Physics 167 – Astronomy

Lab Project 2: Angular Measurements

Introduction

It is very satisfying to make accurate measurements with simple tools and at the same time to measure quantities of fundamental importance. You will use an inclinometer, cross-staff, and pinhole viewer to measure the height of Old Main, the Earth's latitude, and the angular size of Moon.

Procedure

1. Height of Old Main

Use an inclinometer (meterstick with attached protractor) to measure the height of Old Main. To do this, first figure out your stride length, so you can pace off distances accurately. It is convenient to do this in a building with standard 12-inch floor tiles—the basement of SMC is perfect for this. Make a few measurements of your stride length (pace off the length of the hallway, then count tiles, and take the average of a few results). Record your stride length and estimated uncertainty.

Then proceed to Old Main. Pace off a distance from the building. Then, standing at the distance you have paced off, use your inclinometer to measure the angle of elevation to the top of the cupola (just the structure, not the spire with the gold ball). To use the inclinometer, sight the target through the eyehooks, then when the suspended mass comes to rest, pinch the string against the protractor—you can then look at the reading (the angle the string makes on the scale). The complement of the protractor reading is the angle of inclination between the meterstick and the horizontal. Record the angle and your estimate of the uncertainty in your measurement of the angle.

Finally, remember to pace off the distance from the edge of the building to the center (most easily done by going inside, but can also be estimated by pacing outside).

2. Latitude Measurement

Use your inclinometer to measure the altitude of the north star, Polaris. You can easily find Polaris on a clear night using the pointer stars (last two stars of the big dipper). Record the altitude and your estimate of the uncertainty in your measurement of angle.

3. Angular width of the Moon

You will need to mount the moon-viewing aperature (an accurate 0.25" hole punched in an index card) on your meterstick, so that you can slide the aperture securely to different positions along the meterstick. To measure the Moon, rest the meterstick on some stable surface (like a chair, fence, or tree limb) while you sight the Moon through the aperture. Your goal is to adjust the aperture position along the meterstick so that the Moon exactly fits in the aperture. Record the position of the aperture. Take a few measurements and average to get a good result, and estimate the uncertainty in your measurement. Also record the date and time of your observation (something you should always do for astronomical observations).

Questions

1. a. For Procedure 1 (Height of Old Main), make a table showing:
(i) Your stride length and its uncertainty
(ii) The distances measured inside and outside Old Main
(iii) The angle measured with the inclinometer
Show your supporting calculations below the table.

b. Find the percent uncertainty in your stride length. Assuming this same percent uncertainty in the distance d from the center of Old Main to the point you measured the angle, find the uncertainty in d.

c. Find the height of Old Main, using your measured value of d and your measured angle θ.

d. Find the percent uncertainty in your value for the height. You may assume that it is the sum of the percent uncertainty in the distance d and the percent uncertainty in the angle θ.

2. Use your measured value of the angle in Procedure 2 (Latitude Measurement), to determine the latitude of Galesburg. Explain how you used the measured angle to find the latitude. Is your measured value, given the uncertainty in your angle measurement, consistent with the known latitude of Galesburg? Explain briefly. Include in your uncertainty the fact that Polaris is does not lie exactly on the north celestial pole—it makes an angle of approximately $0.74°$ with the pole (so we will consider this to contribute an additional $\pm 0.74°$ of uncertainty).

3. a. Using your data in Procedure 3 (Angular Width of the Moon), estimate the angular width of the Moon in degrees, and the uncertainty in your measurement. Show your calculations. State also the percent uncertainty in your measurement (you may assume it is the same as the percent uncertainty in your measurement of the aperture position along the meterstick).

b. The radius of the Moon is 1738 km. The Moon's average distance from Earth is 3.844×10^5 km, but the Earth-Moon distance varies by $\pm 5.5\%$ over the course of its elliptical orbit. Since this variation is not small compared to the uncertainty in your measurement, you will have to look up the moon's distance from earth at the time and date of your measurement. You can do this using the online calculator on the www.mooncalc.org website. However, the distance you measured is not the Earth-Moon distance measured center-to-center (as provided by the website), but rather that distance minus the radius of the Earth, because you are making your observations from the surface of the Earth, not from its center. Calculate the angular width of the Moon, determined from its known diameter and distance.

c. Is your experimental result (from part a) consistent with the accepted value (from part b)? Explain briefly.