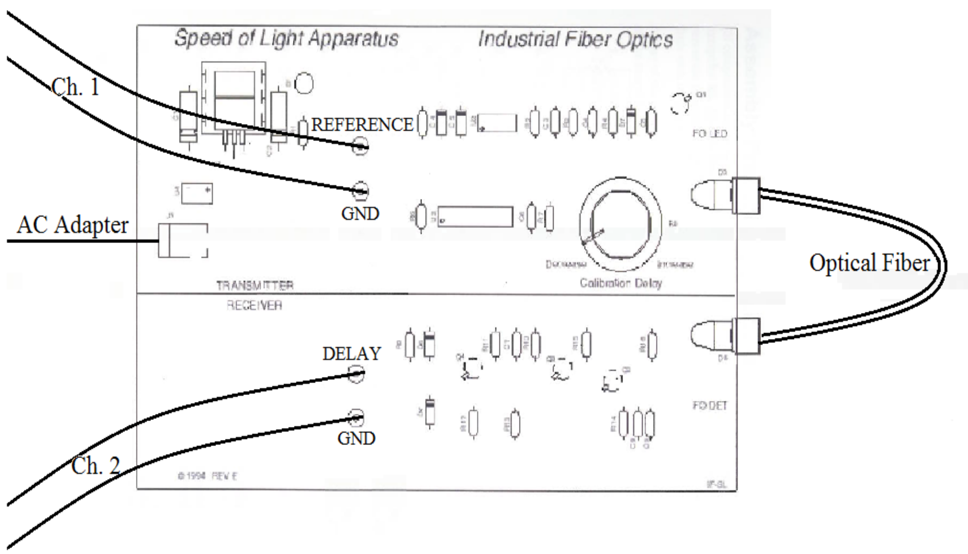
Lab 10: The Speed of Light

An LED rapidly turns on and off creating very brief pulses of light. These pulses travel 20 m through an optical fiber and to a photodetector. One channel of a dual trace oscilloscope shows the voltage pulse that flashes the LED and the other channel shows the voltage pulse caused in the photodiode by the arrival of the light. The delay time between these pulses is the time for the light to travel through the 20 m fiber. Its speed is then just distance ÷ time.

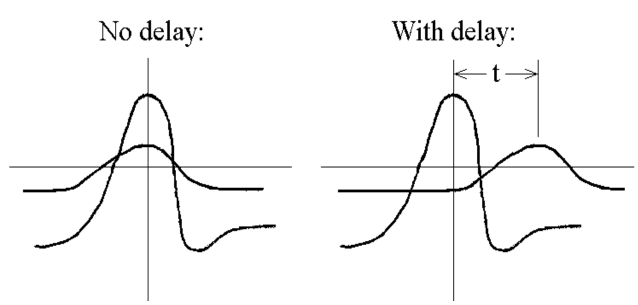
The speed of light in a vacuum can be found from the speed of light in the fiber and its index of refraction. Part 2 of the lab is to measure n for a typical type of plastic.

Part 1. Speed of light in an optical fiber.

Make the connections shown using the wires in the kit. Start with the 15 cm long optical fiber. You shouldn't need to tighten the plastic nuts around the ends of the fiber. If you do tighten them, don't do it very hard. The apparatus should turn on when you plug it in.



On the oscilloscope, the X-MAGN button located under the screen should be pushed in. This makes the display 5 times larger horizontally than the TIMEBASE knob says it is. The red knob in the center of TIMEBASE should be fully counterclockwise, Y- AMPL-1 at 1 V/cm, Y- AMPL-2 at .5 V/cm, TIMEBASE fully clockwise to .5 μs/cm and TRIG SELECTOR on AC or HF. The DUAL button should be pushed in. Turn X POSITION until the taller pulse is at some convenient reference point such as the second vertical line from the left.



On the circuit board, adjust the calibration delay knob to line up the shorter pulse with the first one. (Light covers the 15 cm from its source to the detector almost instantaneously, so the correct adjustment shows both pulses occurring at the same time.)

Replace the 15 cm fiber with the 20 m fiber. Measure the time between the sent peak and received peak. Since X-MAGN is pushed, remember to divide by 5 to get the correct time.

Calculate the speed of light in this plastic. Check with the instructor. An unexpected result could be due to a miscalibrated oscilloscope. Checking it against it against a 100 kHz signal (T = 10μs) from a computer interface may give a correction factor which improves your result.

<u>Part 2</u>. Index of refraction.

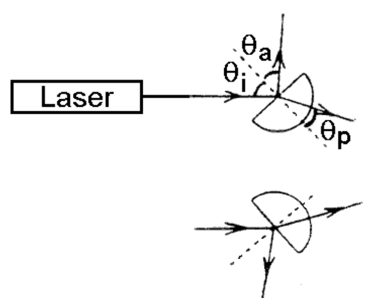
The semicircular block of plastic you will use now has a similar index of refraction to the plastic in the optical fiber. To measure it, you shoot a laser at its flat side, measuring the angles of incidence and refraction using protractors which are attached. The results go into Snell's law to obtain n.

<u>CAUTION</u>: Do not let the laser beam shine into your eyes.

Attach the semicircle to a ring stand with a clamp. Leave the clamp loose enough to turn the semicircle to different angles, but tight enough that it will stay when you let go.

Align the laser with the protractor: For a coarse adjustment, move the clamp up or down the pole until the beam hits by the mark at the center of the protractor. Then, for a fine adjustment, adjust the screws under the laser to tilt it until the law of reflection works. (If the incoming beam is on the 45° mark, the reflected beam should be on the 45° mark. To observe these, you can move the ring stand toward or away from you to make the beam hit the numbers on the protractor. Do not change its distance from the laser, or it may affect the aim of the beam.)

When the beam hits the plastic, part of it reflects back into the air, and part refracts into the plastic. Record the angle of incidence, θ_i and the angle of refraction θ_p (p for "plastic") for four different values of θ_i of over 10°. (Small angles give large percent uncertainties.)



Remember these are all **<u>acute</u>** angles measured <u>from a **normal**</u> (perpendicular) to the surface, so you must subtract the protractor's reading from 90°. It's also a good idea to try it on both sides, as shown, and average to compensate for any misalignment of the protractor.

Compute n, the plastic's index of refraction, from Snell's law. n = 1.00 for air. Average the results. Show the details of these calculations for at least one trial.

Calculate the speed of light in a vacuum from the speed in plastic and your value for n. Assuming an uncertainty of about 15%, does your result match the accepted value?

Put <u>both</u> optical fibers back in their bag. (Don't lose the little one.) Put everything from the box back in the box.

PHY 133 Report on Experiment 10: The Speed of Light

Part one:

Delay time = ________________

Calculation of speed of light in the fiber:

Part two:

θ_a	θ_p	n

n_{ave} = ____________________

Sample calculation of n:

Calculation of speed of light in a vacuum: