transmission angle in degree for case 1
14 mprintf("Transmission angle=%fdegree",theta_t_1)
15 theta_t_2=abs(asind(n1/n2*sind(theta_i_2)))
16 mprintf("\nTransmission angle=%fdegree",theta_t_2)//
    transmission angle in degree for case 2
17
18 theta_t_3=abs(asind(n2/n1*sind(theta_t_2)))// trans
    mission angle for example 2_1 if ray travels
    from glass to air in degrees
19 mprintf("\nTransmission angle if ray travels from
    glass to air=%fdegree",theta_t_3)

```

---

### Scilab code Exa 2.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 2.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 M=1//magnification
9 f=1e-3// focal length in m
10 do=2*f//since di=do object image distance in m
11 mprintf('object and image distance for unity
    magnification=%fm',do)
12 //to find
13 for j = 1:5

```

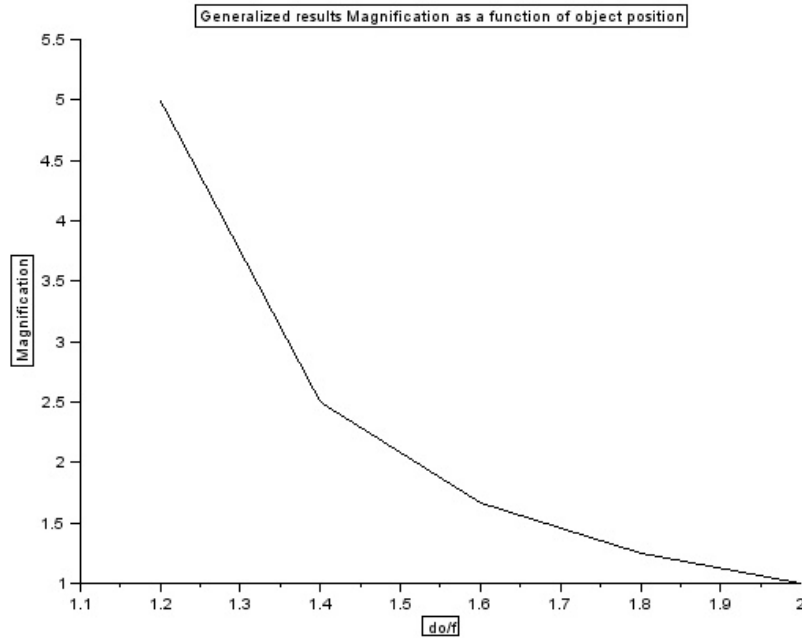


Figure 2.3: 3

```

14     dobyf(j)=1+j*0.2//object image distance to
        focal length in m
15     M(j)=1/(dobyf(j)-1)//magnification
16     end;
17     plot2d(dobyf,M)
18     xtitle( 'Generalized results Magnification as a
        function of object position', 'do/f', '
        Magnification', boxed = 1 );

```

---

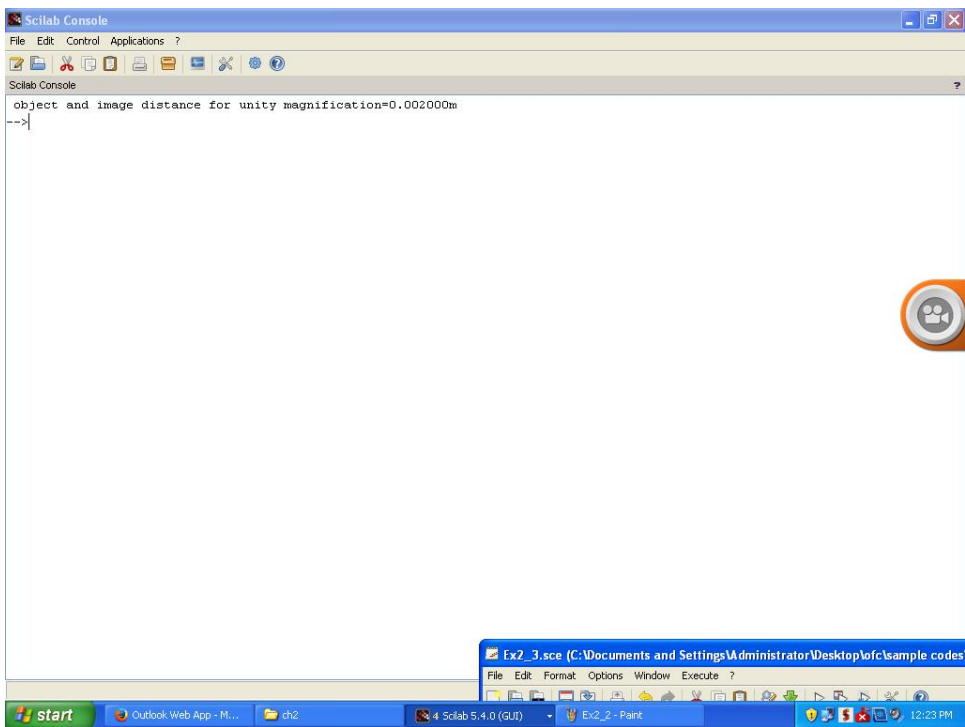


Figure 2.4: 3

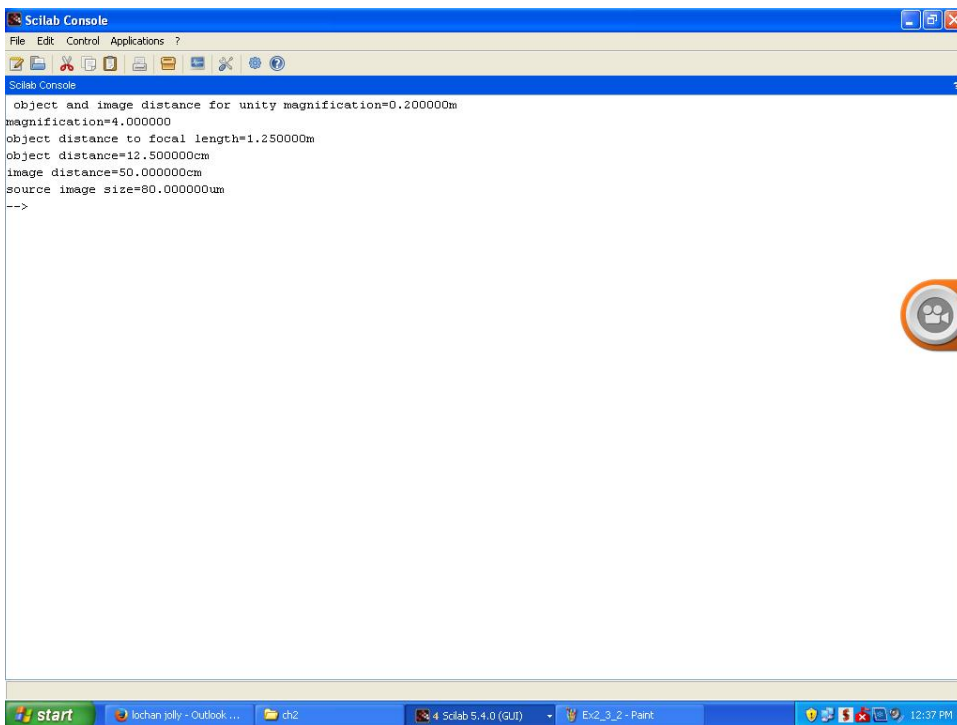


Figure 2.5: 4



#### Scilab code Exa 2.4 4

```
1 //fiber optic communications by joseph c. palais
2 //example 2.4
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 alpha0=40//source radiation cone angle (beam spread)
   in degree
9 alphai=10// new system source radiation cone angle (
   beam spread) in degree
10 f=10e-2//focal length in m
11 do=2*f//since di=do object image distance in m
12 SS=20e-6//source size in m
13 mprintf('object and image distance for unity
   magnification=%fm\n',do)
14 //to find
15 M=alpha0/alphai//magnification
16 dobyf=(1/M)+1//object distance to focal length
17 do=dobyf*f//object distance in m
18 di=M*do//image distance in m
19 SIS=M*SS//source image size in m
20 mprintf('magnification=%f\nobject distance to focal
   length=%fm\nobject distance=%fcm\nimage distance
   =%fcm\nsource image size=%fum',M,dobyf,do*100,di
   *100,SIS*10^6);//multiplication factors in
   results to convert it into required format
```

---

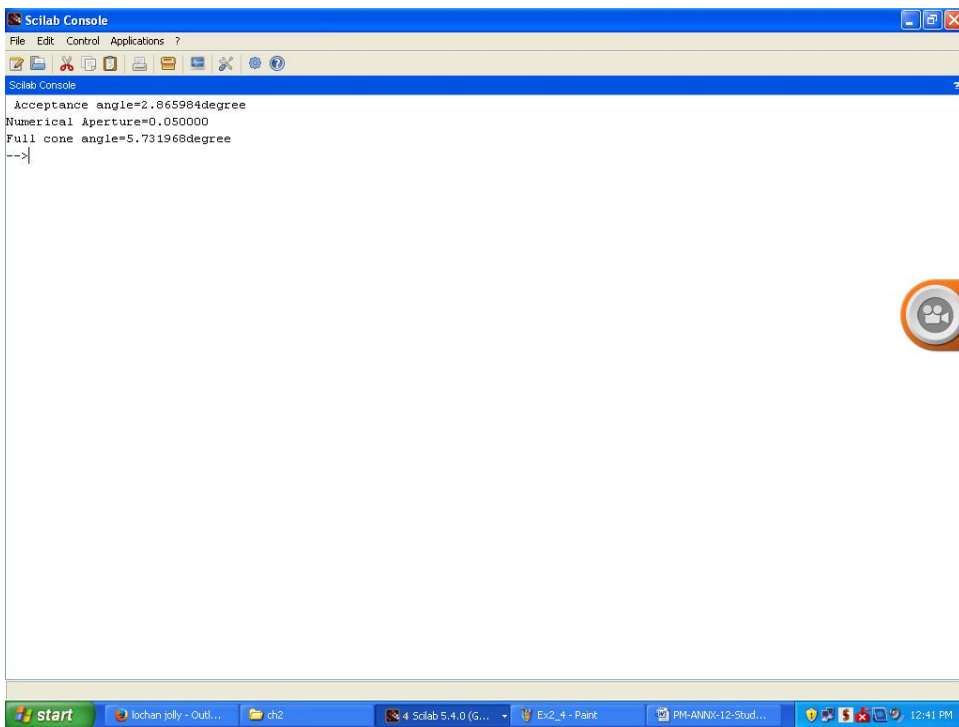


Figure 2.6: 5

### Scilab code Exa 2.5 5

```
1 //fiber optic communications by joseph c. palais
2 //example 2.5
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n1=1//refractive index of air
9 d=1e-2//diameter of circular photodetector in m
10 f=10e-2//lense focal length in m
11 //to find
12 theta=asind(d/(2*f))//acceptance angle in degrees
13 mprintf("Acceptance angle=%fdegree",theta)
14 NA=n1*(sind(theta))//numerical aperture
15 mprintf("\nNumerical Aperture=%f",NA)
16 FCA=2*theta//full cone angle
17 mprintf("\nFull cone angle=%fdegree",FCA)
```

---

### Scilab code Exa 2.6 6

```
1 //fiber optic communications by joseph c. palais
2 //example 2.6
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 spotsize=1e-3//spot size
7 lambda=0.82e-6//wave length
8 d1=10//distance in m
9 d2=1e3//distance in m
10 d3=10e3//distance in m
11 //to find
```

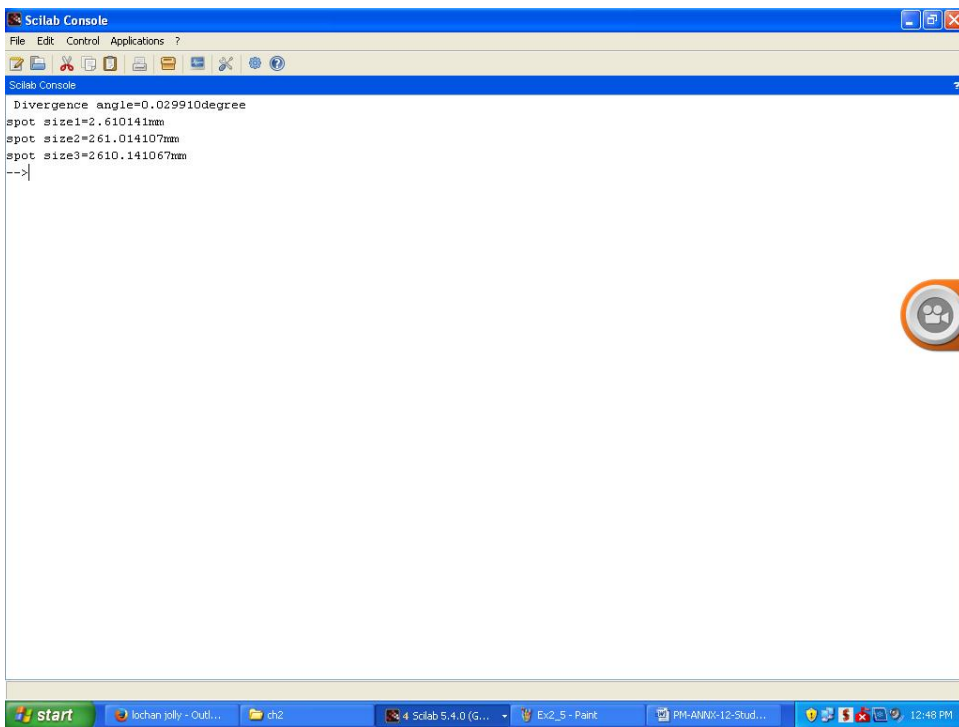


Figure 2.7: 6

```
12 div1=2*lambda/(%pi*spotsize)
13 wo1=lambda*d1/(%pi*spotsize)
14 wo2=lambda*d2/(%pi*spotsize)
15 wo3=lambda*d3/(%pi*spotsize)
16 disp("mm",wo1*1e3,"spot size1=", "mm",wo2*1e3,"spot
      size1=", "mm",wo3*1e3,"spot size1=")
```

---

# Chapter 3

## Lightwave fundamentals

Scilab code Exa 3.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 3.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 SW1=20//spectral width in nm
9 SW2=50//spectral width in nm
10 lambda1=0.82e-6//wave length in m
11 d=10//path length in km
12 lambda2=1.5e-6//wave length in m
13 M1=110//Material dispersion ps/(nmxKm)
14 M2=15//Material dispersion ps/(nmxKm)
15
16 //to find
17 delta_taubyL1=M1*SW1*d// pulse spreading per unit
    length in ps for lambda1
18 delta_taubyL2=M2*SW2*d// pulse spreading per unit
```

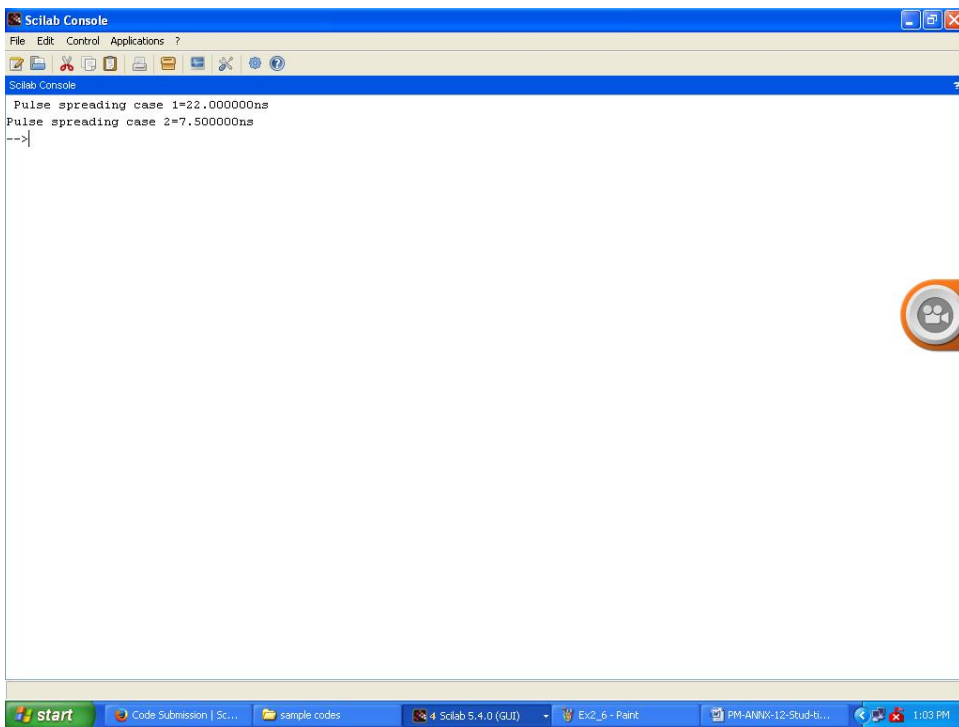


Figure 3.1: 1

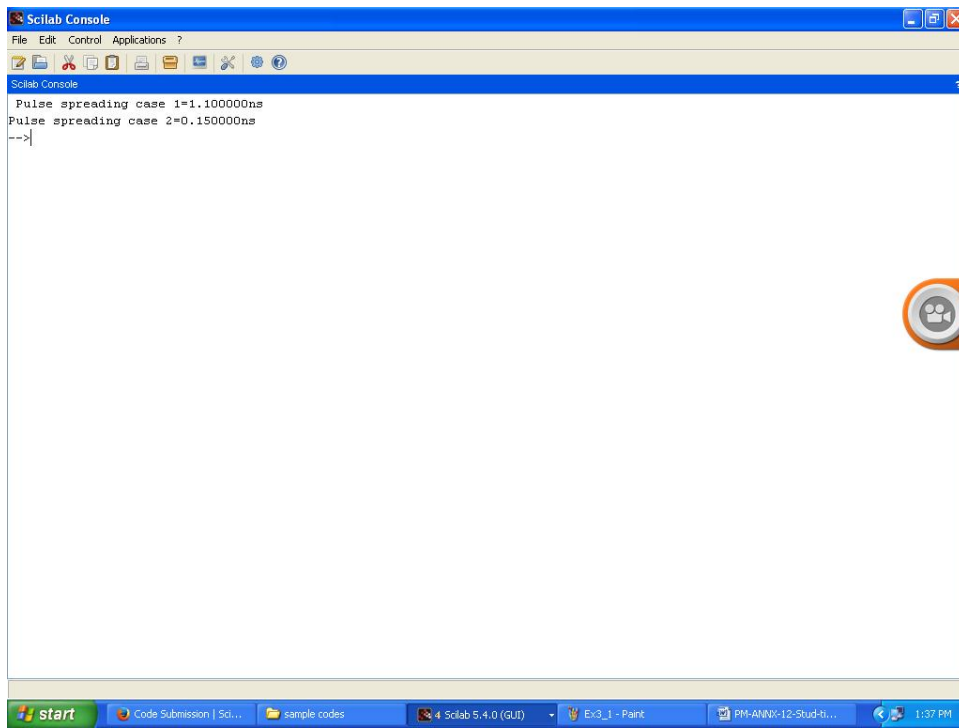


Figure 3.2: 2

```
length in ps for lambda2
19 //multiplication by 1e-3 converts unit from ps to ns
20 mprintf("Pulse spreading case 1=%fns",delta_taubyL1
    *1e-3)
21 mprintf("\nPulse spreading case 2=%fns",
    delta_taubyL2*1e-3)
```

---

### Scilab code Exa 3.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 3.2
```



```

3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 SW=1//spectral width of laser in nm
9 lambda1=0.82e-6//wave length in m
10 d=10//path length in km
11 lambda2=1.5e-6//wave length in m
12 M1=110//Material dispersion ps/(nmKm) for lambda1
13 M2=15//Material dispersion ps/(nmKm) for lambda2
14
15 //to find
16 delta_taubyL1=M1*SW*d// pulse spreading per unit
    length in ps for lambda1
17 delta_taubyL2=M2*SW*d// pulse spreading per unit
    length in ps for lambda2
18 //multiplication by 1e-3 converts unit from ps to ns
19 mprintf("Pulse spreading case 1=%fns",delta_taubyL1
    *1e-3)
20 mprintf("\\nPulse spreading case 2=%fns",
    delta_taubyL2*1e-3)

```

---

### Scilab code Exa 3.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 3.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda=1.55e-6*1e9//wave length in nm

```

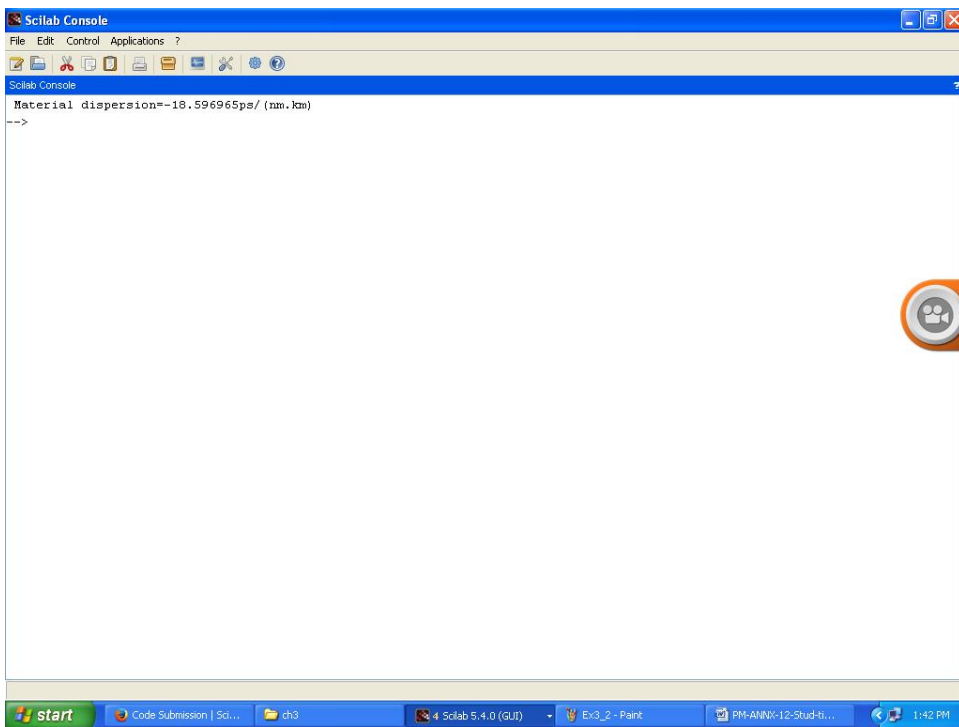


Figure 3.3: 3

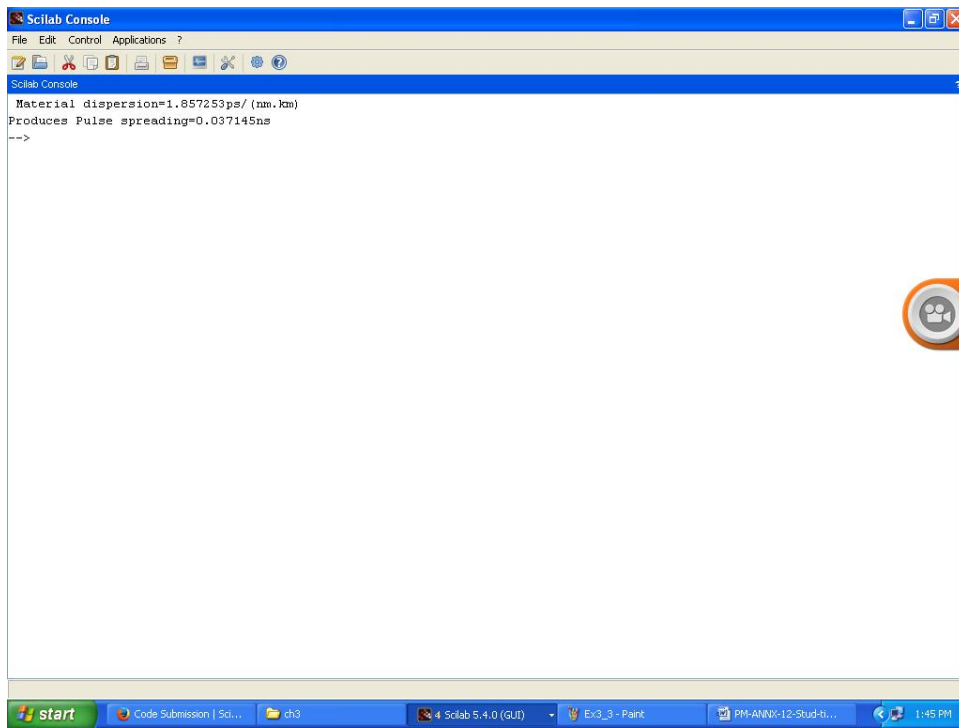


Figure 3.4: 4

```

9 lambda0=1.3e-6*1e9//Zero dispersion wave length in
  mm
10 M0=-0.095//slope at zero dispersion wave length ps/(
  mm^2xKm)
11
12 //to find
13 M=(M0/4)*(lambda-(lambda0)^4/(lambda)^3)//Material
  dispersion ps/(nmxKm)
14
15 mprintf("Material dispersion=%fps/(nm.km)",M)

```

---

### Scilab code Exa 3.4 4

```
1 //fiber optic communications by joseph c. palais
2 //example 3.4
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda=1.32e-6*1e9//wave length in nm
9 lambda0=1.3e-6*1e9//Zero dispersion wave length in
  nm
10 M0=-0.095//slope at zero dispersion wave length ps/(
  nm^2xKm)
11 sw=2//spectral width in nm
12 d=10// length of material in Km
13 //to find
14 M1=abs((M0/4)*(lambda-(lambda0)^4/(lambda)^3))//
  Material dispersion ps/(nmxKm)
15 delta_taubyL=M1*sw*d// pulse spreading per unit
  length in ps
16 mprintf(" Material dispersion=%fps/(nm.km)",M1)
17 mprintf(" \nProduces Pulse spreading=%fns",
  delta_taubyL*1e-3)//multiplication by 1e-3
  converts unit from ps to ns
```

---

### Scilab code Exa 3.5 5

```
1 //fiber optic communications by joseph c. palais
2 //example 3.5
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
```

```
Scilab Console
File Edit Control Applications ?
Scilab Console
for LED at 0.82um
  Optic frequency length product =0.227273 GHz. Km
  Rate length product FOR Not RETURN TO ZERO =0.318182 Gbps. Km
  Electrical 3dB frequency length product =0.159091 GHz. Km
  Rate length product FOR RETURN TO ZERO =0.159091 Gbps.Km

for LED at 1.5um
  Optic frequency length product =0.666667 GHz. Km
  Rate length product FOR Not RETURN TO ZERO =0.933333 Gbps. Km
  Electrical 3dB frequency length product =0.466667 GHz. Km
  Rate length product FOR RETURN TO ZERO =0.466667 Gbps.Km

for LD at 0.82um
  Optic frequency length product =4.545455 GHz. Km
  Rate length product FOR Not RETURN TO ZERO =6.363636 Gbps. Km
  Electrical 3dB frequency length product =3.181818 GHz. Km
  Rate length product FOR RETURN TO ZERO =3.181818 Gbps.Km

for LD at 1.5um
  Optic frequency length product =33.333333 GHz. Km
  Rate length product FOR Not RETURN TO ZERO =46.666667 Gbps. Km
  Electrical 3dB frequency length product =23.333333 GHz. Km
  Rate length product FOR RETURN TO ZERO =23.333333 Gbps.Km
-->
```

Figure 3.5: 5

```

6 clear all
7 //given
8 lambda1=0.82e-6//wave length
9 lambda2=1.5e-6//wave length
10
11 deta_tau_by_L1=2.2*10^-9//delta tau by L for LED at
    0.82um in ns/Km
12 deta_tau_by_L2=0.75*10^-9//delta tau by L for LED at
    1.5um in ns/Km
13 deta_tau_by_L3=0.11*10^-9//delta tau by L for LD at
    0.82um in ns/Km
14 deta_tau_by_L4=0.015*10^-9//delta tau by L for LD at
    1.5um in ns/Km
15 //to find
16 f3dB1=1/(2*deta_tau_by_L1)//frequency length in Hzx
    Km for LED at 0.82um
17 f3dB2=1/(2*deta_tau_by_L2)//frequency length in Hzx
    Km for LED at 1.5um
18 f3dB3=1/(2*deta_tau_by_L3)//frequency length in Hzx
    Km for LD at 0.82um
19 f3dB4=1/(2*deta_tau_by_L4)//frequency length in Hzx
    Km for LD at 1.5um
20
21 f3dBE1=0.35/(deta_tau_by_L1)//Electrical frequency
    length in Hzx Km for LED at 0.82um
22 f3dBE2=0.35/(deta_tau_by_L2)//Electrical frequency
    length in Hzx Km for LED at 1.5um
23 f3dBE3=0.35/(deta_tau_by_L3)//Electrical frequency
    length in Hzx Km for LD at 0.82um
24 f3dBE4=0.35/(deta_tau_by_L4)//Electrical frequency
    length in Hzx Km for LD at 1.5um
25
26 RRZ1=0.35/(deta_tau_by_L1)//Rate length FOR RETURN
    TO ZERO in bpsx Km for LED at 0.82um
27 RRZ2=0.35/(deta_tau_by_L2)//Rate length FOR RETURN
    TO ZERO in bpsx Km for LED at 1.5um
28 RRZ3=0.35/(deta_tau_by_L3)//Rate length FOR RETURN
    TO ZERO in bpsx Km for LD at 0.82um

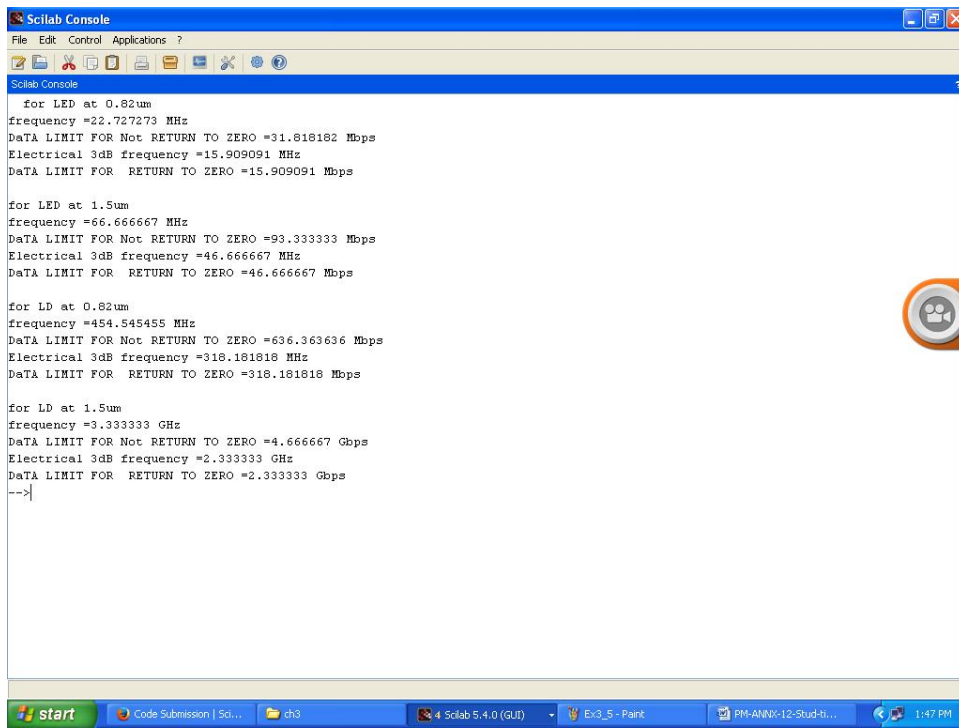
```

```

29 RRZ4=0.35/(deta_tau_by_L4)//Rate length FOR RETURN
    TO ZERO in bpsx Km for LD at 1.5um
30
31 NRZ1=0.7/(deta_tau_by_L1)//Rate length FOR RETURN
    Not TO ZERO in bpsx Km for LED at 0.82um
32 NRZ2=0.7/(deta_tau_by_L2)//Rate length FOR RETURN
    Not TO ZERO in bpsx Km for LED at 1.5um
33 NRZ3=0.7/(deta_tau_by_L3)//Rate length FOR RETURN
    Not TO ZERO in bpsx Km for LD at 0.82um
34 NRZ4=0.7/(deta_tau_by_L4)//Rate length FOR RETURN
    Not TO ZERO in bpsx Km for LD at 1.
35
36
37 mprintf(" for LED at 0.82um \n Optic frequency
    length product =%f GHz. Km \nRate length product
    FOR Not RETURN TO ZERO =%f Gbps. Km \nElectrical
    3dB frequency length product =%f GHz. Km\nRate
    length product FOR RETURN TO ZERO =%f Gbps.Km ",
    f3dB1/10^9, NRZ1/10^9, f3dBE1/10^9, RRZ1/10^9);
38 mprintf(" \n\nfor LED at 1.5um \n Optic frequency
    length product =%f GHz. Km \nRate length product
    FOR Not RETURN TO ZERO =%f Gbps. Km \nElectrical
    3dB frequency length product =%f GHz. Km\nRate
    length product FOR RETURN TO ZERO =%f Gbps.Km ",
    f3dB2/10^9, NRZ2/10^9, f3dBE2/10^9, RRZ2/10^9);
39 mprintf(" \n\nfor LD at 0.82um \n Optic frequency
    length product =%f GHz. Km \nRate length product
    FOR Not RETURN TO ZERO =%f Gbps. Km \nElectrical
    3dB frequency length product =%f GHz. Km\nRate
    length product FOR RETURN TO ZERO =%f Gbps.Km ",
    f3dB3/10^9, NRZ3/10^9, f3dBE3/10^9, RRZ3/10^9);
40 mprintf(" \n\nfor LD at 1.5um \n Optic frequency
    length product =%f GHz. Km \nRate length product
    FOR Not RETURN TO ZERO =%f Gbps. Km \nElectrical
    3dB frequency length product =%f GHz. Km\nRate
    length product FOR RETURN TO ZERO =%f Gbps.Km ",
    f3dB4/10^9, NRZ4/10^9, f3dBE4/10^9, RRZ4/10^9);

```

---



```
Scilab Console
File Edit Control Applications ?
Scilab Console
for LED at 0.82um
frequency =22.727273 MHz
DaTA LIMIT FOR Not RETURN TO ZERO =31.818182 Mbps
Electrical 3dB frequency =15.909091 MHz
DaTA LIMIT FOR RETURN TO ZERO =15.909091 Mbps

for LED at 1.5um
frequency =66.666667 MHz
DaTA LIMIT FOR Not RETURN TO ZERO =93.333333 Mbps
Electrical 3dB frequency =46.666667 MHz
DaTA LIMIT FOR RETURN TO ZERO =46.666667 Mbps

for LD at 0.82um
frequency =454.545455 MHz
DaTA LIMIT FOR Not RETURN TO ZERO =636.363636 Mbps
Electrical 3dB frequency =318.181818 MHz
DaTA LIMIT FOR RETURN TO ZERO =318.181818 Mbps

for LD at 1.5um
frequency =3.333333 GHz
DaTA LIMIT FOR Not RETURN TO ZERO =4.666667 Gbps
Electrical 3dB frequency =2.333333 GHz
DaTA LIMIT FOR RETURN TO ZERO =2.333333 Gbps
-->
```

Figure 3.6: 6

### Scilab code Exa 3.6 6

```
1 //fiber optic communications by joseph c. palais
2 //example 3.6
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda1=0.82e-6//wave length
```



```

9  lambda2=1.5e-6//wave length
10 L=10//link length in Km
11 deta_tau_by_L1=2.2*10^-9//delta tau by L for LED at
    0.82um in ns/Km
12 deta_tau_by_L2=0.75*10^-9//delta tau by L for LED at
    1.5um in ns/Km
13 deta_tau_by_L3=0.11*10^-9//delta tau by L for LD at
    0.82um in ns/Km
14 deta_tau_by_L4=0.015*10^-9//delta tau by L for LD at
    1.5um in ns/Km
15 //to find
16 f3dB1=1/(2*L*deta_tau_by_L1)//frequency in Hz for
    LED at 0.82um
17 f3dB2=1/(2*L*deta_tau_by_L2)//frequency in Hz for
    LED at 1.5um
18 f3dB3=1/(2*L*deta_tau_by_L3)//frequency in Hz for
    LD at 0.82um
19 f3dB4=1/(2*L*deta_tau_by_L4)//frequency in Hz for
    LD at 1.5um
20
21 f3dBE1=0.35/(L*deta_tau_by_L1)//Electrical frequency
    in Hz for LED at 0.82um
22 f3dBE2=0.35/(L*deta_tau_by_L2)//Electrical frequency
    in Hz for LED at 1.5um
23 f3dBE3=0.35/(L*deta_tau_by_L3)//Electrical frequency
    in Hz for LD at 0.82um
24 f3dBE4=0.35/(L*deta_tau_by_L4)//Electrical frequency
    in Hz for LD at 1.5um
25
26 RRZ1=0.35/(L*deta_tau_by_L1)//DaTA LIMIT FOR RETURN
    TO ZERO in bps for LED at 0.82um
27 RRZ2=0.35/(L*deta_tau_by_L2)//DaTA LIMIT FOR RETURN
    TO ZERO in bps for LED at 1.5um
28 RRZ3=0.35/(L*deta_tau_by_L3)//DaTA LIMIT FOR RETURN
    TO ZERO in bps for LD at 0.82um
29 RRZ4=0.35/(L*deta_tau_by_L4)//DaTA LIMIT FOR RETURN
    TO ZERO in bps for LD at 1.5um
30

```

```

31 NRZ1=0.7/(L*deta_tau_by_L1)//DaTA LIMIT FOR Not
    RETURN TO ZERO in bps for LED at 0.82um
32 NRZ2=0.7/(L*deta_tau_by_L2)//DaTA LIMIT FOR Not
    RETURN TO ZERO in bps for LED at 1.5um
33 NRZ3=0.7/(L*deta_tau_by_L3)//DaTA LIMIT FOR Not
    RETURN TO ZERO in bps for LD at 0.82um
34 NRZ4=0.7/(L*deta_tau_by_L4)//DaTA LIMIT FOR Not
    RETURN TO ZERO in bps for LD at 1.
35
36
37 mprintf(" for LED at 0.82um \nfrequency =%f MHz \
    nDaTA LIMIT FOR Not RETURN TO ZERO =%f Mbps \
    nElectrical 3dB frequency =%f MHz\nDaTA LIMIT FOR
    RETURN TO ZERO =%f Mbps ",f3dB1/10^6,NRZ1/10^6,
    f3dBE1/10^6,RRZ1/10^6);
38 mprintf(" \n\nfor LED at 1.5um \nfrequency =%f MHz \
    nDaTA LIMIT FOR Not RETURN TO ZERO =%f Mbps \
    nElectrical 3dB frequency =%f MHz\nDaTA LIMIT FOR
    RETURN TO ZERO =%f Mbps ",f3dB2/10^6,NRZ2/10^6,
    f3dBE2/10^6,RRZ2/10^6);
39 mprintf(" \n\nfor LD at 0.82um \nfrequency =%f MHz \
    nDaTA LIMIT FOR Not RETURN TO ZERO =%f Mbps \
    nElectrical 3dB frequency =%f MHz\nDaTA LIMIT FOR
    RETURN TO ZERO =%f Mbps ",f3dB3/10^6,NRZ3/10^6,
    f3dBE3/10^6,RRZ3/10^6)
40 mprintf(" \n\nfor LD at 1.5um \nfrequency =%f GHz \
    nDaTA LIMIT FOR Not RETURN TO ZERO =%f Gbps \
    nElectrical 3dB frequency =%f GHz\nDaTA LIMIT FOR
    RETURN TO ZERO =%f Gbps ",f3dB4/10^9,NRZ4/10^9,
    f3dBE4/10^9,RRZ4/10^9)

```

---

Scilab code Exa 3.7 7

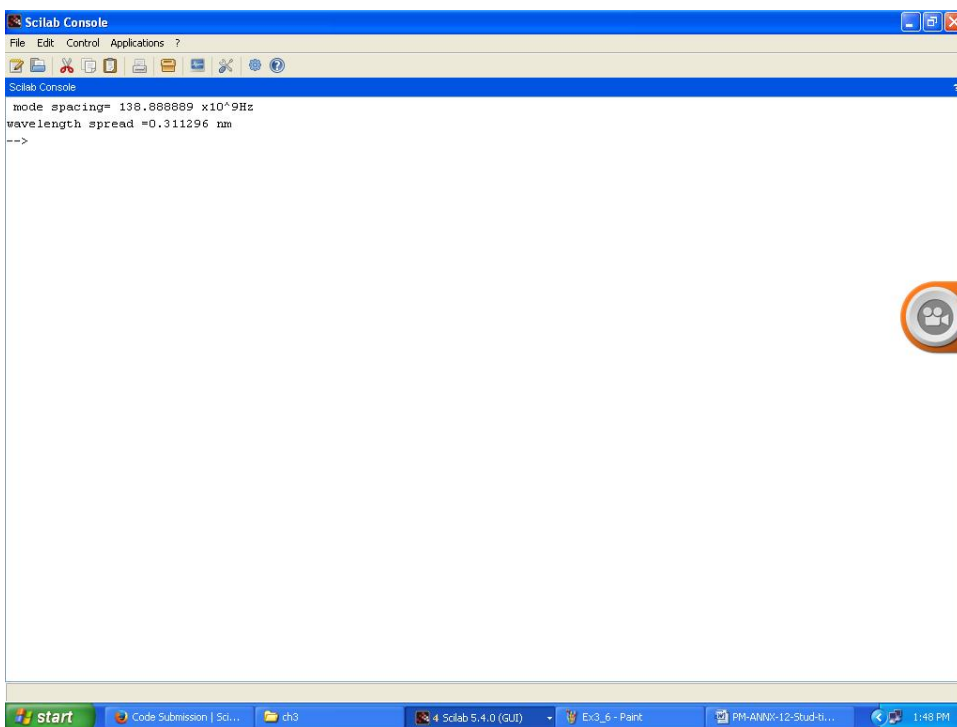


Figure 3.7: 7

```

1 //fiber optic communications by joseph c. palais
2 //example 3.7
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 c=3*10^8//velocity of light in m/s
9 l=0.3*10^-3//length of cavity in m
10 lambda=0.82*10^-6//mean (center) wave length in m
11 n=3.6//refractive index of AlGaAs
12
13 //to find
14 delta_fc=c/(2*l*n)//mode spacing in Hz
15 delta_lambdac=(lambda^2)*delta_fc/c//wavelength
    spread in m
16
17 mprintf("mode spacing= %f x10^9Hz",delta_fc*10^-9)//
    for representation
18 mprintf("\nwavelength spread =%f nm",delta_lambdac
    *10^9)//multiplication factor 10^9 to convert m
    to nm

```

---

### Scilab code Exa 3.8 8

```

1 //fiber optic communications by joseph c. palais
2 //example 3.8
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n=1.5//refractive index of the glass

```

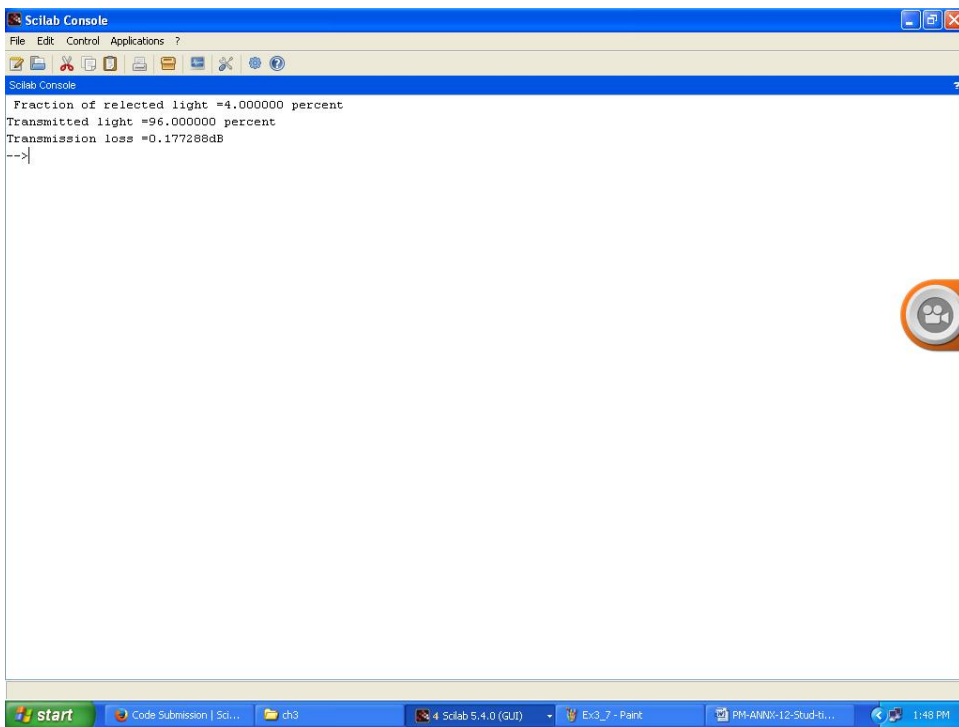


Figure 3.8: 8

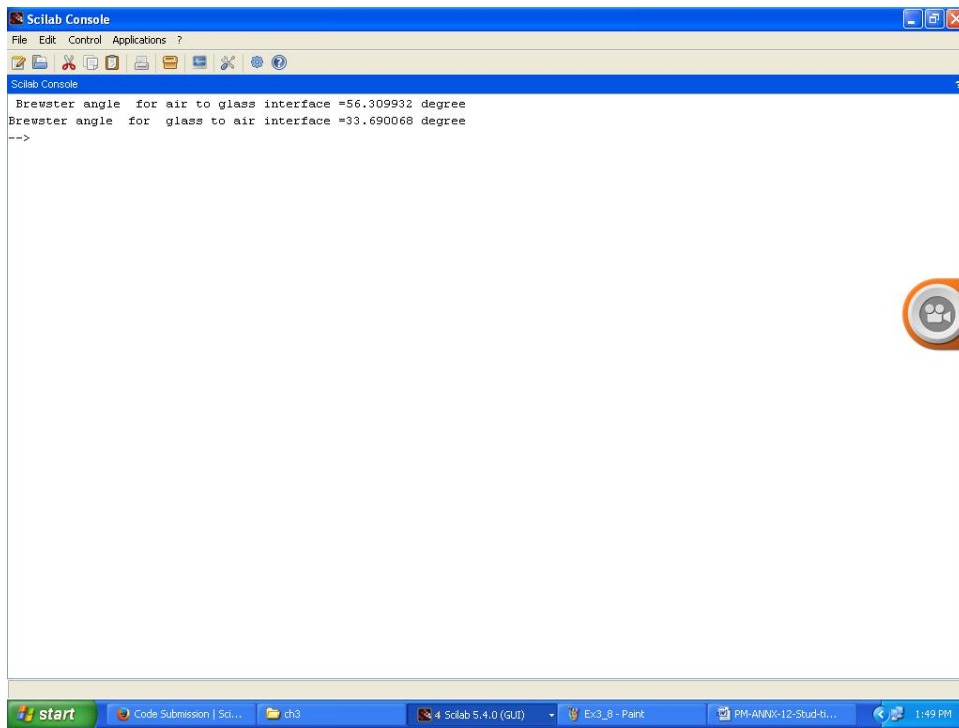


Figure 3.9: 9

```
9
10 //to find
11 R=((1-n)/(1+n))^2*100 //Fraction of relected light in
    percent
12 T=100-R //Transmitted light in percent
13 TL=-10*log10(T/100) //Transmission loss in dB
14 mprintf("Fraction of relected light =%f percent",R)
15 mprintf("\nTransmitted light =%f percent",T)
16 mprintf("\nTransmission loss =%fdB",TL)
```

---

Scilab code Exa 3.9 9

```

1 //fiber optic communications by joseph c. palais
2 //example 3.9
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n2=1.5//refractive index of the glass
9 n1=1//refractive index of the air
10
11 //to find
12 theta_B1=atand(n2/n1)//brewster angle in degree for
    air to glass interface
13 theta_B2=atand(n1/n2)//brewster angle in degree for
    glass to air interface
14 mprintf("Brewster angle for air to glass interface
    =%f degree",theta_B1)
15 mprintf("\\nBrewster angle for glass to air
    interface =%f degree",theta_B2)

```

---

### Scilab code Exa 3.10 10

```

1 //fiber optic communications by joseph c. palais
2 //example 3.10
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n3=1.5//refractive index of the glass
9 n1=1//refractive index of the air
10 lambda=0.8e-6//wave length in m
11 n4=1.38//refractive index of magnesium fluoride

```

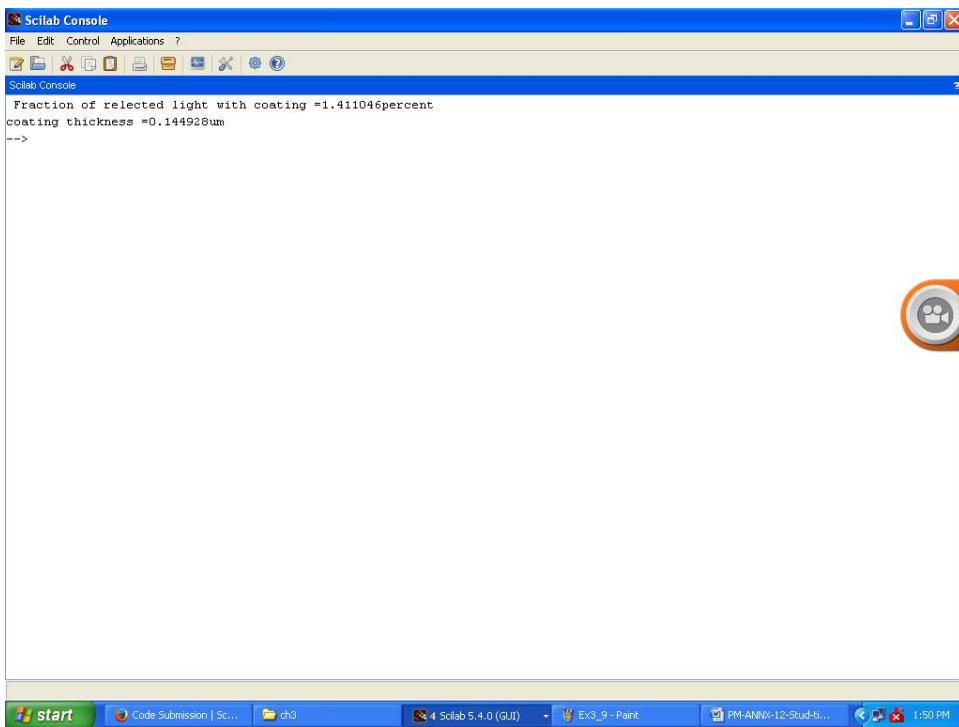


Figure 3.10: 10



