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° 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 -

$$SinC = \frac{1}{\mu_b^a}$$

Where,

C is the critical angle.

μ is the refractive index of the medium.

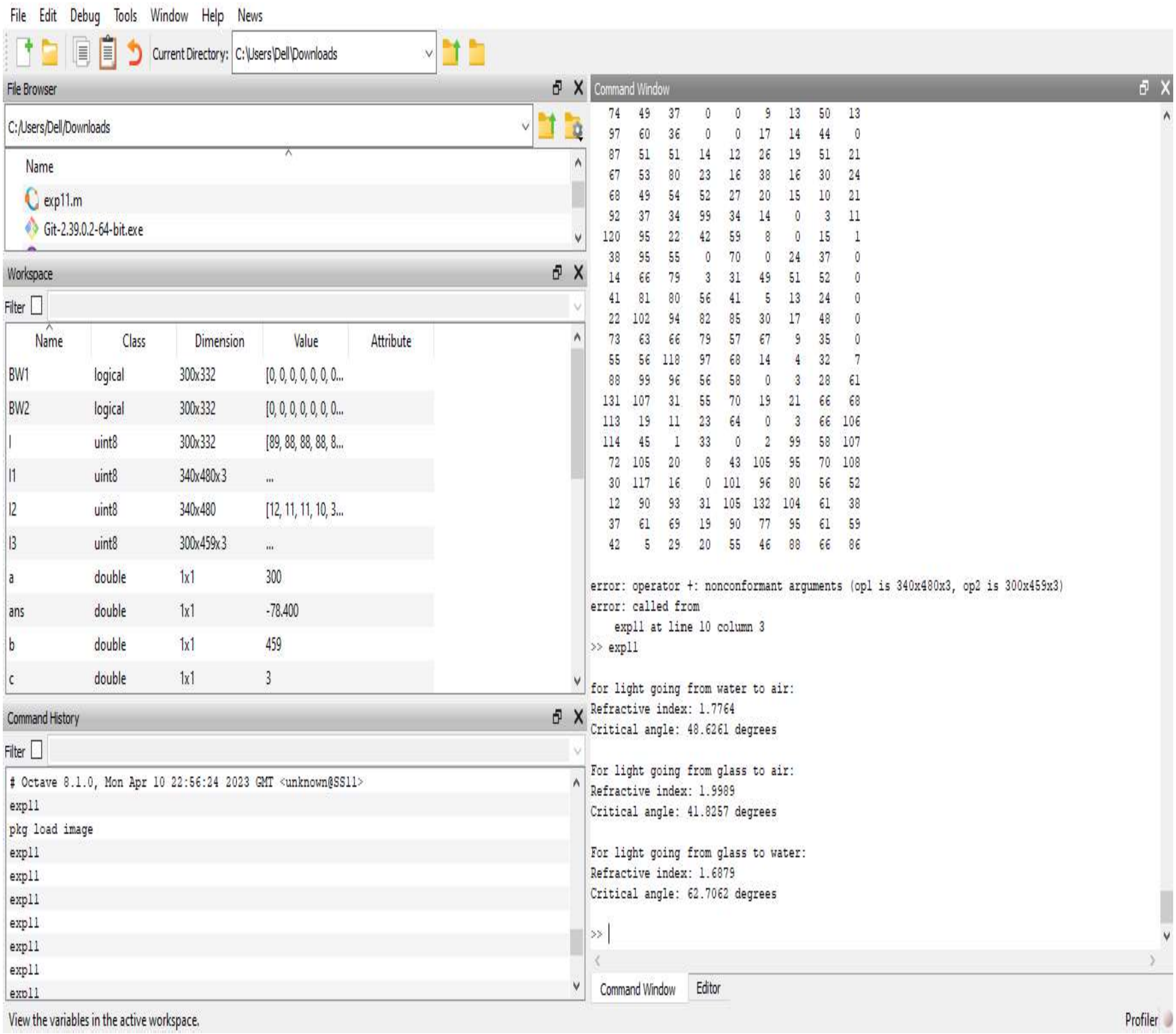
a and b represent two mediums in which light rays travel.

Critical Angle And Refractive Index Formula

	Formula	SI Unit
Critical angle to Refractive index	$SinC = \frac{1}{\mu_b^a}$	degree
Refractive index to Critical angle	$\mu_b^a = \frac{1}{sinC}$	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\Dell\Downloads
File Browser
C:/Users/Dell/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
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
View the variables in the active workspace.
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 θ0 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-

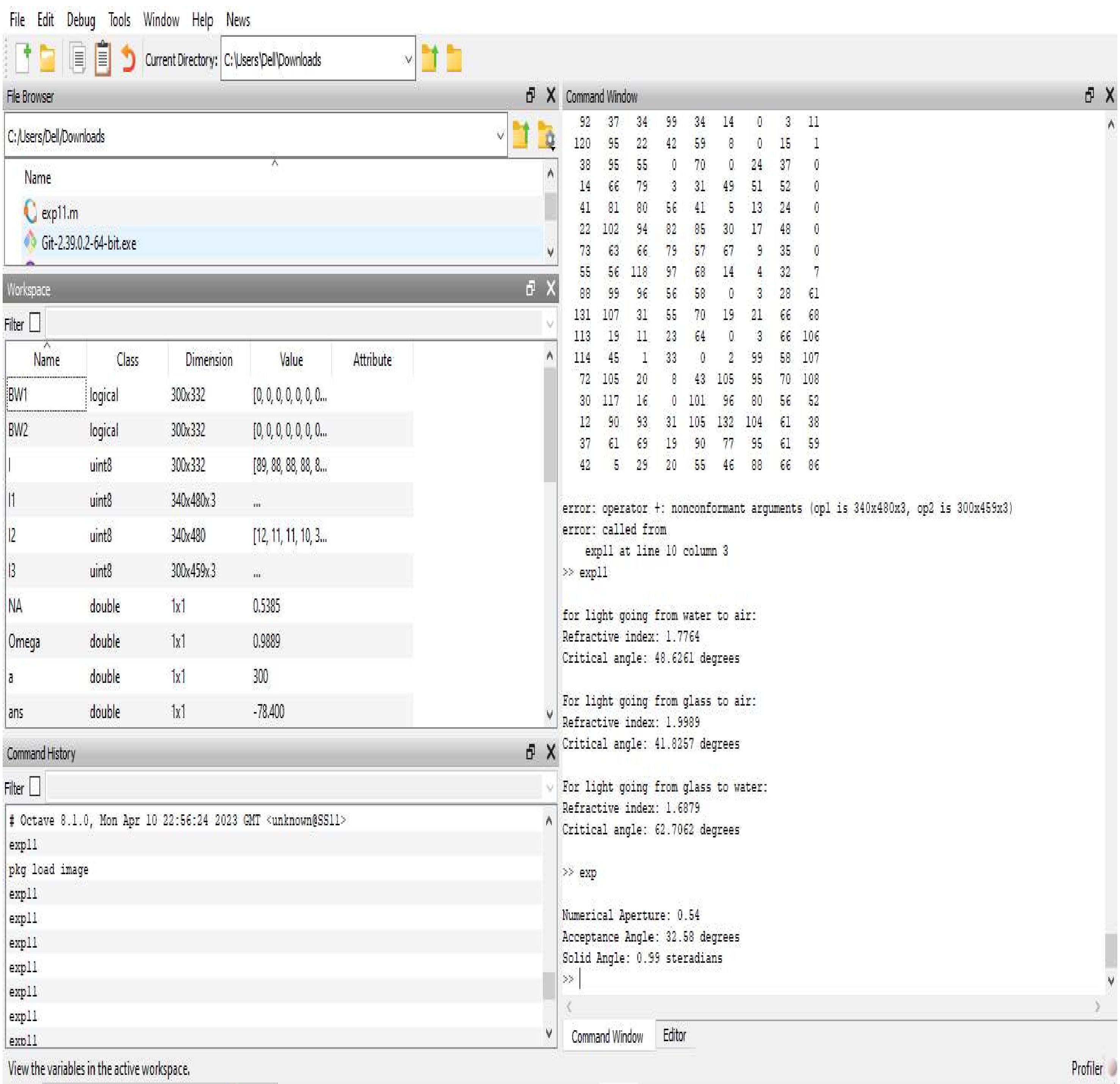
```
% Define the parameters of the fiber

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);



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 ≈ 0.13 for single-mode step-index fiber to ≈ 0.3 for large-core graded-index fiber.A graded indexed optical fiber has a parabolic refractive index profile (α = 2).

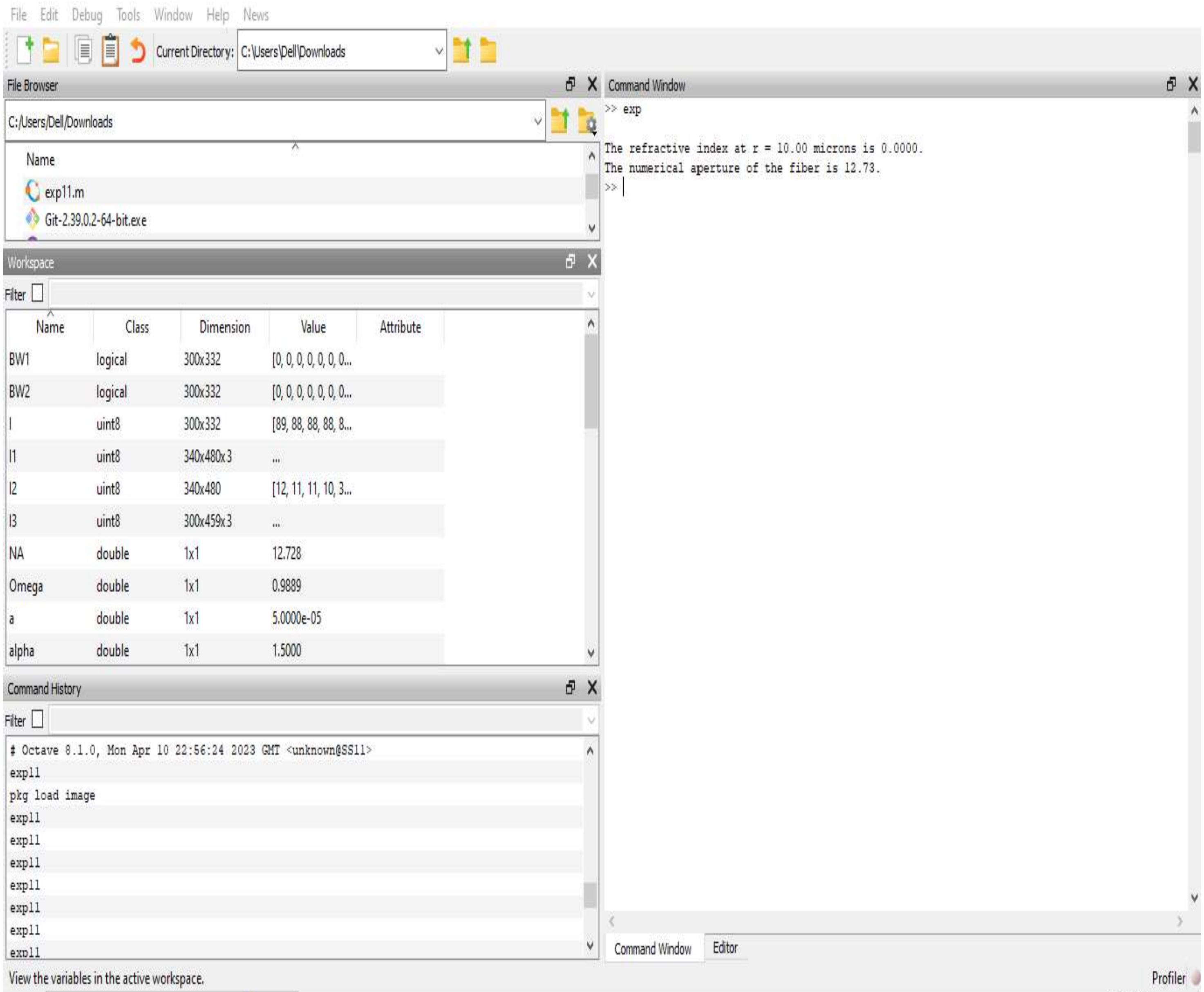
Code and output-

