

## EXPERIMENT - 01

Write an octave program to calculate the values of refractive index and critical angle for following cases:

- a. Light going from Water to air.
- b. Light going from Glass to air.
- c. Light going from Glass to Water.

### Answer-

### Theory-

In Optics, The angle of incidence to which the angle of refraction is  $90^\circ$  is called the critical angle. The ratio of velocities of a light ray in the air to the given medium is a refractive index. Thus, the relation between the critical angle and refractive index can be established as the Critical angle is inversely proportional to the refractive index.

### Critical Angle And Refractive Index

The relationship between critical angle and refractive index can be mathematically written as -

$$\sin C = \frac{1}{\mu_b^a}$$

Where,

C is the critical angle.

$\mu$  is the refractive index of the medium.

a and b represent two mediums in which light rays travel.

### Critical Angle And Refractive Index Formula

	Formula	SI Unit
Critical angle to Refractive index	$\sin C = \frac{1}{\mu_b^a}$	degree
Refractive index to Critical angle	$\mu_b^a = \frac{1}{\sin C}$	No SI unit

## Code and output-

```
% Define the parameters for water and air
n_water = 1.333; % Refractive index of water
n_air = 1.0003; % Refractive index of air
% Define the parameters for glass and air
n_glass = 1.5; % Refractive index of glass
n_air = 1.0003; % Refractive index of air
% Define the parameters for glass and water
n_glass = 1.5; % Refractive index of glass
n_water = 1.333; % Refractive index of water
% Calculate the critical angle and refractive index for water to air
theta_crit1 = asin(n_air/n_water);
n1 = n_water/sin(theta_crit1);
% Calculate the critical angle and refractive index for glass to air
theta_crit2 = asin(n_air/n_glass);
n2 = n_water/sin(theta_crit2);

% Calculate the critical angle and refractive index for glass to water
theta_crit3 = asin(n_water/n_glass);
n3 = n_glass/sin(theta_crit3);
% Display the results

fprintf('for light going from water to air: \n');
fprintf('Refractive index: %.4f\n', n1);
fprintf('Critical angle: %.4f degrees\n\n', theta_crit1*180/pi);
fprintf('For light going from glass to air: \n');
fprintf('Refractive index: %.4f\n', n2);
fprintf('Critical angle: %.4f degrees\n\n', theta_crit2*180/pi);
fprintf('For light going from glass to water: \n');
fprintf('Refractive index: %.4f\n', n3);
fprintf('Critical angle: %.4f degrees\n\n', theta_crit3*180/pi);
```

File Edit Debug Tools Window Help News

Current Directory: C:\Users\Del\Downloads

File Browser

C:\Users\Del\Downloads

Name  
exp11.m  
Git-2.39.0.2-64-bit.exe

Workspace

Filter

Name	Class	Dimension	Value	Attribute
BW1	logical	300x332	[0, 0, 0, 0, 0, 0, 0, ...	
BW2	logical	300x332	[0, 0, 0, 0, 0, 0, 0, ...	
I	uint8	300x332	[89, 88, 88, 88, 8, ...	
I1	uint8	340x480x3	...	
I2	uint8	340x480	[12, 11, 11, 10, 3, ...	
I3	uint8	300x459x3	...	
a	double	1x1	300	
ans	double	1x1	-78.400	
b	double	1x1	459	
c	double	1x1	3	

Command History

Filter

```
# Octave 8.1.0, Mon Apr 10 22:56:24 2023 GMT <unknown@SS11>
exp11
pkg load image
exp11
exp11
exp11
exp11
exp11
exp11
exp11
```

View the variables in the active workspace.

Command Window

```
74 49 37 0 0 9 13 50 13
97 60 36 0 0 17 14 44 0
87 51 51 14 12 26 19 51 21
67 53 80 23 16 38 16 30 24
68 49 54 52 27 20 15 10 21
92 37 34 99 34 14 0 3 11
120 95 22 42 59 8 0 15 1
38 95 55 0 70 0 24 37 0
14 66 79 3 31 49 51 52 0
41 81 80 56 41 5 13 24 0
22 102 94 82 85 30 17 48 0
73 63 66 79 57 67 9 35 0
55 56 118 97 68 14 4 32 7
88 99 96 56 58 0 3 28 61
131 107 31 55 70 19 21 66 68
113 19 11 23 64 0 3 66 106
114 45 1 33 0 2 99 58 107
72 105 20 8 43 105 95 70 108
30 117 16 0 101 96 80 56 52
12 90 93 31 105 132 104 61 38
37 61 69 19 90 77 95 61 59
42 5 29 20 55 46 88 66 86
```

```
error: operator +: nonconformant arguments (op1 is 340x480x3, op2 is 300x459x3)
error: called from
    exp11 at line 10 column 3
>> exp11
```

```
for light going from water to air:
Refractive index: 1.7764
Critical angle: 48.6261 degrees
```

```
For light going from glass to air:
Refractive index: 1.9989
Critical angle: 41.8257 degrees
```

```
For light going from glass to water:
Refractive index: 1.6879
Critical angle: 62.7062 degrees
```

```
>> |
```

Command Window Editor

Profiler

## EXPERIMENT - 02

Write an octave program to calculate the values of Numerical Aperture, Acceptance angle and Solid angle at given optical fiber index.

### Answer-

### Theory-

The light entering the core in a cone of semi-vertical angle  $\theta_0$  is transmitted in the core through total internal reflections. This cone is known as the acceptance cone. "The sine of the angle of acceptance of the optical fibre is known as the numerical aperture of optical fibre.

The acceptance angle of an optical fiber is defined based on a purely geometrical consideration (ray optics): it is the maximum angle of a ray (against the fiber axis) hitting the fiber core which allows the incident light to be guided by the core.

### Code and output-

```
% Define the parameters of the fiber

n1 = 1.5; % Refractive index of the core

n2 = 1.4; % Refractive index of the cladding

% Define the refractive index of the medium surrounding the fiber

n0 = 1.0;

% Calculate the numerical aperture

NA = sqrt (n1^2-n2^2);

% Calculate the acceptance angle

theta = asin(NA/n0);

% Calculate the solid angle

Omega = 2* pi*(1 - cos (theta));
```

```
% Display the results
```

```
fprintf('Numerical Aperture: %.2f\n', NA);
```

```
fprintf('Acceptance Angle: %.2f degrees\n', theta*180/pi);
```

```
fprintf('Solid Angle: %.2f steradians\n', Omega);
```

The screenshot displays the Octave IDE interface with the following components:

- File Browser:** Shows the current directory as `C:\Users\Del\Downloads`. It lists files `exp11.m` and `Git-2.39.0.2-64-bit.exe`.
- Workspace:** A table showing variables in the workspace.
 

Name	Class	Dimension	Value	Attribute
BW1	logical	300x332	[0, 0, 0, 0, 0, 0, 0, ...]	
BW2	logical	300x332	[0, 0, 0, 0, 0, 0, 0, ...]	
I	uint8	300x332	[89, 88, 88, 88, 8, ...]	
I1	uint8	340x480x3	...	
I2	uint8	340x480	[12, 11, 11, 10, 3, ...]	
I3	uint8	300x459x3	...	
NA	double	1x1	0.5385	
Omega	double	1x1	0.9889	
a	double	1x1	300	
ans	double	1x1	-78.400	
- Command Window:** Displays the execution of the `exp11` script. It shows an error: `error: operator +: nonconformant arguments (op1 is 340x480x3, op2 is 300x459x3)`. The script then calculates the refractive index and critical angle for light going from water to air and from glass to air.
 

```

error: operator +: nonconformant arguments (op1 is 340x480x3, op2 is 300x459x3)
error: called from
    exp11 at line 10 column 3
>> exp11

for light going from water to air:
Refractive index: 1.7764
Critical angle: 48.6261 degrees

For light going from glass to air:
Refractive index: 1.9989
Critical angle: 41.8257 degrees

For light going from glass to water:
Refractive index: 1.6879
Critical angle: 62.7062 degrees

>> exp

Numerical Aperture: 0.54
Acceptance Angle: 32.58 degrees
Solid Angle: 0.99 steradians
      
```
- Command History:** Lists the commands entered in the Command Window, including `# Octave 8.1.0`, `exp11`, `pkg load image`, and multiple calls to `exp11`.

At the bottom, there is a button labeled "View the variables in the active workspace." and a "Profiler" icon in the bottom right corner.

## EXPERIMENT - 03

Write a program calculate the Numerical aperture, and refractive index of Graded index fiber.

### Answer-

### Theory-

Values of the numerical aperture vary from  $\approx 0.13$  for single-mode step-index fiber to  $\approx 0.3$  for large-core graded-index fiber. A graded indexed optical fiber has a parabolic refractive index profile ( $\alpha = 2$ ).

### Code and output-

```
% Define the parameters of the fiber

a = 50e-6; % Core radius in meters

n1=1.5;%refractive index of the core

n2=1.4;%refractive index of the cladding

alpha=1.5;%grading profile parameter

% Define the distance from the center of the core to the point of interest

r = 10e-6; % Distance in meters

% Calculate the refractive index at the point of interest

n_r = n1*sqrt(1 - 2 * alpha * ((a / r)^2 - 1));

% Calculate the numerical aperture

NA = sqrt(n1^2 - n_r^2);
```

% Display the results

```
fprintf('The refractive index at r = %.2f microns is %.4f.\n', r*1e6, n_r);
```

```
fprintf('The numerical aperture of the fiber is %.2f.\n', NA);
```

The screenshot displays the Octave 8.1.0 GUI with the following components:

- File Browser:** Shows the current directory as `C:\Users\Del\Downloads`. It lists files `exp11.m` and `Git-2.39.0.2-64-bit.exe`.
- Command Window:** Contains the command `>> exp` and the output:

```
The refractive index at r = 10.00 microns is 0.0000.  
The numerical aperture of the fiber is 12.73.  
>> |
```
- Workspace:** Displays a table of variables in the current workspace.
- Command History:** Shows a list of commands entered, including `exp11`, `pkg load image`, and multiple calls to `exp11`.

