AS-105 — Coastal Navigation

Study Guide and Review Questions

Bob Diamond and Patrick Twohy

Spinnaker Sailing School

Spinnaker Sailing is an affiliate of American Sailing.

Spinnaker Sailing 451 Seaport Court, Redwood City, CA 94063

(650) 363-1390 | office@spinnakersailing.com

How to use this manual

This publication is intended to guide you as you work through the AS-105 Coastal Navigation course. Each chapter corresponds to a lesson lead by your instructor.

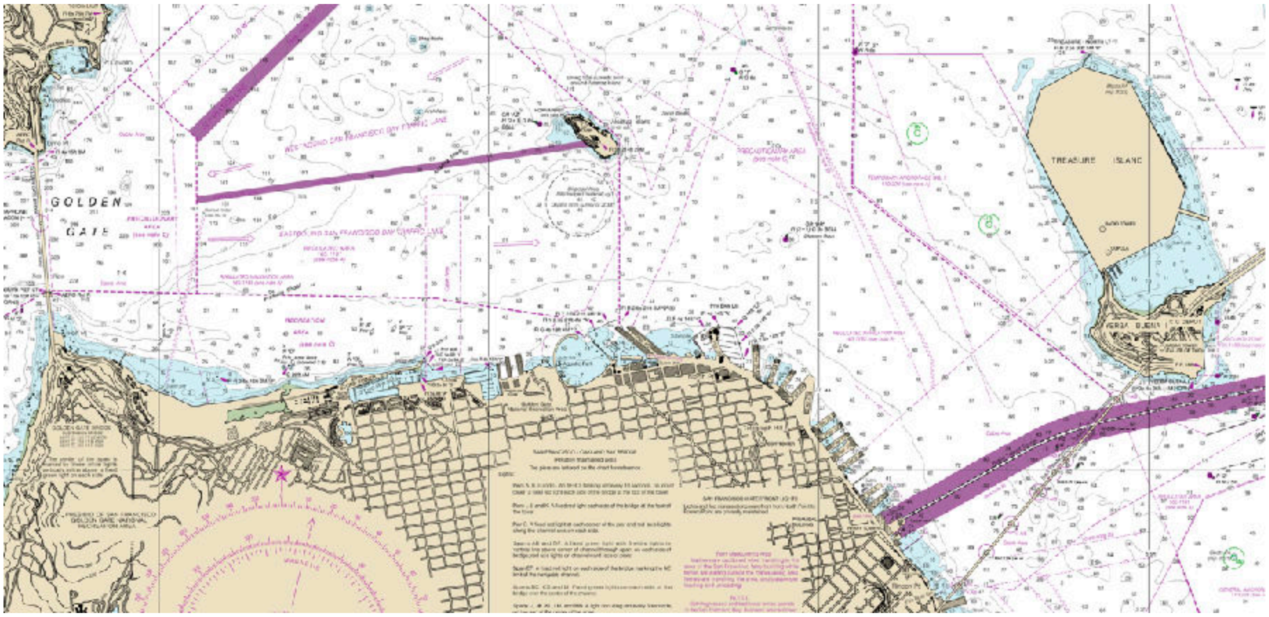
You may find it useful to read a chapter ahead of the lesson presented by your instructor to familiarize yourself with the concepts your that will be presented.

After a lesson has been presented, try the review questions at the end of that chapter to ensure you have learned the essentials and to reinforce your understanding.

There is a glossary at the end of this manual that may also help you throughout this course.

Version: 20240416

Table of contents



Lesson 1

Charts instruments and equipment, how to use plotting tools

I. Charts and maps

Use Google or Apple Maps to show you where you are and you'll get a screen with a little dot. If you're on land and are hoping to get to a new restaurant, your app will likely get you there successfully.

On the water however, your mapping app is insufficient. It is not designed for water routes and could put you in serious danger. Instead of your mapping app, you might want to use an app created for use by mariners. These will involve nautical charts. But to use them effectively you'll need to understand how charts work.

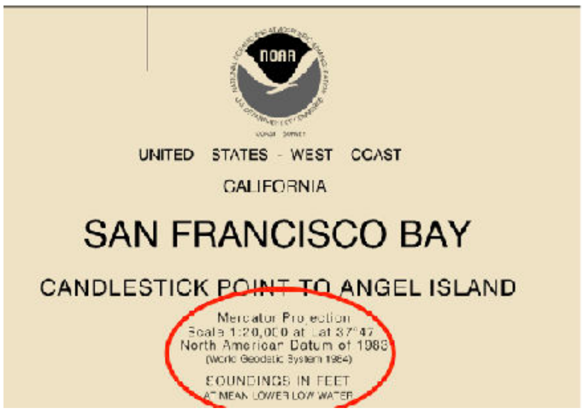
San Francisco Bay Area clean boating map

Nautical charts, whether paper or electronic, offer much greater detail and precision in what is represented than standard maps. The items that appear on a chart are of special interest to the mariner including water depths, aids to navigation, hazards and shoreline features.

When an object on a chart is represented to be a certain distance and a certain direction from another object, that relationship will be as true as possible to the real world. Charts use a worldwide coordinate system using latitude and longitude to describe locations precisely.

Maps for boating do exist but are used differently from the way charts are used. For example, various organizations, including the State of California, create maps to help boaters find necessary services. But navigating safely to those services requires a chart so the mariner can understand exactly where he or she is and plot a safe course to the destination.

Nautical chart title block



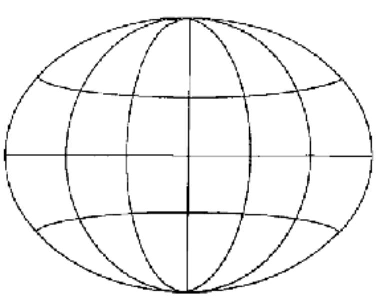
A chart title block with the key information highlighted: Projection, scale, sounding units and datum.

There are four technical specifications printed in the title block of a traditional chart that are critical to using the chart effectively — **projection, scale, sounding units and sounding datum.**

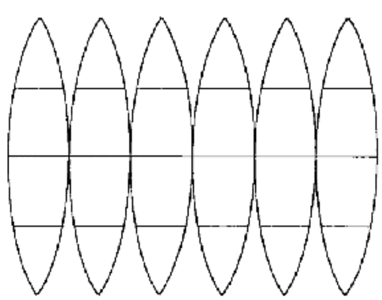
Projection

One of the problems for chart makers is that while the earth is spherical, charts have to be flat. Cartographers overcome this problem by using projections. Essentially, the features are projected (and scaled down) from the surface of the earth, which is curved, to the surface of the chart, which is flat. There are many kinds of projections, and each has its own kind of distortion. If the area covered by the chart is small, such as San Francisco Bay, the amount of distortion is negligible. However, if a large area is covered, such as the eastern Pacific Ocean, the distortion becomes significant. For example, Greenland on a map appears much larger than it does on a globe because of the projection used to create the flat map.

Most charts for marine navigation use the Mercator projection. One of the characteristics of this projection is that lines from pole to pole (meridians) and lines that cross the meridians (parallels) all come out straight on the chart and cross each other at right angles. The equator is a parallel.



Earth's latitude and longitude lines



Mercator projection

A sphere represented on a flat surface

Although it doesn't take a great knowledge of projections to safely navigate, methods for measuring coordinates and distance are different with various chart projections. An awareness of various projections will help if you should encounter a chart that is different.

Scale

The scale of a chart is determined by the amount of area represented and the amount of detail required. If you need a chart showing great detail, it is naturally not going to cover a vast area. Charts that would be most useful in showing details are called large-scale charts that cover a relatively small area with a large amount of detail. These are often called harbor charts and typically have a scale of 1:20000. One unit on the chart represents a unit 20000 times larger on the surface of the earth.

A small-scale chart, such as a sailing chart, would have a scale of 1:600000 or more. It will cover a huge area and show few of the details that a large-scale chart would have. There are also charts with scales ranging from 1:50000 to 1:600000. These general and coast charts are useful in coastwise navigation.

Remember, a large-scale chart shows a *small* area in great detail; a small-scale chart shows a *large* area with less detail.

Sounding Units

Water depth measurements are called soundings. These are printed on the chart wherever the national charting authority — the National Oceanographic and Atmospheric Administration (NOAA) in the United States — has measured the water depth. Sounding units may be in feet, fathoms or meters depending on the body of water covered by the chart. Knowing whether the water is 4 feet or 4 fathoms deep should be of more than a passing interest to anyone navigating a vessel with a 5-foot draft. (At 6 feet to a fathom, 4 fathoms is 24 feet deep.) Note that for rocks that are awash, meaning they can appear above the water at low tide, may be marked with an underlined sounding (5 would mean the rock is five feet *above* the water at datum.

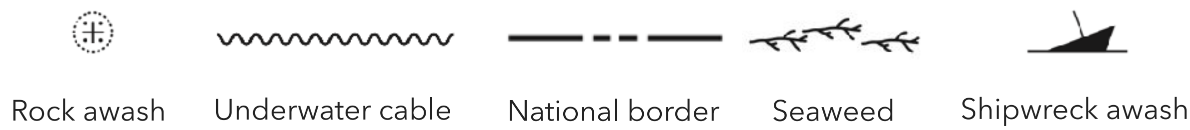
Sounding Datum

Soundings and datum info from a chart Title Block

With tidal action, the depth shown on the chart rarely represents the true depth at any given moment. The sounding datum is the tidal state, or reference point, on which the soundings printed on the chart are based. In most parts of the world, there are, roughly speaking, two low tides and two high tides each day. Many U.S. charts use a datum of Mean Lower Low Water (MLLW) — the average of the lower of those two daily low tides is datum or 0. Some charts use Mean Low Water (MLW) — the average of all low tides — as datum. As an example, a charted depth of 12 feet on a chart using MLLW as datum would mean the water is 12 feet deep at mean lower low water at that spot. Note that charts from other nations may use other datums.

Although not normally noted in the title block, the datum for heights above water is usually established at mean high water, meaning the average of all the high tides. Important height information include the height above water for lights on fixed aids to navigation (not buoys) and also bridge or power line clearances.

Chart Symbols

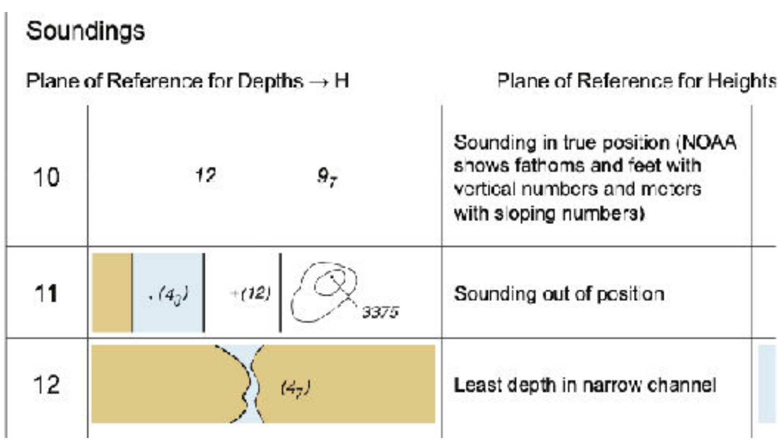


There are many other symbols that can appear on a chart. Some of these indicate shipwrecks, the nature of the bottom, submerged cables or international borders.

Even when you're not plotting, charts are helpful in determining your proximity to the objects around you. The key is to be able to interpret the symbols on the chart. It doesn't take long to learn many of the important ones.

The authoritative reference for symbols and abbreviations on U.S. charts is Chart 1. Charts may be purchased in various marine stores and can be downloaded online. You can get started at https://oceanservice.noaa.gov/facts/find-charts.html

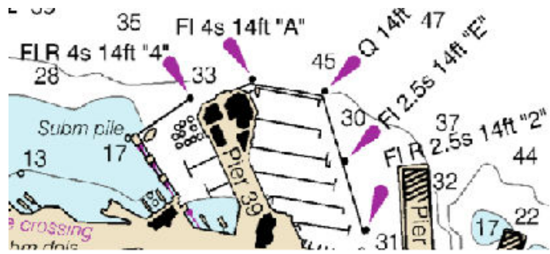
A note about paper charts. For a number of good reasons, NOAA has decided to discontinue updating and publishing its traditional paper charts, each of which covered a specific area. However, that doesn’t mean the end of paper charts. Instead of pre-selected regions covered by traditional charts, mariners will be able to select and print or save to their electronic devices the latest chart for whatever area they choose. Services are available that will print on demand charts representing the areas covered by traditional charts. Also, charts with the latest updated information are always available through charting applications such as Navionics or iNavX.



Detail from Chart 1 regarding depths

Light characteristics

Light characteristics are printed on the chart for most lights. Some of the most common characteristics are Fl, Fl R and Fl G, which translate to flashing white, flashing red and flashing green. The height of the light above high water is often given for lights on fixed structures and sometimes the nominal range of visibility is too. Height is given in feet, such as 15 ft, and visibility is given in miles, for example 4 M.

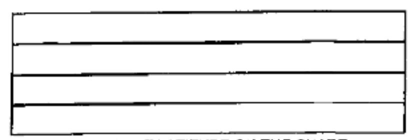


Light characteristics as displayed on a chart.

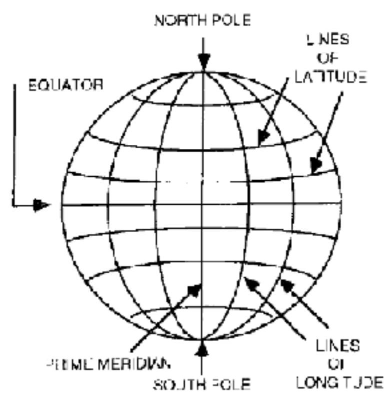
Other characteristics can include Q for quick flashing, IQ for intermittent quick flashing, Gp Fl for group flashing, Mo (A) for Morse code letter A (a short flash followed by a long flash) or Alt for alternating. GP Fl (3) means three flashes followed by a pause. Alt WR means alternating white and red lights

Coordinates

The most important aspect of charts is a worldwide system to provide an absolute reference for positions. This system gives us coordinates of latitude and longitude to identify the location of any point on earth.



LINES OF LATITUDE ON THE CHART



LINES OF LONGITUDE ON THE CHART

Latitude is the measurement north or south of the equator. The equator is the line extending around the middle of the earth equidistant from the north and south poles. It is also zero latitude. All latitude lines run parallel to the equator.

On most charts, the northern edge is oriented to the top and the latitude lines are horizontal, running east and west.

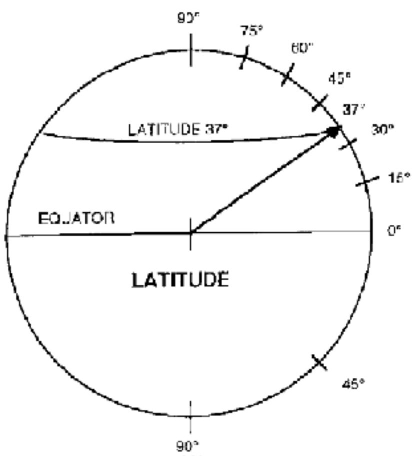
Longitude lines function much the same way except that they measure east and west direction, are *not* parallel and meet at the poles. Since there is no natural meridian (line of longitude) like the equator to use as a reference point, mariners worldwide use the longitude of Greenwich, England, as the longitudinal reference point, or prime meridian. The prime meridian runs through the Royal Observatory in Greenwich.

All lines of longitude are measured east or west from the prime meridian. They appear parallel on Mercator charts and they are perpendicular to the latitude lines. They are the vertical lines if the chart is oriented with north upwards.

Arc distance

Whenever we refer to points along a line of latitude or longitude, we identify the line in terms of arc distance from its reference line. As we've seen, the reference line for measuring latitude is the equator and the reference line for measuring longitude is the prime meridian. The arc is measured in angular degrees from the center of the earth.

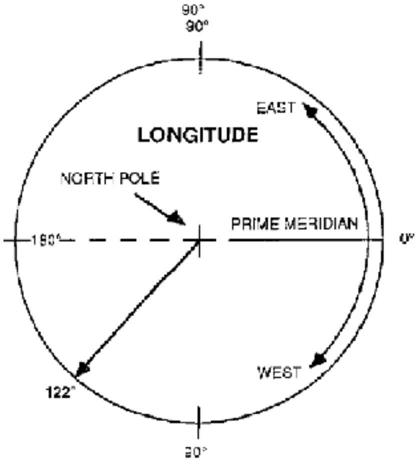
Since even a small angle from the center of the earth covers quite a distance on the surface, it is necessary to divide degrees of latitude and longitude into smaller units. Each degree is divided into 60 minutes. Minutes are divided into tenths of minutes on some charts and others have minutes that are divided into 60 seconds. A few charting systems use degrees and tenths of degrees. On the latitude scale, one degree of arc distance is equal to 60 nautical miles. Therefore, one minute of latitude arc equals one nautical mile. One arc second is about 100 feet.



Latitude

Since the reference for latitude is the equator, the equator is 0° latitude. Arc distance is measured north and south from the equator to 90° north at the north pole and 90° south at the south pole.

The Spinnaker Sailing office at the Port of Redwood City is located 37 degrees, 30 minutes and 12 seconds north latitude. In decimal notation for the minutes it would be 37° 30.2' north. The correct notation for this measurement is L 37° 30' 12" N or L 37° 30.2' N.



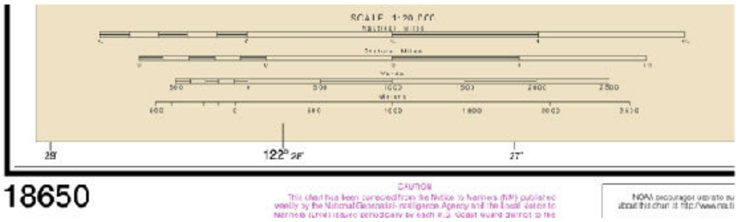
Longitude

The 0° longitude line is the prime meridian running north/south through the Royal Observatory in Greenwich, England. Longitude is measured in arc distance either east or west from this line to 180° longitude on the opposite side of the earth.

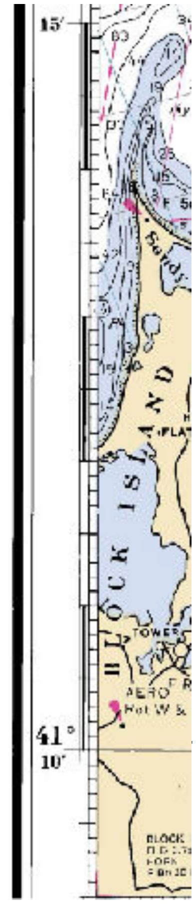
The Spinnaker Sailing office is located 122 degrees, 12 minutes and 48 seconds west of the prime meridian, or 122° 12.8 minutes west. Notation for this measurement is λ 122° 12' 48" W or λ 122° 12.8' W. (λ is the Greek letter lambda, which is commonly used for longitude.)

Distance

The unit of distance in navigation is the nautical mile. It is a little longer than the statute mile that we use on land in the United States. The ratio is about 1.15 statute miles to one nautical mile. A nautical mile measures 6076.115486 feet, but we can round it off to 6076 ft.



Distance scale on Chart 18650. A nautical mile is equivalent to 1 minute of latitude



The **Latitude** scale can be used to measure nautical miles. It is 5 nautical miles from L 41° 10′ N to 41° 15′ N

The reason for such an odd standard (compared to a statute mile) is that a nautical mile is defined as exactly one minute (1/60 of a degree) of latitude. On many small-scale charts, the only way to measure distance is by using the latitude scale at the edge of the chart. And even though many large-scale charts have a distance scale, nautical miles can still be measured on the latitude scale. (Note: Do *not* use the longitude scale for mileage. Units of longitude get smaller as you move away from the equator.)

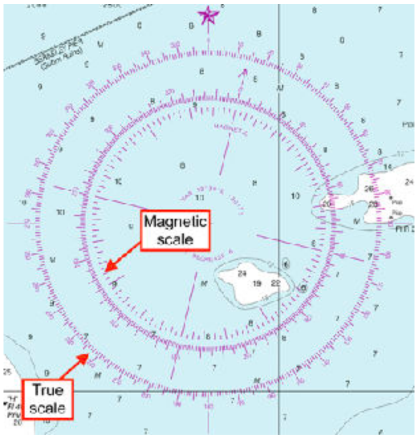
Directions

Many people refer to directions as north, east, south, or west, but this is not specific enough for navigation, so we use a scale of 360°. North is 000° which is the same as 360°. The degrees increase as you turn right, so 090° is east, 180° is south etc.

The earth's magnetic field lines up near the north and south poles, but not exactly so. A compass points to the magnetic north pole, which is some distance from the true north pole. So a compass, or magnetic, reading will differ slightly from the direction to the true north pole — an effect mariners call variation. It's a small but important difference and mariners need to account for it. In addition, variation changes slightly each year as the position of the magnetic north pole moves. In the San Francisco region in 2024, variation was about 13° east. Therefore, magnetic north (and every other direction) is 13° east of the corresponding true direction. On the U.S. East Coast around Martha's Vineyard, the variation was 15° west.

Navigators on small craft generally use magnetic directions and navigators on large craft usually use true. You will learn to use both systems and will learn to convert from one to the other in Lesson 2.

The Compass Rose



Most charts used in boating have a compass rose that gives both true and magnetic directions. Having a compass rose with magnetic directions makes plotting easier. It allows you to do your plotting in magnetic directions so you don't have to convert to magnetic every time you want to steer a compass course.

Measurements are taken from (or brought to) the compass rose with the parallel rule.

On the compass, rose true direction is shown on the outer ring, the one that has a star, at 000°. An inner ring has magnetic directions, also in 360°.

II. Instruments and Equipment

The following equipment is recommended by American Sailing as the minimum required for prudent navigation in a local area. These are the basic items that a skilled navigator can use to get safely from one place to another by day or night. The list doesn't contain electronic equipment such as GPS, which would add a large measure of safety especially on the often-foggy Northern California coast. Once a mariner learns how to use the basic equipment and processes, GPS can be used with a much greater level of understanding.

Steering compass and deviation table

The ship's compass tells you which direction the boat is facing and therefore generally the direction the boat is moving. Because it works by magnetism, its readings are based on magnetic directions, not true directions.

Iron, steel electrical wires or electronic equipment located near the compass will cause erroneous readings for magnetic directions. This kind of compass error is called deviation, and it will change depending on the boat's heading. A deviation table gives the navigator information to mathematically compensate for this error.

Hand-bearing compass

Hand-bearing compass, pelorus

These instruments are used to take directional measurements or bearings to objects visible from the boat. The hand-bearing compass is by far the more popular. It reads the magnetic bearing or direction to the object. Cheap ones may have a resolution of about 5°. There are more expensive ones, notably the hockey puck style ones that are more accurate. Also there are binoculars that have built in compasses that can be accurate to within a degree.

A pelorus measures the direction to an object relative to the boat's heading. 000° relative is straight ahead, 090° is off the starboard beam, 180° is directly behind the boat etc. The measurement from the pelorus must be combined with the boat’s heading in order to get a useful bearing for plotting on the chart. A pelorus can also be used for measuring deviation — compass error caused by magnetic influences aboard the boat.

Parallel rules

Protractor, plotter, parallel rules

These tools are used to measure angles and plot lines at desired angles on a chart. Plotters and protractors measure only in true directions since they work by measuring angles to the meridians. Parallel rules can measure both true and magnetic directions directly if a compass rose with magnetic directions is printed on the chart. They aren't quite as accurate as plotters but are easier to use. For many people, using a parallel rule is more intuitive than using a plotter.

Dividers

Dividers

Dividers, which like a drawing compass, are used to measure distance and coordinates on the chart by spanning a distance and comparing the measurement to a distance scale. Instead of a pinpoint at the end of one arm and a pencil lead on the other, dividers typically have pinpoints on both arms.

Binoculars

Binoculars are useful for finding and identifying aids to navigation and other objects, including hazards, from a distance. Some binoculars also have built in hand bearing compasses and range finders.

Depth sounder or lead line

Knowing the depth can be as important as having visual references. Without advanced electronic aids, the depth may be your only direct reference in the fog. The lead line is simply a weight tied to a line with marks for measuring the depth of the bottom. Electronic depth finders use high frequency sound pulses to measure the distance to the bottom.

Log and/or knot meter

The log measures distance traveled through the water just like a car's odometer. The knot meter measures boat speed through the water. Combination instruments called knot-logs are popular. If you keep track of time, you can calculate distance from speed and vice-versa using a simple formula we’ll discuss in Lesson 3 of this course.

Watch or clock

It doesn't have to be an expensive chronometer. Even a cheap digital wristwatch will work as well for timing runs from waypoint to waypoint.

Pencil, eraser and notebook

These items seem almost too simple to mention but are absolutely essential for plotting and keeping track of courses, bearings, speed, distances, etc.

As we have seen, every point of location on the earth has its own set of coordinates of latitude and longitude. To measure the coordinates on the chart, you need a pair of dividers to carry the latitude measurement to the latitude scale, and the longitude measurement to the longitude scale.

III. Using plotting tools

Measuring Latitude

To measure latitude, you must spread or span your dividers so that one point of the dividers is touching the point you are measuring and the other is touching the nearest latitude line shown on the chart. When you carry this measurement to the scale on the left or right side of your chart you will be able to measure the latitude of any point on the chart.

In the northern hemisphere, higher latitudes are more northward until you get to the north pole, which is 90° north. It's the opposite in the southern hemisphere.

Example: Measure the Latitude of Point Judith Light near the western edge of Chart 1210 TR by spanning the dividers from the symbol for the light at Point Judith to the latitude line 41° 20' North line. Then move the dividers to the latitude scale to measure how far the span of the dividers reaches north from L 41° 20'. It reaches 1.7 minutes north from the line showing the light at latitude 41° 21.7' North. (20 minutes plus 1.7 minutes equals 21.7 minutes)

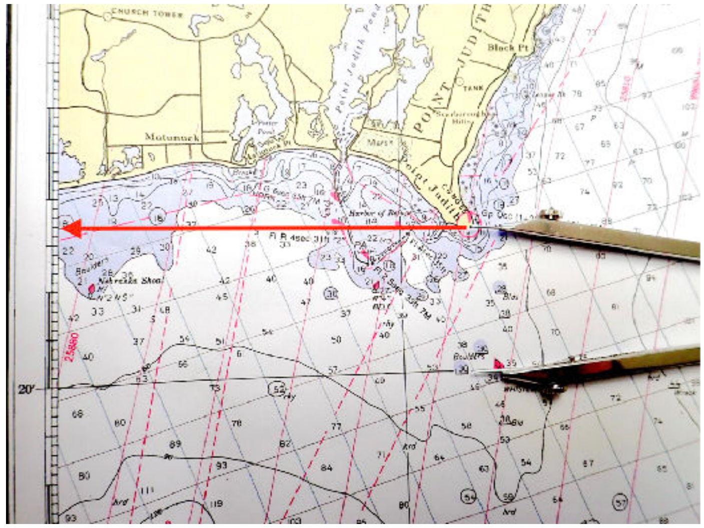
Measuring longitude

Longitude is measured the same way as latitude except that it is an east and west measurement. Since North America is located in the western hemisphere, the value of longitude increases from right to left. This is counter-intuitive for people who are accustomed to using number lines that increase from left to right.

