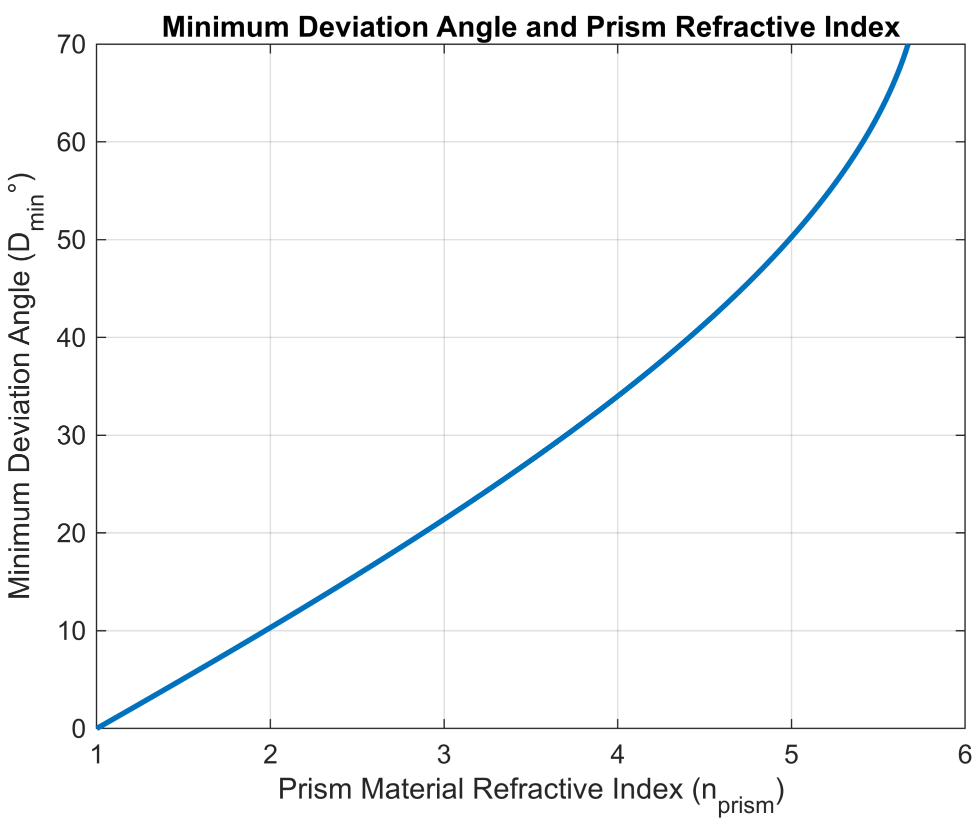
Question 1:

```
% Consider the thin prism subject discussed in class. Assuming an air-prism system,
% (a) Plot the relation between the minimum deviation angle versus the prism
material
% refractive index for a prism angle of 10°. Use MATLAB.
% (b) Search to find a suitable transparent and low-absorption prism material for a
% deviation angle less than 10°.
```

Answer for Part a:

```
A = 10;
n0 = 1;

D_min = linspace(0, 70, 100);
n_prism = n0 * sin(deg2rad((A + D_min))) ./ sin(deg2rad(A));

figure;
plot(n_prism, D_min, 'LineWidth', 2);
xlabel('Prism Material Refractive Index (n_{prism})');
ylabel('Minimum Deviation Angle (D_{min}°)');
title('Minimum Deviation Angle and Prism Refractive Index');
grid on;
```



Question 2:

```
% Consider the interference pattern of two monochromatic plane-wave sources with
same
% intensity I placed at oblique angle teta (case studied in class).
% (a) Design a photolithography experiment to produce features of less than 100 nm.
% (b) For your design, study the effect of the difference in location (Δz) between
the
% two sources on the feature size (produce a plot).
```

