PHY 1033C - Lab 1

Parallax Measurements of Distance

The parallax method of distance measurements has been in use for a long time. Hipparchus used the method to estimate the distance between the Earth and the Moon around 129 BC. It also still sees lots of modern use as well. For example, parallax is the concept behind range finders and even interstellar distance measurements. In today's lab, you will use the parallax method to measure the distance to a far away object in the classroom, use a WWI naval range finder to measure the distance to a nearby building, and will investigate Hipparchus' estimation of the distance to the Moon.

Parallax Method

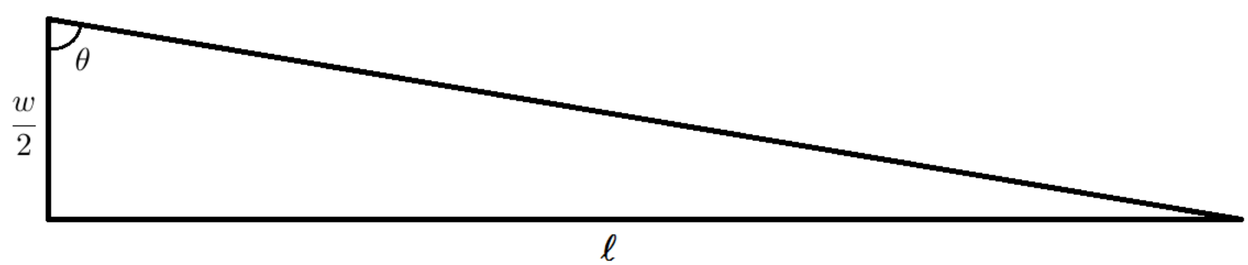
Measuring distances by parallax relies heavily on the concepts of trigonometry. Essentially, you observe an object from two different locations, and use the distance and angles measured to then calculate the distance to the object. For this part of the lab, you will need a protractor, meter stick, and a lamp.

1. Each group will take one of the long tables in the room and place their lamp on one end, roughly centered, and then move to the other with their protractor and meter stick.

2. Place the meter stick across the table so that you can measure its width, w.

3. Line up the protractor's 90° line with the edge of the table and then use your meter stick as a guide to measure the angle to the object. Do this on both edges of the table to get two angles, θ_1 and θ_2, both less than 90° (if you get something like 93°, subtract it from 180° to get the appropriate angle).

4. Since the object is centered on the far end, these two angles should be very close to each other. Using $\theta = (\theta_1 + \theta_2)/2$, draw a right triangle in your lab book similar to the one below



5. The distance to the object is ℓ in the above diagram, and since we know $w/2$ and θ, we can use tangent to find ℓ,

$$\ell = \frac{w}{2}\tan(\theta)$$

Compute and record ℓ in you lab book.

6. Using your meter stick, measure and record the actual distance to the object, L, and compute the percent error between L and ℓ,

$$\%\ \text{error} = \frac{\ell - L}{L} \cdot 100\%$$

Hipparchus and the Moon

During a solar eclipse, the Moon gets directly between the Sun and the Earth. For certain locations on Earth, the eclipse may be total, completely blocking the Sun from view, while at other locations it will be partial. Hipparchus was an ancient astronomer who did a lot of research on the Moon. Though the exact date for this estimate is unknown, it is believed to have occurred in 129 BC. During a solar eclipse in this year, Hipparchus knew that at the Hellespont (a narrow strait in northwestern Turkey) the eclipse was total while at Alexandria, in Egypt, the eclipse was partial, covering about four fifths of the Sun.

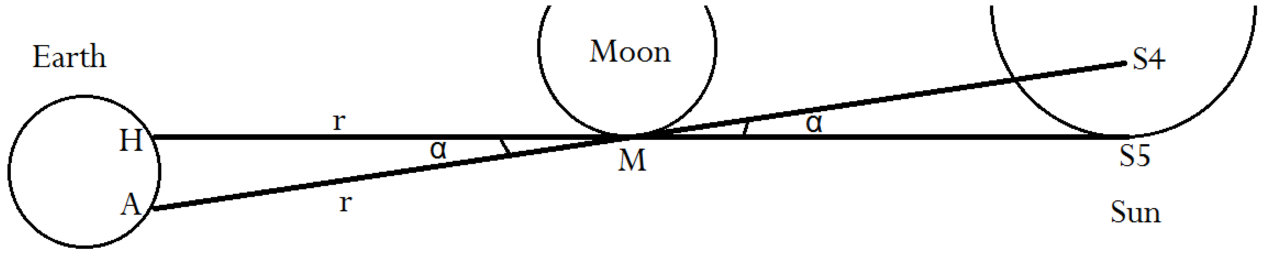


Figure 1: Diagram (not to scale!) showing the geometry behind Hipparchus' data. H is the Hellespont, A is Alexandria, M is the bottom point of the Moon, S4 is a point on the Sun that is 4/5 of its height from the top, S5 is the bottom of the Sun, α is the angle between H and A as viewed from the Moon, and r is the approximate distance between the Earth and the Moon.

7. Hipparchus had also measured the apparent sizes of the Sun and the Moon and found that they subtended about 0.5° of the sky. Since 4/5 of the Sun was covered by the Moon in Alexandria and 5/5 of the Sun was covered in the Hellespont, the difference must indicate the angular difference between the two locations as seen from the Moon, hence

$$\alpha = \left(1 - \frac{4}{5}\right) \cdot 0.5^\circ$$

   Compute and record the value of α in your lab notebook.

Hipparchus also knew the latitudes of the Hellespont and Alexandria and so knew the difference between them was 9°. If we let $\overline{\mathrm{HA}}$ be the distance between the Hellespont and Alexandria and r_E be the radius of Earth (we will be computing this in a future lab), then the distance between them can be computed as

$$\overline{\mathrm{HA}} = 2\pi r_E \cdot \left(\frac{9^\circ}{360^\circ}\right) \tag{1}$$

where the 9°/360° comes from the fact that a full circle has 360° and we're only interested in a distance covering 9°. Since we also know the angle between them from the Moon, we can similarly form another equation for this same distance,

$$\overline{\mathrm{HA}} = 2\pi r \cdot \left(\frac{\alpha}{360^\circ}\right) \tag{2}$$

8. Use equations (1) and (2) to find r, the distance to the Moon, a) in terms of r_E, and b) in kilometers, given that $r_E = 7,360$ km, according to Eratosthenes c. 250 BC (which is an overestimate, $r_E \simeq$ 6,400 km by modern measurements).

9. Note that Hipparchus' estimate is too large, as the actual distance to the Moon is about 405,000 km (or about 63 Earth radii) at max. Comment on the likely sources of this discrepancy.

Naval Range Finder (2 Pts. extra credit)

One group at a time may go out to the balcony on the west side of the building *after* they are finished with the main part of the lab, and use the **naval range finder to measure the distance** to the white peak on the building across the street, standing on the large white chalked X (Hume Hall).

10. To use the range finder, look through the viewfinder and point the openings on the ends at the object to which you want to measure the distance. There should be a horizontal line through the middle and as you adjust the large black roller, the two halves come together or move further apart.

11. There is also a small circle above the image as you're looking through the view finder that shows the distance in yards. That distance will correspond to the actual distance when the image is adjusted so that it does not appear to be split. There will be someone outside to help you with the naval range finder and explain its use.

12. Record the distance to the building in your lab notebook.