Name_____KEY_____Date_____Period _____

Shadow Analysis – 2nd Observation

Lab # 13

Introduction

On October 17, 2017 we repeated our shadow experiment because of the clear skies. We used an iPad to record our measurements using time lapse photography. Periodically, a pin was placed in the observation sheet and the time was recorded. At the end of the day the length of those shadows and the azimuths were measured.

Watch the video to obtain the values recorded by the iPad. Then complete the calculations and graphs to compare the results to our first observations on 9/29/17.

Analysis

Completing Data Table One

1. Watch the video and record information in Columns B and C.

2. Calculate the azimuth of the sun based on the azimuth of the shadow. The sun is opposite the shadow so add 180° if the shadow is below 180 or subtract 180° if the azimuth of the shadow is greater than 180. (Column D)

3. Determine the Altitude of the Sun by constructing a Triangle drawn to scale on a piece of graph paper. Record your measured altitude into Data Table One. (Column E) This step can be done mathematically using the formula Altitude of Sun = $\tan^{-1}$ (height of nail /length of shadow)

Completing Data Table Two

4. Calculate the change in Azimuth of the Sun (Column D) and record the differences into Data Table Two.

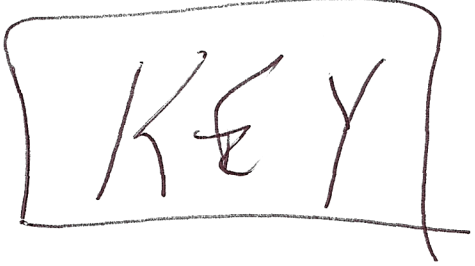
5. Calculate the number of minutes between each observation (use Column A). Be careful, you are working with time. Record your answers on data table two.

6. Calculate the rate of motion of the shadow in degrees per minute for each pair of observations. Your answer should be a decimal. Do not round your answer. Record the value to 4 decimal places into Data Table Two. The formula for rate is

$$\text{Rate} = \frac{\text{Change in azimuth}}{\text{Change in time (minutes)}}$$

11. Calculate the rate of change in degrees per hour by using the following formula

$$\text{Rate (°/hour)} = \text{Rate (°/min)} * 60$$



Graphical Analysis

Construct 3 line graphs based on the data collected in Data Table One.

- Graph #1 Time of Day (Column A) and Length of Shadow (Column B)
- Graph #2 Time of Day (Column A) and Azimuth of Sun (Column D)
- Graph #3 Time of Day Column A) and Altitude of Sun (Column E)

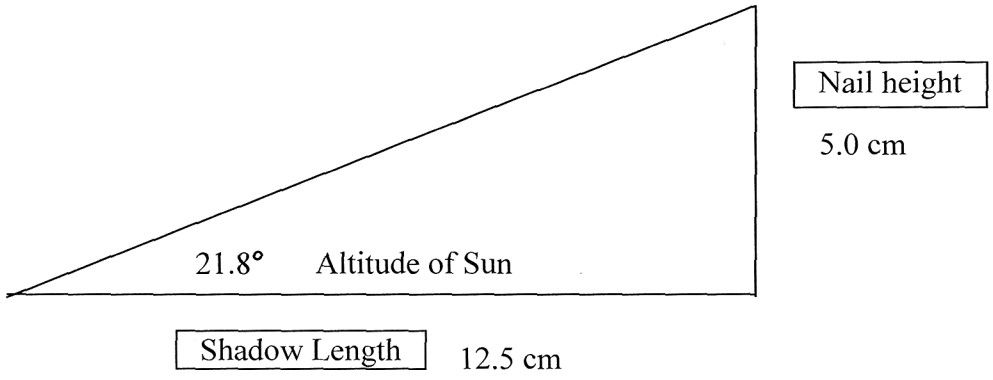
Directions for Determining the Altitude of the Sun by Construction of triangles to Scale

Materials - protractor, graph paper and metric ruler

Procedure –

For each observation of the sun you will need to draw a triangle to scale to determine the altitude of the sun. You will need the measurements for length of the shadow and height of the nail from your observation sheet. Your drawings should be constructed on the graph paper to help make the shadow and the nail at right angles.

1) Use the ruler to draw a vertical line the exact same length as the nail. Make sure that the bottom of the line begins at the bottom of a box on the graph paper. Label the line Nail height and record the height in centimeters.
2) Draw a horizontal line that extends from the bottom of your nail line that is the same length as the shadow. Make sure your line extends along the horizontal line of your graph paper. Label this line shadow length and record the length in centimeters.
3) Draw a line from the end of the shadow to the top of the nail. (The hypotenuse of the triangle)
4) Measure the angle between the shadow and the hypotenuse using the protractor. This angle is the altitude of the sun. Right the measured angle on your triangle.



Shadow Analysis Data Table One

Height of nail = 4.5 cm Date of Observation 10/17/17

Observation	Time of Day	Length of Shadow (cm)	Azimuth of Shadow (° from North)	Azimuth of Sun (° from North)	Altitude of Sun (° above horizon)
1	**8:30 AM**	16.3	303	123	15.4
2	**9:40 AM**	8.7	317	137	27.3
3	**10:11 AM**	7.4	325	145	31.3
4	**11:45 AM**	5.3	351	171	40.3
5	**12:50 PM**	5.2	13	193	40.9
6	**1:59 PM**	5.8	32	212	37.8
7	**2:42 PM**	6.8	42	222	33.5
Column	A	B	C	D	E

Data Table Two

Observations	Change in Azimuth (°)	Difference in Time (min)	Rate (° / min)	Rate (° / hour)
1-2	14	70	.200	12
2-3	8	31	.258	15.5
3-4	26	94	.277	16.6
4-5	22	65	.338	20.3
5-6	19	69	.275	16.5
6-7	10	43	.233	13.95
Column	**X**	Y	Z	
	Based on Column D	**Based on Column A**	Column X/Y Don't Round	Column Z x 60 Round to tenth

Rate (°/hour) = Rate (°/min) * 60

What was the total change in Azimuth of the Sun from Observation 1 to Observation 7? _**99**_ °

What was the total change in Time (min) from Observation 1 to Observation 7? _**372**_ min

Questions

1. Calculate the overall rate of change of the shadow in degrees/hour based on the last 2 values. (Write formula, Substitute with units, Solve with units, round to the nearest tenth)

   Rate = Change in Value / Time
   Rate = 99° / 372 min X 60 min / hour = 16.0° /hour

2. Calculate % error for your value using 15°/hour as the accepted value. (Round to the nearest tenth)

   % Error = 1°/hour / 15°/ hour X 100 = 6.7 %

3. How did the length of the shadows recorded on October 17th compare to the shadow lengths recorded on September 29th?

   The shadows recorded on October 17th were longer than the shadows on 9/29/17.

4. What has happened to the maximum altitude of the sun between September and October?

   The maximum altitude of the sun on October 17th was lower.

5. If you repeated this procedure again on December 3rd, 2017, what would happen to the length of the shadows?

   The shadows would be longer in December than in October.

6. How is the length of the shadow related to the altitude of the Sun?

   They are indirectly related. As the altitude of the sun decreases, shadow length increases.

7. Around what time of day does an object cast the shortest shadow?

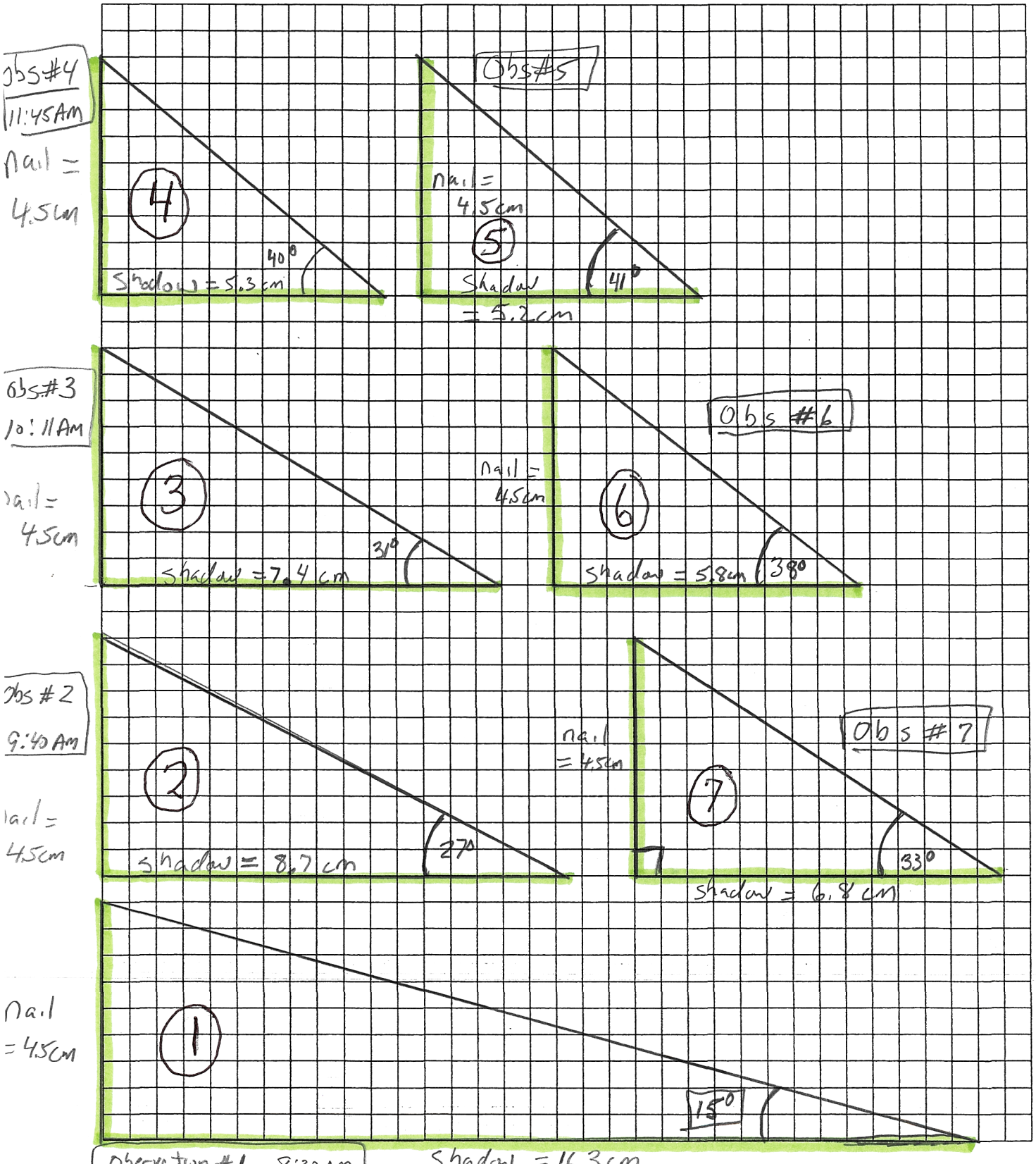
   The shortest shadow of the day is cast at solar noon. (Sun at the highest altitude)

8. When will an object cast the longest shadow?

   The longest shadows are cast at Sunrise and Sunset.(altitude of sun = 0°)

0.5 cm Graph Paper

Two lines per centimeter. Black lines.



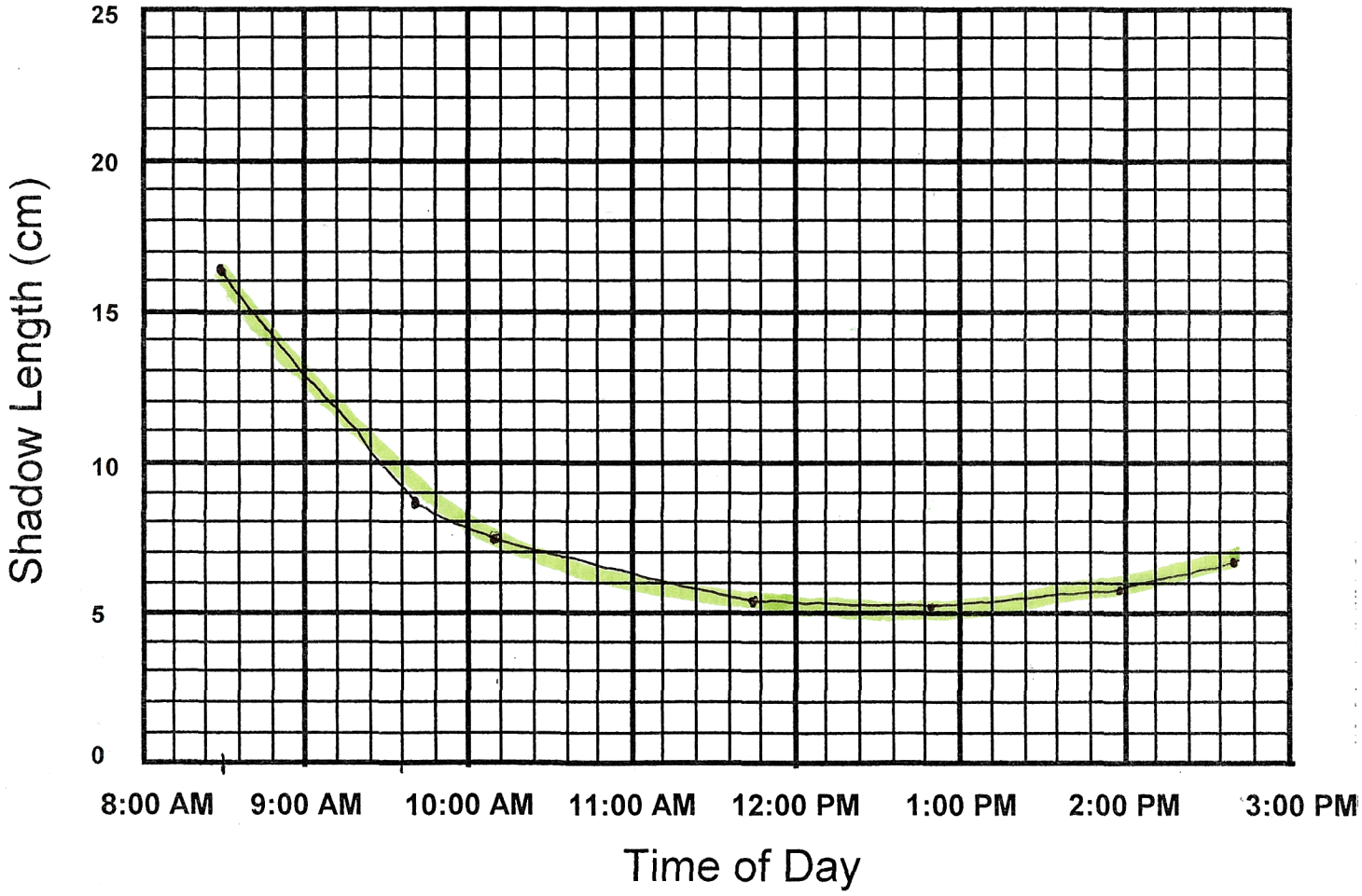
Students will construct Triangles to Scale on this Page.

Shadow Analysis Lab

Graph #1

Key

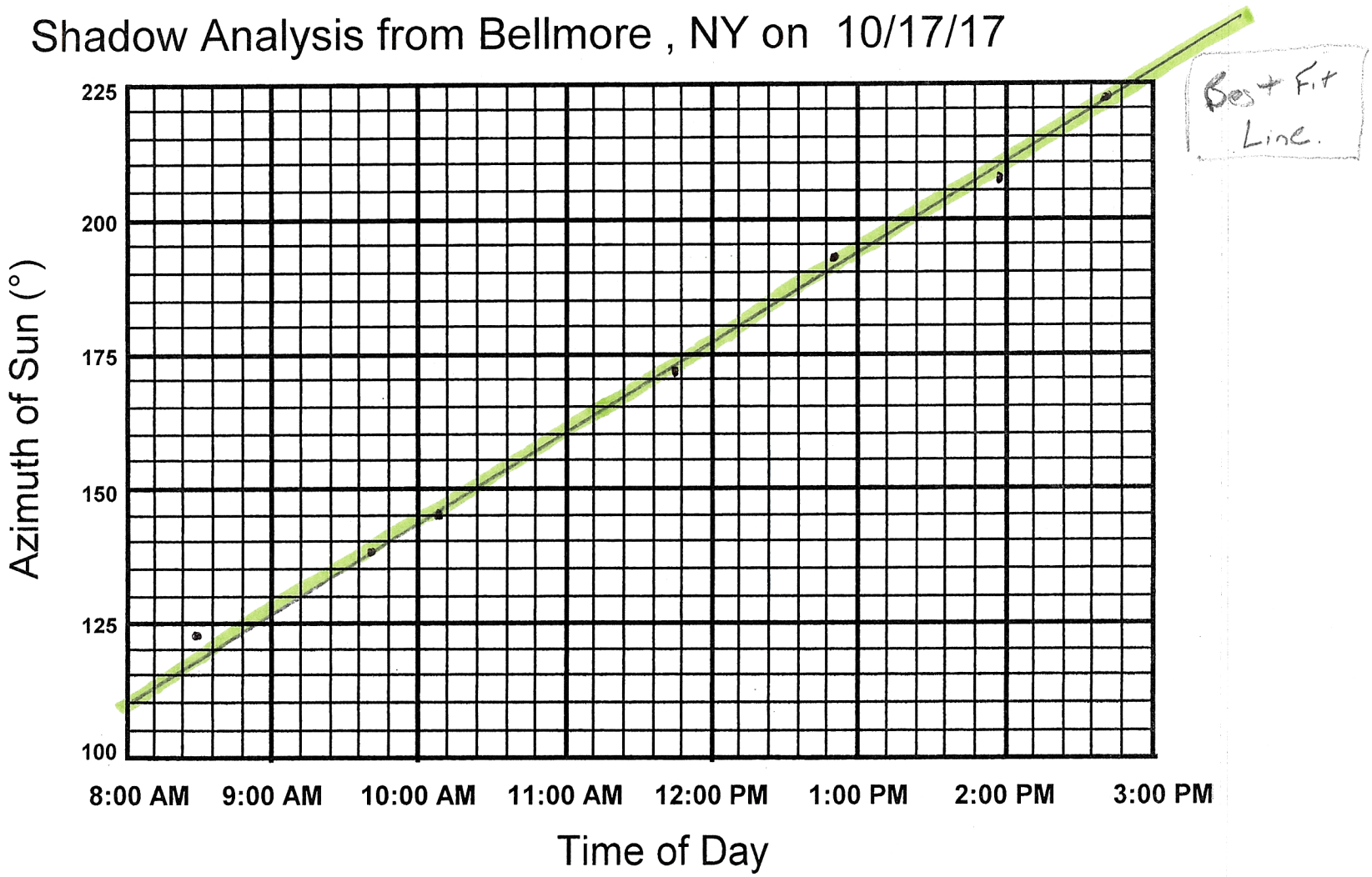
Length of Shadow of 4.5 cm Nail from Bellmore, NY on 10/17/17



