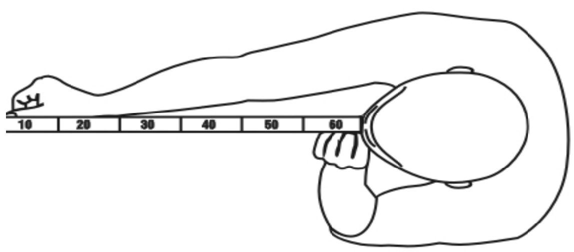
Physics 104- *Astronomy*
Measuring the Sky

Part 1- Measuring angles

Objects in the night sky appear to be imprinted on a two dimensional sphere called the **celestial sphere** that surrounds the Earth. Astronomers use angles to measure the relative positions of objects on the celestial sphere. We are going to learn to use a ruler held at arms length to measure angles.



Using a meter stick, measure the distance between your eyeball and the end of your thumb, as in the picture above. Have each group member read the yardstick for you and record the results in the table below. Calculate the average and record it in the table below.

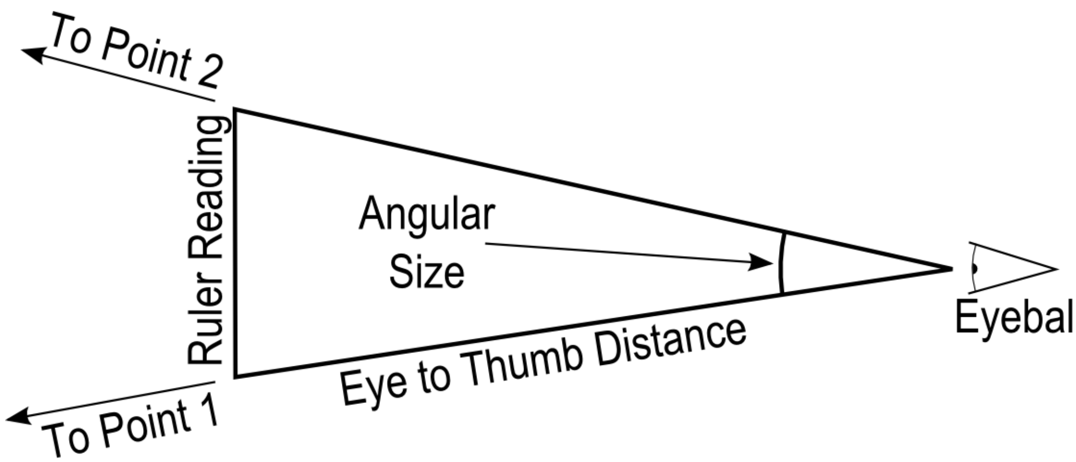
Group Member	GM1	GM2	GM3	GM4	Avg

Holding a clear ruler at arms length, the markings on the ruler tell us the "distance" between two distant points. According to the rules of trigonometry, the study of triangles, if the angular size is small we can write

$$\text{Angluar Size (in degrees)} \approx \text{Ruler Reading} \times \text{Conversion Factor}$$

where

$$\text{Conversion Factor} = \frac{180}{\pi \times \text{Eye to Thumb}}$$



Using your Average Eye to Thumb distance from page one, calculate your personal Conversion Factor and record it on the next page.

Now calculate the angular size of our hand, fist, thumb, and pinkie. First, use your ruler to measure the distance between your outstretched pinkie and thumb, the width of your closed fist, and the widths of your thumb and pinkie. Use your personal conversion factor to calculate their angular sizes. Record all of this information on the table on the next page.

Personal Conversion Factor: ____________ (Degrees/cm)

	Size (cm)	**Angular Size** (Degrees)
Outstretched Hand		
Closed Fist		
Thumb		
Pinkie		

Take a two meter stick out into the hallway and measure its angular size at four different distances using each of the measurement tools that we've just devised.

Distance	Hand		Fist		Thumb		Pinkie		Ruler	
	#	Angle	#	Angle	#	Angle	#	Angle	cm	Angle
1/4										
2/4										
3/4										
4/4										

Answer the following questions.

1. What happens to the angular size of the two meter stick as it is moved further away?

2. Which measuring instrument achieves the most accurate results? Why?

3. What would the angular size of the meter stick be if it were 100 km away? How many centimeters is that on your ruler? Could you accurately measure that angle? Why or why not?

4. Imagine that two photons leave a star 4 light years away. If the photons hit opposite sides of our planet, what was their angular separation as they left the star?

5. What does question 4 suggest about the lines of sight from the surface of the Earth to the stars?

Part 2- The Sun and the Zodiac

Over the course of a year, the Sun's apparent position among the background stars changes. In this section, we'll explore why this is true.

On the back wall of the room, the positions of two "constellations" are marked on the wall. In the front of the room are three tape marks representing where the Earth is in its orbit on three different dates, one for February 1st, one for March 1st,and one for February 15th. The "Sun" is on the table in the center of the room. Have each group member stand on each of the three tape marks and use your ruler to measure the angular distance between the Sun and the two constellations.

February 1st					
	GM1	GM2	GM3	GM4	Avg
Capricorn					
Aquarius					
February 15th					
Capricorn					
Aquarius					
March 1st					
Capricorn					
Aquarius					

Answer the following questions

1. How fast (in degrees per hour) does the sky appear move due to the Earth's rotation?

2. If the Sun is at Meridian on February 15th, how long (in minutes) will it be before Aquarius crosses the meridian?

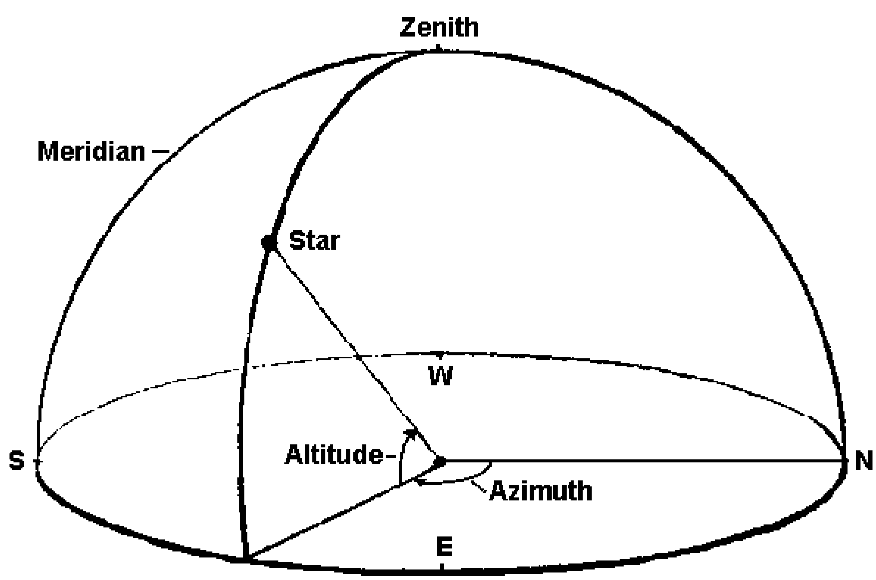
3. How fast (in degrees per day) does the Sun's position appear to change with respect to the background stars?

4. Why does the Sun's position against the background stars appear to change?

Part 3- The Sun's Coordinates

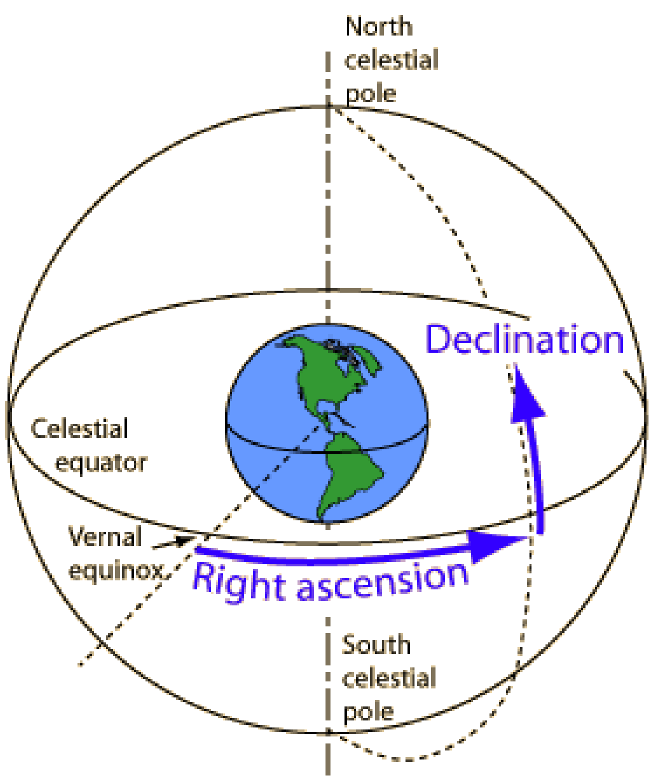
The sky, from our perspective, is two dimensional. To locate an object on a two dimensional surface, we need two numbers or ***coordinates***. On this piece of paper, our coordinates might be the horizontal and vertical distance from the lower left corner. On the celestial sphere, however, we use ***angles***.

