The Colonial Williamsburg Foundation

NAVIGATION AND VIRGINIA'S MARITIME ECONOMY INFORMATION PACKET AND HOME ACTIVITY

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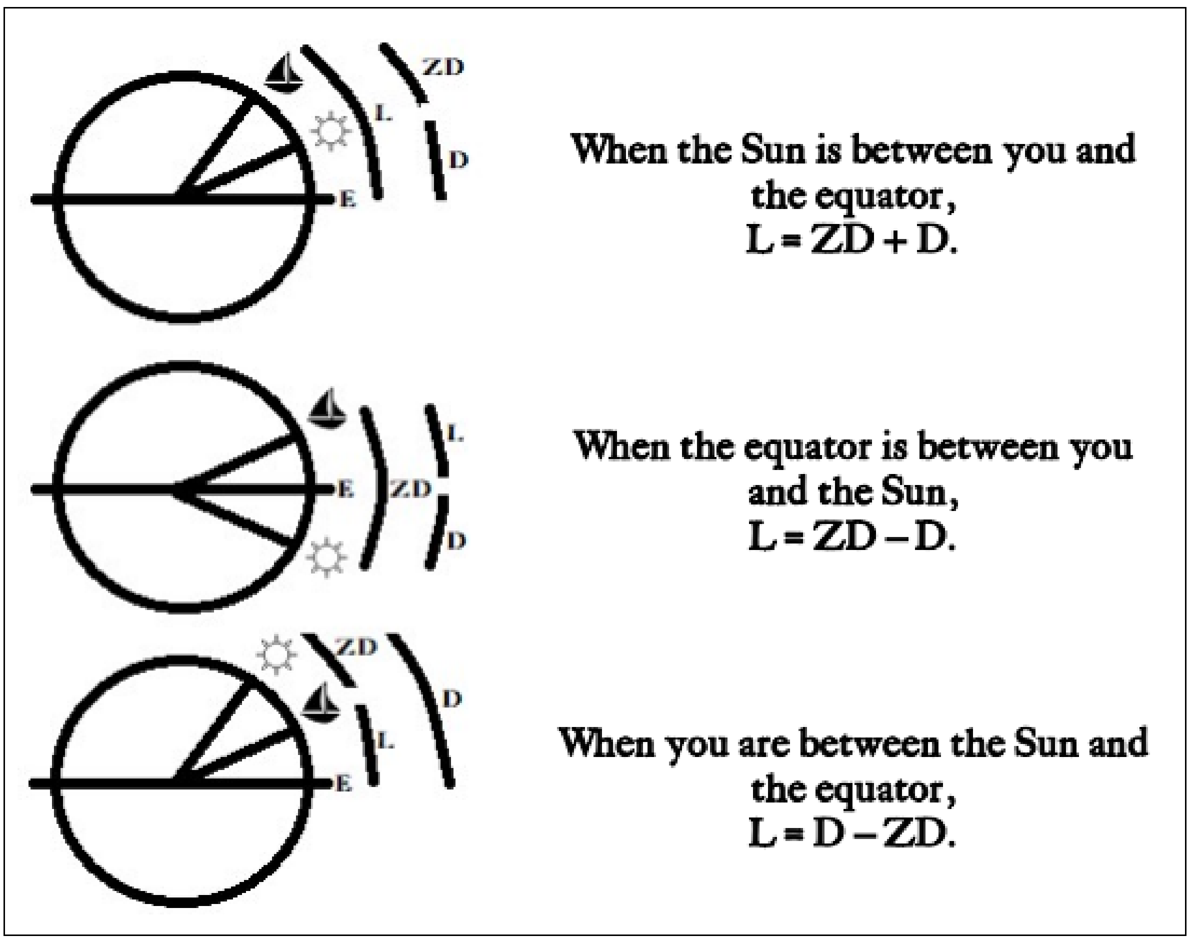
Words in **bold face** are excellent vocabulary terms to look up and learn a bit more!

A Quick Refresher on Latitude…

Latitude is simply your position north or south of the **equator**, which corresponds with 0° latitude. If you look at latitude lines on a globe, you'll see that they never touch. That's why they're also called "**parallels**."

Finding your latitude at noon is one of the easiest navigation problems to solve. When the Sun is due north or south of you (it'll also seem to be at its highest point in the sky), this is called **local apparent noon**. Use your sextant to measure the Sun's **altitude** above the horizon. Subtract that number from 90° to find your **zenith distance**. Use the *Nautical Almanac* to find the Sun's declination for that day. Depending on your location there are three ways you can use your zenith distance and the Sun's declination to find your latitude:



What About Longitude?

The livestream program discussed latitude, but that was only one part of navigation at sea. Ship captains would also need to know their **longitude**, or their position east or west around the globe. Since latitude lines are parallel, calculating latitude was relatively easy. Because the spherical shape of the earth, longitude lines (also called "**meridians**") grow steadily closer from the equator until they converge at the poles. Longitude was much more difficult to calculate, and the problem plagued navigators for many years.

In 1714, during the reign of **Queen Anne,** the **Longitude Act** was passed in Great Britain. This act offered a grand prize of £20,000 to anyone who could develop a practical means of determining longitude at sea. The winner's method had to be accurate to within half a degree, or less than thirty nautical miles. Over the decades that followed, many candidates tried to win the longitude prize with ideas ranging from the creative to the bizarre. A carpenter named **John Harrison** became famous beginning in the 1730s for developing a series of amazingly accurate clocks. These clocks would come to be known as **marine chronometers**, and very nearly won Harrison the longitude prize.

John Harrison's H4 Chronometer, held in the British National Maritime Museum in Greenwich. Read about it here: https://collections.rmg.co.uk/collections/objects/79142.html

In 1759, Harrison unveiled his fourth marine chronometer: a watch (commonly referred to as H4 or the "**longitude watch**") that resisted changes in ambient temperature and dampness in the air, remained balanced no matter how it was moved about, and ran constantly even while being wound. Harrison's watch spent 81 days at sea and remained accurate to within five seconds! With a chronometer like that, finding longitude became a simple matter of multiplication and addition.

Since the Earth makes one full rotation, or rotates 360° of **arc**, every 24 hours of **time**, dividing 360 by 24 tells us that the Earth rotates 15° (degrees) every hour. You can break it down further to discover that the Earth rotates 1° of arc every 4 minutes of time, 15' (minutes) of arc every 1 minute of time, 1' of arc every 4 seconds of time, and 15" (seconds) of arc every second of time. Those are a lot of numbers to see all at once, but they will come in handy.

Here's how to find longitude with a chronometer:

1. Set your chronometer to **Greenwich Mean Time**, which corresponds with 0° longitude. (The Royal Observatory in Great Britain is in Greenwich, and the **prime meridian** runs right through it.)
2. Remember that the Sun is due south of Greenwich at noon GMT.

3. Take your sighting for latitude at local apparent noon at your location.
4. Look at your chronometer and multiply GMT as appropriate. If your local apparent noon takes place at 4:00 P.M. GMT, then the Earth has rotated 15° four times since then: 4 x 15° = 60° West longitude!

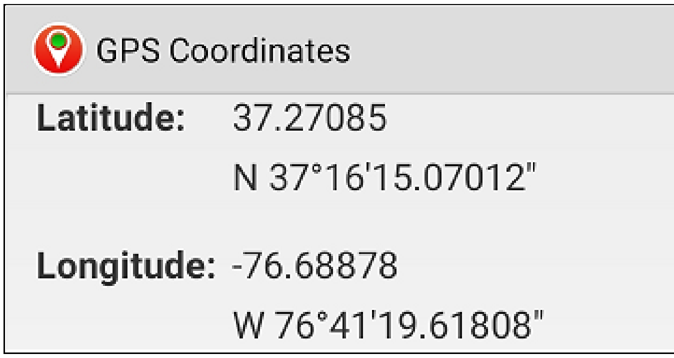
Here's another example. When I took my latitude sighting from the Capitol gate for our livestream at local apparent noon, my pocket watch (set to GMT) read 5:06:46 P.M. Not it's time to multiply:

5:06:47 = 5 hours, 6 minutes, and 47 seconds of time.

5	6	46
x 15°	x 15’	x 15”
75°	90’ or 1°30’	690” or 11’30”

75° + 1°30’ + 11’30” = 76°41’30” West

That's how easy longitude is with a chronometer!



A screen capture from a cell phone app showing the GPS coordinates of the Capitol gate. How does it compare with what our navigator's chronometer determined?

Unfortunately, early marine chronometers were prohibitively expensive. A copy of H4 built by clock maker **Larcum Kendall** was estimated to cost some £450. It fell to future clock makers such as **John Arnold** to make marine chronometers somewhat more affordable. Even so, Arnold's box chronometers produced in the 1780s cost about £80…almost nine months' wages for a newly promoted captain in the British Royal Navy.