```
12 //to find
13 n2=n3^0.5// index of coating layer for zero
    reflection
14 R=(n3-n4^2)^2/(n3+n4^2)^2*100//Fraction of relected
    light in percent
15 lambda_mf=lambda/n4//wavelength in magnesium
    flouride
16 t=lambda_mf/4//coating thickness in m
17 mprintf("Fraction of relected light with coating =
    %fpercent",R)
18 mprintf("\\ncoating thickness =%fum",t*10^6)//
    multiplication factor 10^6 to convert unit from m
    to um
```

---

# Chapter 4

## Integrated Optic waveguides

Scilab code Exa 4.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 4.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 d=1.64//Diameter of waveguide in um
9 lambda=0.82//wavelength in um
10
11 //to find
12 dbylambda=d/lambda//d by lambda ratio normalized
   thickness
13 neff1=3.594//for TE0 mode from figure 4.5 for
   calculated normalized thickness
14 theta1=86.7//for TE0 mode from figure 4.5 for
   calculated normalized thickness
15 neff2=3.578//for TE1 mode from figure 4.5 for
   calculated normalized thickness
```

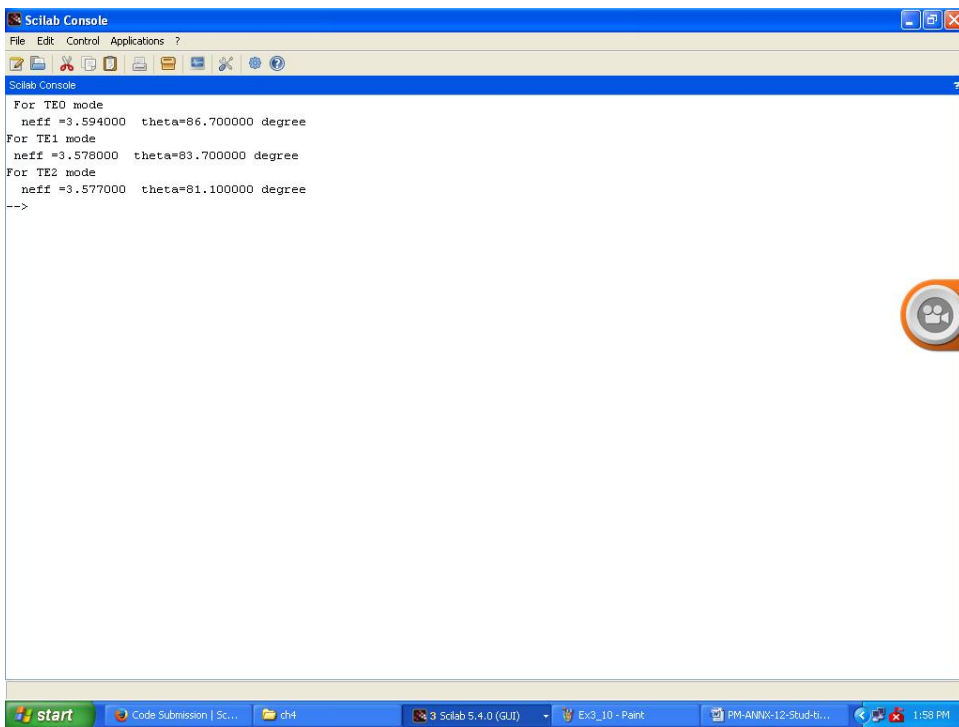


Figure 4.1: 1

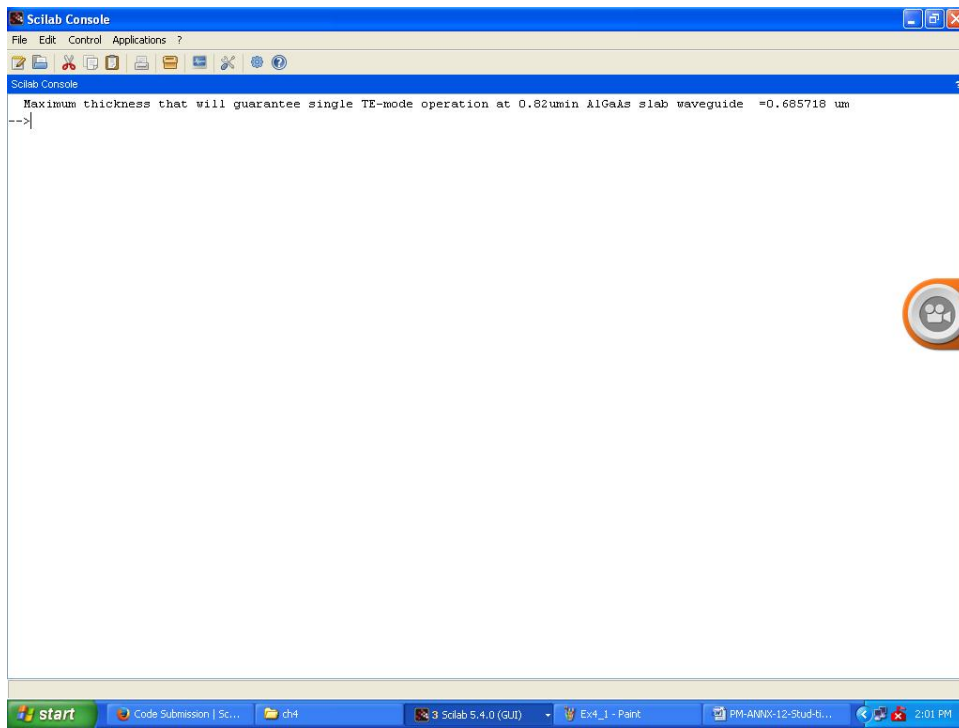


Figure 4.2: 2

```
16 theta2=83.7//for TE1 mode from figure 4.5 for
   calculated normalized thickness
17 neff3=3.577//for TE2 mode from figure 4.5 for
   calculated normalized thickness
18 theta3=81.1//for TE2 mode from figure 4.5 for
   calculated normalized thickness
19 mprintf('For TE0 mode \n neff =%f theta=%f degree '
   ,neff1,theta1)
20 mprintf(' \nFor TE1 mode \n neff =%f theta=%f
   degree ',neff2,theta2)
21 mprintf(' \nFor TE2 mode \n neff =%f theta=%f
   degree ',neff3,theta3)
```

---

### Scilab code Exa 4.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 4.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda=0.82//wavelength in um
9 n1=3.6//refractive index of core AlGaAs slab
10 n2=3.55//refractive index of cladding
11 //to find
12 d=lambda/(2*sqrt(n1^2-n2^2))//Largest thickness in
    um
13
14 mprintf(' Maximum thickness that will guarantee
    single TE-mode operation at 0.82um in AlGaAs slab
    waveguide   =%f um',d)
```

---

### Scilab code Exa 4.3 3

```
1 //fiber optic communications by joseph c. palais
2 //example 4.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda=0.82//wavelength in um
```

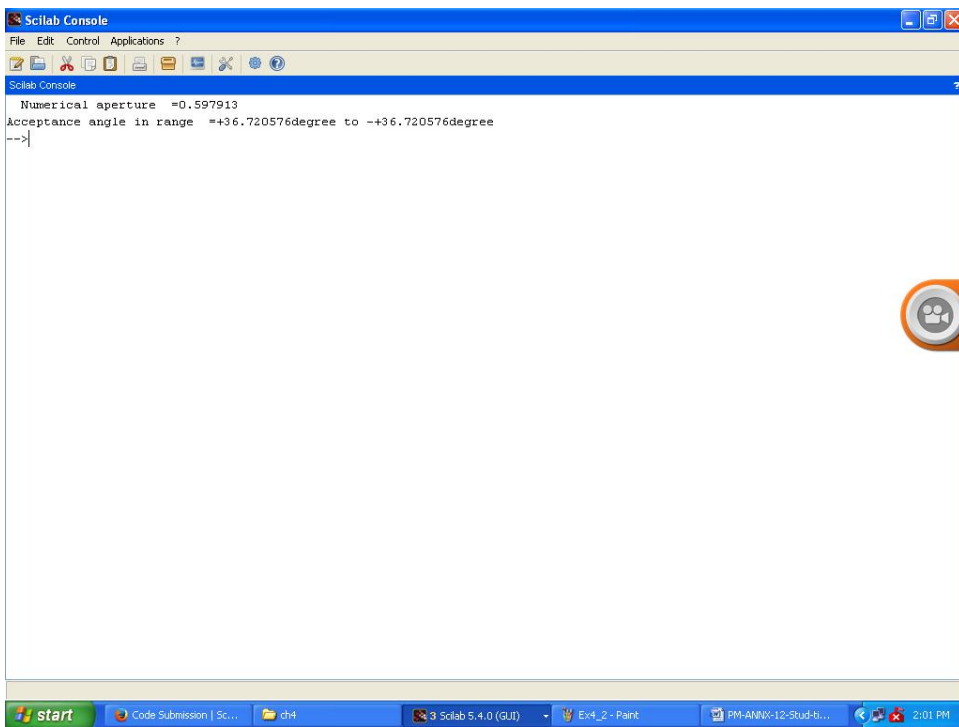


Figure 4.3: 3

```
9 n1=3.6//refractive index of core AlGaAs slab
10 n2=3.55//refractive index of cladding
11 n3=3.55//refractive index of cladding
12 n0=1//refractive index of Air
13
14
15 //to find
16 NA=sqrt(n1^2-n2^2)//Numerical aperture
17 alpha0=asind(NA/n0)//Acceptance angle in degree
18
19 mprintf(' Numerical aperture   =%f ',NA)
20 mprintf(' \nAcceptance angle in range   =+%fdegree to
    -+%fdegree ',alpha0,alpha0)
```

---

# Chapter 5

## Optic fiber waveguides

Scilab code Exa 5.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 5.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n1=1.46//core refractive index
9 n2=1//cladding refractive index (air)
10
11 //to find
12 Thetac=asind(n2/n1)//critical angle in degree
13
14 mprintf(' Critical angle =%i degree',Thetac)
```

---



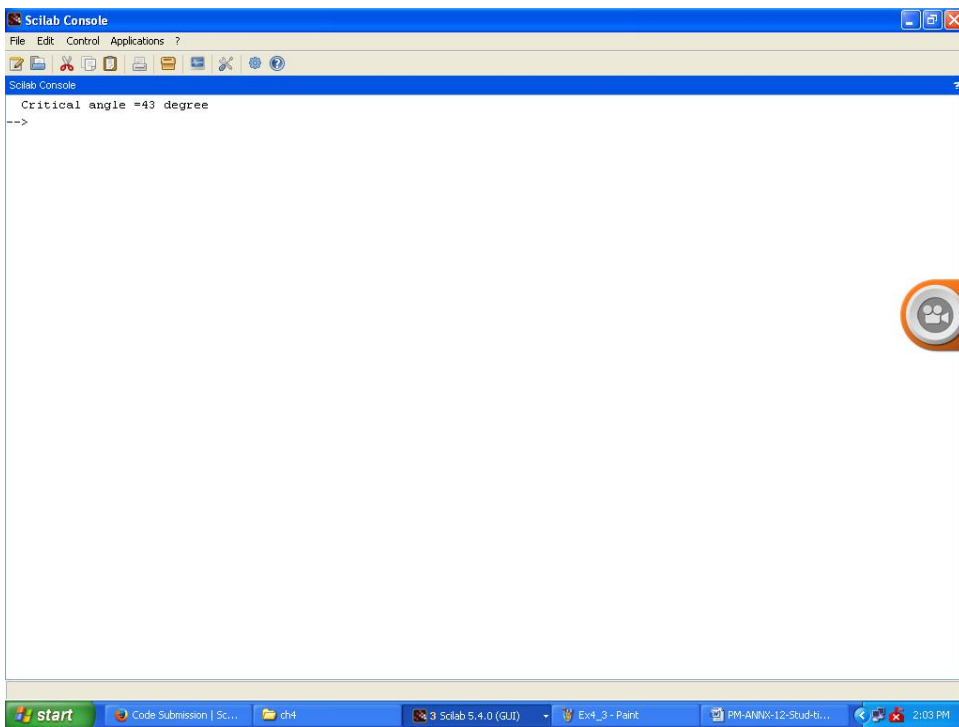


Figure 5.1: 1

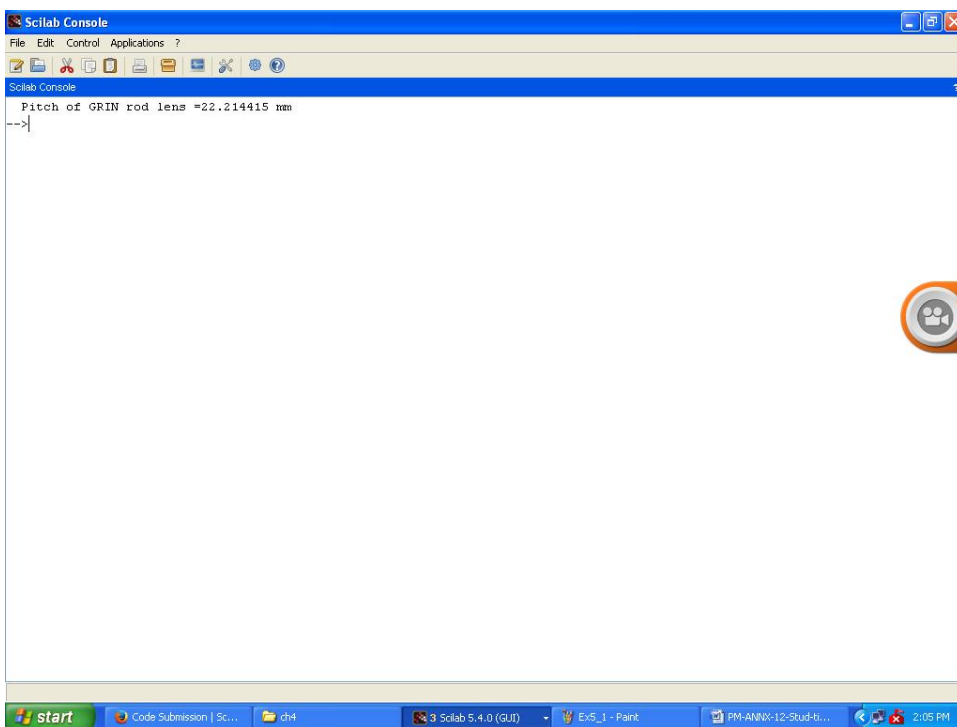


Figure 5.2: 2

### Scilab code Exa 5.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 5.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 d=1//Diameter in mm
9 delta=0.01//change in refractive index
10
11 //to find
12 a=d/2//radius in mm
13 P=a*pi*sqrt(2/delta)//Pitch of GRIN rod lens in mm
14
15 mprintf(' Pitch of GRIN rod lens =%f mm',P)
```

---

### Scilab code Exa 5.3 3

```
1 //fiber optic communications by joseph c. palais
2 //example 5.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 d=62.5*10^-3//Diameter in mm
9 delta=0.01//change in refractive index
10
11 //to find
12 a=d/2//radius in mm
13 P=a*pi*sqrt(2/delta)//Pitch of GRIN rod lens in mm
```

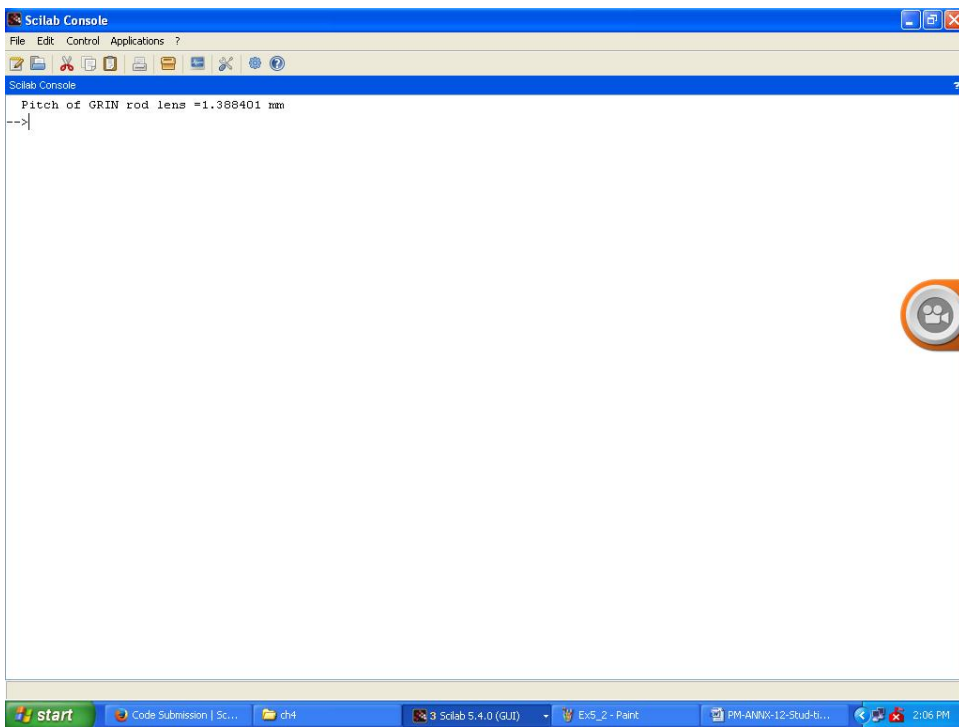


Figure 5.3: 3

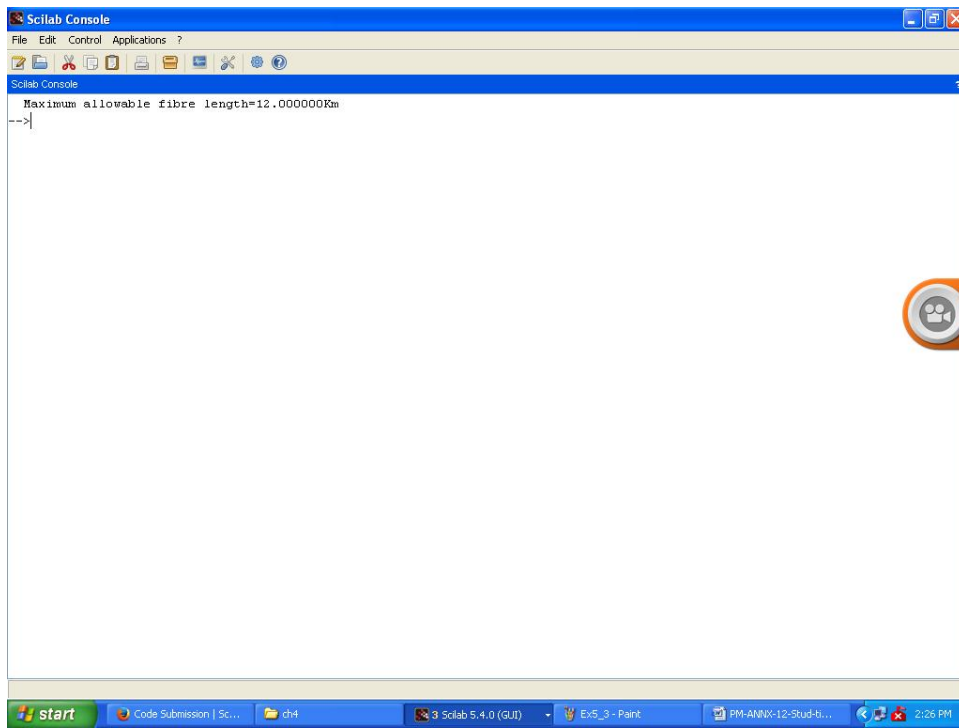


Figure 5.4: 4

```
14  
15 mprintf(' Pitch of GRIN rod lens =%f mm',P) //  
    converting P to mm
```

---

#### Scilab code Exa 5.4 4

```
1 //fiber optic communications by joseph c. palais  
2 //example 5.4  
3 //OS=Windows XP sp3  
4 //Scilab version 5.4.1  
5 clc
```

```

6 clear all
7 //given
8 led_output_power=2//led output power in dBm
9 fiber_loss=0.5//fiber loss /dB
10 receiver_sensitivity=30//receiver sensitivity in dBm
11 coupling_loss=16//coupling loss in dB
12 connector_and_splices=6//connector and splices loss
   in dB
13 power_margin=4//power margin in dB
14 //to find
15 loss_budget=led_output_power+receiver_sensitivity;//
   loss budget in dB
16 total_losses=coupling_loss+connector_and_splices+
   power_margin;//total losses in dB
17 available_fibre_loss=loss_budget-total_losses;//
   available fibre loss in dB
18 maximum_allowable_fibre =available_fibre_loss/
   fiber_loss;//maximum allowable fibre length in Km
19 mprintf(' Maximum allowable fibre length=%fKm',
   maximum_allowable_fibre)

```

---

### Scilab code Exa 5.5 5

```

1 //fiber optic communications by joseph c. palais
2 //example 5.5
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 d=50//core diameter in um
9 a=d/2//core radius in um
10 n1=1.48//core refractive index

```

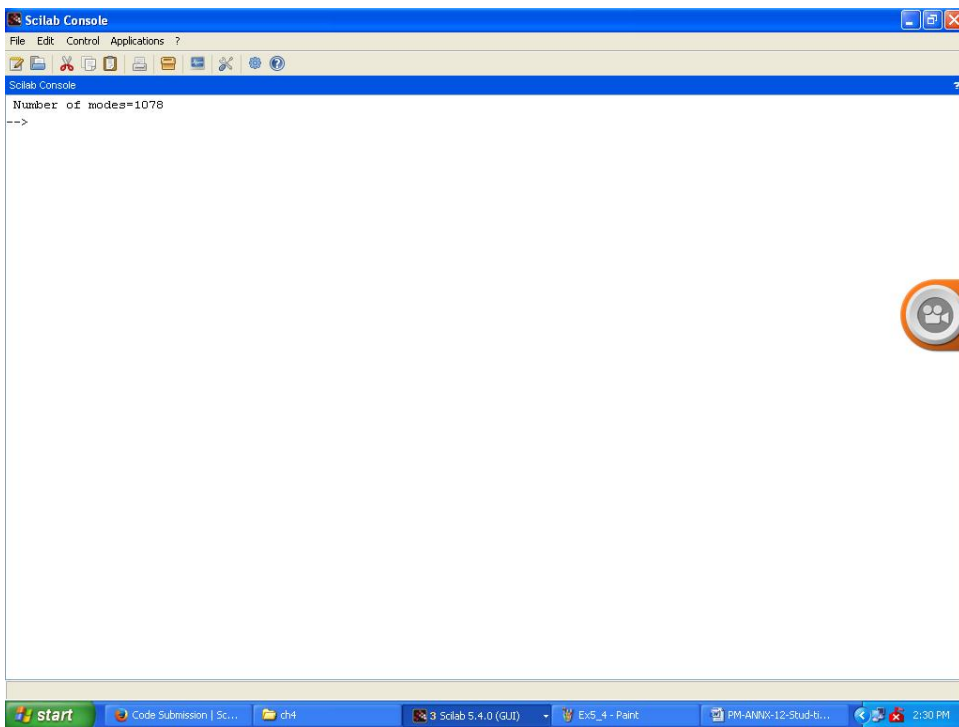


Figure 5.5: 5

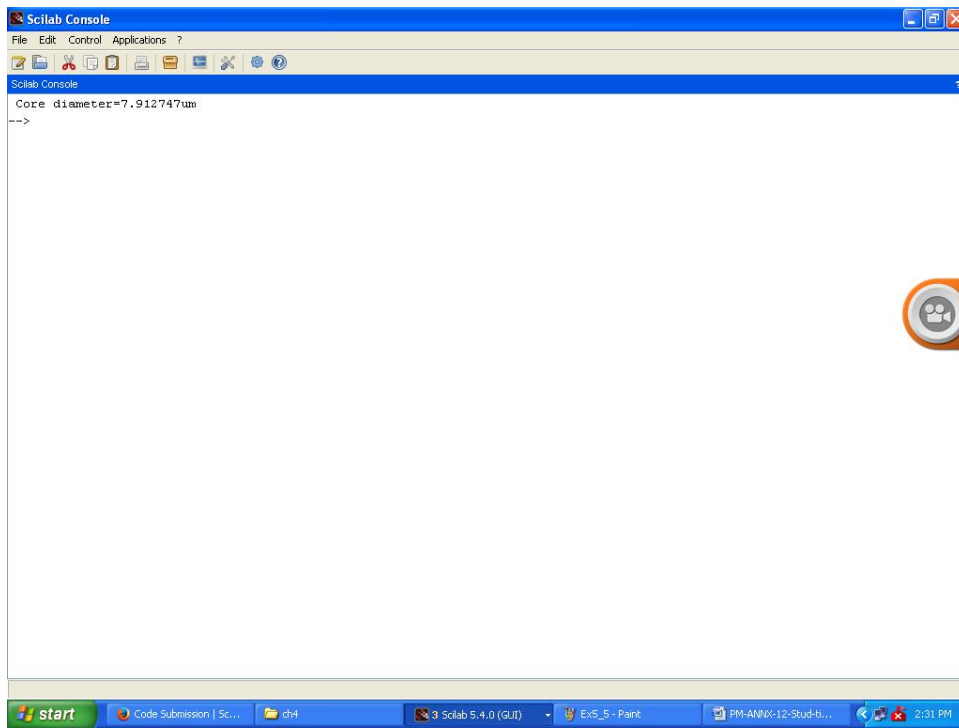


Figure 5.6: 6

```
11 n2=1.46//cladding refractive index
12 lambda=0.82//wavelength in um
13 //to find
14 V=((2*%pi*a*sqrt((n1^2)-(n2^2)))/lambda)// V number
15 n=(V^2/2)//number of modes
16 mprintf("Number of modes=%i",n)
```

---

### Scilab code Exa 5.6 6

```
1 //fiber optic communications by joseph c. palais
2 //example 5.6
```



```

3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 n1=1.465//core refractive index
9 n2=1.46//cladding refractive index
10 lambda=1250*10^-3//wavelength in um
11 //to find
12 a=((2.405*lambda)/(2*%pi*sqrt((n1^2)-(n2^2))))//
    radius of the core in um
13 d=a*2//core diameter in um
14 mprintf("Core diameter=%fum",d)

```

---

### Scilab code Exa 5.7 7

