

Locating a ship at sea

An early example of data fusion

Oceans cover more than 70 percent of the Earth's surface;
without landmarks for reference, **a ship may go off course and be lost.**

<https://www.americoceans.org/wp-content/uploads/2023/01/biggest-oceans.jpg>

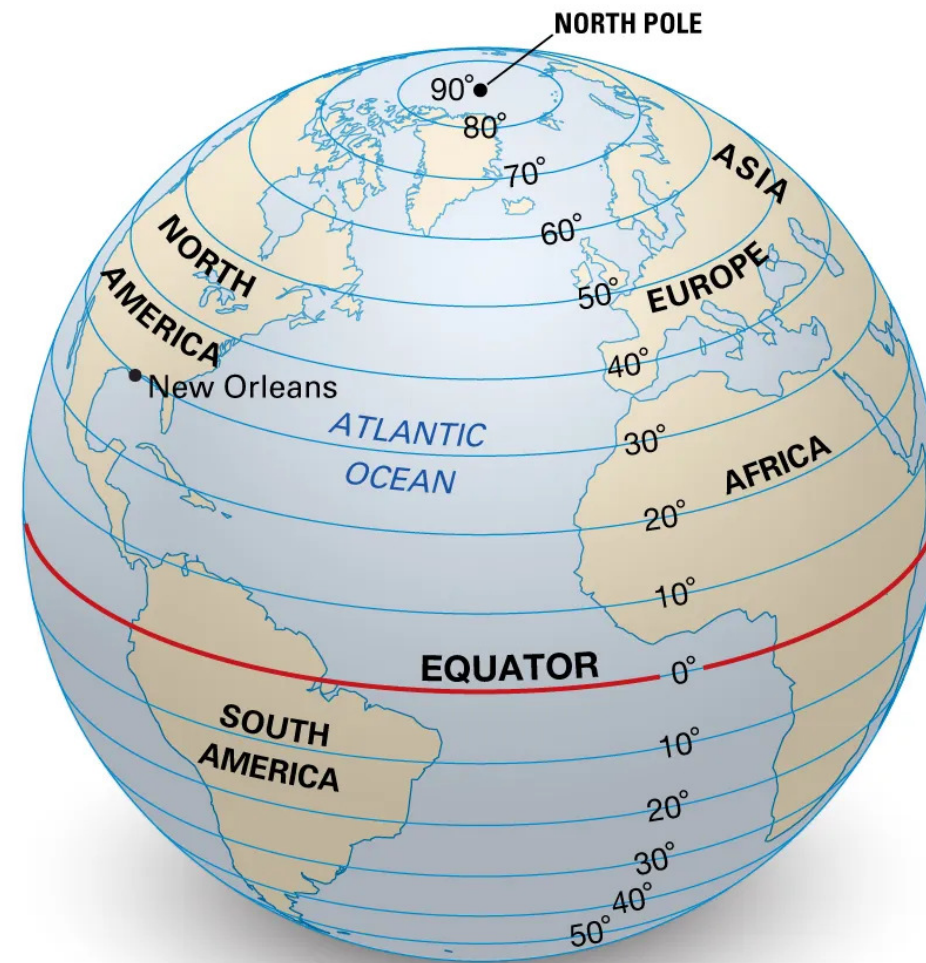
A ship's position is the intersection of two lines:

- Latitude, $38^{\circ} 53' 42.4''$ N (or 38.9072°)
- Longitude, $77^{\circ} 2' 10.93''$ W (or -77.0369°)



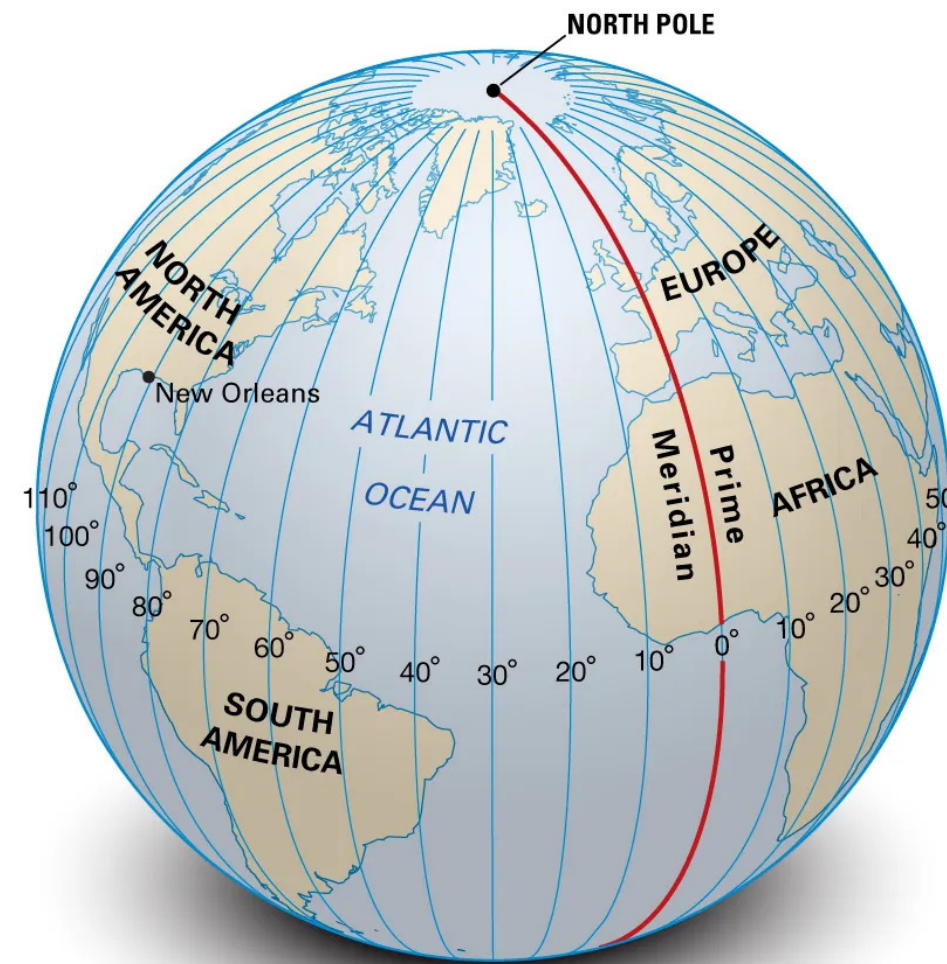
<https://cdn.britannica.com/03/64903-050-3E1ED75A/globe-perspective-north-line-crossing-Washington-DC.jpg>

Latitude is measured with reference to the Earth's equator — north or south, positive or negative.



<https://cdn.britannica.com/07/64907-050-7ACA69C8/Facts-parallels-Lines-of-Latitude-angles-direction.jpg>

Longitude is measured with reference to a prime meridian, typically centered on Greenwich, England — east or west, positive or negative.



<https://cdn.britannica.com/06/64906-050-675D6688/meridians-Facts-Lines-of-Longitude-angles-halves.jpg>

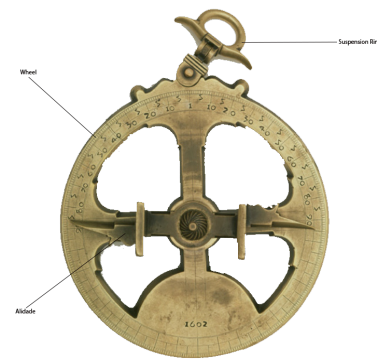
Latitude may be found by measuring the angle of the sun, in early days using an astrolabe and later a sextant.

The sun reaches its highest point at noon.

The angle at the highest point changes with the seasons.

Thus, to find the latitude, the angle must be correlated with the date, typically by looking it up in a reference table.

Mariners Astrolabe



Sextant



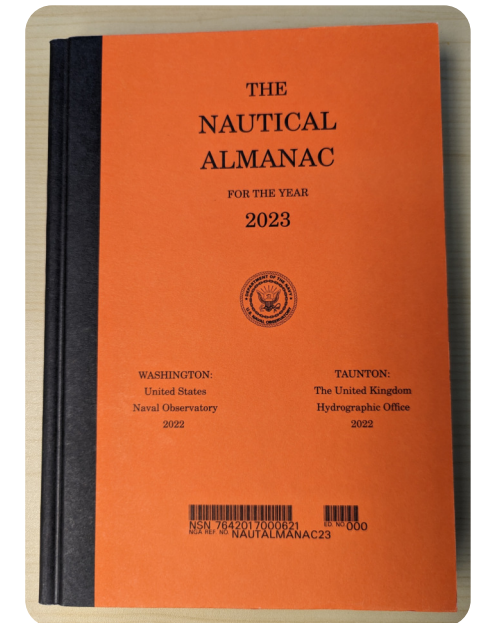
Date (Calendar)