When measuring points west of a longitude line, add the difference of longitude from the point to the line to the longitude of the line. When measuring east of a line, the measurement is subtracted.

Example: Measure the longitude of Point Judith Light by spanning the dividers from the symbol for the light to the longitude line (in this case) at the edge of the chart near Point Judith. Then move the dividers to the longitude scale at the bottom (or top) of the chart to measure how far the span of the dividers reaches east from Longitude 71° 35 minutes west. It reaches to 71° 28.9 minutes west.

Locating coordinates



Locating coordinates on a chart can be done for two likely reasons. One is to help you find objects such as buoys or other aids to navigation. The other is to position yourself (or others) on the chart if you have GPS coordinates. This is similar to the process of measuring coordinates, but done somewhat in reverse.

You will be taking measurements from the nearest latitude and longitude lines on the chart in order to locate the objective. This process requires parallel rules in addition to dividers. The following example gives steps to easily locate coordinates.

The Coordinates for Pt. Judith Light are:

L 41° 21.7' N

λ 71° 28.9' W

Locate the object on Chart 1210TR at

L 41° 17.0' N

λ 71° 04.0' W

1. On the longitude scale at the bottom of the chart find the nearest printed (vertical) longitude line to 71° 04' W. (Hint: It happens to be at 71°.) Try to remember where that line is.

2. On the latitude scale at the left or right edge of the chart locate 41° 17.0' N.

3. Use your dividers to measure the distance from L 41° 17.0 N to the nearest printed latitude line on the scale. (Hint: It's L 41° 20' N.) Keep your divider span at this distance. Also remember if the coordinate (41° 17.0' N) is above or below the printed latitude line. In this case it's below. You will need this information in the next step.

4. Find the intersection of the 41° 20' Latitude line and the 71° 00' Longitude line. Keep your dividers opened to the same span from step 3 and move the dividers to put one point onto the intersection and put the other point where 41° 17.0 would be if the latitude scale were on that longitude line. Your dividers are already set at that distance. You just need to remember

The coordinates for the Spinnaker Sailing office are:

L 37° 30' 12" N

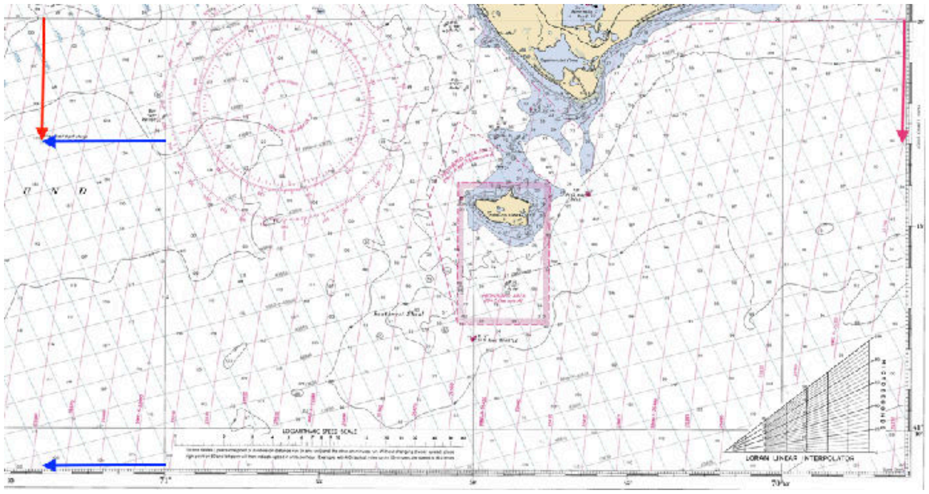
λ 122° 12' 48" W

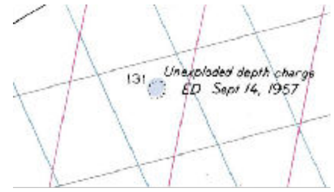
Or

L 37° 30.2' N

λ 122° 12.8' W

Notes: Latitude is first when giving coordinates. Often the lambda symbol λ is used to indicate longitude.





Detail from the chart at left.

The item at L 41° 17.0′N, λ71° 04.0 W on Chart 1210TR is an unexploded depth charge.

which direction the coordinate is relative to the latitude line. Hint: In this case it's south of the latitude line.

Now you have a point at the exact latitude of the objective on the longitude line that's near the objective. Mark that point.

5. You will be drawing a line from the mark on the 71° longitude line. This line will need to be not only straight but parallel to the latitude lines on the chart. Line up one blade of your parallel rule to the nearest latitude line printed on the chart. Hold that blade in position while moving the second blade to the mark you made in step 4 and then draw a line along the edge of the second blade. This line will need be extended from the point on the 71° longitude line past the approximate longitude of the object. (λ 71° 04.0' W)

6. Span your dividers on the longitude scale to measure 71° 04' from 71° 00'.

7. Bring that measurement up to the line drew in step 5. Put one point on the 71° line and the other along the line plotted in step 5. This point will be L 41° 17.0' N, λ71° 04.0' W (It happens to be an unexploded depth charge.)

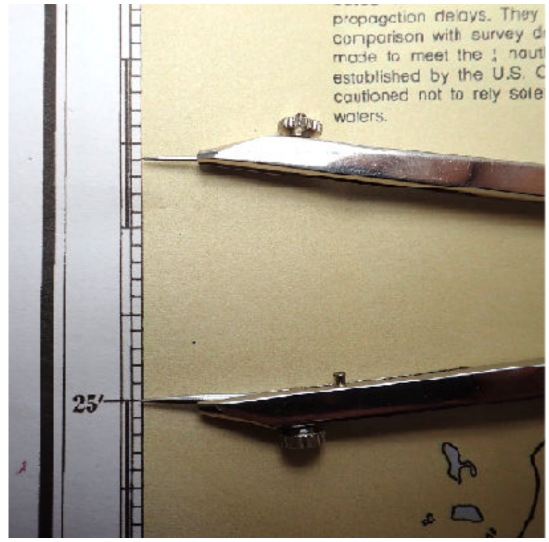
Measuring distance

Short distances can be measured by simply spanning the dividers to both ends of what you are measuring and bringing that span to the latitude scale on the left or right edge of your chart at the approximate latitude of what you are measuring. Large-scale charts will also have a mileage scale.

Small-scale charts don't have a mileage scales because of the distortion inherent in a Mercator projection chart. In this case you have to use the latitude scale. **One minute of latitude equals one**

To measure distance span the distance with dividers…

… then measure the distance on a mileage or latitude scale.



Dividers can be spanned to measure any distance on a chart and then compared to the the scale on the left or right side of that chart. Here we see the distance measured was 1.4 minutes of latitude or 1.4 nautical miles.

nautical mile. You will get the most accurate measurement by using the portion of the latitude scale at the same latitude as the area you are measuring from.

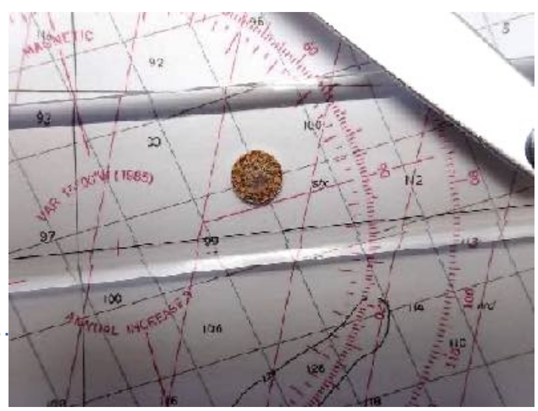
Note: Using the Longitude scale at the bottom or top of your chart will give you an incorrect measurement (unless you happen to be measuring something exactly on the equator).

Sometimes two points on the chart are too far apart to span the dividers. Draw a straight line between the points and use a convenient distance measurement to step the dividers along the line until the remaining distance is shorter than a full step. Multiply the number of steps by the distance of each step and add the remainder to get your overall distance.

A YouTube video clip from West Marine that demonstrates how to use dividers and how to walk them along a chart to measure longer distances is at: http://tinyurl.com/using-dividers

Measuring directions

Direction measuring can be done with a plotter protractor, navigation triangles or a set of parallel rules. Plotters, protractors and triangles can only be used to measure true direction relative to the longitude or latitude lines on the chart. Parallel rules can indicate either true or magnetic directions by taking



A parallel rule is used to measure a direction using a chart's compass rose. In this situation, the rule shows a direction of 100° magnetic or 85° true.

Using a parallel rule to measure the direction from Berkeley Pier light to the entrance to the Emeryville channel. The direction is 84° magnetic or 98° true.

Using a plotter to measure the direction from Berkeley Pier light to the entrance to the Emeryville channel: 98° true.

measurements off the compass rose. Using the parallel rules with the magnetic compass rose saves having to convert true to magnetic directions and vice versa. Plotters allow for tighter tolerances, but mistakes in conversion can be whoppers.

Using parallel rules: Directions can be taken between two points on the charts by placing one blade of the rules against the both points and then spreading the rules to reach the compass rose with the other blade. Then the reading on the compass rose is taken from under the edge of the blade in the direction being measured. The true directions are indicated on the outside ring of the compass rose. The inner ring indicates the magnetic directions. The blade must align precisely through the center of the compass rose for accuracy.

A video clip from West Marine that demonstrates how to use parallel rules to measure direction on a chart is available at: http://tinyurl.com/using-parallel-rules

Scan for video on using dividers

Scan for video on using parallel rules.

Electronic charts

In the United States, the National Oceanographic and Atmospheric Administration (NOAA) has gotten out of the business of creating, maintaining and publishing paper charts. The chart office instead puts its efforts into electronic charts, which can provide far more information than paper charts.

There's only so much space for information about a particular space on a paper chart, whereas on an electronic chart, the user can use a chart reader to get any piece of available navigational information about an area or aid to navigation, no matter how detailed.

For example, much of the information about a lighted aid to navigation traditionally resided in the Coast Guard's Light List. With electronic charts, that information is embedded in the chart itself.

Boaters devoted to paper charts can always download and print sections of electronic charts, order custom printed chart portions they want or buy pre-selected charts from vendors. Those charts will be current as of the moment they were downloaded for printing.

On-screen or on-paper electronic charts appear slightly different from traditional paper charts, but the differences are minor and most chart symbols on electronic charts are easily understood by navigators familiar with traditional paper charts.

The skills learned in this course apply to electronic charting systems as well as to users of paper charts, though the specific tools the navigator may use, like parallel rules or dividers, may be different.

For more on custom electronic charts, read this article from Spinnaker Sailing: https://www.spinnakersailing.com/electronic-navigational-charts/

Review questions for lesson 1

Plot the coordinates (latitude and longitude) for the following Aids to Navigation.

1. Brenton Reef Light - Gp Fl (2) 10sec 87ft 25M
2. Point Judith Light - Gp Occ 1+2 15sec 65ft 16m
3. Pt. Judith Whistle Buoy - R “2” Fl 10sec
4. Sakonnet River Approach Buoy – BW “SR” Mo (A) Whistle

Find the Aids Located at the following coordinates.

5. L41°27.8’N λ71° 20.2’ W
6. L41°22.2’N λ71° 23.3’ W
7. L41°23.3’N λ71° 20.3’ W
8. L41°19.7’N λ71° 24.0’ W

Measure the distance between the following Aids to Navigation.

9. From Pt. Judith Light to Pt. Judith R ”2” Fl 10sec whistle buoy
10. Brenton Reef Light to Buoy BW “A”Fl 3 sec Priv Maint
11. Pt. Judith Light to Sakonnet River Approach Buoy

Measure the directions between the following Aids to Navigation.

12. Point Judith Light to Sakonnet River Approach Buoy
13. Sakonnet River Approach Buoy to Point Judith Light
14. Brenton Reef Light to a point at L41° 20.0’ N, λ71° 20.0’ W

Find the Aid to Navigation that lies on the following bearings

15. 256° Magnetic to Point Judith Light
16. 049° Magnetic to Pt. Judith Light
17. 280° Magnetic to Brenton Reef Light
18. 045° Magnetic to Brenton Reef Light

(All hand bearings are assumed to be magnetic unless otherwise stated.)

Answers for Lesson 1 questions

1. L 41° 25.6’ N, λ71° 23.3’ W
2. L41°21.7’N, λ71° 28.9’ W
3. L41°20.0’N, λ71° 28.6’ W
4. L41°26.4’N, λ71° 13.5’ W
5. Flag Pole on Newport Neck
6. Sunken Wreck PA (Position Approximate)
7. Unexploded Depth Charge
8. White and Orange “C” Buoy
9. 1.7 Miles
10. 4.8 Miles
11. 12.4 Miles
12. 68° True, 83° Magnetic
13. 248° True, 263° Magnetic
14. 156° True, 171° Magnetic
15. W OR “G” Bell Buoy
16. “1B1” Fl G 4sec Bell Buoy
17. B W “A” Fl 3sec PRIV MAINTD Buoy (Privately Maintained Buoy)
18. W Or “H” Fl 2sec Bell Buoy

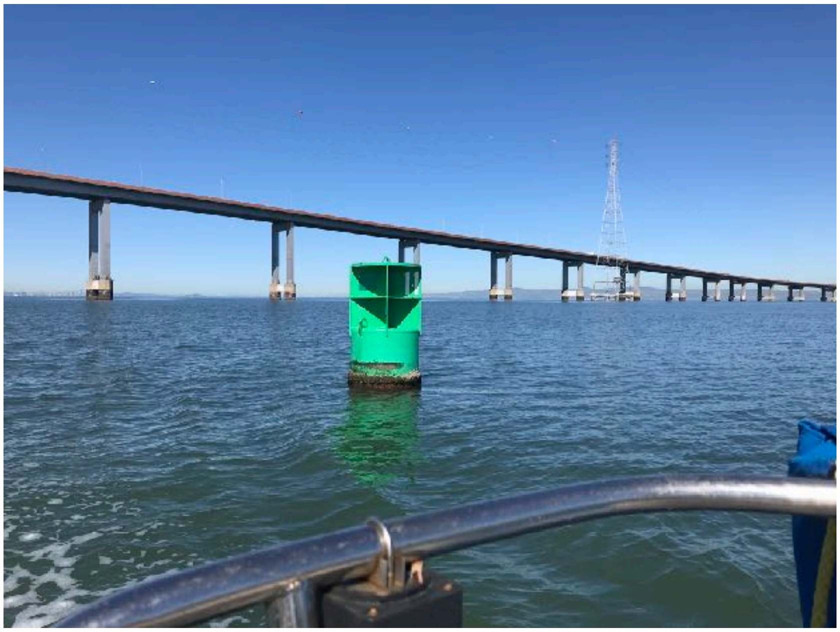
Lesson 2

Aids to Navigation, useful publications, the compass

Aids to Navigation, also known as ATONs, are the street signs on the water. They consist of buoys, beacons, lights and other devices to help mariners find safe passage through channels and to avoid hazards to navigation. The primary system for aids to navigation in U.S. waters is the lateral system, though U.S. authorities also use certain non-lateral aids. The other system used in waters not controlled by the United States is the cardinal system.

I. Lateral and non-lateral buoy systems

The lateral system is the basic system of buoyage in U.S. waters. Under this system, the buoys and marks indicate the direction of safe passage relative to the mariner's direction of travel. For example, when navigating in a channel from seaward toward a harbor, red buoys are kept to the right and green ones to the left. This is often described as the "Red - Right - Returning" system. The United States has



A green Can Buoy with an odd number marks the left side of a navigable channel when coming in from seaward in U.S. waters.

This is how Mark 11 shown at left appears on a nautical chart.

adopted this system to conform with what's known as the International Association of Lighthouse Authorities (IALA) System "B".

System "A" is the lateral system used in Europe, Africa, the South Pacific and most of Asia.

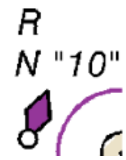
In addition to the lateral buoyage system, many seafaring nations also mark their waterways with what's known as the cardinal system. In the cardinal system, the observer's direction of travel isn't considered. The marks indicate the direction of dangers relative to the buoy or mark by compass bearing.

In U.S. waters, it's most important to remember to keep the red markers to the right whenever underway moving inland from the sea. Green markers must be kept on the left.

Identifying lateral aids

In addition to consulting the chart, there are a number of ways to identify the function of various aids to navigation. These include the ATON's color, number, shape and light characteristics.

When proceeding from the sea toward a harbor, the markers on the right side of the channel will be red and the markers on the left side will be green. Channel markers are numbered with even numbers on the right and odd numbers on the left. Numbers ascend from the where channels are entered from the sea.



This is how Mark 10 shown at left appears on a chart.

Mark 10 an unlighted red Nun Buoy carries an even number and is conical in shape meaning it just be passed on the mariner's right when approaching a harbor from sea.

Lighted channel markers flash with red or green lights depending on which side they mark. Some markers can also be identified by their shape, with markers on the right having pointy or conical tops and markers on the left having flat tops.

These shapes apply to unlighted buoys and to what are called day beacons, which look like signs on posts. Red unlighted buoys, called nun buoys, come to almost a point on the top. Unlighted green buoys, which are flat on top in the shape of a cylinder, are called can buoys. Day beacons, also called day marks, are signs that are placed on pilings or other fixed structures. The red ones are triangular and the green ones are square.

Junction markers

Channels sometimes split into two. When this happens, one of the new channels is designated as the primary channel and the other the secondary. The primary channel is considered the preferred channel leading to the more important harbors, or it can just lead through the preferred path due to its depth or width. Aids that indicate which way to go to enter the primary or secondary channel are called junction bifurcation markers or preferred channel markers. These have both the lateral colors red and green arranged in horizontal bands.

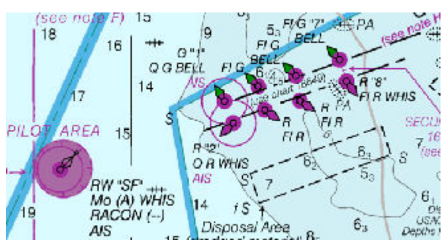
This is how the preferred channel buoy shown at left appears on a chart.

A green preferred channel marker with a red band indicates to mariners that the preferred route to avoid this tower of the San Francisco-Oakland Bay Bridge is to pass the buoy on the left.

The San Francisco approach buoy is a safe water mark that acts as a reference position for ships to safely enter San Francisco Bay.

A red buoy with a green band around the middle is considered a red buoy (to be kept on the right when encountered from open water) for the primary channel. It's a green buoy (to be kept on the left) for the secondary channel. A green buoy with a red band around the middle is the opposite.

Safe water buoys



How the San Francisco approach buoy shown at the left appears on a chart.

Safe Water buoys, also known as approach buoys, are located a safe distance at sea from channel entrances. They are placed so vessels can approach from any direction in order to line up to safely enter a channel into a harbor. An example is the San Francisco “Light Bucket.” Its location lines up with the deep water channel that leads toward the Golden Gate over the San Francisco Bar. The buoy is located three miles out to sea beyond the entrance to the deep water channel, giving ships lots of space to line up in the direction of the channel.

Mid-Channel buoys have exactly the same appearance as safe water buoys but are located in deep water in the middle of a channel to mark the boundary between inbound and outbound shipping lanes. Smaller recreational craft can generally go anywhere in the channel so long as they don’t interfere with shipping traffic.

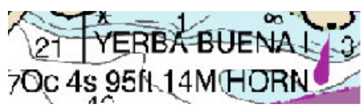
Lights

When a navigational aid is lighted, most charts will give the light’s characteristics, meaning its color and whether and how often it flashes. The chart may also describe the light’s intensity and its height above the water.

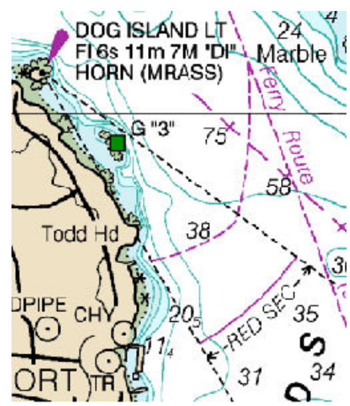
Some of the most common light characteristics noted on charts are Fl, Fl R and Fl G for flashing white, flashing red and flashing green. On U.S. charts, a navigational aid’s height would be noted in feet. Its light intensity or visibility would be in nautical miles under standard conditions.

Seacoast lights — lighthouses (which in earlier times came with a dwelling for the lighthouse keeper) — have a number of light characteristics to help in identifying them from a distance. These characteristics range from groups of flashes and even color changes depending on the direction or sector from which the light is viewed.

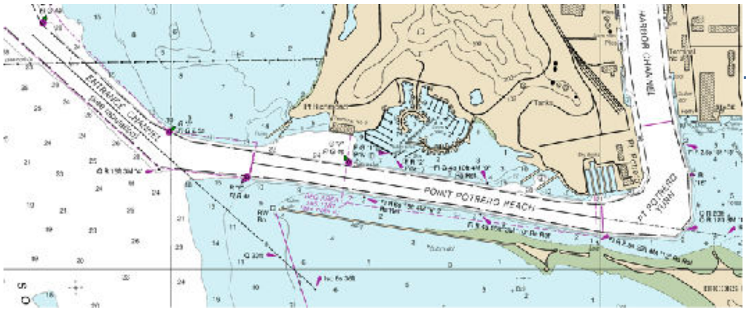
Yerba Buena Light marks the south extremity of Yerba Buena Island in San Francisco Bay.



On a nautical chart, Yerba Buena Light is described as **OC 4s 95ft 14M** – meaning its light Occults (it dims for a short period) every 4 seconds, it’s 95 feet above the water, and it has an intensity making it visible for 14 miles in standard conditions.



This sector light appears red in the sector shown and white from every other direction.



The port of Richmond, California, has two sets of ranges to guide mariners to the center of its entrance channel.

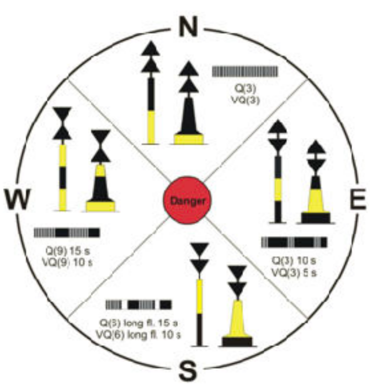
Ranges

Ranges, also called leading marks or leading lights, are a set of two lights or day marks arranged so that when the observer is in mid-channel the two marks appear one above the other.

The cardinal system

In this system, “cardinal” refers to the cardinal points of the compass; north, east, south and west. Here the markers are placed either north, east, south or west of some particular hazard such as a rock, a reef or shoal (shallow water) to indicate where to stay to avoid the hazard.

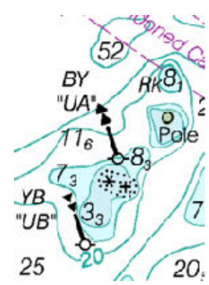
Two black cones placed vertically apex upward indicates the marker is north of the hazard, meaning “Stay north of me.” Two cones apex downward indicate “Stay south of me.” Base to base indicates “Stay east of me,” and apex to apex indicates “Stay west of me.”



A guide to cardinal marks.

As with lateral marks, each cardinal mark carries multiple indications of its meaning. In addition to the cones noted above, each mark also carries black and yellow horizontal bands that are more easily seen from a distance than the cones. Black over yellow indicates a north cardinal mark. Yellow over black indicates a south mark. Black - yellow - black indicates east, and yellow - black - yellow indicates west. Think of the point of the cones as pointing toward black and the color schemes will make sense.

Cardinal marks are used extensively in the Mediterranean, the South Pacific and many other places outside that United States that are popular with charterers.

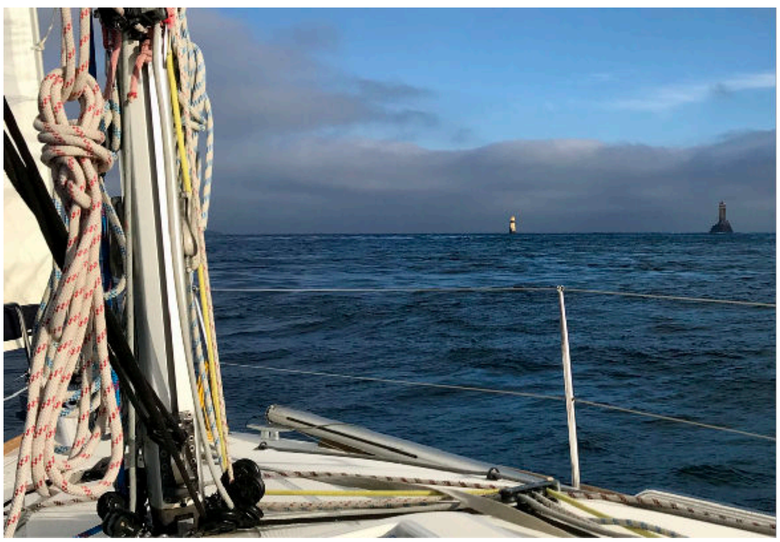


Cardinal marks on a chart of Canadian waters.

There are lots of mnemonics to help you distinguish east from west cardinal marks. For one example, tracing the triangles for an east mark yields a classic E/epsilon. Tracing the triangles for a west mark results in a sideways W.

A north cardinal mark in the British Virgin Islands.

A south cardinal mark in French Polynesia



The yellow and black colors of west cardinal mark off Pointe du Raz on the Atlantic coast of Brittany, France, appears bright even in the distance.

The meaning of an east cardinal mark off Bora Bora is clear from its colors even with its triangles obscured.

