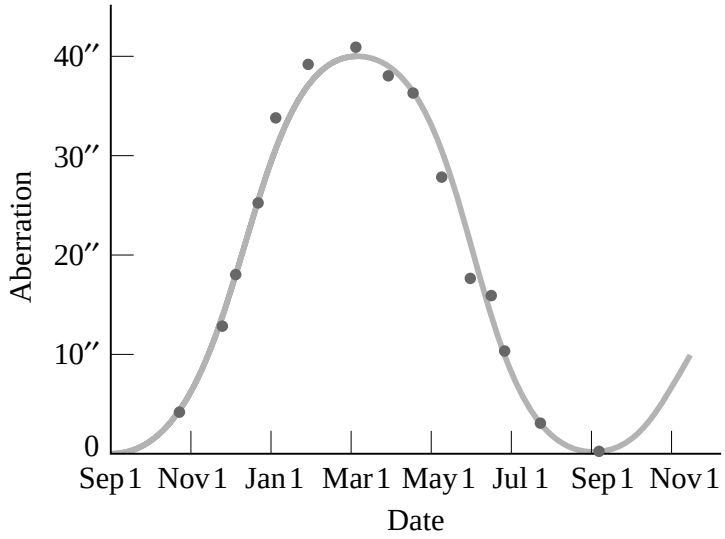
PHY 140Y – FOUNDATIONS OF PHYSICS
2001-2002
Tutorial Questions #11
November 26/27

Note: Answers are given in brackets. Try getting full solutions before the tutorials!

Aberration of Starlight and the Michelson-Morley Experiment

1. The figure below shows a plot of James Bradley's data on the aberration of light from the star γ Draconis, recorded in 1727-1728.
(a) From the data, determine the magnitude of Earth's orbital velocity. [29 km/s]
(b) The data very nearly fit a perfect sine curve. What does this say about the shape of Earth's orbit?



2. What would be the difference in light travel times in the two arms of the Michelson-Morley experiment if the ether existed and if Earth moved relative to it at:
(a) its orbital speed relative to the Sun (see Appendix E)? [3.67×10^{-16} s]
(b) 0.01 c? [3.67×10^{-12} s]
(c) 0.5 c? [13.1 ns]
(d) 0.9 c? [3.17 μs]
Assume that each light path is exactly 11 m in length, and that the paths are oriented parallel and perpendicular to the ether wind.

Lorentz Transformations

Answer Questions 3 and 4 using Lorentz transformations. Do not use short cuts associated with time dilation and/or length contraction. Once you have answered the questions, think about the implications for our concept of space and time.

3. How long would it take a spacecraft travelling at 65% of the speed of light to make the 5.8×10^9 km journey from Earth to Pluto according to clocks
   (a) on Earth, and [8.3 hours]
   (b) on the spacecraft? [6.3 hours]

4. An observer in a reference frame A observes two events to be simultaneous. The events are seen to occur at x = 0 km and x = 1 km in frame A. An observer moves at speed βc relative to reference frame A (where c is the speed of light). This observer sees the events occur with a time difference of 10^{-6} seconds. What is β? [0.287]

5. Jessica embarks on a cosmic journey at a speed of $\frac{24}{25}c$ relative to the Earth. Before leaving, she tells her twin brother, Tom, who stays on Earth, that she will travel outwards for 25 years of Earth time, then back for another 25 years of Earth time. Tom will thus be 50 years older when she returns. She promises to send a radio message on each of her birthdays. According to an Earth-based clock,
   (a) when will these messages reach Tom, and [one every 7 yrs for 49 yrs and one every 1/7 yr for 1 year]
   (b) how much older than the age of the clock at which she leaves will Jessica be when she returns to Earth? [14 years]
   Think about the implications of this answer for our concept of space and time!