```
% 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);



EXPERIMENT – 04

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

Answer-

Theory-

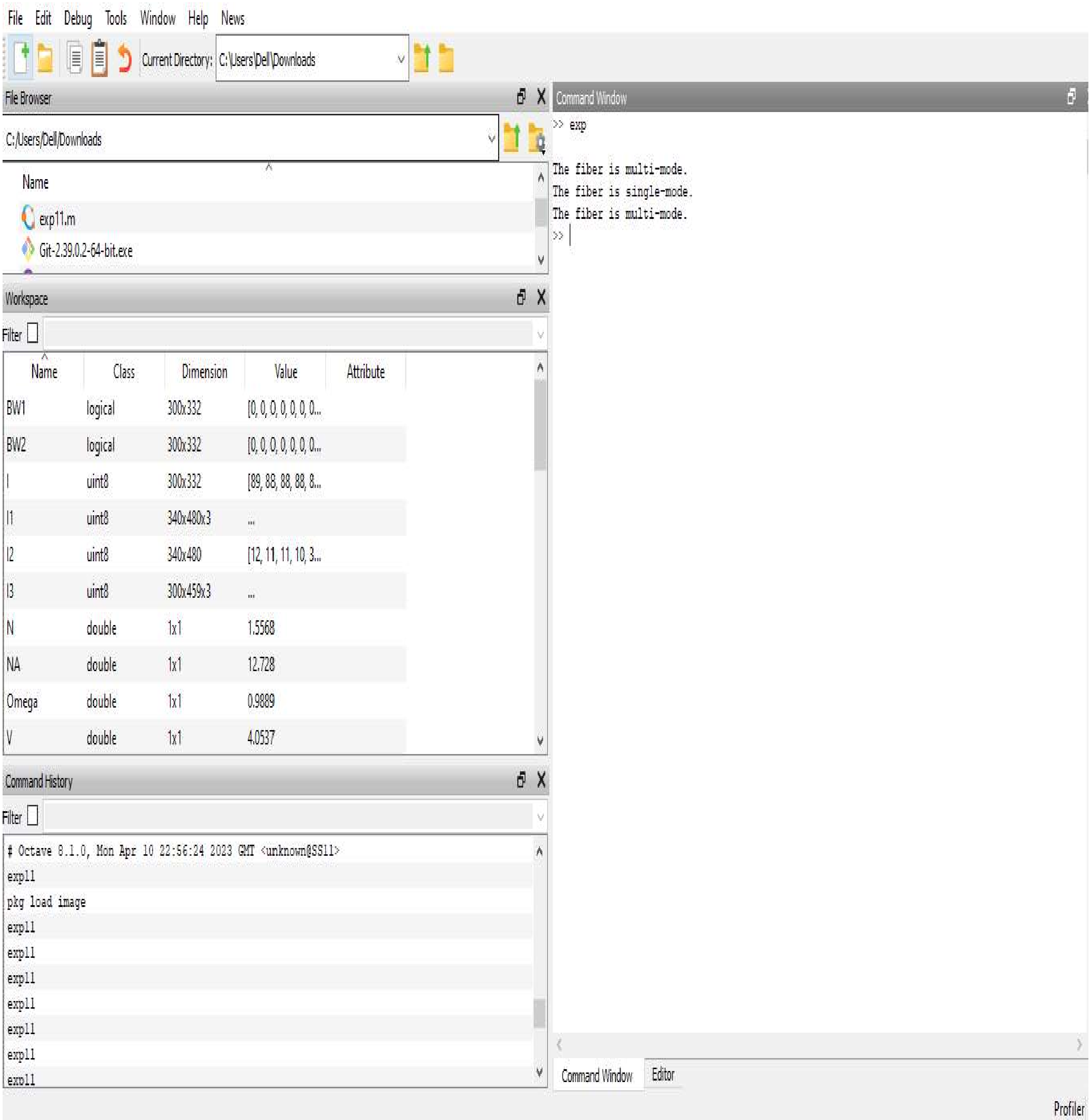
Single mode step index fibres have less core diameter (<10 µm) and the difference between the refractive indices of core and cladding is very small.

2. Multimode step index fibres have larger core diameter (50 to 200 µm) 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
Current Directory: C:\Users\Dell\Downloads
File Browser
C:/Users/Dell/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 ...
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
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 & MaximumTransmission 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.