Because we're stuck to the Earth's surface, it feels natural to measure positions with respect to our local horizon. An object's height above the horizon is its ***altitude***. The horizon is at 0^0 degrees and zenith is at 90^0. Direction (North, South, East, West) is called ***azimuth***. North is 0^0, East is 90^0, South is 180^0, and West is 270^0.



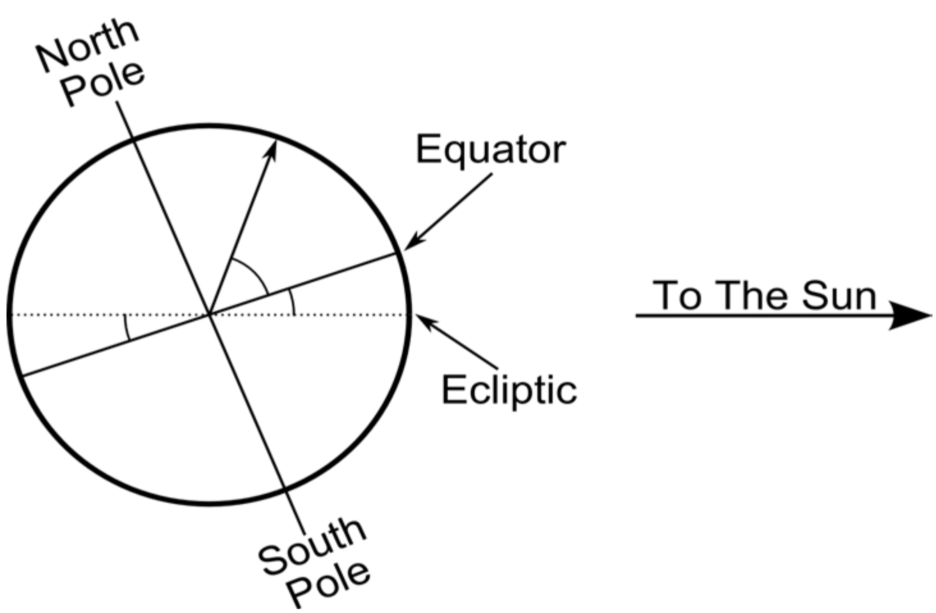
The altitude and azimuth of a given celestial object is not fixed. The altitude of Polaris is 90^0 at the North Pole but 0^0 at the equator. In St. Paul, the Sun is low in the East in the morning, high in the South at noon, and low in the West in the evening.

We need a coordinate system that is fixed to the sky. Astronomers use a system whose axis are parallel to the lines of longitude and latitude on the Earth. The lines of latitude are called lines of ***declination***. The lines of longitude are called ***right ascention***. The Celestial Equator is 0^0 declination and the North Celestial Pole is 90^0 declination. Right ascension is 0^0 at the position of vernal equinox and increases Eastward.



Because the Earth's axis is tilted 23^0 with respect to the ecliptic, the Sun's declination changes throughout the year. This means that the Sun's altitude at meridian as well as its azimuth at sunset change throughout the year. Assume that you're in St. Paul (44^0 North Latitude) and use the picture below as a guide to complete the following table:

Date	Declination	Altitude at Meridian	Sunset Position
Vernal (spring) equinox (March 21st)			Due West
Mid-May (approximately)	12^0		
Summer Solstice (June 21st)	23^0		
Autumnal equinox (September 22nd)		44^0	
Mid-November (approximately)		32^0	
Winter Solstice (December 21st)			South of West



Turn in one copy of this lab with each group member's printed name and signature. By signing, you certify that you have actively participated in the exercise and have put forth effort in equal share to your fellow group members.

Printed Name	**Signature**
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________