Measuring the Speed of Light

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Abstract

The speed at which light propagates through air at standard temperature and pressure was studied using a time-of-flight technique. A value of $(2.95 \pm 0.03) \times 10^8$ m/s was obtained, with the dominant error arising from the bandwidth of the oscilloscope used to observe the light pulses. This value is consistent with literature values for c and the refractive index of air. [*Make the abstract short, comprehensive, and quantitative. Note: even though the abstract appears first, usually one writes it last. It is the most concise statement of your findings. Usually you need to finish the whole paper before you are in a position to extract (abstract) its essence.*][1]

Introduction

Introduce the experiment. What physics are you testing and how? Why is it important to measure the speed of light? Remember to cite properly any work to which you refer using an endnote.[1] Taper quickly down from the general introduction to the experiment at hand. The introduction should be a concise paragraph.

Theory

What theory underpins the experiment and the measurements you made? For further consideration, the speed of light may be determined from the extra distance d traveled by the pulse encountering the parallel mirrors and the delay t experienced by this pulse,

$$v = \frac{d}{t} \tag{1}$$

where $v = c/n$, and n is the index of refraction of air. This shows how to incorporate an equation. *Note how this equation is part of a sentence. The 'w' in 'where' is typed in lower case, because it introduces a subordinate clause.* Should you need to reference that equation later, you can mention Eq. (1). [*Although it is possible to introduce an equation*

[1] The page limit for this report is 6 pages. This is a firm limit on the length of the entire report, including text, figures, references, etc. You are not allowed to fiddle with the font size or line spacing to cram in more text or figures. Writing "tight" is a challenging but necessary part of technical communication.

with a colon, most equations aren't. Check out a textbook for examples. Be sure to define all variables and to explain what the equations mean.]

Just for confusion's sake, I will introduce the equation obeyed by a damped torsional oscillator, to which I refer later. Such an oscillator can be used to measure G, the constant of universal gravitation. The angular displacement θ of such an oscillator set into motion and allowed to swing freely is given by

$$\theta(t) = \theta_0 + A \sin\left(\frac{2\pi t}{T} + \phi_0\right) \exp(-t/\tau) \tag{2}$$

where T is the period, τ is the damping time, θ_0 is the equilibrium position, A is the amplitude, and ϕ_0 is the initial phase of the motion.

Experiment

The apparatus for the experiment is shown in Fig. 1. [Now explain the important things about it.] Your sketch of the apparatus should include the symbols you will use. Make sure to put an informative caption underneath. People often read the figures first, so it's very

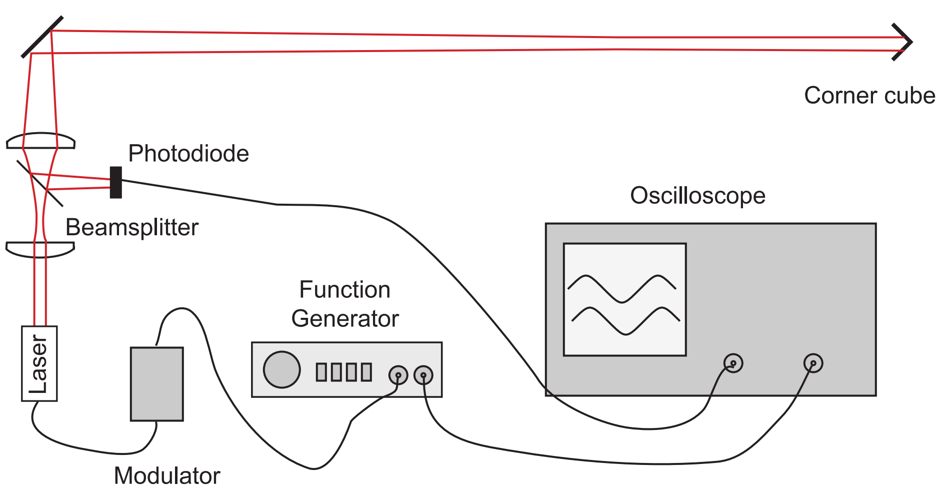

Figure 1: Apparatus used to measure the speed of light. A diode laser emits 5-ns pulses of light at 720 nm, which are split by a 30/70 beam splitter. The main beam bounces between two parallel mirrors separated by a distance $d = 5.673 \pm 0.001$ m, making a total of 4 round trips. The vertical displacement has been greatly exaggerated. A photodiode detects both the direct pulse from the beam splitter and the delayed pulse from the mirrors, both of which are displayed on a 50-MHz oscilloscope. **NB:** All figures need captions.

helpful to put useful information in the caption. However, the important stuff must appear in the text as well.

Your goal in this section is to describe the experiment well enough that someone can understand what you did, but not so well that she will necessarily be able to reproduce every detail. Tell me the *important* details of the procedure — not the blow-by-blow, but the important stuff. If there are subtleties to the experimental procedure, clarify them here.

Do not place figures "in line". Rather, introduce them in the text as shown above. Do not just plop in the figure and figure you're done with a section! Also note that diagrams of apparatus as well as graphs of data are both called "Figures" in technical papers and each one needs a descriptive caption.

For purposes of Physics 53 laboratory reports, you are hereby granted permission to use figures from the Physics 53 laboratory manual in your report, provided that you attribute your source properly. Head to the Word or PDF versions on the course web site for the appropriate documents.

Results

So what did you find? Your results should be summarized in one figure that shows a comparison of your measurements and your theoretical analysis, as illustrated in Fig. 2. Include appropriate error bars where possible, and a panel of residuals if you can. Help in computing these is available on the physics web page.[2] This should be the focal point of your work. The words that come before set the context for this figure; the words that come after explain what is shown in the figure and what it means. Don't assume that the figure speaks entirely for itself. You must explain what is on the figure and what it means. Be sure to tie your analysis to the physics you discussed in the introduction and theory sections.

[2] See `http://www.physics.hmc.edu/howto/`

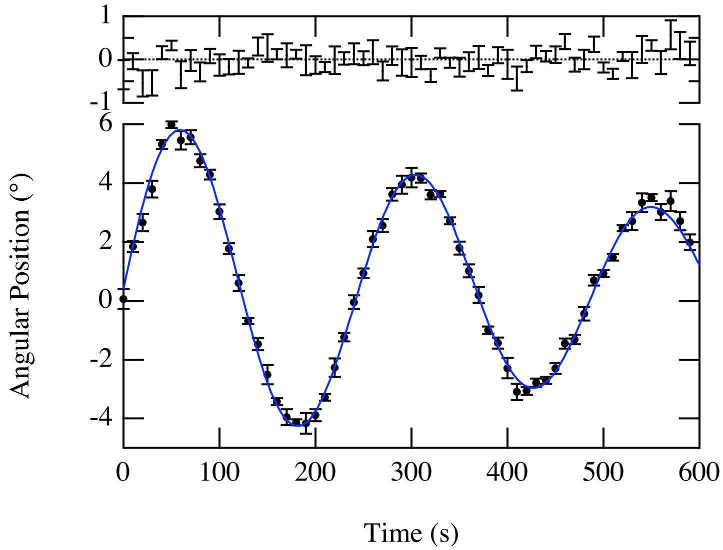

Figure 2: Angular displacement of the torsion balance as a function of time. Smooth curve is a fit to Eq. (2), yielding $T = 245.3 \pm 0.5$ s and $\theta_0 = 0.36° \pm 0.02°$, with $\tilde{\chi}^2 = 86.6/60 = 1.44$. The upper panel shows residuals, which appear to be random. A similar figure was obtained with the weights reversed. *[Note: you should interpret the quality of the fit in the text. Don't just report a value for* $\tilde{\chi}^2$*]*

Conclusion

So, tell me what you really found here and then how things might be improved or how this relates to the world.

References

[1] P. N. Saeta, *private communcation*, 2003.

[2] R. Resnick, D. Halliday, and K. S. Krane, Physics, Vol. 1 (Wiley, New York, 1992), pp 12345-12346.

[3] J. D. Quayle, J. Irrepro. Res. **23**, 1992, 123.

[4] Ref. [3], p. 126.

[5] M. Carey, "How to Solve California's Budget Crisis," Los Angeles Times, 28 August 2003, p. A23.

[Do not include references that are not specifically cited with a numerical endnote in the text.]