Speed of Light in a Cable

Phys 1301 F99
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Introduction

Although it may not appear to be so, the speed of light is not infinitely fast but a measurable quantity. It is an amazing fact that under suitable conditions every one in the Universe would measure the same value for the speed of light *c*. That this is so has profound implications and you will see some of these implications when you learn about special relativity in lecture. For now, we will perform a simple measurement and measure the speed of light in an electrical cable. Then, we will repeat the experiment using visible light and a plastic fiber cable.

When we speak of the ”speed of light”, it is important to understand that what we mean by *light* encompasses much more than what call “light” when we look at, say, a light bulb. Light is a so-called *electromagnetic* wave that means, first of all, that it is wave-like in nature and secondly, that it is composed of an oscillating electric field *and* a magnetic field wave. It turns out that these two waves oscillate at right angles to one another as they travel through space. It is also the case that both waves are synchronized in the sense that the crests of the electric field wave occur at the same time as the crests of the magnetic field wave and similarly for the troughs. The distance between successive crests of either the electric field wave or the magnetic field wave is the *wavelength* of the light wave. The speed of light is simply the amount of time it takes for the crests of the light wave to travel a distance equal to a wavelength.

We will measure the speed of light using a very low frequency radio wave. We will launch this wave down two cables of a particular geometry. The cables are identical except for their length. The radio wave will travel down the length of the shorter cable in a shorter period of time than it takes to traverse the longer cable. By measuring the transit time difference for the two cables and knowing the cable length difference, we will be able to measure allow the speed of light in a cable. It will turn out for reasons that are not important now, that this speed is somewhat smaller than the speed of light in air (or vacuum).

Procedure

1. Verify that the oscilloscope is turned on. Several small green lights on the oscilloscope panel should be illuminated. Connect one end of the 3 meter long black cable to the *waveform* generator. The instructor will show you how. Connect the other end of the same cable to the input of oscilloscope channel #1. Again, the instructor will assist you.

2. Connect one end of the very long cable to the waveform generator. Connect the other end of the cable to input channel #2 of the oscilloscope. The instructor will assist you. (The instructor will set the function generator so that it is oscillating at f=50 kHz and producing a so-called square wave.)

3. Adjust the “time sweep” on the oscilloscope so that each centimeter on the screen’s horizontal axis equals 10 μs. (1 μs = 10^{-6} sec.) The instructor will assist you. Look at channel #1. What do you see? Pay attention to the height and width of the trace features in units of squares. **Question 1.** Sketch what you see on the oscilloscope for channel #1. Label your sketch somehow so the reader knows how long in time the features are that she is looking at.

4. Adjust the time sweep on the oscilloscope until each centimeter equals 5 μs. (1ns = 10^{-9} sec.) How does the oscilloscope display for channel #1 compare to the one for the previous sweep setting? **Question 2.** Now sketch again what you see and again indicate the duration of key features.

5. Adjust the time sweep on the oscilloscope so that each square is worth 2 μs. Depress the small “x10” button found beneath the knob labeled HOLDOFF (located along the top row of knobs). Each square is now worth 2/10 μsec or 200nsec. (1ns = 10^{-9} sec.) Measure the time difference between corresponding points on the waveforms for channel #1 and channel #2. You may also find that a time sweep of 1μsec/cm also works. Use this setting if you can. **Question 3.** What is this time difference? Be careful that you measure equivalent points or features for the two waveforms. **Question 4.** What is the <u>difference</u> in cable lengths for the two cables?

6. Disconnect the long cable form the wave form generator. Connect the second long cable to the first one to make a very long cable. Connect this cable back to the waveform generator like you did for the first long cable. **Question 5.** Sketch what you see now on the oscilloscope. Indicate the duration of key features. **Question 6.** Again, measure the time difference between similar features for the two waveforms. What is this time difference? **Question 7.** What is the cable length now?

7. **Question 8.** Using the difference in cable lengths for part 5, what is the speed of light in the particular kind of cable we used? **Question 9.** Repeat this calculation for the very long cable used in part 6. **Question 10.** Average these two values and tell me the speed of light in a cable of the type we used today. Express your answer in scientific notation.

Equipment: Oscilloscope, waveform generator, coaxial cables, tee and barrel connectors.

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Abstract

Question 1:

Question 2:

Question 3:

Question 4:

Question 5:

Question 6:

Question 7:

Question 8:

Question 9:

Question 10:

Conclusion