MARINE NAVIGATION LESSON PLAN

Plot Your Course

Theme

Marine Navigation

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/navops/marinenav/

Subject Area

Earth Science

Grade Level

9-12

Focus Question

What information is provided on nautical charts?

Learning Objectives

- Students will determine distance and direction between selected features on a nautical chart.
- Students will identify obstacles to navigation on a nautical chart.
- Students will identify the characteristics of common aid to navigation described on a nautical chart.

Materials Needed

- Computers with internet access; if students do not have access to the internet, see suggestion in "Learning Procedure" Step 1.
- Copies of "Introduction to Nautical Charts Worksheet" and "Figure 2," one copy for each student or student group
- Rulers or dividers for measuring distance
- Parallel rules or two drafting triangles for transferring course lines to a compass rose

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods, plus time to complete worksheet problems

Seating Arrangement

Classroom style or groups of two to four students

Maximum Number of Students

30

Key Words

Marine navigation
Nautical chart
Aid to navigation
Latitude and longitude
Compass rose
Buoy

Background Information

One of the most fundamental tools used by marine navigators is the navigational chart. The task of charting U.S. coastal waters began in 1807 when President Thomas Jefferson ordered the first survey of the nation's coast. The Office of Coast Survey (OCS) was charged with this task, and is now the oldest scientific organization in the U.S. and is part of the National Ocean Service (NOS). Some of the nation's earliest nautical charts still exist in the OCS Historical Map & Chart Collection which contains over 20,000 documents. The collection also includes topographic and geodetic surveys, city plans and Civil War battle maps. Images of documents in the collection are free to the public via the Coast Survey Web site (visit *http://historicals.ncd.noaa.gov/historicals/histmap.asp* for an image catalog and link to software for viewing downloaded maps).

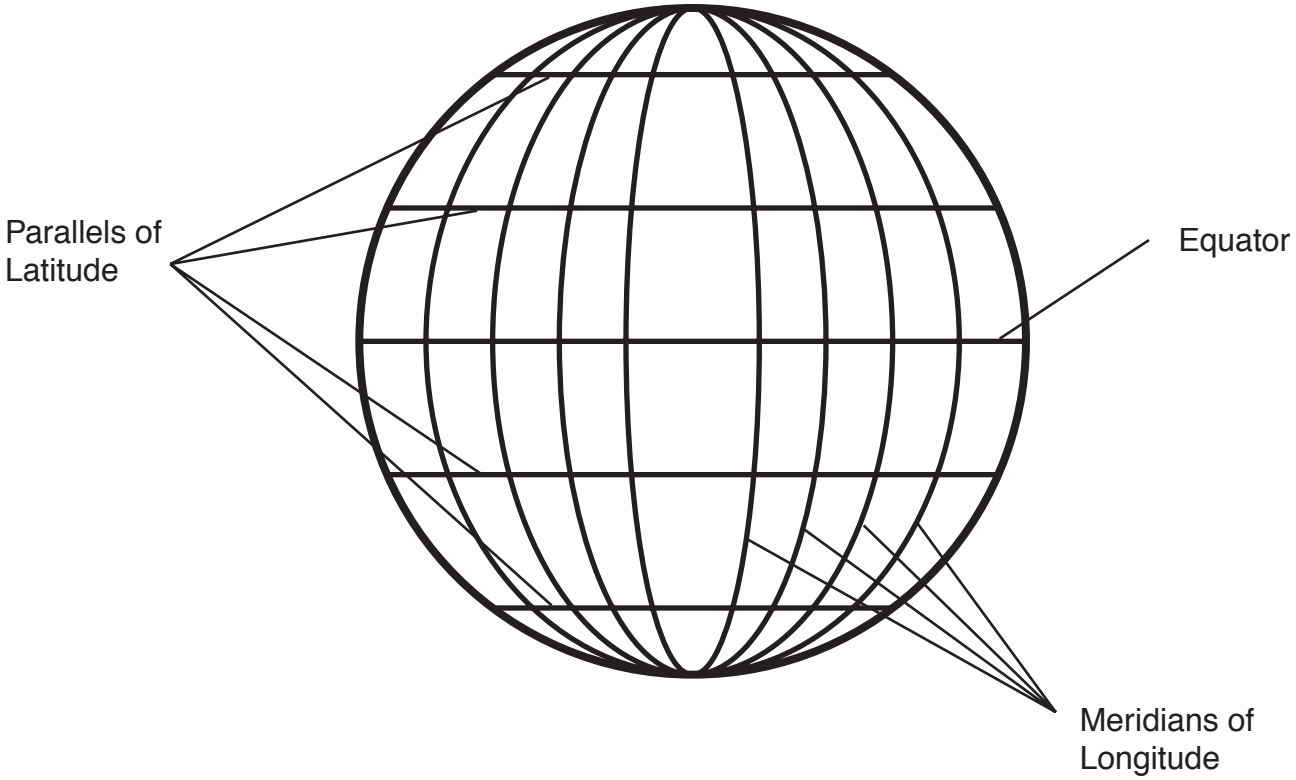
Modern nautical charts provide a graphic portrayal of the marine environment including the general configuration of the sea bottom, water depths, currents, locations of dangers to navigation (e.g., wrecks, rocks, sandbars), and information about aids to navigation (such as buoys, beacons, and conspicuous objects). In addition to traditional paper charts, OCS also produces nautical charts in electronic formats that can be used by computers and electronic navigation instruments

