	Name :	Date :	
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		$1^{ère}$ – T^{ale}	
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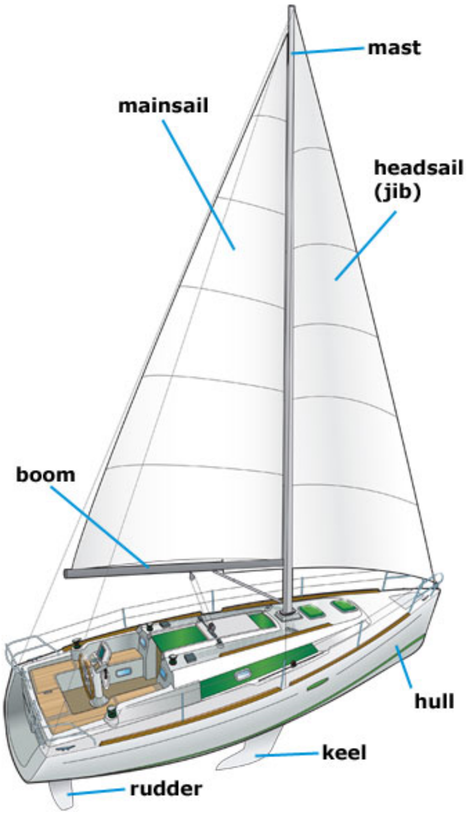
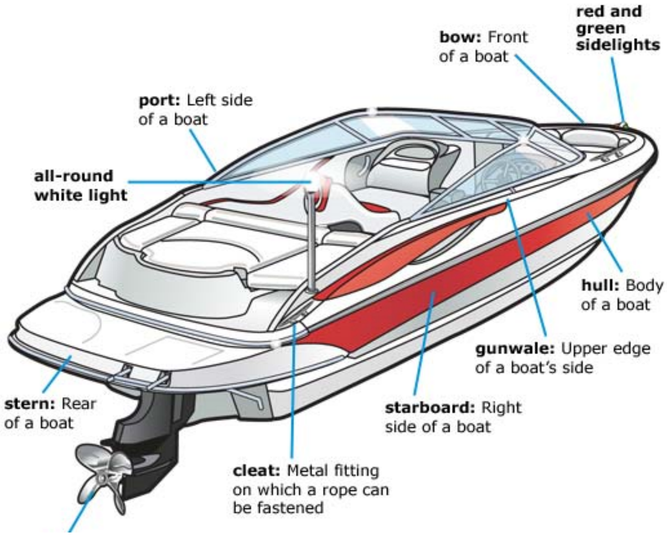
There are three different aspects when you are on a boat:

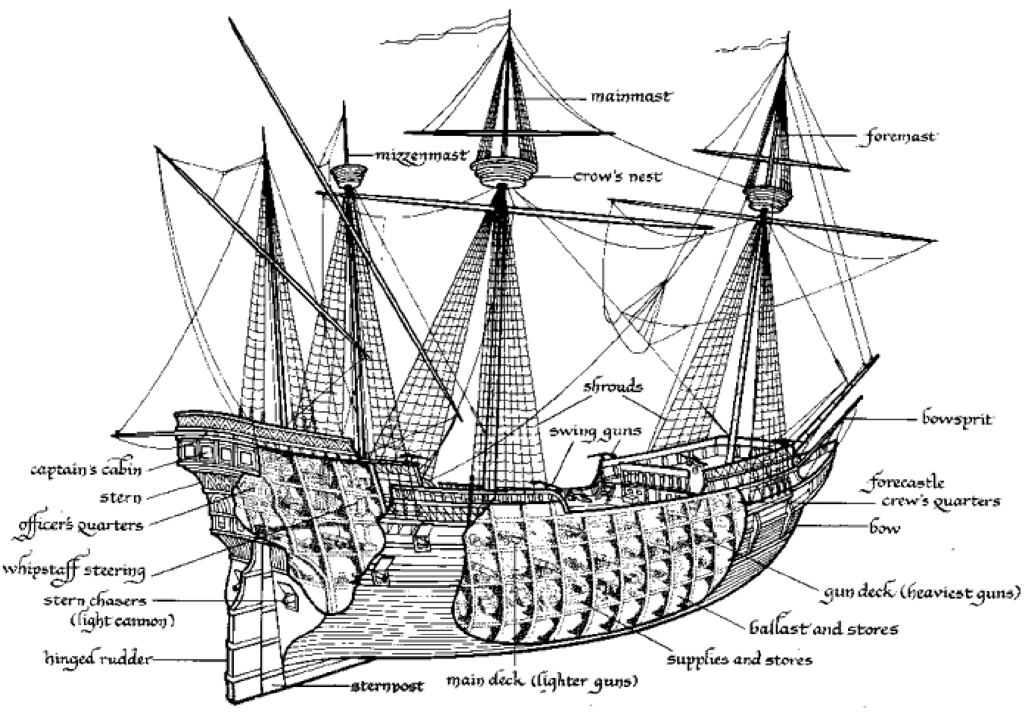
- How a boat can float,
- How to go forward with it,
- How to know where you are when you're in the middle of nowhere.

