Our Corner of the Universe
AST 101, Fall 2007
MEASUREMENTS AND ERRORS
Week of September 25

The aim of this activity is to introduce you to the theory of measurement and errors. You will also become familiar with two instruments used to measure the angular separation between objects: the cross-staff and the quadrant.

To complete this activity you will need a cross-staff and quadrant. The lab T.A will provide these.

You will be shown how to use both the cross-staff and the quadrant during the lab sessions.

PRE-LAB EXERCISE

Please read the entire lab before class.

I. The Cross-staff

The cross-staff is a simple instrument for the measurement of angle and angular size.

Draw two marks 1 meter apart (1 yard apart if you are using a yardstick) on a piece of paper hung on a wall. Stand 2 meters from the marks. Rest the zero end of the meter stick against your cheekbone and sight along the length of the stick, sliding the crosspiece back and forth until the left-hand mark on the wall is lined up with the left-hand edge of one of the three (narrow or 1", medium or 2" and large or 4") sights on the cross-staff and the right-hand mark is lined up with the right-hand edge of the sight. Then remove the stick from your cheek and read off the value on the meter stick where the vertical crosspiece on the cross-staff is found. Try to read it to the next millimeter. Record this measurement on the first column of Table 1 below. Do not forget to specify if you have used the narrow, medium or large sight of the cross-staff.

Repeat the same measurement the other four times; in order to get five data for the same quantity. Remember to move the cross-staff on the meter stick before repeating the experiment so that the next measurement will be completely independent of the other. Again, record the data in the first column of the Table 1.

Now move 4 meters (or 4 yards) away from the marks on the wall. As before, make five independent measurements by using the cross-staff. Record these measurements on the second column of Table 1.

Then repeat the entire procedure from a distance of 8 and 12 meters (or 8 and 12 yards) and record your data in the third and fourth column of Table 1 respectively.

Table 1

Distance (m., yd.) 1", 2" or 4" sight?	**2**	**4**	**8**	**12**
Measurement #1				
Measurement #2				
Measurement #3				
Measurement #4				
Measurement #5				

Now you have to convert the meter stick readings into angles. This is done by using a *nomogram*, a graphical device that can be used, instead of a formula, to relate two different quantities. You will find the nomogram and the instructions to use it in the last page of this reading. Try to read the nomogram to the next tenth of a degree.

Convert all the meter stick measurements recorded in Table 1 into angles and fill in Table 2.

Table 2

Distance (m., yd.)	**2**	**4**	**8**	**12**
Angle #1				
Angle #2				
Angle #3				
Angle #4				
Angle #5				

You have five independent measurements of the same angle. To find a better approximation of the true value and estimate the mistake you made in the measurement process you have now to average your data and calculate the error, $\frac{\text{maximum reading} - \text{minimum}}{2}$

Record your results below:

Angle for 2 m. =		±	°
Angle for 4 m. =		±	°
Angle for 8 m. =		±	°
Angle for 12 m. =		±	°

On the graph paper below make a plot of your measurements: the horizontal axis represents the distance that you were standing from the marks, the vertical axis is the angle you measured. Plot the four average values and their corresponding error, as explained in the previous section. Then join the point by a smooth curve.

Now that you have the graph, you can use it to predict new observational results. For example you can estimate what the angle would have been if you were standing 10 meters (or 10 yards) away from the marks. To do that, draw a straight line up from the point on the horizontal axis representing 10 meters that will meet the smooth curve at a point. You can then read the angle corresponding to this point by drawing a horizontal line intersecting the vertical axis. Record your results below:

Angle corresponding to 10 m. (yd.) = _________°

Recall that there exists a theoretical formula that allows you to compute the angular size of an object, given its true size and distance:

$$(angular\ size) = \frac{57.3 \times (true\ size)}{(distance)}.$$

Using this formula calculate the angle that you should have observed for each of the distances you used, namely 2, 4, 8 and 12 meters (yards). Record these values below and plot them on a graph in a different color.

Theoretical Angle for 2 m. =		±	°
Theoretical Angle for 4 m. =		±	°
Theoretical Angle for 8 m. =		±	°
Theoretical Angle for 12 m. =		±	°

Are the theoretical values within the error bars on the graph? If not, can you think of any reason why they should be?

II. The Quadrant

The quadrant is an instrument for measuring the altitude of celestial objects, i.e. the angle between the horizon and the object, as shown in the first picture below.

To use the quadrant, sight along the top edge of the board at the object whose altitude you want to measure. When the thread has stopped swinging, trap it against the scale with your fingers, remove the quadrant from your eyes and read off the value where the thread crosses the scale.

You will measure the altitude of a small object (less than 10°) and a high object (more than 50°). Measure the altitude of the two objects you have chosen for a total of five times each. Compute then the average and the error of your measurements. Record your results in the Table 3 below.

	Small Altitude	Large Altitude
Measurement #1		
Measurement #2		
Measurement #3		
Measurement #4		
Measurement #5		
Average ± Error	±	±

Now that you got acquainted with the quadrant, you will use it to measure the height of a building.