May						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3

Solar Declinations (within the Nautical Almanac)

h	Sun			Moon				
	GHA	Dec		GHA	ν	Dec	d	HP
0	180°41.8	N21°23.0		81°46.1	16.0'	N11°31.6	12.9'	54.5'
1	195°41.7	23.4		96°21.1	16.0'	11°18.7	13.0'	54.5'
2	210°41.6	23.9		110°56.1	16.0'	11°05.7	13.1'	54.5'
3	225°41.6	· · 24.3		125°31.1	16.0'	10°52.6	13.1'	54.5'
4	240°41.5	24.7		140°06.1	16.1'	10°39.5	13.1'	54.5'
5	255°41.4	25.1		154°41.2	16.1'	10°26.4	13.2'	54.5'
6	270°41.3	N21°25.5		169°16.2	16.1'	N10°13.2	13.2'	54.5'
7	285°41.3	25.9		183°51.4	16.1'	10°00.0	13.3'	54.6'
8	300°41.2	26.3		198°26.5	16.1'	09°46.7	13.3'	54.6'
9	315°41.1	· · 26.7		213°01.6	16.2'	09°33.4	13.4'	54.6'
10	330°41.0	27.1		227°36.8	16.2'	09°20.0	13.4'	54.6'
11	345°41.0	27.5		242°12.0	16.2'	09°06.6	13.4'	54.6'
12	0°40.9	N21°27.9		256°47.2	16.2'	N08°53.2	13.5'	54.6'
13	15°40.8	28.3		271°22.4	16.2'	08°39.7	13.6'	54.7'
14	30°40.7	28.7		285°57.6	16.2'	08°26.1	13.5'	54.7'
15	45°40.6	· · 29.1		300°32.9	16.3'	08°12.6	13.6'	54.7'
16	60°40.6	29.5		315°08.1	16.3'	07°59.0	13.7'	54.7'
17	75°40.5	29.9		329°43.4	16.3'	07°45.3	13.7'	54.7'
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19	105°40.3	30.7		358°53.9	16.3'	07°17.9	13.8'	54.8'
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	SD = 15.8'	d = 0.4'				SD = 14.9'		
Mon	GHA	Dec		GHA	ν	Dec	d	HP
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15	45°38.7	· · 38.5		290°39.7	16.2'	02°36.4	14.3'	55.2'
16	60°38.6	38.9		305°15.0	16.2'	02°22.1	14.4'	55.2'
17	75°38.6	39.3		319°50.1	16.2'	02°07.7	14.4'	55.3'
18	90°38.5	N21°39.7		334°25.2	16.2'	N01°53.2	14.4'	55.3'