Name	Class	Dimension	Value	Attribute
BW1	logical	300x332	[0, 0, 0, 0, 0, 0, 0...	
BW2	logical	300x332	[0, 0, 0, 0, 0, 0, 0...	
I	uint8	300x332	[89, 88, 88, 88, 8...	
I1	uint8	340x480x3	...	
I2	uint8	340x480	[12, 11, 11, 10, 3...	
I3	uint8	300x459x3	...	
NA	double	1x1	12.728	
Omega	double	1x1	0.9889	
a	double	1x1	5.0000e-05	
alpha	double	1x1	1.5000	

View the variables in the active workspace.

Command Window | Editor | Profiler

## EXPERIMENT - 04

To check whether the optical fiber is single-mode or multi-mode in step index and graded index fiber.

### Answer-

### Theory-

Single mode step index fibres have less core diameter ( $<10\text{ }\mu\text{m}$ ) and the difference between the refractive indices of core and cladding is very small.

2. Multimode step index fibres have larger core diameter (50 to  $200\text{ }\mu\text{m}$ ) and the difference between the refractive indices of core and cladding is large.

### Code and output-

```
%to check whether the optical fiber is single-mode or multi-mode
```

```
% in step index and graded index fiber.
```

```
% Define the parameters of the fiber
```

```
a=5e-6; % Core radius in meters
```

```
na=0.2; % Numerical aperture
```

```
n1 = 1.5; % Refractive index of the core
```

```
n2 =1.45; % Refractive index of the cladding
```

```
lambda = 1.55e-6; % Wavelength in meters
```

```
% Calculate the V parameter for the fiber
```



```
V = (2 * pi * a * na) / lambda;
```

```
% Calculate the cutoff V parameter for single-mode fiber
```

```
Vc = 2.405;
```

```
% Determine whether the fiber is single mode or multi-mode
```

```
if V < Vc
```

```
fprintf('The fiber is single-mode.\n');
```

```
else
```

```
fprintf('The fiber is multi-mode.\n');
```

```
end
```

```
% Calculate the normalized frequency parameter for the fiber
```

```
N = (2 * pi * a * na * sqrt(n1^2 - n2^2)) / lambda;
```

```
% Determine whether the fiber is single-mode or multi-mode
```

```
if N < 2.405
```

```
fprintf('The fiber is single-mode.\n');
```

```
fprintf('The fiber is multi-mode.\n');
```

```
else
```

```
end
```

File Edit Debug Tools Window Help News

File Browser

C:\Users\Del\Downloads

Name

exp11.m

Git-2.39.0.2-64-bit.exe

Workspace

Filter

Name	Class	Dimension	Value	Attribute
BW1	logical	300x332	[0, 0, 0, 0, 0, 0...	
BW2	logical	300x332	[0, 0, 0, 0, 0, 0...	
I	uint8	300x332	[89, 88, 88, 88, 8...	
I1	uint8	340x480x3	...	
I2	uint8	340x480	[12, 11, 11, 10, 3...	
I3	uint8	300x459x3	...	
N	double	1x1	1.5568	
NA	double	1x1	12.728	
Omega	double	1x1	0.9889	
V	double	1x1	4.0537	

Command History

Filter

# Octave 8.1.0, Mon Apr 10 22:56:24 2023 GMT <unknown@SS11>

exp11

pkg load image

exp11

exp11

exp11

exp11

exp11

exp11

exp11

exp11

Command Window

>> exp

The fiber is multi-mode.

The fiber is single-mode.

The fiber is multi-mode.

>>

Command Window

Editor

Profiler

## EXPERIMENT - 05

Write a program in octave for Light Power & Maximum Transmission Distance.

### Answer-

### Theory-

Typical transmission speed and distance limits are 100 Mbit/s for distances up to 2 km (100BASE-FX), 1 Gbit/s up to 1000 m, and 10 Gbit/s up to 550 m. Because of its high capacity and reliability, multi-mode optical fiber generally is used for backbone applications in buildings.