(visit *http://chartmaker.ncd.noaa.gov/staff/charts.htm*). Because some information is difficult to include in a chart format, OCS produces the United States Coast Pilot®, a series of books that contain supplemental information such as channel descriptions, anchorages, currents, tide and water levels, weather, ice conditions, wharf descriptions, dangers, routes, traffic separation schemes, small-craft facilities, and Federal regulations applicable to navigation (visit *http://chartmaker.ncd.noaa.gov/nsd/coastpilot.htm* for more information, downloads, and aerial photographs of harbors). OCS has also created nowCOAST, a map-based internet gateway to real-time observations and forecasts of marine weather and oceanographic conditions. For more information about nowCOAST, and an introductory lesson on how to use this tool, see "Do You Need a Map?" at *http://oceanservice.noaa.gov/education/classroom/18_marinenav.html*.

The primary purpose of a nautical chart is to give a navigator the information needed to decide how a vessel should be maneuvered to safely reach a desired destination. A typical chart includes a great deal of information. Because features shown on nautical charts are often quite close together, symbols and abbreviations are used extensively. A complete list of chart symbols is provided in a booklet known as "Chart No. 1," which can be purchased from marine supply stores or downloaded from *http://nauticalcharts.noaa.gov/mcd/chart1/chart1hr.htm* (the file containing the entire publication is 85 Mb, but smaller files containing specific data are also available).

All nautical charts are based on a system of geographic coordinates that can be used to describe a specific location on a body of water. One of the best-known and most widely used set of geographic coordinates is the latitude–longitude system. This system is based on two sets of imaginary circles on the Earth's surface. One set includes circles that pass through the north and south poles. These circles are known as "meridians of longitude." The other set includes circles that would lie on plane surfaces cutting through the Earth perpendicular to the polar axis (and therefore perpendicular to meridians of longitude). This second set of circles is known as "parallels of latitude" (see Figure 1).

Figure 1: Parallels of Latitude and Meridians of Longitude



Geographic coordinates using the latitude–longitude system are measured in terms of degrees. The reference point for all measurements of longitude is the meridian passing through Greenwich, England; this meridian is called the "prime meridian," and is represented by 0 degrees. The meridian of longitude that passes through any position on Earth is described in terms of how many degrees that meridian is to the east or west of the prime meridian. The maximum in either direction is 180 degrees. Parallels of latitude are measured in terms of how many degrees a given parallel is north or south from the equator (which is assigned a latitude of 0 degrees). Fractions of degrees are expressed in minutes (there are 60 minutes in one degree) and seconds (there are 60 seconds in one minute). Minutes and seconds are sometimes divided decimally for very precise descriptions of geographic location. Each degree of latitude corresponds to sixty nautical miles, so one minute of latitude corresponds to one nautical mile (a nautical mile is equal to about 6,076 ft, or about 1.15 statute miles).

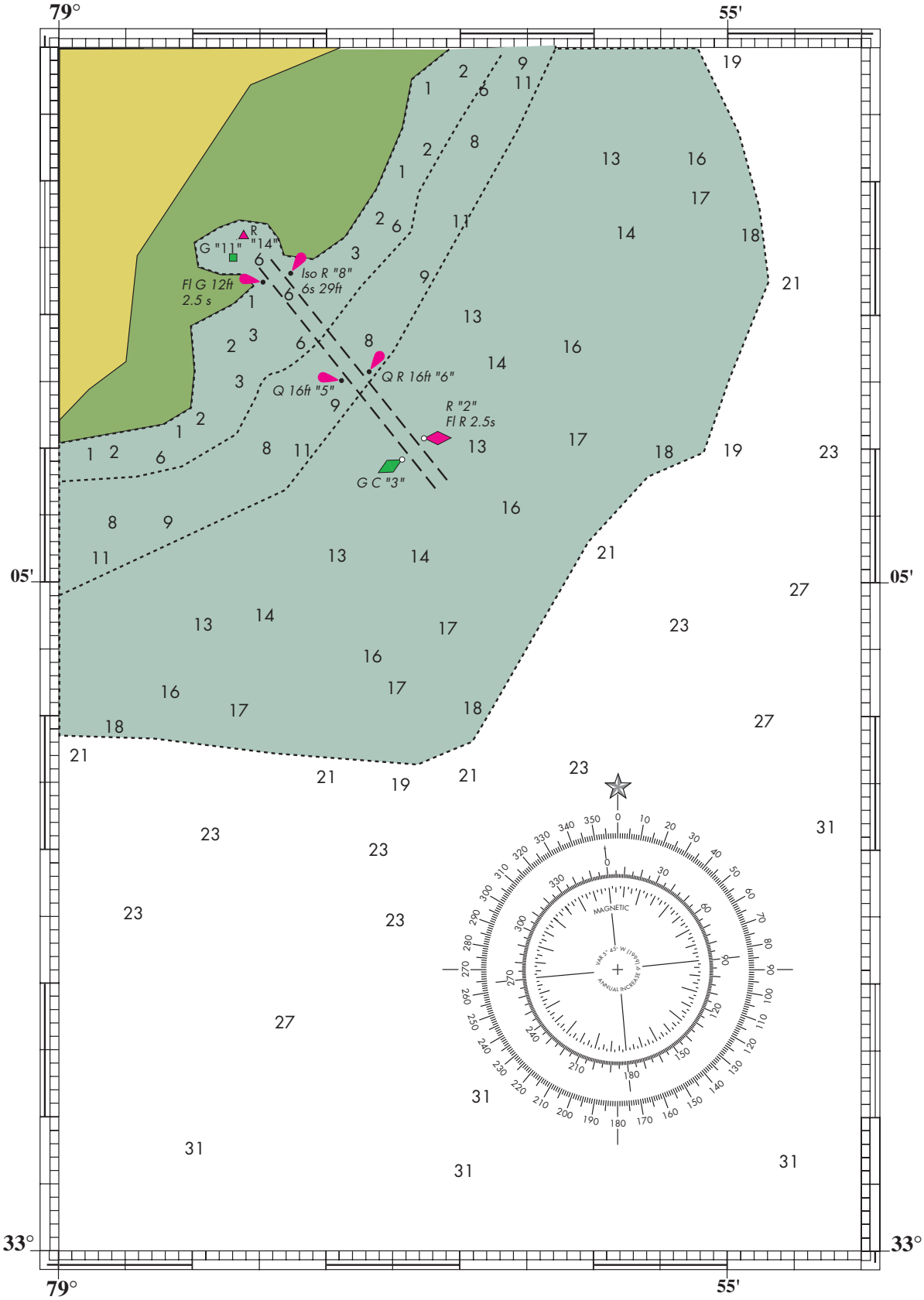
A fundamental problem faced by all mapmakers is how to depict the three-dimensional curved surface of Earth on the

