Speed of Light

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1 Introduction

2 Theory

To find the value for the speed of light, we considered the equation for velocity,

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

where d is the distance traveled and t is the time taken to travel the distance. However, given a time shift due to the delay in the input of the oscilloscope and a distance shift due to the schematics of the light box, we modified Equation 1 to be of the form

$$v = \frac{d + d_{shift}}{t + t_{shift}}. \tag{2}$$

After obtaining Eqn 2, we can solve for distance and obtain

$$d = v(t + t_{shift}) - d_{shift}. \tag{3}$$

Since Eqn 3 is of the form of a line, we took the line's slope to be our value for the speed of light.

3 Methods

The experimental setup shown in Figure 1 included an LED that emitted short pulses of light, a Fresnel lens to collimate the light, a reflective surface to return the light, and an oscilloscope to take account of the time between pulses leaving and returning. The distance the light traveled was then varied by the placement of the mirror and measured by a tape measure. The distances the light traveled and the times it took were then fit to the line from Equation 3.

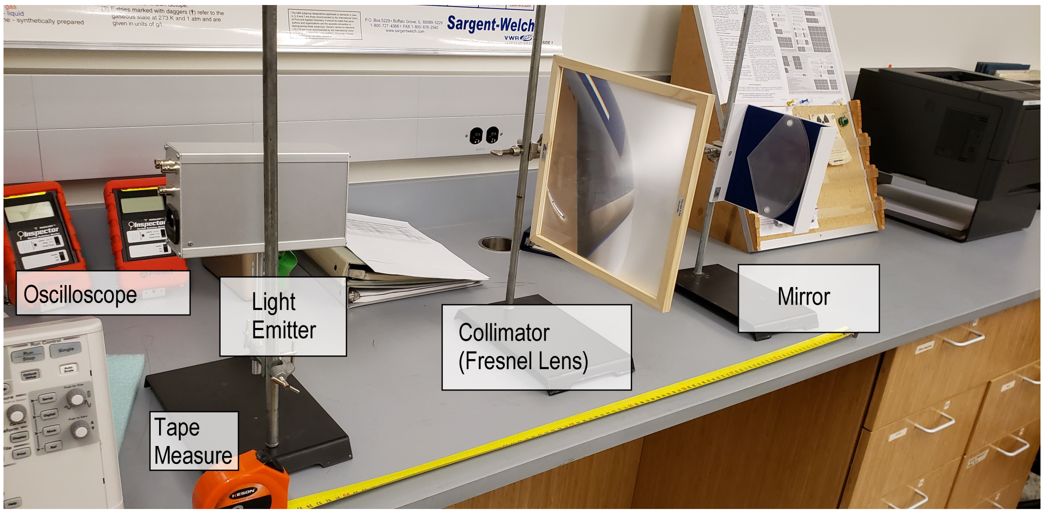

Figure 1: The Experimental Setup

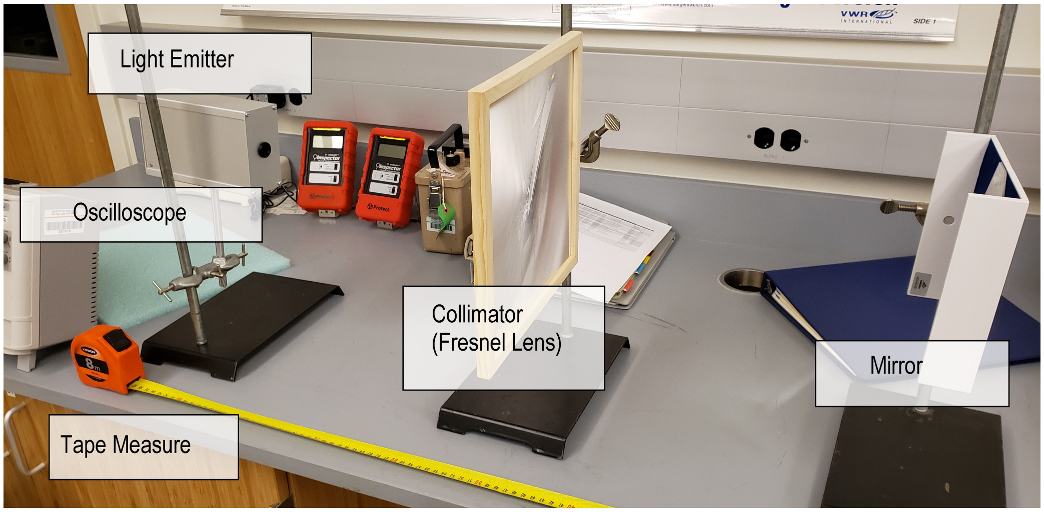

Figure 2: Another Angle of the Setup

4 Data and Analysis

The raw distance data was corrected for the distance from the lens to the LED and the distance the LED extended over the stand. These distances and the times read from the oscilloscope were fit to the line from Equation 3 and plotted. The data was then fit with a weighted fit from Python and the fit's slope was returned. The uncertainty in the slope was then found with

$$\delta v = v\sqrt{(\frac{\delta D}{D_i})^2 + (\frac{\delta t}{t_i})^2}. \tag{4}$$

The SDOM of the found values for the speed of light was also analyzed to compare to the propagation of errors and is shown in Figure 4.

Run Number	Distance(cm)	Times$\times 10^8$(s)
1	341.0$\pm$0.5	0.92$\pm$0.5
2	879.5$\pm$0.5	2.84$\pm$0.5
3	987.5$\pm$0.5	3.22$\pm$0.5
4	1034.5$\pm$0.5	3.40$\pm$0.5
5	1131.5$\pm$0.5	3.78$\pm$0.5
6	1242.5$\pm$0.5	4.18$\pm$0.5
7	1347.5$\pm$0.5	4.50$\pm$0.5
8	1465.5$\pm$0.5	4.82$\pm$0.5
9	484.5$\pm$0.5	1.48$\pm$0.5
10	413.5$\pm$0.5	1.26$\pm$0.5
11	683.1$\pm$0.5	2.23$\pm$0.5
12	757.1$\pm$0.5	2.44$\pm$0.5

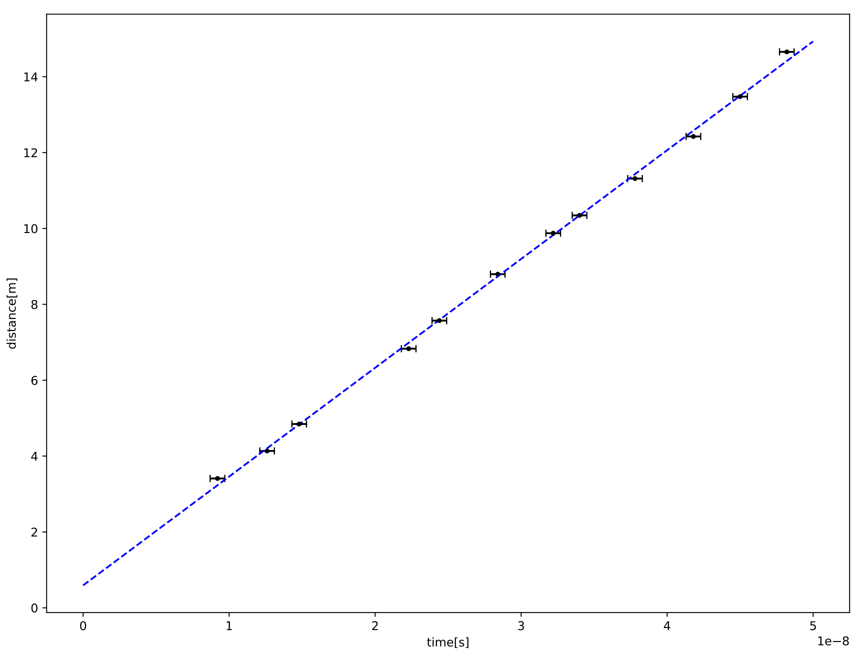

Figure 3: Distance vs Time to find speed of light from slope

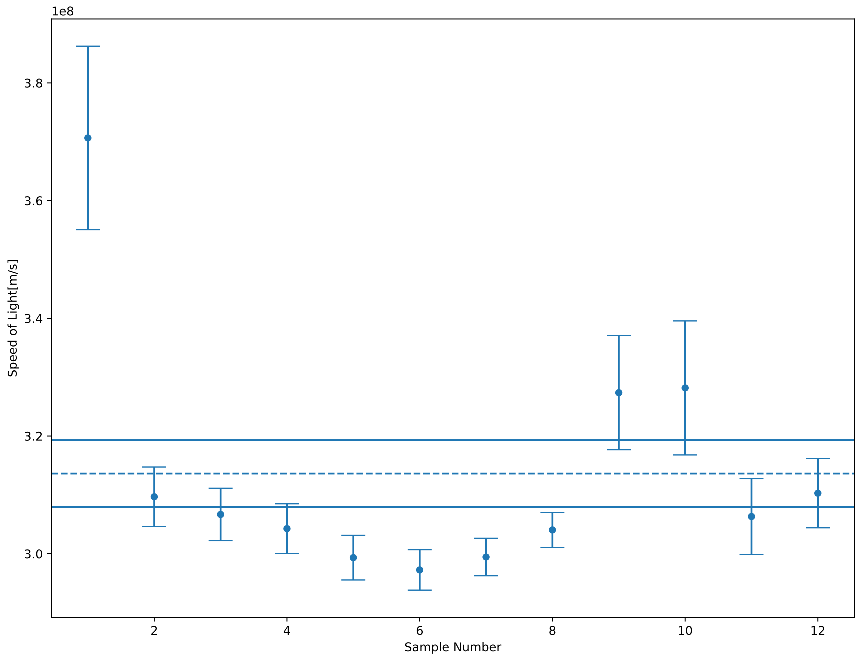

Figure 4: Speed Value vs Sample Number

Appendix: Code

```
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from scipy.optimize import curve_fit


# Reading in the data
with open('speedofLight.csv','r') as sl:
    header = sl.readline()
    info = header.split(',')

    line = sl.readline()
    distList = []
```

```python
    tList = []
    dt = []
    dD = []
    while line:
        line = line.split(',')
        distList.append(float(line[1]))
        tList.append(float(line[2]))
        dt.append(float(line[3]))
        dD.append(float(line[4]))
        line = sl.readline()

# Getting the data into vars
distList = 2*np.array(distList)*10**-2
tList = np.array(tList)*10**-9
dt = (np.array(dt)*10**-9)
dD = (np.array(dD))*10**-2

# The fit
def func(x,A,B):
    return A*x+B

popt,pcov = curve_fit(func,tList,distList,sigma = dt)
perr = np.sqrt(np.diag(pcov))
slopeErr = perr[0]
p_weight = np.poly1d(popt)
xtheory = np.linspace(0,5e-8)
yfit = func(xtheory,popt[0],popt[1])

# Values from line fit
c = np.format_float_scientific(popt[0],precision=3)
print('c:',c)
c = float(c)
cerr = c*np.sqrt((dD/distList)**2 + (dt/tList)**2)

# SDOM Analysis
v = distList/tList
sdom = np.std(v)/np.sqrt(len(v))
vBar = np.mean(v)
```

```
sample = np.arange(1,len(v)+1)

# Console Output
print('cerr:',cerr)
print('SDOM: ',np.format_float_scientific(sdom))

# The Plots
# plt.figure(figsize = (12,9))
# plt.plot(tList, distList, 'k.',markersize = 12)
# plt.errorbar(tList, distList, yerr=dD, xerr = dt,fmt='k.', capsize = 3)
# plt.plot(xtheory, yfit, 'b--')
# plt.xlabel('time[s]')
# plt.ylabel('distance[m]')
# plt.savefig('SpeedOfLight.pdf')
# plt.show()

# plt.figure(figsize = (12,9))
# plt.errorbar(sample,v,yerr = cerr,fmt = '.',markersize = 10,capsize =
# plt.axhline(vBar,ls = '--')
# plt.axhline(vBar + sdom)
# plt.axhline(vBar - sdom)
# plt.xlabel('Sample Number')
# plt.ylabel('Speed of Light[m/s]')
# plt.savefig('SpeedOfLightSDOM.pdf')
# plt.show()

# Pandas to LaTeX
dataDict = {'Distance': distList, 'Times': tList}
df = pd.DataFrame(data = dataDict)
print(df.to_latex())
```