Answer for Part a:

```
target_feature_size = 100e-9; % Target feature size in meters (100 nm)

fprintf('Target feature size: < %.2f nm\n', target_feature_size * 1e9);
```

```
Target feature size: < 100.00 nm
```

```
lambda_193 = 193e-9; % Wavelength in meters (193 nm, for example, ArF laser)
lambda_13_5 = 13.5e-9; % Wavelength in meters (13.5 nm, for example, X-ray
lithography)

min_sin_theta_193 = lambda_193 / target_feature_size;

fprintf('For lambda = 193 nm:\n');
```

```
For lambda = 193 nm:
```

```
fprintf('Minimum required sin(theta): %.4f\n', min_sin_theta_193);
```

```
Minimum required sin(theta): 1.9300
```

```
if min_sin_theta_193 > 1
    fprintf('The calculated sin(theta) exceeds 1, which is not physically
possible.\n');
else
    fprintf('The calculated sin(theta) is valid.\n');
end
```

```
The calculated sin(theta) exceeds 1, which is not physically possible.
```

```
min_sin_theta_13_5 = lambda_13_5 / target_feature_size;

fprintf('For lambda = 13.5 nm:\n');
```

```
For lambda = 13.5 nm:
```

```
fprintf('Minimum required sin(theta): %.4f\n', min_sin_theta_13_5);
```

```
Minimum required sin(theta): 0.1350
```

```
min_theta_rad_13_5 = asin(min_sin_theta_13_5);
min_theta_deg_13_5 = rad2deg(min_theta_rad_13_5);

fprintf('Minimum required angle theta: %.2f degrees\n', min_theta_deg_13_5);
```

```
Minimum required angle theta: 7.76 degrees
```

```
fprintf('To achieve feature sizes < 100 nm:\n');
```

```
To achieve feature sizes < 100 nm:
```

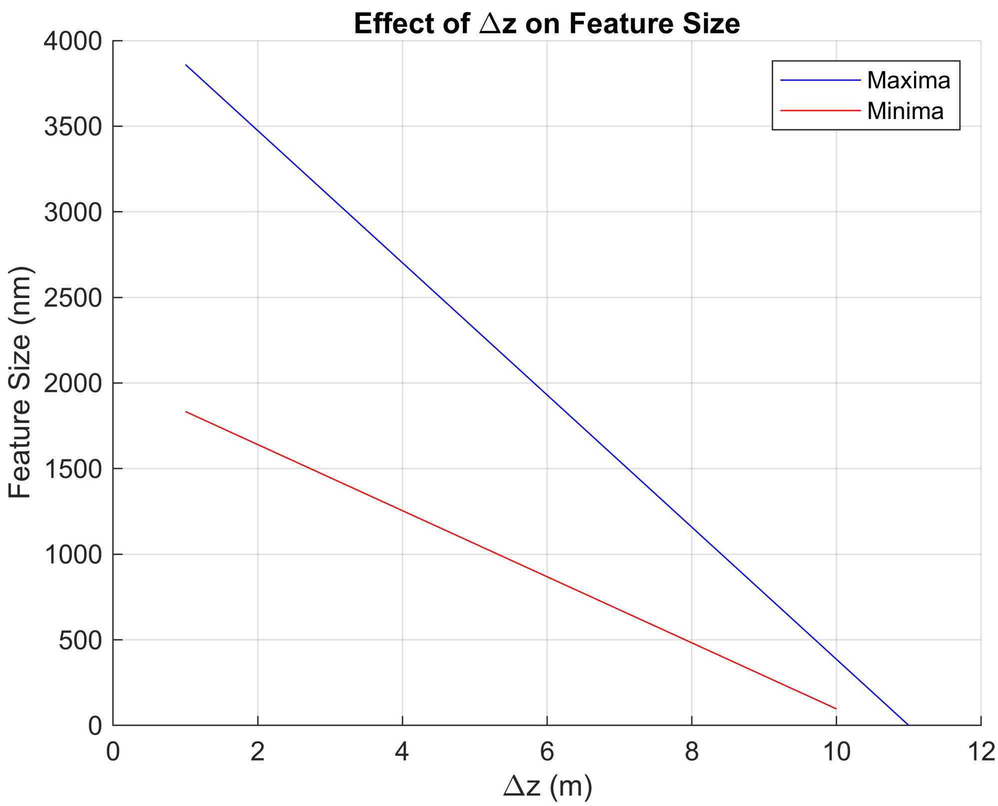
```
fprintf('Use a wavelength of 13.5 nm and an angle theta of at least %.2f
degrees.\n', min_theta_deg_13_5);
```

```
Use a wavelength of 13.5 nm and an angle theta of at least 7.76 degrees.
```