First of all, we must know the different parts:



- The hull (Body of a vessel; basic structure or shell) carries the passengers and supports the rigging.
- The rigging includes many parts of the sailboat, such as the lines (sheets: *Lines (ropes)* used to control the angle of the sails to the wind and halyards: *Lines (ropes)* used to raise and lower the sails), mainsail, headsail (jib), boom, and mast.
- The keel or centreboard is attached to the bottom of the hull and keeps the boat from sliding sideways through the water.
- The rudder (Steering device, usually a vertical blade attached to a post at, or near, the stern of the boat) is used to steer the sailboat, turned by a tiller or steering wheel.





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	Navigation and technology	Course	*Note :*
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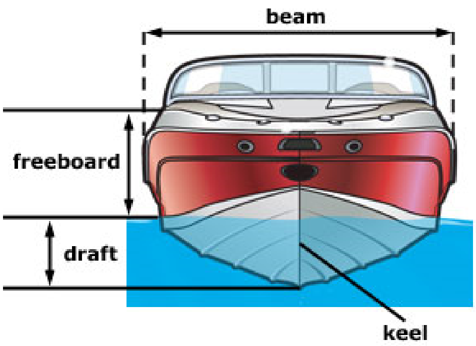
1. How a boat can float:

The buoyancy : an application of Archimedes's laws

An object in a fluid experiences an upward force equal to the weight of the fluid displaced by the object. So if a boat weighs 1,000 pounds (or kilograms), it will sink into the water until it has displaced 1,000 pounds (or kilograms) of water. Provided that the boat displaces 1,000 pounds of water before the whole thing is submerged, the boat floats.



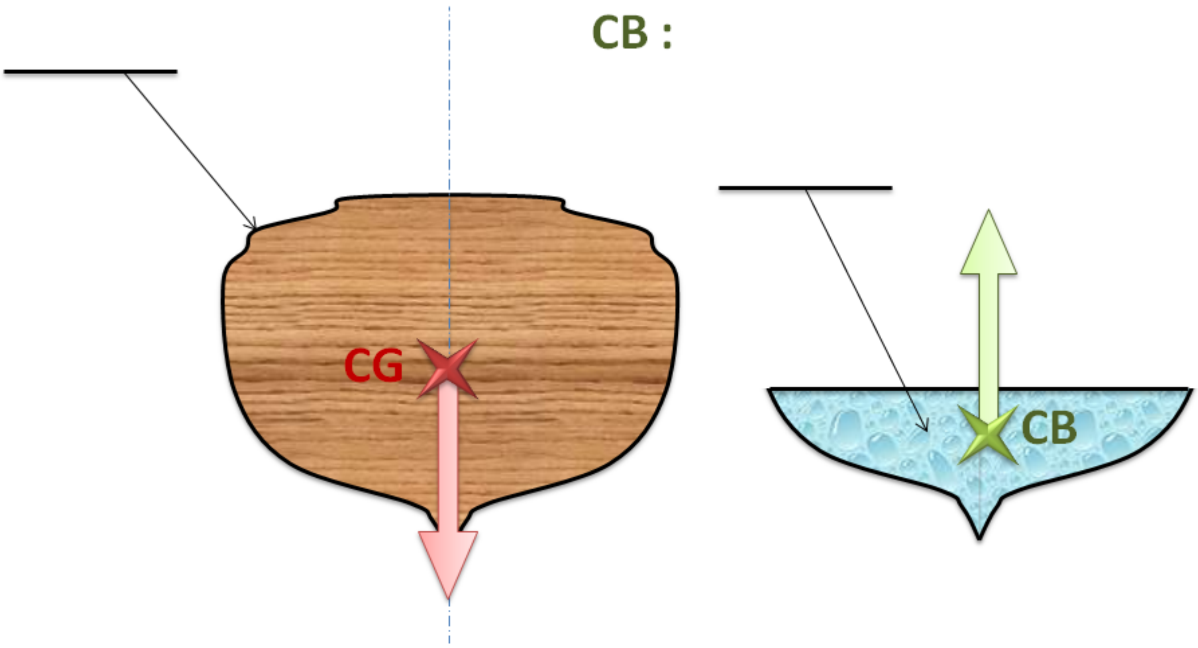
- **Beam:** Maximum width of a vessel
- **Freeboard:** Distance from water to lowest point of the boat where water could come on board
- **Draft:** Depth of water needed to float a vessel
- **Propeller:** Rotates and powers a boat forward or backward
- **Keel:** Main centerline (backbone) of a vessel or the extension of hull that increases stability in the water.

Force due to ___________

Force due to ___________

CG :

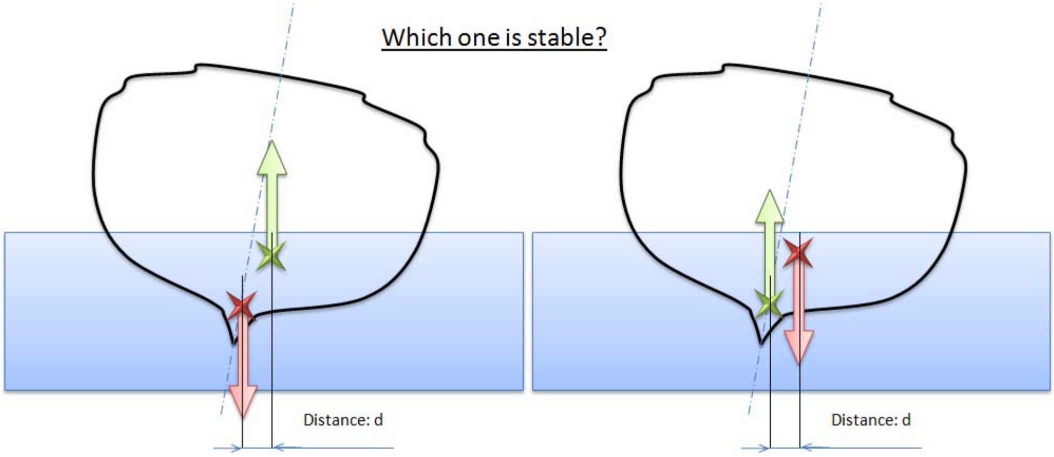
CB :



The mass is equal to the mass per volume multiplied by the volume ; $m= \rho.V$

But there is another matter: a boat is not something resting on flat, or calm, water: there are waves which undermine the stability.

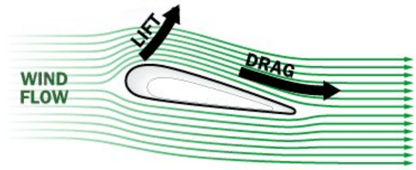
A boat has two centers: a center of gravity and a center of buoyancy. The center of gravity is the force that pulls the boat down toward the water, while the center of buoyancy is the force that pushes back on the boat. A regular sailboat has a center of gravity that's lower than its center of buoyancy, which helps keep the boat upright.



2. How to go forward with it:

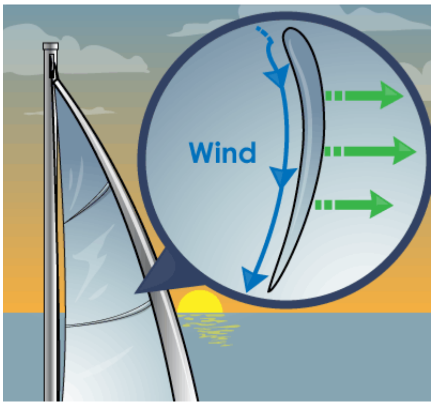
Going forward: an application of the theorem of Bernoulli or Newton's third law ?

When you see a kite catch the wind and swoop up into the air, you're witnessing lift. You can feel the forward acceleration in the pull on your end of the string. Likewise, the mainsail and jib harness wind energy with their aerodynamic shapes that puff out on one side when the wind hits them. You also might notice that the kite flies angled to the wind, just as the mainsail and jib capture wind when tacking.
Sailing aficionados use two prominent -- yet often disputed -- theories to explain how exactly the wind interaction generates lift: Bernoulli's theorem and Newton's Third Law.

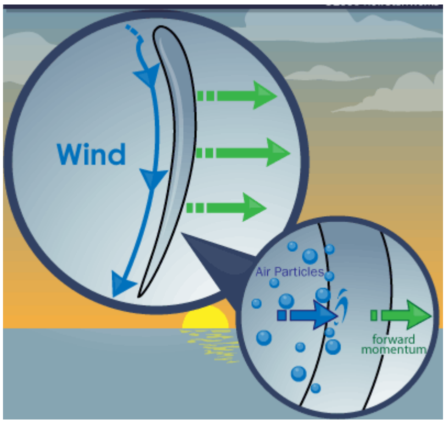


Bernoulli's theorem, also called the Longer Path Explanation, explains lift in terms of high and low air pressures on either side of the sail.

Imagine the front of the boat angled upwind, or into the wind. As the breeze hits the sails, the air particles rush over both sides. Theoretically, the air particles moving across the outer, convex side of the sail have a longer distance to travel in the same amount of time as the particles moving across the inner, concave side.



If the particles on the outer side are travelling farther in the same amount of time, they must have a higher velocity, or speed, than the particles on the other side. These higher-velocity particles have more room to spread out, forming a low-pressure area. On the inside of the sail, the slower air particles are packed together more densely, creating a higher-pressure area. This difference in the pressure on the sails acts as a forward suction, producing lift.



Newton's Third Law describes lift in terms of the reaction of the wind's air particles to the mainsail and jib. The law states that every action has an equal and opposite reaction. As the wind hits the sails from an opposing direction (remember, you're sailing upwind to tack), it generates drag, or backward pull. Drag is parallel to the original wind current and occurs naturally when something is moving against a fluid or gas. Swimmers wear specialized suits and caps to reduce drag as much as possible in the water.

Examining lift through the Newtonian lens, the air particles' movement creates an equal, opposite reaction -- or forward pull. It can also be applied to the interaction of the sails and the keel, described in the previous section.
The sails and the keel create equal and opposite reactions to focus the boat's energy forward rather than sideways.

3. How to know where you are when you’re in the middle of nowhere.

The Genoese Wold navigation

When there is no lighthouse or when you can’t see the coastline, you must find your position with a bit of geometry and calculation.

How do navigators use the stars, including our sun, the moon, and planets to find their way? Well, for at least two millennia, navigators have known how to determine their latitude — their position north or south of the equator. At the North Pole, which is 90 degrees latitude, Polaris (the North Star) is directly overhead at an altitude of 90 degrees. At the equator, which is zero degrees latitude, Polaris is on the horizon with zero degrees altitude. Between the equator and the North Pole, the angle of Polaris above the horizon is a direct measure of terrestrial latitude. If we were to go outside tonight and look in the northern sky, we would find Polaris at about 40 degrees 13 minutes altitude - the latitude of Coimbra.
In ancient times, the navigator who was planning to sail out of sight of land would simply measure the altitude of Polaris as he left homeport, in today’s terms measuring the latitude of home port. To return after a long voyage, he needed only to sail north or south, as appropriate, to bring Polaris to the altitude of home port, then turn left or right as as appropriate and "sail down the latitude," keeping Polaris at a constant angle.
The Arabs knew all about this technique. In early days, they used one or two fingers width, a thumb and little finger on an outstretched arm or an arrow held at arms length to sight the horizon at the lower end and Polaris at the upper.

Throughout antiquity, the Greeks and Arabs steadily advanced the science of astronomy and the art of astrology. About a thousand years ago, in the 10th century, Arabs introduced Europe to two important astronomical instruments—the quadrant and the astrolabe.
The astronomer's beautiful, intricate and expensive astrolabe was the grandfather of the much simpler, easy to use mariner's quadrant and astrolabe. The mariner’s quadrant—a quarter of a circle made of wood or brass--came into widespread use for navigation around 1450, though its use can be traced back at least to the 1200s.
During the 1400’s, Portuguese explorers were travelling south along the coast of Africa searching for a route to the orient. As a seafarer nears the equator heading south, Polaris disappears below the horizon. So, in southern seas, mariners had to have a different way of finding their latitude. Under orders from the Portuguese Prince Henry, The Navigator, by 1480, Portuguese astronomers had figured out how to determine latitude using the position of the sun as it moved north and south of the equator with the seasons, what we now call its "declination." In simple terms, the navigator could determine his altura, his latitude, by using his quadrant to

take the altitude of the sun as it came to it’s greatest altitude at local apparent noon, and then making a simple correction for the position of the sun north or south of the equator according to the date.

Celestial navigation is the process whereby angular measurements (sights) taken between celestial bodies in the sky and the visible horizon are used to locate one's position on the globe, on land as well as at sea. At any given instant of time, any celestial body is located directly over only one specific geographic point, or position on the Earth, whose address is described by latitude and longitude. This geographic position is known as the celestial body’s "GP," and its precise location can be determined by referring to tables in the Nautical or Air Almanac for that exact second of time, for that calendar year.

58m INCREMENTS AND CORRECTIONS 59m

m 58	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 30·0	14 32·4	13 50·4	0·0	0·0	6·0	5·9	12·0	11·7
01	14 30·3	14 32·6	13 50·6	0·1	0·1	6·1	5·9	12·1	11·8
02	14 30·5	14 32·9	13 50·8	0·2	0·2	6·2	6·0	12·2	11·9
03	14 30·8	14 33·1	13 51·1	0·3	0·3	6·3	6·1	12·3	12·0
04	14 31·0	14 33·4	13 51·3	0·4	0·4	6·4	6·2	12·4	12·1
05	14 31·3	14 33·6	13 51·6	0·5	0·5	6·5	6·3	12·5	12·2
06	14 31·5	14 33·9	13 51·8	0·6	0·6	6·6	6·4	12·6	12·3
07	14 31·8	14 34·1	13 52·0	0·7	0·7	6·7	6·5	12·7	12·4
08	14 32·0	14 34·4	13 52·3	0·8	0·8	6·8	6·6	12·8	12·5
09	14 32·3	14 34·6	13 52·5	0·9	0·9	6·9	6·7	12·9	12·6

m 59	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 45·0	14 47·4	14 04·7	0·0	0·0	6·0	6·0	12·0	11·9
01	14 45·3	14 47·7	14 04·9	0·1	0·1	6·1	6·0	12·1	12·0
02	14 45·5	14 47·9	14 05·2	0·2	0·2	6·2	6·1	12·2	12·1
03	14 45·8	14 48·2	14 05·4	0·3	0·3	6·3	6·2	12·3	12·2
04	14 46·0	14 48·4	14 05·6	0·4	0·4	6·4	6·3	12·4	12·3
05	14 46·3	14 48·7	14 05·9	0·5	0·5	6·5	6·4	12·5	12·4
06	14 46·5	14 48·9	14 06·1	0·6	0·6	6·6	6·5	12·6	12·5
07	14 46·8	14 49·2	14 06·4	0·7	0·7	6·7	6·6	12·7	12·6
08	14 47·0	14 49·4	14 06·6	0·8	0·8	6·8	6·7	12·8	12·7
09	14 47·3	14 49·7	14 06·8	0·9	0·9	6·9	6·8	12·9	12·8

Example of a nautical almanac

Navigation by the North Star: Finding Your Latitude and Direction.

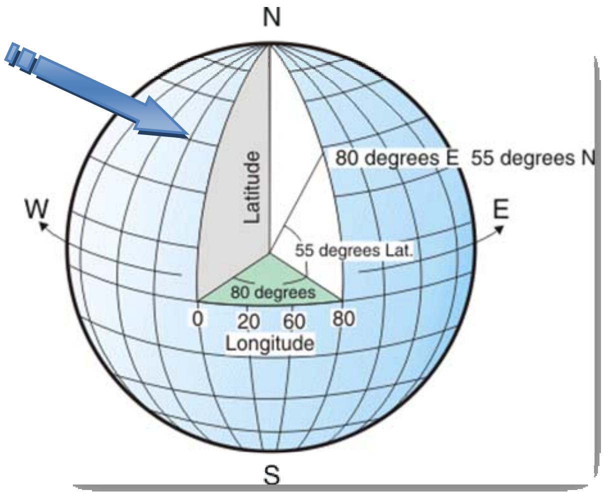
Sailors have always faced great risks when they travelled at sea. Sudden storms could break their masts and shred their sails. Giant waves could sink their ships or wash men overboard. Hidden reefs could tear open their hulls. And even if they were lucky enough to avoid these, sailors could still become hopelessly lost and wander until starvation, thirst or disease set in.

There was nothing they could do about the weather, but, with proper navigation, sailors could avoid hidden reefs and keep from getting lost. One strategy that early mariners used to avoid getting lost was to stay close to the coast. If they hugged the coast, they could get their bearings from recognizable landmarks such as mountains, rivers, and islands.

The problem with this form of navigating was that it limited the places where sailors could go. There were no landmarks on the open ocean. Also, if sailors strayed into unknown waters, they wouldn’t be able to recognize any of the landmarks even if there were some. And so, they needed more reliable methods to find their way.

Fortunately, there were things that could be seen from anywhere on the globe that could give sailors their bearings: the stars, the sun, and the earth’s magnetic field. But even these could only solve part of the puzzle. To avoid getting lost sailors needed to know two things: **where they were** and **where they were going**. To know where they were, they needed to know their **latitude** and **longitude**. To know where they were going, they needed to know their **compass direction**