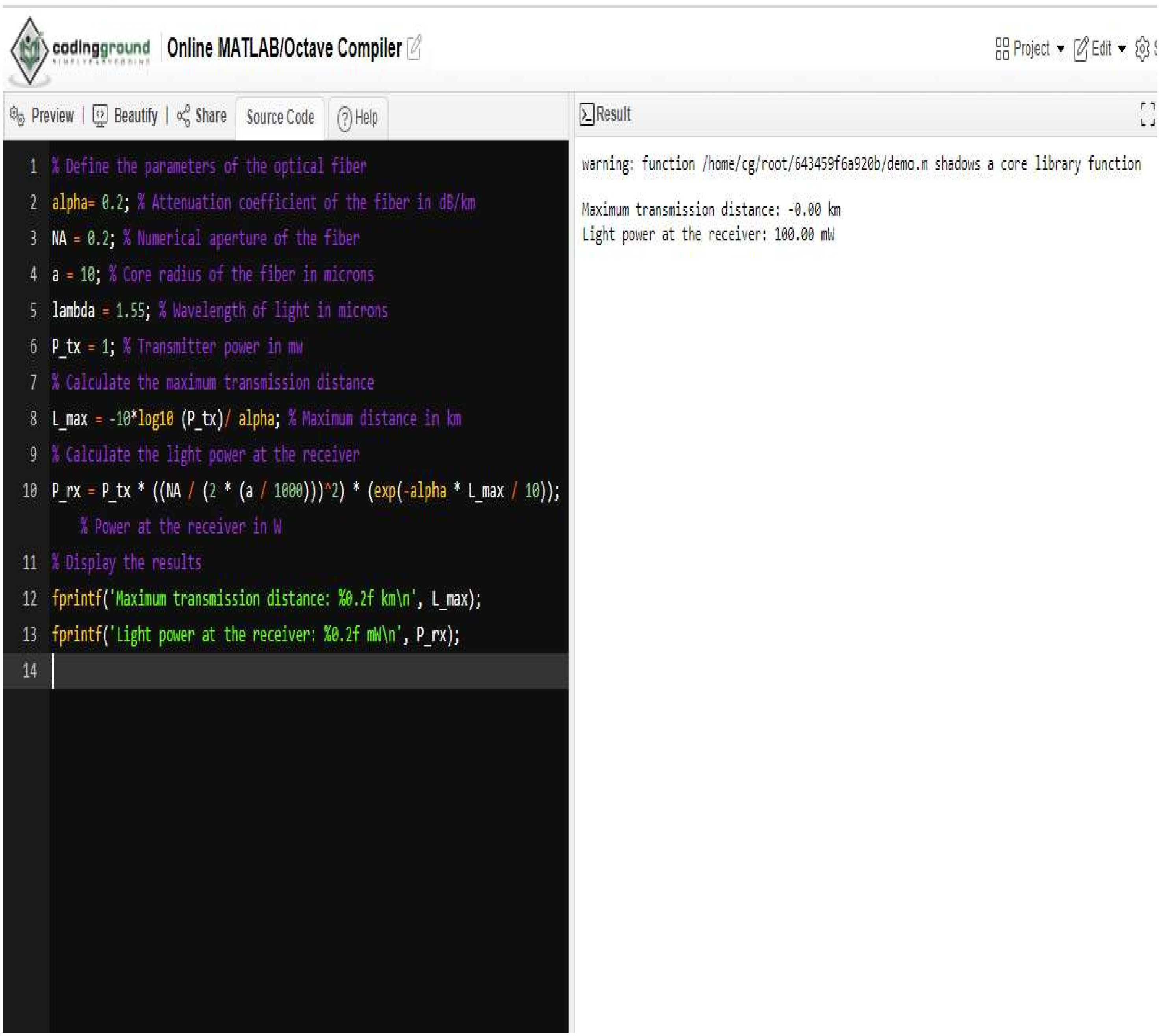
Code and output-

```
% 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);



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

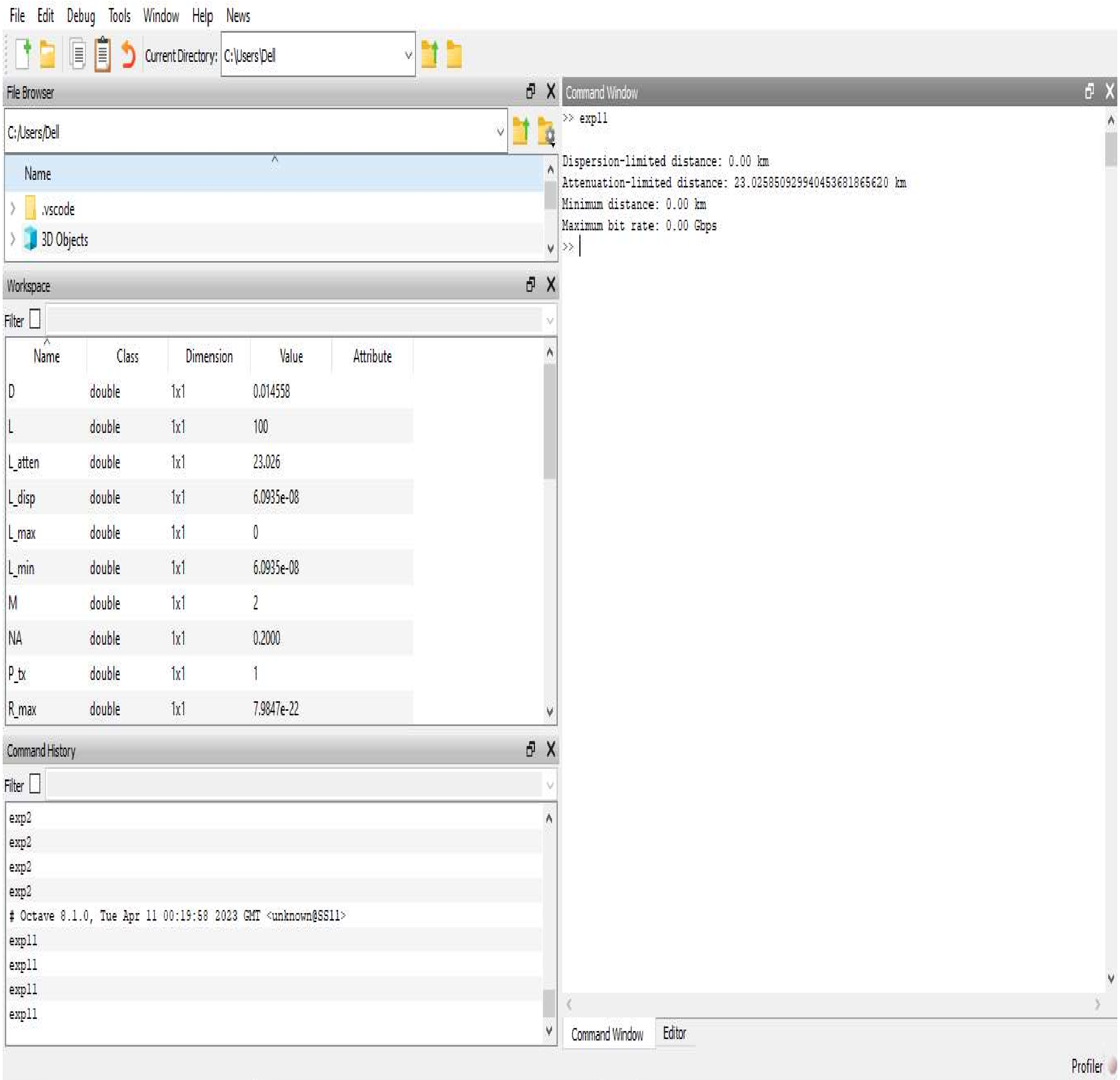
a = 10; % Core radius of the fiber in microns