```

1 //fiber optic communications by joseph c. palais
2 //example 5.7
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 n1=1.47//core refractive index
9 n2=1.46//cladding refractive index
10 lambda=1.3//wavelength in um
11 //to find
12 delta=((n1-n2)/n1)//fractional refractive index
13 abylambda=(1.4/(%pi*sqrt(n1*(n1-n2))))//radius to
    wavelength ratio
14 a=lambda*abylambda//radius of core in m
15 d=a*2//core diameter in m
16 neff=n1-((sqrt(2*delta))/(2*%pi*abylambda))//value

```

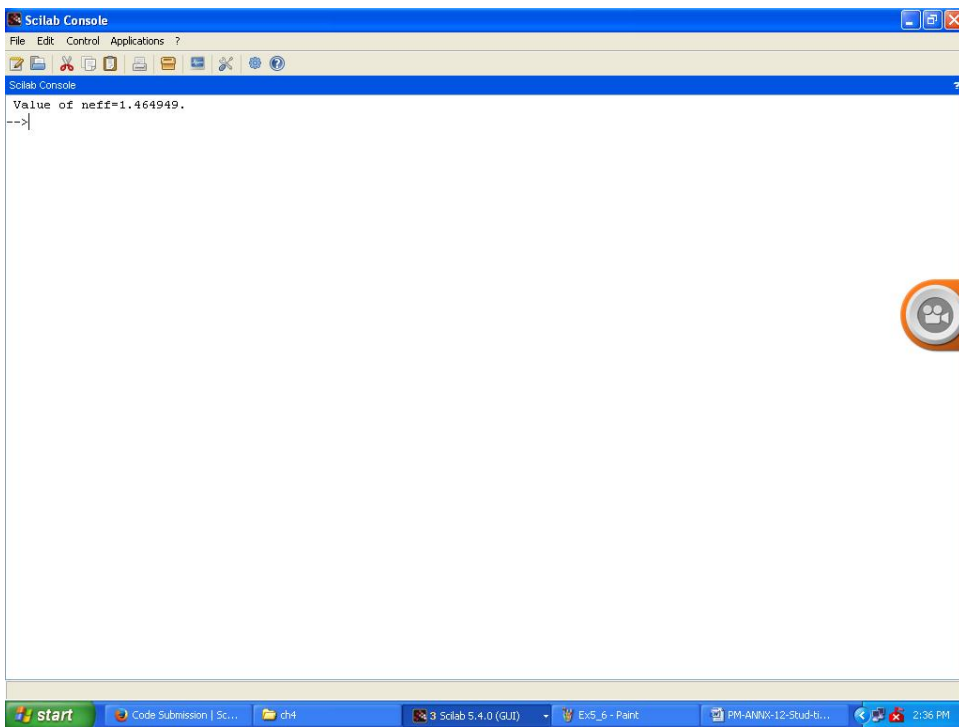


Figure 5.7: 7

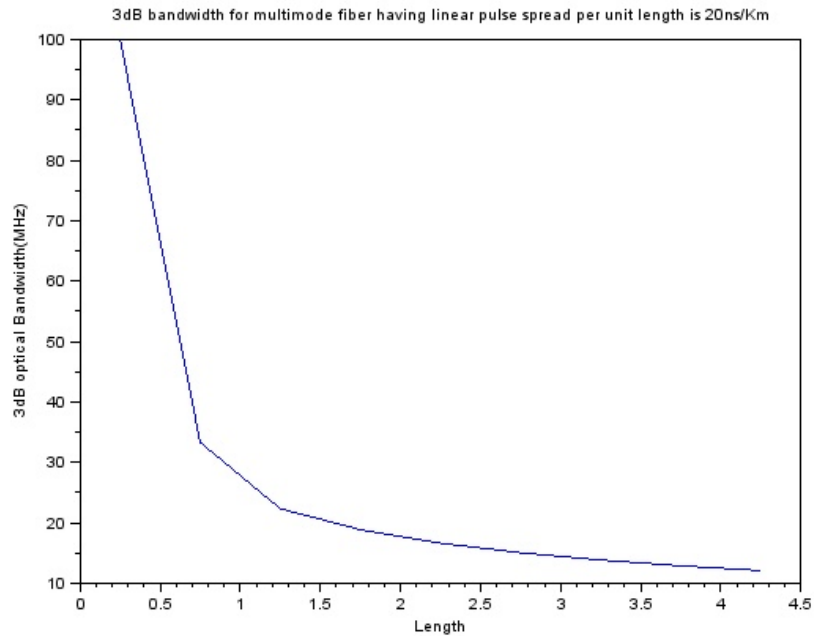


Figure 5.8: 8

```

of neff.
17 mprintf(" Value of neff=%f.",neff)

```

---

### Scilab code Exa 5.8 8

```

1 //fiber optic communications by joseph c. palais
2 //example 5.8
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;

```

```

7 //given
8 delta_tau_by_Lp=20; //linear pulse spread in ns/Km
9 Le=1; //equilibrium length in km
10 //to find
11 L=0.25:0.5:4.25 //Length in Km
12 for i=1:9
13     if L(i) > 1 then
14 f3db(i)=(25/(sqrt(L(i)))) //for lengths beyond 1km
15 else
16 f3db(i)=25/L(i); //maximum bandwidth(3db) for length
    less than 1 km
17 end
18 end
19 plot(L,f3db)
20 xtitle( "3dB bandwidth for multimode fiber having
    linear pulse spread per unit length is 20ns/Km",
    "Length", "3dB optical Bandwidth(MHz)" ) ;

```

---

# Chapter 6

## Light Sources

Scilab code Exa 6.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 6.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 w=25//spot size in um
9 lambda=0.633//wavelength in um
10 //to find
11 thetar=(2*lambda)/(%pi*w)//divergence angle in
    radians
12 thetad=thetar*180/(%pi)//divergence angle in degrees
13 mprintf("divergence angle is=%fradians or =%fdegrees
    ",thetar,thetad)
```

---

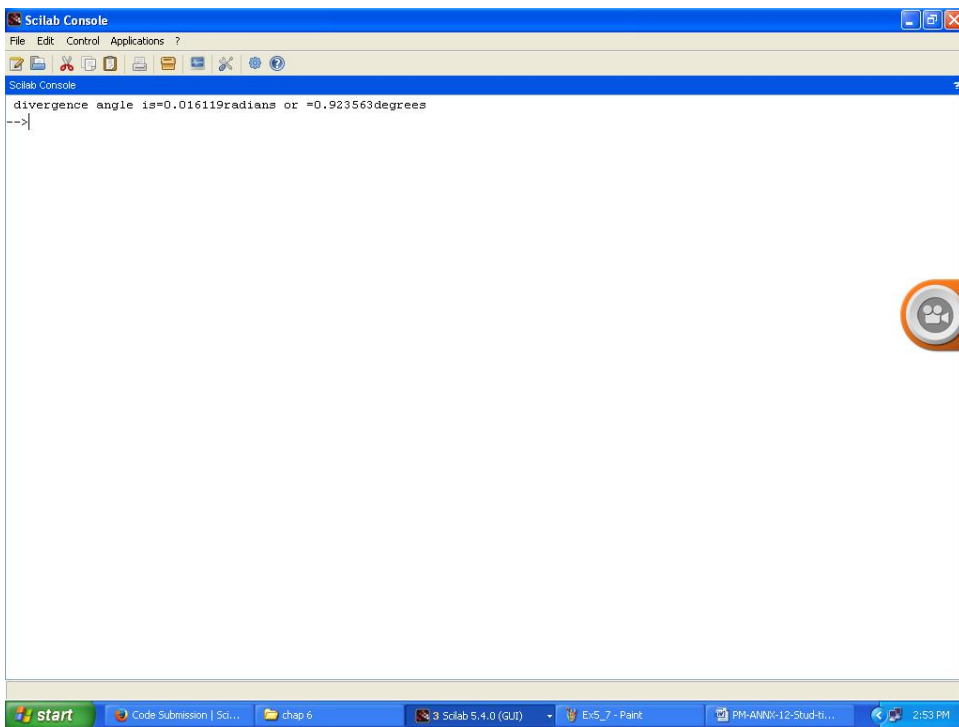


Figure 6.1: 1

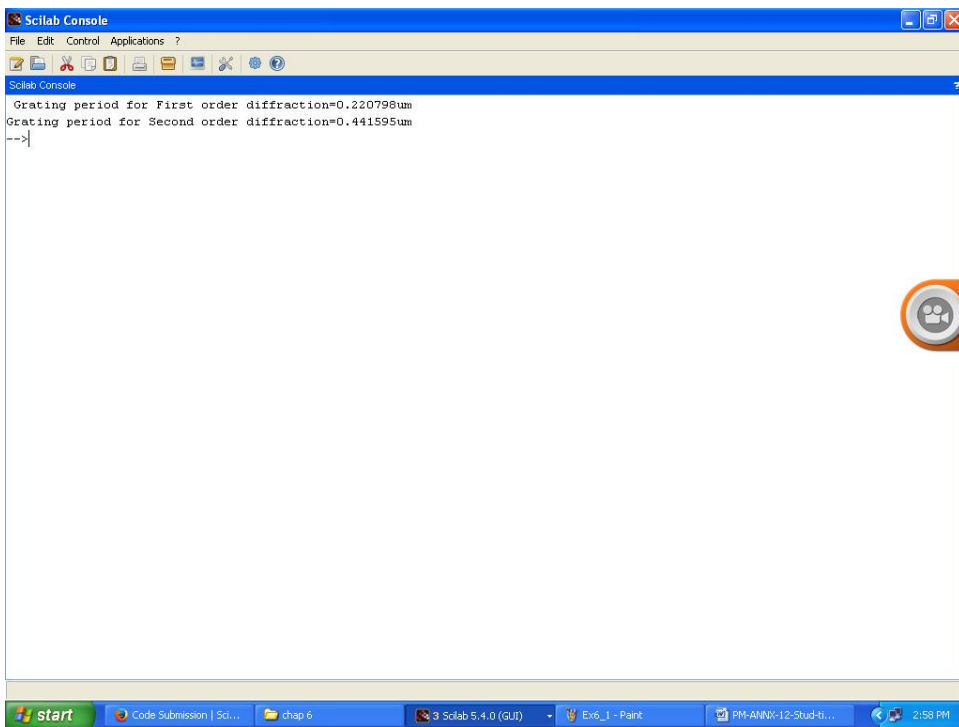


Figure 6.2: 2

### Scilab code Exa 6.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 6.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 n=3.51; //for GaAsP refractive index
9 Lambda=1.55; //wavelength in um
10 //to find
11 grating_period1=Lambda/(2*n); //grating period in um
    for firstorder diffraction
12 grating_period2=2*grating_period1; //grating period
    in um for second order diffraction
13 mprintf("Grating period for First order diffraction=
    %fum",grating_period1);
14 mprintf("\nGrating period for Second order
    diffraction=%fum",grating_period2);
```

---

### Scilab code Exa 6.3 3

```
1 //fiber optic communications by joseph c. palais
2 //example 6.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
```



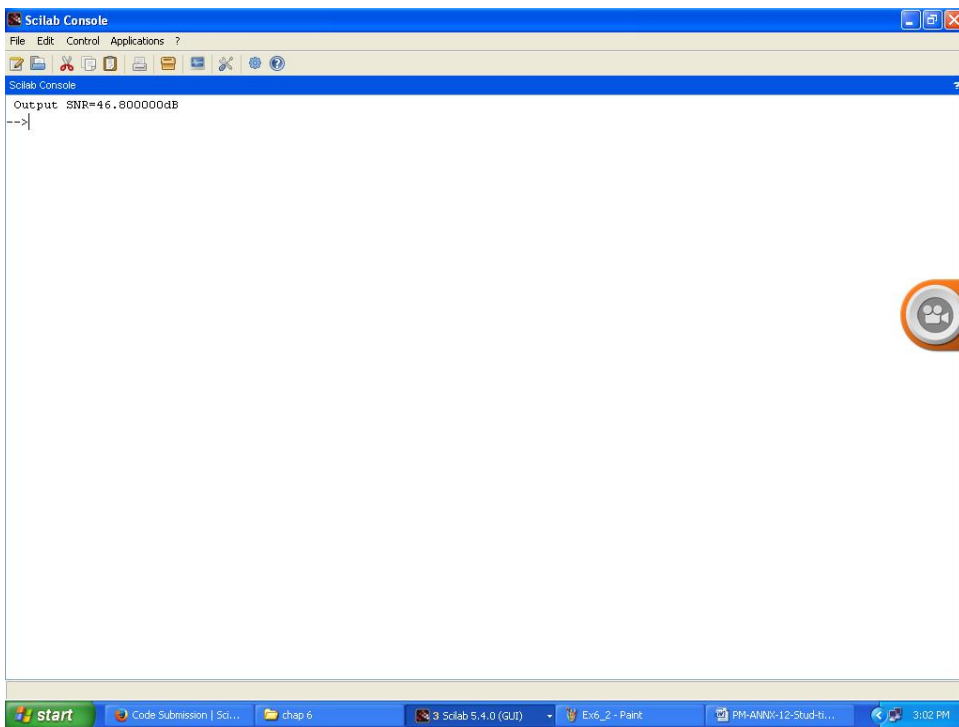


Figure 6.3: 3

```
8 NFdb=3.2//noise figure in dB
9 SNRidb=50//input snr in dB
10 //to find
11 NF=10^(NFdb/10)//converting from decibels to ratios
12 SNRi=10^(SNRidb/10)//converting from decibels to
    ratios
13 SNRo=SNRi/NF//output signal to noise ratio
14 SNRodb=10*log10(SNRo)//converting from ratios to
    decibels
15 mprintf("Output SNR=%fdB",SNRodb)
```

---

# Chapter 7

## Light Detectors

Scilab code Exa 7.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 7.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 phi=1.9//workfunction of photoemissive material
   Cesium in eV
9 //to find
10 lambda=1.24/(phi)//cutoff wavelength in um
11 mprintf("Cutoff wavelength =%f um",lambda)
```

---

Scilab code Exa 7.2 2

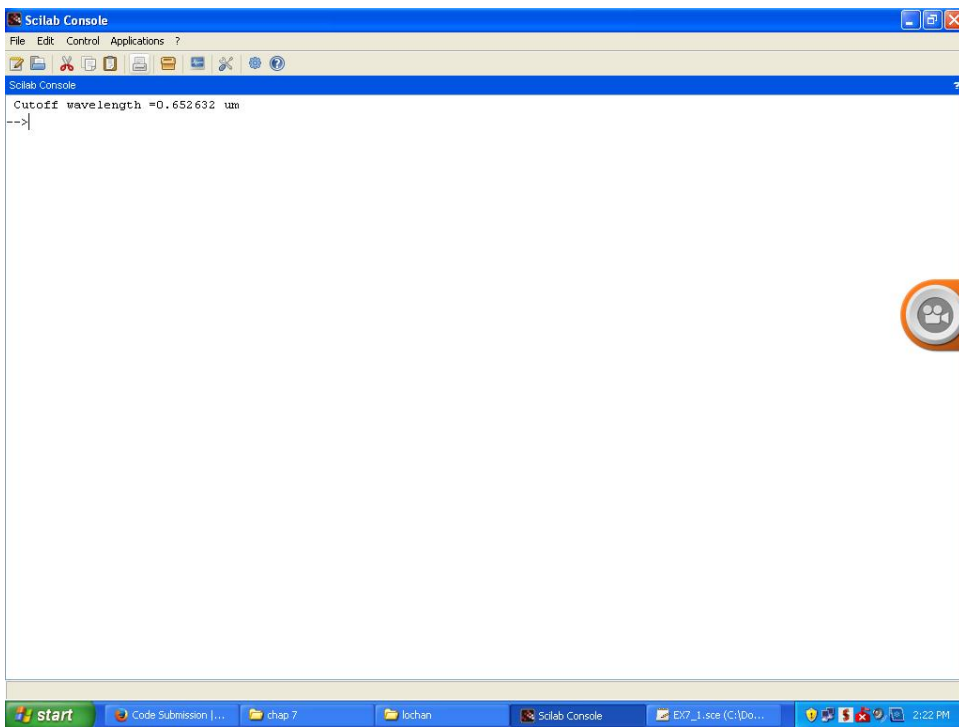


Figure 7.1: 1

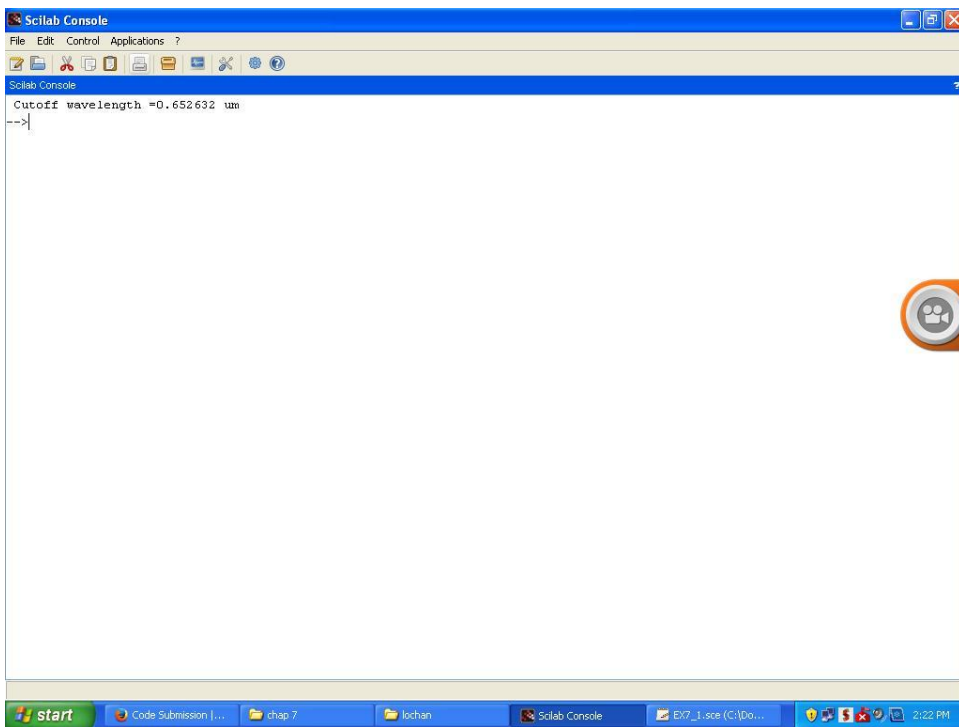


Figure 7.2: 2

```

1 //fiber optic communications by joseph c. palais
2 //example 7.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 eta=0.01//quantum efficiency of a detector
9 lambda=0.8*(10^-6)//wavelength in m
10 e=1.6*10^-19//charge of an electron in coulomb
11 h=6.63*10^-34//plancks constant
12 c=3*10^8//velocity of light in m/s
13 // to find
14 Row=(eta*e*lambda)/(h*c)//responsivity of detector
    in mA/W
15 mprintf("Responsivity of detector=%f mA/W",Row*10^3)
    //multiplication with 10^3 converts the unit from
    A/W to mA/W

```

---

### Scilab code Exa 7.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 7.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 R=50;//load resistor in ohm
9 P=1*10^-6;//optic power absorbed by the detector
10 Row=6.4*10^-3;//responsivity in A/W
11 //to find
12 i=Row*P;//current produced by detector in A

```

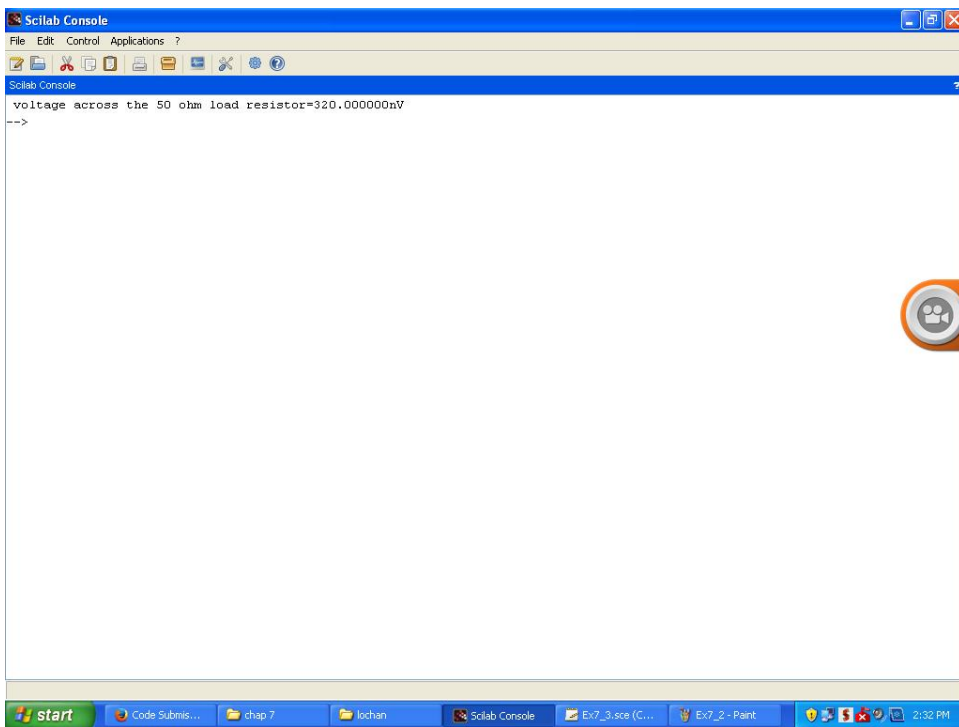


Figure 7.3: 3

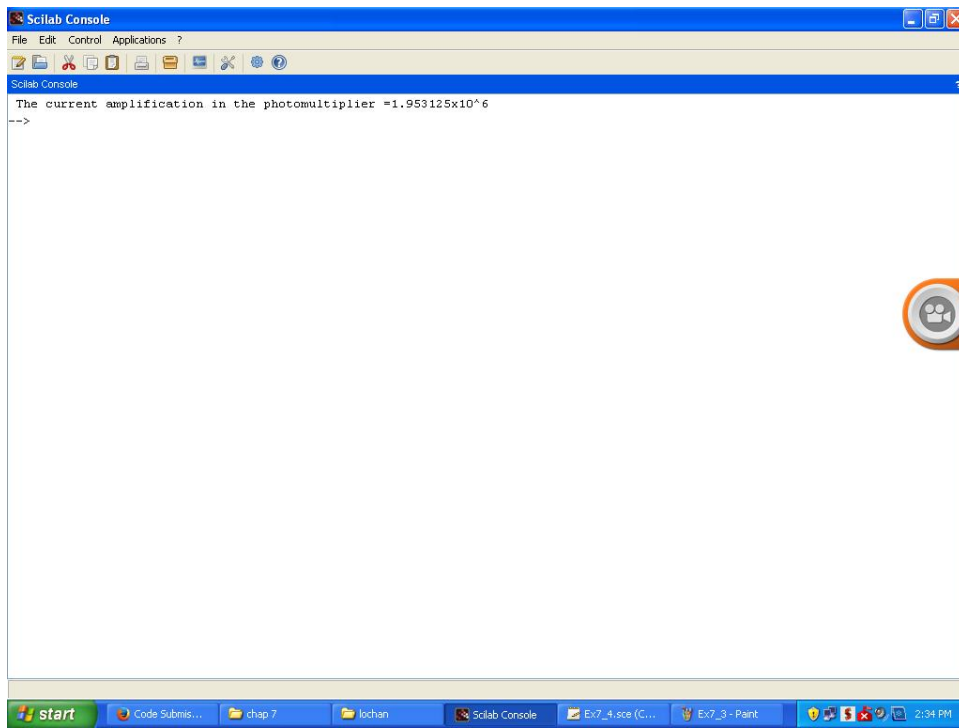


Figure 7.4: 4

```
13 v=i*R; //output voltage in V
14 mprintf('voltage across the 50 ohm load resistor=
    %fnV',v*1e9) //multiplication by 1e9 converts unit
    from V to nV
```

---

#### Scilab code Exa 7.4 4

```
1 //fiber optic communications by joseph c. palais
2 //example 7.4
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
```



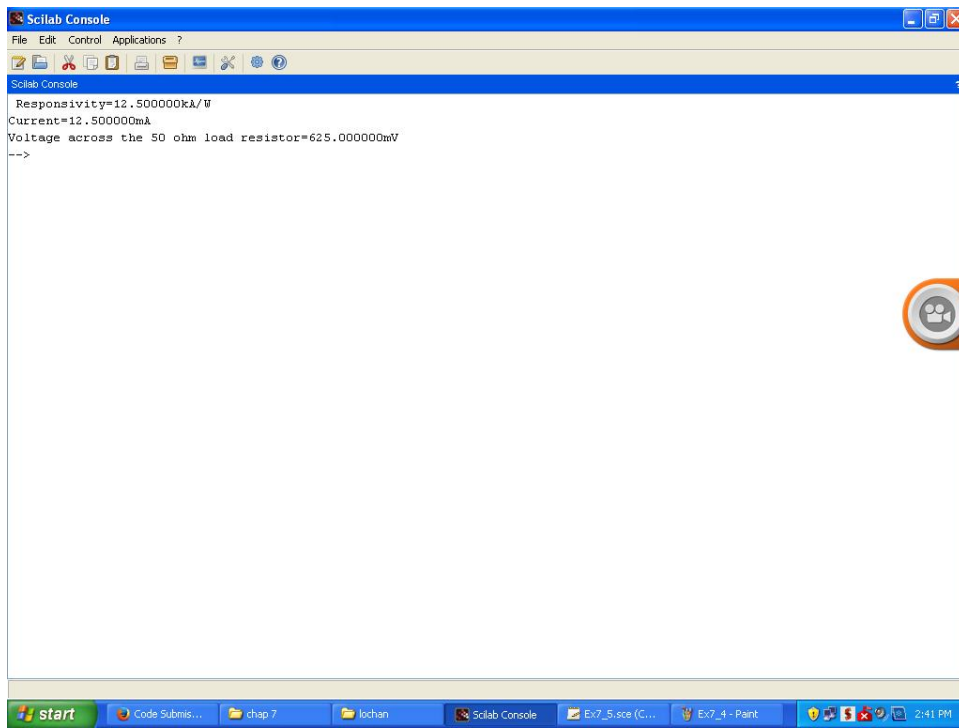


Figure 7.5: 5