Answer for Part b:

```
lambda = 193e-9;
theta = pi/6;
I0 = 1;
k = 2 * pi / lambda;
delta_z = linspace(0, 1e-6, 100);
x_max = zeros(length(delta_z), 11);
x_min = zeros(length(delta_z), 10);

for i = 1:length(delta_z)
    k_adjusted = k + (2 * pi / lambda) * delta_z(i);
    x_max(i, :) = (0:10) * (lambda / sin(theta));
    x_min(i, :) = ((0:9) + 0.5) * (lambda / (2 * sin(theta)));
    x_max(i, :) = flip(x_max(i, :));
    x_min(i, :) = flip(x_min(i, :));
end

figure;
hold on;

plot(x_max(1, :) * 1e9, 'b', 'DisplayName', 'Maxima');
plot(x_min(1, :) * 1e9, 'r', 'DisplayName', 'Minima');

for i = 1:length(delta_z)
    plot(x_max(i, :) * 1e9, 'b');
    plot(x_min(i, :) * 1e9, 'r');
end

xlabel('\Deltaz (m)');
ylabel('Feature Size (nm)');
title('Effect of \Deltaz on Feature Size');
legend('Maxima', 'Minima');
```

```
grid on;
hold off;
```



Question 3:

```
% Refer to the air-glass interface case discussed in class. Considering both TE and
TM
% polarizations, produce the reflection curves (|Reflection Coefficient| vs.
teta(i)) for the following cases.
% (a) IR light incident from air on human skin.
% (b) UV light from glass to DI water.
% Use MATLAB and discuss your results.
```

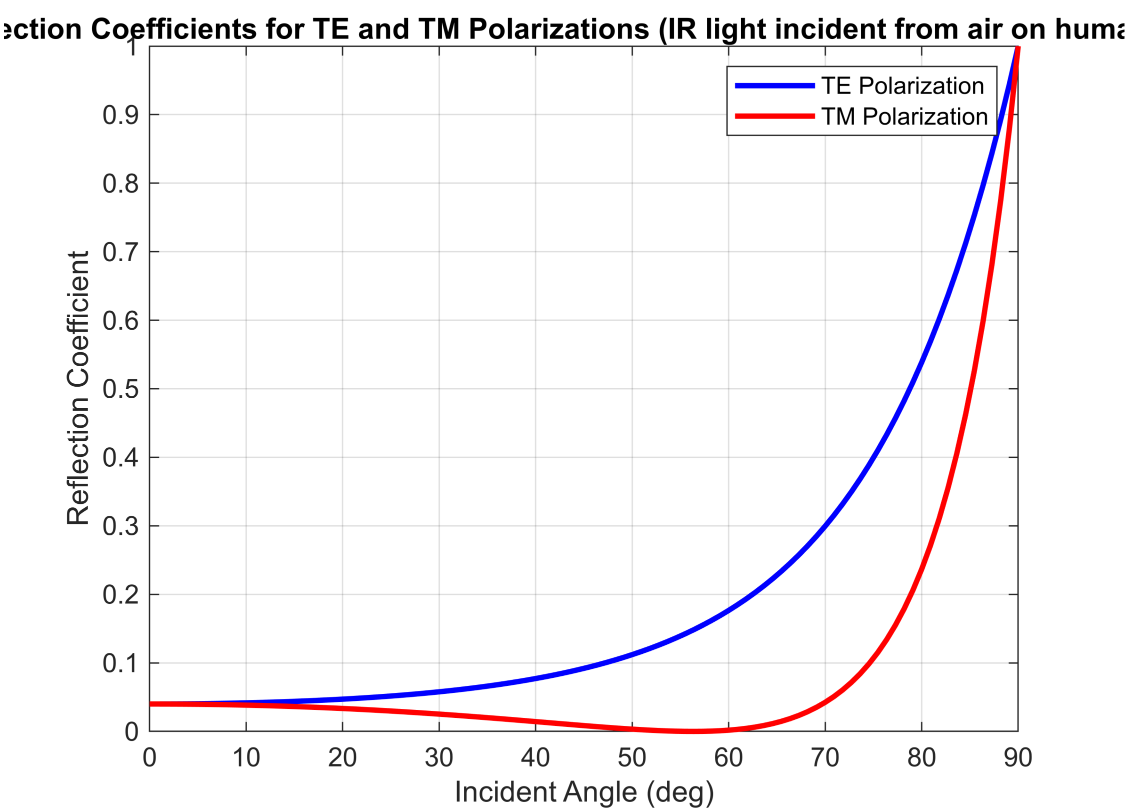
Answer for Part a:

```
n1 = 1;
n2 = 1.5;

theta_i = linspace(0, 90, 100);
theta_i_rad = deg2rad(theta_i);
theta_t_rad = asin(n1/n2 * sin(theta_i_rad));

cos_theta_i = cos(theta_i_rad);
cos_theta_t = cos(theta_t_rad);
```

```
Gamma_TE = (n1 * cos_theta_i - n2 * cos_theta_t) ./ (n1 * cos_theta_i + n2 *
cos_theta_t);
Gamma_TM = (n1 * cos(theta_t_rad) - n2 * cos_theta_i) ./ (n1 * cos(theta_t_rad) +
n2 * cos_theta_i);
R_TE = abs(Gamma_TE).^2;
R_TM = abs(Gamma_TM).^2;
Brewster_angle_rad = atan(n2/n1);
Brewster_angle_deg = rad2deg(Brewster_angle_rad);

disp(['Brewster Angle (TM polarization): ', num2str(Brewster_angle_deg), '
degrees']);
```

```
Brewster Angle (TM polarization): 56.3099 degrees
```

```
figure;
plot(theta_i, R_TE, 'b', 'LineWidth', 2); hold on;
plot(theta_i, R_TM, 'r', 'LineWidth', 2);
xlabel('Incident Angle (deg)');
ylabel('Reflection Coefficient');
title('Reflection Coefficients for TE and TM Polarizations (IR light incident from
air on human skin)');
legend('TE Polarization', 'TM Polarization');
grid on;
xlim([0 90]);
ylim([0 1]);
```