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

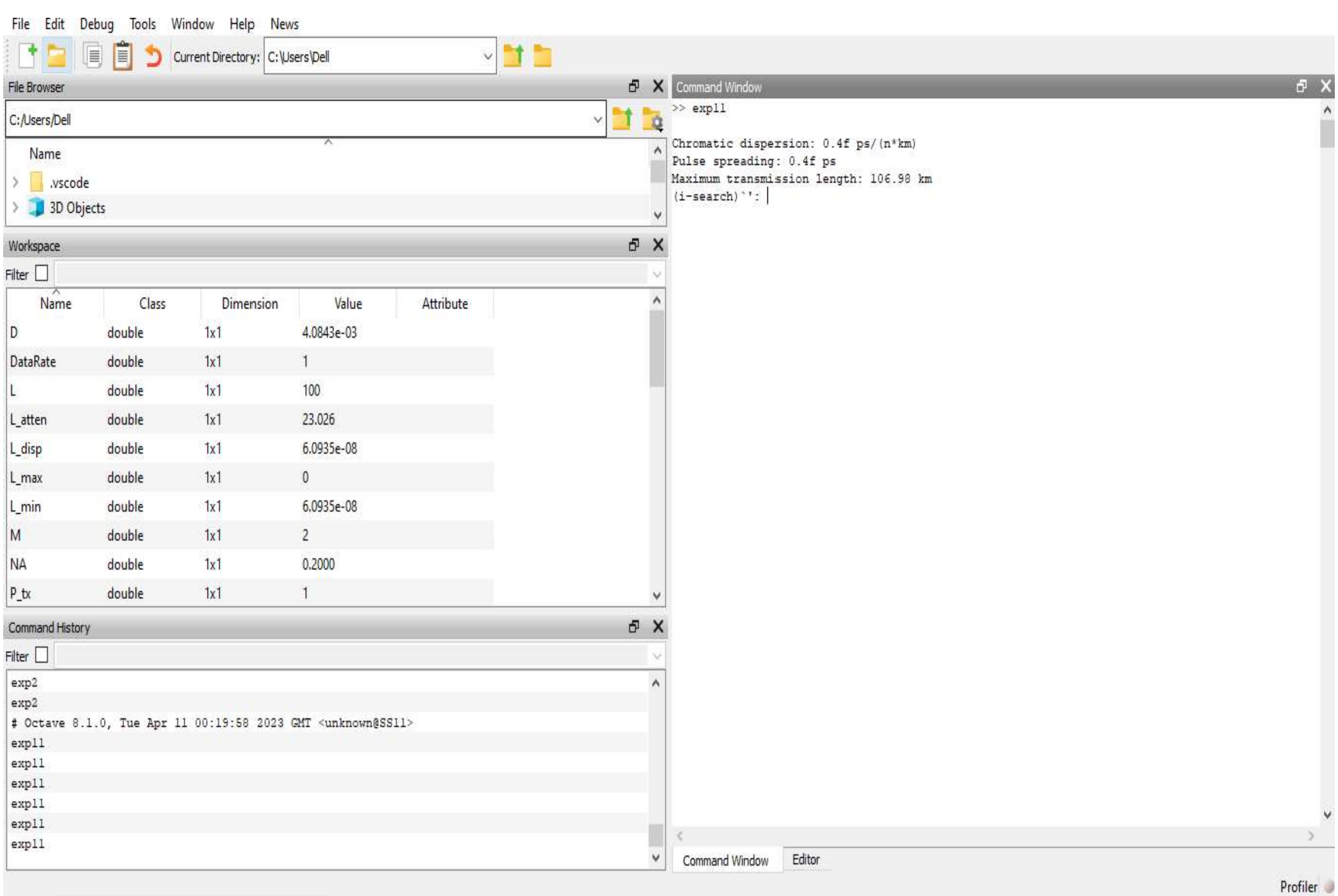
TransmissionLength = (TxBandwidth / (2 * D * (PulseWidth/1000)^2))^(1/3)/1000; % Transmission length in km

% 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
```

