13 September, 2006

Junior Lab

SPEED of LIGHT — c

The measurement of the finite speed of light was of fundamental importance to physics. Moreover, the ability to measure the speed of light in different media finally settled the corpuscular versus wave controversy that existed in the 1800s and discrepancies in the speed of light in moving media was one of the experiments that pointed Einstein toward special relativity.

In the packet I have included several discussions about the history of measuring the speed of light. This starts with astronomic observations in the late 1600s, the first laboratory-based measurements in the mid-1800s, first by Fizeau and then Foucault, and finishes with the very precise work by the American, Michelson, who used a variant of the Foucault method. The speed of light poster in the lab, shows still more precise methods using microwaves. Try to understand these other measurement techniques. By the end of the Lab you should have a general understanding of all these methods, and a very good knowledge of the Foucault method – the one you will use. Also in the packet there is a concise description of this lab itself. Read it carefully. Since you now have the recommended procedure, what I want, by your first class, is for you to *really* understand the procedure, *i.e.* what each step is meant to accomplish.

To quantitatively understand the Foucault method, first look at Michelson's speed of light apparatus in Fig 23-3 of Physics by Giancolli (see packet). (This experiment does not have all the lenses of the Foucault method and is simpler to understand.) *Determine the angular change in the light ray to the observer in terms of the distance from the rotating mirror and stationary mirror, D, and the speed of the rotation of the mirror,* ω*.* (Watch your factors of 2.)

Now let's consider the Foucault method that we will use. *Follow through the derivation and then re-derive it yourself by putting it in your own words*. Note there are some simple typos in some of the formulae in the packet. I leave it to you to find and correct them.

Now consider the following sets of questions.

1. *Explain the function of the two lenses F1 and F2. Why are they necessary? (What is the size of the beam coming straight out of the laser?)* Do their focal lengths make sense for the separations between them?
2. The fixed mirror has a radius of curvature of 13.5 meters. *Why is this important?*
3. Actually in this measurement a wave train (pulse) is used to measure the speed of light. (As it turns out this has led to confusion in the past, even with Michelson himself).

a) *How long (in time) is the wave train that returns to be observed?* Assume the mirror rotates at the maximum rate and the fixed mirror is 13.5 m from the rotating mirror and about 5 cm in radius. How many wavelengths is that? (For a HeNe laser λ=632.8 nm.)

b) But remember there are *two types* of velocities for waves. *What are they, and which one applies to the speed of wave trains? Under what sort of conditions would we measure a speed much lower than the usual value?* It turns out that for carbon disulphide (CS_2) Michelson, to his great surprise, did measure a velocity considerably below *c.* This was very unexpected, but eventually Lord Rayleigh (a theorist, and *worse* British) explained the situation. *How would you explain it?* Finally, note that the microwave measurements, described in the poster, are fundamentally different from the Foucault method*. Which speed of light do they measure?*

Helpful hints regarding aligning the optics include:

1. Pay close attention to the vertical alignment of the beam.
2. Make sure you focus the beam on the fixed mirror, see step 17.
3. It is imperative that you have as sharp an image as possible. Make sure you focus the image in step 21 and step 22 may be helpful in cleaning up the image.
4. Before rotating the mirror center the crosshairs over the stationary image. Now start the mirror rotating at a slow speed. You should be able to see a faint flashing spot where the stationary image was. This is the spot that will move as the rotation rate increases.
5. The position of lenses L1 and L2 are critical for the actual determination of *c*. They are used to determine A as explained in 5 of the Section on Making the Measurement. Unfortunately the scribe on the side of the lens holders does not reflect the true positions of the lenses. We will discuss how to work around this in class, but it is important during the experiment to note the orientation of the holders on the track and the lenses on the holders and to keep them consistent.