Nautical Almanac

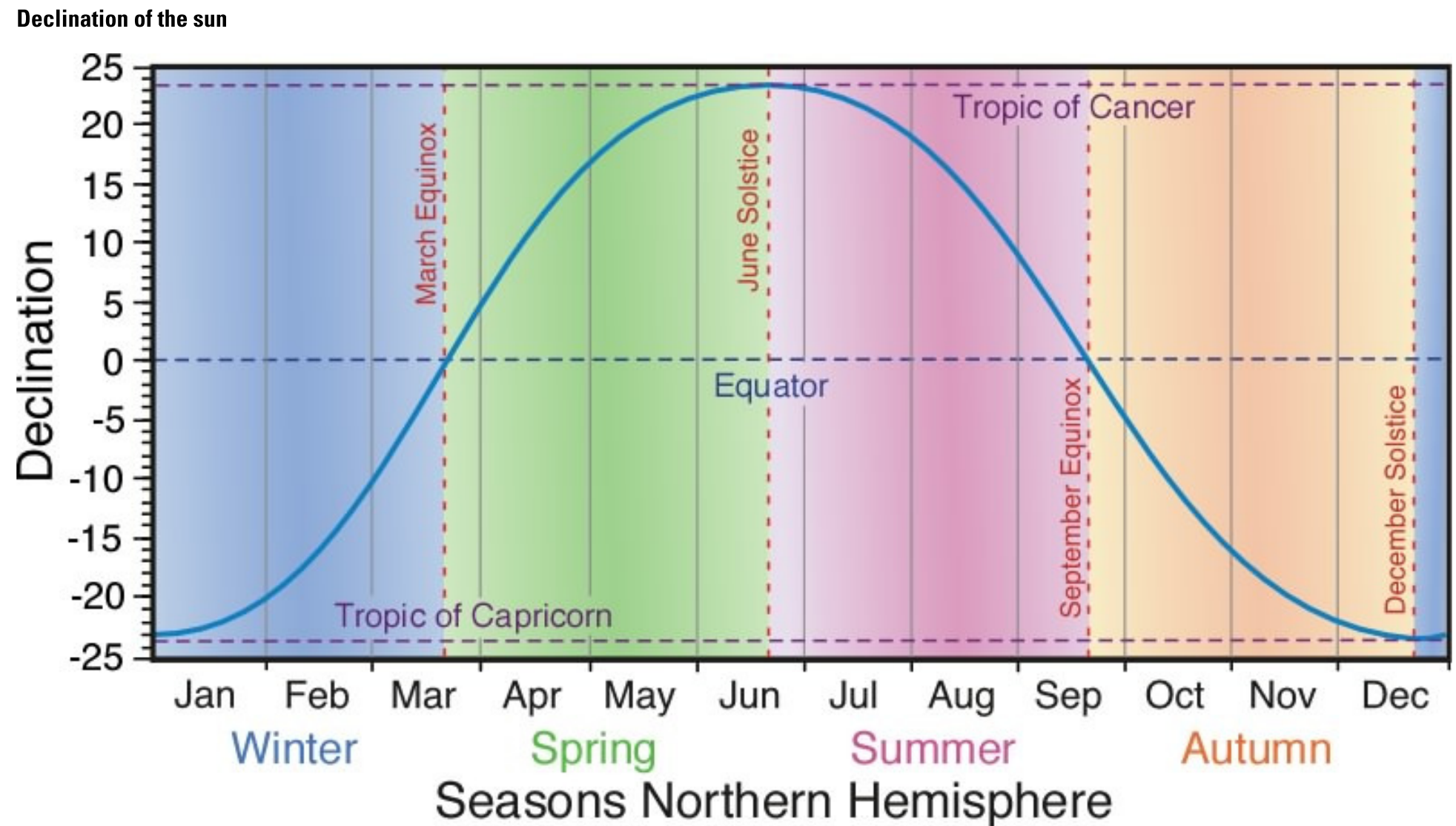
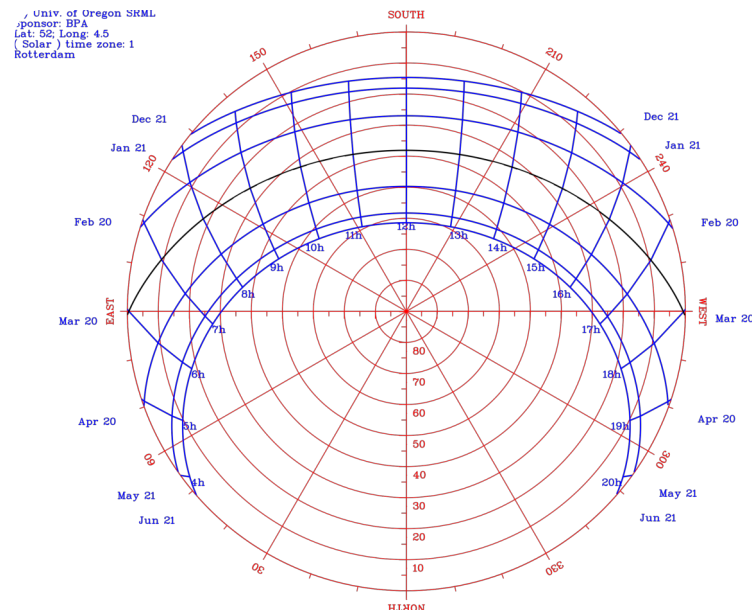


<https://exploration.marinersmuseum.org/object/astrolabe/> • <https://marinesavvy.com/what-is-a-sextant/>
https://thenauticalalmanac.com/TNARegular/2023_Nautical_Almanac.pdf • https://aa.usno.navy.mil/publications/na_history

The sun is highest at the beginning of summer; lowest at the beginning of winter.