Answer for Part b:

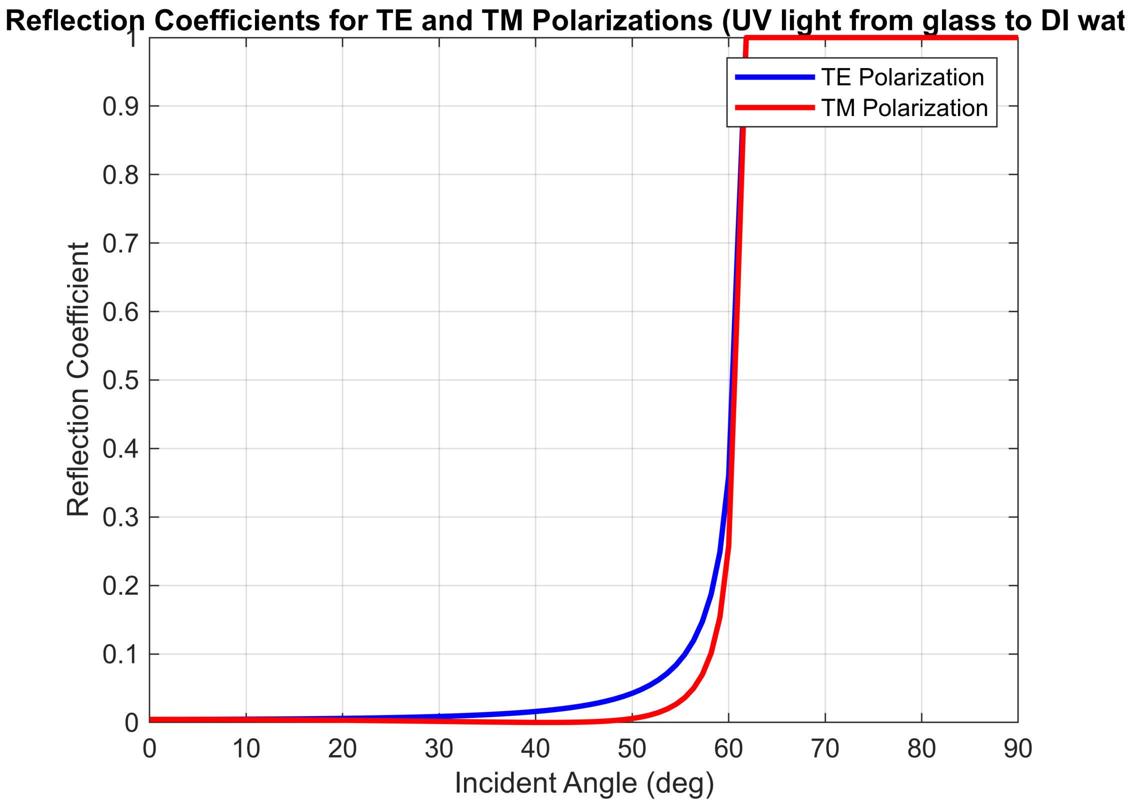
```
n1 = 1.52;
n2 = 1.33;
theta_i = linspace(0, 90, 100);
theta_i_rad = deg2rad(theta_i);

Gamma_TE = zeros(size(theta_i));
Gamma_TM = zeros(size(theta_i));

for i = 1:length(theta_i)
    theta_t = asin(n1/n2 * sin(theta_i_rad(i)));

    Gamma_TE(i) = (n1*cos(theta_i_rad(i)) - n2*cos(theta_t)) / ...
                  (n1*cos(theta_i_rad(i)) + n2*cos(theta_t));

    Gamma_TM(i) = (n1*cos(theta_t) - n2*cos(theta_i_rad(i))) / ...
                  (n1*cos(theta_t) + n2*cos(theta_i_rad(i)));
end

R_TE = abs(Gamma_TE).^2;
R_TM = abs(Gamma_TM).^2;
theta_B = atan(n2/n1);
theta_B_deg = rad2deg(theta_B);

disp(['Brewster Angle (TM polarization): ', num2str(theta_B_deg), ' degrees']);
```

```
Brewster Angle (TM polarization): 41.1859 degrees
```

```
theta_C = asin(n2/n1);
theta_C_deg = rad2deg(theta_C);

disp(['Critical Angle (Both TE and TM polarizations): ', num2str(theta_C_deg), '
degrees']);
```

```
Critical Angle (Both TE and TM polarizations): 61.045 degrees
```

```
figure;
plot(theta_i, R_TE, 'b', 'LineWidth', 2); hold on;
plot(theta_i, R_TM, 'r', 'LineWidth', 2);
xlabel('Incident Angle (deg)');
ylabel('Reflection Coefficient');
title('Reflection Coefficients for TE and TM Polarizations (UV light from glass to
DI water)');
legend('TE Polarization', 'TM Polarization');
grid on;
axis([0 90 0 1]);
```