Other navigational aids

Certain buoys, lights and day marks can be used as aids with no lateral significance. They can mark quarantine zones, an anchorage, fish net or dredging areas. Hazards such as rocks or submerged obstacles are often marked. These are often called special marks. They will often be yellow with an X on top.

In the United States, in addition to marks placed by the Coast Guard, other entities with authority over a waterway can place what are referred to as information or regulatory marks. As buoys, these will be white with an orange band top and bottom, or white with an orange stripe around it if it's a day mark. The symbol in the middle indicates what kind of mark it is. A circle indicates a speed limit. A diamond indicates danger. A diamond with a cross through it indicates a no-entry zone.

A special mark in French Polynesia tells mariners what areas to avoid near the airport on the island of Raiatea.

Keep in mind that aids to navigation are just that — aids. They cannot take the place of good navigational skills. When sailing in familiar waters, you can navigate by visual reference only. But when sailing in unfamiliar areas, it pays to know and use more sophisticated techniques. Aids to navigation are part of that but they won't do everything for you.

Virtual marks

Some aids to navigation appear on electronic and paper charts but do not actually exist on the water. These are called virtual marks.

II. Useful Publications

The following are from the list recommended by American Sailing for prudent navigation in a local area. Many government publications are only available online.

Regulatory marks

Circle for Restriction: Don't go faster than this mark indicates.

Diamond for Danger: Avoid the danger noted by this mark.

Exclusion zone: A diamond with a cross denotes an area where boating is not allowed.

Large scale charts and Chart No. 1

Charts of a local area are the most important tool for navigating. Chart No. 1 is the reference book that explains all U.S. chart symbols and abbreviations.

Tide and current tables

In San Francisco Bay, the tide can rise and fall eight feet or more. The resulting currents can run as much as 6 knots in certain places. Tide and current tables allow you to generally predict these effects for more accurate navigating and safer sailing. The tables published by the government may be in standard time, so mariners may have to convert to daylight savings time when applicable.

State small vessel regulations

Pamphlets such as “ABC's of California Boating Law” are free and available at the state Department of Motor Vehicles, many harbor offices, boating stores and at Spinnaker Sailing. They give information about state requirements for boaters.

USCG navigation rules

This book provides detailed information about the rules of the road, such as light and shape requirements for commercial vessels of all kinds and sizes. A copy of the Navigation Rules is required aboard vessels 12 meters and greater in the United States. It is available in book form in most boating stores. It’s also available as a download.

Local rules and regulations (if applicable)

Some harbors have written rules for conduct of vessels within their jurisdictions.

Local cruising guides

Boating and cruising guides are available for many popular locations. They provide much useful information for bareboat cruisers in places like the Virgin Islands, the Windward Antilles, the Leeward Islands etc. Charter companies like Moorings and Sunsail publish their own cruising guides for areas where they operate.

List of lights, buoys and fog signals

Called the Light List, this publication provides a comprehensive list of detailed information about aids to navigation. This information is also embedded in electronic charts from the National Oceanographic and Atmospheric Administration (NOAA) — the official U.S. supplier of nautical charts.

Coast Pilot

The Coast Pilot, also from NOAA, gives written descriptions of navigable waters within the area covered by the particular edition. It is a useful supplement for charts, which depict their information graphically and symbolically.

Local Notice to Mariners

Published weekly by the U.S. Coast Guard, the Local Notice to Mariners gives sailors updated information about any changes to charts or other publications. They are published by each Coast Guard district. Updates in the LNM can be temporary, such as aids to navigation that are not functioning properly or are missing, or permanent, such as changes to depth measurements on the chart or the removal or a change to any aid to navigation. Traditionally, professional and commercial mariners use the Local Notice to update their charts by hand to keep their charts current. Electronic charts update with LNM information automatically.

III. The compass

The magnetic compass is one of the most important tools available to the small craft operator. It works without electrical power and is quite dependable providing the user understands how to cope with its limitations. The most severe limitation is that a compass is almost always in error from the true direction. This error, called compass error or CE, is a combination of two kinds of errors — deviation and variation.

Deviation

Deviation is the component of compass error that is caused by how and where the compass is installed on the vessel. Certain metal objects and electrical devices onboard will affect the compass. Because the source of the error is aboard the vessel, the amount of deviation varies with the boat's heading. Sometimes a compass may be adjusted to minimize deviation.

If adjusting can't be done to within reasonable limits, a deviation table should be made. The deviation table is a listing of the deviation in degrees and direction for a minimum of every 30-degree change in heading. Warning: Changing the location of metal objects, electrical equipment or wiring near the compass can change the compass' deviation.

Use the sample deviation table in the back of this handbook for handbook practice problems.

Ferrous metals and electronics will affect a nearby compass.

Variation

The earth's magnetic field doesn't line up exactly with the earth's axis. The magnetic north pole that compasses point to is not in the same location as the true north pole. So even a compass with no deviation will have an error, which mariners call variation. Variation is the difference between true direction and magnetic direction.

In the San Francisco Bay region, a compass that is otherwise accurate will point about 13° to the right (east) of the direction relative to true north. When this happens, it is called easterly variation. It doesn't matter what direction the boat is facing. Geographic location is the only thing that affects variation.

The earth's magnetic field does not line up exactly with the planet's north and south poles.

The way to deal with compass error is to convert from compass directions to true directions when true directions are desired, and from true to compass when compass directions are desired. Compass directions are necessary for steering the boat. True directions may be necessary for plotting or communicating information to other parties.

Terms used in compass conversion

Compass Direction - The direction indicated by the ship's compass. This direction will be in error from true direction due to deviation and variation.

True Direction - The direction in reference to the earth's true axis. The north pole is in the direction of true north. (000° True)

Magnetic Direction - The direction in reference to the earth's magnetic axis. This is the direction indicated by a compass that is not influenced by any nearby disturbances.

Deviation - The amount and direction of magnetic error caused by shipboard disturbances to a compass. It changes with the boat's heading.

Variation - The amount and direction of magnetic error caused by the difference between the earth's true axis and its magnetic axis.

Compass Error - The total error of the ship's compass. The compass error is the algebraic sum of deviation and variation.

Correcting - Converting directions from compass to magnetic, magnetic to true or compass to true.

Uncorrecting - Converting directions from true to magnetic, magnetic to compass or true to compass.

Correcting

It's important to compensate for both kinds of error — variation and deviation — when they are present. Deviation can be minimized by having the compass properly mounted and adjusted. Variation is present almost everywhere in the world, so it is dealt with either by ignoring true directions and using magnetic directions only, or by conversion using simple mathematics.

Deviation must always be corrected mathematically.

The five terms you will use when correcting are, in order:

Compass
Deviation
Magnetic
Variation
True

Compass, Magnetic and True are directions. These are expressed in degrees. Deviation and Variation are compass errors. These are expressed in degrees of error either east or west.

It's important to remember these terms in the correct order. You can use the phrase “Can Dead Men Vote Twice” to help you remember the initial letters. Add “At Elections” to remind yourself to Add Easterly corrections (or subtract westerly directions) for deviation and variation.

Conversion is done by algebraically adding the deviation to the compass direction to get magnetic direction. One would algebraically add the variation to magnetic direction to get true direction. Add all errors that are east and subtract all errors that are west.

For example, suppose you have a compass course of 065° and you want to correct to true degrees. You will have to know the deviation of your ship’s compass at this heading and the variation your compass will have in this geographic location.

You can find the deviation in the deviation table for your vessel.

There is a sample deviation table for a theoretical vessel at the back of this handbook. In it, you’ll see that a compass course of 065° suggests a deviation of either 3° or 4° west. (There is a choice because table entries show that deviation at 060° is 4°, and at 070°deviation is 3°.) A half degree will make little difference in navigation, so we’ll use 3°. For this exercise, suppose variation is 13° east in your location.

C: 065°	C: 065°
D: 3°W	D: - 3°
M:	M: 062°
V: 13°E	V: +13°
T:	T: 075°

First make a little chart with five elements filling in the elements you know.

The deviation is west, therefore you need to subtract it from the compass direction to get magnetic direction. The result is 062° magnetic. Next, convert magnetic direction to true by adding the 13° variation to the magnetic direction. You add the variation because variation in your location is east. The result is 075° True.

The total compass error is the combined error of deviation and variation. You combine the errors by adding algebraically. In our example, 3° W. deviation combined with 13° E variation yields a compass error of 10° E. That added to a compass direction of 065° yields a true direction of 075°

Uncorrecting

If you need to find a compass course and know the true course, you will have to uncorrect to covert true direction to compass direction. You can use the same chart you made for correcting a compass course but work backwards.

If that feels complicated, use a different mnemonic phrase to create a chart to uncorrect. With apologies, here is one that has been used by generations of mariners: Timid Virgins Make Dull Companions, Add Whiskey.

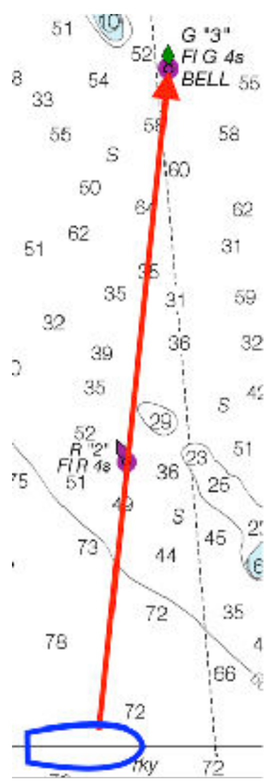
Uncorrecting is the opposite of correcting. Instead of adding east you would add west (and thus subtract east). The first part is easy. Subtract 13° from 075° true and you get 062° magnetic. The deviation is westerly, so you will do the opposite of what you did with the easterly variation, which is to add it — yielding a compass course of 066°.

Checking your ship's compass for deviation

T: 075°	T: 075°
V: 13° E	V: - 13°
M:	M: 062°
D: 4° W	D: + 4°
C:	C: 066°

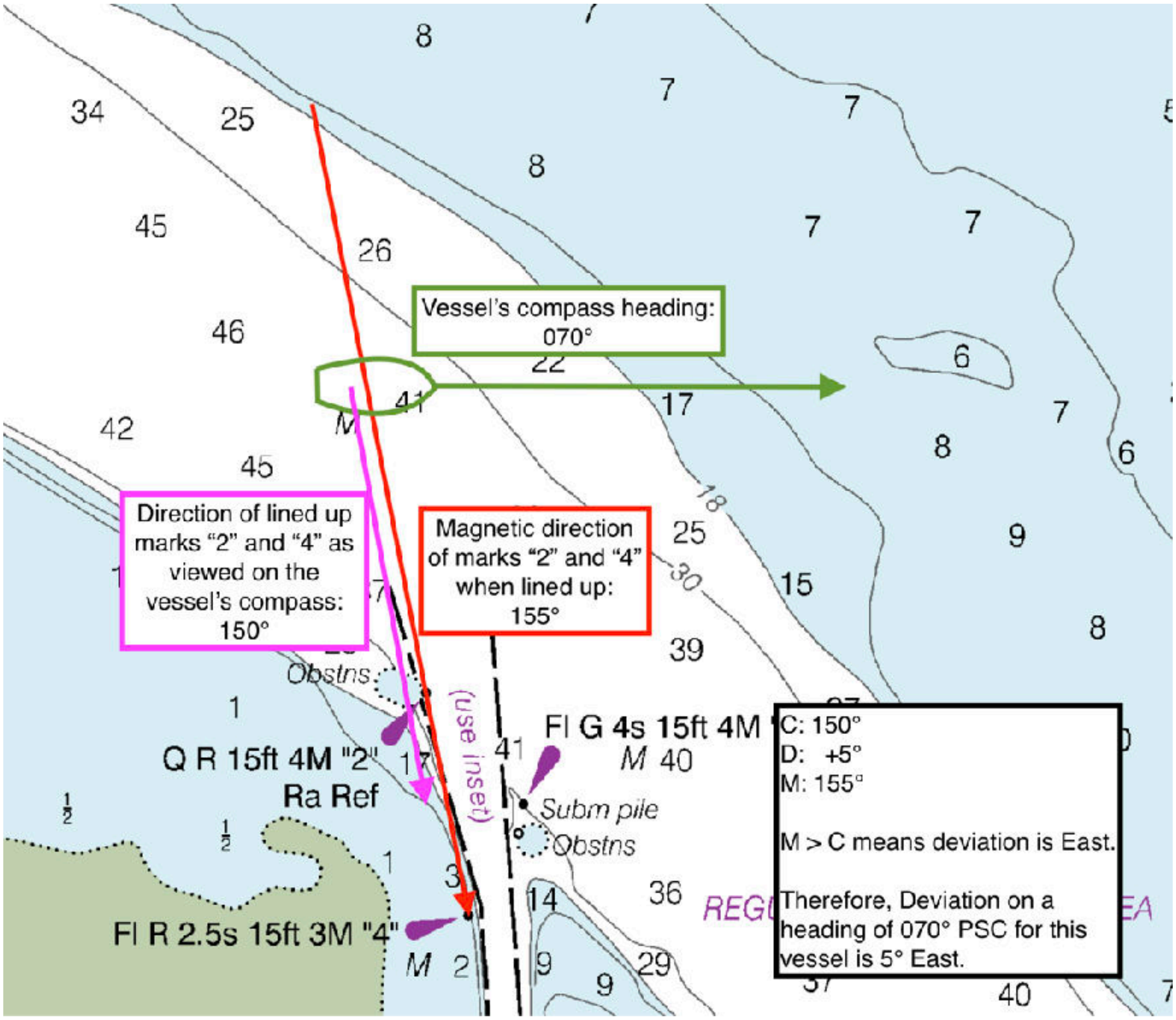
Compass deviation is the difference between the direction shown on the ship's compass and the magnetic direction. To find that difference on any particular boat's heading is just to compare the two. An easy way to do it is sight over the compass in any direction where that direction can be measured on the chart.

The key to making it possible to compare a compass direction with a magnetic direction is to move the boat into a location where you can sight along a transit or a range. A transit forms when an observer can sight along two charted objects such as landmarks or fixed aids to navigation so that the objects line up one directly behind the other. A range is where two beacons are intentionally placed to be viewed one behind the other. These are placed to enable mariners to see if they are in the center of a channel.



The magnetic direction can be measured by plotting a straight line through both objects on the chart. The direction on the chart from the nearer object as viewed from the boat to the farther object is the magnetic direction to use for comparison with the compass direction. The compass direction can be determined by sighting over the compass toward the direction of the transit or range at the moment when the two objects line up one behind the other.

Once the direction to the transit or range is measured in magnetic from the chart and compass by sighting over the compass, the two measurements can be compared using the "Can Dead Men…" mnemonic. The calculated difference is the amount of deviation, and whether the magnetic direction is greater or less than the compass direction determines whether the deviation is east or west. If the magnetic is greater, the deviation is east.



To build a deviation table for a vessel's compass a mariner would need to take multiple bearings of this transit with the vessel on various headings.

In the example illustrated here, the direction from marker "2" to marker "4" in the Redwood Creek channel is 155° magnetic on the chart. The observer on a boat sees 150° looking over the vessel's compass at the two markers as they line up one behind the other. The difference between the two numbers is 5° and the magnetic direction is greater than the compass direction meaning the deviation is 5° East.

In this case, the boat is holding a heading of 070° compass, so the deviation is 5° east at a heading of 070° compass. That compass heading isn't part of the calculation to figure out the deviation. It is only the heading where this deviation reading took place. To create a deviation table, the mariner would take the same sight with boat in these position but on different headings.

Review questions for Lesson 2

While returning from the sea, should you be turning to the right or the left of the buoy to enter the preferred channel?

Note: On older charts the color black was used to indicate green for left-hand channel buoys. Training chart 1210TR has numerous black markers left over from that lateral system.

1. BR C Buoy at L 41° 24.7' N, λ70° 45.9' W
2. RB I Qk Fl R Gong Buoy at Dutch Is. L41° 29.7'N, λ71° 24.3'W
3. GR I Qk Fl G Bell Buoy at L41° 34.1'N, λ70° 52.5'W

Describe the function of the following aids:

4. L41° 24.3'N, λ70° 51.2' W
5. L41°39.4'N, λ70°41.3'
6. L41°39.4'N, λ70°41.1'W
7. L41°26.6'N, λ71°09.5'W
8. L41°23.8'N, λ71°02.0'W

Convert the following compass courses to true courses:
(Use Deviation Table in the appendix and Variation on chart 1210TR)

9. 207° cc
10. 357° cc
11. 137° cc
12. 007° cc
13. 277° cc

Convert the following true courses to compass:

14. 298° True
15. 313° True
16. 118° True
17. While sailing on a compass course of 220°, you see a transit formed by Brenton Reef Light with Beavertail Point Light. At the moment of alignment, you measure the bearing to both lights at 350° per ship's compass (PSC). Determine the deviation at the boat's heading.

Do the following problems for additional practice related to the use of the compass.

1. The Algebraic sum of variation and deviation is known as...
   a. Declination b. Annual Increase or decrease c. Compass error
   d. Diurnal variation

2. The difference between the meridian of true north and the meridian of magnetic north is...
   a. Deviation b. Diurnal variation c. Valuation d. Variation

3. Compass error is the...
   a. Sum of variation and annual increase or decrease
   b. Total difference between true and compass directions
   c. Algebraic sum of variation and deviation
   d. Both b and c are correct

4. You are on course 105° true and your magnetic course is 110°. Variation is... a. 5° west b. 10° c. 5° east. d. Unknown

5. Variation is found by looking...
   a. In Chart 1
   b. In the center of the compass rose
   c. In the Coast Pilot
   d. In the title block of a chart

6. Variation is 11° west, deviation is 11° east, magnetic course is 100°. What is the true course, compass course, and compass error?
   a.111°, 089,° 0° b.089°, 111°, 22°. c.089°, 089°, 0° d.111°, 089°, 22°

7. Which of the following would be correct way to describe compass error in variation or deviation?
   a. 6 degrees b. 6 degrees west c. 6 degrees North d. Six

8. The compass rose on a chart indicates...
   a. True and magnetic direction
   b. Annual change in variation
   c. Variation
   d. All of the above

9. You are navigating straight down a channel on a range that is indicated on the chart as being 050° magnetic. Your heading is 055° PSC. What is the deviation?
   a. 5° b. 330° c. 5° west d. Unknown w/o knowing variation

10. If you are on a course of 210° true and an object bears 120° relative. What is the true bearing to the object?
    a. 090° b. 300° c. 330° d. Can't be calculated

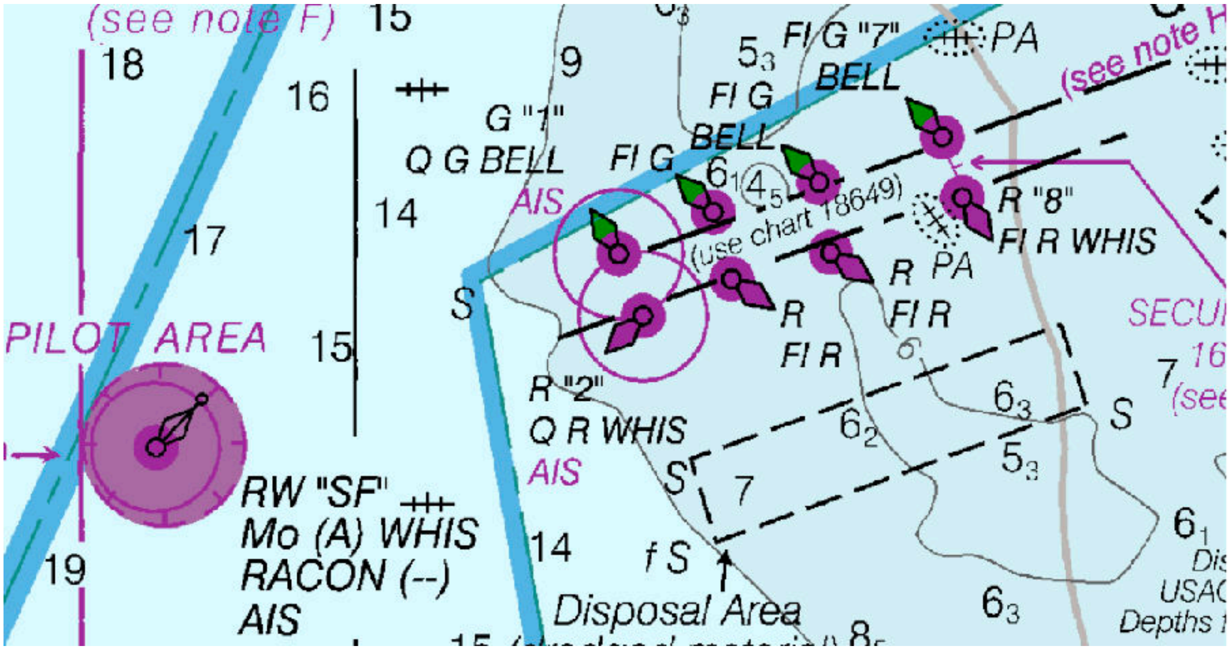
11. If you are on a course of 030° true and a light bears 340° relative, what is the true bearing to the object?
    a. 020° b. 310° c. 030° d. 010°

Answers for Lesson 2 questions

1. Right
2. Left
3. Right
4. Safe Water (Approach) Buoy
5. Left Hand Channel Buoy “3”
6. Right Hand Channel Buoy “4”
7. Junction Buoy (Marking obstruction or isolated danger)
8. Major Light
9. 198° True
10. 337°True
11. 132°True
12. 347°True
13. 256° True
14. 319° cc
15. 333° cc
16. 125° cc
17. Deviation = 5° East

Compass problems:

1.c 2.d 3.d 4.a 5.b 6.c 7.b 8.d 9.c 10.c. 11.d



Lesson 3

Dead reckoning, plotting, speed/distance/time formula

Basically, dead reckoning is the method of navigating by keeping track of courses and distances from known departure points. The expression "dead reckoning" comes from the term deductive reckoning. If you leave a particular place and go a known distance in a certain direction, you can deduce your new location.

I. Plotting and dead reckoning vocabulary

The following terms are used in plotting and dead reckoning:

Course

In dead reckoning, course (C) is simply the direction you are moving through the water. If your reference is the boat's compass, it's a compass course (CC). If you were plotting in magnetic (using the compass rose on your chart as a reference) and figured out a course based on magnetic directions, it would be a magnetic course (CM). If your plot was based on true directions, it would be a true course. If the kind of course is not specified, it is usually assumed to be true but if you are in the habit of using magnetic or compass, it would be a good idea to label true courses as true (T).

Course line

The line you draw on your chart to represent a course is called a course line. You label it True, Magnetic or Compass as suits your needs. Though course lines are drawn straight on the chart, they do not always follow the shortest path from one place to another. A straight line on a Mercator chart actually follows a curved path called a rhumb line.

A rhumb line crossing all meridians at the same angle (courtesy Wikipedia).

A rhumb line is a line that intersects all meridians or lines of longitude at the same angle. If you were to draw one on a globe, it would spiral toward either the north pole or the south pole. (Exceptions: Rhumb lines are straight when heading exactly east, west, north or south. Lines of latitude and longitude are rhumb lines.)

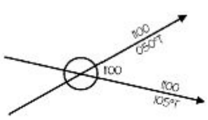
On short courses, the rhumb line doesn't carry you out of the way very much. Its advantage is that when you plot a course, the course line is straight and its direction remains constant.

The most direct route for a long course would be what's called a great circle, which looks curved when drawn on a chart and is difficult to plot. From San Francisco to Hawaii, a rhumb line course and a great circle course are, at most, 90 miles apart. You wouldn't be able to measure the difference in shorter coastal navigation situations.

Course made good

Course made good, or CMG, is the direction the boat has actually traveled. Sometimes this is referred to as the boat's track or TR. It may differ from your plotted course due to current or leeway. Course made good is found by measuring the direction between two fixes.

Fix



A fix (FIX) is an accurate known position at a particular time. Many fixes are found by intersecting two or more lines of position. Another way to establish a fix is to note the time when you pass close to a known aid to navigation.

Speed

Speed, or S, is measured by your vessel's knot meter and only refers to the speed your boat is making through the water. Even though current will affect your arrival time, it is not considered when referring to speed.

Speed made good

Speed made good, or SMG, (also called Speed Over Ground or SOG) refers to your actual progress. It may differ from speed discussed in the previous paragraph due to current or motion of the water. You can determine your speed made good by finding the average speed between two fixes.

Position

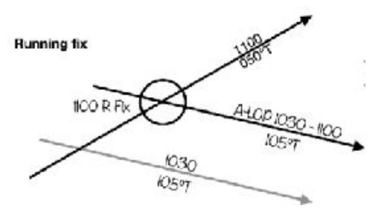
Position is a fancy term for saying where you are at a particular time. It can be an estimated position (EP), a dead reckoning position (DR), or a fix (FIX).

Line of position (LOP)

A line of position is a line that crosses your vessel's assumed position. It can be a straight line such as a bearing from a particular object, a circle such as a distance off a particular object, or a free form line such as a depth contour.

Running fix

A running fix is similar to a regular fix except that it is done when only one LOP can be obtained at a time. It is done by advancing an earlier LOP the distance traveled by the time you create a second LOP. It is not always as accurate as a regular fix, and not as easy to do. But creating a running fix is sometimes necessary when landmarks are few and far between.



Dead reckoning position

Sometimes you can can't get a fix at all and you must get a position by plotting the distance run, the direction and the time since your last fix. If you plot that information on your chart, you can deduce your position.

Heading

Your heading is the direction your boat is facing. It differs from course in that it refers to the direction at a particular moment rather than over a period of time.

ETA, ETD, ATA, ATD, ETE

Abbreviations are used frequently to make record-keeping easier. These abbreviations refer to estimated time of arrival (ETA), estimated time of departure (ETD), actual time of arrival (ATA), actual time of departure (ATD) and estimated time en route (ETE).

II. Plotting

DR plot

Your DR plot is a graphical representation on a chart of a course or series of courses starting from a known position. The plot should be labeled with the speed and direction of each course. It should also be labeled with a fix or DR position for each hour, and with the time and location of each course change. The DR plot is the way you keep track of where you are and where you are going.

DR position

Plotting is essential to coastal navigation. When starting out on a voyage, you will need to draw a course line on a chart from your point of departure to your first destination. If the visibility is poor, you should select a course that will take you to the nearest aid to navigation along the route of travel. By dividing your trip in to a number of shorter legs, you can improve your chances of finding each mark along the way and ultimately get to your final destination without getting lost.

