Name ______________________

Date ______________________

Lab Partner(s) ______________________

Project Score [ ]

MEASURING THE SKY

PROJECT LEVEL: Introductory
PROJECT GOALS: Students will learn about angular measurements, how they change with distance, and how they are used to estimate linear distances

1 INTRODUCTION

The point of this lab is to get you outside, looking at and thinking about the sky. You will also become acquainted with angular measure and the **HORIZON SYSTEM** for specifying the coordinates of an astronomical object.

THIS WEEK'S PROJECT WILL HAVE THREE PARTS.

I. We will make a simple scientific device with which you can measure the angular distance between two astronomical objects, such as a bright star and the Moon or a planet.

II. We will go on the roof of Van Allen Hall and become acquainted with the Horizon System for describing the positions of astronomical objects, and use instruments called **THEODOLITES**. We will measure the **AZIMUTH** and **ALTITUDE** angles of landmarks around Iowa City. We will also measure the altitude and azimuth angles of the Sun, and see how they change during the lab period.

III. In coming weeks you will use these Theodolites to determine distances via **PARALLAX** measurement, observe the changing position of sunset, and make other basic astronomical measurements.

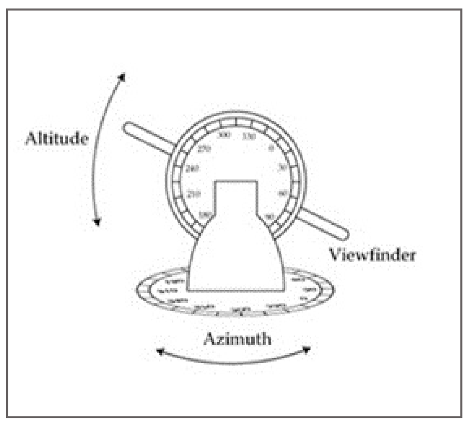

FIGURE 1 - DIAGRAM OF A BASIC THEODOLITE; A DEVICE USED TO MEASURE AZIMUTH AND ALTITUDE ANGLES

2 SIMPLE SCIENTIFIC DEVICE

2.1 Building an Angular Measuring Device

Ask your instructor for a length of string. While in the lab room, there is a mark on the outer wall which indicates 8 degrees. If you stand on the far side of the room (inner wall), this mark subtends 8 degrees. Hold your string at arm's length and hold your fingers at the points corresponding to the tips of the mark. Either make knots here or use a pen to mark the string at these two points. Put another knot or mark halfway between. You now have knots or pen marks at intervals of 4 degrees. Divide these to provide 2 degree intervals. Finally, copy this whole sequence over, so you have a string capable of measuring a total angle of 24 - 30 degrees. ***Note the resolution and total angular span below***.

Question 1:

What is the Resolution and Total Angular Span of your home-made measuring device?

Resolution	
Angular Span	

2.2 Testing your Measuring Device

Before testing your string out on the sky, let's try it out on something indoors. Go into the hallway and have your lab partner stand 50 feet away. There is a mark on the wall in the hallway indicating a point 50 feet from the far wall. Now, use your string device to measure the height of your lab partner in degrees.

Question 2:

What is the Angular Size of your Lab Partner?

Angular Size (θ)	

Using the relationship below, now convert the angular measurement to a linear measurement. (This is a common application of angular measurements, one you will perform multiple times throughout the course.)

To convert angular size to linear size, use the following relationship:

$$d = D \times \frac{\Delta\theta}{57.30\ deg}$$

Here, **D** is the distance to your lab partner (50 feet in this case), $\Delta\theta$ is the angular size in degrees, and **d** is the linear size (or in this case, the height of your lab partner).

How well did you do? If you wanted to express this (your accuracy) as a number, what would that number be? One way would be to subtract the known value from the measured one. However, this does not take into consideration the size of the object you are measuring. For example, if you are off by a few feet measuring the height of your lab partner, the error is much more significant than if you were measuring the height of a building.

To express this *significance*, we will use a formula called the **FRACTIONAL ERROR EQUATION**.

The Fractional Error is expressed as:

$$\text{Fractional Error} = \frac{\text{Known Value} - \text{Experimental Value}}{\text{Experimental Value}}$$

Measure your lab partner's height directly using the provided tape measure (if unknown) and calculate the Fractional Error of the linear size you measured above.

QUESTION 3:

Calculate the Fractional Error in your height measurement?

Known Height (feet)	Measured Height (feet)	Fractional Error

2.3 MEASURING LARGER OBJECTS

You are now ready to use your string measuring device to make a larger measurement. Follow your lab instructor to the West end of Van Allen Hall and use your string to measure the angular distance from the bottom of the First Congregation Church steeple to the top. Consider the steeple to start where the red bricks end and stop at the very top of the tower peak. Consult the image below for more information.

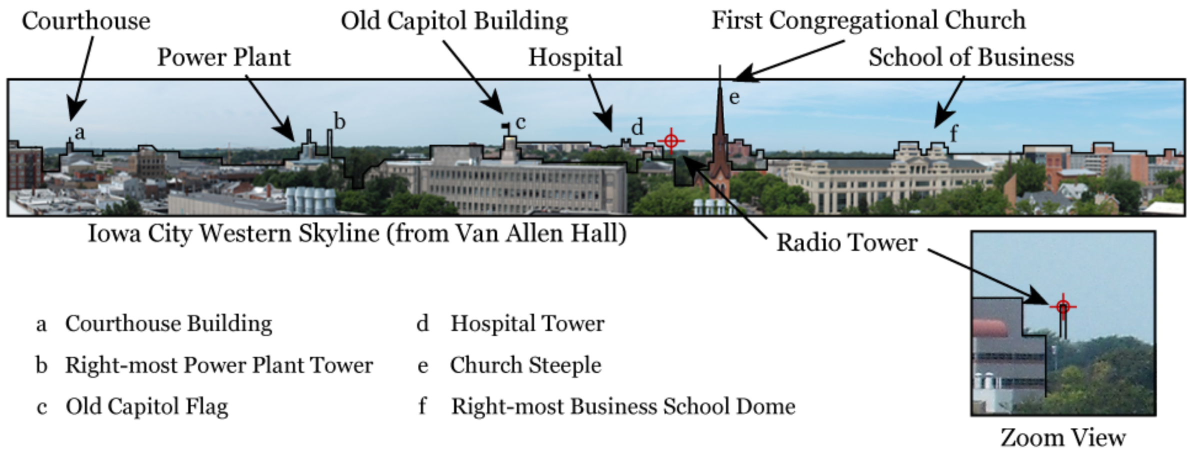

FIGURE 2 - IOWA CITY SKYLINE

QUESTION 4:

What is the Angular Distance between the bottom and top of the Church steeple? If the distance to the Church is 120 meters, how tall is the steeple?

Angular Distance (θ)	
Steeple Height (m)	

You are now done with Part 2 and can put away your string.

Later in the semester, we will use the string to measure angular distances between stars, and between stars and planets, so make sure you keep your string.

3 MEASUREMENTS WITH THE THEODOLITES

The Theodolites are mounted on the west railing of the roof of Van Allen Hall. A schematic illustration of one is shown in Figure 1.

3.1 GETTING FAMILIAR WITH THE THEODOLITES

To use the Theodolite, sight through the tube at the object you are measuring. The viewfinder tube will move in both azimuth angle (horizontal scale) and altitude angle (vertical scale). Start out by familiarizing yourself with the instrument. When pointing the tube at the horizon, due south, you should measure an azimuth angle of 180 degrees, and an altitude angle of 0 degrees. Move the sighting tube to the west. You should see the azimuth angle change to an angle greater than 180 degrees. Point the sighting tube higher up in the sky. You should measure an altitude angle greater than 0 degrees. Carefully read the scales on the Theodolites. ***Record the resolution of both scales in the table below. Note that this is also the UNCERTAINTY in your measurements.***

Question 5:

What is the Resolution of the Theodolite?

Azimuth Resolution	
Altitude Resolution	

3.2 Measuring the Landscape

The teaching assistant will point out a few objects in the Iowa City western skyline. Use the Theodolite to measure the Azimuth and Altitude positions of the objects given. If you forget which object is which, please consult Figure 2 showing the Iowa City skyline.

Question 6:

Measure the azimuth and altitude angle of all three objects, and record them here. Make sure to measure these values to the precision of the device.

Object	Azimuth	Altitude
Courthouse Building Flag (a)		
Power Plant Tower (b)		
Old Capitol Building Flag (c)		
Hospital Tower (d)		
Church Steeple (e)		
Business School Dome (f)		

3.3 Comparison to String Measuring Device

Now that you are more familiar with the Theodolites, let's repeat the Church steeple measurement you made in Part 1 and compare the results. With the Theodolite, record the position of the bottom and top of the steeple. Next, use the positions to calculate the **ANGULAR DISTANCE** between the two points.

The **ANGULAR DISTANCE (θ)** is given by:

$$\Delta\theta = \sqrt{\Delta AZ^2 + \Delta AL^2}$$

Where **ΔAZ** is the difference between the azimuth angles of the tree and the Jefferson building, and **ΔAL** is the difference in the altitude angles.

QUESTION 7:

What is the Angular Distance between the top and bottom of the Church steeple, measuring now with the Theodolite? Using the Theodolite measurement as the *known* value, what is the Fractional Error in your measurements with the string? Use the workspace provided.

Bottom	***AZ***		***AL***	
Top	***AZ***		***AL***	
Change in Angle	***ΔAZ***		***ΔAL***	

Δθ Theodolite	
Δθ String (from Question 4)	
Fractional Error	

4 CONCEPT QUESTIONS

Please answer the following questions relating to concepts from this lab. Most of the information needed can be found in the introductory material or presented throughout the lab text.

QUESTION 8:

What range of angles does Azimuth cover? What range does Altitude cover?

QUESTION 9:

In Part 2, you measured the height of your lab partner standing 50 feet away. What, if anything, would change if your partner was standing 100 feet away? How about 1,000 feet?

QUESTION 10:

Imagine you are describing the location of the sun you just measured with your Theodolite to a friend who is studying abroad in Europe. Will he/she observe the sun in the same location as you observed it in Iowa City? Can you describe a coordinate system that would be better to use in the situation?

Name of Student

MEASURING THE AZIMUTH OF SUNSET THROUGH THE SEMESTER

This part of the lab project is to be done during the next 2-3 months of the semester. During your lab section, you should go to the roof of Van Allen Hall on clear days and measure the altitude of the sun. Try and do this 4 times throughout the semester to observe how the position of the sun changes from month to month when observed at similar times. Use the table below to record your results and turn it in after the final session.

	Date	Time	Azimuth
Session 1			
Session 2			
Session 3			
Session 4			