```
5 clc ;
6 clear all ;
7 //given
8 G=5//Gain of each dynode
9 N=9//No. of Dynode
10 //to find
11 M=G^N//current amplification in photomultiplier
12 mprintf('The current amplification in the
    photomultiplier =%fx10^6 ',M/10^6)//division by
    10^6 to represent the result in th form ax10^6
```

---

### Scilab code Exa 7.5 5

```
1 //fiber optic communications by joseph c. palais
2 //example 7.5
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 R=50//load resistor in ohms
9 eta=0.01//efficiency
10 e=1.6*10^-19//Charge of electron in columbs
11 lambda=0.8*10^-6//wavelength in m
12 h=6.63*10^-34//planks constant
13 c=3*10^8//speed of light in m/s
14 P=1*10^-6//optic power in W
15 G=5^9//current amplification
16 Row=.0064//reponsivity in A/W
17 //to find
18 Row_amp=G*Row//amplified responsivity in A/W
19 i=Row_amp*P//current in A
20 v=i*R//output voltage in V
21 mprintf(' Responsivity=%fkA/W',Row_amp/1000) //
    division by 1000 to make unit from A to KA
22 mprintf('\nCurrent=%fmA',i*1000) //multiplication by
    1000 to make unit from A to mA
23 mprintf('\nVoltage across the 50 ohm load resistor=
    %fmV',v*1000) //multiplication by 1000 to make
    unit from V to mV
```

---

### Scilab code Exa 7.6 6

```
1 //fiber optic communications by joseph c. palais
```

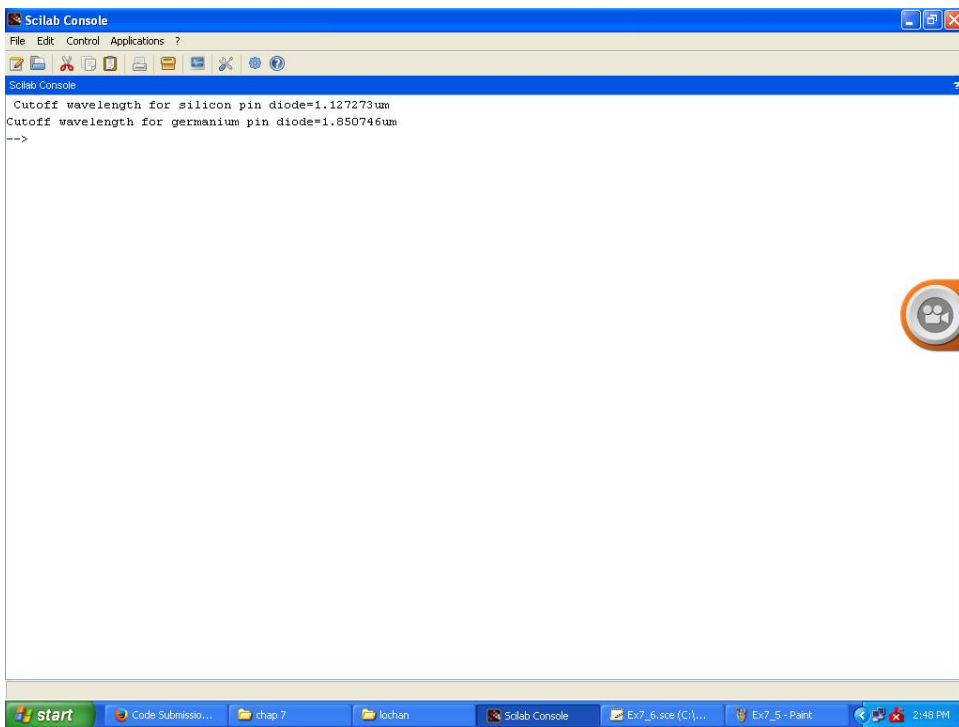


Figure 7.6: 6

```

2 //example 7.6
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 Wg1=1.1//band gap energy of silicon pin diode in eV
9 Wg2=0.67//band gap energy of germanium pin diode in
   eV
10 //to find
11 lambda_c1=1.24/Wg1//wavelength in um
12 lambda_c2=1.24/Wg2//wavelength in um
13 mprintf('Cutoff wavelength for silicon pin diode=
   %fum',lambda_c1)
14 mprintf('\nCutoff wavelength for germanium pin diode
   =%fum',lambda_c2)

```

---

#### Scilab code Exa 7.7 7

```

1 //fiber optic communications by joseph c. palais
2 //example 7.7
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 Row=0.5//responsivity in A/W
9 Id=1*10^-9//dark current in A
10 //to find
11 P=Id/Row//minimum detectable power in W
12 mprintf('minimum detectable power =%fnW',P*10^9)//
   multiplication by 10^9 to convert unit from W to
   nW

```

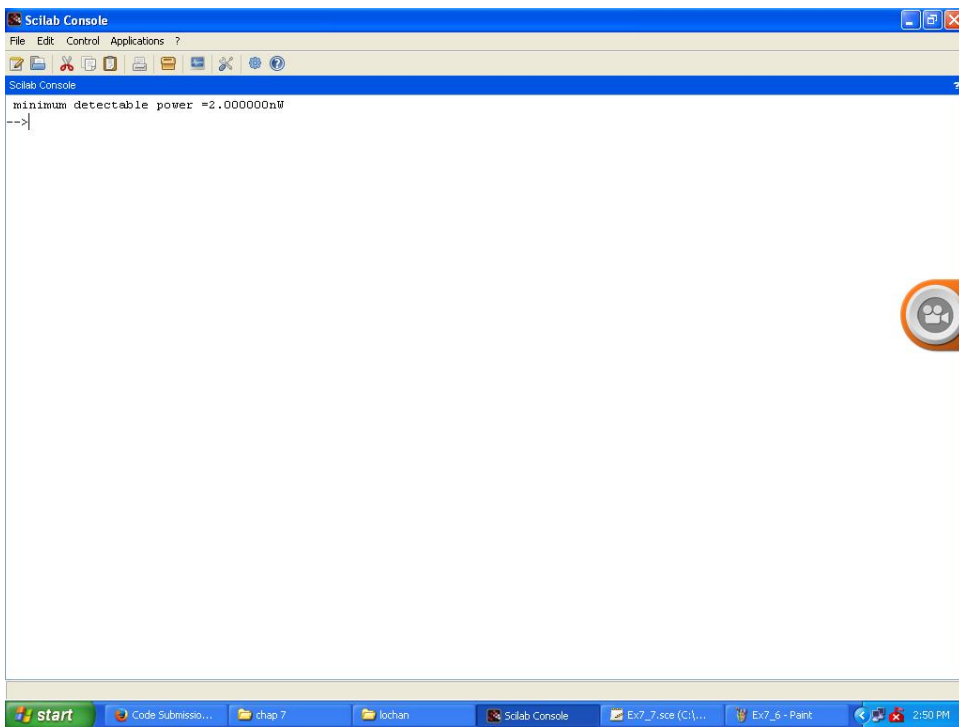


Figure 7.7: 7

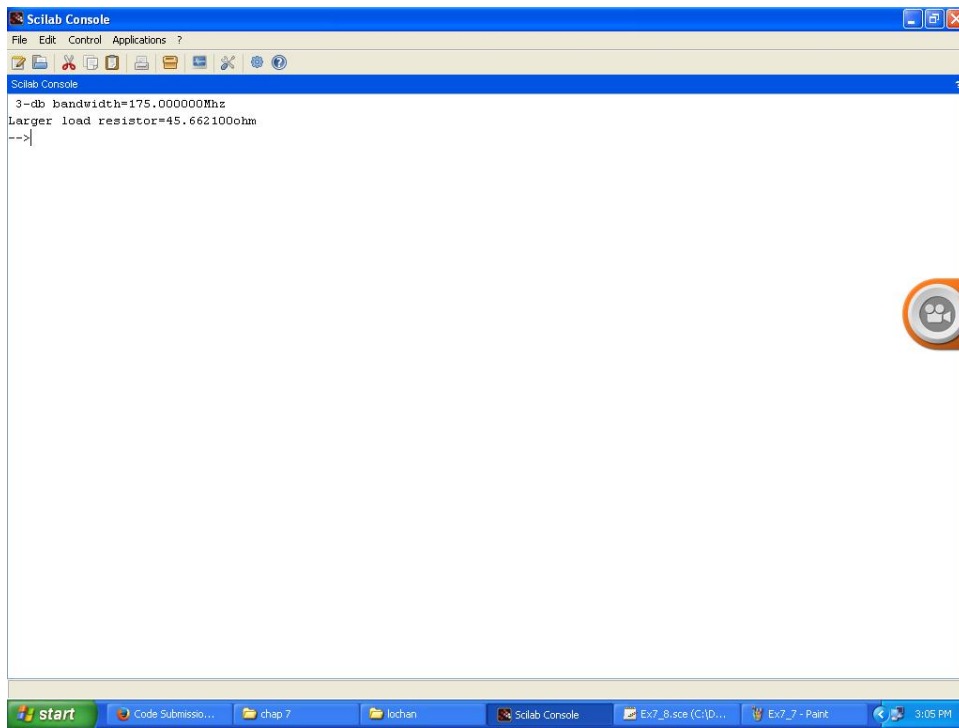


Figure 7.8: 8

---

### Scilab code Exa 7.8 8

```
1 //fiber optic communications by joseph c. palais
2 //example 7.8
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc;
6 clear all;
7 //given
8 Cd=5*(10^-12)//capacitance in Farads
```

```
9 tr=2*(10^-9)//transit time in s
10 f3db=0.35/tr//3dB bandwidth in Hz
11 mprintf("3-db bandwidth=%fMhz",f3db*10^-6)//
    multiplication by 10^-6 to convert bandwith unit
    from Hz to MHz
12 Tc=tr/4// RC time constant condition for
    insignificant Load resistance in s
13 Rl=Tc/(2.19*Cd)//largest load resistance in ohm
14 mprintf("\nLarger load resistor=%fohm",Rl)
```

---

# Chapter 8

## Couplers and connectors

Scilab code Exa 8.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 8.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 d=50//core daimeter in um
9 a=d/2//core radius in um
10 L1=1//coupling loss in dB case 1
11 L2=0.5//coupling loss in dB case 2
12 L3=0.1//coupling loss in dB case 3
13 //to find
14 eta1=10^(-L1/10)//coupling efficiency for L1
15 eta2=10^(-L2/10)//coupling efficiency for L2
16 eta3=10^(-L3/10)//coupling efficiency for L3
17 dby2a1=(1-eta1)*(%pi/4)//displacement by twice
    radius ratio d/2a for case 1
18 dby2a2=(1-eta2)*(%pi/4)//displacement by twice
```



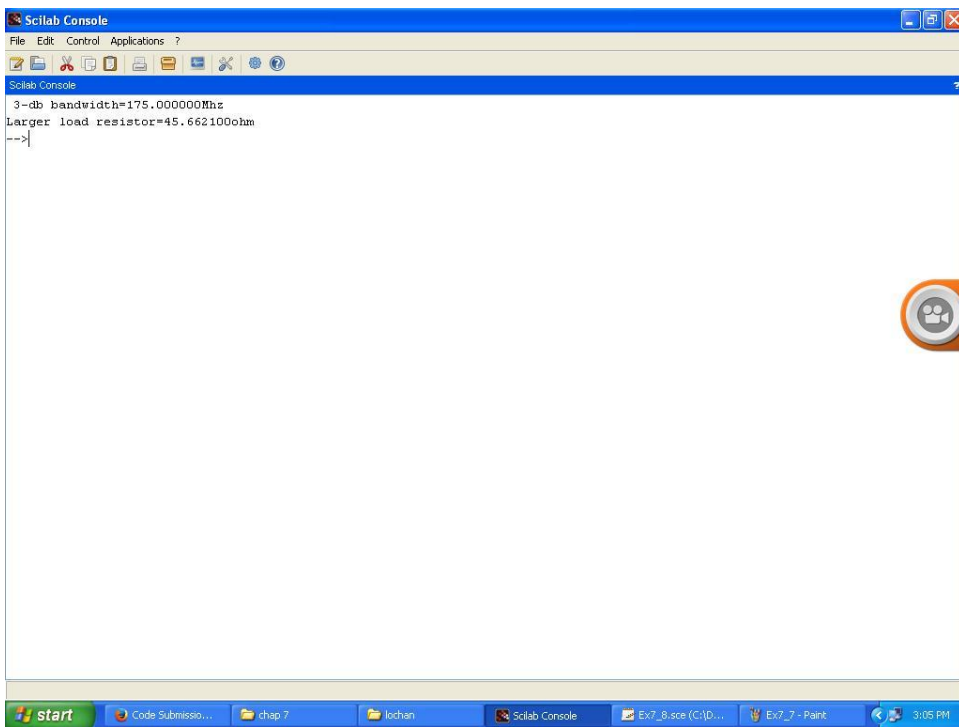


Figure 8.1: 1

```

    radius ratio d/2a for case 2
19 dby2a3=(1-eta3)*(%pi/4)//displacement by twice
    radius ratio d/2a for case 3
20 d1=(1-eta1)*(%pi*a/2)//axial displacement for
    coupling loss=1dB since d/2a<0.2
21 d2=(1-eta2)*(%pi*a/2)//axial displacement for
    coupling loss=0.5dB since d/2a<0.2
22 d3=(1-eta3)*(%pi*a/2)//axial displacement for
    coupling loss=0.1dB since d/2a<0.2
23 mprintf('Axial displacement for coupling loss=1dB
    with d/2a=%f is=%fum',dby2a1,d1)
24 mprintf('\nAxial displacement for coupling loss=0.5
    dB with d/2a=%f is=%fum',dby2a2,d2)
25 mprintf('\nAxial displacement for coupling loss=0.1
    dB with d/2a=%f is=%fum',dby2a3,d3)

```

---

### Scilab code Exa 8.2 2

```

1 //fiber optic communications by joseph c. palais
2 //example 8.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 n1=1.465//core refractive index
9 n2=1.46//cladding refractive index
10 lambda1=1.3//wavelength in um
11 lambda2=1.55//wavelength in um
12 a=3.96//core radius in um
13 d=0:0.1:5//offset in um
14 //to find
15 V1=2*%pi*a/lambda1*(sqrt(n1^2-n2^2))//V number for

```

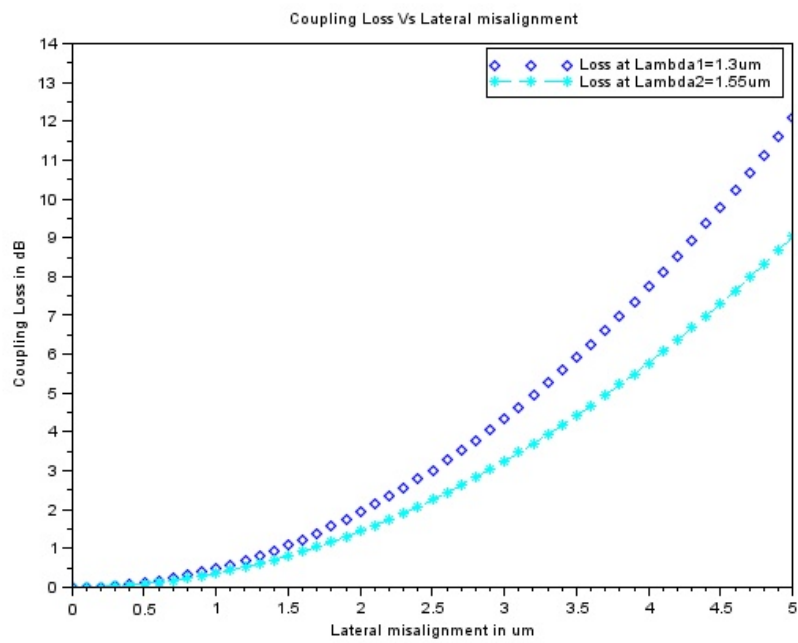


Figure 8.2: 2

```

    lambda1
16 V2=2*%pi*a/lambda2*(sqrt(n1^2-n2^2))//V number for
    lambda2
17 wbya1=0.65+1.69*V1^(-1.5)+2.879*V1^(-6)//mode field
    radiusto core radius for lambda1
18 wbya2=0.65+1.69*V2^(-1.5)+2.879*V2^(-6)//mode field
    radiusto core radius for lambda2
19 w1=wbya1*a//mode field radius in um for lambda1
20 w2=wbya2*a//mode field radius in um for lambda2
21 dbyw1=d./w1//d/w ratio for lambda1
22 dbyw2=d./w2//d/w ratio for lambda2
23 L1=-10*log(exp(-(dbyw1)^2))//Coupling Loss for
    lambda1
24 L2=-10*log(exp(-(dbyw2)^2))//Coupling Loss for
    lambda2
25 xtitle('Coupling Loss Vs Lateral misalignment', '
    Lateral misalignment in um', 'Coupling Loss in dB
    ');
26 plot(d,L1,'d')
27 plot(d,L2,'*cya—')
28 hl=legend(['Loss at Lambda1=1.3um';'Loss at Lambda2
    =1.55um']);

```

---

### Scilab code Exa 8.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 8.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear all
8 n1=1.465//refractive index of core

```

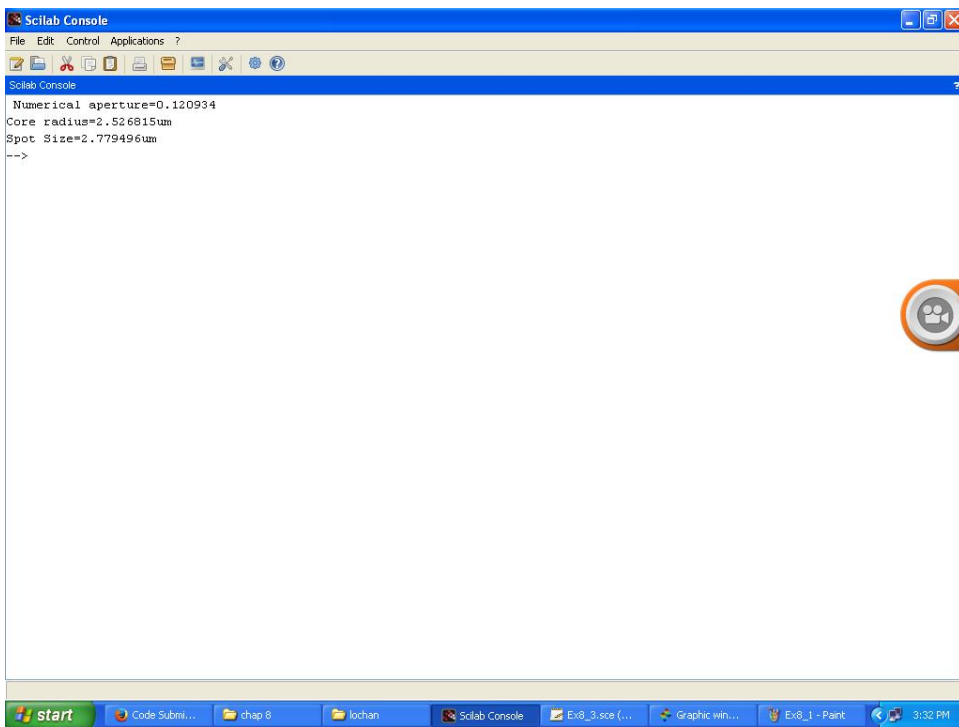


Figure 8.3: 3

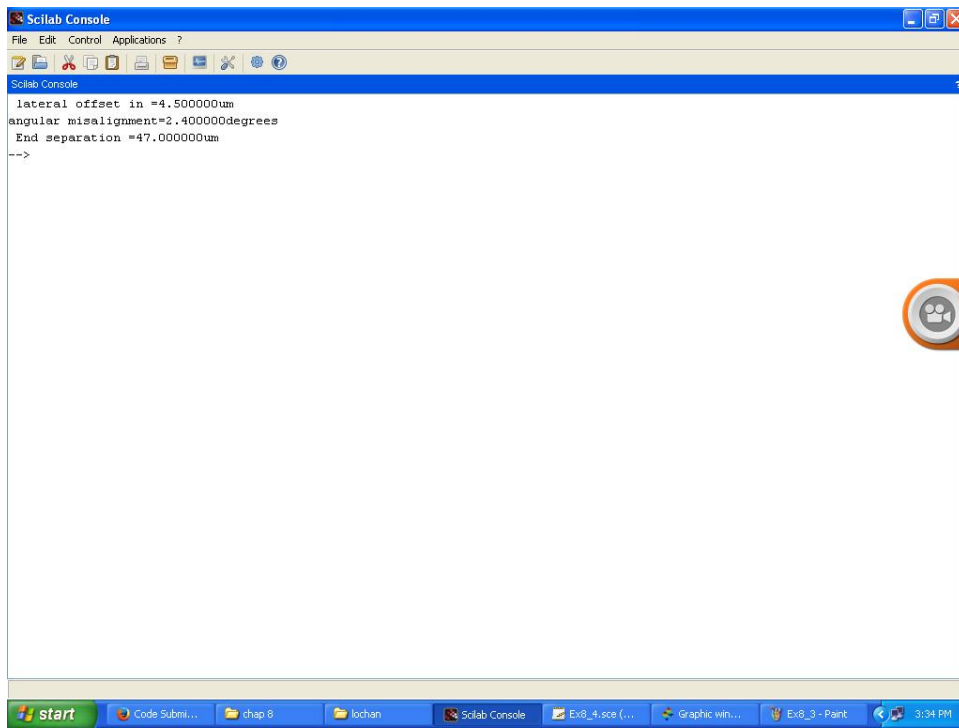


Figure 8.4: 4

```
9 n2=1.46//refractive index of cladding
10 lambda=0.8//wave length in um
11 V=2.4//normalized frequency
12 wbya=1.1//w/a ratio for V=2.4
13 na=sqrt((n1^2)-(n2^2))//numerical aperture
14 mprintf(" Numerical aperture=%f",na)
15 a=(lambda*V)/(2*pi*na)//core radius
16 mprintf("\nCore radius=%fum",a)
17 spot_size=wbya*a//spot size in um
18 mprintf("\nSpot Size=%fum",spot_size)
```

---

#### Scilab code Exa 8.4 4

```
1 //fiber optic communications by joseph c. palais
2 //example 8.4
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear all
8 loss=0.25//loss for each type of misalignment in dB
9 a=50//core radius in um
10 NA=0.24//numerical aperture
11 dby2a=0.045//lateral offset from given plots for
    loss of 0.25dB
12 theta=2.4//angular misalignment from given plots for
    loss of 0.25dB
13 xbya=0.94//end separation from given plots for loss
    of 0.25dB
14
15 //tofind
16 d=dby2a*a*2//lateral offset in um
17 x=xbya*a//end separation in um
18 mprintf("lateral offset in =%fum",d)
19 mprintf("\n angular misalignment=%fddegrees",theta)
20 mprintf(" \n End separation =%fum",x)
```

---

#### Scilab code Exa 8.5 5

```
1 //fiber optic communications by joseph c. palais
2 //example 8.5
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
```

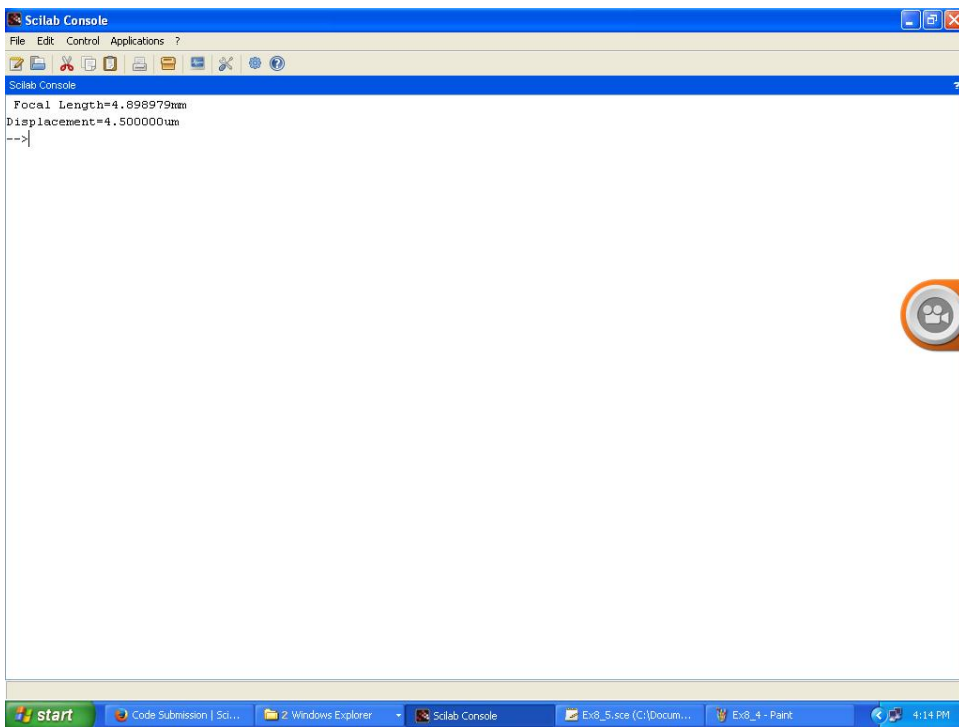


Figure 8.5: 5