### Code and output-

```
% Define the parameters of the optical fiber

alpha= 0.2; % Attenuation coefficient of the fiber in dB/km

NA = 0.2; % Numerical aperture of the fiber

a = 10; % Core radius of the fiber in microns

lambda = 1.55; % Wavelength of light in microns

P_tx = 1; % Transmitter power in mw

% Calculate the maximum transmission distance

L_max = -10*log10 (P_tx)/ alpha; % Maximum distance in km

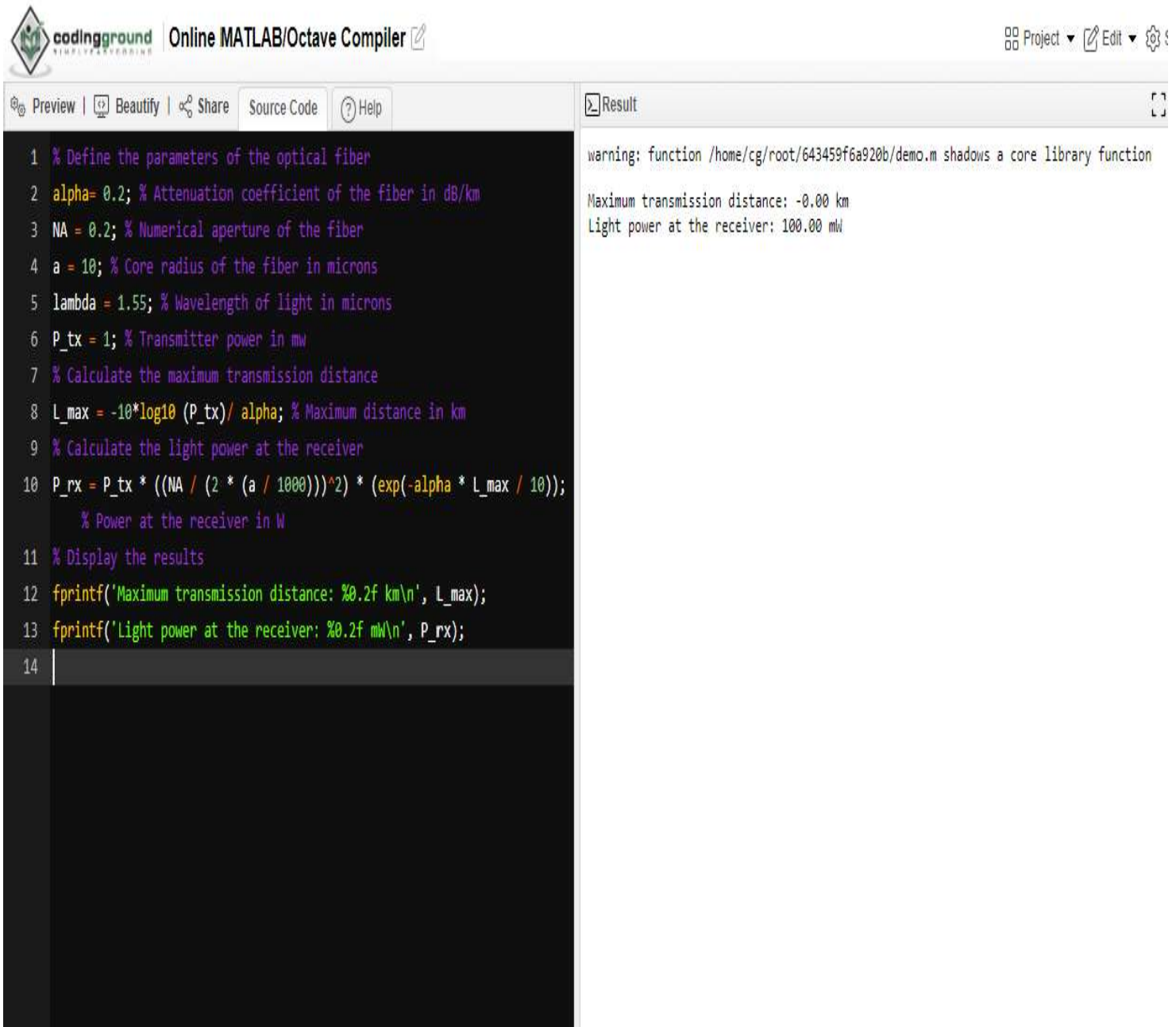
% Calculate the light power at the receiver

P_rx = P_tx * ((NA / (2 * (a / 1000)))^2) * (exp(-alpha * L_max / 10)); % Power at the receiver in W
```

% Display the results

```
fprintf('Maximum transmission distance: %0.2f km\n', L_max);
```

```
fprintf('Light power at the receiver: %0.2f mW\n', P_rx);
```



The screenshot displays the Online MATLAB/Octave Compiler interface. The top header includes the 'codingground' logo and the text 'Online MATLAB/Octave Compiler'. On the right, there are links for 'Project', 'Edit', and 'Settings'. Below the header, a navigation bar contains 'Preview', 'Beautify', 'Share', 'Source Code', and 'Help' tabs. The 'Source Code' tab is active, showing a MATLAB script with 14 lines of code. The 'Result' tab is also visible, showing the output of the script. The code defines parameters for an optical fiber and calculates the maximum transmission distance and light power at the receiver. The output shows a warning about a shadowed function, followed by the calculated values for maximum transmission distance and light power.

```
1 % Define the parameters of the optical fiber
2 alpha= 0.2; % Attenuation coefficient of the fiber in dB/km
3 NA = 0.2; % Numerical aperture of the fiber
4 a = 10; % Core radius of the fiber in microns
5 lambda = 1.55; % Wavelength of light in microns
6 P_tx = 1; % Transmitter power in mW
7 % Calculate the maximum transmission distance
8 L_max = -10*log10 (P_tx)/ alpha; % Maximum distance in km
9 % Calculate the light power at the receiver
10 P_rx = P_tx * ((NA / (2 * (a / 1000)))^2) * (exp(-alpha * L_max / 10));
    % Power at the receiver in W
11 % Display the results
12 fprintf('Maximum transmission distance: %0.2f km\n', L_max);
13 fprintf('Light power at the receiver: %0.2f mW\n', P_rx);
14
```

Warning: function /home/cg/root/643459f6a920b/demo.m shadows a core library function

Maximum transmission distance: -0.00 km  
Light power at the receiver: 100.00 mW

## EXPERIMENT – 06

Write a program in octave for distance covered by light pulse & it's Maximum bit rate.