For example, if the sun is directly overhead, and the date is June 21, then your position is on the Tropic of Cancer.

23d 26' 22" (23.4394°) north of the Equator.



<https://commons.wikimedia.org/wiki/File:Sun-path-polar-chart.svg> • <http://www.atmo.arizona.edu/students/courselinks/spring15/atmo336/lectures/sec4/declination.jpg>

Longitude is found by measuring the difference in time between the current location and the reference location (i.e., Greenwich).

If the time at the current location is noon and the time in Greenwich is 5:08:09 pm, then the ship has traveled 77.0369° west, 4 minutes of time for each degree of longitude.

Time at Current Location



Greenwich Mean Time (5:08:09pm)



Measurement of longitude requires a very accurate clock, neither gaining or losing minutes or seconds over months at sea.

Making such a clock was a technical challenge. About 1759, John Harrison solved the problem with the H4 nautical chronometer.

In H4's first sea trial, an 81 day and 5 hour voyage from Portsmouth to Kingston, Jamaica— H4 only lost 3 minutes 36.5 seconds per day.

However, Harrison's next iteration of the nautical chronometer, H5, only lost 1/3 of a second per day.

John Harrison's 'H4'



John Harrison's 'H5'



Harrison was prompted to his invention by King George III, who offered a **prize of £20,000**, about \$3,000,000 in today's terms.

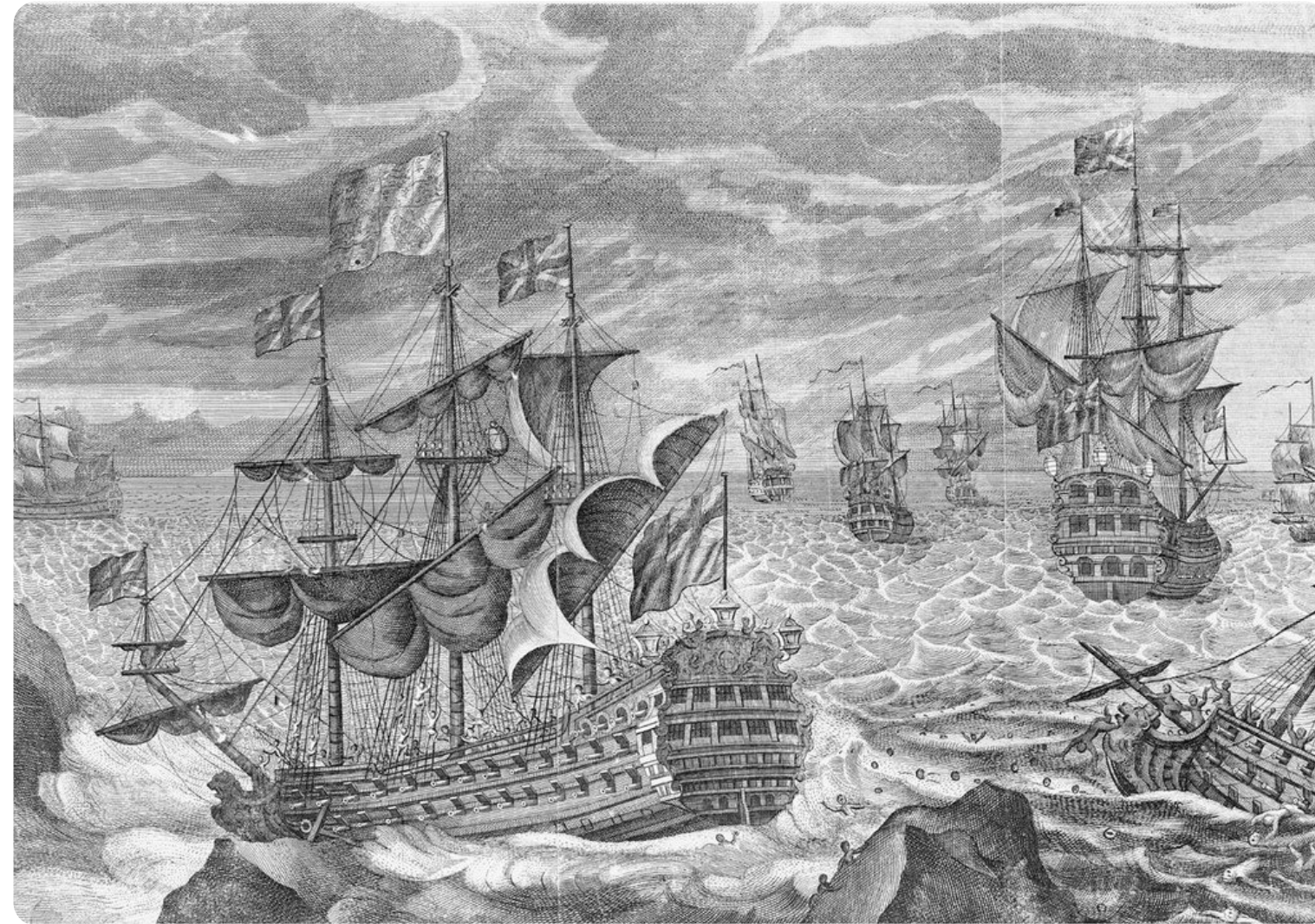
British Pound (1700s)