Shadow Analysis Lab

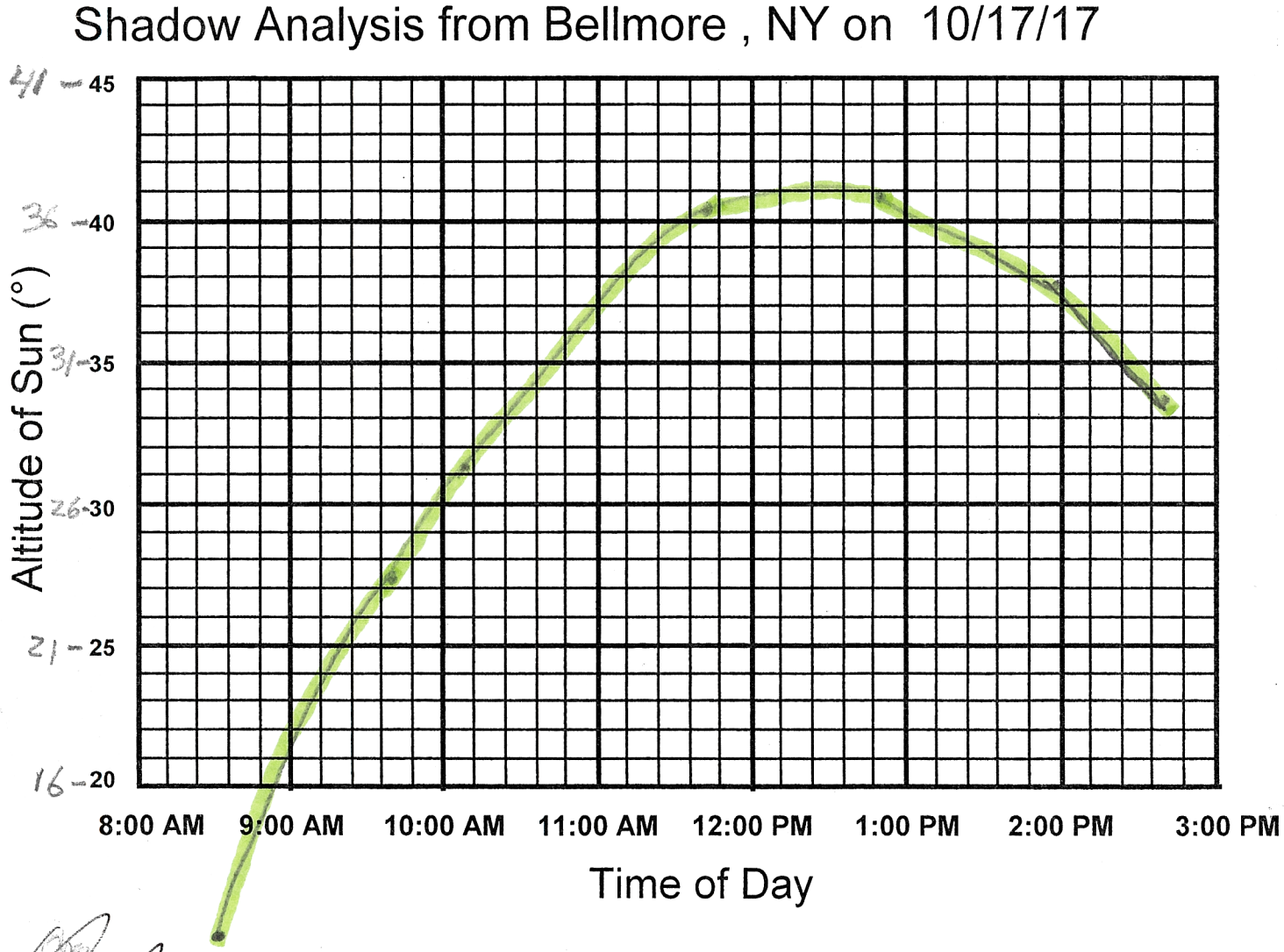
Graph #2

Key



Shadow Analysis Lab

Graph #3 KEY.



Have students skip / not plot observation #1

Sorry could have students remember the scale so it goes from 16 to 41