

Astronomy 350: Speed of Light Lab

- 1. The speed of light is a constant, independent of the motion of the source or observer. Try to give concrete examples of how the speed of an object depends on the motion of the source or observer to contrast with how light is different. $c = 2.99792458 \times 10^8 m/s$.
- 2. What's the frequency of red light times the wavelength of red light equal to? How about the wavelength of gamma rays times the frequency of gamma rays?
- 3. The basic idea for the experiment is given in figure 1. By measuring the displacement between the dots E, E' and knowing the frequency of the rotating mirror, it's possible to estimate the speed of light.
- 4. Light from a source S traverses the glass plate G , and after reflection from the plane mirror, R , is focused by the lens L on a stationary concave mirror M . If R is also stationary, the light retraces its path and an image of S is formed at E by partial reflection in G .
- 5. If now R is rotated at high speed about an axis perpendicular to the plane of the figure, it will have turned a small angle by the time the light has returned from M . The reflected beam will then turn through an angle 2α and a displaced image E' will be produced by L . The displacement EE' depends on the angular velocity of R and on the distances RM and RGE . If these quantities are known, the velocity of light may be found.
- 6. Make sure you understand the above.
- 7. The detailed experimental setup is given in figure 2 and I will have gone over it.
- 8. In our experiment, the light source is a HeNe gas laser.
- 9. Study figure 2.
- 10. With the mirror not rotating, align the various mirrors and lenses (as shown by me) so that the light coming back follows the same path as the light going out: initially carefully adjust the rotating mirror housing so that it reflects the light to the far lens (L in figure 2). Now place a piece of paper over the intermediate lens and adjust L using the knobs gently so that the beam goes through the center of the intermediate lens. Now remove the paper and you should see two dots on the lens L . Again adjust the knobs so that the two dots coincide. Now the light is coming back the same way that it went. Now you should see a dot on the observation spot X . You may need to turn the lights out to see this. When you turn the lights out, use the flashlights to walk about.

- 11. There is a Vernier scale on the apparatus X so practice reading that first. Align the dot on the line and note where it is.
- 12. Now rotate the mirror at roughly $100Hz$ clockwise. With the lights of the dot should move slightly. Note carefully its position on the vernier scale.
- 13. Obtain the position of the dot at different frequencies going up a maximum of $1000Hz$. Now go back down but stopping at 950, 850, 750 etc. Hz.
- 14. Repeat but for counterclockwise rotations of the mirror. The dot should move the other way.
- 15. At the end you should have a bunch of numbers representing the dot displacement and the frequency of the rotating mirror.
- 16. Plot the displacement on the y axis and the frequency of the rotating mirror on the x axis. Get the slope of the best fit line.
- 17. Note the light goes and comes back. With the mirror not rotating the return path is the same as the outward path. But with the mirror rotating the return path after the mirror is slightly different.
- 18. Let D_1 be the total path that is the same independent of whether the mirror is rotating or not. Identify this on a diagram and carefully measure it.
- 19. Travelling at speed c , what time does light take to travel the path identified in 18 above - note the time there and back is needed.
- 20. Now let D_2 be the distance between the rotating mirror and the beam splitter. Let D_3 be the distance from the beam splitter to the light spot. Let X be the spot displacement for a given frequency of the rotating mirror. Measure these lengths.
- 21. The return beam after the mirror makes an angle of 2α with the the outward beam. What is 2α in terms of D_2 , D_3 and X the spot displacement when the mirror is rotating?
- 22. What's the connection between angular frequency and frequency?
- 23. During the time t identified in 19, by what angle does the mirror rotate?
- 24. Substitute this in the expression for X which you can get from the answer for 21.

- 25. This should show a relation of the form $X = mf$, where X is the spot displacement, f is the frequency of the rotating mirror, and m is a constant which depends on measured distances and the speed of light c .
- 26. Getting a set of X, f , you can fit a least squares line, get the slope and with this estimate c .
- 27. How accurate is your result compared to the accepted value?
- 29. What are the sources of error and how could you improve this experiment?
- 28. How is the Michelson-Morely experiment different to this. Describe in detail what are the implications of the Michelson-Morely experiment.
- 29. If you were observing a true binary and the speed of light was not independent of the source or observer, what might you observe?