Comments on Part a Results:

```
% Brewster Angle: The code calculates the Brewster angle, identifying the angle at
which
% reflection is minimized for TM polarization. This angle represents a condition
where light
% is completely transmitted and reflection is zero.

% Reflection Coefficients: The reflection coefficients for TE and TM polarizations
vary
% with the incident angle. Generally, the reflection coefficients for TE
polarization are
% higher, while TM polarization reaches a minimum at the Brewster angle.

% Graph: The graph shows the variation of reflection coefficients for TE and TM
polarizations
% between 0° and 90°. The reflection coefficients for TE polarization tend to
increase as the
% incident angle increases, while the reflection coefficients for TM polarization
show a
% decrease at the Brewster angle.

% In conclusion, this code serves as a useful tool for understanding the reflection
behavior
```

```
% of different polarization types and provides important insights, especially in
optical applications.
```

Comments on Part b Results:

```
% Brewster Angle (TM polarization): The Brewster angle is approximately 41.19
degrees.
% This indicates the angle at which the reflection for TM polarization is
minimized, allowing
% most of the light to transmit into the water. This angle is crucial for
applications where
% minimizing reflection is desired.

% Critical Angle (Both TE and TM polarizations): The critical angle is
approximately 61.05 degrees.
% This is the angle beyond which total internal reflection occurs for both TE and
TM polarizations.
% At angles greater than this, all incident light is reflected back into the glass,
which is
% important for understanding light behavior at interfaces.

% Graph: The graph displays the reflection coefficients for TE and TM polarizations
against
% incident angles ranging from 0 to 90 degrees. The reflection coefficient for TE
polarization
% reaches a minimum at the Brewster angle, while for TM polarization, the
reflection coefficient
% approaches 1 after the critical angle.

% In summary, this code provides important insights into the reflection behavior
during the
% transition from glass to water. The Brewster angle is a critical point for
reducing reflection
% in optical applications.
```

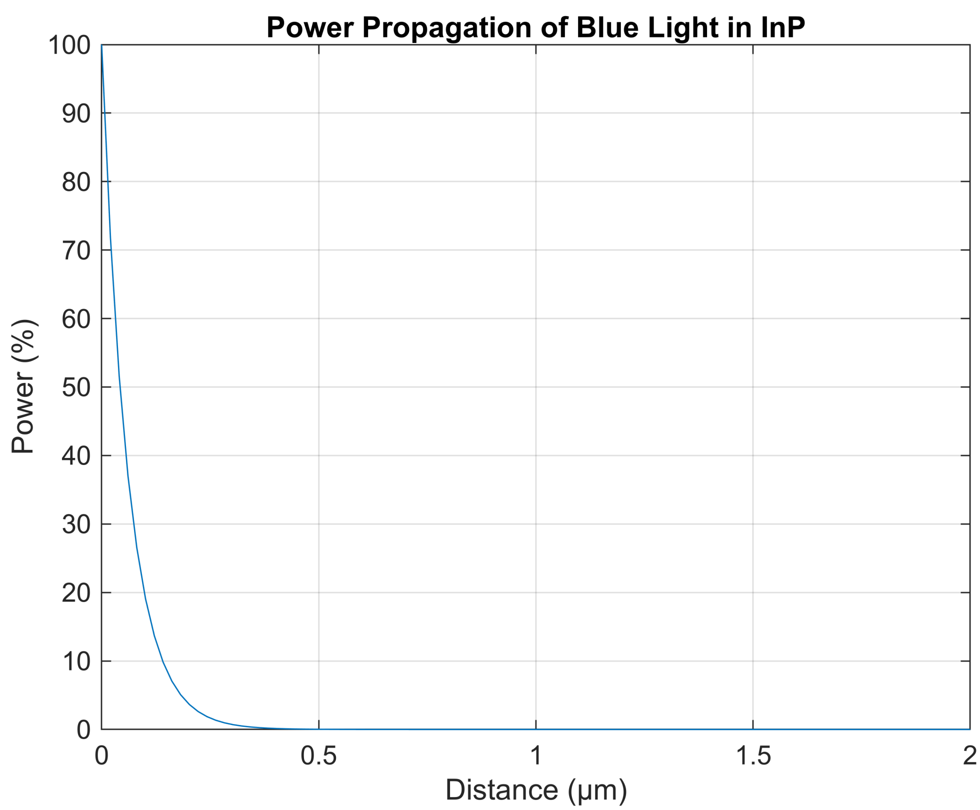
Question 4:

```
% Study the propagation of blue light (wavelength=470 nm) inside InP material.
Specifically,
% find the complex refractive index, attenuation coefficient, wavenumber and
absorption
% coefficient at the given wavelength. Plot blue light power propagation (in
percentage)
% inside a 2-micrometer slab of InP. Comment on your results.
```

Answer:

```
lambda = 470e-9;
n_r = 3.9424;
```

```
n_i = 0.61331;
n = n_r + 1i*n_i;

k = (2 * pi * n) / lambda;
alpha = 2 * pi * n_i / lambda;
absorption_coefficient = 2 * pi * imag(n) / lambda;
d = 2e-6;
z = linspace(0, d, 100);
P0 = 1;
P = P0 * exp(-2 * alpha * z);

figure;
plot(z * 1e6, P * 100);
xlabel('Distance (μm)');
ylabel('Power (%)');
title('Power Propagation of Blue Light in InP');
grid on;
```




```
fprintf('Complex Refractive Index: n = %.4f + j%.5f\n', n_r, n_i);
```

```
Complex Refractive Index: n = 3.9424 + j0.61331
```

```
fprintf('Wavenumber (k): %.4f + j%.4f m^-1\n', real(k), imag(k));
```

```
Wavenumber (k): 52703893.0958 + j8199022.0867 m^-1
```

```
fprintf('Attenuation Coefficient (α): %.4f m^-1\n', alpha);
```

```
Attenuation Coefficient (α): 8199022.0867 m^-1
```

```
fprintf('Absorption Coefficient: %.4f m^-1\n', absorption_coefficient);
```

```
Absorption Coefficient: 8199022.0867 m^-1
```

Comments on Results:

```
% Complex Refractive Index (n): The values n_r = 3.9424 and n_i = 0.61331 represent the
% optical properties of InP. Here, n_r indicates the real part of the refractive index,
% while n_i represents the imaginary part, which accounts for losses.

% Wavenumber (k): The k value determines the propagation characteristics of light within InP.
% The real part reflects the effect of the wavelength, while the imaginary part represents losses.

% Attenuation Coefficient (α): The α value indicates the rate at which light diminishes within
% the material. A high α value suggests that light is attenuating more rapidly.

% Absorption Coefficient: This value indicates how much light is absorbed by the material.
% A high absorption coefficient means greater energy loss.

% Power Distribution: The graph shows how the percentage of power decreases with distance along
% the z-axis. As the distance increases, the power rapidly declines due to absorption.

% In summary, the InP material significantly attenuates and absorbs blue light,
% which is an important consideration in optical applications.
```