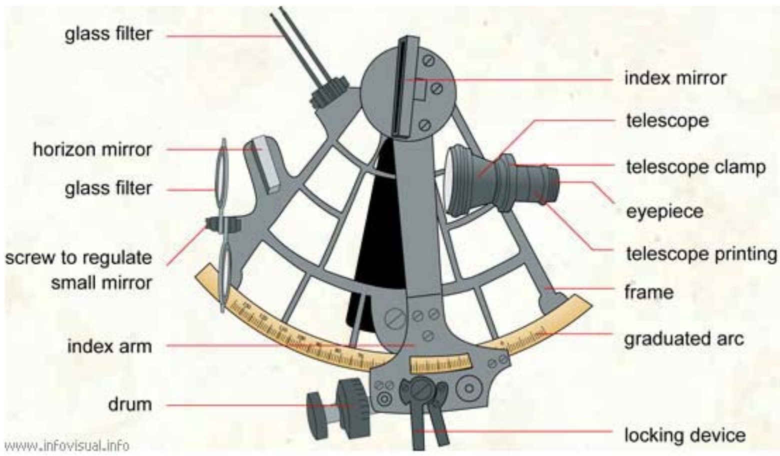
Things a Sailor Needed to Know to Avoid Getting Lost: Latitude, Longitude, and Direction



To find their direction, sailors could use a compass or the stars. The needle of a compass points in a northern direction from almost anywhere on Earth. The North Star was also a reliable way to determine north. As it turns out, the North Star is located directly over the North Pole so wherever the North Star is in the sky, that direction is north.

Of the two methods for determining north, early navigators preferred using the stars because early compasses were unreliable. They sometimes lost their magnetic charge and became useless. Also, the ship's motion made it difficult to get a steady reading from the compass. For centuries, many great scientists worked on the technical problem of keeping a compass needle steady. And then there was the problem of variation: a compass needle doesn't point to true north, it points to magnetic north. As you sail around the globe, magnetic north changes in relation to true north. The North Star on the other hand was always located at true north. And as long as sailors could see it, they could get their bearing from it. But that was the problem: the North Star was hidden when the sky was overcast.

To figure out their location, sailors needed to know their latitude and longitude. Again, the stars and the sun could be used to solve part of the puzzle: latitude. Because the North Star is located directly over the North Pole, it appears fixed in the sky at night. All of the other stars appear to travel in circular arcs across the night sky (around the North Star). Sailors only had to measure the angle of elevation of the North Star and they could figure out their latitude on the map. It turns out that the angle of elevation of the North Star is equal to your latitude on the map. Measuring the angle of elevation was easy to do. Sailors used a tool called a **sextant** to measure the angle of the sun or the stars. Nowadays, ships use satellite signals to determine their location, but they still carry a compass on board and most captains still know how to take a reading of off the stars.



Longitude was a lot more difficult to determine accurately. To determine longitude, sailors needed a very precise clock. The clock could not run too fast or too slow. It also had to withstand the constant motion of the ship at sea. Newton, Galileo, and Hooke all worked on the problem of determining longitude, but it took many centuries before someone finally invented a clock that was accurate enough to be relied upon. But that is another story.

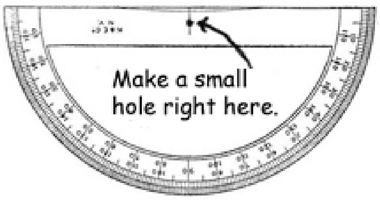
In this lesson you will:

(1) Make a sextant
(2) Find the North Star.
(3) Measure your latitude on the map.

Making a Crude Sextant Using Classroom Materials

In this class, you will make a crude sextant out of materials that you can easily find in any stationary store. Using your sextant, you can then take a measurement of the North Star and calculate your latitude.

Materials You Will Need:
Protractor, Straw, Fishing line, Weight, Tape, Paper.



Step 1: If your protractor doesn't already have a hole in the center, make a small hole there.

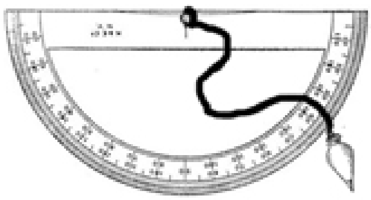


Figure A -The right way to tie the fishing line

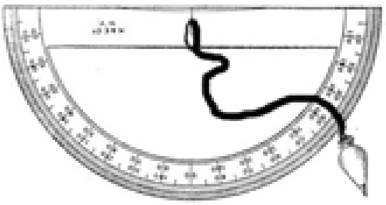


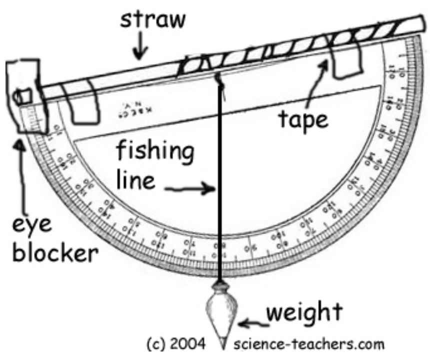
Figure B -The wrong way to tie the fishing line

Step 2: Tie a small fishing weight to a piece of fishing line and then tie the other end to the protractor. Make sure you tie it the way it is tied in figure A and not the way it is tied in figure B. If you tie it the way it is tied in figure B, your sextant will be inaccurate. It is also a good idea to cut a very tiny groove at the top of the protractor to fit the fishing line into.

