I. Purpose
The purpose of this experiment is to introduce the basics of plastic waveguides, fibers, and the fiber coupler.

II. Background

Numerical Aperture
The numerical aperture (NA) of a fiber is found to be

\[ NA = \sqrt{n_{\text{core}}^2 - n_{\text{cl}}^2} \]  

(1)

where \( n_{\text{core}} \) is the refractive index of the core of the fiber and \( n_{\text{cl}} \) is the refractive index of the cladding. The fractional index difference \( \Delta \) is defined as

\[ \Delta = \frac{(n_{\text{core}} - n_{\text{cl}})}{n_{\text{core}}} \]  

(2)

As an example, a typical multimode communications fiber may have \( \Delta = 0.01 \). For silica-based fibers, \( n_{\text{core}} \) have an approximate numerical aperture of \( NA = 0.2 \). This gives a value of 11.5° for the maximum incident angle \( \alpha_{\text{max}} \). The maximum incident angle is related to the NA according to

\[ \sin \alpha_{\text{max}} = \frac{NA}{n_0} \]

where \( \alpha_{\text{max}} \) is in units of radians.

Values of NA range form about 0.1 for single-mode fibers to 0.2-0.3 for multimode fibers up to about 0.5 for large-core fibers. Note that \( \alpha_{\text{max}} \) occurs when the angle of the light at the core/cladding interface is the critical angle for total internal reflection.

Figure 1: Coupling of light into a fiber cable.
III. Procedure

Part A: Optical Fiber Coupling

Set-up
1. In this lab a fiber optics communication link will be built. The system consists of a transmitting unit, a fiber optic cable, and a receiving unit. Read the specification sheets found in the lab for the system.

2. Mount your Class II He-Ne laser. Measure the output voltage with your power meter. You will need this value later for your calculations.

3. You need two sections of optical fiber, one fiber connector, and one fiber coupler. The fiber is a plastic light waveguide protected with a black plastic coating.

4. Measure the length of one of your fibers. Mount the fiber coupler and then fix the fiber that you measured in the chuck of the fiber coupler. The final experiment setup can be seen below in figure 2.

5. Align the laser with the fiber connector so that the laser couples with the fiber.

Experiment

Figure 2: Experimental setup for Optical fiber coupling.
1. Using the optical power meter, maximize the power exiting the fiber. What do you measure? Calculate the attenuation coefficient of your optical fiber in decibels per unit length.

2. Calculate the numerical aperture of the fiber using your green lab book and the following table. The necessary information is in the documentation for the fiber communication system that you looked at in step 1. of the lab set-up.

<table>
<thead>
<tr>
<th>Material</th>
<th>Refractive Index (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
</tr>
<tr>
<td>Fluorine Polymer</td>
<td>1.35</td>
</tr>
<tr>
<td>Polymethyl Octadecyl Siloxane</td>
<td>1.44</td>
</tr>
<tr>
<td>Polyisopropyl Acrylate</td>
<td>1.47</td>
</tr>
<tr>
<td>Polymethyl Methacrylate</td>
<td>1.49</td>
</tr>
<tr>
<td>Polyisobutylene</td>
<td>1.51</td>
</tr>
<tr>
<td>Mylar</td>
<td>1.64</td>
</tr>
</tbody>
</table>

| Table 1: Refractive indices. |

3. Connect another piece of plastic fiber to the first using one of the connectors provided. Measure the output light power. Calculate the coupling loss in dB units.

**Part B: Transmitter and Receiver System**

**Set-up**

1. Get the transmitter/receiver unit and a power supply from your cabinet. The transmitter consists of an infrared LED and associated circuitry which allows a 0 to 5 volt pulsed signal to be used as the input signal. Examine the specification sheet and determine the wavelength of your LED transmitter.

2. Set the input terminal and the transmitter terminal of the circuit to +5 volts. Verify that the LED is on using your infrared sensor card. Connect the fiber to the transmitter and measure the optical power output of the LED.

3. Turn on the HP 33120A function generator. First you will set the output termination impedance setting on the generator to “HI Z.” To do this:
   - Push ‘shift’ and then ‘enter’ to get to the menu system
   - Use the right arrow key to get to “D: SYS MENU”
   - Push the down arrow. You should read “1: OUT TERM”
   - Push the down arrow once. Push the right arrow until it reads “HI Z”
   - Push ‘enter.’ The screen should briefly read “ENTERED” and then exit out of the menu system.

   Now set the function generator to output a 5V amplitude square wave with a 50% duty cycle and a 2.5V DC offset. **Note:** The duty cycle of the square wave is 50% by default.

4. Set the signal frequency to 100 mHZ and check that you have a 0 to 5 pulse signal by viewing it using a multimeter. **Note:** the multimeter is in your cabinet.
5. Set the function generator to a frequency of 1 Hz. Unplug the +5V connection to the transmitter terminal. Plug the output of the function generator into the transmission terminal. You should observe the LED turn on and off.

6. Connect the fiber optic cable to the receiver. Verify that the system is working by viewing the input electrical signal to the transmitter and output electrical signal from the receiver using an oscilloscope.

**Experiment**

1. Using a frequency of 2.5 kHz, measure the time delay from the input to the output of the system. Do this for both the rising edge and the falling edge of the input signal.

2. Using your results from above, estimate what the maximum operation frequency is. Measure the maximum frequency of operation by increasing the signal frequency until no received pulse can be seen on the oscilloscope. How close was your estimate?

**IV. Conclusion**

Summarize what you have done in lab and draw conclusions on applications of plastic waveguide fibers, and the particular transmitter/receiver system used in lab.