There's more to good navigation than simply following a course. You should also be able to estimate your time of arrival for each segment of the trip. Without an ETA, you can miss a mark without realizing it. In order to deal with time while sailing, you must work with three elements: speed, distance and time. Using a simple formula allows you to find any element if you have the other two.

$$\boxed{60D = ST}$$

"Sixty D Street" speed-time-distance mnemonic.

A mnemonic to simplify working with this formula is "**Sixty D Street.**" The equation 60 x D = S x T, where D is distance in nautical miles, S is speed in knots and T is time in minutes, can be manipulated algebraically to give you any solution you need.

The "60" in Sixty D Street allows you to use minutes instead of fractions or tenths of hours in your calculations.

D = ST/60

… gives you distance in nautical miles.

While underway, you can find your distance traveled since your last fix by multiplying your speed by the time since of your fix and dividing the result 60: Distance in nautical miles = (Speed in knots x Time in minutes)/60

If you mark this distance on your course line, you will have a DR position.

S = 60D/T

… gives you speed in knots.

You can find speed made good between two fixes while under way by multiplying the distance between the fixes by 60 and dividing the result by the time it took to travel that distance. Speed in knots = (Distance in nautical miles x 60)/Time in minutes.

T = 60D/S

… gives you time in minutes

To estimate the time to your next mark while under, way multiply the distance to your next mark by 60 and divide the result by your speed. Time in minutes = (Distance in nautical miles/60)/Speed in knots.

In-class exercise using the time-distance-speed formula: To practice, we'll plot a course using Chart 18651 showing the southern portion of San Francisco Bay. We're going to plot a course from Redwood Creek Channel marker 2 to Coyote Point channel marker 1.

Our Actual Time of Departure (ATD) is 1400.

Assume it's foggy, so you will have to plot and sail from marker to marker. Appropriate markers along the way would be South Bay channel marker 12, marks 11 or 10 at the San Mateo Bridge and mark 8 north of the San Mateo Bridge before reaching the entrance channel to Coyote Point Marina.

To keep things simple, assume there's no current and that your vessel's compass has no deviation — meaning compass and magnetic directions will be the same.

You can use the blank DR Log in back of this handbook for this exercise.

Begin by plotting a course line from marker 2 at the north end of the Redwood Creek Channel to mark 12. The line should be labeled with the time of departure, course and speed. Measure the magnetic course using your parallel rules. It should be about 286°M.

Dead reckoning log

Vessel: Millenium Falcon

From: Redwood Creek

To: Coyote Point

Date: April 1, 2000

Magnetic variation°: 14° East

Leg	Course T°	Course M°	Dist.	ETE	ATE	Speed made good
RWC mark 2 to South Bay mark 12	300°	286°	0.75	9 min.	10 min.	4.5

The first line of your DR log in our exercise might look like this.

The chart shows your magnetic deviation is about 14° east. You don't have a knot meter, so you guess your speed will be about 5 knots.

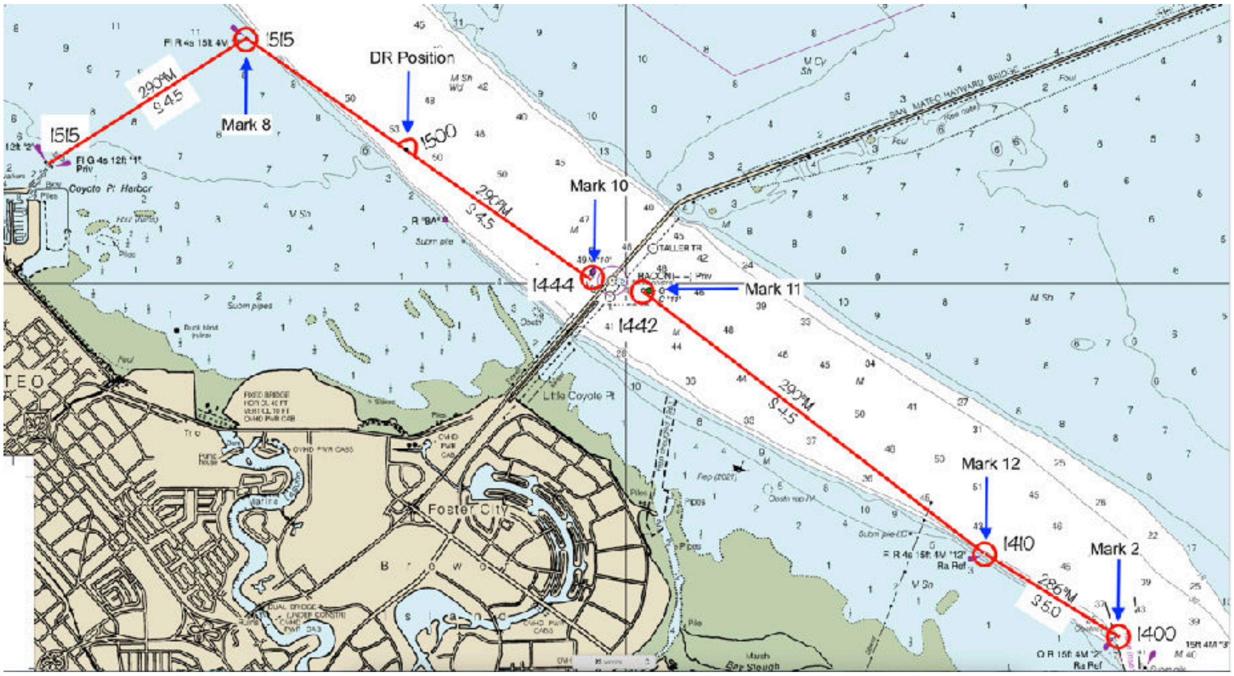
You need to determine an ETA to mark 12. You measure the distance from mark 2 to mark 12 at about .75 nautical miles. Using Sixty D Street, we plug in the numbers:

D = .75 nautical miles and S = 5 knots so the filled-in formula would be:

T = (60 x .75)/5

You do the math and find that T = 9 minutes.

Since you left mark 2 at 1400, your ETA to mark 12 is 1409.



Your plot for our exercise might looks like what's shown in red here.

Suppose you actually arrive at mark 12 at 1410. You can now figure out your speed made good using the Sixty D Street tool.

S = 60D/T

S = (60 x .75)/10

S = 4.5 knots (SMG)

Now you can complete your DR log.

The next step is to plot your course from ark 12 to mark 10. The course is about 290°M and the distance is 2.5 nautical miles. You can find your ETA to mark 10 with your known speed made good from mark 2 to mark 12. Use the same formula to find elapsed time first. You should come up with about 33 minutes, which means your ETA to mark 10 should be 1443.

At 1440 you see a buoy ahead, but it's the wrong one! It's mark 11. No problem… this gives you a chance to plot a fix. As you pass close to mark 11, you note the time is 1442 and you can see mark 10 off your port bow. Plot a fix at mark 11 and head for mark 10, which is visible close by.

There's not much point in plotting between the two buoys because they're so close together. Start a new plot from mark 10 when you get there at 1444.

Your next waypoint is mark 8. You measure a course and calculate an ETA. The course is still 290°M and your ETA should be about 1513. 1500 is a good time to plot a DR position. Use the time since your last fix and your known speed to find the distance. The time since your last fix at mark 10 is 16 minutes and your speed is still 4.5 knots.

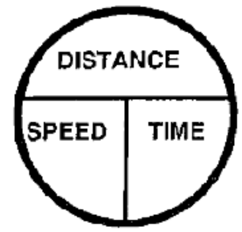
D = ST/60

D = 1.2 nautical miles

You plot your DR position 1.2 nautical miles along the course line from mark 10 to mark 8.

Your ATA at mark 8 is 1515. You now plot your course to Coyote Point channel marker 1. The distance is 1.25 nautical miles and the course is about 220°M.

For people who think visually, another mnemonic for solving the speed-distance-time problem is this wheel. Cover the element you want to find to determine the relationship of the other two elements. The wheel works best for long courses and legs where you can think mainly in hours and tenths of hours rather than in minutes for your time element.



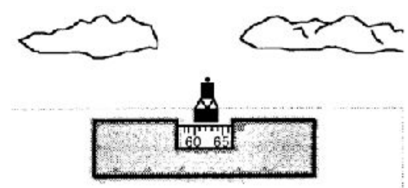
III. Positioning

Lines of position

The line of position, called LOP, is one of the most useful tools in navigation. When an LOP is established, your position must be somewhere along the line. When two or more LOPs intersect, your position becomes fixed at the location of the intersection. LOPs can be obtained in various ways. Among the most commonly used are bearings, distance circles, depth contours and ranges.

Bearings

A bearing is an angular measurement from the boat to another object. When the object's location is known, the bearing becomes an LOP. Almost any kind of object that is charted can be used. Fixed markers, radio towers, prominent buildings and buoys all make good targets for bearings. Even though you can't be 100 percent sure a buoy is on station, buoys are used quite often.

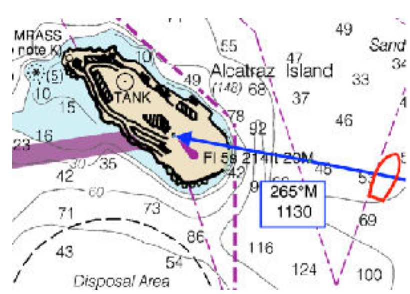


How a buoy might look when viewing it with a hand bearing compass.

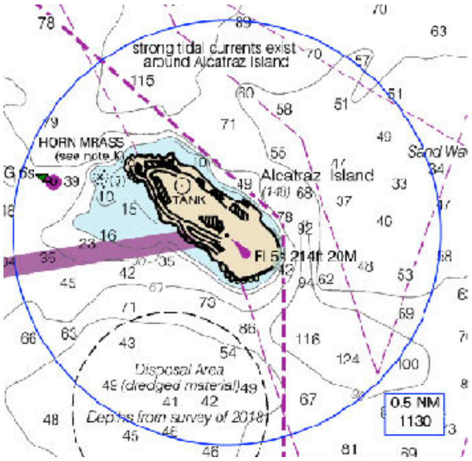
Bearings can be relative, compass, magnetic or true.

On board, bearings taken are either magnetic or relative. Magnetic bearings can be easier to obtain because they can be done in one step with a single instrument — the hand-bearing compass. To obtain a bearing with the hand-bearing compass, all you have to do is hold it in the direction of the object you are sighting and read the bearing off the instrument.

Once a bearing is found, it can be plotted on the chart to make an LOP. Measure the angle on the compass rose with your parallel rules and carefully move the rules over so you can draw a line to the object at the correct angle. When you label the line with the bearing and the time, you have an LOP.



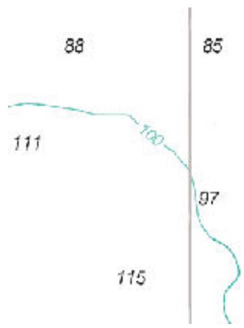
A bearing on Alcatraz light.



A circle of position line 0.5 nautical miles from Alcatraz light.

A relative bearing is the angular measurement to an object from the boat's bow. Straight ahead is 000°, abeam on the starboard side is 090°, astern is 180° etc. In order to get an LOP from a relative bearing, you must combine the relative bearing with the boat's heading. A relative bearing of 142° would combine with a boat heading of say 68° to make a bearing of 210°. The bearing is compass, magnetic or true depending on whether the heading as measured was compass, magnetic or true. This is a rather complicated way of obtaining bearings on a small boat since it requires two simultaneous measurements — the relative bearing (done with a pelorus), and the heading (done with the boat's compass.)

Distance off circle of position



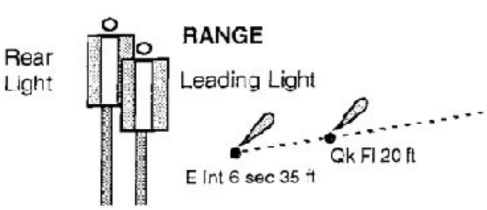
Another kind of LOP the distance off circle of position can be made if you know how far away an object is. The distance circle is made by using the distance from the object as the radius of a circle drawn from the object on the chart. This is an easy way to get an LOP if you have the means to measure distance, such as a range finder, radar or sextant.

Depth Contours

A chart depth contour line showing 100 feet.

A depth contour or fathom curve can become a useful LOP in areas where the depth drops off constantly from the shore. Once you measure the depth and compensate for the height of any tide, you can draw an LOP by connecting the numbers representing that depth on the chart. When sailing along a coast, it's easy to stay on a depth contour line that is already charted by watching your depth finder. Then you can plot fixes as you pass charted objects onshore. On U.S. charts, these depth contours are usually charted in 10-fathom increments depending on the scale of the chart. (A fathom is 6 feet.) You can select the contour line that carries you as far offshore as you want to be.

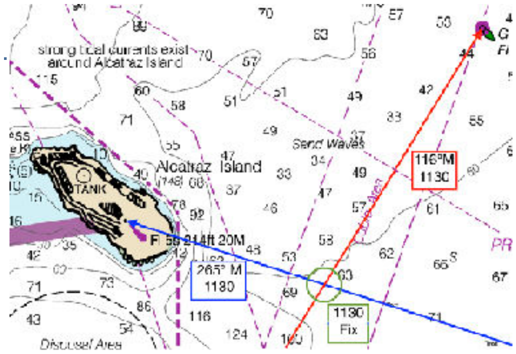
Transit or Range



A range is an LOP that you can get when two fixed objects line up one in front of the other. Any two charted objects will do the job as long as you can see them line up from your position. Some ranges are set up purposely as aids to navigation. These range markers are sometimes set up at the end of a channel so that vessels can be sure when they are in the center of the channel. This is a real help in narrow channels where the edges aren't well defined.

Getting a fix

Anytime you have two simultaneous LOPs that intersect each other, you have an accurate indication of your position. This is called a fix. Where one or both LOPs is curved, there is a possibility of two intersections making an ambiguity. But this is rare and when it happens it's seldom difficult to figure out the correct fix. These are the most important methods of obtaining a fix without electronic equipment.



Cross bearings on Alcatraz light and a navigational buoy yield a fix at 1130.

Cross bearings

The most commonly used method of obtaining a fix is by crossing bearings. All you have to do is take bearings on two different objects within a short span of time. Objects about 90° from each other will yield the most accurate fix. Also, use the time of the bearing most abeam for greater accuracy. The other bearing won't change as much in the time it will take to complete the operation.

Two ranges

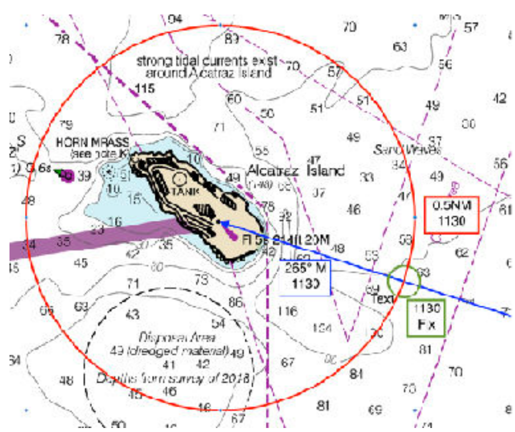
Crossing two ranges will give a very accurate fix but you may not always be able to find two sets of ranges simultaneously. Ranges are good LOPs because you don't need any instruments other than your plotting equipment. And they're very accurate because you don't have to read from any instruments, especially if the boat is in motion, which can make instruments difficult to read.

Range and bearing

If two ranges may be hard to find, a range and bearing is easier. While lined up on a range, you can take a bearing off any convenient object. The intersection of the range and the bearing is the location of your fix.

Bearing or range and distance off

If you know your distance from an object, you can plot a distance off circle of position. Take a bearing or get a range from the same object to get a fix. You can also use a different object than the one at the center of the distance circle, but this may result in a double fix and you will have to figure out which is the right one.



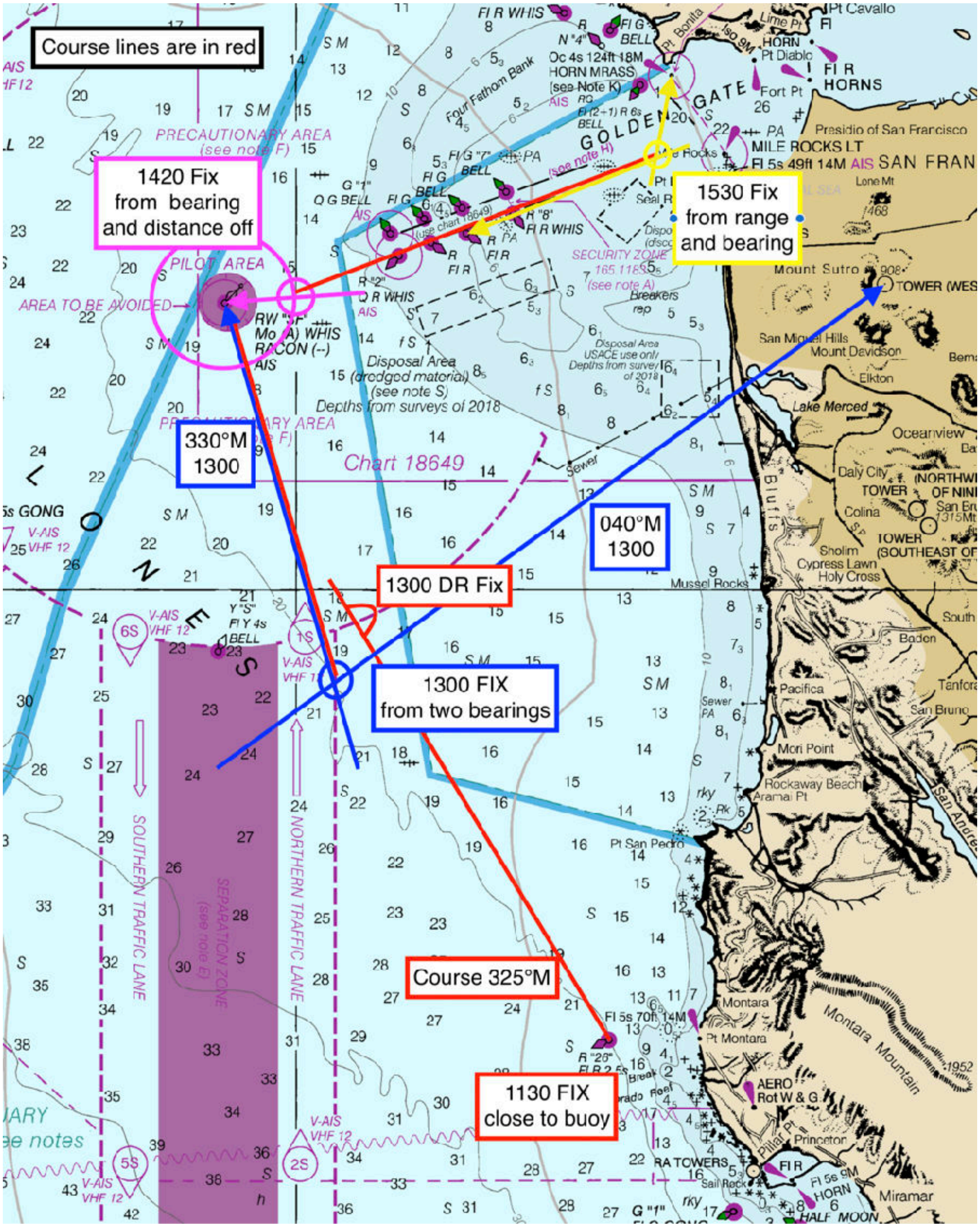
A fix from a bearing and a distance off from Alcatraz light.

A fix using a bearing on the Casino dome at Santa Cruz, California, and the chart’s 20 fathom depth contour.

Sounding and Range or Bearing

Soundings are used frequently when sailing along a coast. In many areas, the depth contours are fairly straight and give long LOPs parallel to the shore. As you pass a landmark that is charted, you can get a second LOP to cross with your depth contour for an easy fix.

Whenever you obtain a fix, you should include it in your plot. You can draw it as a dot or a cross within a small circle. It should also be labeled with the time and “FIX." You will often find that your fix doesn't line up exactly on your course line. When this happens, end your course line with a DR at the time of the fix. Then start a new course line at the fix.



Sample plot using fixes of different kinds.

Review questions for Lesson 3

1. How far is it, and how long will it take to sail from the BW "A" buoy at L 41° 26.0'N, λ71° 16.9 W to Brenton Reef Light at a speed of 6 knots?
2. How far is it, and how long will it take to sail from Brenton Reef Light to the R "2" Whistle Buoy off Pt. Judith at a speed of 4.5 knots?
3. Leaving R "2" Whistle Buoy at 1000 at 5 knots on a course of 240° magnetic, how far will you get in 15 minutes?
4. Continuing from problem 3, what will your position be at 1050? What do you call this kind of position?
5. Leaving R"2" Whistle buoy at 1000 and arriving at the G "1B1" bell buoy at 1100, what is your speed made good (SMG) and distance traveled?

Plot a course leaving R "2" Whistle buoy off Pt. Judith at 1200 to the BW "SR" Approach buoy for the Sakonet River via the W Or "D" bell buoy and the BW "A" buoy.

6. Going at 4 knots, what is your course in true° and magnetic°, and what is your ETA to "D"?
7. You arrive at "D" at 1300. What is your SMG and distance traveled?
8. Continuing from "D" to the BW "A" buoy at 4 knots plot a DR for 1400. How far is it from "D"?
9. What is the distance and your ETA to BW "A"?
10. Leaving BW "A" at 1440 at 4.0 knots, what is your course in true° and magnetic°, and ETA to BW "SR"?
11. At 1200, you get the following hand bearings: 319° to the BW "A" buoy and 052° to the BW "SR" buoy. What are the coordinates of your 1200 fix?
12. At the moment you see a transit formed by the W Or "H" bell buoy lining up with Brenton Reef Light, you get a hand bearing of 138° to the W Or "G" bell buoy. What are the coordinates of your fix?

At 1.2 nautical miles from the Pt. Judith Light, you get a bearing of 336° (magnetic of course) to it.

13. What are your coordinates?
14. What are the coordinates when you have a bearing of 105° to the BW "SR" whistle buoy and a bearing of 026° to the eastern edge of the Sachuest portion of Aquidneck Island?
15. You get three bearings at the same time: 099° to Brenton Reef Light, 148° to the W Or "H" Bell buoy, and 232° to Point Judith Light. What is your position?

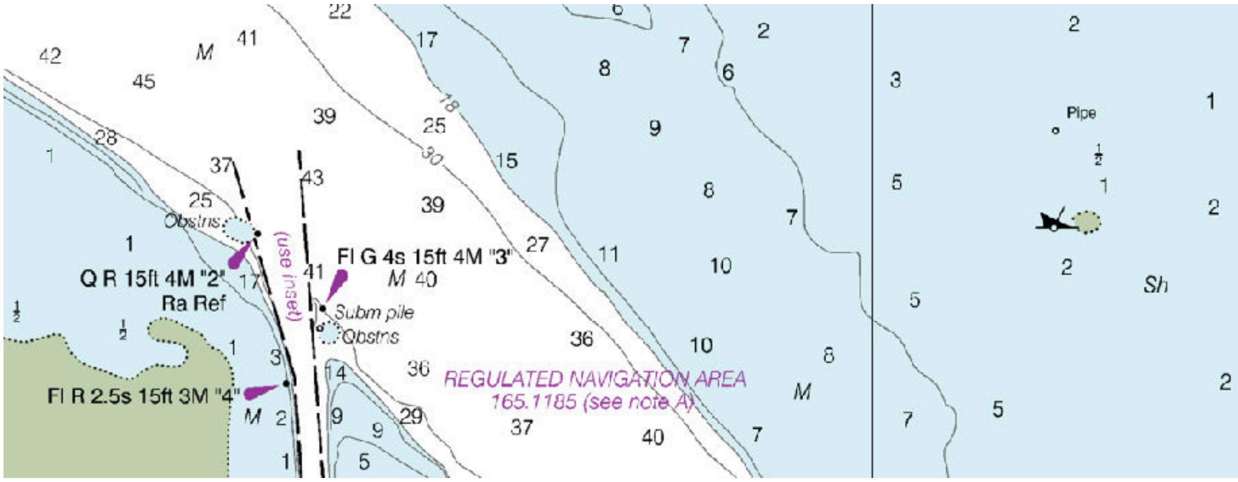
Plot a course from the "SR" approach buoy at 0900 back to the R "2" Whistle buoy off Pt. Judith via the BW "A" buoy and the W Or "H" Bell buoy.

16. At 5 knots, what is the course in true° and magnetic°, and ETA to BW "A"?

17. Leave BW “A” at 0930 for the W Or “H” buoy. At 1000, you get the following hand bearings: To Brenton Reef Light: 294°; To the R”2” Fl R 4 sec whistle buoy: 013°. What are your coordinates?
18. Plot a new course from your fix to the W Or “H” bell buoy. What is the course in true°, magnetic° and compass°? (Use the sample deviation table in the appendix)
19. Leaving the W Or “H” Bell Buoy at 1030, what is your course in true°, magnetic° and compass°, and ETA to the R “2” Whistle buoy off Pt. Judith?

Answers for Lesson 3 questions

1. 48 minutes 4.8 nautical miles
2. 1 hour 31 minutes 6.8 nautical miles
3. 1.25 nautical miles
4. L 41° 17.1’N, λ71° 32.4’ W; Dead Reckoning
5. 6.4 knots 6.4 nautical miles
6. 066°T 081°M 1255
7. 3.7 knots 3.7 nautical miles
8. 4 nautical miles
9. 7.0 nautical miles 1445
10. 080°T 095°M 1519
11. L 41° 25.0’ N λ 71° 15.0’ W
12. L 41° 24.0’ N, λ71° 24.5’ W
13. L 41° 20.7’ N, λ 71° 27.9 W
14. L 41° 26.5’ N, λ71° 14.9’ W
15. L 41° 25.5’ N, λ71° 25.0’ W
16. 259°T, 274° Mag, 0931
17. L 41° 25.4’N, λ71° 21.7’W
18. 247°T, 262° Mag, 267° Compass
19. 216°T, 231° Mag, 229° Compass, 1140



Lesson 4

The running fix

Sometimes only one object is available for a bearing. Using the techniques already covered, all you would be able to do is get a single LOP. But in fact, fixes can be obtained from single objects if you are moving and can take bearings at different times. The information from the two bearings can be correlated to produce what's known as a running fix.