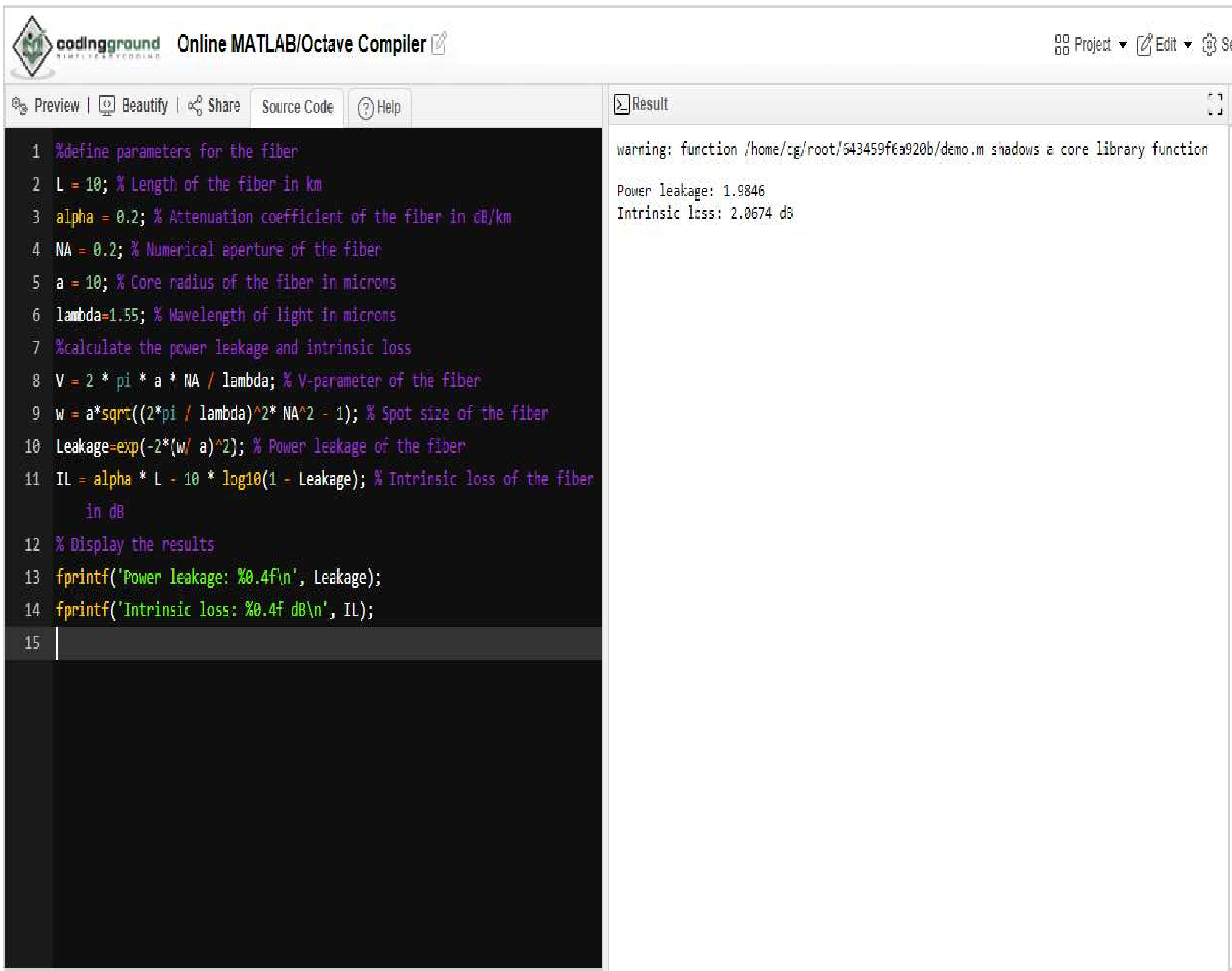
Leakage=exp(-2*(w/ a)^2); % Power leakage of the fiber