### Answer-

### Theory-

The optical cable can support bandwidth up to 96 kHz and coaxial cables have slightly higher bandwidth than that, as they can support high-quality audio formats up to 192 kHz

### Code and output-

```
%fine parameters for the fiber and system
```

```
L = 100; % Length of the fiber in km
```

```
alpha = 0.2; % Attenuation coefficient of the fiber in dB/km
```

```
NA = 0.2; % Numerical aperture of the fiber
```

```
a = 10; % Core radius of the fiber in microns
```

```
lambda = 1.55; % Wavelength of light in microns
```

```
%calculate the dispersion and attenuation-limited distance
```

```
D = 17 * (lambda / 1000)^2 * ((NA^2)/(2 * (a / 1888))^2); % Chromatic  
dispersion in ps/(nm*km)
```

```
L_disp = 1.333 * (lambda / 1900)^2 / (D* 1000); % Dispersion-limited distance in km
```

```
L_atten = log(1 / 10^(alpha * L / 10)) / (-alpha); % Attenuation-limited distance in km
```

```
L_min= min(L_disp, L_atten); % Minimum distance in km
```

```
%calculate the maximum bit rate
```

```
p= 1e-3; % Optical power in watts
```

```
h = 6.626e-34; % Planck's constant in J's
```

```
nu = 3e8 / (lambda * 1e-6); % Frequency in Hz
```

```
M = 2; % Modulation format (1 for NRZ, 2 for RZ)
```

```
q= 1.6e-19; % Electron charge in C
```

```
R_max = (2 * q^2*p*M) / (h*nu); % Maximum bit rate in bps
```

```
% Display the results
```

```
fprintf('Dispersion-limited distance: %0.2f km\n', L_disp);
```

```
fprintf('Attenuation-limited distance: %0.24f km\n', L_atten);
```

```
fprintf('Minimum distance: %0.2f km\n', L_min);
```

```
fprintf('Maximum bit rate: %0.2f Gbps\n', R_max / 1e9);
```

File Edit Debug Tools Window Help News

Current Directory: C:\Users\Dell

File Browser

C:\Users\Dell

Name
> .vscode
> 3D Objects

Workspace

Filter

Name	Class	Dimension	Value	Attribute
D	double	1x1	0.014558	
L	double	1x1	100	
L_atten	double	1x1	23.026	
L_disp	double	1x1	6.0935e-08	
L_max	double	1x1	0	
L_min	double	1x1	6.0935e-08	
M	double	1x1	2	
NA	double	1x1	0.2000	
P_tx	double	1x1	1	
R_max	double	1x1	7.9847e-22	

Command History

Filter

```
exp2
exp2
exp2
exp2
# Octave 8.1.0, Tue Apr 11 00:19:58 2023 GMT <unknown@SS11>
exp11
exp11
exp11
exp11
```

Command Window

```
>> exp11
Dispersion-limited distance: 0.00 km
Attenuation-limited distance: 23.025850929940453681865620 km
Minimum distance: 0.00 km
Maximum bit rate: 0.00 Gbps
>> |
```

Command Window Editor

Profiler

## EXPERIMENT – 07

Write an octave program to find limitation in Transmission Length, chromatic dispersion & pulse spreading of light.

### Answer-

### Theory-

The chromatic dispersion of an optical material is the phenomenon that the phase velocity and group velocity of light propagating in a transparent medium depend on the optical frequency. That dependency results mostly from the interaction of light with electrons of the medium, and is related to absorption in some spectral regions; see the article on Kramer's–Kronig relations. A quantitative measure is the group velocity dispersion.

The attribute “chromatic” is used to distinguish that type of dispersion from other types, which are relevant particularly for optical fibers: intermodal dispersion and polarization mode dispersion.

### Code and output-

```
%fine parameters for the fiber and system
```

```
L= 100; % Length of the fiber in km
```

```
alpha = 0.2; % Attenuation coefficient of the fiber in dB/km
```

```
NA = 0.2; % Numerical aperture of the fiber
```

```
a = 10; % Core radius of the fiber in microns
```

```
lambda = 1.55; % Wavelength of light in microns
```

```
DataRate = 1; %data rate in Gbps
```

```
PulseWidth = 10; % Pulse width in ps
```

```
%calculate the dispersion, pulse spreading, and transmission length
```



```
D = 17 * (lambda / 1000)^2 * ((NA^2)/(2 * (a / 1000))^2); % Chromatic dispersion in ps/(nm*km)
```

```
PulseSpread = D * L * PulseWidth^2; % Pulse spreading in ps
```

```
TxBandwidth = DataRate * 1e9; % Transmitter bandwidth in Hz
```

```
RxBandwidth = TxBandwidth; % Receiver bandwidth in Hz
```