Select a relatively tall building, surrounded by a sufficient amount of level ground so that you can stand off from it at a distance approximately equal to its height. Back away from the building, taking once in a while a sighting with the quadrant, until the altitude of the building is 45°. Then pace off the distance to the building and record below the number of steps:

Number of steps to the building = ___________

To convert the number of steps into meters (or yards) you need to know the length of one of your steps. To measure your pace, step off 10 paces and measure this distance with your meter stick (yardstick), then divide this number by 10:

Length of ten steps = __________
Length of one step = __________

Compute now the distance to the building, by multiplying the number of steps to the building by the length of your pace:

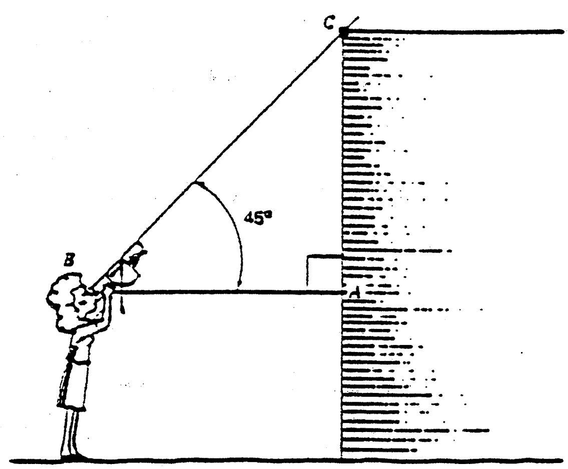
Distance to the building = ___________

Now you can estimate the height of the building. As it is shown in the picture below when the altitude of the building is just 45°, the distance AB from the building is equal to the distance AC, the amount of the building that is above eye level.

In the space below report the total height of the building (not only the distance AC!) and explain how you took into account the effect of your height.

Height of the building = _________

Due week of October 2



Measuring the height of a building with the quadrant.

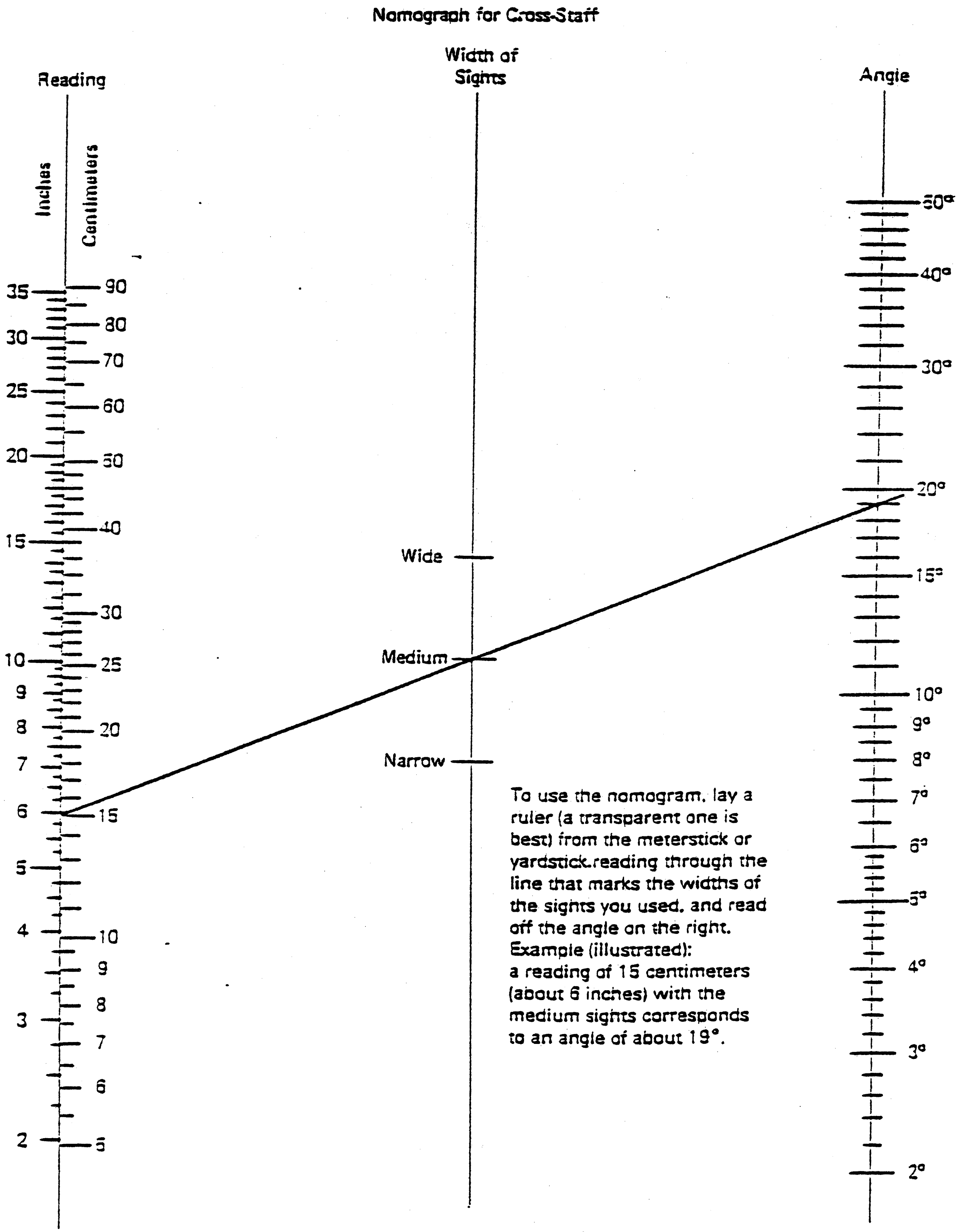


Figure 2-19 Nomogram for converting readings on the cross-staff into angles.