[https://d3k6u6bv48g1ck.cloudfront.net/coin-image-1_Guinea-Gold-Kingdom_of_Great_Britain_\(1707_1801\)-t.bBwcl0FqUAAAEpGkEFQRcl.jpg](https://d3k6u6bv48g1ck.cloudfront.net/coin-image-1_Guinea-Gold-Kingdom_of_Great_Britain_(1707_1801)-t.bBwcl0FqUAAAEpGkEFQRcl.jpg)

King George III was acting after a series of naval disasters;
in particular the 1707 wreck at Scilly, in which
4 ships and ~2,000 lives were lost due to navigation errors.

Scilly Naval Disaster Etching



https://en.wikipedia.org/wiki/Scilly_naval_disaster_of_1707

Appendix

Approximately between the early 16th through 18th centuries, a 'Chip Log' was used by mariners to **measure the speed of a vessel.**

They done so by counting 7–8 tied knots in the rope of the chip log shown at right.

This method of measuring is where the term / units 'Knots' came from.

Using the Chip Log in conjunction with the other tools aforementioned such as the Astrolabe, Declination Tables, and Chronometer, is the process of Dead Reckoning.

"In navigation, dead reckoning is the process of calculating the current position of a moving object by using a previously determined position, or fix, and incorporating estimates of speed, heading (or direction or course), and elapsed time."



Using the Sextant and Almanac

Before using the solar declinations of a nautical almanac, there are prior corrections that need to be made for:

1. Index errors

Aligning the mirrors of the Sextant.

2. Dip errors

Correcting for the height of the Sextant above the horizon.

3. Refraction errors

Correcting for the amount that the light bends before reaching the Sextant.

4. Semi-diameter errors

Correcting for the apparent size of the Sun during a certain time of year.

5. Parallax errors

Correcting for the differences of your vantage point to the Sun.

Sextant in use



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21	135°40.2	· · 31.5	28°04.5	16.3'	06°50.3	13.8'	54.8'
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https://thenauticalalmanac.com/TNARegular/2023_Nautical_Almanac.pdf · [https://commons.wikimedia.org/wiki/File:180423-N-DL434-149_\(27894845758\).jpg](https://commons.wikimedia.org/wiki/File:180423-N-DL434-149_(27894845758).jpg)

<https://www.wikihow.com/Use-a-Sextant#:~:text=Add%20or%20subtract%20the%20declination,the%20equator%2C%20add%20the%20declination.>

Using the Sextant and Almanac

1. Then you can take a reading with the Sextant and combine with the information previously described to get a 'corrected altitude'.
2. Subtract the 'corrected altitude' from 90° . (i.e. the equinox— the time of year when the sun is at 90° to the equator)
3. Find the declination that corresponds with the required date and time.
4. Add or subtract the declination from your corrected altitude. (Since these declinations are all North of the equator, they would be added)

Sextant in use



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18	90°38.5	N21°39.7	334°25.2	16.2'	N01°53.2	14.4'	55.3'

https://thenauticalalmanac.com/TNARegular/2023_Nautical_Almanac.pdf · [https://commons.wikimedia.org/wiki/File:180423-N-DL434-149_\(27894845758\).jpg](https://commons.wikimedia.org/wiki/File:180423-N-DL434-149_(27894845758).jpg)
<https://www.wikihow.com/Use-a-Sextant#:~:text=Add%20or%20subtract%20the%20declination,the%20equator%2C%20add%20the%20declination.>