Step 3: Turn the protractor upside down and tape a straw along the top. As an option you can add a paper eye guard to eliminate interfering light. Your finished product should look something like the picture below.

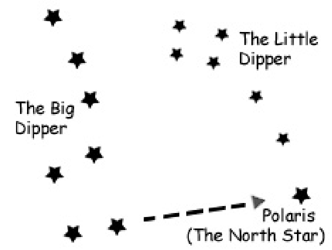
The Finished Product: A Crude Sextant

To find the angle of elevation of any object, first locate the object in the straw. Next, stop the weight from swinging and press the taught fishing line to the protractor. The angle of elevation is the same as 90 degrees minus the angle you read off of the protractor. In this case the protractor reads 80 degrees so the angle of elevation is 10 degrees.



Finding the North Star

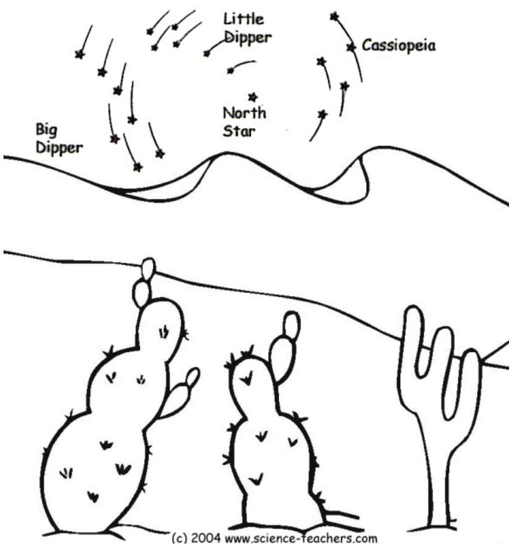
If you want to use the North Star to navigate, the first thing you have to do is find it: First, locate the Big Dipper. Then using the two stars at the end of the spoon to make a straight line, follow the line until you come to a bright star. That is Polaris, the North Star. The North Star is also the last star on the handle of the little dipper.



How to Find the North Star

Star Swirls

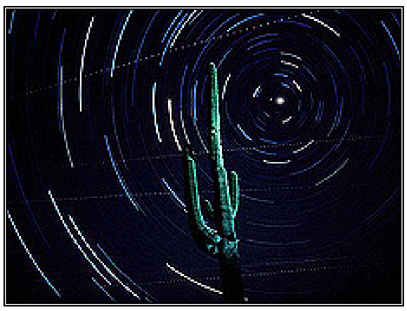
Throughout the night, stars appear to travel across the sky in circular arcs. This apparent motion is caused by the Earth spinning on its axis. Stars that appear close to the North Star travel in small circles. Stars that appear far from the North Pole travel in wide circles. Because the North Star is directly over the Earth's axis of spin, it barely appears to move at all. If you take a picture of the night sky and leave the camera shutter open for a period of time, you can see star swirls that result from the apparent movement of stars across the sky.



This diagram shows the apparent movement of the stars across the night sky. Only the North Star, which is directly above the Earth's axis, remains fixed. That is why the North Star is used to take absolute measurements of latitude.

The closer you get to the North Pole, the higher the swirl is in the sky. At the North pole, the center of the swirl is directly above you. As you go closer to the equator, the center of the swirl moves closer and closer to the horizon.

This is a picture of the night sky taken with the shutter left open for a period of time. The North Star is the bright star that you can see in the center of the photo.



(This photo has been sharpened using Photoshop to highlight the swirl effect)

Measuring Your Latitude Using a Sextant

Figure 1.

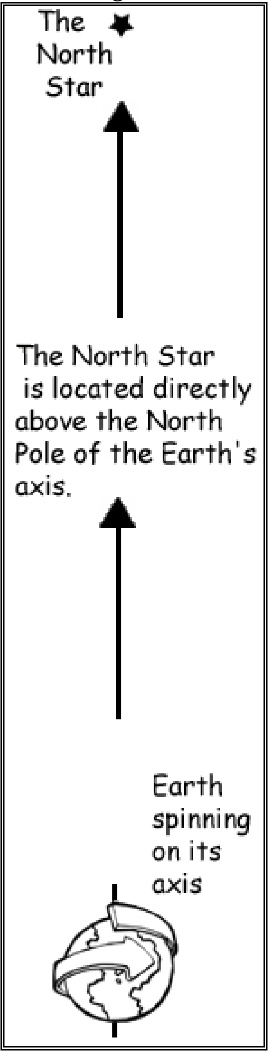


Figure1: *The picture to the left shows the North Star is located directly over the Earth's axis of spin.*