```

6  clc
7  clear all
8  NA=0.2//numerical aperture
9  dia=50*(10^(-6))//core diameter in m
10 a=dia/2//core radius in m
11 lateral_loss=0.5//allowable lateral loss in dB
12 Beam_dai=2//beam diameter in mm
13 dby2a=0.09//since loss is 0.5dB d/2a is 0.09 from
    given figure 8.3
14 //to find
15 r=Beam_dai/2//beam radius in mm
16 Beam_divergence=asind(NA)//beam diverges in degrees
17 f=r/tand(Beam_divergence)//focal length in mm
18 d=dby2a*2*a//allowed offset in m
19 mprintf(" Focal Length=%fmm",f)
20 mprintf("\nDisplacement=%fum",d*1e6)//multiplication
    by 1e6 will convert the unit from m to um

```

---

### Scilab code Exa 8.6 6

```

1  //fiber optic communications by joseph c. palais
2  //example 8.6
3  //OS=Windows XP sp3
4  //Scilab version 5.4.1
5  //given
6  clc
7  clear all
8  NA1=0.24//numerical aperture SI fiber 1 All glass
9  NA2=0.41//numerical aperture SI fiber 2 PCS
10 NA3=0.48//numerical aperture SI fiber 3 All plastic
11 NA_loss1=-10*log10(NA1^2)//losses SI fiber 1
12 NA_loss2=-10*log10(NA2^2)//losses SI fiber 2
13 NA_loss3=-10*log10(NA3^2)//losses SI fiber 3

```

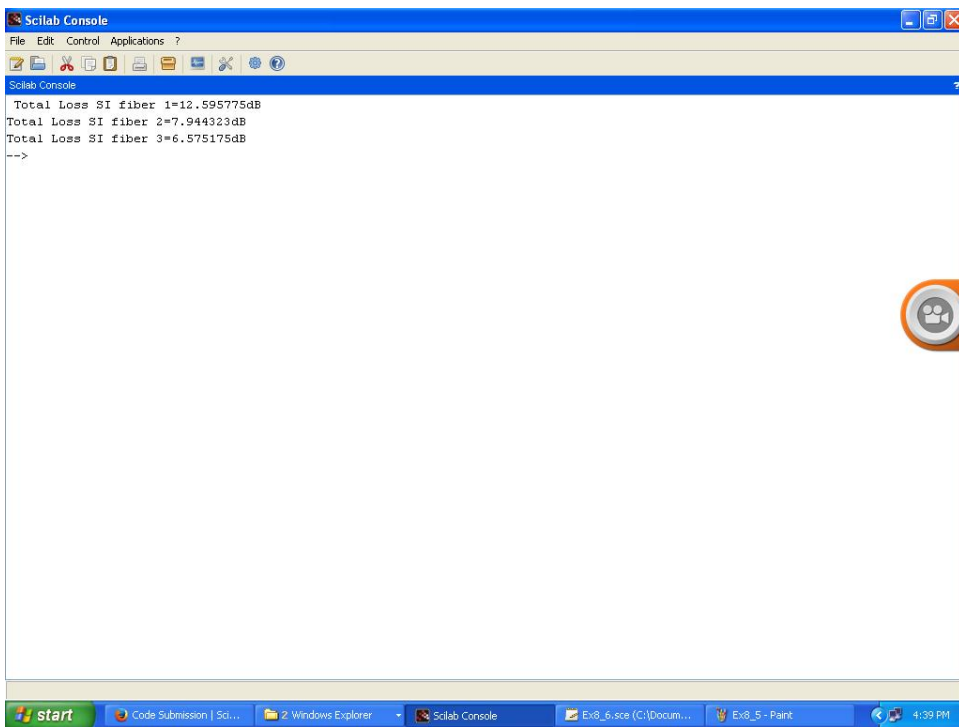


Figure 8.6: 6

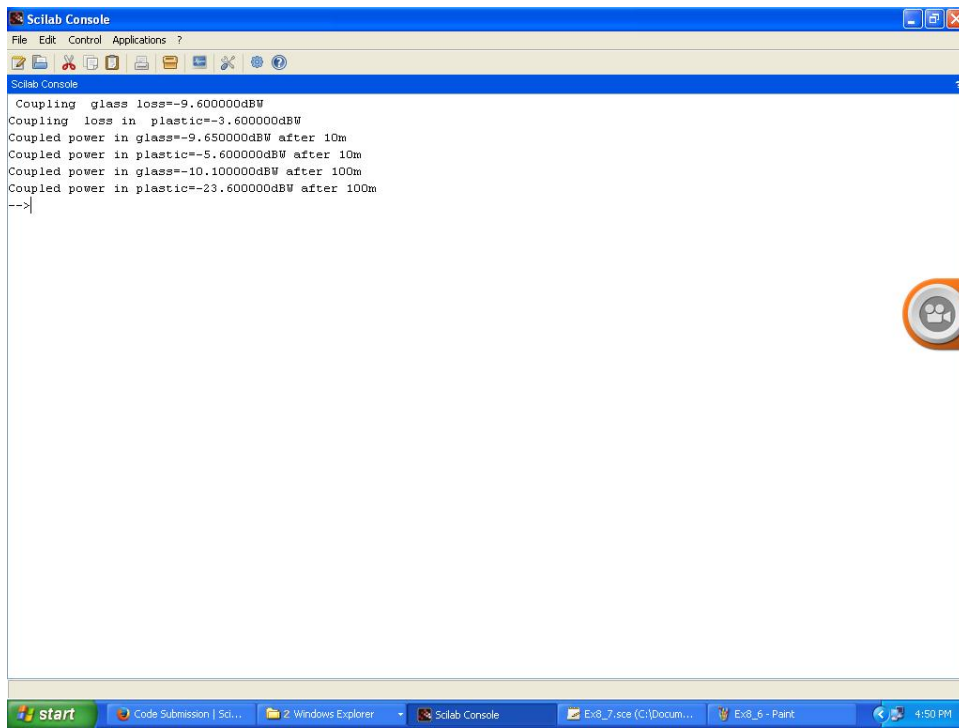


Figure 8.7: 7

```

14 ref_loss=0.2// Reflection_loss in dB
15 total_loss1=NA_loss1+ref_loss//Total Loss in dB
16 mprintf('Total Loss SI fiber 1=%fdB',total_loss1)
17 total_loss2=NA_loss2+ref_loss
18 mprintf('\nTotal Loss SI fiber 2=%fdB',total_loss2)
19 total_loss3=NA_loss3+ref_loss
20 mprintf('\nTotal Loss SI fiber 3=%fdB',total_loss3)

```

---

### Scilab code Exa 8.7 7

```

1 //fiber optic communications by joseph c. palais

```

```

2 //example 8.7
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear all
8 Ps=3//source power in dBm
9 NA_glass=0.24//numerical aperture for glass
10 NA_plastic=0.48//numerical aperure for plastic
11 loss_glass=12.4//loss for glass fiber in dB
12 loss_plastic=6.4//loss for plastic fiber in dB
13 reflectn_loss=0.2// reflection losses in dB
14 atten_glass=5//attenuation in glass dB/Km
15 atten_plastic=200//attenuation in plastic dB/Km
16 L1=10*10^-3//fiber length in Km
17 L2=100*10^-3//fiber length in Km
18 //to find
19 glass_coup_loss=Ps-(reflectn_loss + loss_glass)//
    Glass fiber coupling Loss in dBW
20 mprintf('Coupling glass loss=%fdBW',glass_coup_loss
    )
21 plastic_coup_loss=Ps-(reflectn_loss + loss_plastic)
    //plastic coupling fiber loss in dBW
22 mprintf('\nCoupling loss in plastic=%fdBW',
    plastic_coup_loss)
23 glass_cp= glass_coup_loss-atten_glass*L1//Coupled
    power in glass in dBW for 10m
24 mprintf('\nCoupled power in glass=%fdBW after 10m',
    glass_cp)
25 plastic_cp=plastic_coup_loss-atten_plastic*L1//
    Coupled power in plastic in dBW for 10m
26 mprintf('\nCoupled power in plastic=%fdBW after 10m',
    ,plastic_cp)
27 glass_cp= glass_coup_loss-atten_glass*L2// Coupled
    power in glass in dBW for 100m
28 mprintf('\nCoupled power in glass=%fdBW after 100m',
    glass_cp)
29 plastic_cp=plastic_coup_loss-atten_plastic*L2 //

```

```
    Coupled power in plastic in dBW for 100m
30 mprintf('\\nCoupled power in plastic=%fdBW after 100m
    ',plastic_cp)
```

---

# Chapter 9

## Distribution networks and Fiber components

Scilab code Exa 9.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 9.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 LE=1//coupler has excess loss of 1dB
9 P2byP1=(10^(-LE/10))/2//since P2/P1 is equal to P3/
    p1 since splitting ratio is 1:1
10 Ltap=-10*log10(P2byP1)//Taploss in dB
11 Lthp=-10*log10(P2byP1)//throughput Loss in dB
12 Ltap1=Ltap-LE//excess loss of 1 dB
13 Lthp2=Lthp-LE//excess loss of 1dB
14 mprintf('\n\nThe portion of the input power reaching
    output for splitting ratio 1:1 is =%f',P2byP1)
```

---

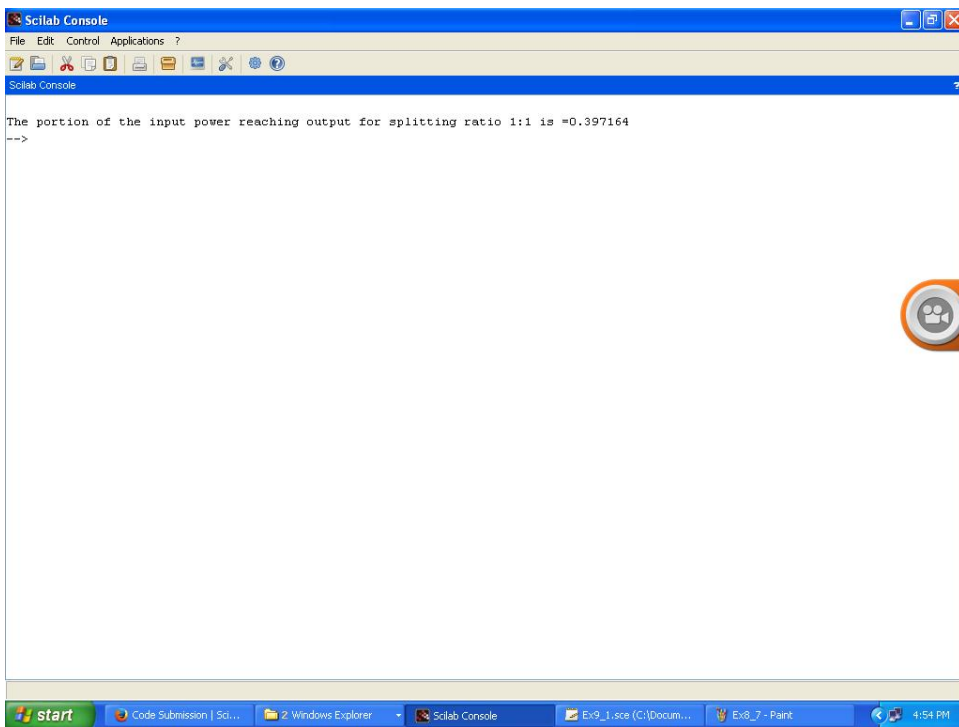


Figure 9.1: 1

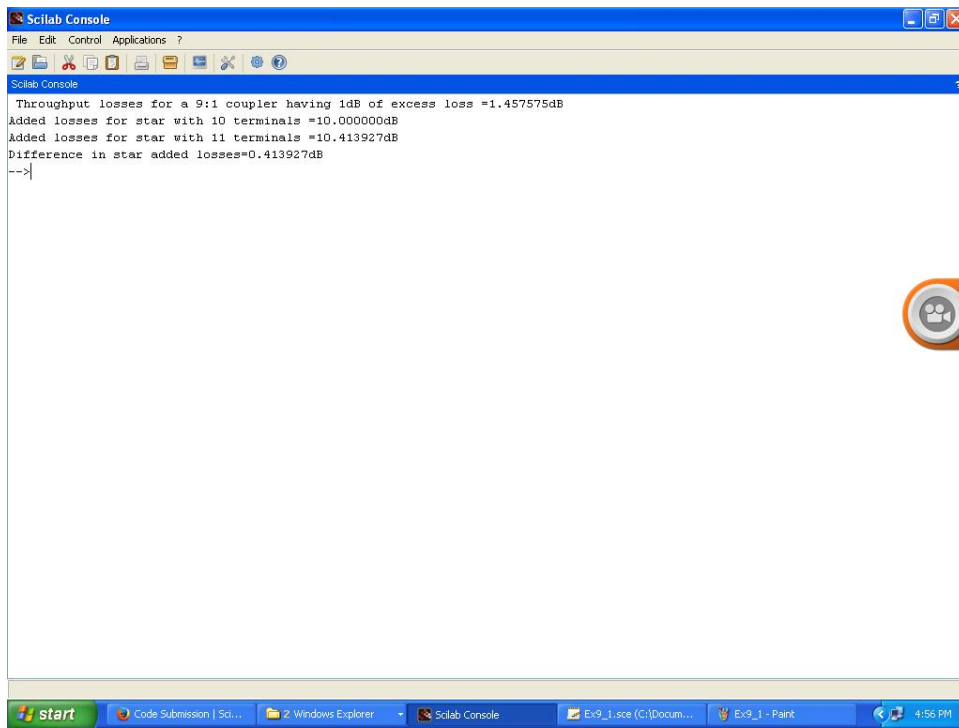


Figure 9.2: 2

### Scilab code Exa 9.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 9.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 terminals_in=10//initial terminals
```



```

 9 terminals_ex=11//extended terminals
10 S_ratio=9//splitting ratio
11 ELT=1//excess loss tee coupler in dB
12 connector_loss=1//connector loss in dB
13 //to find
14 P2byP1=10^-0.1*0.9//P2/P1 for splitting ratio 9:1
15 lthp=-10*log10(P2byP1)//through loss loss for a 9:1
    coupler having 1dB of excess loss
16 tee_adlos=lthp+2//loss of one directional coupler
    plus the loss of two connectors
17 star_adlos1= -10*log10(1/terminals_in)//Loss for
    star network with 10 terminals in dB
18 star_adlos2= -10*log10(1/terminals_ex)//Loss for
    star network with 11 terminals in dB
19 d2=star_adlos2 - star_adlos1//Change in loss with
    change in no. of terminals from 10-11
20 mprintf('Throughput losses for a 9:1 coupler having
    1dB of excess loss =%fdB',lthp)
21 mprintf('\nAdded losses for star with 10 terminals =
    %fdB',star_adlos1)
22 mprintf('\nAdded losses for star with 11 terminals =
    %fdB',star_adlos2)
23 mprintf('\nDifference in star added losses=%fdB',d2)

```

---

### Scilab code Exa 9.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 9.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc;
7 clear all;

```

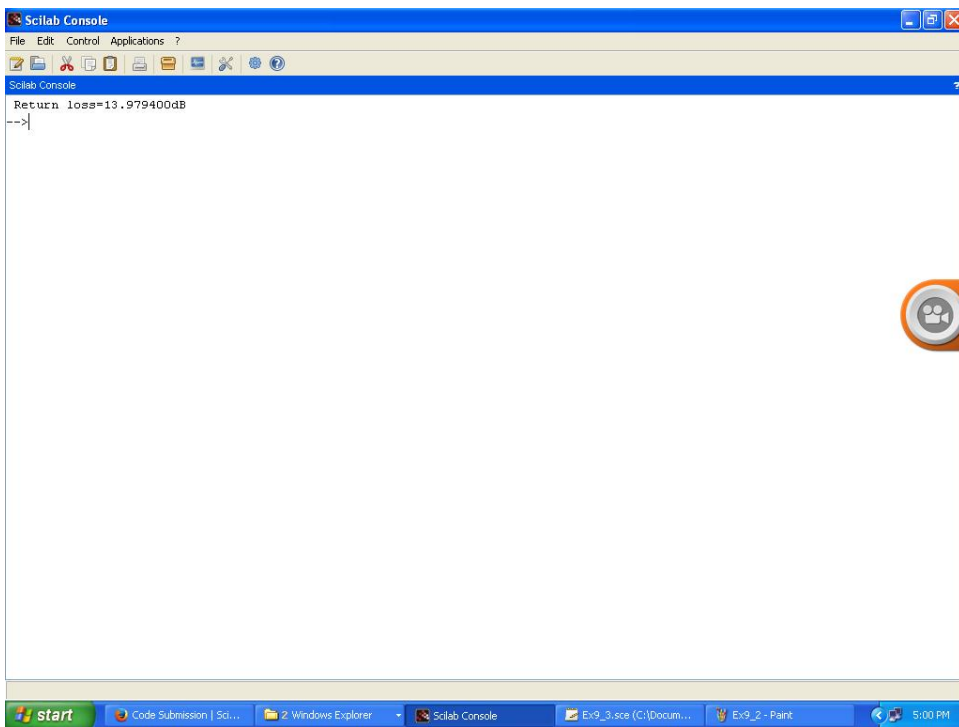


Figure 9.3: 3

```
8 n2=1.5//Assuming refractive index of glass fiber
9 n1=1//refractive index if air
10 R=((n1-n2)/(n1+n2))^2// fraction of light reflected
11 //to find
12 LR=-10*log10(R)//Return loss in dB
13 mprintf('Return loss=%f dB',LR)
```

---

# Chapter 10

## Modulation

Scilab code Exa 10.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 10.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 clc;
9 clear all;
10 Vdc=5;//Power supply across transistor in V
11 R=45//Resistance in ohm
12 vd=1.4//forward bias voltage drop in V
13 vce=0.3//cut-off voltage in V
14 //to find
15 ic=(Vdc-vce-vd)/R//diode current when fully on in A
16 mprintf("Collector current=%fmA",ic*1000)
```

---

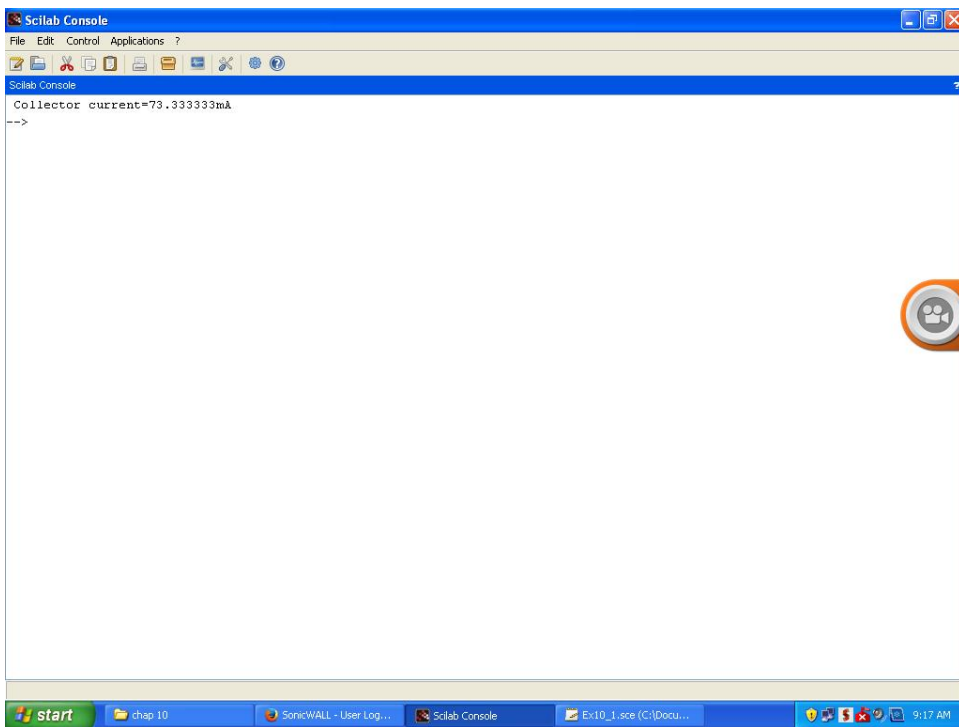


Figure 10.1: 1

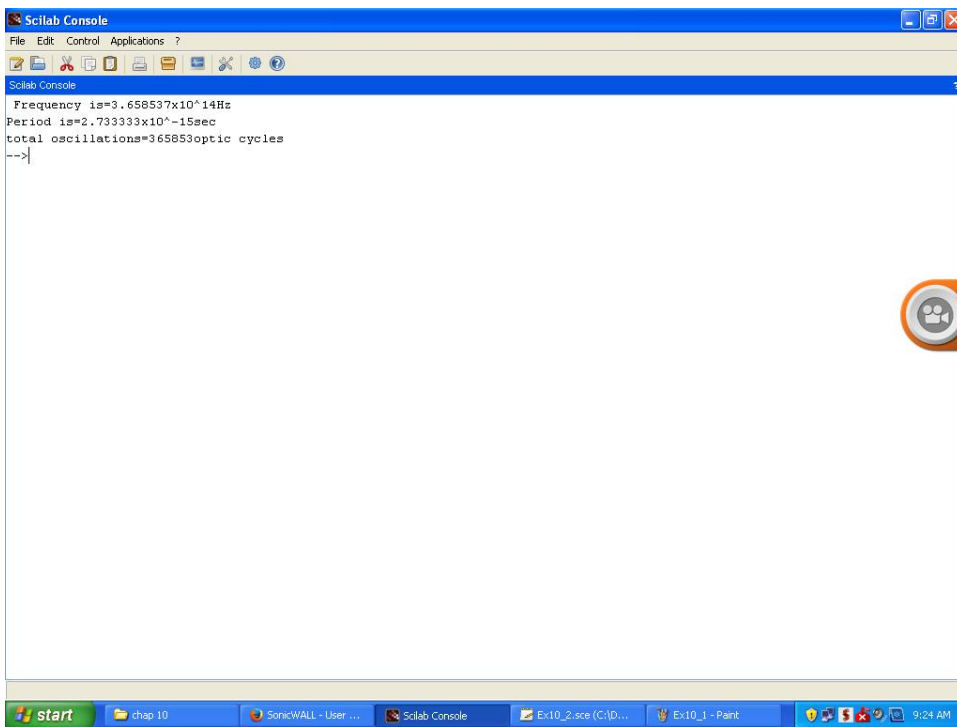


Figure 10.2: 2

### Scilab code Exa 10.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 10.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc;
7 clear all;
8 lambda=0.82*(10^-6)//wavelength in m
9 pulse=10^-9//duration of pulse in sec
10 c=3*10^8//velocity of light in m/s
11 //to find
12 f=c/lambda;//frequency of oscillation in Hz
13 mprintf("Frequency is=%fx10^14Hz",f/10^14) //
    division by 10^14 AND SHOWING THE RESULT AS X
    10^14
14 T=1/f;//Pulse duration in sec
15 mprintf("\\nPeriod is=%fx10^-15sec",T*10^15)//
    MULTIPLICATION by 10^15 AND SHOWING THE RESULT AS
    X 10^-15
16 Oscillations=pulse/T;//no. of oscillations
17 mprintf("\\ntotal oscillations=%ioptic cycles",
    Oscillations)
```

---

### Scilab code Exa 10.3 3

```
1 //fiber optic communications by joseph c. palais
2 //example 10.3
3 //OS=Windows XP sp3
```

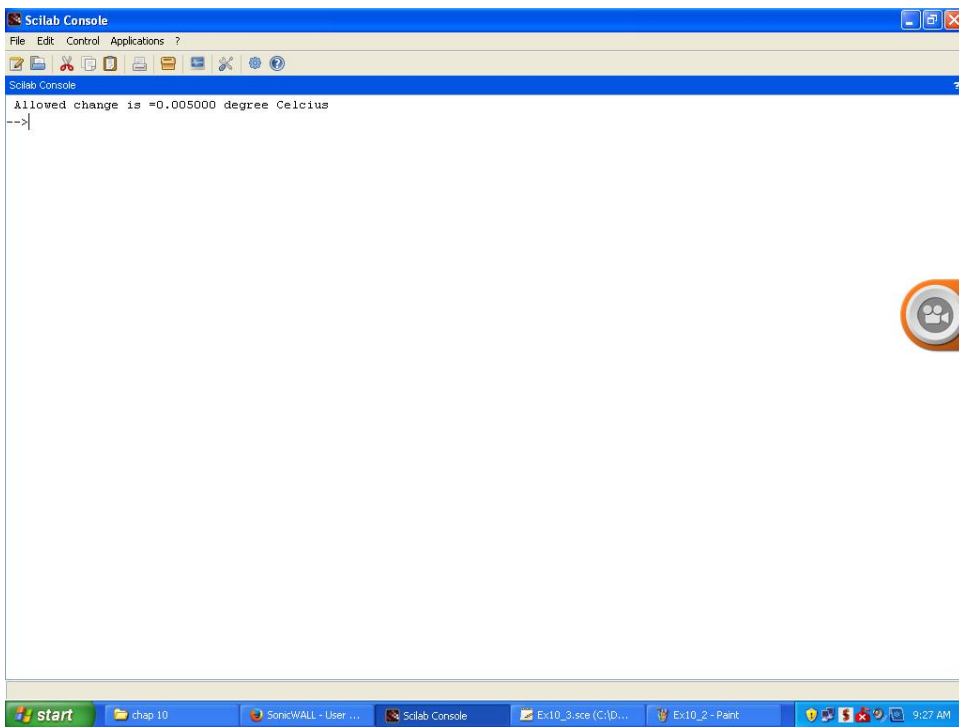


Figure 10.3: 3



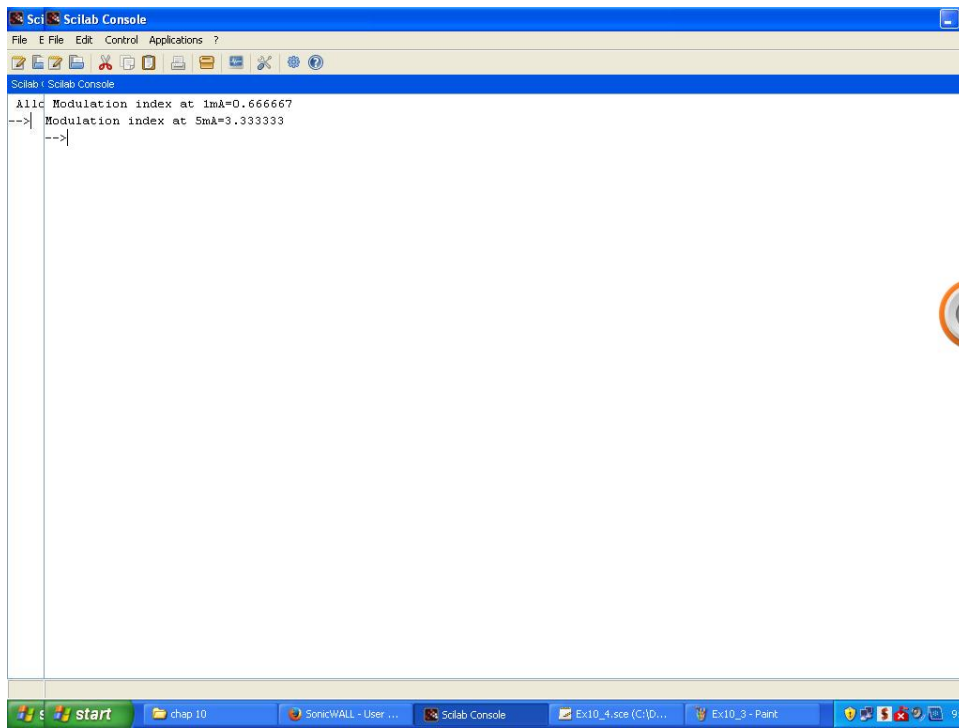


Figure 10.4: 4

```
4 //Scilab version 5.4.1
5 //given
6 clc;
7 clear all;
8 wc=20//wavelength change in Ghz/degree celcius
9 fo=100//frequency offset in MHz
10
11 //to find
12 allowed_change=fo*10^-3/wc//allowed change in
    temperature in degree celcius
13 mprintf("Allowed change is =%f degree Celcius",
    allowed_change)
```