two-dimensional flat surface of a paper chart. To deal with this problem, mapmakers use mathematical constructions known as "projection systems" to approximate Earth's curved surface in two dimensions. One of the most familiar projection systems is the Mercator projection, which is often explained as projection of Earth's surface features onto a cylinder wrapped so that the long axis of the cylinder is parallel to Earth's polar axis and the inner surface of the cylinder touches Earth's equator. A conspicuous feature of the Mercator projection is that meridians of longitude appear as straight vertical lines, and do not converge at the poles. This creates distortion that would significantly alter the shapes of surface features. To minimize this shape distortion, the mathematical procedure for generating a Mercator projection introduces additional distortion to make shapes on the map surface more closely resemble the actual shape of the features being depicted. The main advantage of charts that use the Mercator projection is that the geographic position of an object on the chart can be easily measured using the latitude and longitude scales along the four outer borders of the chart. A straight line drawn between two points on a Mercator chart corresponds to the compass direction between these points, and to the course that should be steered to navigate from one point to the other. Such a line is known as a "rhumb line;" the path of a ship that maintains a fixed compass direction (a rhumb line on a map using the Mercator projection crosses all meridians at the same angle). In addition, the distance between the two points can be easily determined by transferring the length of a line between these points to the latitude scale on the left or right sides of the chart (most often using a pair of dividers), since one minute of latitude corresponds to one nautical mile as described above.

Figure 2 is a simplified example of some features found on nautical charts. Land areas on NOS charts are shown in shades of gold. Areas that are submerged at some point in the tidal cycle are shown in green. Shallow areas of water (in Figure 2, 18 feet or less) are shown in blue, while other water areas are white.

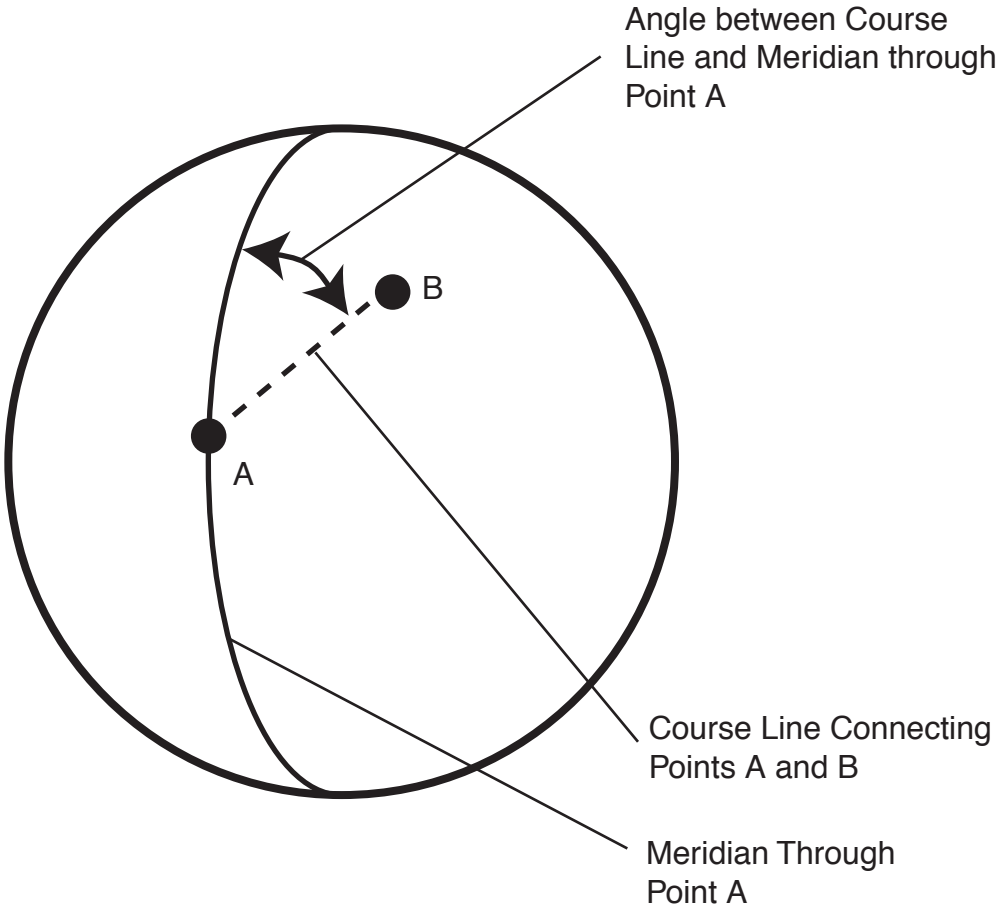
The compass rose is a tool provided on all nautical charts to simplify the process of measuring directions. The most commonly used reference point for direction on nautical charts