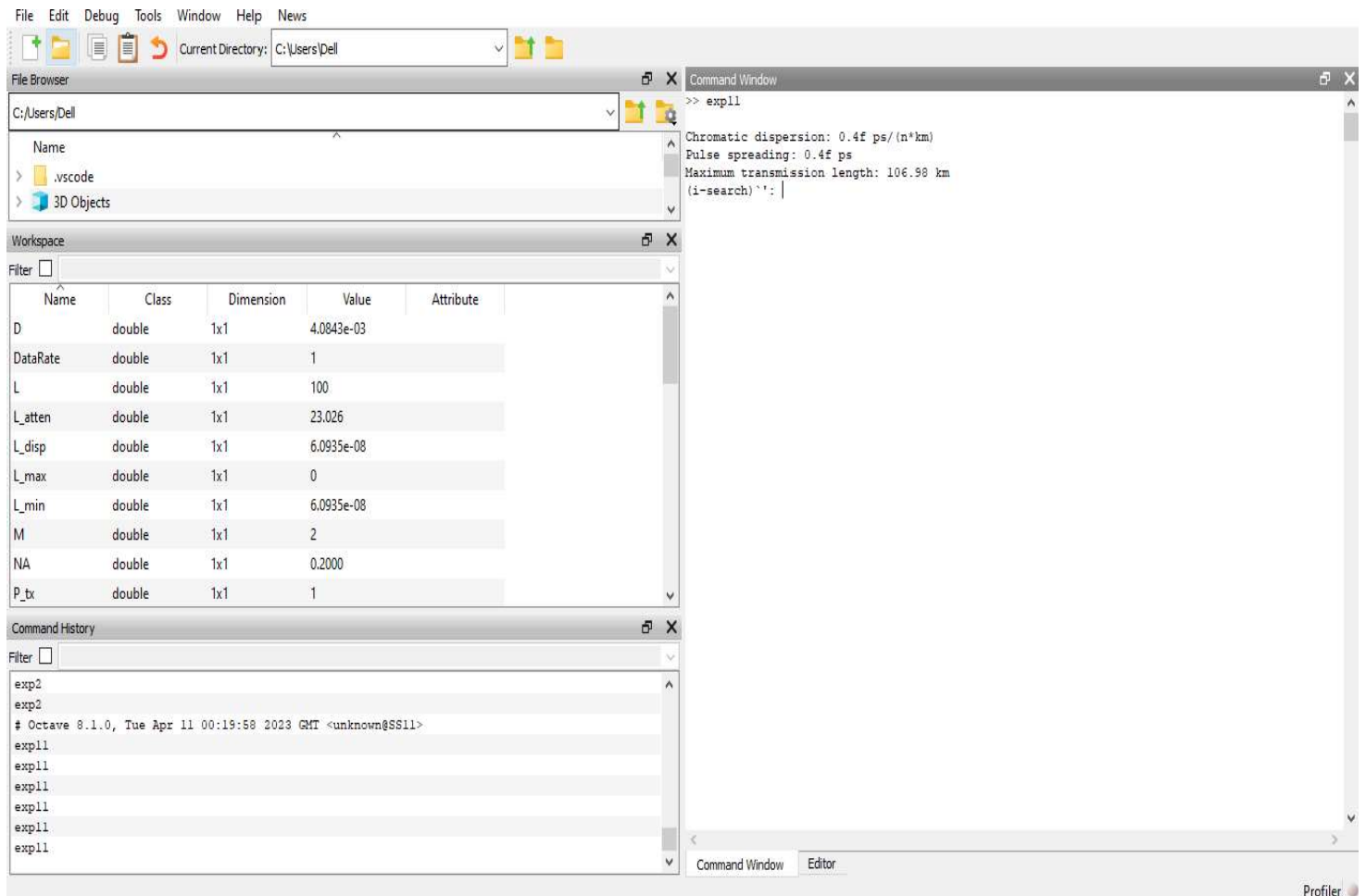
```
TransmissionLength = (TxBandwidth / (2 * D * (PulseWidth/1000)^2))^(1/3)/1000; %  
Transmission length in km
```

```
% Display the results
```

```
fprintf('Chromatic dispersion: 0.4f ps/(n*km)\n', D);
```

```
fprintf('Pulse spreading: 0.4f ps\n', PulseSpread);
```

```
fprintf('Maximum transmission length: %0.2f km\n', TransmissionLength);
```



## EXPERIMENT - 08

Write a program in octave to find power leakage & Intrinsic Loss of fiber.

### Answer-

### Theory-

Optical fiber is a fantastic medium for propagating light signals, and it rarely needs amplification in contrast to copper cables. High-quality single mode fiber will often exhibit attenuation (loss of power) as low as 0.1dB per kilometer.

intrinsic loss is due to fundamental properties of glass materials used to construct the fiber core and cladding, including Rayleigh scattering, infrared absorption, and ultraviolet absorption.

### Code and output-

```
%define parameters for the fiber  
  
L = 10; % Length of the fiber in km  
  
alpha = 0.2; % Attenuation coefficient of the fiber in dB/km  
  
NA = 0.2; % Numerical aperture of the fiber  
  
a = 10; % Core radius of the fiber in microns  
  
lambda=1.55; % Wavelength of light in microns  
  
%calculate the power leakage and intrinsic loss  
  
V = 2 * pi * a * NA / lambda; % V-parameter of the fiber  
  
w = a*sqrt((2*pi / lambda)^2* NA^2 - 1); % Spot size of the fiber
```

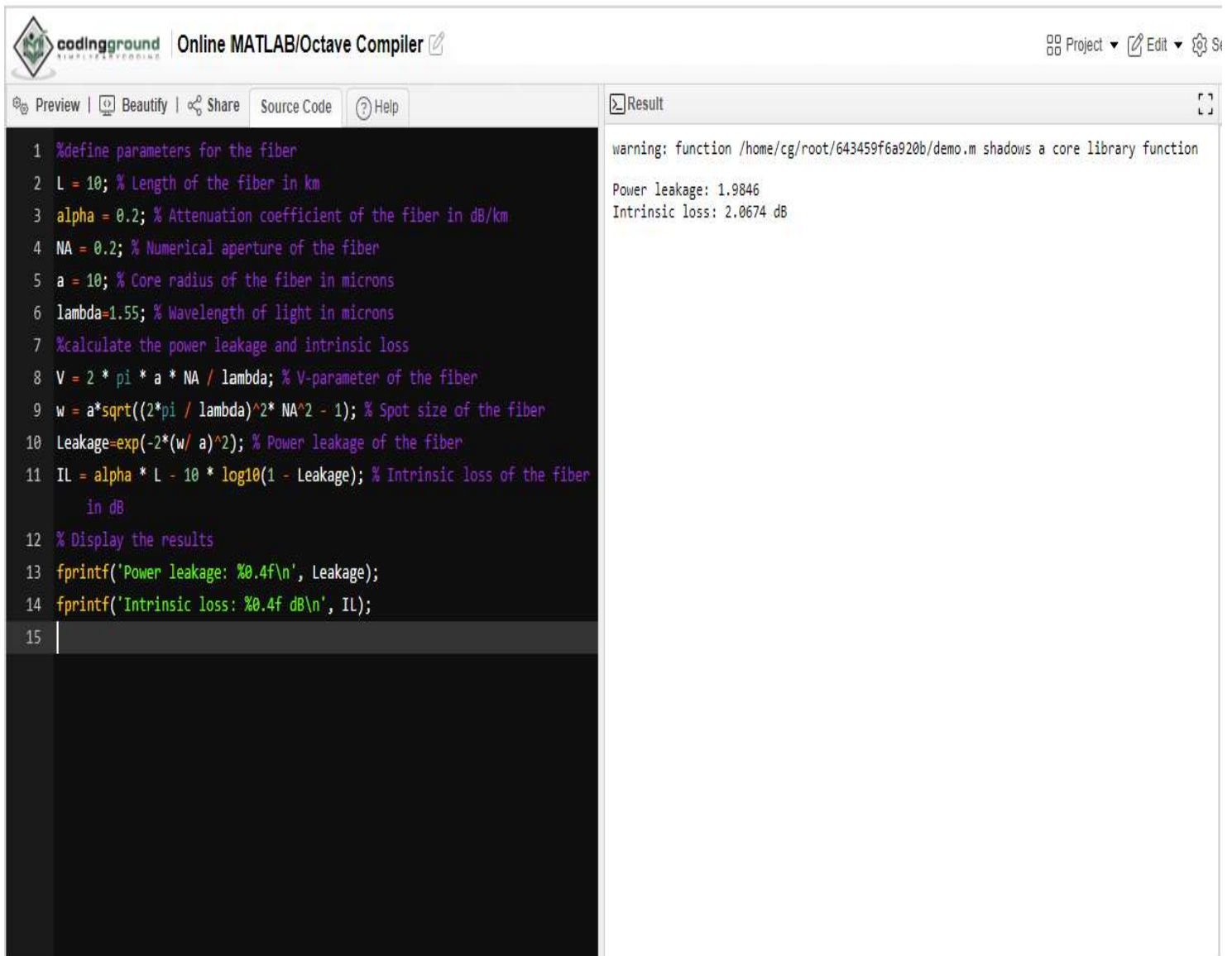
```
Leakage=exp(-2*(w/ a)^2); % Power leakage of the fiber
```

```
IL = alpha * L - 10 * log10(1 - Leakage); % Intrinsic loss of the fiber in dB
```

```
% Display the results
```

```
fprintf('Power leakage: %0.4f\n', Leakage);
```

```
fprintf('Intrinsic loss: %0.4f dB\n', IL);
```



The screenshot displays the Online MATLAB/Octave Compiler interface. The top bar includes the 'codingground' logo and the title 'Online MATLAB/Octave Compiler'. On the right, there are icons for 'Project', 'Edit', and 'Share'. Below the top bar, a navigation menu contains 'Preview', 'Beautify', 'Share', 'Source Code', and 'Help'. The main area is split into two panels. The left panel, titled 'Source Code', contains the following MATLAB code:

```
1 %define parameters for the fiber
2 L = 10; % Length of the fiber in km
3 alpha = 0.2; % Attenuation coefficient of the fiber in dB/km
4 NA = 0.2; % Numerical aperture of the fiber
5 a = 10; % Core radius of the fiber in microns
6 lambda=1.55; % Wavelength of light in microns
7 %calculate the power leakage and intrinsic loss
8 V = 2 * pi * a * NA / lambda; % V-parameter of the fiber
9 w = a*sqrt((2*pi / lambda)^2* NA^2 - 1); % Spot size of the fiber
10 Leakage=exp(-2*(w/ a)^2); % Power leakage of the fiber
11 IL = alpha * L - 10 * log10(1 - Leakage); % Intrinsic loss of the fiber
    in dB
12 % Display the results
13 fprintf('Power leakage: %0.4f\n', Leakage);
14 fprintf('Intrinsic loss: %0.4f dB\n', IL);
15
```

The right panel, titled 'Result', shows the output of the code:

```
warning: function /home/cg/root/643459f6a920b/demo.m shadows a core library function
Power leakage: 1.9846
Intrinsic loss: 2.0674 dB
```

## EXPERIMENT – 09

Write a program in octave to evaluate power coupling and power radiated by LED.