---

#### Scilab code Exa 10.4 4

```
1 //fiber optic communications by joseph c. palais
2 //example 10.4
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc;
7 clear all;
8 deltaf=200//Frequency deviation in MHz/mA
9 fm=300//modulation frequency in MHz
10 pac_current1=1//peak ac current in mA
11 pac_current2=5//peak ac current in mA
12
13
14 //to find
15 deltaf1=deltaf*pac_current1//frequency deviation for
    1mA in MHz
16 deltaf2=deltaf*pac_current2//frequency deviation for
    5mA in MHz
17 beta1=deltaf1/fm//modulation index at 1mA
18 mprintf(" Modulation index at 1mA=%f",beta1)
19 beta2=deltaf2/fm//modulation index at 5mA
20 mprintf("\nModulation index at 5mA=%f",beta2)
```

---

#### Scilab code Exa 10.5 5

```
1 //fiber optic communications by joseph c. palais
2 //example 10.5
3 //OS=Windows XP sp3
```

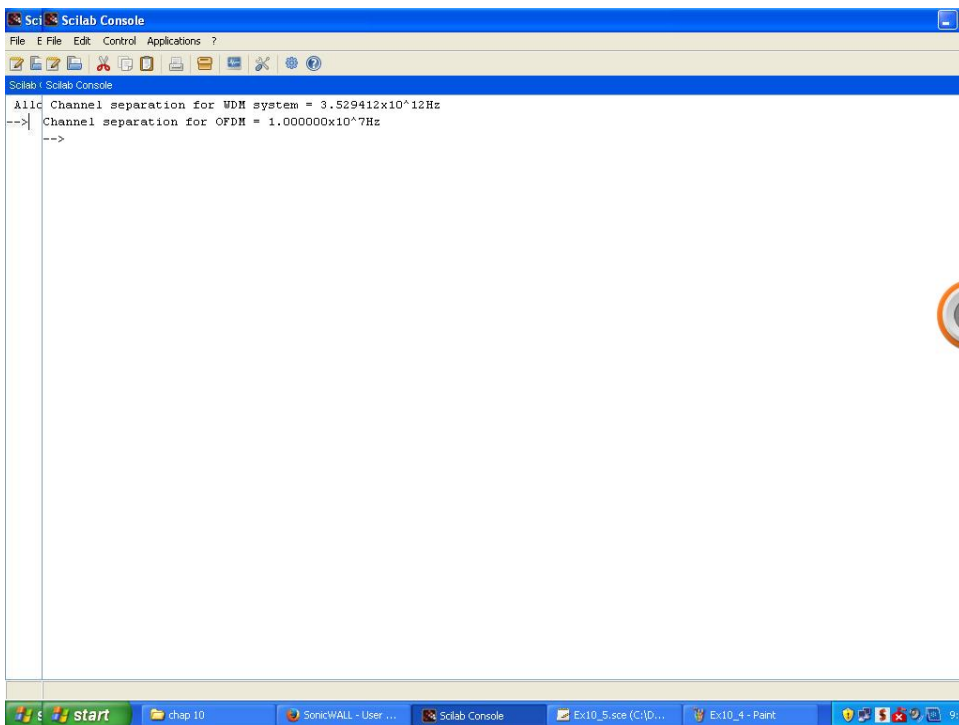


Figure 10.5: 5

```

4 //Scilab version 5.4.1
5 clc
6 //given
7 lambda=850*10-9//spectral width in m
8 f_bw=0.01//fractional bandwidth
9 OS=1*109//optic separation in short wavelength
   window and IF frequency in Hz
10 delta_lambda=lambda*f_bw//spectral separation in m
11 c=3*108//speed of light
12 delta_f1=c*delta_lambda/(lambda2)//channel
   separation in GHz in WDM
13 delta_f2=OS*f_bw//channel separation in GHz in OFDM
14 mprintf('Channel separation for WDM system = %fx10
   ^12Hz',delta_f1/1012)//division by 1012 to
   convert the result in the form x1012
15 mprintf('
\nChannel separation for OFDM = %fx107Hz',
   delta_f2/107)//division by 107 to convert the
   result in the form x107

```

---

# Chapter 11

## Noise and Detection

Scilab code Exa 11.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 11.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear all
8 //given
9 lambda=0.85e-6//wave length in um
10 Pi=10*10^-3//led Power in W
11 L=20//fiber cable loss in dB
12 Row=0.5//responsivity in A/W
13 ID=2*10^-9//Detector dark current in A
14 RL=50//load resistance in ohm
15 BW=10*10^6//receiver's bandwidth in Hz
16 Ta=300//temperature in Kelvin
17 SCL=14//source coupling loss in dB
18 CL=10//connector loss in dB
19 e=1.6*10^-19//charge of electron in coulombs
```

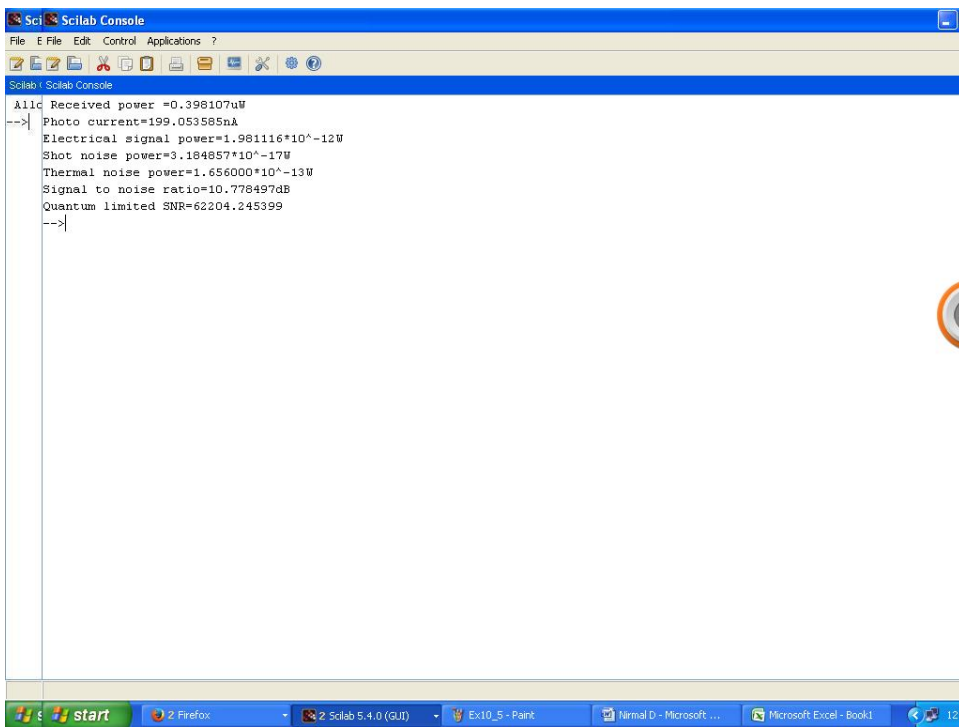


Figure 11.1: 1

```

20 k=1.38e-23//boltzman constant
21 //to find
22 TL=SCL+CL+L//total Loss in dB
23 Tn=10^(-TL/10)//transmission efficiency
24 PR=Pi*Tn//received power in W
25 is=Row*PR//photo current in A
26 PES=is^2*RL//Electrical signal power in W
27 PNS=2*e*is*BW*RL//shot noise power in W
28 PNT=4*k*Ta*BW//Thermal noise power in W
29 SNR=PES/PNT//signal to noise ratio
30 SNRdB=10*log10(SNR)//signal to noise ratio in dB
31 SNRQL=is/(2*e*BW)//quantum limited SNR
32
33
34 mprintf("Received power =%fuW",PR*10^6)//
    multiplication by 10^6 to convert the unit from W
    to uW
35 mprintf("\nPhoto current=%fnA",is*10^9)//
    multiplication by 10^9 to convert the unit from A
    to nA
36 mprintf("\nElectrical signal power=%f*10^-12W",PES
    *10^12)//multiplication by 10^12 to convert the
    unit from W to x10^-12W
37 mprintf("\nShot noise power=%f*10^-17W",PNS*10^17)//
    multiplication by 10^17 to convert the unit from
    W to x10^-17W
38 mprintf("\nThermal noise power=%f*10^-13W",PNT
    *10^13)//multiplication by 10^13 to convert the
    unit from W to x10^-13W
39 mprintf("\nSignal to noise ratio=%fdB",SNRdB)
40 mprintf("\nQuantum limited SNR=%f",SNRQL)
41 //this is the exact answer, book has taken
    approximated values of parameters and its
    Quantum limited SNR is 62500

```

---

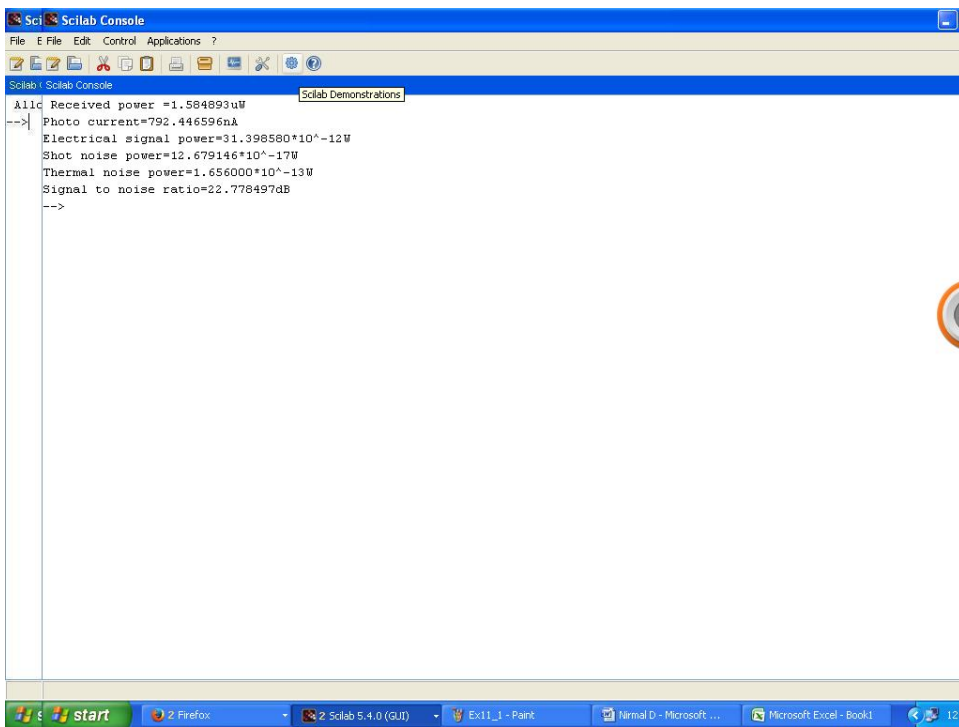


Figure 11.2: 2



## Scilab code Exa 11.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 11.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear all
8 //given
9 lambda=0.85e-6//wave length in um
10 Pi=10*10^-3//led Power in W
11 L=20//fiber cable loss in dB
12 Row=0.5//responsivity in A/W
13 ID=2*10^-9//Detector dark current in A
14 RL=50//load resistance in ohm
15 BW=10*10^6//receiver's bandwidth in Hz
16 Ta=300//temperature in Kelvin
17 SCL=14//source coupling loss in dB
18 CL=10//connector loss in dB
19 e=1.6*10^-19//charge of electron in columbs
20 k=1.38e-23//boltzman constant
21 DL=6//decreased loss in dB
22 //to find
23 TL=SCL+CL+L-DL//total Loss in dB
24 Tn=10^(-TL/10)//transmission efficiency
25 PR=Pi*Tn//received power in W
26 is=Row*PR//photo current in A
27 PES=is^2*RL//Electrical signal power in W
28 PNS=2*e*is*BW*RL//shot noise power in W
29 PNT=4*k*Ta*BW//Thermal noise power in W
30 SNR=PES/PNT//signal to noise ratio
31 SNRdB=10*log10(SNR)//signal to noise ratio in dB
32
```

```

33 mprintf(" Received power =%fuW",PR*10^6) //
    multiplication by 10^6 to convert the unit from W
    to uW
34 mprintf("\nPhoto current=%fnA",is*10^9) //
    multiplication by 10^9 to convert the unit from A
    to nA
35 mprintf("\nElectrical signal power=%f*10^-12W",PES
    *10^12)//multiplication by 10^12 to convert the
    unit from W to x10^-12W
36 mprintf("\nShot noise power=%f*10^-17W",PNS*10^17) //
    multiplication by 10^17 to convert the unit from
    W to x10^-17W
37 mprintf("\nThermal noise power=%f*10^-13W",PNT
    *10^13)//multiplication by 10^13 to convert the
    unit from W to x10^-13W
38 mprintf("\nSignal to noise ratio=%fdB",SNRdB)

```

---

### Scilab code Exa 11.3 3

```

1 //fiber optic communications by joseph c. palais
2 //example 11.3
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear all
8 //given
9 lambda=0.85e-6//wave length in um
10 Pi=10*10^-3//led Power in W
11 L=20//fiber cable loss in dB
12 Row=0.5//responsivity in A/W
13 ID=2*10^-9//Detector dark current in A
14 RL=50//load resistance in ohm

```

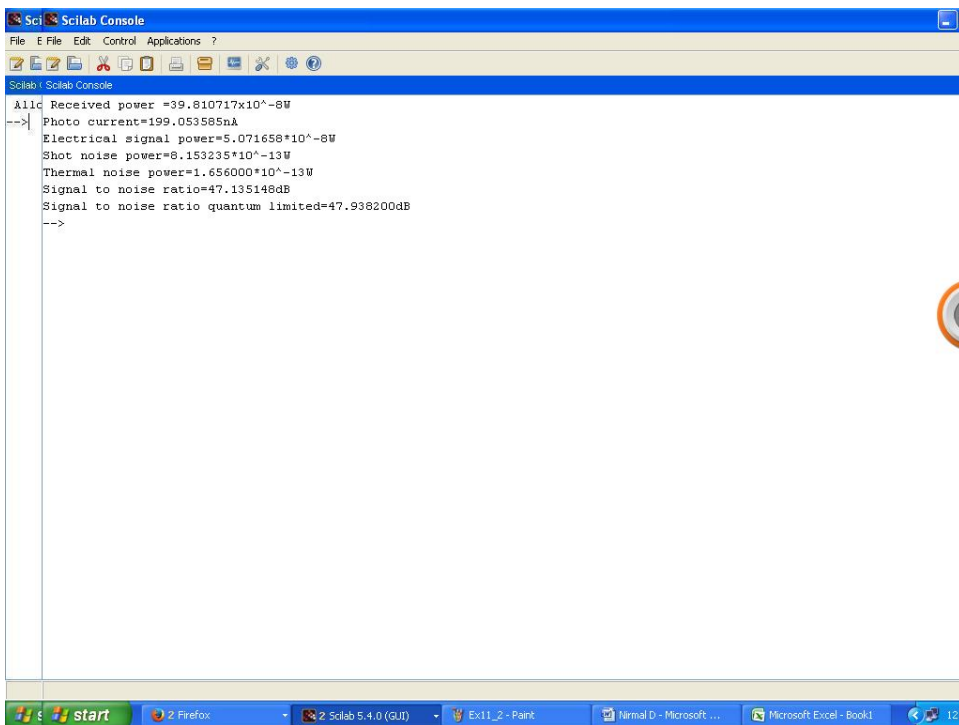


Figure 11.3: 3

```

15 BW=10*10^6//receiver's bandwidth in Hz
16 Ta=300//temperature in Kelvin
17 SCL=14//source coupling loss in dB
18 CL=10//connector loss in dB
19 e=1.6*10^-19//charge of electron in coulombs
20 k=1.38e-23//boltzman constant
21 M=160//multiplication factor
22 //to find
23 TL=SCL+CL+L//total Loss in dB
24 Tn=10^(-TL/10)//transmission efficiency
25 PR=Pi*Tn//received power in W
26 is=Row*PR//photo current in A
27 PES=is^2*RL*M^2//Electrical signal power in W
28 PNS=2*e*is*BW*RL*M^2//shot noise power in W
29 PNT=4*k*Ta*BW//Thermal noise power in W
30 SNR=PES/(PNT+PNS)//signal to noise ratio
31 SNRdB=10*log10(SNR)//signal to noise ratio in dB
32 SNRQL=is/(2*e*BW)//quantum limited SNR
33 SNRQLdB=10*log10(SNRQL)//quantum limited SNR in dB
34 //mprintf("Received power =%fx10^-8W",PR*10^8)//
    multiplication by 10^8 to convert the unit from W
    to x10^-8W
35 //mprintf("\nPhoto current=%fnA",is*10^9)//
    multiplication by 10^9 to convert the unit from A
    to nA
36 mprintf("\nElectrical signal power=%f*10^-8W",PES
    *10^8)//multiplication by 10^12 to convert the
    unit from W to x10^-8W
37 mprintf("\nShot noise power=%f*10^-13W",PNS*10^13)//
    multiplication by 10^13 to convert the unit from
    W to x10^-13W
38 mprintf("\nThermal noise power=%f*10^-13W",PNT
    *10^13)//multiplication by 10^13 to convert the
    unit from W to x10^-13W
39 mprintf("\nSignal to noise ratio=%fdB",SNRdB)//The
    answers vary due to round off error
40 mprintf("\nSignal to noise ratio quantum limited=
    %fdB",SNRQLdB)// The answers vary due to round

```

off error

---

#### Scilab code Exa 11.4 4

```
1 //fiber optic communications by joseph c. palais
2 //example 11.4
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 //given
6 clc
7 clear
8 //given
9 lambda=0.85e-6//wave length in um
10 Row=0.5//responsivity in A/W
11 ID=2*10^-9//Detector dark current in A
12 RL=100//load resistance in ohm
13 deltaf=1*10^6//receiver's bandwidth in Hz
14 T=300//temperature in Kelvin
15 e=1.6*10^-19//charge of electron in coulombs
16 k=1.38e-23//boltzman constant
17
18 //to find
19
20 for i=1:6
21     RL1(i)=10^(i*2);//range of load resistance in
        ohm
22     logRL(i)=log10(RL1(i))//log scale representation
        of load resistance
23     iNT(i)=sqrt(4*k*T*deltaf/RL1(i))//rms thermal
        noise current in A
24 iNSD(i)=sqrt(2*e*ID*deltaf)//rms shot noise current
        in A
25 NEP(i)=sqrt(iNSD(i)^2+iNT(i)^2)/(RL*sqrt(deltaf))//
        Noise equivalent power (NEP) in W/Hz^1/2
26
```

```

27 logNEP(i)=log10(NEP(i))
28 end
29 iNT1=sqrt(4*k*T*deltaf/RL)//rms thermal noise
    current in A
30 iNSD1=sqrt(2*e*ID*deltaf)//rms shot noise current in
    A
31 NEP1=sqrt(iNSD1^2+iNT1^2)/(RL*sqrt(deltaf))//Noise
    equivalent power (NEP) in W/Hz^1/2
32 Pmin=NEP1*sqrt(deltaf)//minimum detectable power
33 mprintf("Minimum detectable power =%fnW",Pmin*10^9)
    //multiplication by 10^9 to convert unit from W
    to nW
34 plot2d('ll', RL1, NEP)
35
36 xtitle("Noise equivalent power for a PIN diode
    having 2nA of Dark current and a 0.5W/A
    responsivity at 300K", "Load Resistance (Ohms)",
    "NEP (W/Hz^1/2)");

```

---

### Scilab code Exa 11.5 5

```

1 //fiber optic communications by joseph c. palais
2 //example 11.5
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 RL=100//load in ohm
9 T=300//temperature in kelvin
10 lambda=0.82*10^-6//wavelength in um

```

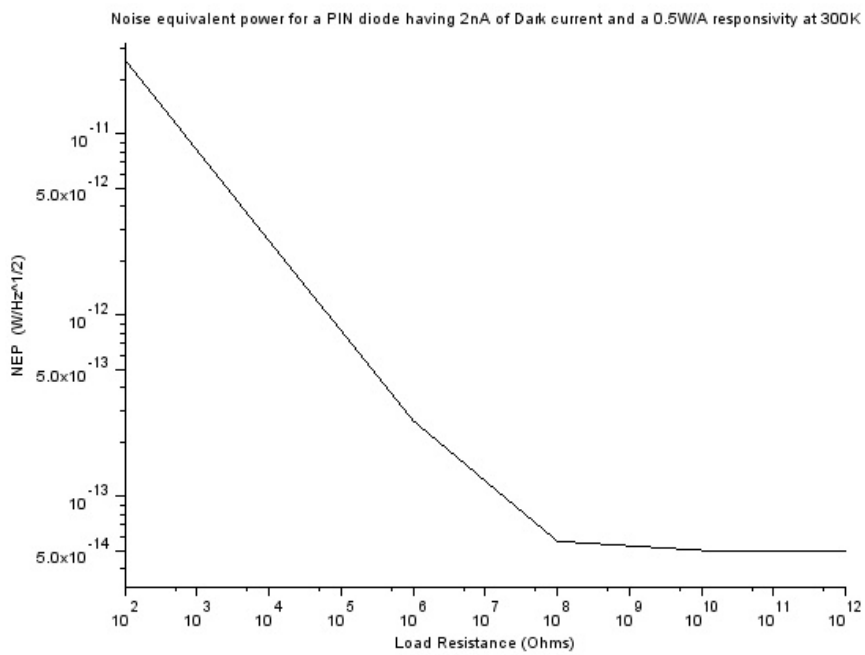


Figure 11.4: 4

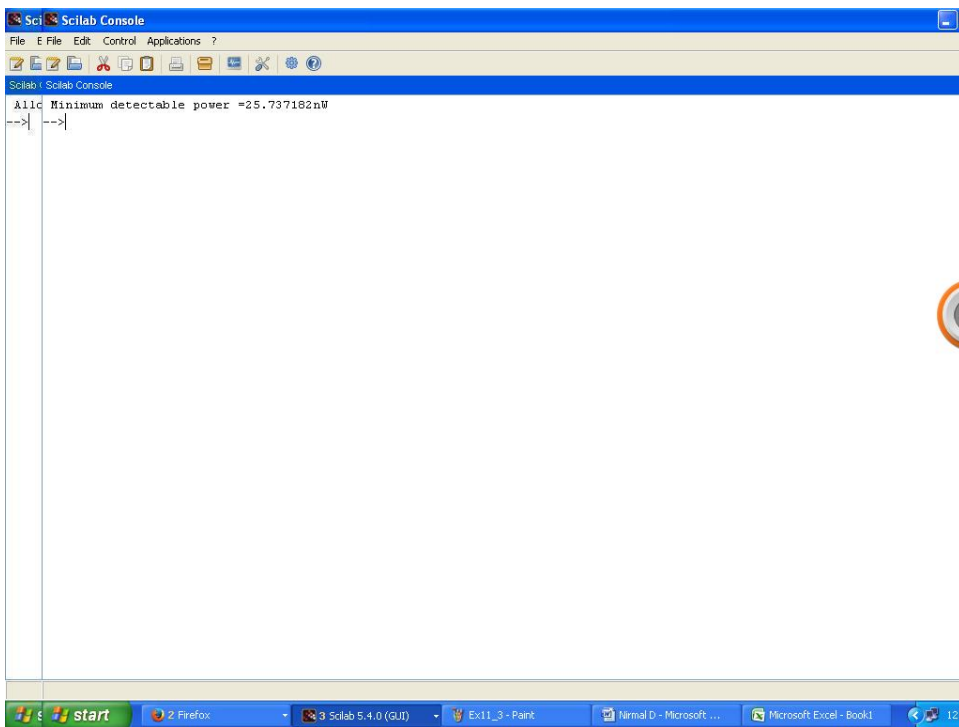


Figure 11.5: 4



```

11 e=1.6e-19//charge of electron in coulombs
12 k=1.38e-23//boltzman constant
13 h=6.63e-34//plancks constant
14 deltaf=1e6//link bandwidth in Hz
15 Error_rate=10^-4//desired error rate
16 eta=1//quantum efficiency
17 c=3*10^8//speed of light in m/s
18 snr=17.5//Signal to noise ratio from plot
    corresponding to error rate of 10^-4 in dB
19 SNR=10^(snr/10)//signal to noise ratio in normal
    scale
20 tau=10^-6//bit interval in Sec
21 //to find
22 f=c/lambda//optic frequency in Hz
23 P=(h*f/(eta*e) )*sqrt((4*k*T*deltaf)/RL)*sqrt(SNR)//
    Optic power incident in Watts
24 mprintf(" Optic power incident=%fnW",P*10^9)//
    multiplication by 10^9 is to convert the unit
    from W to nW
25 i=eta*e*P/(h*f)//current in Amperes
26 mprintf("\nCurrent=%fnA",i*10^9)//multiplication by
    10^9 is to convert the unit from A to nA
27 np=P/(h*f)*tau// No. of photons per bit
28 mprintf("\nNo. of Photons per bit=%fx10^5 photons/
    bit",np/10^5)//multiplication by 10^5 is to
    convert the unit x10^5