Figure 2: A Mock Nautical Chart



is Earth's geographic north pole ("true north"). The direction from one point on Earth's surface to another point on Earth's surface is usually described as the angle between a line connecting the two points and the meridian that passes through the first point. It may be easier to visualize this angle as the compass course that one would follow to move from one point to the next if the compass pointed toward true north (see Figure 3).

Figure 3: Direction Between Two Points on Earth's Surface



This angle is measured in degrees moving clockwise from the meridian. A compass rose on most charts consists of two or three concentric circles, several inches in diameter. Each circle is subdivided into smaller segments. The outer circle is divided into 360 segments (degrees) with zero at true north, usually indicated by a star. The next inner circle describes magnetic direction, also in degrees, with an arrow at the zero point which corresponds to the direction of magnetic north. The innermost circle (if there is one) is also oriented to magnetic

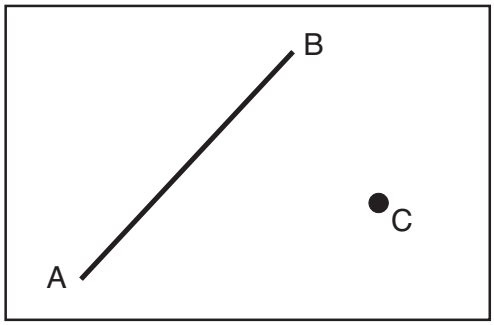
north, but is divided into "points." This is a traditional way to express nautical directions based on subdividing the intervals between the four "cardinal" directions (north, east, south, and west). There are 32 points on the traditional mariner's compass (in this system, the points between north and east are named north, north by east, north-northeast, northeast by north, northeast, northeast by east, east-northeast, and east by north), and each point may be further divided into half- and quarter-points. This system is rarely used, except that north, northeast, east, southeast, etc. are sometimes used to give rough descriptions of direction, particularly wind direction.

To use a compass rose to determine direction (or "bearing") between two points, draw a line from the origin point to the destination point, then transfer the angle of this line to the nearest compass rose on the chart using parallel rulers or a pair of drafting triangles. Parallel rulers are two rulers connected by linkages that keep their edges parallel. To measure direction, line up the edge of one ruler with origin and destination points (or the bearing line), then "walk" the rulers (see Figure 4) to the nearest compass rose by alternately holding one ruler and moving the other until the edge of one ruler intersects the center point of the compass rose. Read the true direction on the scale of the outermost circle of the compass rose. To use a pair of drafting triangles, place the hypotenuses of the triangles together, then line up one of the other sides with the origin and destination points (or the bearing line). Holding one triangle in place, slide the other along the hypotenuse (see Figure 5) to the nearest compass rose, and read the direction as described above.

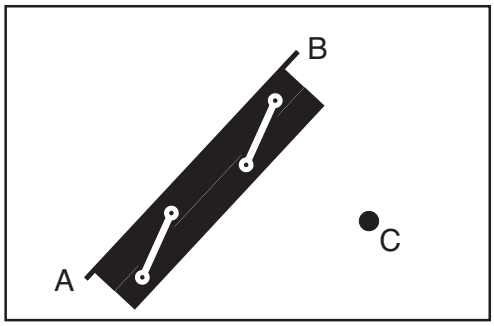
Depths on nautical charts are shown as many small numbers scattered over water areas. Depths indicated by these numbers are expressed in feet, fathoms (one fathom is equal to six feet), or meters. Contour lines (called "depth curves") connect points of equal depth, typically 6, 12, 18, 30, 60 and multiples of 60 feet. Depths shown on NOS charts correspond to depths at "mean lower low water;" in other words the average depth at the lowest tide for each day over a certain period of time (usually 19 years). Because these are average depths, the actual depth at a given location may be less than that shown on the chart.

Figure 4: How to Transfer the Angle of a Line to Another Point Using Parallel Rules

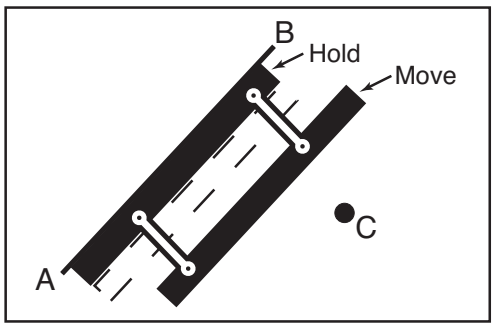
1. The Problem: How to transfer the angle of Line AB to Point C?



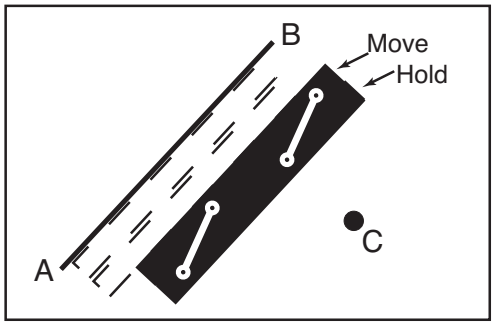
2. Align one edge of the parallel rules with Line AB.



3. Hold the rule next to LineAB, and "walk" the other rule toward Point C.



4. Hold the rule that was "walked," and move the other rule in the direction of Point C.



5. Continue "walking" the rules until Point C is reached. You can now draw a line through Point C that is parallel to Line AB.

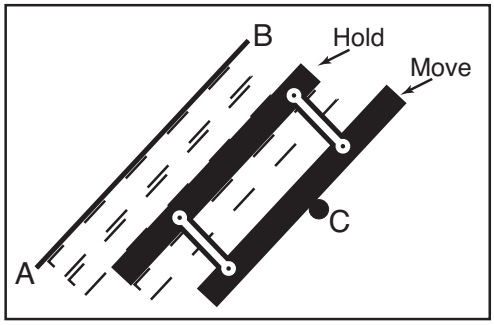
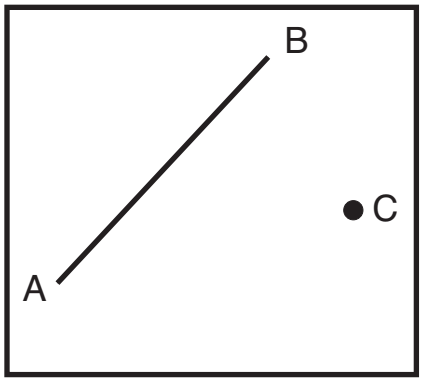
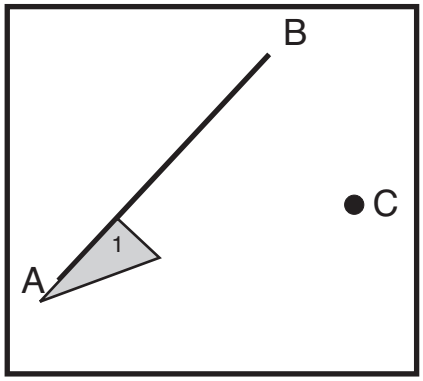


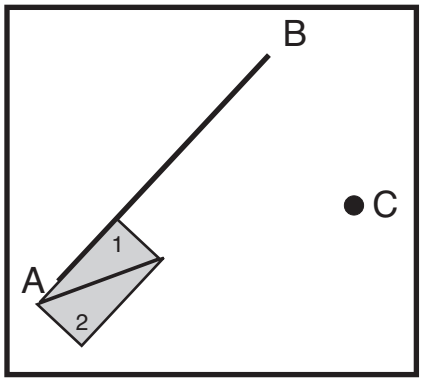
Figure 5: How to Transfer the Angle of a Line to Another Point Using Drafting Triangles



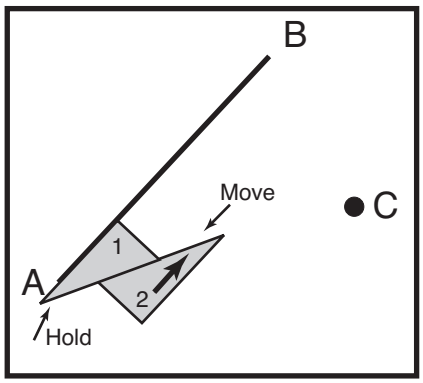
1. The Problem: How to transfer the angle of Line AB to Point C?



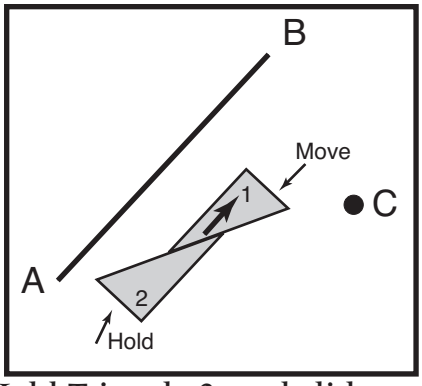
2. Align Triangle 1 so that one of the sides that forms a right angle coincides with Line AB.



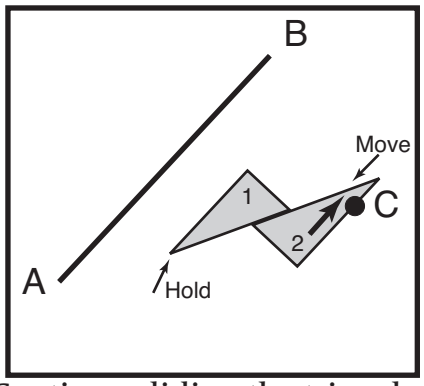
3. Hold Triangle 1 against line AB, and align Triangle 2 so the hypotenuses of the two triangles are touching.



4. Hold Triangle 1 and slide the hypotenuse of Triangle 2 against the hypotenuse of Triangle 1 so that Triangle 2 moves toward Point C.



5. Hold Triangle 2, and slide the hypotenuse of Triangle 1 against the hypotenuse of Triangle 2 so that Triangle 1 moves toward Point C.



6. Continue sliding the triangles until Point C is reached. You can now draw a line through Point C that is parallel to Line AB.

The parallel dashed lines in Figure 2 show a dredged channel. The chart also shows the location and physical characteristics of the buoys, lights, and daybeacons used to show mariners where the sides of the channel are located. Buoys are shown on the chart by diamond-shaped symbols and a small open circle that indicates the location of the buoy. Red buoys are printed in magenta and often have the letter "R" nearby; green buoys are printed in green with the letter "G" nearby. A number in quotation marks is the number painted on the buoy's structure. Lighted buoys are indicated by a magenta disk printed over the small circle that marks the buoy's position. Red buoy number "2" at the outer end of the dredged channel in Figure 2 is a lighted buoy; green buoy number "3" is not lighted. The shape of unlighted buoys is normally shown by a letter. "C' indicates a "can" buoy whose top has a cylindrical shape; "N" indicates a "nun" buoy whose top is shaped like a truncated cone.

Lights on NOS charts are all shown by a magenta "flare" (which looks like the upper part of an exclamation point) and a black dot indicating the light's position. Notes alongside these symbols describe the color and flashing characteristics of each light. In Figure 2:

- [Q] indicates a white light flashing at a rate of not less than 60 flashes per minute (if no color is indicated for a light, it is understood to be a white light; on some charts, the symbol "Qk Fl" may be used instead of "Q" but the meaning is identical)

- [Q R 16ft "6"] indicates a red light, 16 ft high, flashing at a rate of not less than 60 flashes per minute ("quick flashing"), with the number "6" painted on the structure;

- [Iso R "8" 6s 29ft] indicates a red light, 29 ft high, flashing at equal intervals of 3 seconds on followed by 3 seconds off ("6s" is the period of the light in seconds, or time required to complete one flash cycle), with the number "8" painted on the structure (the symbol "E Int" may be used on some charts instead of "Iso" which stands for isophase);

- [Fl G 12ft 2.5s] indicates a green light, 12 ft high, flashing at intervals of 2.5 seconds.

The approximate range of visibility may also be shown for some lights; "6M" would indicate that a light is visible at a maximum range of 6 miles.

Fixed daybeacons (usually a pole driven into the bottom with reflective boards attached to the top of the pole) are indicated on the chart by a small square colored green, or a small triangle colored red. Figure 2 shows two daymarkers, one green numbered "11" and the other red numbered "14."

Actual nautical charts use many other symbols to describe various features useful to marine navigators. See Chart No. 1 for a complete list.

In this lesson, students will use an online version of a nautical chart to create a plan for the safe navigation of a small boat in the Florida Keys.

Learning Procedure

1.

To prepare for this lesson:

- Review the "Background" section;
- Make copies of Figure 2 for each student or student group;
- Work through questions on the "Introduction to Nautical Charts Worksheet;" and
- Download the following sections of Chart No. 1 from *http://nauticalcharts.noaa.gov/mcd/chart1/chart1hr.htm*

  From the "Hydrography" section:

  "Nature of the Seabed" (3 pages, 2.4 MB)

  "Rocks, Wrecks, Obstructions" (4 pages, 4.5 MB)

  From the "Aids and Services" section:

  "Lights" (7 pages, 5.9 MB)

  "Buoys, Beacons" (8 pages, 7.7 MB)

The worksheet assumes that students will be using an online version of chart number 11445. If students do not have classroom internet access, this worksheet may be done as a homework assignment using other internet resources, or you may purchase paper copies of chart number 11445 (visit *http://chartmaker.ncd.noaa.gov/staff/charts.htm* for purchase options).

2.

Briefly review the historical and present-day importance of marine navigation. While the prevalence of air travel and advances in aerospace technology may cause some students to assume that the ability to safely navigate Earth's ocean is of diminishing importance, consideration of the ocean's role in freight transportation, energy production, and recreation should alleviate this misconception. In addition, the ability to safely navigate coastal waters is personally relevant to anyone who enjoys fishing or boating.

Discuss the importance of nautical charts to marine navigation, and briefly review the concepts of the latitude–longitude system of geographic coordinates, meridians of longitude and parallels of latitude, and major features of typical nautical charts including compass rose, latitude and longitude scales, depths, and symbols for buoys, lights, and daybeacons. You may want to demonstrate how distance and direction can be determined from a chart (Worksheet Steps 1 and 2), or have students do this on their own.

3.

Provide a copy of the "Introduction to Nautical Charts Worksheet" and Figure 2 to each student or student group. Have one or more copies of the downloaded sections of Chart No. 1 available for reference. Tell students that their assignment is to take an imaginary cruise around some of the Florida Keys, and use chart 11445 to answer questions on the Worksheet.

4.

Lead a discussion of students' answers to Worksheet questions. The correct responses are:

1. The distance between green daymarker number "11" and green can buoy number "3"? is 2.0 nautical miles.

2. The true course to steer from green daymarker number "11" to green can buoy number "3" is about 141°.

3. Three shipwrecks are shown between the channel outside the marina on Ohio Key and Bahia Honda Key.

4. Light # "2" is a red light, 16 ft high, flashing every 4 seconds.

5. You will have to pass under the bridges to the west of Bahia Honda Key, because the "bridge note" indicates that the bridge between Ohio Key and Bahia Honda Key only has a vertical clearance of 7 feet.

6. The seabed in the vicinity of the fish haven at latitude 24°37'N, longitude 81°18'W may consist of mud or a mixture of sand and shells (shown as "M" and "S Sh" on the chart).

7. Numerous coral reefs, indicated by "Co" on the chart, are in the vicinity of Newfound Harbor Keys.

8. The buoys near the Newfound Harbor Keys mark the Newfound Harbor Sanctuary Preservation Area, which is part of the Florida Keys National Marine Sanctuary (visit *http://floridakeys.noaa.gov/* for more information about the Florida Keys NMS). The lighted buoys are colored white and orange in horizontal bands, with white lights that flash once every 4 seconds. The unlighted buoys are yellow "cans", and are marked "A", "B", "C", and "D."

9. The water depth between Big Munson Island and Hopkins Island is less than one foot, and the seabed is a combination of rock ("rky") and grass; so this would not be a good way to get to Ramrod Key.

10. The northern edge of the red sector of American Shoal Light is about halfway between the western end of Big Munson Island and Looe Key, so it should take about 5 more minutes to reach Looe Key.

11. The flashing red light with a period of 2.5 seconds is on Big Pine Shoal.

12. There is a small island to the southwest of Bahia Honda Key that has no light or other navigational aid. You could use a depth sounder to be sure that you stay in at least 20 feet of water.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Human Activities," then "Maritime Heritage" for links to resources about the historical development of marine navigation.

The Me Connection

Have students write a brief essay describing why nautical charts are important to people who are not marine navigators.

Extensions

Have students use NOAA's On-Line Chart Viewer to develop a set of directions for their own "cruise" of an assigned coastal area, including important features and navigation aids noted from the chart(s).

Resources

http://historicals.ncd.noaa.gov/historicals/histmap.asp – OCS Historical Map & Chart Collection which contains over 20,000 documents that also include topographic and geodetic surveys, city plans and Civil War battle maps.

http://chartmaker.ncd.noaa.gov/nsd/coastpilot.htm – Description and links for downloading the United States Coast Pilot®

http://chartmaker.ncd.noaa.gov/staff/charts.htm – Information and links for nautical charts

http://www.ruf.rice.edu/~feegi/index.html – Links and resources about 15th century navigation from Rice University

Maloney, E.S. 2003. Chapman Piloting & Seamanship. The complete reference for small boat handling and navigation.

http://www.usm.maine.edu/maps/lessons/nrindex.htm – "Charting Neptune's Realm: From Classical Mythology to Satellite Imagery," a series of lesson plans from the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland

Heyerdahl, T. 1979. Early Man and the Ocean: A Search for the Beginnings of Navigation and Seaborne Civilizations. Doubleday. New York. 438 pp.

National Science Education Standards

Content Standard D: Earth and Space Science

- Energy in the Earth system

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H3 – Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

MARINE NAVIGATION WORKSHEET

INTRODUCTION TO NAUTICAL CHARTS

1. Refer to Figure 2. What is the distance between green day-marker number "11" and green can buoy number "3"?

2. What true course would you steer to travel from green day-marker number "11" to green can buoy number "3"?

3. Open the NOAA online chart viewer for the Atlantic coast at *http://www.nauticalcharts.gov/viewer/AtlanticCoastTable.htm*, and select chart number 11445 ("Intracoastal Waterway Bahia Honda Key to Sugarloaf Key"). The "NOAA Online Viewer" window will open, with an overview of the entire chart on the left side of the window, and a detail window on the right that can be zoomed and panned to see portions of the chart in greater detail. The black square containing a smaller red square in the overview window shows the portion of the chart that is currently displayed in the detail window. If you click on a portion of the the overview window, these squares and the detail window will shift to that location.

   Use the pan and zoom buttons to display chart details around Bahia Honda Key and Ohio Key. These islands are located on the right side of the chart, about halfway between the top and bottom of the chart. Use the navigation buttons to reposition the detail window on the chart as you take an imaginary cruise around the Florida Keys, and answer the following questions:

   Locate the marina on the northwest corner of Ohio Key, and the channel just outside the marina. What obstructions are shown between the channel and Bahia Honda Key?

4. What are the characteristics of light # "2" at the north end of the channel?

5. You are piloting a boat from the marina on Ohio Key, and want to go fishing in the Atlantic Ocean south of Bahia Honda Key. What is the shortest route to this area if the highest point on your boat is 10 feet above the waterline? (Hint: Check the "bridge note" at the top of the chart.)

6. Now that you are south of Bahia Honda Key, you decide to check out the fish haven located at about latitude 24°37′N, longitude 81°18′W. What type of seabed do you expect in this area?

7. After catching enough grouper for tonight's dinner, you decide to do some snorkeling near Newfound Harbor Keys, which are approximately west of the fish haven. What seabed features are you likely to see in this area?

8. As you approach the Newfound Harbor Keys, you see eight buoys clustered around a small area. What color are the lighted buoys, and what are the characteristics of their lights?

What color are the unlighted buoys, what is their shape, and how are they marked?

What feature are these buoys supposed to mark?

9. You work up a strong appetite snorkeling, and decide to have lunch at the marina on Ramrod Key. Can you get to Ramrod Key by going between Big Munson Island and Hopkins Island?

10. After lunch, you leave Ramrod Key and pass flashing red light number "2" off the western end of Big Munson Island, heading for Looe Key (near the bottom of the chart). After 5 minutes, you notice that the color of the light on American Shoal suddenly changes from white to red. About how much longer will it take to reach Looe Key?

11. After snorkeling at the Looe Key National Marine Sanctuary it's getting dark, so you decide to head back to Bahia Honda Key. A red light is visible to the northwest, flashing about four times every 10 seconds. Where is this light?

12. You steer a straight course from Looe Key to Bahia Honda Key. What obstacle do you need to worry about before you pass under the bridges between Bahia Honda Key and Spanish Harbor Keys? How could you use a depth sounder to stay out of danger?

MARINE NAVIGATION WORKSHEET

INTRODUCTION TO NAUTICAL CHARTS
Teacher Answer Key

1. Refer to Figure 2. What is the distance between green day-marker number "11" and green can buoy number "3"?
[Using the latitude scale, the distance is 2.0 nautical miles.]

2. What true course would you steer to travel from green day-marker number "11" to green can buoy number "3"?
[The correct course is about 141°]

3. Open the NOAA online chart viewer for the Atlantic coast at *http://www.nauticalcharts.gov/viewer/AtlanticCoastTable.htm*, and select chart number 11445 ("Intracoastal Waterway Bahia Honda Key to Sugarloaf Key"). The "NOAA Online Viewer" window will open, with an overview of the entire chart on the left side of the window, and a detail window on the right that can be zoomed and panned to see portions of the chart in greater detail. The black square containing a smaller red square in the overview window shows the portion of the chart that is currently displayed in the detail window. If you click on a portion of the the overview window, these squares and the detail window will shift to that location.

   Use the pan and zoom buttons to display chart details around Bahia Honda Key and Ohio Key. These islands are located on the right side of the chart, about halfway between the top and bottom of the chart. Use the navigation buttons to reposition the detail window on the chart as you take an imaginary cruise around the Florida Keys, and answer the following questions:

   Locate the marina on the northwest corner of Ohio Key, and the channel just outside the marina. What obstructions are shown between the channel and Bahia Honda Key?
[Three shipwrecks]

4. What are the characteristics of light # "2" at the north end of the channel?
[A red light, 16 ft high, flashing every 4 seconds]

5. You are piloting a boat from the marina on Ohio Key, and want to go fishing in the Atlantic Ocean south of Bahia Honda Key. What is the shortest route to this area if the highest point on your boat is 10 feet above the waterline? (Hint: Check the "bridge note" at the top of the chart.)
[You will have to pass under the bridges to the west of Bahia Honda Key, because the "bridge note" indicates that the bridge between Ohio Key and Bahia Honda Key only has a vertical clearance of 7 feet.]

6. Now that you are south of Bahia Honda Key, you decide to check out the fish haven located at about latitude 24°37'N, longitude 81°18'W. What type of seabed do you expect in this area?
[Mud or possibly a mixture of sand and shells (shown as "M" and "S Sh" on the chart).]

7. After catching enough grouper for tonight's dinner, you decide to do some snorkeling near Newfound Harbor Keys, which are approximately west of the fish haven. What seabed features are you likely to see in this area?
[Numerous coral reefs, indicated by "Co" on the chart.]

8. As you approach the Newfound Harbor Keys, you see eight buoys clustered around a small area. What color are the lighted buoys, and what are the characteristics of their lights?
[The lighted buoys are colored white and orange in horizontal bands; with white lights that flash once every 4 seconds.]

What color are the unlighted buoys, what is their shape, and how are they marked?
[The unlighted buoys are yellow "cans", and are marked "A", "B", "C", and "D."]

What feature are these buoys supposed to mark?
[The yellow and white/orange buoys mark the Newfound Harbor Sanctuary Preservation Area, which is part of the Florida Keys

National Marine Sanctuary (visit http://floridakeys.noaa.gov/ for more information about the Florida Keys NMS).]

9. You work up a strong appetite snorkeling, and decide to have lunch at the marina on Ramrod Key. Can you get to Ramrod Key by going between Big Munson Island and Hopkins Island?
[The water depth between Big Munson Island and Hopkins Island is less than one foot, and the seabed is a combination of rock ("rky") and grass; so this would not be a good way to get to Ramrod Key.]

10. After lunch, you leave Ramrod Key and pass flashing red light number "2" off the western end of Big Munson Island, heading for Looe Key (near the bottom of the chart). After 5 minutes, you notice that the color of the light on American Shoal suddenly changes from white to red. About how much longer will it take to reach Looe Key?
[The northern edge of the red sector of American Shoal Light is about halfway between the western end of Big Munson Island and Looe Key, so it should take about 5 more minutes to reach Looe Key.]

11. After snorkeling at the Looe Key National Marine Sanctuary it's getting dark, so you decide to head back to Bahia Honda Key. A red light is visible to the northwest, flashing about four times every 10 seconds. Where is this light?
[The flashing red light with a period of 2.5 seconds is on Big Pine Shoal.]

12. You steer a straight course from Looe Key to Bahia Honda Key. What obstacle do you need to worry about before you pass under the bridges between Bahia Honda Key and Spanish Harbor Keys? How could you use a depth sounder to stay out of danger?
[There is a small island to the southwest of Bahia Honda Key that has no light or other navigational aid. You could use a depth sounder to be sure that you stay in at least 20 feet of water.]