### Answer-

### Theory-

Power emitted from the light source The launching and coupling efficiency depends on the type of fiber that is attached to the source and on the coupling process. The optical power that can couple into a fiber depends on the radiance or brightness which is given through a diode drive current.

### Code and output-

```
% Define parameters for the LED and coupling optics
P_LED = 10; % LED optical power in mw
FWHM=30; % Full-width half-maximum beam angle of the LED in degrees
d = 5; % Distance between LED and coupling optics in mm
f =10; % Focal length of the coupling optics in mm
D_lens=5; % Diameter of the coupling optics in mm
n_lens = 1.5; % Refractive index of the coupling optics
% Calculate the power coupling efficiency
theta_max = deg2rad (FWHM / 2);
theta_aperture = atan (D_lens / (2 * f));
eta_coupling = (1 / pi) * ((theta_max / theta_aperture)^2);
```

% Calculate the power radiated by the LED

```
P_rad = P_LED * (1 - eta_coupling);
```

% Display the results

```
fprintf('Power coupling efficiency: %0.4f\n', eta_coupling);
```

```
fprintf('Power radiated by LED: %0.4f mW\n', P_rad);
```

The screenshot displays the MATLAB R2020a interface. The Command Window on the right shows the execution of the script 'exp11', resulting in the following output:

```
>> exp11
Power coupling efficiency: 0.3635
Power radiated by LED: 6.3648 mW
>>
```

The Workspace window on the left shows the following variables:

Name	Class	Dimension	Value	Attribute
D	double	1x1	4.0843e-03	
D_lens	double	1x1	5	
DataRate	double	1x1	1	
FWHM	double	1x1	30	
L	double	1x1	10	
L_atten	double	1x1	23.026	
L_disp	double	1x1	6.0935e-08	
L_max	double	1x1	0	
L_min	double	1x1	6.0935e-08	
M	double	1x1	2	

The Command History window at the bottom left shows a list of executed commands, all labeled 'exp11'. The status bar at the bottom indicates 'View the variables in the active workspace.' and 'Profiler'.

## EXPERIMENT – 10

Write a program in octave to find time to download data from fiber and for Linked Power budget.

### Answer-

### Theory-

Link Budget = [fiber length (km) × fiber attenuation per km] + [splice loss × # of splices] + [connector loss × # of connectors] + [safety margin] For example: Assume a 10 km single mode fiber link at 1310nm with 2 connector pairs and 2 splices.

### Code and output-

```
% Define parameters for the fiber and system
```

```
L = 100; % Length of the fiber in km
```

```
alpha=0.2; % Attenuation coefficient of the fiber in dB/km
```

```
Ptx = 0.5; % Transmitter output power in mw
```

```
Prx_min = 0.1; % Minimum receiver sensitivity in mW
```

```
Margin=3% Safety margin for link budget in dB
```

```
DataRate =1; % Data rate in Gbps
```

```
% Calculate the attenuation and power budget
```

```
Att = alpha * L; % Total attenuation in de
```

```
Prx = Ptx - Att; % Received power at the end of the fiber in mW
```

Budget = Prx-Prx\_min - Margin; % Linked power budget in dB

% Calculate the time to download data

DataSize = 10; % Size of data in Gb

DataRate\_bps = DataRate \* 1e9; % Data rate in bps

DownloadTime = DataSize / DataRate\_bps; % Time to download data in seconds

% Display the results

fprintf('Linked power budget: %0.2f dB\n', Budget);

fprintf('Time to download data: %0.2f seconds \n', DownloadTime);

The screenshot shows the MATLAB IDE interface. The top menu bar includes File, Edit, Debug, Tools, Window, Help, and News. Below the menu is a toolbar with icons for file operations and a 'Current Directory' dropdown set to 'C:\Users\Dell'. The main workspace is divided into three panes:

- File Browser:** Shows the directory structure of 'C:\Users\Dell', including '.vscode' and '3D Objects'.
- Workspace:** A table listing variables in the workspace. The table has columns for Name, Class, Dimension, Value, and Attribute.
- Command Window:** Displays the output of the MATLAB script, showing the results of the calculations.
- Command History:** A list of commands entered in the Command Window, showing multiple instances of 'exp11'.

The Command Window output is as follows:

```
>> exp11
Margin = 3
Linked power budget: -22.60 dB
Time to download data: 0.00 seconds
>> |
```

The Command History pane shows a list of commands, all labeled 'exp11'.

Name	Class	Dimension	Value	Attribute
Att	double	1x1	20	
Budget	double	1x1	-22.600	
D	double	1x1	4.0843e-03	
D_lens	double	1x1	5	
DataRate	double	1x1	1	
DataRate_bps	double	1x1	1.0000e+09	
DataSize	double	1x1	10	
DownloadTime	double	1x1	1.0000e-08	
FWHM	double	1x1	30	
L	double	1x1	100	