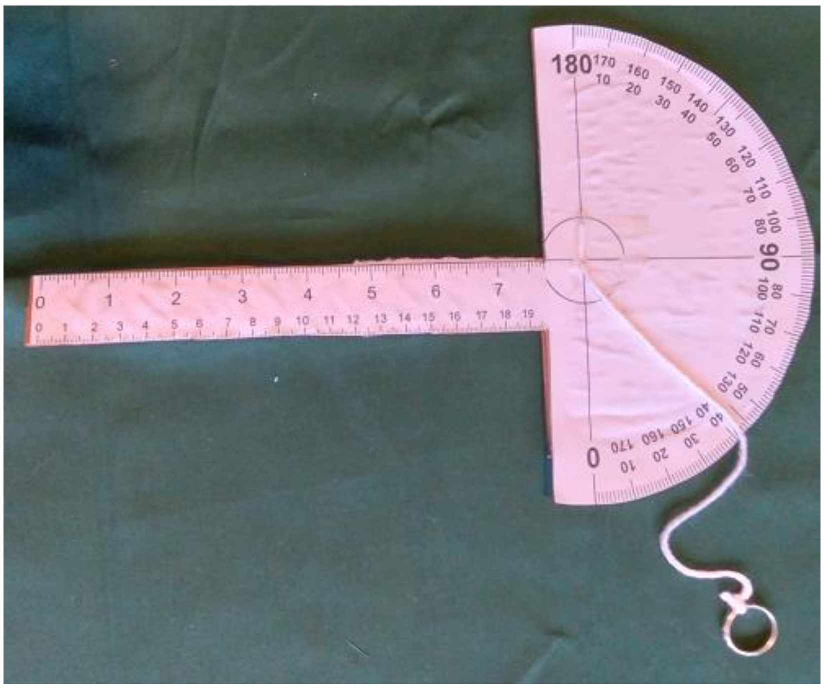
The main competitor to the marine chronometer was the **Lunar-Distance Method**. This was a relatively involved set of calculations that measured the distance (using a sextant) between the Moon and the Sun or another prominent star, then computing and comparing the apparent times at the ship and Greenwich. (A worldwide prime meridian wasn't agreed upon until the late 1800s, so maps produced in different countries used different locations like Paris for their prime meridian.) At first, the time needed to "work your lunars" was upwards of four hours, which was hardly practical. The pre-calculated tables published with the ***Nautical Almanac and Astronomical Ephemeris*** beginning in 1766 reduced this time to a more manageable 30 minutes.

Over the years, it became common practice among mariners to use both a chronometer and the lunars to check one another in accurately finding longitude at sea.

Take Your Own Sightings!

Here's where you get to try out some basic sextant operations yourself!

All you need to make a rudimentary sextant at home is a ruler, protractor, string, and a small weight like a washer or paper clip. If you don't have a ruler or protractor on hand, you can print out the templates included with this packet and glue them to some cardboard. Attach the protractor so the 90° line is even with the top edge of the ruler, and the curved end of the protractor is even with the 12 inch mark on the ruler. Tie your washer or paper clip to the bottom end of the string and attach the other end to the protractor along the 0° line. Make sure you attach the string so that it can pivot from the point where the 0° and 90° lines cross.



Your homemade sextant should look something like this.

Now you're ready to take some sightings. Go outside and find a place where you can see multiple objects with different heights…things like treetops, roof lines or chimneys, radio towers, etc. Face the object you want to sight, hold your homemade sextant with the protractor facing you so that you can see down to the end of the ruler, and point it straight ahead so the string reads 0°. Without touching the string, slowly tilt your sextant upwards until the top of the ruler is even with the top of your object. Carefully hold the string against the protractor so you can see the angle measured.

Use the table below to record your sightings. Don't forget to subtract the altitudes you measure from 90° to find their zenith distance!

Object		Altitude	Zenith Distance
	90° -		=
	90° -		=
	90° -		=
	90° -		=
	90° -		=

If you want to try something a little more challenging, you can practice "shooting a lunar" for longitude. Before getting to the half hour of math required to use the Lunar-Distance Method you read about earlier, navigators used a sextant to measure the altitudes of two objects (like the Sun and Moon, or Moon and the star Aldebaran, for example) AND the distance between them. These measurements had to be very precise, so navigators would take them multiple times, find an average of those measurements, and use that in their longitude calculations. The altitude of each object was usually measured twice, and the distance between them was usually measured four times.

You might need someone to help you make the distance measurements by holding the string for you. Turn your sextant sideways so the top edge of the ruler is now on the right…this way, when you tilt the sextant "up," it really tilts to the right, and the protractor will still work properly. Face your first object, line the right-hand edge of the ruler up with the top of your object, and make sure the string reads 0°. Have someone hold the end of the string while you rotate the ruler to the right until the right-hand edge lines up with the top of your second object and use the string to read your angle. Don't worry if it takes a few tries to move the sextant exactly right, or you get slightly different results each time: navigators in the 1700s had these same difficulties, which is one of the reasons they calculated average measurements.

Fill in the tables below with your "lunar" measurements:

	Object 1	**Object 2**
Altitude 1		
Altitude 2		
Add Alts. 1 and 2		
	Divide This By 2	**Divide This By 2**
Average Altitude		

Distance 1	
Distance 2	
Distance 3	
Distance 4	
Add Dist. 1-4	
	Divide By 4
Average Distance	

Congratulations! You've now made the same basic measurements that navigators in the 1700s used to guide their ships across the ocean!

For More Information:

- Read *Carry On, Mr. Bowditch* by Jean Lee Latham, a novel based upon the life of Nathaniel Bowditch. Bowditch's New American Practical Navigator was a must-have text for American navigators in the early 1800s, and versions are still in print today!

- Read *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time* by Dava Sobel, the story of John Harrison, the mind behind the marine chronometer. There's also a wonderful *Longitude* miniseries that was produced by A&E in 2000 that dramatizes the story of Harrison's chronometers, and the work undertaken by a Royal Navy officer to restore the chronometers during the 1920s and 1930s.

- Read "A Woman Computer" on the Colonial Williamsburg Blog at https://www.colonialwilliamsburg.org/learn/deep-dives/woman-computer/ for information on how the *Nautical Almanac and Astronomical Ephemeris* was produced and by whom.

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