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);



EXPERIMENT – 09

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

Answer-

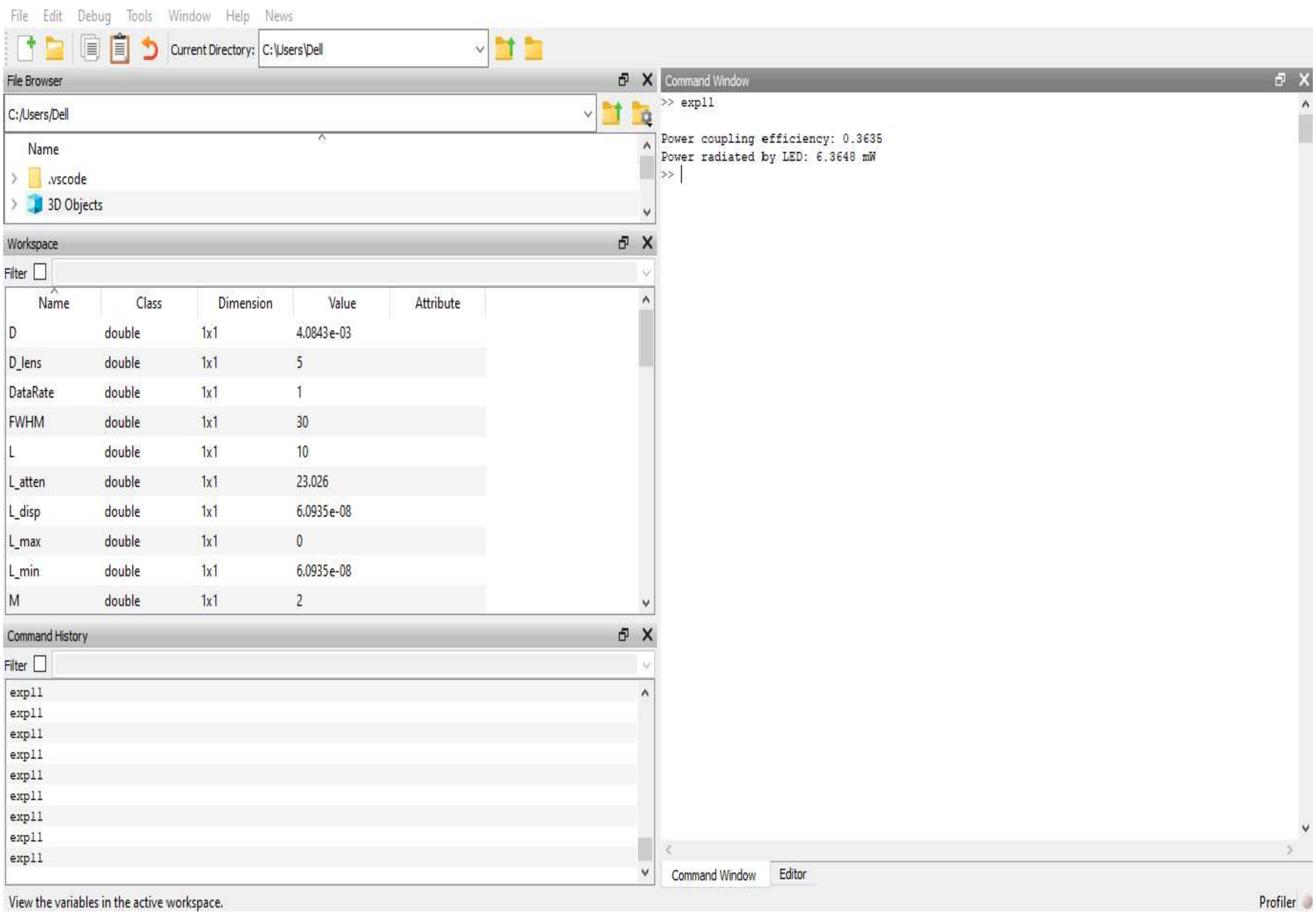
Theory-

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);
```



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);
```