Now that you've made a sextant, you can take that sextant and measure the angle of objects relative to the horizon. If you examine the diagrams below, you can see that measuring the angle of elevation of the North Star is the same as your latitude on the Earth. So, using your sextant and the stars, you can figure out your latitude on the map. To calculate your latitude use this formula:

Latitude =

90 Degrees – Protractor Angle

Figure 2: *As you move from the equator to the North Pole, the angle of elevation of the North Star relative to the horizon changes.*

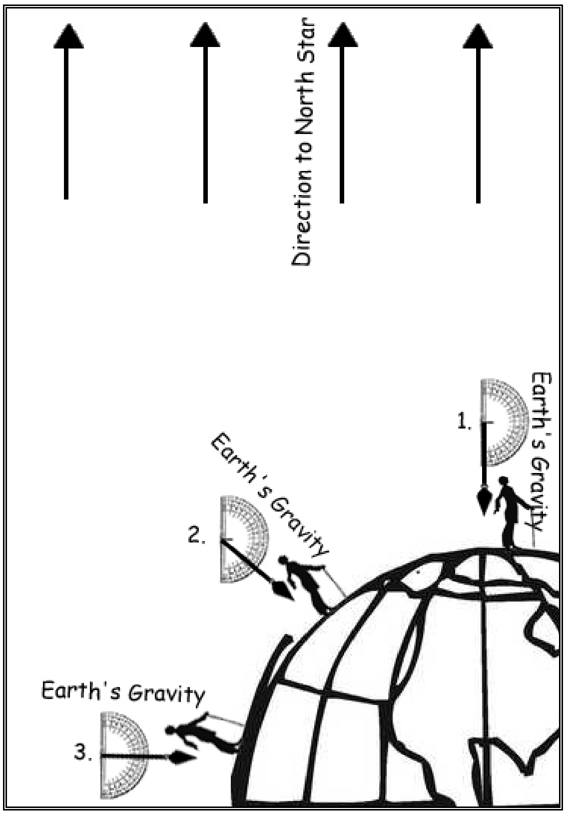
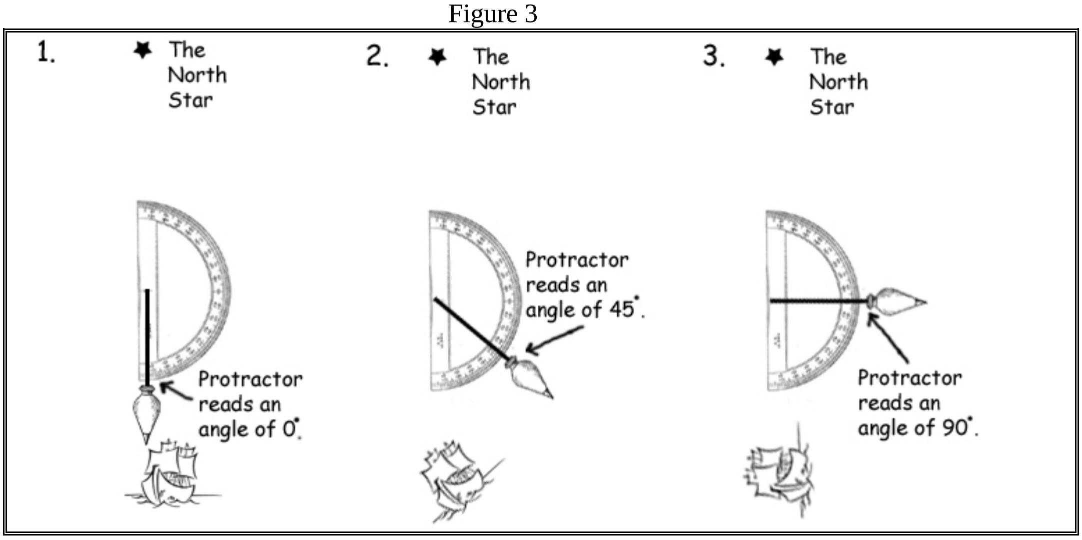


Figure 2

Figure 3



At the North Pole, your protractor should read 0 degrees. Your latitude is (90-0) degrees.

At 45 degrees latitude, your protractor should read 45 degrees. Your latitude is (90-45) degrees.

At the equator, your protractor should read 90 degrees. Your latitude is (90-90) degrees.

Homework: On the next clear night, try to find the North Star and measure your latitude according to your homemade sextant.