```

---

### Scilab code Exa 11.6 6

```

1 //fiber optic communications by joseph c. palais
2 //example 11.6

```

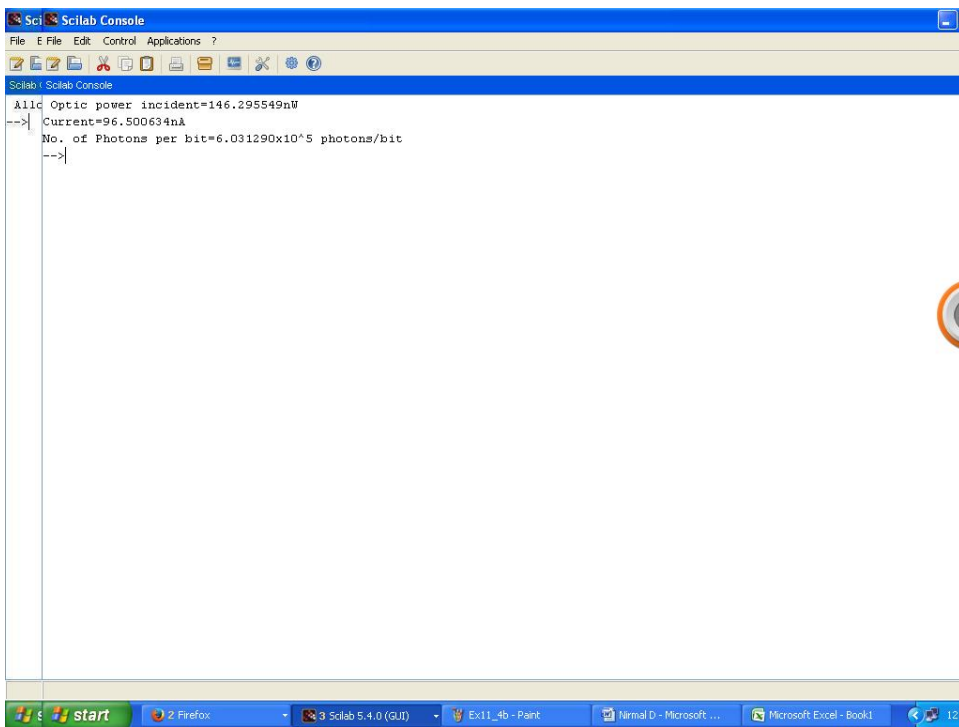


Figure 11.6: 5

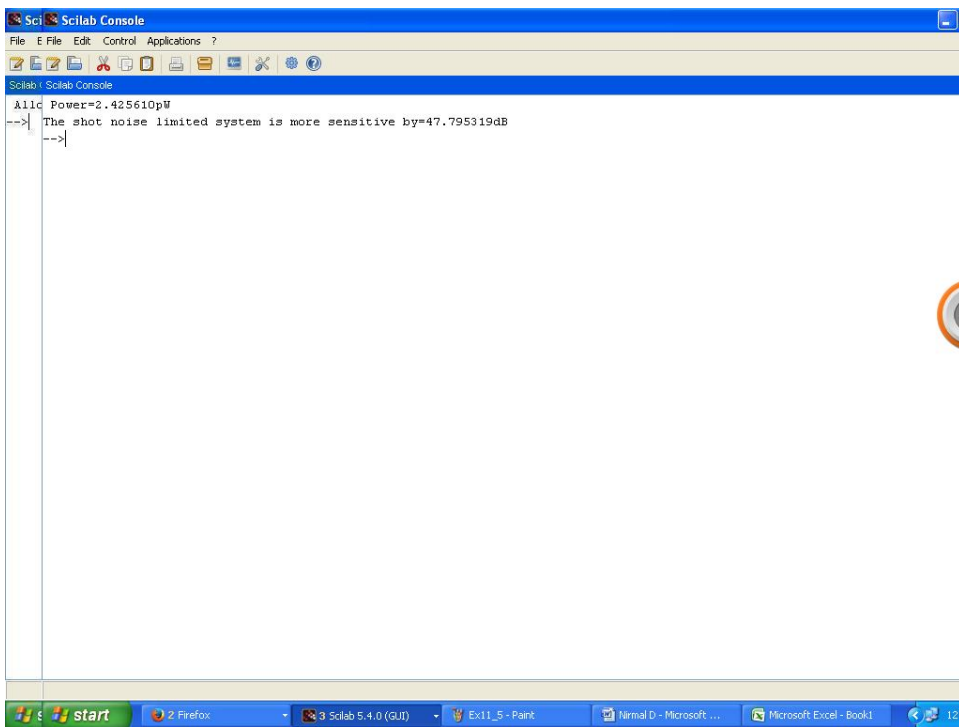


Figure 11.7: 6

```

3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda=0.82e-6//wave length in m
9 h=6.63e-34//planks constant
10 tau=1e-6//bit period in Sec
11 c=3e8//light speed in m/s
12 ns=10//no. of photons required per bit
13 eta=1//Quantum efficiency
14 Pt=146*10^-9//power in thermal system from Ex11
    .5=146nW
15 //to find
16 P=(h*c*ns)/(eta*lambda*tau)// optic power in W
17 mprintf("Power=%fpW",P*10^12)
18 sensitivity=10*log10(Pt/P)//The shot noise limited
    system sensitivity
19 mprintf("\nThe shot noise limited system is more
    sensitive by=%fdB",sensitivity)

```

---

### Scilab code Exa 11.7 7

```

1 //fiber optic communications by joseph c. palais
2 //example 11.7
3 //OS=Windows XP sp3
4 clc
5 clear all
6 //given
7 Pi=2e-12//signal power in W
8 K=1.38e-23//temperature in kelvin
9 deltaf=1e7//bandwidth in Hz
10 TA=300//Ambient temperature in Kelvin

```

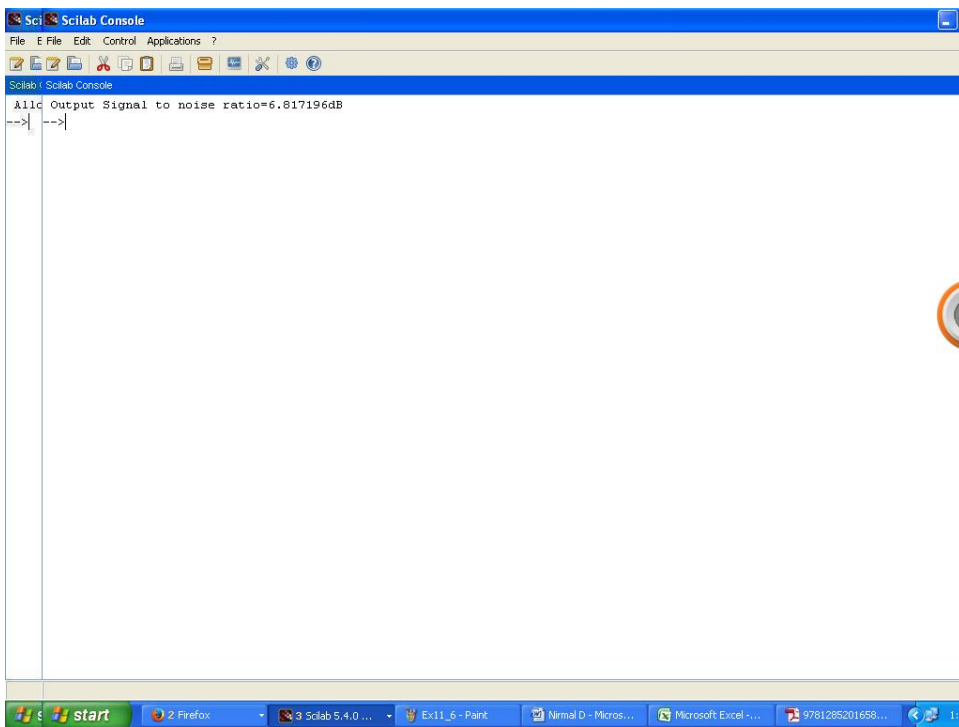


Figure 11.8: 7

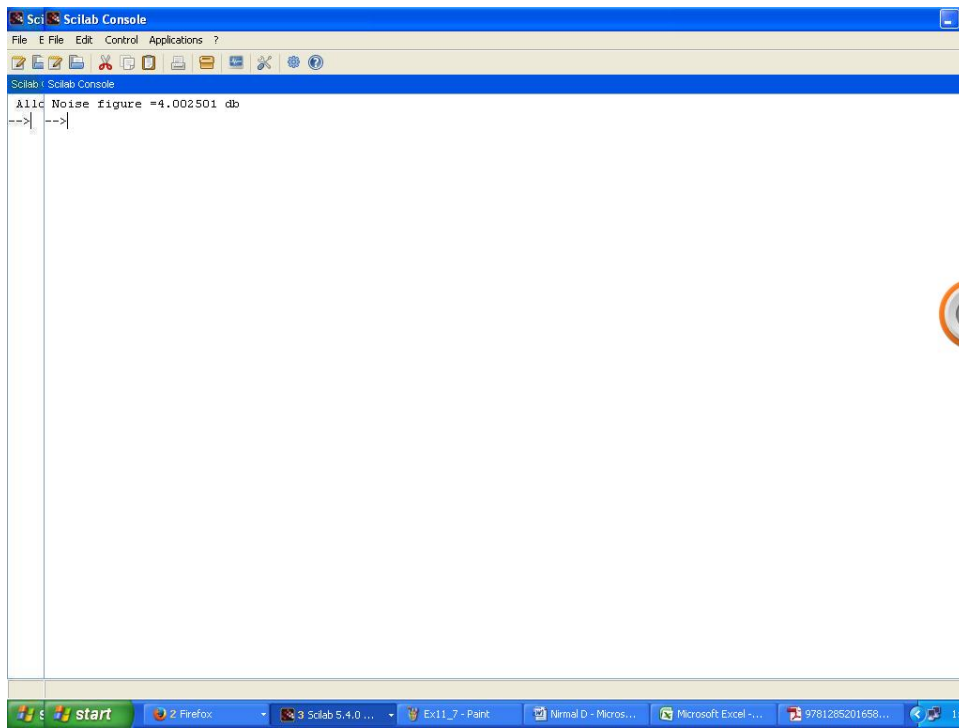


Figure 11.9: 8

```

11 T=454 //noise temperature in Kelvin
12 PNT=1.66*10^-11 //thermal noise power in W at 300K
13 G=10 //power gain of amplifier in dB
14 //to find
15 Te=T+TA //equivalent noise temperature in Kelvin
16 PN=4*K*Te*deltaf //Noise power in W
17 SNR=Pi/PN //Signal to noise ratio
18 SNRdb=10*log10(SNR) //Signal to noise ratio in dB
19 mprintf("Output Signal to noise ratio=%fdb",SNRdb)

```

---

Scilab code Exa 11.8 8

```

1 //fiber optic communications by joseph c. palais
2 //example 11.8
3 //given
4 //OS=Windows XP sp3
5 //Scilab version 5.4.1
6 clc
7 clear all
8 //given
9 TA=300//Ambient temperature in Kelvin
10 T=454//noise temperature in Kelvin
11 //to find
12 F=1+(T/TA)//Noise figure
13 Fdb=10*log10(F)//Noise figure in dB
14 mprintf("Noise figure =%f db",Fdb)

```

---

#### Scilab code Exa 11.9 9

```

1 //fiber optic communications by joseph c. palais
2 //given
3 //example 11.9
4 //OS=Windows XP sp3
5 //Scilab version 5.4.1
6 clc
7 clear all
8 //given
9 alphadb=30//transmission loss in dB
10 Gi=1e3//gain
11 Fldb=3//noise figure of amplifier in dB
12 N=10//Number of amps
13 SNRin=1e8//signal to noise at transmitter at input
14 //to find
15 alpha=10^(alphadb/10)//transmission loss in normal
    scale

```

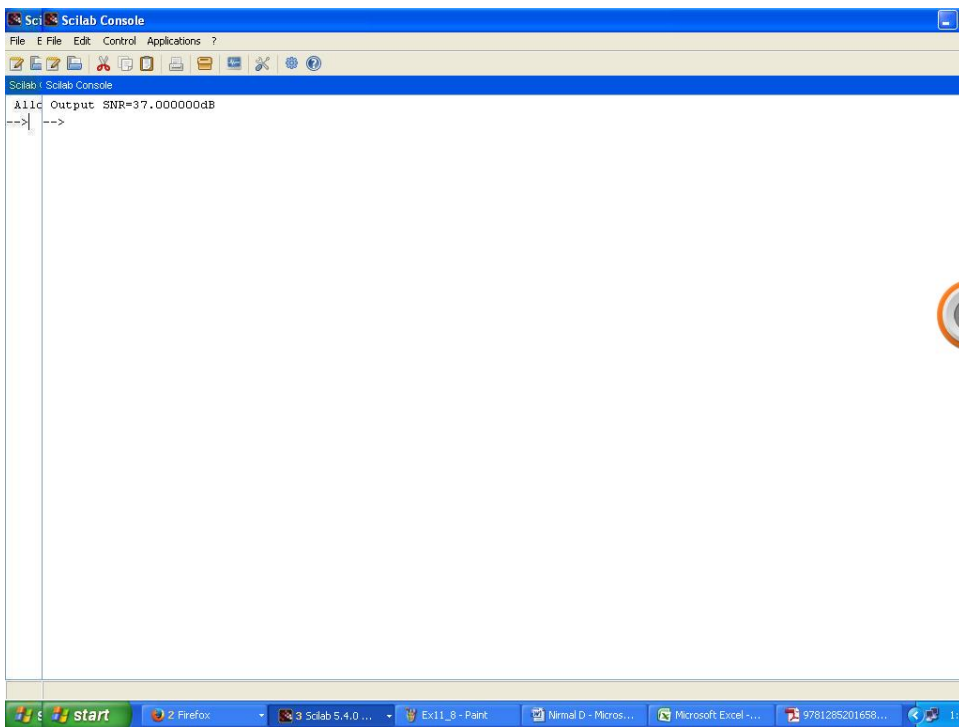


Figure 11.10: 9



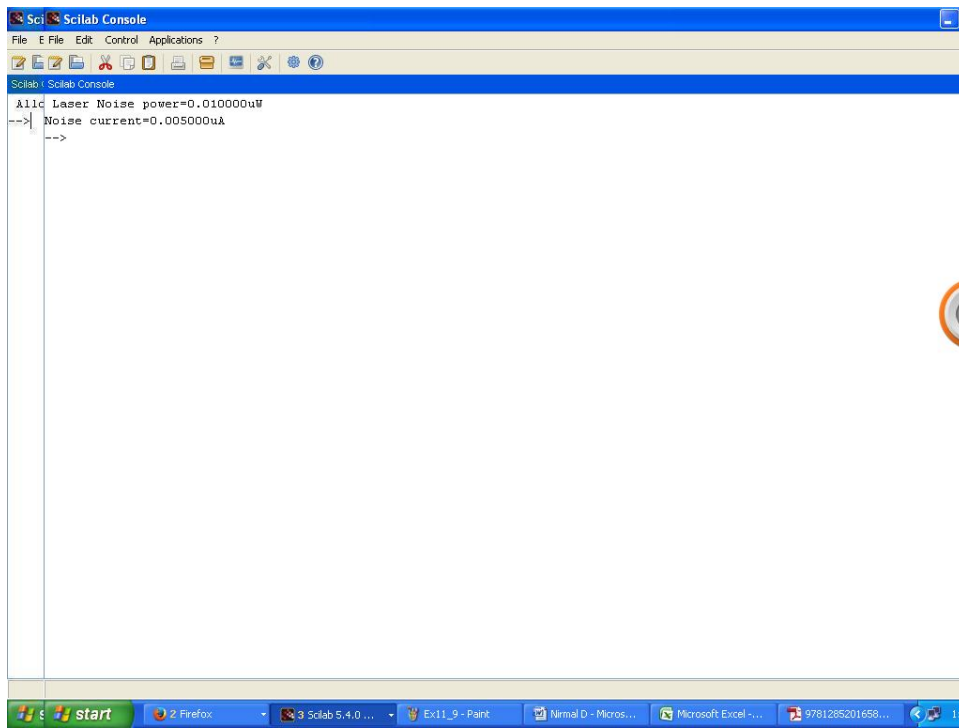


Figure 11.11: 10

```

16 Fi=10^(Fidb/10)//noise figure of amplifier in normal
    scale
17 F=N*Fi*Gi//Noise Figure
18 SNRout=SNRin/F//output signal to noise
19 SNRoutdb=10*log10(SNRout)//output signal to noise in
    dB
20 mprintf(" Output SNR=%fdB",SNRoutdb)

```

---

Scilab code Exa 11.10 10

```

1 //fiber optic communications by joseph c. palais

```

```

2 //example 11.10
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 RINdB=-140//RIN in dB/Hz
9 deltax=100*10^6//bandwidth in Hz
10 P=10*10^-6//Average incident power in Watts
11 Row=0.5//Responsivity in uA/uW
12
13 //to find
14 RIN=10^(RINdB/10)//RIN in /Hz
15 PNL=sqrt(RIN*P^2*deltax)//Laser Noise power in Watt
16 mprintf(" Laser Noise power=%fuW",PNL*10^6)//
    multiplication by 10^6 to convert the unit from W
    to uW
17 IN=Row*PNL// Noise current in A
18 mprintf(" \nNoise current=%fuA",IN*10^6)//
    multiplication by 10^6 to convert the unit from A
    to uA

```

---

# Chapter 12

## System Design

Scilab code Exa 12.1 1

```
1 //fiber optic communications by joseph c. palais
2 //example 12.1
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
7 //given
8 lambda=0.82//wavelength in um
9 ER=10^-9//Error rate
10 datarate=100//data rate for RZ system in Mbps
11 NRZ_Qp1=-63//power level for NRZ in dBm from figure
    12.4
12 NRZ_TL=-36//thermal limit for NRZ in dBm from figure
    12.4
13 //to find
14 RZ_Qp1=NRZ_Qp1+3//power level for RZ in dBm
15 RZ_TL=NRZ_TL+3//thermal limit for RZ in dBm
16 //mprintf("Power level for NRZ=%fdBm",NRZ_Qp1)
17 //mprintf("\nThermal limit for NRZ =%fdBm",NRZ_TL)
18 mprintf("Power level for RZ=%fdBm",RZ_Qp1)
19 mprintf(" \nThermal limit for RZ =%fdBm",RZ_TL)
```

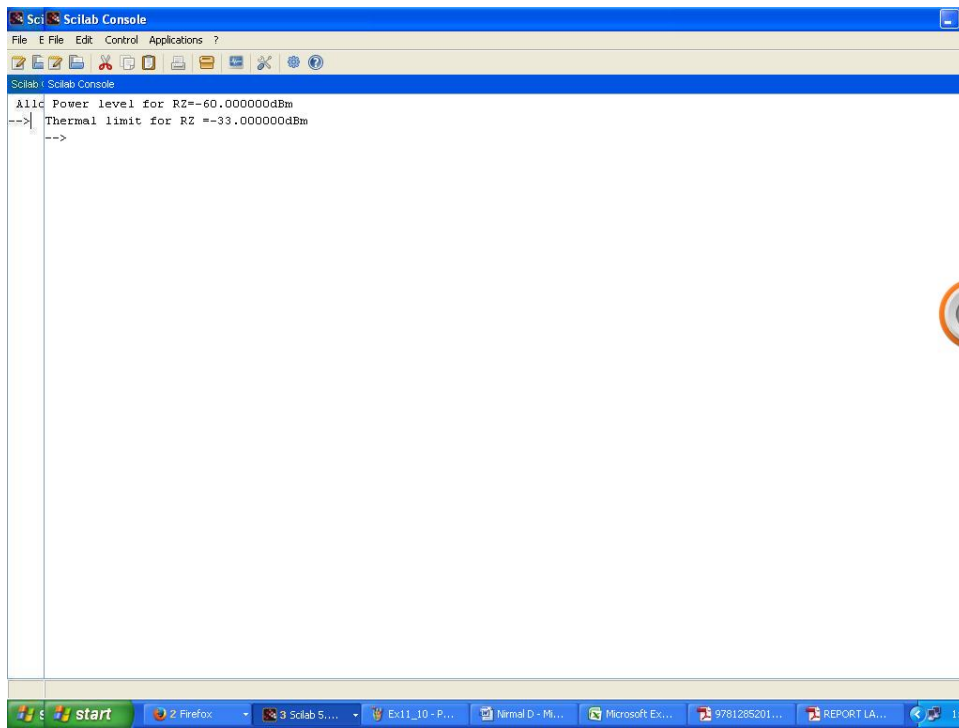


Figure 12.1: 1

### Scilab code Exa 12.2 2

```
1 //fiber optic communications by joseph c. palais
2 //example 12.2
3 //OS=Windows XP sp3
4 //Scilab version 5.4.1
5 clc
6 clear all
```

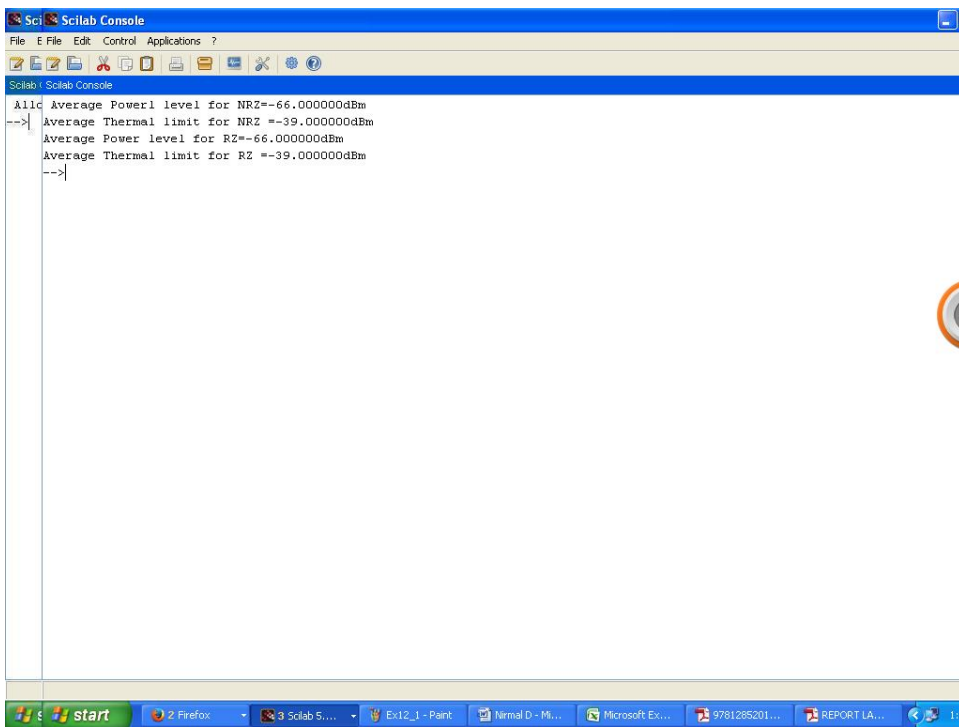


Figure 12.2: 2

```

7 //given
8 //from example 12.1
9 lambda=0.82//wavelength in um
10 ER=10^-9//Error rate
11 datarate=100//data rate for RZ system in Mbps
12 NRZ_Qp1=-63//power level for NRZ in dBm
13 NRZ_TL=-36//thermal limit for NRZ in dBm
14 //to find
15 RZ_Qp1=NRZ_Qp1+3//power level for RZ in dBm from
    fig 12.4
16 RZ_TL=NRZ_TL+3//thermal limit for RZ in dBm from fig
    12.4
17 Avg_NRZ_Qp1=NRZ_Qp1-3//Average for NRZ is half so 3
    db LESS in dBm
18 Avg_NRZ_TL=NRZ_TL-3//Average for NRZ is half so 3db
    LESS in dBm
19 Avg_RZ_Qp1=RZ_Qp1-6//Average for RZ is ONE FOURTH so
    6db LESS in dBm
20 Avg_RZ_TL=RZ_TL-6//Average for RZ is ONE FOURTH so 6
    db LESS in dBm
21
22 mprintf(" Average Power level for NRZ=%fdBm",
    Avg_NRZ_Qp1)
23 mprintf(" \nAverage Thermal limit for NRZ =%fdBm",
    Avg_NRZ_TL)
24 mprintf(" \nAverage Power level for RZ=%fdBm",
    Avg_RZ_Qp1)
25 mprintf(" \nAverage Thermal limit for RZ =%fdBm",
    Avg_RZ_TL)

```

---