Since the correlation is based on the distance and direction traveled between the two bearings, its accuracy depends on the accuracy of your speed instrument and your steering. Therefore, running fixes are usually considered not as good as regular fixes. Nevertheless, they can be more accurate than any other technique when only one object is available for a bearing.

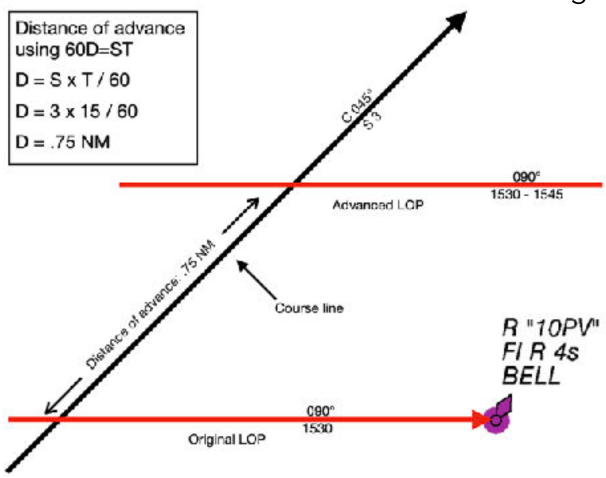
Advancing an LOP

The key to making a running fix is advancing the LOP. The advanced LOP is the original LOP replotted at a later point in time. The advanced LOP is always parallel to the original. Its distance from the original is determined by the distance covered by the boat between the time of the original bearing, and the time of second bearing.

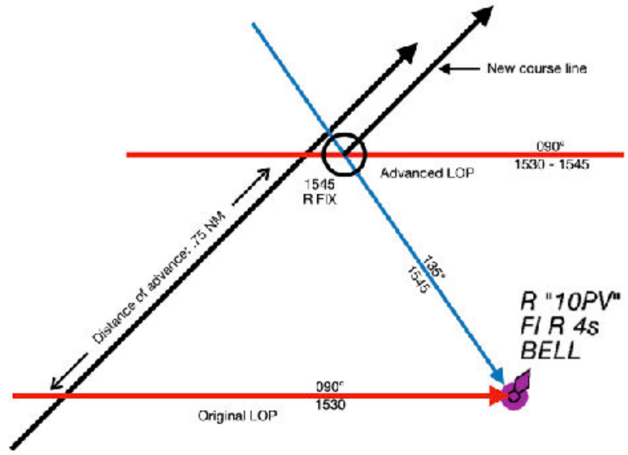
In the example shown below, an LOP is advanced .75 miles on a course 045°. The distance was found by calculating the distance covered in 15 minutes at a speed of 3 knots. The distance of advance is up to the navigator but it must be consistent with the time of advance and the speed of the boat.

Note: The original and advanced LOP's are parallel. The distance is measured along the course line — not the shortest distance between the two LOP's.

Advancing a line of position



Take a bearing on an object and note the time. After continuing on your course, draw an advanced LOP parallel to the original LOP the appropriate distance along the course line.



Take a new bearing at the time of your advanced LOP. Your running fix is where the LOP of this new bearing crosses the advanced LOP of your original bearing.

Obtaining a Fix

Once you know how to advance an LOP, you can establish a fix using the advanced LOP and a new bearing on the original (or another) object. The junction of the advanced LOP and the new bearing is your running fix. Start a new course line to your destination from there.

WARNING: Don't fall into the trap of calling the intersection of either the first or second bearing and your course line a fix. Odds are that the running fix will not lie exactly on your course line.

You can make your advanced LOP as far as you want from the original. It should be far enough that the second bearing will cross the advanced LOP at a reasonable angle and not so far as to lose sight of the object. In fact, most of the time you'll take the second bearing whenever it looks good and advance the LOP afterwards.

Details from the example above: Sailing on a course of 045° at 3 knots, you get a bearing at 1130 of 090° on the R "10PV" bell buoy. You plot the bearing to this buoy on your chart. Fifteen minutes later, you take a new bearing of the same buoy. This time it bears 135°. You plot that, and also advance your original LOP by .75 nautical miles (the distance you traveled in 15 minutes) along your course line. Your running fix is where the new bearing's LOP crosses the advanced LOP.

Bow and beam bearings

Taking bow and beam bearings is an interesting type of running fix. Under the right circumstances, this technique will allow you to make a running fix without having to plot the whole problem on a chart — it's possible to do the entire thing in your head.

If you recall taking geometry in high school this method may seem familiar.

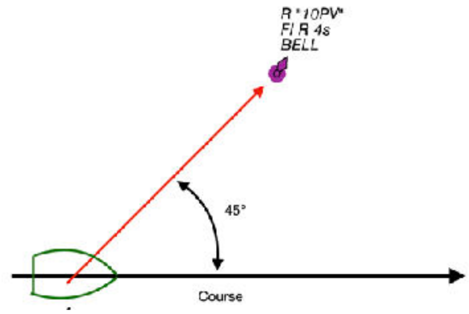
There are three steps to do bow and beam bearings. Step 1: Note the time when a landmark appears 45° off the bow of your boat. Step 2: Note the time when the same object is on the beam, or 90° off the bow. Step 3: Calculate the distance you traveled between the the two sightings. You can use the Sixty D Street formula for this.

Your distance traveled is equal to your distance off the mark.

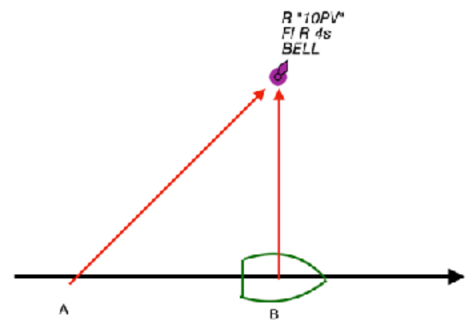
On your chart, one line of position goes through the object you sighted and crosses your course line at 90°. Your other LOP is the distance from the object that you calculated in Step 3 above. Your running fix is where those two LOPs cross.

The relative bearing of 90° can be converted to a compass bearing by subtracting 90° from your ship's heading if it is on the port or adding 90° if the targeted object is on the starboard.

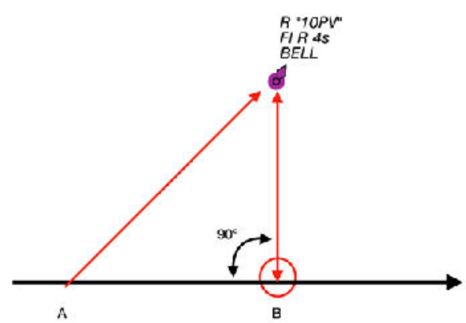
Example: Find the distance between the bow and beam bearings using Sixty D Street speed-distance-time formula and apply the result as the distance away from the mark. The direction to the mark is 90° from your heading at the time of the beam bearing. Convert that relative bearing to a compass or true bearing and you can plot your fix. Draw the bearing to the mark on your chart. Plot an LOP on the bearing line the distance you calculated away from the mark. That's your fix.



Step 1: Take a bearing of an object 45° off the bow note the time. Call this point A.



Step 2: Note the time when the same object is abeam (90° off the bow).



Step 3: Calculate the distance run been point A and point B. That's your distance from the object. With the bearing to it and the distance from it you can plot a fix.

Review questions for Lesson 4

1. Sailing past Block Island from approximately 41° 10' N and λ71° 24.5' W at 4.0 knots on a course of 310° True you get a hand bearing (Magnetic) of 275° to Block Island Southeast Light (Fl G 3.7 sec). 45 minutes later the light bears 245°. How far must you advance your first LOP?

What is your position at the time of the second bearing?

2. Plot a course from the W Or "A" Fl 4sec BELL buoy to the Brenton Rf Light. ATD is 1000. Speed is 4 knots. At 1040 you get a bearing of 297° to Pt. Judith Light. At 1100 you get a bearing of 280° to the same light. How far will you have to advance your 1040 bearing to get an 1100 running fix?

What is your position at the time of the second bearing?

3. Set a course from Pt. Judith R "2" buoy to the BW "SR" Whistle buoy. Speed is 4.0 knots. At 1200 you get a hand bearing of 015° to Brenton Reef light. At 1240 you get a bearing of 330° to the same.

What is your position at the time of the second bearing?

4. Plot a course from a point 0.5 Miles south of Brenton Reef Light to R"2" 10 sec Whistle Buoy. ATD is 1000 and the speed is 4.5 knots.

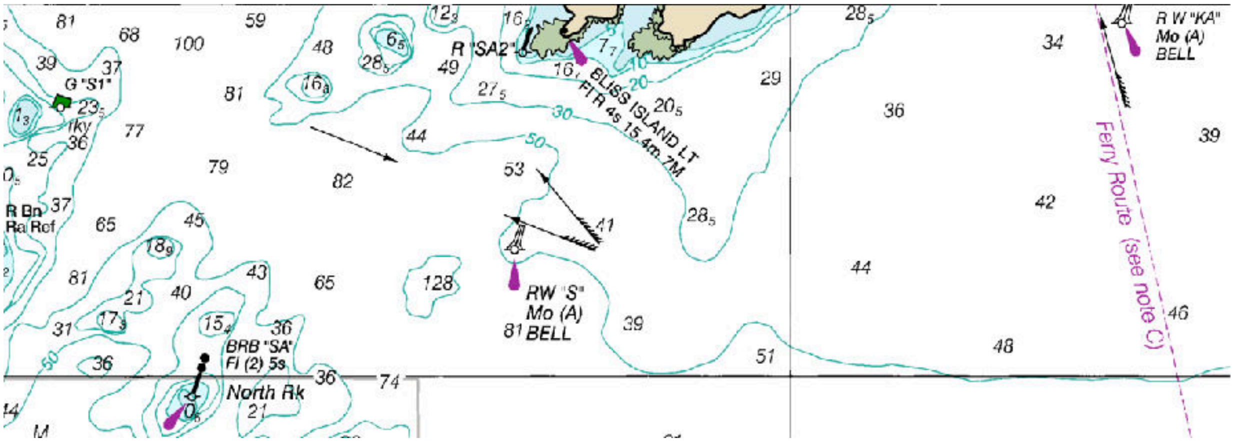
What does Gp Fl (2) 10 sec 87 ft 25M mean? What is your True Course?
What is your Magnetic Course?
What is your Compass Course?
What are the coordinates of your 1030 DR?

5. At 1100 Point Judith Light Bears 283°. At 1120 it bears 320°. (continued from problem #4) What is your 1120 position?

What is your SMG (Speed Made Good)?
What is your new magnetic course to R "2"?
What is your new compass course to R "2"?

Answers for Lesson 4 questions

1. 3.0 Miles L 41° 12.0' N λ71° 28.6' W
2. 1.33 Miles L 41° 22.1' N λ71° 22.8' W
3. L 41° 23.3 N λ 71° 20.3' W
4. Group Flashing (group of 2 flashes) every 10 seconds 87 feet high visible for 25 Miles.
   218° 233° 231° L 41° 23.3' N λ71° 25.2' W
5. L 41° 20.6' N λ71° 26.8' W 3.9 knots 261° Mag 265° Compass



Lesson 5

Current sailing and leeway

I. Current sailing vocabulary

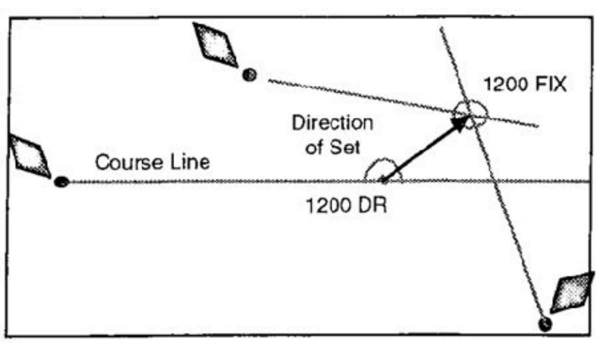
Up to now, we have been dealing with navigational problems as though no current or leeway exists. In fact, these factors can have a major effect on your progress from one place to another and must be dealt with when they exist. Here are the most important terms in current sailing:

Estimated Current — This is the sum of the current effects expected during a passage. This information can be obtained from NOAA Tide and Current Tables Current Charts or from various electronic applications.

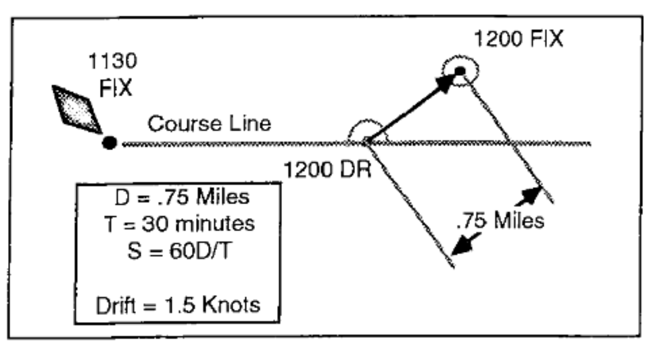
Actual Current — This is the current that you measure by the displacement of your boat's location from your expected track. This measurement is the sum of all current effects including leeway.

Set — The direction the current is flowing expressed in degrees.

Drift — The speed of the current in knots.

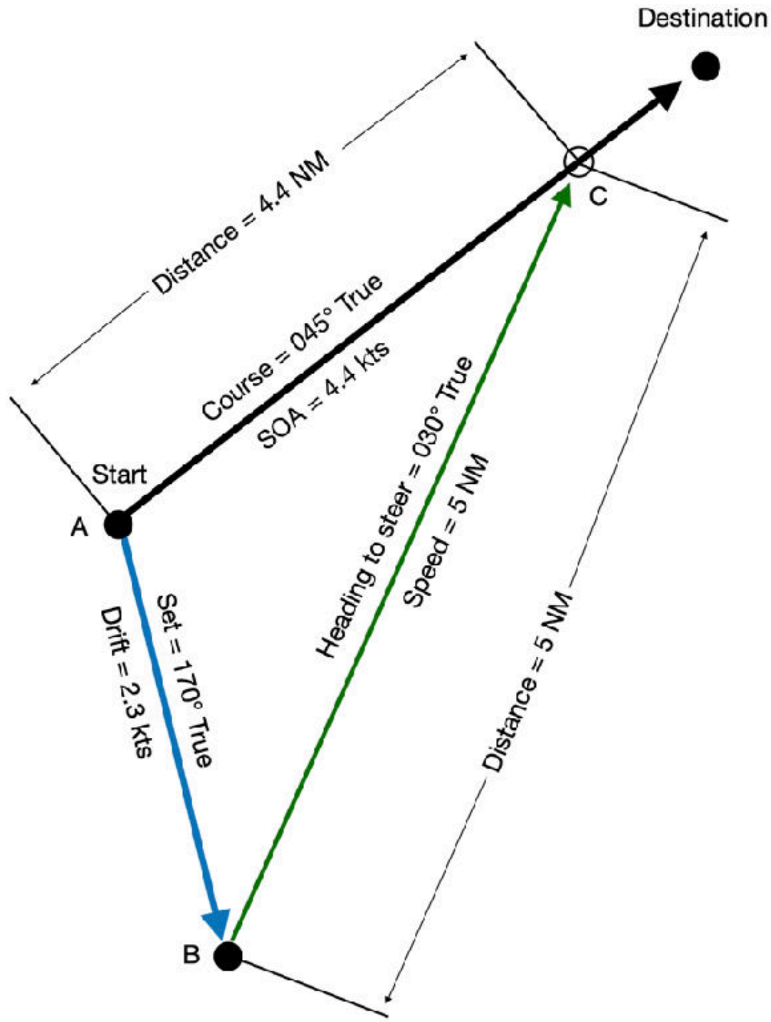


Set is the direction of water movement.



Drift is the speed of water flow.

Leeway — The leeward motion of the boat through the water caused by wind and/or waves. Even though it is not caused by the current flow of water, it is treated as a component of the current since it affects the boat's course made good in the same way as current.



Course — This is the anticipated path of the boat relative to the earth. The intended track is found by compensating your course for the current and will closely resemble the course made good if your compensation is accurate. This is sometimes referred to as intended track, or ITR.

Course made good (CMG) — The straight line from one fix to the next. The actual path of your vessel is ignored for CMG measurements.

Heading — The direction the boat must be steered while current sailing. Texts using "ITR" may use the expression "course to steer" when referring to heading.

Speed — Your vessel's speed through the water as measured by your knot meter. The effects of current are ignored when measuring speed.

Speed of advance (SOA) — The is the anticipated speed of your boat over the the bottom after compensating for current.

Speed made good (SMG) — This is the actual calculated speed of your vessel from one fix to the next. Only the distance between the two fixes and the elapsed time in transit are considered.

II. Current

In any situation where you take a fix and find it different from your DR position, you are seeing the results of actual current. In order to employ this information, you need to measure the direction and speed of that actual current.

First measure the set as the direction from your DR to your fix. In traditional piloting this is done in true degrees.

Then measure the speed of the current. If it has been exactly one hour since your last fix, the distance between the your DR position and the new fix will be your drift. If the time since your previous fix is not exactly one hour, you'll have to calculate the speed of the current based on the distance between the fix and the DR position and the time since the previous fix. (Use the Sixty D Street formula: Speed = Distance x 60 / Time.)

Once you have determined the set and drift, you can compensate for the effect of the current and compute a heading that will take you to your next destination by the most efficient route. The results of this computation will also give you speed of advance so you can calculate an accurate ETA as well.

Compensating for a known current

1. Plot a course line from your starting location, A, to your destination.

2. Plot a Set and Drift line from your starting location, A, indicating the direction of the set and the distance of the drift over one hour. In this example, the set and drift line is plotted on a bearing of 170° True for a distance of 2.3 miles ending at B.

3. Span your dividers to represent the distance you will cover through the water in one hour (your speed through the water in knots). With one point at B, rotate the dividers until the other point touches the course line. Call this location C.

4. Using parallel rules, measure the bearing of the line from B to C to find the heading you'll need to steer your boat on.

5. Measure the distance from A to C. Do the math using Sixty D Street to find your speed of your advance.

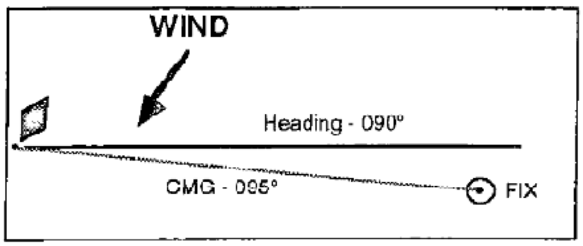
Do not confuse Point C with your destination! C can be located along the course line before your destination, or after it. If it is located after your destination, simply extend your course line long enough for point C to be on it. Assuming the set and drift are constant, the heading will carry you along the course line any distance and the speed of advance will stay constant.

III. Leeway

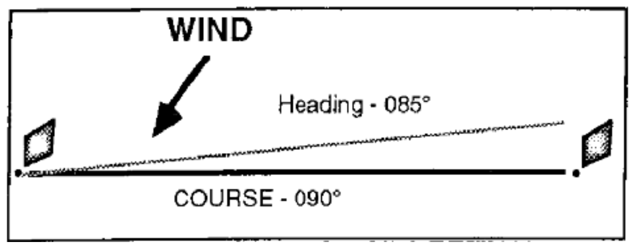
Although leeway affects your progress in the same way current does, it is handled in a simpler way. Leeway is measured in degrees from your course rather than as set and drift. Sailboats experience the most leeway when sailing close hauled. Motorboats can also experience leeway. A mariner develops an idea of his or her vessel's leeway through experience.

To correct for leeway, plot a course from where you are to your destination and adjust your heading to windward by the amount of leeway you expect to experience.

For example, let's say your know your sailboat has about 5° of leeway when sailing on a close reach. You should steer 5° to windward of your destination when on that point of sail. Bear in mind a sailboat can't sail efficiently above close hauled.



Leeway is the direction a vessel is pushed to leeward from its intended course by wind and waves.



To compensate for leeway, turn your vessel to windward by the amount of leeway.

Review questions for Lesson 5

1. Plot a course from the W Or “D” Bell buoy to R “2A” (Near Brenton Reef) Bell buoy leaving at 1400 at a speed of 5 knots.

   At 1448, you get the following bearings:
   277° to W Or “H” fl 2 sec Bell buoy
   338° to Brenton Reef Light
   041° to R”2” Fl R 4 sec Whistle buoy

   What is your set? What is your drift?

2. Plot a course from 1 mile east of Pt. Judith Light to the R “2” Bell buoy off Sakonnet Pt. (East of the BW “SR” Whistle buoy)
   ATD is 0930. Speed is 4.6 knots.

   At 1145 you get the following bearings:
   105° to the BW “SR” Whistle buoy;
   026° to the eastern edge of Sachuest portion of Quidneck Island;
   064° to the R “2A” Bell buoy west of Sakonnet Pt.

   What is your set? What is your drift?

3. Plot a course from R “2” 10-sec whistle buoy off Point Judith to the W Or “A” Fl 4 sec bell buoy, allowing for a set of 240° (True) and a drift of 1.2 knots. Your speed is 4 knots and your ATD is 1200.

   What is your course (track)?
   What is your heading in true° mag° and compass°?
   What is your SOA (Speed of Advance)?
   What is your ETA to W Or “A”?

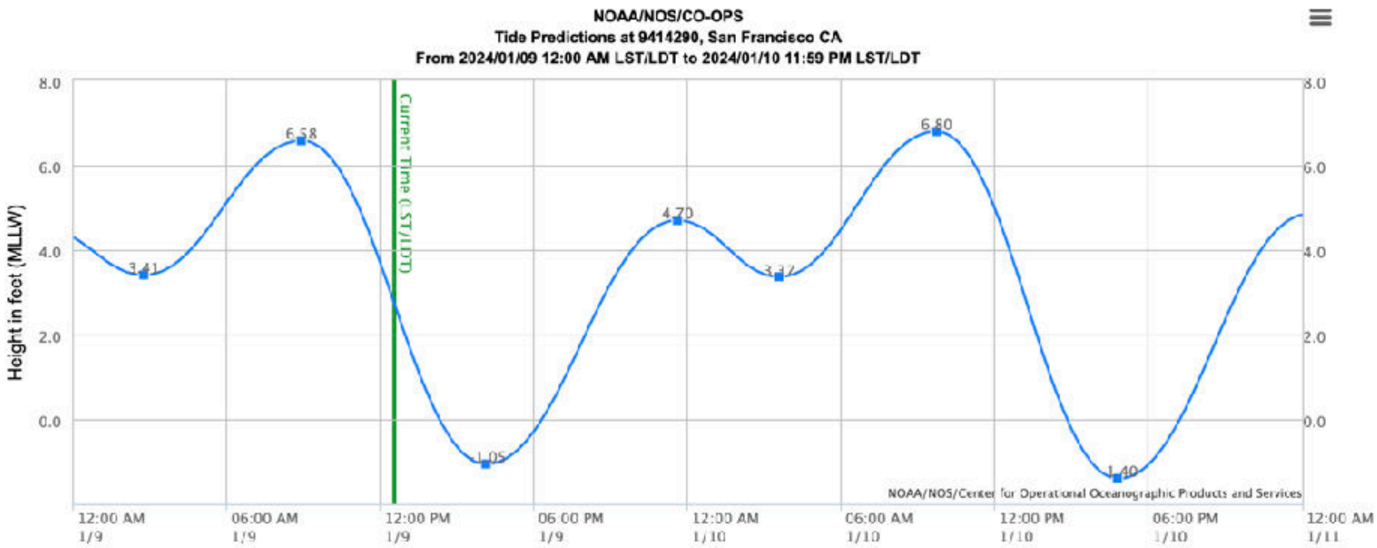
4. Plot a course from a position L 41° 20.0’N, λ71° 20.0’ W through a point 1.5 miles east of the R “2” Bell buoy off Sakonnet Point. Boat speed is 5.5 knots. Allow for a set of 110° and a drift of 2.7 knots.

   What is your heading in true° mag° and compass°?
   What is your SOA?

5. Motoring from R “2” off Pt. Judith to G “1B1” in a strong west wind, you get a fix at L 41° 17.0’ N, λ71° 32.0’ W.
   What is the original course?
   What is your CMG (Course Made Good)?
   What is your leeway?
   What is the new course to “1B1”?
   What is the new heading to “1B1”?

Answers for Lesson 5 questions

1. 259°, 1 knot
2. 353°, 0.45 knots
3. 135° (150° Mag),119 °true, 133° Mag, 125° Compass, 3.5 knots, 1322
4. 025° True, 040° Mag, 044° Compass, 6.4 knots
5. Course: 225°, CMG: 221°, LeewayL 4°, New course: 231°, Heading: 235°



Lesson 6

Tides and currents, danger bearings

Tides and currents can be a significant factor in boating, especially in estuaries like San Francisco Bay. Much of the bay is shallow, so if you stray into the wrong area at the wrong time, you can find yourself stranded for hours. Currents in parts of the bay can be as strong as 6 knots, faster than some sailboats can go at full speed.

I. Tide and current vocabulary

Tide — The height of the water compared with charted datum (reference depth).

High tide (high water) — The highest level reached by a rising tide.

Low tide (low water) — The lowest level reached by a falling tide.

Range — The vertical difference between high and low tides.

Mean high water — The average high tide of all high tides over a period. Vertical distances such as bridge clearances will be stated in reference to mean high water.

Mean low water — The average of all low tides over a period. Mean low water is used as the chart datum in places where the two daily low tides are about the same.

Mean lower low water (MLLW) — The average of the lower of the two low daily tides. This measurement is used where there is a mixed tide, with two low tides of unequal heights each day, such on the West Coast of North America. Datum on U.S. charts in such regions is mean lower low water.

Minus tide — Occurs when the tide falls below the chart datum.

Current — The horizontal movement of water expressed in knots.

Ebb — Tidal current flowing from inland towards the sea.

Flood — Tidal current flowing from the sea toward inland areas.

Slack water — The time of minimum current flowing in or out. The water isn't really slack, or motionless. It's called that when the amount of water flowing out is about the same as the amount flowing in.

II. Using tide and current tables

Tide and current information may be obtained form official government publications published by NOAA, in unofficial booklets that are often free from places like Spinnaker Sailing, and from electronic tide and current applications.

NOTE: Traditionally, official NOAA tables have listed all events in standard time. During daylight savings time, the navigator must convert time by adding an hour to all times listed in official tide and current tables. Unofficial publications and applications typically use daylight savings time when it is in effect. Care should be taken that you don't confuse standard time for daylight time when using any tide or current tables. Typically, examinations by the Coast Guard, and American Sailing, require aspiring navigators to make this time conversion when calculating times of tides and currents.

In printed publications, tide and current information is based on tide and current events as they are happening at a reference location. In San Francisco Bay, one reference location is the Golden Gate. The tide differs in other locations in both the height of the water and the times of high and low tides. Current differs in the speed of the current, and the times of maximum flood, maximum ebb and slack or minimum tidal current.

StationId: 9414290
Source: NOAA/NOS/CO-OPS
Station Type: Primary
Time Zone: LST
Datum: MLLW

NOAA Tide Predictions

San Francisco, CA,2024
(37 48.4N / 122 28.0W)
Times and Heights of High and Low Waters

April

	Time	Height			Time	Height	
	h m	ft	cm		h m	ft	cm
1	03:15	5.2	158	16	05:05	4.7	143
	10:45	0.0	0		12:24	0.1	3
M	19:05	3.9	119	Tu	19:58	4.6	140
	22:33	3.5	107				
2	04:29	5.2	158	17	01:03	2.7	82
	11:58	-0.2	-6		06:21	4.5	137
Tu	19:56	4.2	128	W	13:19	0.2	6
◑					20:35	4.7	143
3	00:10	3.3	101	18	01:56	2.2	67
	05:50	5.2	158		07:29	4.5	137
W	13:02	-0.4	-12	Th	14:04	0.4	12
	20:33	4.5	137		21:05	4.9	149

May

	Time	Height			Time	Height	
	h m	ft	cm		h m	ft	cm
1	04:09	4.9	149	16	00:32	2.5	76
	11:20	-0.4	-12		05:38	4.0	122
W	19:02	4.5	137	Th	12:17	0.6	18
◑					19:34	4.9	149
2	00:04	2.8	85	17	01:27	1.9	58
	05:32	4.8	146		06:54	3.8	116
Th	12:19	-0.3	-9	F	13:02	0.9	27
	19:40	4.9	149		20:02	5.0	152
3	01:10	2.0	61	18	02:13	1.4	43
	06:53	4.7	143		08:04	3.8	116
F	13:12	-0.1	-3	Sa	13:41	1.2	37
	20:15	5.3	162		20:28	5.3	162

June

	Time	Height			Time	Height	
	h m	ft	cm		h m	ft	cm
1	00:57	1.4	43	16	01:38	1.2	37
	06:48	4.1	125		07:43	3.5	107
Sa	12:28	0.8	24	Su	12:37	2.0	61
	19:25	5.9	180		19:23	5.6	171
2	01:54	0.5	15	17	02:21	0.7	21
	08:12	4.1	125		08:59	3.6	110
Su	13:19	1.3	40	M	13:22	2.5	76
	20:03	6.3	192		19:54	5.8	177
3	02:46	-0.3	-9	18	03:00	0.2	6
	09:27	4.2	128		10:02	3.9	119
M	14:08	1.9	58	Tu	14:06	2.8	85
	20:42	6.6	201		20:28	6.0	183

NOAA tide table excerpt for the Golden Gate.

Newport, Rhode Island, 2011

Times and Heights of High and Low Waters

April								May								June							
	Time	Height			Time	Height			Time	Height			Time	Height			Time	Height			Time	Height	
	h m	ft	cm		h m	ft	cm		h m	ft	cm		h m	ft	cm		h m	ft	cm		h m	ft	cm
1	0623	3.3	101	16	0551	4.0	122	1	0626	3.2	98	16	0001	−0.4	−12	1	0055	0.2	6	16	0132	−0.2	−6
F	1143	0.1	3	Sa	1130	−0.5	−15	Su	1139	0.1	3	M	0622	4.0	122	W	0710	3.3	101	Th	0747	3.9	119
	1835	3.7	113		1817	4.8	146		1837	3.9	119		1146	−0.5	−15		1226	0.1	3		1304	−0.1	−3
													1849	5.0	152	●	1920	4.0	122		2012	4.6	140
2	0024	0.0	0	17	0015	−0.7	−21	2	0036	0.1	3	17	0054	−0.5	−15	2	0137	0.1	3	17	0216	−0.1	−3
Sa	0659	3.3	101	Su	0642	4.2	128	M	0701	3.3	101	Tu	0713	4.0	122	Th	0751	3.4	104	F	0836	3.9	119
	1217	0.0	0		1216	−0.7	−21		1217	0.0	0		1235	−0.5	−15		1308	0.1	3		1354	0.0	0
	1909	3.8	116	○	1907	5.1	155		1911	3.9	119	○	1939	5.0	152		2000	4.1	125		2101	4.4	134

TABLE 2 – TIDAL DIFFERENCES AND OTHER CONSTANTS

No.	PLACE	POSITION		DIFFERENCES				RANGES		Mean Tide Level
				Time		Height				
		Latitude	Longitude	High Water	Low Water	High Water	Low Water	Mean	Spring	
		North	West	h m	h m	ft	ft	ft	ft	ft
	MASSACHUSETTS Martha's Vineyard Time meridian, 75° W			on Newport, p.52						
933	Wasque Point, Chappaquiddick Island	41° 21.8'	70° 27.0'	+2 02	+3 20	*0.31	*0.31	1.1	1.4	0.6
935	Squibnocket Point	41° 18.7'	70° 46.1'	−0 45	−0 02	*0.82	*0.82	2.9	3.7	1.6
937	Nomans Land	41° 15.7'	70° 49.0'	−0 19	+0 18	*0.85	*0.85	3.0	3.6	1.6
939	Gay Head	41° 21.2'	70° 49.8'	−0 06	+0 45	*0.82	*0.82	2.9	3.5	1.5
941	Cedar Tree Neck	41° 26.1'	70° 41.8'	+0 10	+1 32	*0.62	*0.62	2.2	2.8	1.2
				on Boston, p.40						

If you want to know tides at the Golden Gate, you can use figures directly out of the tables correcting only for daylight savings time when necessary.

As an example, NOAA predicted that on June 1, 2024, the morning low tide at the Golden Gate would be 1.4 feet above datum at MLLW at 12:57 a.m. Since daylight savings time would be in effect on that date, you would have to add one hour to that time to get the actual time of low tide.

If you want tide information at another location than at a reference location, traditionally you'd have to adjust the figures using data tables titled Tidal Differences and Other Constants.

As an example where such an adjustment would be required, NOAA's tide table for Newport, RI, for 2011 shows a morning high tide on April 1 of 3.3 feet at 6:23 a.m.

The tidal difference tables for Martha's Vineyard, Mass., shows high water at Wasque Point on Chappaquiddick Island occurs 2 hours and 2 minutes later, and is 0.31 feet higher than at the reference location of Newport. Low water is 3 hours 20 minutes later, and is also 0.31 feet higher than at the Newport reference location.

Similarly, current information must also be adjusted from the reference location using Current Differences and Other Constants tables.

For example, in Pollock Rip Channel, Mass., in 2011, NOAA predicted the morning slack tide on April 1 would be at 1:46 a.m., and the morning maximum flood would occur at 5:14 a.m. The current at that time would be 2.0 knots.

To adjust that for Black Point, the navigator would refer to the current differences table associated with Pollock Rip Channel and find that the time of slack or minimum water movement occurs 2 hours and 54 minutes earlier than at Pollock Rip Channel. Flood happens 1 hour and 55 minutes earlier. And the current is only 20 percent (a ratio of 0.2) of the current at the Pollock Rip Channel reference location.

Examine the tide table excerpts (above) and current table excerpts (below) for clarity.

Pollock Rip Channel, Massachusetts, 2011

F–Flood, Dir. 035° True E–Ebb, Dir. 225° True

April							
	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1 F	0146	0514	2.0F	16 Sa	0056	0418	2.1F
	0806	1105	1.7E		0727	1011	2.0E
	1402	1734	2.1F		1320	1643	2.2F
	2029	2326	1.7E		1953	2237	2.0E
2 Sa	0225	0554	2.1F	17 Su	0146	0508	2.3F
	0847	1141	1.7E		0818	1102	2.1E
	1440	1811	2.1F		1411	1731	2.3F
	2106	2358	1.8E	○	2040	2325	2.1E

May							
	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1 Su	0149	0521	2.1F	16 M	0124	0451	2.3F
	0818	1108	1.7E		0802	1045	1.9E
	1408	1737	2.0F		1353	1714	2.1F
	2030	2321	1.8E		2017	2305	2.0E
2 M	0226	0558	2.1F	17 Tu	0214	0543	2.3F
	0858	1143	1.7E		0855	1138	1.9E
	1446	1811	1.9F		1446	1805	2.1F
	2108	2354	1.8E	○	2107	2354	2.0E

June							
	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1 W	0230	0602	2.1F	16 Th	0252	0628	2.3F
	0911	1150	1.6E		0936	1222	1.7E
	1456	1815	1.8F		1527	1849	1.9F
●	2115	2358	1.8E		2142		
2 Th	0307	0636	2.1F	17 F		0033	1.9E
	0952	1228	1.7E		0341	0718	2.3F
	1535	1848	1.8F		1026	1312	1.7E
	2154				1617	1939	1.8F
					2231		

TABLE 2 – CURRENT DIFFERENCES AND OTHER CONSTANTS

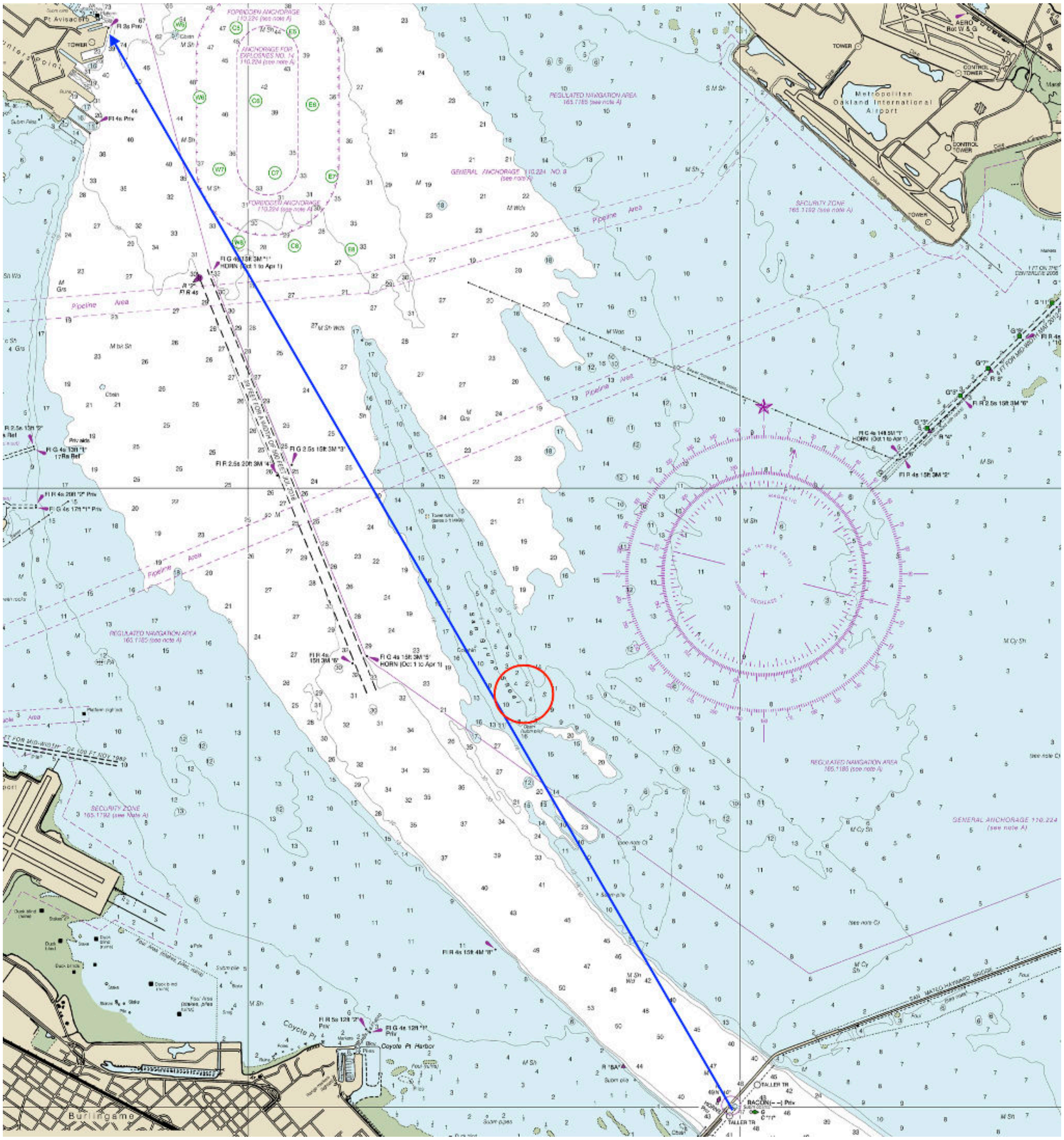
No.	PLACE	Meter Depth	POSITION		TIME DIFFERENCES				SPEED RATIOS		AVERAGE SPEEDS AND DIRECTIONS							
			Latitude	Longitude	Min. before Flood	Flood	Min. before Ebb	Ebb	Flood	Ebb	Minimum before Flood		Maximum Flood		Minimum before Ebb		Maximum Ebb	
		ft	North	West	h m	h m	h m	h m			knots	Dir.	knots	Dir.	knots	Dir.	knots	Dir.
	NARRAGANSETT BAY <B> Time meridian, 75° W				on Pollock Rip Channel, p.38													
2031	Sakonnet River (except Narrows)		– – –	– – –	Current weak and variable													
2036	Black Point, SW of, Sakonnet River	15	41° 30.4'	71° 13.2'	−2 54	−1 55	−2 13	−2 26	0.2	0.2	– –	– –	0.4	012°	– –	– –	0.4	194°
2041	Almy Point Bridge, south of, Sakonnet River	15	41° 37.3'	71° 13.2'	−3 00	−2 10	−2 30	−3 13	0.2	0.8	– –	– –	0.4	034°	– –	– –	1.5	180°
2046	Tiverton, Stone bridge, Sakonnet R. <9>		41° 37.5'	71° 13.0'	−2 58	−5 02	−2 26	−3 08	1.4	1.6	– –	– –	2.7	010°	– –	– –	2.7	190°
						−2 54			0.3				0.6	010°				
						−0 36			1.3				2.5	010°				
2051	Tiverton, RR. bridge, Sakonnet R. <10>		41° 38.3'	71° 12.9'	−3 26	−5 06	−2 46	−3 41	1.2	1.4	– –	– –	2.3	000°	– –	– –	2.4	180°
						−3 04			– –				– –					
						−1 15			0.8				1.5	000°				
2056	Common Fence Point, northeast of	10	41° 39.5'	71° 12.5'	−2 38	−4 50	−2 32	−2 41	0.1	0.2	– –	– –	0.2	026°	– –	– –	0.3	210°
						−2 25			0.0				0.1	058°				
						−0 56			0.1				0.1	046°				
2061	Brenton Point, 1.4 n.mi. southwest of	7	41° 25.9'	71° 22.6'	−1 03	−0 33	−1 20	−1 04	0.2	0.4	– –	– –	0.4	347°	– –	– –	0.6	170°
2066	Castle Hill, west of, East Passage	15	41° 27.4'	71° 22.7'	−0 06	−0 42	−1 07	−0 29	0.4	0.7	– –	– –	0.7	013°	– –	– –	1.2	237°

III. Danger bearings

A danger bearing is a method navigators use to help ensure they don't wander into dangerous waters. The actual danger usually isn't visible, thus the need for a danger bearing! Any landmark in the right proximity from the danger can be used. The landmark must be situated so that when a bearing to it is taken, bearing measurements will determine whether the observer is in dangerous or safe water.

For example, to avoid running onto San Bruno Shoal when proceeding north from the San Mateo Bridge in the southern part of San Francisco Bay, a mariner could take a sight on Point Avisadero in San Francisco and note that as long as the right edge of the point is AT LEAST 316° magnetic, he or she will be west of the shoal and in safe water. If the mariner's bearing to Point Avisadero is less than 316°M, there's a chance of hitting the unseen shoal.

Remember that a danger bearing has nothing to do with a vessel's heading. It has only to do with the bearing to the landmark the navigator is using to indicate the danger.



A danger bearing on Point Avisadero of 316° magnetic will allow mariners heading north from the San Mateo Bridge in San Francisco Bay to avoid the unmarked San Bruno Shoal circled in red. Any bearing of Point Avisadero *less than* 316° would mean the mariner is in danger of hitting San Bruno Shoal.

IV. Electronic navigation

Of all the aspects of boating, electronic aids to navigation are in the most rapid state of advancement. Instead of teaching how to use these tools, this course will deal only with how different kinds of electronic tools function and note some of their limitations.

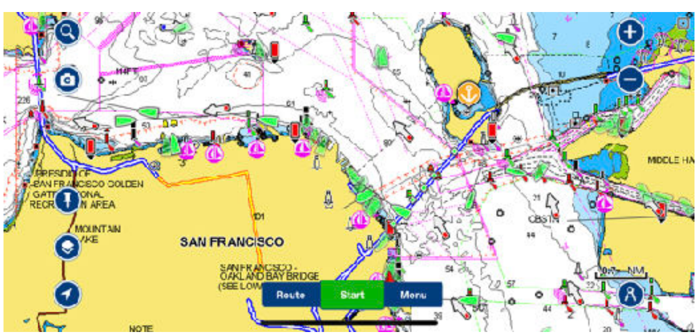
A marine VHF radio

VHF radio

Though not truly navigational tools, communications radios are a vital part of safe navigation. The VHF (Very High Frequency) radio can be used to communicate when both parties are in line of sight from each other — typically no more than about 25 miles, sometimes less. It is used for contacting the Coast Guard, communicating with other vessels or harbor facilities and listening to weather forecasts. For sailors in the San Francisco Bay and coastal areas, the range for communicating with the Coast Guard can be farther because Coast Guard antennas are atop several of the the region's highest peaks.

AIS

AIS (Automatic Identification System) transceivers are by law aboard most commercial vessels worldwide. The system is primarily intended to prevent collisions. Instruments on board transmit the vessel's position, direction, speed and other data every few moments.



Vessel AIS data as displayed on an iPad navigation app screen. Vessels with AIS transponders are shown in green. Information about a particular vessel can be obtained by tapping on it.

The devices calculate the trajectory of all AIS signals received and sound alarms whenever a collision is likely.

For vessels not on collision courses, AIS units can display time until, and distance from what the system calls Closest Point of Approach or CPA.

The positions of all vessels transmitting AIS signals can be displayed on a boat's GPS charting screens. Also, for vessels equipped with onboard wifi, for example, those positions can also appear on a boater's smart phone or other handheld device.

Commercial vessels carry what are called Class A systems that have greater functionality than the Class B systems that recreational vessels are allowed to carry.

In addition to information about vessels, AIS is also used to transmit information from and about certain aids to navigation. In some cases, aids to navigation exist only virtually, meaning they appear on charts and transmit information about themselves via AIS, but they don't actually exist on the water.

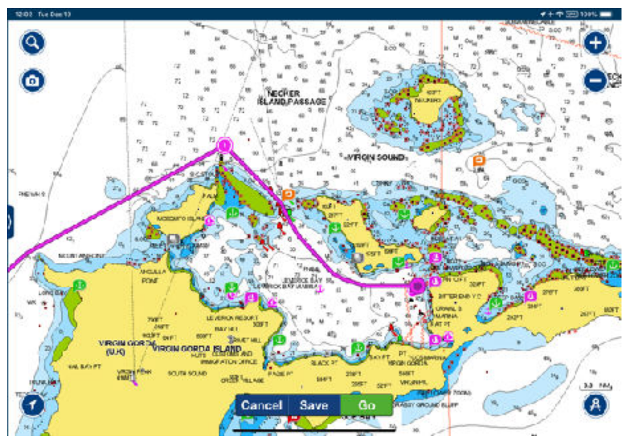
Boaters don't need an AIS transceiver system to take advantage of what AIS can provide. AIS receive-only apps are available for most smart devices that can provide valuable safety information in busy places like major ports.

In looking at AIS information on an app or an electronic charting screen, it may seem like every vessel in a busy waterway has an AIS transponder. But they don't. And therein lies one potential weakness of the system — that it can give a mariner a false sense of security. Not every vessel on the water will appear on your screen. You still have to maintain a proper lookout at all times while under way.

GPS-based navigation tools

GPS, or Global Positioning System, was developed by the U.S. Defense Department to provide ultra-precise position information — accurate to within a few feet about the device's actual position. Devices use that data to display a vessel's speed and direction of travel. The system works by measuring the precise time lapse of reception of radio signals broadcast by a constellation of satellites. GPS is one of a number of satellite-based navigation systems developed by countries around the world.

Most recreational vessels have some sort of GPS navigation system or systems on board either permanently installed or in the mariner's pocket as a handheld app.



Navigation apps can provide a suggested route plot automatically. The navigator must examine the route closely and make changes manually as necessary for safety.

Review questions for Lesson 6

1. Plot a course from “1” ISO G 6sec Buoy (L41° 25.8’ N, λ71° 02.3’ W) to the W Or “H” Fl 2 sec Bell Buoy (L 41° 24.7’ N, λ71° 24.0’ W).
   What is the course in Magnetic° and Compass°?

   Using Brenton Reef Light Gp Fl (2) 10sec 87ft 25M, plot a Danger Bearing to avoid the wreck (L 41° 25.6’ N λ71° 07.4’’ W) that is south of your course line. What is the danger bearing in Magnetic°?

   Brenton Reef Light should bear NO MORE or NO LESS than for the Danger Bearing to remain safe?

2. Plot a course from the same “1” ISO G 6 sec Buoy (L 41° 25.8’ N, λ71° 02.3’ W) to a position L 41° 10.0’ N, λ71° 05.0’ W.
   What is the course in Magnetic° and Compass°?

   Using Buzzards Light plot a danger bearing to avoid the Unexploded Depth Charge (L 41° 17.0’ N, λ71° 04.0’ W) that is west of your course line. What is the danger bearing in Magnetic°?

   Buzzards Light should bear NO MORE or NO LESS than for the Danger Bearing to remain safe?

3. On June 1, 2020, you plan to sail from South Beach Harbor in San Francisco to Redwood City on the evening flood current.
   (Use the current tables in the appendix. You’ll need to calculate current differences in reference to the San Mateo Bridge.)

   What is the time of max flood in Redwood Creek in PST and PDT?

   How fast will the current be in Redwood Creek at that time, and what direction will it run?

   The afternoon flood in Redwood Creek runs from what time to what time PDT after which the current begins to ebb on June 2?

4. You plan to arrive at Redwood City Wharf 5 at high tide on June 1.
   (Use the tide tables in the appendix. You’ll need to calculate differences based tides at the Golden Gate.)

   What is the time and height of the evening high tide there?
   What is the tidal range between the afternoon low and the evening high tide at Wharf 5?.

Answers for Lesson 6 questions

1. Course: 280° Magnetic, 286° PSC (Per Ship's Compass)
   Danger bearing: 284° Magnetic
   NO MORE

2. 201° Magnetic, 195° PSC
   Danger bearing: 025° Magnetic
   NO MORE

3. Max flood: 1804 PST; 1904 PDT; 0.9 knots; 234°T
   Flood runs from 1541 PDT to 2208 PDT

   The current differences tables show that Max Flood at Redwood Creek is 2 minutes later than at the San Mateo Bridge

   The difference tables show that slack (minimum) before flood happens 36 minutes earlier in Redwood creek than at the San Mateo Bridge; slack before ebb is 22 minutes earlier.

4. Wharf 5 high tide Time: 2152 PDT, Height: 7.45 feet
   Tidal range: 5.7 feet
   Dumbarton High Tide is at 2229 PDT

   High tide at Wharf 5 is 1.45 feet higher than at the Golden Gate.
   Low tide at Wharf 5 is 1.05 feet higher than at the Golden Gate.

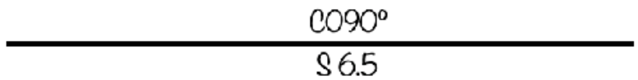
Sample deviation table

Compass direction	Deviation	Magnetic direction	Compass direction	Deviation	Magnetic direction
000°	5° W	355°	190°	9° E	199°
010°	5° W	005°	200°	9° E	209°
020°	5° W	015°	210°	5° E	215°
030°	5° W	025°	220°	4° E	224°
040°	5° W	035°	230°	2° E	232°
050°	4° W	046°	240°	0°	240°
060°	4° W	056°	250°	2° W	248°
070°	3° W	067°	260°	4° W	256°
080°	2° W	078°	270°	5° W	265°
090°	1° W	089°	280°	6° W	274°
100°	1° E	101°	290°	6° W	284°
110°	4° E	114°	300°	6° W	294°
120°	7° E	127°	310°	6° W	304°
130°	9° E	139°	320°	6° W	314°
140°	10° E	150°	330°	5° W	325°
150°	10° E	160°	340°	5° W	335°
160°	10° E	170°	350°	5° W	345°
170°	11° E	181°	360°	5° W	355°
180°	10° E	190°			

Use this table for practice problems in this handbook.

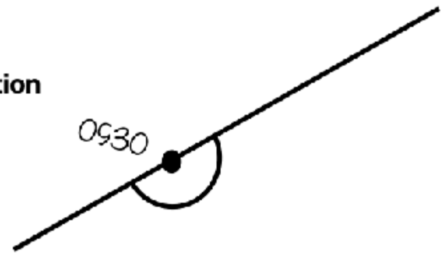
Commonly used navigation plotting symbols

DR plot



Course (090° True) written above the course line, speed (6.5 knots) written below the course line.

DR position

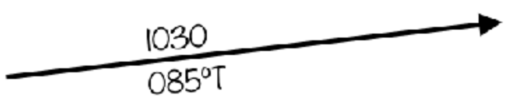


Time (24 hour notation) written at an angle, semicircle denoting DR position along the course line.

Departure

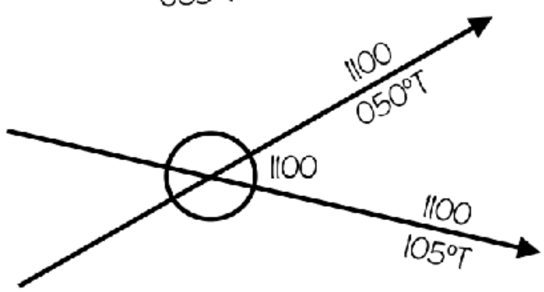
Course line with a circle and a dot at the departure point. Time written horizontally.

LOP



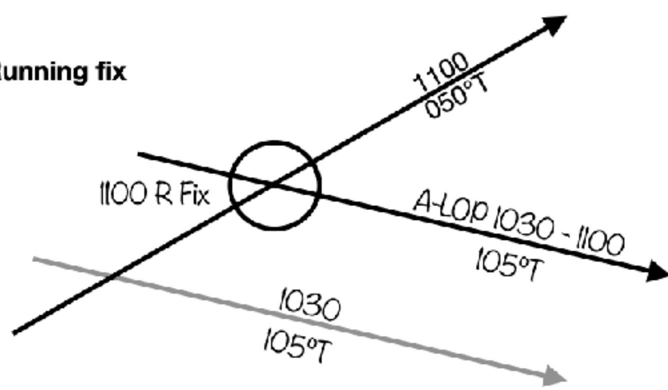
LOP with time above and bearing to sighted object below in true degrees.

Fix



Circle where two or more LOPs cross. Time of fix written horizontally.

Running fix



Circle where LOPs cross. Advanced LOP labeled with original time and advanced time. Time of fix labeled with "R Fix".

San Francisco (Golden Gate), California, 2020

Times and Heights of High and Low Waters

April

Day	Time (h m)	Height (ft)	Height (cm)
1 W	0419 1137 1934 2353	5.0 0.2 4.1 3.2	152 6 125 98
2 Th	0533 1243 2020	5.1 -0.1 4.4	155 -3 134
3 F	0104 0647 1340 2059	2.8 5.2 -0.4 4.7	85 158 -12 143
4 Sa	0200 0754 1429 2133	2.3 5.5 -0.5 5.0	70 168 -15 152
5 Su	0250 0855 1515 2207	1.6 5.6 -0.5 5.4	49 171 -15 165
6 M	0338 0953 1558 2241	0.9 5.7 -0.3 5.7	27 174 -9 174
7 Tu	0426 1050 1639 2316	0.3 5.7 0.0 6.0	9 174 0 183
8 W	0514 1147 1721 2352	-0.3 5.5 0.5 6.2	-9 168 15 189
9 Th	0603 1245 1804	-0.7 5.3 1.1	-21 162 34
10 F	0030 0654 1346 1850	6.3 -0.9 4.9 1.7	192 -27 149 52
11 Sa	0111 0747 1452 1941	6.2 -0.8 4.6 2.3	189 -24 140 70
12 Su	0156 0845 1606 2044	6.0 -0.7 4.4 2.8	183 -21 134 85
13 M	0247 0950 1727 2205	5.6 -0.4 4.4 3.0	171 -12 134 91
14 Tu	0348 1100 1842 2335	5.2 -0.2 4.5 3.0	158 -6 137 91
15 W	0500 1208 1942	4.9 0.0 4.7	149 0 143
16 Th	0051 0616 1309 2028	2.7 4.7 0.1 4.8	82 143 3 146
17 F	0150 0725 1359 2105	2.3 4.6 0.2 5.0	70 140 6 152
18 Sa	0238 0824 1441 2135	1.8 4.6 0.3 5.1	55 140 9 155
19 Su	0319 0916 1517 2201	1.4 4.7 0.5 5.1	43 143 15 155
20 M	0355 1002 1549 2224	1.0 4.6 0.8 5.2	30 140 24 158
21 Tu	0428 1046 1619 2247	0.7 4.6 1.1 5.3	21 140 34 162
22 W	0500 1129 1648 2310	0.4 4.5 1.4 5.4	12 137 43 165
23 Th	0530 1212 1718 2334	0.1 4.4 1.8 5.5	3 134 55 168
24 F	0602 1256 1748	-0.1 4.4 2.2	-3 134 67
25 Sa	0001 0636 1344 1822	5.5 -0.2 4.3 2.5	168 -6 131 76
26 Su	0031 0715 1437 1859	5.5 -0.3 4.2 2.8	168 -9 128 85
27 M	0106 0759 1538 1946	5.4 -0.3 4.1 3.1	165 -9 125 94
28 Tu	0148 0851 1646 2050	5.3 -0.3 4.1 3.3	162 -9 125 101
29 W	0241 0952 1753 2215	5.1 -0.3 4.2 3.3	155 -9 128 101
30 Th	0348 1057 1848 2340	4.9 -0.2 4.4 3.0	149 -6 134 91

May

Day	Time (h m)	Height (ft)	Height (cm)
1 F	0506 1201 1933	4.8 -0.2 4.7	146 -6 143
2 Sa	0049 0625 1258 2011	2.4 4.8 -0.2 5.1	73 146 -6 155
3 Su	0146 0740 1349 2047	1.7 4.8 0.0 5.5	52 146 0 168
4 M	0237 0848 1437 2123	0.8 4.9 0.2 5.8	24 149 6 177
5 Tu	0326 0951 1522 2158	0.1 5.0 0.6 6.2	3 152 18 189
6 W	0414 1052 1606 2235	-0.6 5.0 1.1 6.4	-18 152 34 195
7 Th	0501 1151 1651 2314	-1.1 5.0 1.6 6.5	-34 152 49 198
8 F	0549 1250 1738 2354	-1.4 4.9 2.1 6.5	-43 149 64 198
9 Sa	0638 1350 1828	-1.4 4.8 2.5	-43 146 76
10 Su	0037 0728 1452 1925	6.3 -1.3 4.7 2.8	192 -40 143 85
11 M	0123 0821 1556 2032	5.9 -1.0 4.7 3.1	180 -30 143 94
12 Tu	0214 0918 1702 2153	5.4 -0.6 4.6 3.1	165 -18 140 94
13 W	0313 1019 1803 2316	4.9 -0.2 4.7 2.9	149 -6 143 88
14 Th	0422 1119 1855	4.5 0.1 4.8	137 3 146
15 F	0027 0538 1216 1937	2.5 4.2 0.4 5.0	76 128 12 152
16 Sa	0125 0652 1306 2012	2.0 4.1 0.6 5.1	61 125 18 155
17 Su	0214 0800 1349 2041	1.5 4.0 0.9 5.2	46 122 27 158
18 M	0255 0859 1428 2106	1.0 4.1 1.2 5.4	30 125 37 165
19 Tu	0332 0952 1503 2131	0.6 4.1 1.6 5.5	18 125 49 168
20 W	0405 1041 1537 2157	0.2 4.2 1.9 5.7	6 128 58 174
21 Th	0437 1128 1610 2224	-0.1 4.3 2.2 5.8	-3 131 67 177
22 F	0509 1214 1645 2254	-0.4 4.3 2.5 5.9	-12 131 76 180
23 Sa	0542 1259 1720 2326	-0.6 4.4 2.8 5.9	-18 134 85 180
24 Su	0618 1346 1759	-0.8 4.4 3.0	-24 134 91
25 M	0002 0658 1435 1844	5.8 -0.9 4.4 3.2	177 -27 134 98
26 Tu	0041 0742 1527 1937	5.7 -0.9 4.4 3.3	174 -27 134 101
27 W	0128 0831 1621 2043	5.5 -0.8 4.5 3.3	168 -24 137 101
28 Th	0223 0926 1713 2203	5.2 -0.6 4.7 3.1	158 -18 143 94
29 F	0329 1023 1800 2323	4.9 -0.3 4.9 2.6	149 -9 149 79
30 Sa	0447 1121 1844	4.6 0.0 5.2	140 0 158

June

Day	Time (h m)	Height (ft)	Height (cm)
1 M	0132 0733 1310 2004	1.1 4.3 0.7 6.0	34 131 21 183
2 Tu	0225 0849 1400 2042	0.3 4.4 1.2 6.4	9 134 37 195
3 W	0315 0957 1450 2122	-0.5 4.5 1.6 6.6	-15 137 49 201
4 Th	0403 1059 1538 2202	-1.0 4.7 2.1 6.8	-30 143 64 207
5 F	0450 1157 1628 2244	-1.4 4.8 2.4 6.8	-43 146 73 207
6 Sa	0536 1252 1719 2327	-1.5 4.9 2.7 6.6	-46 149 82 201
7 Su	0622 1346 1812	-1.5 4.9 2.9	-46 149 88
8 M	0011 0709 1438 1909	6.3 -1.3 4.9 3.1	192 -40 149 94
9 Tu	0058 0756 1531 2013	5.9 -1.0 4.9 3.1	180 -30 149 94
10 W	0146 0845 1622 2123	5.4 -0.6 4.9 3.0	165 -18 149 91
11 Th	0240 0935 1711 2238	4.9 -0.1 4.9 2.8	149 -3 149 85
12 F	0341 1026 1755 2348	4.4 0.3 5.0 2.5	134 9 152 76
13 Sa	0453 1117 1835	4.0 0.8 5.1	122 24 155
14 Su	0049 0613 1206 1909	2.0 3.7 1.2 5.3	61 113 37 162
15 M	0141 0733 1253 1941	1.4 3.7 1.6 5.5	43 113 49 168
16 Tu	0225 0843 1337 2011	0.9 3.8 2.0 5.7	27 116 61 174
17 W	0304 0944 1419 2042	0.5 3.9 2.3 5.9	15 119 70 180
18 Th	0340 1036 1459 2114	0.0 4.1 2.6 6.0	0 125 79 183
19 F	0414 1124 1539 2149	-0.3 4.3 2.9 6.2	-9 131 88 189
20 Sa	0448 1208 1619 2225	-0.6 4.5 3.0 6.2	-18 137 91 189
21 Su	0524 1251 1700 2304	-0.9 4.6 3.1 6.3	-27 140 94 192
22 M	0602 1333 1744 2345	-1.0 4.7 3.2 6.2	-30 143 98 189
23 Tu	0643 1415 1832	-1.1 4.8 3.2	-34 146 98
24 W	0029 0726 1459 1927	6.1 -1.0 4.8 3.1	186 -30 146 94
25 Th	0118 0811 1543 2032	5.8 -0.8 5.0 2.9	177 -24 152 88
26 F	0214 0900 1627 2145	5.4 -0.5 5.2 2.6	165 -15 158 79
27 Sa	0320 0951 1712 2302	4.9 0.0 5.4 2.1	149 0 165 64
28 Su	0439 1045 1757	4.4 0.5 5.8	134 15 177
29 M	0014 0609 1140 1841	1.4 4.1 1.1 6.1	43 125 34 186
30 Tu	0117 0738 1237 1926	0.7 4.0 1.7 6.4	21 122 52 195

TABLE 2. – TIDAL DIFFERENCES AND OTHER CONSTANTS

No.	PLACE	POSITION		DIFFERENCES				RANGES		Mean Tide Level
		Latitude	Longitude	Time		Height		Mean	Diurnal	
				High Water	Low Water	High Water	Low Water			
		North	West	h m	h m	ft	ft	ft	ft	ft
	CALIFORNIA Channel Islands-cont. Time meridian, 120° W			**on Los Angeles, p.76**						
475	Prisoners Harbor, Santa Cruz Island	34° 01.2'	119° 41.0'	+0 19	+0 18	*0.94	*1.01	3.54	5.25	2.72
477	Bechers Bay, Santa Rosa Island	34° 00.5'	120° 02.8'	+0 27	+0 27	*0.93	*1.03	3.45	5.14	2.69
479	Cuyler Harbor, San Miguel Island	34° 03'	120° 21'	+0 33	+0 34	*0.94	*0.94	3.5	5.2	2.7
	Outer Coast			**on Port San Luis, p.80**						
481	Point Arguello	34° 35'	120° 39'	-0 03	-0 08	*0.96	*0.96	3.5	5.2	2.7
483	PORT SAN LUIS	35° 10.1'	120° 45.1'	*Daily predictions*				3.58	5.33	2.83
485	San Simeon	35° 38'	121° 11'	+0 08	+0 07	*0.99	*1.00	3.6	5.3	2.8
487	Mansfield Cone	35° 57.0'	121° 28.9'	+0 16	+0 16	*0.98	*0.99	3.50	5.24	2.78
				on Monterey, p.84						
489	Carmel Cove, Carmel Bay	36° 31'	121° 56'	-0 03	-0 04	*0.97	*0.99	3.5	5.2	2.8
	Monterey Bay									
491	MONTEREY, MONTEREY BAY	36° 36.3'	121° 53.3'	*Daily predictions*				3.54	5.34	2.86
493	General Fish Company Pier	36° 48.1'	121° 47.2'	+0 01	+0 01	*0.98	*0.95	3.56	5.31	2.84
495	Moss Landing, Ocean Pier	36° 48'	121° 47'	-0 01	-0 01	*0.95	*0.90	3.5	5.2	2.8
497	Elkhorn Yacht Club	36° 48.8'	121° 47.2'	+0 00	+0 02	*0.97	*0.95	3.52	5.27	2.82
499	Elkhorn Slough, Highway 1 Bridge	36° 48.6'	121° 47.1'	+0 03	-0 02	*0.95	*0.90	3.5	5.2	2.8
501	Pacific Mariculture Dock	36° 49'	121° 46'	+0 15	+0 07	*1.00	*0.98	3.6	5.4	2.9
503	Elkhorn, Elkhorn Slough	36° 49.1'	121° 44.8'	+0 23	+0 13	*1.01	*0.94	3.63	5.37	2.85
505	Kirby Park, Elkhorn Slough	36° 50'	121° 45'	+0 26	+0 08	*1.02	*0.96	3.7	5.5	2.9
507	Elkhorn Slough railroad bridge	36° 51.4'	121° 45.3'	+0 33	+0 08	*1.02	*0.96	3.74	5.52	2.94
509	Santa Cruz, Monterey Bay	36° 58'	122° 01'	-0 06	-0 11	*0.97	*0.99	3.5	5.3	2.8
				on San Francisco, p.88						
511	Ano Nuevo Island	37° 06'	122° 20'	-1 24	-1 04	-0.7	-0.1	3.5	5.2	2.7
513	Pillar Point Harbor, Half Moon Bay	37° 30.1'	122° 28.9'	-1 04	-0 43	*0.95	*0.97	3.85	5.60	3.03
515	Southeast Farallon Island	37° 42'	123° 00'	-0 39	-0 19	-0.3	0.0	3.8	5.6	3.0
517	San Francisco Bar	37° 46'	122° 38'	-0 35	-0 31	-0.2	0.0	3.9	5.6	3.0
519	Ocean Beach, outer coast	37° 46'	122° 31'	-0 49	-0 35	+0.1	0.0	4.2	6.0	3.2
	San Francisco Bay									
521	Point Bonita, Bonita Cove	37° 49'	122° 32'	-0 17	-0 10	+0.3	0.0	4.3	6.0	3.3
523	SAN FRANCISCO (Golden Gate)	37° 48.4'	122° 27.9'	*Daily predictions*				4.10	5.84	3.18
525	Alcatraz Island	37° 50'	122° 25'	+0 14	+0 18	0.0	0.0	4.1	5.8	3.1
527	San Francisco, North Point, Pier 41	37° 49'	122° 25'	+0 13	+0 11	+0.2	0.0	4.3	6.1	3.3
529	Rincon Point, Pier 22 1/2	37° 47'	122° 23'	+0 23	+0 25	+0.4	0.0	4.6	6.3	3.4
531	Yerba Buena Island	37° 48.6'	122° 21.6'	+0 25	+0 33	*1.06	*0.99	4.43	6.16	3.34
533	Oakland, Matson Wharf	37° 49'	122° 20'	+0 28	+0 36	+0.3	0.0	4.4	6.2	3.3
535	Oakland Middle Harbor	37° 48.3'	122° 20.3'	+0 21	+0 31	*1.07	*0.96	4.52	6.22	3.36
537	Oakland Pier	37° 48'	122° 20'	+0 33	+0 48	+0.2	0.0	4.3	6.0	3.2
539	Oakland Inner Harbor	37° 47.7'	122° 16.9'	+0 24	+0 31	*1.12	*0.99	4.71	6.45	3.49
541	Alameda Naval Air Station	37° 47.6'	122° 18.9'	+0 24	+0 33	*1.11	*1.00	4.65	6.40	3.46
543	Alameda	37° 46.3'	122° 17.9'	+0 29	+0 39	*1.11	*0.99	4.84	6.60	3.55
545	Oakland Harbor, Grove Street	37° 48'	122° 17'	+0 33	+0 42	+0.4	0.0	4.5	6.2	3.3
547	Oakland Harbor, Park Street Bridge	37° 46.3'	122° 14.1'	+0 24	+0 32	*1.13	*0.98	4.77	6.51	3.50
549	San Leandro Channel, San Leandro Bay	37° 44.9'	122° 14.1'	+0 42	+0 52	*1.16	*0.98	4.98	6.69	3.60
551	Oakland Airport	37° 43.9'	122° 12.5'	+0 40	+0 45	*1.15	*0.96	4.95	6.65	3.56
553	Potrero Point	37° 46'	122° 23'	+0 33	+0 46	+0.5	0.0	4.6	6.3	3.4
555	Hunters Point	37° 43.8'	122° 21.4'	+0 28	+0 43	*1.18	*1.00	5.03	6.80	3.66
557	San Leandro Marina	37° 41.7'	122° 11.5'	+0 54	+1 23	*1.28	*1.01	5.55	7.31	3.92
559	Roberts Landing, 1.3 miles west of	37° 40'	122° 12'	+0 52	+1 28	+1.4	+0.1	5.4	7.2	3.9
561	South San Francisco	37° 40'	122° 23'	+0 38	+0 56	+1.2	0.0	5.3	7.0	3.8
563	Oyster Point Marina	37° 39.9'	122° 22.6'	+0 41	+1 00	*1.23	*1.00	5.30	7.06	3.78
565	Point San Bruno	37° 39'	122° 23'	+0 38	+1 10	+1.1	+0.1	5.1	6.9	3.7
567	Seaplane Harbor	37° 38'	122° 23'	+0 42	+1 03	+1.4	0.0	5.4	7.2	3.9
569	Coyote Point Marina	37° 35.5'	122° 18.8'	+0 42	+1 08	*1.29	*1.01	5.61	7.37	3.94
571	San Mateo Bridge (west end)	37° 34.8'	122° 15.2'	+0 44	+1 11	*1.36	*1.04	5.90	7.72	4.11
573	San Mateo Bridge (east end)	37° 36'	122° 11'	+0 48	+1 19	+1.8	0.0	5.9	7.7	4.1
575	Alameda Creek	37° 35.7'	122° 08.7'	+0 57	+2 25	*1.05	*0.27	5.20	6.12	2.91
577	Coyote Hills Slough entrance	37° 33.8'	122° 07.7'	+0 52	+2 21	*1.17	*0.45	5.63	6.74	3.33
579	Bay Slough, west end	37° 33.1'	122° 14.6'	+0 48	+1 28	*1.35	*1.00	5.91	7.66	4.09
581	Bay Slough, east end	37° 32.7'	122° 13.3'	+0 49	+1 52	*1.27	*0.77	5.79	7.28	3.77
583	Redwood Creek Marker 8	37° 32'	122° 12'	+0 53	+1 28	*1.41	*1.05	6.2	8.0	4.3
585	South Bay Wreck	37° 33'	122° 10'	+1 02	+1 37	+2.2	+0.1	6.2	8.0	4.3
587	Corkscrew Slough	37° 30'	122° 13'	+1 03	+1 42	+2.2	+0.1	6.2	8.0	4.3
589	Redwood City, Wharf 5	37° 30.4'	122° 12.6'	+0 48	+1 15	*1.45	*1.05	6.39	8.22	4.41
591	West Point Slough	37° 30.3'	122° 11.5'	+0 56	+1 30	*1.44	*1.04	6.33	8.14	4.34
593	Smith Slough	37° 30'	122° 14'	+1 15	+1 58	+2.1	0.0	6.2	7.9	4.2
595	Newark Slough	37° 31'	122° 05'	+1 11	+1 58	+2.6	+0.1	6.6	8.4	4.2
597	Dumbarton Highway Bridge	37° 30.4'	122° 06.9'	+0 47	+1 14	*1.53	*1.10	6.74	8.61	4.63
599	Ravenswood Slough <17>	37° 29.8'	122° 10.3'	+0 58	- - -	- -	- -	- -	- -	- -
601	Granite Rock, Redwood Creek	37° 29.7'	122° 12.8'	+0 55	+1 31	*1.43	*1.04	6.28	8.08	4.32
603	Palo Alto Marker 8 <18>	37° 28.1'	122° 05.8'	+1 01	- - -	- -	- -	- -	- -	- -
605	Palo Alto Yacht Harbor	37° 27.5'	122° 06.3'	+0 59	+2 14	*1.34	*0.68	6.22	7.62	3.88
607	Mowry Slough	37° 30'	122° 02'	+1 12	+2 07	+2.6	0.0	6.7	8.4	4.4
609	Calaveras Point, west of	37° 28'	122° 04'	+1 05	+1 49	+2.8	+0.1	6.8	8.5	4.6
611	Mud Slough railroad bridge <18>	37° 28.1'	121° 59.2'	+1 12	- - -	- -	- -	- -	- -	- -
613	Guadalupe Slough	37° 27.2'	122° 02.0'	+1 06	- - -	- -	- -	- -	- -	- -
615	Upper Guadalupe Slough	37° 26.1'	122° 00.4'	+1 14	+2 13	*1.66	*1.13	7.40	9.29	4.98

San Mateo Bridge, Calif. 2020

F–Flood, Dir. 136° True   E–Ebb, Dir. 298° True

April

Day	Slack h m	Maximum h m	knots
1 W	0040	0315	0.8F
	0543	0934	1.3E
	1325	1627	1.0F
◐	2040	2315	0.8E
2 Th	0200	0424	0.9F
	0701	1045	1.4E
	1434	1737	1.2F
	2139		
3 F		0022	1.0E
	0309	0531	1.0F
	0819	1154	1.6E
	1533	1835	1.4F
	2226		
4 Sa		0119	1.3E
	0407	0633	1.3F
	0930	1258	1.8E
	1626	1922	1.6F
	2306		
5 Su		0208	1.5E
	0500	0730	1.5F
	1033	1355	1.9E
	1715	2004	1.8F
	2343		
6 M		0254	1.8E
	0549	0823	1.8F
	1133	1450	2.0E
	1801	2045	1.9F
7 Tu	0017	0339	2.0E
	0637	0913	2.0F
	1230	1542	2.0E
○	1846	2126	2.0F
8 W	0052	0422	2.1E
	0725	1002	2.0F
	1326	1634	1.9E
	1931	2208	1.9F
9 Th	0127	0505	2.1E
	0812	1051	2.0F
	1422	1725	1.7E
	2017	2252	1.8F
10 F	0204	0548	2.1E
	0901	1141	1.9F
	1520	1817	1.5E
	2105	2337	1.6F
11 Sa	0244	0632	1.9E
	0952	1234	1.7F
	1622	1912	1.3E
	2158		
12 Su		0027	1.4F
	0327	0719	1.7E
	1048	1333	1.5F
	1729	2013	1.1E
	2258		
13 M		0121	1.1F
	0416	0812	1.5E
	1150	1443	1.3F
	1842	2125	0.9E
14 Tu	0008	0222	0.9F
	0514	0915	1.3E
	1257	1611	1.2F
◑	1955	2245	0.9E
15 W	0125	0330	0.7F
	0624	1031	1.3E
	1403	1734	1.3F
	2100	2358	1.0E
16 Th	0237	0444	0.7F
	0739	1145	1.3E
	1502	1832	1.4F
	2152		
17 F		0057	1.2E
	0339	0555	0.8F
	0849	1245	1.3E
	1553	1914	1.5F
	2233		
18 Sa		0145	1.3E
	0431	0655	1.0F
	0951	1332	1.3E
	1637	1946	1.5F
	2306		
19 Su		0226	1.5E
	0516	0745	1.2F
	1046	1412	1.3E
	1716	2012	1.5F
	2333		
20 M		0300	1.6E
	0558	0829	1.3F
	1137	1448	1.3E
	1751	2036	1.4F
	2357		
21 Tu		0328	1.6E
	0636	0909	1.4F
	1224	1523	1.2E
	1823	2103	1.4F
22 W	0019	0352	1.7E
	0711	0945	1.4F
	1308	1559	1.2E
●	1855	2133	1.4F
23 Th	0040	0415	1.7E
	0743	1020	1.4F
	1350	1636	1.1E
	1927	2206	1.4F
24 F	0102	0439	1.7E
	0813	1054	1.4F
	1431	1716	1.1E
	2002	2241	1.3F
25 Sa	0127	0508	1.6E
	0842	1129	1.4F
	1514	1758	1.0E
	2040	2320	1.2F
26 Su	0157	0542	1.6E
	0913	1207	1.3F
	1602	1844	0.9E
	2124		
27 M		0003	1.1F
	0233	0622	1.6E
	0952	1251	1.2F
	1657	1937	0.9E
	2215		
28 Tu		0052	1.0F
	0316	0709	1.5E
	1040	1343	1.2F
	1801	2036	0.8E
	2317		
29 W		0149	0.9F
	0411	0805	1.5E
	1139	1444	1.2F
	1906	2143	0.8E
30 Th	0030	0254	0.8F
	0520	0910	1.4E
	1246	1550	1.2F
◐	2006	2251	1.0E

May

Day	Slack h m	Maximum h m	knots
1 F	0143	0402	0.9F
	0642	1020	1.5E
	1353	1654	1.3F
	2056	2353	1.2E
2 Sa	0249	0510	1.1F
	0806	1129	1.5E
	1455	1750	1.5F
	2139		
3 Su		0048	1.5E
	0347	0615	1.3F
	0922	1235	1.6E
	1551	1840	1.6F
	2218		
4 M		0137	1.7E
	0440	0714	1.6F
	1029	1336	1.6E
	1643	1927	1.7F
	2255		
5 Tu		0224	2.0E
	0531	0808	1.8F
	1131	1434	1.7E
	1733	2012	1.8F
	2331		
6 W		0310	2.1E
	0619	0859	2.0F
	1229	1529	1.6E
	1821	2056	1.8F
7 Th	0009	0355	2.2E
	0707	0948	2.0F
	1326	1623	1.6E
○	1910	2141	1.7F
8 F	0047	0439	2.1E
	0755	1037	2.0F
	1422	1716	1.5E
	1959	2227	1.6F
9 Sa	0127	0522	2.0E
	0842	1126	1.9F
	1518	1809	1.3E
	2050	2314	1.4F
10 Su	0209	0606	1.9E
	0931	1218	1.7F
	1617	1903	1.2E
	2144		
11 M		0004	1.2F
	0253	0650	1.7E
	1022	1314	1.5F
	1718	2002	1.1E
	2245		
12 Tu		0058	1.0F
	0341	0737	1.5E
	1117	1417	1.4F
	1820	2106	1.0E
	2352		
13 W		0158	0.8F
	0439	0830	1.3E
	1215	1526	1.3F
	1920	2215	1.0E
14 Th	0104	0304	0.7F
	0548	0932	1.2E
	1313	1633	1.3F
◑	2013	2321	1.1E
15 F	0213	0417	0.7F
	0706	1039	1.1E
	1409	1727	1.3F
	2057		
16 Sa		0017	1.2E
	0313	0529	0.8F
	0823	1145	1.0E
	1500	1809	1.3F
	2134		
17 Su		0103	1.4E
	0405	0633	1.0F
	0932	1242	1.0E
	1546	1844	1.3F
	2206		
18 M		0142	1.5E
	0450	0726	1.2F
	1033	1331	1.0E
	1629	1917	1.3F
	2234		
19 Tu		0215	1.6E
	0531	0811	1.3F
	1126	1416	1.0E
	1710	1950	1.3F
	2302		
20 W		0243	1.7E
	0609	0851	1.4F
	1215	1459	1.0E
	1749	2025	1.3F
	2328		
21 Th		0309	1.7E
	0643	0927	1.5F
	1300	1542	1.0E
	1829	2101	1.3F
	2356		
22 F		0337	1.7E
	0715	1001	1.5F
	1344	1624	1.1E
●	1909	2139	1.2F
23 Sa	0024	0408	1.7E
	0746	1035	1.5F
	1428	1708	1.1E
	1949	2218	1.2F
24 Su	0055	0443	1.7E
	0817	1110	1.5F
	1513	1752	1.0E
	2032	2300	1.2F
25 M	0130	0522	1.8E
	0853	1150	1.5F
	1601	1839	1.0E
	2118	2346	1.1F
26 Tu	0211	0605	1.8E
	0934	1234	1.5F
	1651	1929	1.0E
	2209		
27 W		0036	1.0F
	0300	0654	1.7E
	1021	1323	1.5F
	1743	2023	1.0E
	2308		
28 Th		0132	1.0F
	0358	0749	1.6E
	1115	1418	1.4F
	1833	2121	1.1E
29 F	0014	0235	1.0F
	0510	0850	1.5E
	1214	1515	1.4F
◐	1921	2221	1.2E
30 Sa	0123	0342	1.0F
	0633	0957	1.4E
	1315	1613	1.4F
	2006	2320	1.4E
31 Su	0227	0451	1.2F
	0759	1106	1.4E
	1417	1709	1.4F
	2049		

June

Day	Slack h m	Maximum h m	knots
1 M		0016	1.6E
	0327	0558	1.4F
	0917	1215	1.3E
	1517	1802	1.5F
	2130		
2 Tu		0108	1.8E
	0422	0700	1.6F
	1028	1321	1.3E
	1614	1854	1.5F
	2211		
3 W		0158	2.0E
	0515	0756	1.8F
	1131	1423	1.3E
	1709	1943	1.6F
	2253		
4 Th		0247	2.1E
	0605	0849	1.9F
	1231	1521	1.3E
	1802	2032	1.5F
	2335		
5 F		0334	2.1E
	0653	0939	1.9F
	1327	1617	1.3E
○	1854	2119	1.5F
6 Sa	0017	0419	2.1E
	0740	1027	1.9F
	1421	1710	1.3E
	1945	2206	1.4F
7 Su	0059	0502	2.0E
	0825	1114	1.8F
	1515	1801	1.2E
	2037	2254	1.3F
8 M	0142	0543	1.9E
	0910	1202	1.7F
	1607	1852	1.2E
	2130	2343	1.1F
9 Tu	0225	0622	1.7E
	0955	1250	1.6F
	1657	1943	1.1E
	2226		
10 W		0035	1.0F
	0313	0703	1.6E
	1039	1339	1.5F
	1745	2036	1.1E
	2328		
11 Th		0131	0.8F
	0408	0747	1.4E
	1125	1429	1.4F
	1830	2130	1.1E
12 F	0033	0234	0.7F
	0514	0838	1.2E
	1212	1518	1.3F
◑	1911	2226	1.1E
13 Sa	0138	0342	0.7F
	0631	0936	1.0E
	1302	1606	1.2F
	1950	2318	1.2E
14 Su	0238	0454	0.8F
	0753	1040	0.8E
	1354	1654	1.2F
	2026		
15 M		0005	1.4E
	0331	0602	0.9F
	0908	1146	0.8E
	1447	1740	1.1F
	2101		
16 Tu		0046	1.5E
	0419	0702	1.1F
	1014	1249	0.8E
	1539	1825	1.1F
	2136		
17 W		0122	1.5E
	0501	0751	1.2F
	1111	1345	0.8E
	1631	1909	1.1F
	2212		
18 Th		0156	1.6E
	0539	0832	1.3F
	1201	1437	0.9E
	1720	1952	1.1F
	2247		
19 F		0230	1.7E
	0615	0909	1.4F
	1248	1526	1.0E
	1807	2035	1.2F
	2322		
20 Sa		0306	1.7E
	0649	0943	1.5F
	1334	1613	1.1E
●	1853	2117	1.2F
	2357		
21 Su		0344	1.8E
	0723	1018	1.6F
	1419	1658	1.1E
	1937	2200	1.2F
22 M	0035	0425	1.9E
	0759	1055	1.7F
	1503	1743	1.2E
	2021	2244	1.2F
23 Tu	0116	0508	2.0E
	0837	1134	1.7F
	1547	1828	1.2E
	2107	2330	1.2F
24 W	0202	0553	2.0E
	0918	1216	1.7F
	1629	1913	1.2E
	2157		
25 Th		0021	1.2F
	0255	0642	1.9E
	1003	1301	1.7F
	1710	2001	1.3E
	2252		
26 F		0116	1.2F
	0356	0734	1.8E
	1051	1349	1.6F
	1750	2052	1.3E
	2354		
27 Sa		0217	1.1F
	0507	0832	1.5E
	1144	1441	1.5F
	1832	2147	1.4E
28 Su	0059	0323	1.2F
	0629	0937	1.3E
	1242	1536	1.4F
◐	1915	2246	1.6E
29 M	0205	0432	1.2F
	0755	1048	1.2E
	1345	1633	1.4F
	2001	2345	1.7E
30 Tu	0308	0543	1.3F
	0916	1202	1.1E
	1449	1730	1.3F
	2050		

Time meridian 120° W. 0000 is midnight. 1200 is noon. Times are not adjusted for Daylight Saving Time.

TABLE 2. – CURRENT DIFFERENCES AND OTHER CONSTANTS

No.	PLACE	Meter Depth	POSITION Latitude	POSITION Longitude	TIME DIFFERENCES Min. before Flood	TIME DIFFERENCES Flood	TIME DIFFERENCES Min. before Ebb	TIME DIFFERENCES Ebb	SPEED RATIOS Flood	SPEED RATIOS Ebb	Minimum before Flood knots	Minimum before Flood Dir.	Maximum Flood knots	Maximum Flood Dir.	Minimum before Ebb knots	Minimum before Ebb Dir.	Maximum Ebb knots	Maximum Ebb Dir.
		ft	North	West	h m	h m	h m	h m			knots	Dir.	knots	Dir.	knots	Dir.	knots	Dir.
	SAN FRANCISCO BAY, South <8> Time meridian, 120°W					on Golden Gate Bridge, p.12												
171	Rincon Point	9d	37° 47.42'	122° 22.40'	−0 09	−0 32	−0 27	−0 20	0.7	1.3	– –	– –	1.8	149°	0.1	241°	2.1	333°
	... do.	22d	37° 47.42'	122° 22.40'	−0 13	−0 35	−0 25	−0 17	0.7	1.2	– –	– –	1.8	148°	– –	– –	2.0	330°
	... do.	58d	37° 47.42'	122° 22.40'	−0 31	−0 39	−0 21	−0 11	0.5	0.8	0.1	234°	1.4	143°	0.1	051°	1.2	321°
173	Rincon Point, midbay	11	37° 47.00'	122° 21.23'	−0 22	−0 33	−0 38	−0 24	0.8	1.3	– –	– –	2.1	166°	– –	– –	2.1	322°
175	Mission Rock, 0.6 mile east of	8	37° 46.4'	122° 22.1'	−0 09	−0 21	−0 08	+0 06	0.9	1.4	– –	– –	2.5	160°	– –	– –	2.3	320°
177	Mission Rock, 1.3 mile east of	8	37° 46.5'	122° 21.2'	+0 01	−0 31	−0 02	+0 14	0.8	1.2	– –	– –	2.1	182°	– –	– –	2.0	344°
179	Mission Rock, 2.0 miles east of	8	37° 46.6'	122° 20.3'	−0 49	−0 51	−0 18	−0 20	0.6	1.4	– –	– –	1.7	142°	– –	– –	2.3	330°
181	Potrero Point, 1.08 nmi. east of	20d	37° 45.45'	122° 21.47'	−0 08	−0 25	−0 06	−0 04	0.6	1.1	0.1	259°	1.7	169°	0.1	342°	1.8	342°
	... do.	49d	37° 45.45'	122° 21.47'	−0 15	−0 32	−0 05	+0 13	0.4	0.7	0.1	239°	1.2	139°	0.1	055°	1.1	327°
183	Potrero Point, 2 miles east of		37° 45'	122° 20'	−0 08	−0 44	+0 03	−0 02	0.6	1.0	– –	– –	1.6	159°	– –	– –	1.6	328°
185	Alameda Radar Tower, 0.9 nmi. SSW of	4d	37° 44.73'	122° 16.98'	−0 55	−1 14	−1 18	−1 12	0.2	0.4	– –	– –	0.5	132°	– –	– –	0.7	309°
						on San Mateo Bridge, p.20												
187	Point Avisadero, 0.3 mile east of	8d	37° 43.8'	122° 20.9'	−0 30	−0 21	−0 13	−0 20	1.2	1.3	– –	– –	1.6	156°	– –	– –	1.9	337°
189	Point Avisadero, 1 mile east of	8d	37° 43.8'	122° 20.2'	−0 32	+0 02	+0 25	−0 07	1.2	1.0	– –	– –	1.6	154°	– –	– –	1.5	352°
191	Point Avisadero, 2 miles east of	6d	37° 43.9'	122° 18.8'	−0 32	−0 06	−0 10	−0 24	1.1	1.1	– –	– –	1.5	148°	– –	– –	1.6	335°
193	Point Avisadero, 0.6 nmi. ESE of	21d	37° 43.38'	122° 19.43'	−0 32	−0 25	−0 14	−0 39	1.0	1.0	– –	– –	1.4	140°	0.1	064°	1.4	335°
	... do.	37d	37° 43.38'	122° 19.43'	−0 37	−0 23	−0 10	−0 43	0.8	0.7	– –	– –	1.1	132°	0.1	066°	0.9	327°
195	Point Avisadero Tower, 1.25 nmi. SSE of	20d	37° 42.47'	122° 20.97'	−0 45	−0 15	−0 29	−0 52	0.9	0.8	– –	– –	1.2	175°	0.1	274°	1.1	004°
	... do.	32d	37° 42.47'	122° 20.97'	−0 43	−0 06	−0 33	−0 48	0.7	0.6	– –	– –	0.9	186°	0.1	273°	0.8	008°
197	Hunters Point, 1.6nm SE of	5d	37° 41.76'	122° 20.29'	−0 39	−0 37	−0 36	−0 40	0.9	0.9	0.1	113°	1.3	202°	– –	– –	1.3	023°
	... do.	24d	37° 41.76'	122° 20.29'	−0 50	−0 37	−0 37	−0 42	0.7	0.7	– –	– –	1.0	201°	– –	– –	0.9	022°
199	Oakland Airport, southwest of	3d	37° 40.93'	122° 13.85'	−1 05	−0 46	−0 39	−1 18	0.5	0.5	0.1	212°	0.7	125°	– –	– –	0.7	304°
201	Sierra Point, 1.3 miles ENE of		37° 41.08'	122° 21.40'	−0 47	−0 34	−0 25	−0 40	0.8	0.7	– –	– –	1.0	180°	– –	– –	1.0	003°
203	Sierra Point, 1.2 nmi. east of	18d	37° 40.68'	122° 19.05'	−0 42	−0 30	−0 26	−0 22	0.6	0.5	0.1	072°	0.9	210°	0.1	279°	0.8	358°
205	Oyster Point, 2.8 miles east of	8d	37° 39.9'	122° 19.4'	−0 29	−0 20	−0 13	−0 16	0.7	0.8	– –	– –	1.0	172°	– –	– –	1.2	345°
207	Sierra Point, 4.4 miles east of	8d	37° 40.4'	122° 17.7'	−0 48	−0 34	−0 09	−0 33	0.7	0.6	– –	– –	1.0	152°	– –	– –	0.8	329°
209	Point San Bruno, 0.51 nmi. east of	10d	37° 39.25'	122° 21.83'	−1 16	−0 27	−0 21	−1 07	0.5	0.3	– –	– –	0.6	174°	– –	– –	0.5	359°
211	Mulford Gardens Channel Approach	4d	37° 39.00'	122° 15.77'	−1 12	−0 58	−0 43	−1 07	0.7	0.6	– –	– –	1.0	138°	– –	– –	0.8	321°
213	Coyote Point, 2.3 nmi. NNE of	3d	37° 37.53'	122° 17.76'	+0 07	−0 15	−0 17	+0 07	0.8	1.0	0.1	054°	1.1	144°	0.1	236°	1.5	325°
	... do.	12d	37° 37.53'	122° 17.76'	+0 05	−0 18	−0 19	+0 06	0.7	0.9	– –	– –	1.0	144°	– –	– –	1.3	324°
	... do.	22d	37° 37.53'	122° 17.76'	−0 03	−0 18	−0 21	+0 04	0.6	0.7	– –	– –	0.9	144°	– –	– –	1.1	322°
215	Little Coyote Pt., 3.4 nmi. NNE of	4d	37° 37.43'	122° 13.88'	−1 06	−0 54	−0 50	−1 01	0.4	0.4	0.1	220°	0.6	128°	– –	– –	0.6	310°
217	Little Coyote Pt., 3.1 nmi. ENE of	4d	37° 35.88'	122° 12.33'	−1 52	−1 34	−0 58	−1 49	0.4	0.4	0.2	230°	0.5	135°	– –	– –	0.5	317°
219	Little Coyote Pt., 1.2 nmi. NE of	10d	37° 35.42'	122° 14.92'	−0 09	−0 26	−0 11	−0 11	1.1	1.1	– –	– –	1.5	121°	– –	– –	1.5	303°
	... do.	20d	37° 35.42'	122° 14.92'	−0 17	−0 27	−0 07	−0 13	0.9	1.0	0.1	220°	1.3	122°	– –	– –	1.4	307°
	... do.	39d	37° 35.42'	122° 14.92'	−0 24	−0 21	−0 12	−0 09	0.7	0.8	0.1	230°	0.9	138°	– –	– –	1.1	310°
221	San Mateo Bridge	11d	37° 35.27'	122° 15.01'		Daily predictions					– –	– –	1.4	136°	0.1	219°	1.4	298°
	... do.	21d	37° 35.37'	122° 15.01'	−0 03	−0 04	+0 01	−0 02	1.0	1.0	0.1	218°	1.3	136°	– –	– –	1.4	299°
	... do.	30d	37° 35.37'	122° 15.01'	−0 05	−0 09	+0 00	−0 01	0.9	0.9	0.1	220°	1.2	135°	– –	– –	1.3	300°
223	Redwood Pt., Blair I., 1.15 nmi. NNE of	19d	37° 33.48'	122° 11.93'	−0 02	−0 21	−0 02	−0 06	1.0	1.1	– –	– –	1.5	120°	– –	– –	1.5	310°
	... do.	42d	37° 33.48'	122° 11.93'	−0 17	−0 27	−0 10	−0 06	0.8	0.7	0.1	020°	1.0	107°	0.1	021°	1.1	300°
225	Redwood Point, 1.7nm East of	7d	37° 31.84'	122° 09.61'	−0 04	−0 01	+0 00	+0 01	1.1	1.2	– –	– –	1.5	127°	– –	– –	1.7	305°
	... do.	20d	37° 31.84'	122° 09.61'	−0 09	−0 05	−0 02	−0 05	1.0	1.1	– –	– –	1.4	125°	– –	– –	1.6	305°
	... do.	30d	37° 31.84'	122° 09.61'	−0 13	−0 07	−0 07	−0 07	0.9	1.0	0.1	213°	1.2	121°	0.1	034°	1.4	305°
227	Redwood Creek	4d	37° 31.55'	122° 11.95'	−0 36	+0 02	−0 22	−0 56	0.6	0.6	– –	– –	0.9	234°	– –	– –	0.8	051°
	... do.	20d	37° 31.55'	122° 11.95'	−0 40	−0 07	−0 27	−1 03	0.5	0.5	– –	– –	0.7	233°	– –	– –	0.7	049°
229	Dumbarton Highway Bridge	4d	37° 30.11'	122° 06.96'	−0 01	+0 26	−0 07	−0 47	1.1	0.9	0.1	225°	1.5	139°	– –	– –	1.3	320°
	... do.	17d	37° 30.11'	122° 06.96'	−0 16	+0 17	−0 09	−0 49	1.1	0.9	– –	– –	1.5	140°	– –	– –	1.3	319°
	... do.	40d	37° 30.11'	122° 06.96'	−0 50	+0 08	−0 15	−0 55	1.0	0.8	– –	– –	1.3	138°	– –	– –	1.2	318°
231	Dumbarton Hwy. Bridge, 0.28 nmi. SE of	25d	37° 30.08'	122° 06.93'	−0 21	+0 06	+0 02	−0 37	1.0	1.2	0.1	227°	1.4	141°	– –	– –	1.8	319°
	... do.	42d	37° 30.08'	122° 06.93'	−0 36	+0 10	+0 01	−0 45	0.9	0.7	0.1	056°	1.2	137°	– –	– –	1.0	322°
233	Dumbarton Point, 1.15 nmi. SE of	17d	37° 29.25'	122° 04.88'	−0 12	−0 20	+0 12	+0 54	0.8	0.6	– –	– –	1.0	131°	– –	– –	0.8	320°
235	Dumbarton Point, 2.25 miles SE of	8d	37° 28.5'	122° 04.2'	+0 08	−0 06	+0 00	+0 56	0.9	0.8	– –	– –	1.2	127°	– –	– –	1.1	302°
237	Yellow Bluff, 0.81nmi. NE of	19d	37° 50.73'	122° 27.43'	−0 27	−0 28	−0 37	−0 59	1.2	1.1	0.1	302°	1.6	013°	0.1	300°	1.5	211°
	... do.	51d	37° 50.73'	122° 27.43'	−0 42	−0 31	−0 06	−0 33	0.8	0.6	– –	– –	1.0	012°	0.3	297°	0.9	226°

Endnotes can be found at the end of table 2.

Dead reckoning log

Vessel:

From:

To:

Date:

Magnetic variation°:

Leg	Course T°	Course M°	Dist.	ETE	ATE	Speed made good
		Totals:				

Expected average speed:

Speed made good:

Est. Time of Departure:

Actual Time of Departure:

Est. Time of Arrival:

Actual Time of Arrival:

ETE = Estimated Time En route. ATE = Actual Time En route

Convert True to Ship's Compass direction: **T**rue **V**irgins **M**ake **D**ull **C**ompanions, **A**dd **W**hisky
Convert Ship's Compass to True direction: **C**an **D**ead **M**en **V**ote **T**wice **A**t **E**lections

Distance - speed - time calculation: **60D = S * T** (Distance in nautical miles, Speed in knots, Time in minutes)

Dead reckoning log

Vessel: Millenium Falcon

From: Redwood Creek

To: Coyote Point

Date: April 1, 2000

Magnetic variation°: 14° East

Leg	Course T°	Course M°	Dist.	ETE	ATE	Speed made good
RWC mark 2 to South Bay mark 12	300°	286°	0.75	9 min.	10 min.	4.5
South Bay mark 12 to South Bay mark 10	304°	290°	2.5	33 min	34 min	4.4
South Bay mark 10 to South Bay mark 8	304°	290°	2.25	30 min	31 min	4.4
South Bay mark 8 to Coyote Point Marina mark 2	234°	220°	1.25	17 min	17 min	4.4
		Totals:				

Expected average speed: 5 knots

Speed made good: 4.4 knots

Est. Time of Departure: 1400

Actual Time of Departure: 1400

Est. Time of Arrival: 1529

Actual Time of Arrival: 1531

ETE = Estimated Time Enroute. ATA = Actual Time Enroute
Convert True to Ship's Compass direction: **T**rue **V**irgins **M**ake **D**ull **C**ompanions, **A**dd **W**hisky
Convert Ship's Compass to True direction: **C**an **D**ead **M**en **V**ote **T**wice **A**t **E**lections
Distance - speed - time calculation: **60D = S * T** (Distance in nautical miles, Speed in knots, Time in minutes)

Glossary

Term	Definition
Approach buoy	Safe water buoys, also known as approach buoys, are located a safe distance at sea from channel entrances. They are placed so vessels can approach from any direction in order to line up to enter a channel into a harbor safely.
Arc distance	Whenever we refer to points along a line of latitude or longitude, we identify the line in terms of arc distance from its reference line. The reference line for measuring latitude is the equator, and the reference line for measuring longitude is the prime meridian that runs through Greenwich, England. For example, San Francisco Bay is between 37° and 38° north of the equator, and about 122° west of Greenwich.
AtoN	An Aid to Navigation placed on a waterway by the national maritime authority — the Coast Guard in the United States.
Bearing	The direction of one object from another in degrees.
Can buoy	A green lateral navigational buoy marking the left side of a navigable waterway when entering from sea.
Cardinal system	A system of marks used frequently outside U.S. waters that indicate the bearing of a danger from the mark.
Chart	A nautical map.
Chart 1	The authoritative reference for symbols and abbreviations on U.S. charts.
Chart title block	The portion of a nautical chart that states the chart's name, sounding units, projection, scale and datum.
Compass direction	The direction indicated by a compass relative to magnetic north.
Compass rose	A chart marking that indicates true and magnetic directions.
Coordinates	A pair of figures that indicate latitude and longitude for something's position.
Course made good (CMG)	The direction a vessel has actually traveled, also sometimes referred to as the vessel's track.
Current	Horizontal movement of water.
Danger bearing	The bearing to a mark or visible feature that can be used to indicate when a vessel may in a position to hit an unseen danger.

Term	Definition
Datum	A reference point for water depth on a chart. The water level considered a zero tide. May be a calculated number, for example the average all low tides. Or may an absolute figure, such as the lowest astronomical tide. A chart's title block will specify the chart's datum.
Day beacon	An unlighted, fixed navigational mark.
Dead reckoning	Deducing a boat's position using speed, direction and duration of travel from the last fix.
Depth contour	A line on a chart where all points along the line are the same depth.
Deviation	The error to a ship's compass due to the ferrous metals or electrical interference where the compass is installed.
Drift	The speed at which water is flowing.
Ebb	Movement of water away from a region during a tide cycle.
Equator	An imaginary line around the world equidistant from each of the poles.
Fix	A boat's charted position. Can be ascertained by where two or more lines of position cross, for example.
Flood	Movement of water into a region during a tide cycle.
Heading	The direction a vessel is facing.
Latitude	Imaginary lines parallel to the equator that mariners use to describe geographic positions north or south of the equator.
Leeway	The movement of a vessel to leeward due to the effect of wind and/or waves.
Line of Position (LOP)	A line on which a boat's must be located. Lines of position can be a bearing from a charted object, a range, a distance off or a depth contour, among other things.
Longitude	Imaginary lines from the earth's geographic north pole to its geographic south pole that mariners use to describe positions east or west of Greenwich, England.
Magnetic direction	The direction that a compass unaffected by its shipboard installation indicates.
Magnetic variation	The difference due to the orientation of the earth's magnetic field between a compass reading and a true, geographic direction.
Mean high water	The average high tide height over a period of time.
Mean low water	The average low tide height over a period of time.

Term	Definition
Mean lower low water	In a region where the two tide heights in a day are different, the average of the lower of the two low tides over a period of time.
Mercator projection	A method of representing an area on a sphere like the earth on a flat surface. A rhumb line drawn on a chart with a mercator projection will cross each longitude line at the same angle.
Meridian	A line of longitude.
Minus tide	When the tide's height is below datum.
Nautical mile	Defined as one arc minute of latitude. Equal to about 1.15 statute miles.
Nun Buoy	A red lateral navigational buoy marking the right side of a safe waterway for a mariner entering from the sea.
Parallel	A line of latitude.
Pelorus	A device that allows a mariner to measure directions relative to a vessel's heading.
Prime meridian	The reference point for measuring longitude on earth in Greenwich, England.
Projection	Any method of representing a spherical body like the earth on a flat surface.
Range	An aid to navigation with two marks forming a transit that, when lined up, indicate that a vessel is on the center line of channel.
Reference line	A point to measure position from: The equator in the case of latitude; Greenwich, England, in the case of longitude.
Rhumb line	A line is a line that intersects all meridians, or lines of longitude, at the same angle.
Safe water buoy	A buoy used as a reference point for mariners. It can mark where to enter a channel into a harbor or the center of a navigable channel.
Scale	The amount of area covered by a chart relative to the chart's size. For example, each inch of a chart with a scale of 1:60,000 covers 60,000 inches of real area.
Set	The direction of water is flowing.
Slack	The time of minimum movement of water during a tide cycle.
Small-scale	Charts that show a large area in limited detail.
Sounding datum	The zero reference point for measuring heights of tides.

Term	Definition
Sounding units	Depths on charts can be noted in feet, fathoms or meters.
Speed made good (SMG)	A vessel's actual progress as measured by fixes.
Speed of advance	A vessel's calculated speed taking current drift into account.
Speed over ground (SOG)	Same as speed made good.
Tide range	The vertical distance between water level at low tide and the water level at high tide.
Transit	Formed when an observer sights along two charted objects such as landmarks or fixed aids to navigation so that the objects line up one directly behind the other.
True direction	Directions relative to true, geographical north
Variation	See magnetic variation