OUTSIDE LAB 5: Celestial Navigation

OBJECTIVE: To find your latitude and longitude.

DISCUSSION:

To determine locations on the surface of the Earth requires the use of some kind of coordinate system. The system most commonly used is that of longitude and latitude. By means of a simple measurement it is always possible to determine your latitude. Longitude is more difficult. However, you can also determine it in a straightforward manner if you have a way to know the time in Greenwich, England. This is called Greenwich Mean Time (GMT), or Universal Time, and is the standard time used throughout the world.

A. Finding latitude.

Finding your latitude is easy because, as can be seen from the following diagram, your latitude is equal to the altitude of the north celestial pole. In the southern hemisphere, it would be the altitude of the south celestial pole. In the northern hemisphere, the star Polaris is within one degree of the north celestial pole. So, you can get a good estimate of your latitude simply by measuring the altitude of Polaris.

B. Finding Longitude.

This is harder because the zero of longitude is arbitrary. It is set as the half circle which goes through the poles and passes through Greenwich, England. This half circle is called the Prime Meridian. You find your longitude by knowing what time it is locally (this is local time as measured astronomically, not the time in your time zone) and knowing GMT. Your longitude is just the difference in these times. So if the difference is 6 hours and you are East of Greenwich then you have longitude 6 hours E. If you are west of Greenwich and the difference is 9 hours then you are 9 hours W. Since there are 24 hours in a day and 360 degrees in a circle, each hour of longitude corresponds to 360/24 = 15 degrees.
EXERCISES:

EXERCISE 1:
Using a quadrant find the altitude of Polaris. Make five measurements and average them together. **The altitude of Polaris equals your latitude.**

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXERCISE 2:
Next record the correct time in the box below. Then immediately measure the altitude of a bright star whose name you know. Make sure that the star is **not** one of those near the north celestial pole. It can be anywhere else in the sky. Again, make several measurements and average them. Finally record the correct time right after you finish your measurements. The average time is the time on the clock in between when you started and finished your measurement.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Start Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>End Time</th>
<th>Average Time</th>
<th>Average Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXERCISE 3:
Any given star will be at the altitude you measured twice in one day, unless it is at its highest altitude when you measure it. At the stars highest altitude, it lies on a half circle of the celestial sphere which passes through the zenith. This half circle, called the meridian, goes through the north celestial pole and through the zenith. It extends to the horizon in both the north and south directions. (If you are having trouble visualizing this, simply point to the location of the north celestial pole, and then trace out a path through the zenith and continue towards the southern horizon and also go back and trace the bath to the northern horizon). In order to know what the star’s position in the sky is, you will need to note whether the star is to the East of to the West of the meridian when you measure its altitude.

Determine whether the star whose altitude you measured is to the East or West of the Meridian and write down the answer here.

EXERCISE 4:
The next task is to determine Greenwich Mean Time. To do this simply compute the average time at which you took the measurements and add 5 hours to it if you are going by Eastern Standard Time or add 4 hours to it if you are going by Eastern Daylight Time.

**GMT time:** _________________

Outside 5-2
EXERCISE 5:

Having determined Greenwich Mean Time it is now necessary to determine the local solar time. Recall that your longitude is given by the difference between these two times. The trick is to note that two observers at the same latitude see the configuration of stars in the sky, but at different times. If the two observers are at the same place, they will of course see the same thing at the same time. If one observer is at Greenwich and a second is one-fourth of the way around the Earth to the West from Greenwich then the second observer will see the same configuration of the stars in the sky six hours later than the first observer. (Note to really be precise we would need to be working with Sidereal time which differs from solar time by four minutes each day. However, we can get a very good approximation to our longitude without taking this complication into account.) You will compare the altitude you measured for a star with a hypothetical second observer who is at your latitude but who is at the same longitude as Greenwich. To accomplish this all you have to do is to use “Stellarium” to go to the location where the longitude is zero and the latitude is your latitude. Then find the time at which the star has the same altitude and is in the same part of the sky as you observed when you measured its altitude.

To do this, start “Stellarium” and press F6 (In some cases you will have to use the function or ‘fn’ key to be able to press ‘F6’) to bring up the locations window. Select the Latitude. For latitude type the latitude you measured. Set the longitude to zero and uncheck the box that says ‘Daylight savings time”. Press enter and close the location box and you should be positioned due south of Greenwich observatory at the latitude of Winston-Salem.

Next find the star that you observed and change the time until it has the same altitude and is in the same part of the sky as you measured. This can be a bit tricky. First find your target star by pressing Ctrl-F or $F$ and typing in the name of the star. Once the correct star is selected you can see its local position next to ‘Az/Alt’. Next, turn on the meridian line by pressing the semicolon key ( ; ) on your keyboard. Make sure the star is on the correct side of the meridian, just as you measured it outside. Now try increasing or decreasing the time until using the ‘J’ and ‘L’ buttons to slow down or speed up and place the star is in the approximately correct position on the correct day. Next you need to fine tune the time to get the altitude of the star just right. Note that you can press the ‘K’ button twice to stop the motions all together. If you have the wrong case, simply change the time until the star is correctly moving. Once you have it just right, check the time and use this as your time at the Prime Meridian.

**Time at Prime Meridian:** ______________

Finally subtract the time at the Prime Meridian from the GMT at which you made the measurement outside. That is your longitude in hours and minutes. Is it East or West? Convert it to degrees. Each hour is 15 degrees, and each minute is ¼ of a degree.

**Longitude:** ________________  In degrees: _____________
EXERCISE 6:

*Stellarium* gives you the latitude and longitude of Winston-Salem. Compare your results with the correct ones. You can look this up in *Stellarium* by pressing F6 on your keyboard and choosing Winston-Salem as your location again.

<table>
<thead>
<tr>
<th>Position of Winston-Salem:</th>
<th>Winston-Salem</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your Measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Values</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

How accurate are they? Are they as accurate as you would expect them to be? Why or why not?

EXERCISE 7:

Early navigators had an additional problem. They could measure local time by doing something similar to what you did. But without good portable clocks, they did not know GMT. Imagine that your watch was only accurate to 20 minutes a day. On any given day that is not so bad but if you set it to Greenwich time at the beginning of your voyage, then two months later you would not have any accurate knowledge of what time it was according to Greenwich mean time. What early voyagers had instead of accurate watches were almanacs that gave the times at which certain celestial events occurred at familiar places such as Greenwich, England. Given that they were able to determine their local time, how would they have been able to use the times of these events to determine Greenwich mean time and therefore their longitude?

Form a group with 1-2 other tables, i.e. 4-6 people and come up with 5-6 possible events that might be useful for this and simply list them below.
EXERCISE 8:
   Pick the two best choices for the events from the list your group came up with and discuss whether they would work and why or why not.

Celestial Event 1:

Celestial Event 2: