OCEAN CURRENTS LESSON PLAN
Ready, Set, Drift!

Theme
Coastal ocean currents

Links to Overview Essays and Resources Needed for Student Research
http://oceanservice.noaa.gov/topics/navops/ports/
http://oceanservice.noaa.gov/education/kits/currents

Subject Area
Physical Science/Earth Science

Grade Level
9-12

Focus Question
How can navigators of ships and boats predict and compensate for the effects of coastal ocean currents?

Learning Objectives
- Students will define and explain the terms set, drift, course over the ground, and speed over the ground.
- Students will use online databases to recover specific data on water movement for selected geographic areas.
- Students will use information about currents, winds, and tides to solve practical problems relevant to coastal navigation.
- Students will demonstrate the use of a maneuvering board in solving problems involving ocean currents and navigation.

Materials Needed
- (Optional) Computers with internet access; if students do not have access to the internet, download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group
- Copies of "Navigating with Currents Worksheet," one copy for each student or student group

- Copies of Figure 2 (maneuvering board) at least four copies for each student or student group
- Parallel rules or drafting triangles, one for each student or student group (see Learning Procedure Step 3)

Audio/Visual Materials Needed

None

Teaching Time

One 45-minute class period, plus time for student research

Seating Arrangement

Classroom style or groups of 3-4 students

Maximum Number of Students

30

Key Words

Ocean current
Set
Drift
Maneuvering board
Navigation

Background Information

Ocean currents are caused by three driving forces. The first is tidal motion resulting from the gravitational attraction of the moon and the sun. The second is wind motion acting on the ocean through friction with the ocean's surface. Finally, when the density of one water mass is different from the density of another water mass, the more dense water mass tends to move beneath the less dense water mass (when this happens, the water masses are said to move toward "equilibrium positions"). Such density differences are the result of variations in temperature and salinity (the concentration of dissolved substances such as sodium chloride, salts of magnesium and calcium, etc.) among different water masses. Water movement caused by these differences is known as "thermohaline circulation."

Regardless of their cause, ocean currents are critical to life on Earth, as they transport food materials, as well as certain life stages of some organisms (e.g., seeds, eggs, larvae, juveniles,

adults) over thousands of miles. In addition, ocean currents have a major impact on global climate, transferring heat from equatorial regions to higher latitudes (e.g., the Gulf Stream in the Atlantic Ocean and the Kuroshio Current in the Pacific). At a much smaller scale, currents can be a serious issue for swimmers since strong "rip" currents can quickly move a swimmer away from the shore. Similarly, anyone who operates a boat in coastal waters needs to understand the movement of currents and how to handle their effects. Shipmasters, in particular, need accurate real-time information about coastal water movements to avoid dangerous and expensive groundings and collisions.

Providing this information is part of the mission of NOAA's Center for Operational Oceanographic Products and Services (CO-OPS). This Center:
- provides information on water levels, coastal currents, and tides;
- establishes standards for collecting and processing these data;
- conducts research into new or improved oceanographic observing systems;
- designs software to improve data processing capabilities;
- performs regular data analysis and quality control of data; and
- disseminates this information to the public.

CO-OPS also manages a national network of Physical Oceanographic Real-Time Systems (PORTS®) located in major U.S. harbors. The PORTS® network provides real-time information such as water levels, currents, air gap (the clearance between the water surface and the bottom of a bridge), weather data, and other oceanographic information to help mariners avoid groundings and collisions (visit *http://tidesandcurrents.noaa.gov/products* for more information on CO-OPS information and data products; and *http://tidesandcurrents.noaa.gov/programs* for more information on PORTS® and other CO-OPS programs)

In this lesson, students will explore some of the information available through the CO-OPS program Web site, and will apply this information to hypothetical coastal navigation problems.

Learning Procedure

1.

To prepare for this lesson, review the introductory information on tides and currents at *http://oceanservice.noaa.gov/topics/navops/ports/* and *http://oceanservice.noaa.gov/education/kits/currents*, as well as the "Navigating with Currents Worksheet." Make copies of these worksheets, and extra copies of the M Board (Figure 2), at least four for each student or student group.

You may also want to review the "Tides and Water Levels" Discovery Kit (*http://oceanservice.noaa.gov/education/kits/tides/*), which offers a tutorial on the complex systems that govern the movement of tides and water levels, a "Roadmap to Resources" that directs you to specific tidal and current data, and lesson plans for students in grades 9–12.

2.

If students have not completed the "Motion in the Ocean" lesson, you may want to direct them to the Currents Tutorial at *http://oceanservice.noaa.gov/education/kits/currents*. If students do not have access to the internet, you will need to make copies of the Currents Tutorial for each student or student group.

If you have not already done so, discuss the importance of real-time information to safe navigation, and have students brainstorm the types of information that would be useful to a present-day mariner. Tell students that their assignment is to learn how some of this information can be used to solve practical problems involving coastal navigation.

3.

Provide a copy of the "Navigating with Currents Worksheet" to each student or student group, and have students work through introductory material to learn how to solve the problems at the end of the worksheet. You may need to demonstrate how to transfer angles using parallel rules or triangles, if students are unfamiliar with this procedure (see Figures 4a and 4b).

4.

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

(1) Figure 5 shows the solution to the problem. 6 am (PDT) corresponds to 1300 UTC. At 1300 UTC on September 18, 2005, the current at Richmond was setting 341° with a drift of 1.28 knots. Drawing the vectors as described in the example produces the solution shown in Figure 5 (each circle represents a distance of one nautical mile). The course over the ground is 054° and the speed over the ground is 8.2 knots.

(2) Figure 6 shows the solution to the problem. At 0400 UTC on April 12, 2005, the current at Bolivar Roads was setting 113° with a drift of 2.5 knots. First, draw the vector for the desired course over the ground from the origin with an angle of 020°. The length (which corresponds to speed over the ground) isn't known at this point, so just draw the line to the edge of the outer circle (Fig. 5A). Next, let each circle represent one nautical mile, and draw the current vector from the origin with an angle of 113° and a length of 2.5 circles (Fig. 5B). Transfer the current vector so that the head of the current vector touches the course over the ground vector, and the tail of the vector touches the sixth circle (which represents a distance of 6 nautical miles, and corresponds to the vessel's speed through the water; Fig 5C). Finally, draw the course steered vector from the origin to the tail of the current vector (Fig. 5D). The course to steer is 354°, and the speed over the ground is approximately 5.3 knots.

(3) The ebb tide on July 3, 2005 occurred from 0400 – 0930 UTC (0000 – 0630 EDT) and 1600 – 2300 UTC (1200 – 1900 EDT).

(4) Low tide at Eastport on Dec 23 and 24, 2005 occurred at 1506 UTC and 1600 UTC respectively. So the required interval was 1306 – 1706 UTC on Dec 23 and 1400 – 1800 UTC on Dec 24.

(5) 6:40 am CST corresponds to 1240 UTC. At this time on January 3, 2003, the current at Bolivar Roads was setting 118° with a drift of 1.5 knots. Two hours later, the current was setting 107° with a drift of 2.1 knots. Averaging these values, the victim could be estimated to have drifted 3.6 nautical miles on a bearing line of 113°.

(6) Students should use the "Tide Data" and "Meteorological" buttons in the "Data Type" list. 11:30 am (EDT) corresponds to 1530 UTC. Ebb tide at Trident Pier on April 12, 2006 occurred approximately between 1200 and 1800 UTC. At 1530 UTC, winds were blowing at 17.11 knots from 053°, gusting to 23.7 knots from 074°. Since these are essentially easterly winds coinciding with an ebb tide, the boater would be well advised to choose another time to attempt the inlet.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Physics," then one of the headings at the top of the page for links and resources about tides, waves, and currents.

The Me Connection

Have students write a short essay or fictional story about on how information about coastal winds, tides, and currents could be personally important.

Extensions

1. Visit the "Tides and Water Levels" Discovery Kit (*http://oceanservice.noaa.gov/education/kits/tides/*) for additional resources and lesson plans.

2. Visit *http://www.usm.maine.edu/maps/lessons/nr11.htm* and *http://www.usm.maine.edu/maps/lessons/nr11.htm* for additional lesson plans and activities about currents from the University of Southern Maine's Osher Map Library.

3. Visit Multimedia Learning Objects at *http://www.learningdemo.com/noaa/* Click on the links to Lessons 8 and 9 for interactive multimedia presentations and Learning Activities on Ocean Currents and Ocean Waves, including an activity involving landing safely on an aircraft carrier by allowing for the Coriolis Effect.

Resources

http://oceanservice.noaa.gov/education/kits/tides/ – NOAA's "Tides and Water Levels" Discovery Kit

http://tidesandcurrents.noaa.gov – NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) Web page, with links to data and information about tides, water levels, currents, predictions, weather observations, forecasts, and harmonic constituents

http://www.usm.maine.edu/maps/lessons/nr10.htm and http://www. usm.maine.edu/maps/lessons/nr11.htm – Lesson plans and activities about currents from the University of Southern Maine's Osher Map Library

http://www.eeb.ucla.edu/test/faculty/nezlin/PhysicalOceanography.htm — Online tutorial with additional details about ocean currents

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard D: Earth and Space Science
- Energy in the Earth system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

OCEAN CURRENTS WORKSHEET
Navigating with Currents

The purpose of this lesson is to learn how to obtain real-time ("right-now" or nearly right-now) and historic data about tides and currents, and to explore some practical ways in which these data might be used.

Retrieving CO-OPS Data

Data on water levels, currents, weather, and other information important to mariners is provided for many U.S. coastal areas by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS). The CO-OPS interactive Data Map provides an easy way to access these data:

(1) Open the Data Map Web page at *http://tidesandcurrents. noaa.gov/station_retrieve.shtml*, and click on "INTERACTIVE MAP." A new window will open containing a map of North America and a smaller world map, as well as a tool bar on the left side of the page.

(2) Nine different types of data are listed beneath "Data Type." To select the data you want to retrieve, click on the button to the left of your selection so that a black dot appears in the middle of the button. For this example, click the button next to "Currents." The map will re-draw, so that orange squares appear at the locations for which current data are available.

(3) Use the six tools under "Navigation" and the two tools under "Data" to navigate around the map and retrieve the information you want:

(a) Use the Zoom In tool by selecting the magnifying glass icon with a plus sign, then click once on the map or click and drag to draw a rectangle around the area you wish to zoom into.

(b) Use the Zoom Out tool by selecting the magnifying glass icon with a minus sign, then click once on the map.

(c) Pan around the map by selecting the hand icon, then click and drag across the map in any direction.

(d) You can return to the previous view of the map by clicking on the magnifying glass icon with a black arrow on top.

(e) Zoom to the fullest possible extent on the map by clicking the empty magnifying glass on top of the yellow symbol.

(f) Zoom to the fullest possible extent of the data type currently selected by clicking the empty magnifying glass on top of the yellow and red symbol.

(g) Link to the data from a particular station by selecting the Link to Station Data tool (lightning bolt), then click on the desired station on the map.

(h) To retrieve information about a particular stations (such as exact location), select the Link to Station Information tool (circle with an "i" in the center), then click on the desired station on the map.

If you do not see labels for the stations, they will appear when you zoom in closer.

(4) For this example, select the Link to Station Data tool, and zoom in so that two orange squares are visible on the western side of Florida. Now, click on the orange square labelled "Old Port Tampa." A new window should appear showing a graph of current speed and direction at Old Port Tampa during the last 48 hours. Beneath the graph are eight windows in which you can specify another date and time range for which current data are desired. For this example, set the "Begin Date:" to 05/16/2005 00:00 and the "End Date:" to 05/17/2005 23:00. When you have set these values, click on the "View Plot" button to display a graph of current data for the new date range. Alternatively, you can click on "View Tabular Data" which will return a text listing of each data point for the specified date range.

Using the specified date range, you should see a graph showing seven cycles in which current speed increases from nearly zero to a maximum, then declines to nearly zero again. The maximum speed in these cycles varies from about 0.5 knots to about 1.1 knots, and the time required to complete a cycle varies from about 5 hours to about 8 hours. Notice that the direction of the current is shown by the gray line on the graph, which refers to the "Direction (true)" scale on the right side of the graph. "True" means that these directions are referenced to "true north," which is the true direction of the north pole rather than the direction indicated by a compass which is often distorted by Earth's magnetic field and other influences. So, during the first current cycle on 5/16/2005 (between 00:00 and 08:00) the direction of the current flow was about 220° (roughly southwest). During the next current cycle (between 08:00 and 16:00) the direction of the current flow was about 30° (roughly north-northeast). Why the difference? We might suspect tidal influences, so let's check that out. But first, print a copy of the current graph for future reference.

(5) To find out what the tide was doing in Old Port Tampa on the same dates, click on the "Products" tab near the top of the window, scroll down to "Tides," then across to "Active Stations." A new window will open titled "Tide Data - Station Selection." Scroll down to station number 8726607 in the right column (which is Old Port Tampa). Click on this station, and a graph will appear showing tide heights for the last 48 hours. Change the date range as in step 4, and click on the "View Plot" button. A new graph will appear for 05/16/2005, 00:00 through 05/17/2005, 23:00. Compare this graph to the printed copy of your graph for currents at Old Port Tampa on the same dates. Notice that the first minimum current occurred at about 0800 on 5/16/2005, which coincides with the first low water level on the tide graph. This was the time at which tidal flow changed from ebb (falling tide) to flood (rising tide). So the direction of the current during the ebb tide was about 220°.

The second minimum current occurred at about 1600 on 5/16/2005, and coincided with the first high water level, as

the tidal flow changed from flood to ebb. So it seems that current flow during the flood tide was in a north-northeast-erly direction.

Similarly, the third and fourth minimum current times coincided with the second low and high water levels respectively. Notice that the second "low water" was not as low as the first, and that the corresponding tidal current did not achieve the same speed as currents that coincided with the larger tidal range; but the general direction of the ebb and flood currents was about the same.

Finding the Effects of Currents on a Vessel's Course and Speed

Mariners refer to the direction of a current as the current's "set," and called the speed of a current its "drift." One of the basic navigation skills is knowing how to steer a vessel to compensate for the effects of current on the vessel's course and speed. In confined areas such as rivers or channels in harbors, the basic concern is steering a course that allows the mariner to safely navigate the passage. In open waters, the issues are:

- What is the vessel's actual course (called the "course over the ground") after the current has altered the course steered; and
- What is the vessel's actual speed (called the "speed over the ground") after the current has altered the vessel's speed through the water.

The simplest cases are those in which a vessel runs directly against a current or directly with the current. In these cases, the set of the current has no effect on the course over the ground, and the effect on speed over the ground is simply a matter of addition or subtraction. If a vessel has a speed of 8 knots through the water, and runs with a 2-knot current, the speed over the ground is 8 + 2 = 10 knots. If the vessel runs directly against this current, her speed is 8 - 2 = 6 knots.

If the current sets at an angle (other than 180°) to the vessel's course, the course over the ground and speed over the ground will be different from the course steered and the speed through the water. In Figure 1, the vessel is steered on course 090° at a speed of 12 knots. A current setting 180° with a drift 3 knots will deflect the vessel so that her course over

the ground is line AC rather than line AB. So in one hour, she will have travelled sideways the distance BC. Her speed over the ground will be the distance AC divided by the time (one hour). You can solve this right triangle for AC using the Pythagorean theorem:

$$AC^2 = AB^2 + BC^2$$

$$AC^2 = (12)^2 + (3)^2$$

$$AC^2 = 144 + 9 = 153$$

$$AC = 12.36$$

In practice, a current rarely sets exactly 90° to the course steered, so the Pythagorean theorem cannot be used. The simplest way to solve the problem is to plot the vectors (vessel's course steered and speed through the water, and the current's set and drift) on a suitable scale, then measure the resultant vector (AC in the example above) on the same scale. Professional navigators use a printed form called a Maneuvering Board (also known as an "M Board" or "Mo Board") to simplify this kind of plotting. A basic M Board consists of a series of equally spaced concentric circles called "distance circles, 36 radial lines called "bearing lines, and a circular scale outside the largest circle. M Boards published by the National Imagery and Mapping Agency also have several other scales printed outside the circles, as well as a nomograph for solving time-speed-distance problems. For this lesson, we will use the simplified M Board shown in Figure 2.

Suppose that a vessel is travelling on course 060° at a speed through the water of 15 knots, and a current is setting 030° with a drift of 5 knots. To use the M Board to find course over the ground and speed over the ground:

  (a) Assign a suitable scale to the concentric circles. For this problem, let each circle represent a distance of 5 nm.

  (b) Plot the vessel's velocity vector by using a straightedge to draw a line from the origin (center) of the circles to a distance of 15 nm (which on our scale is equal to three circles out from the origin). Draw this line along a bearing of 060°, which can be read from the outer scale (Figure 3a). The end

of the vector at the origin is called the "tail" of the vector,
and the other end is called the "head" of the vector.

(c) Draw the current vector using a parallel rule. Align the
parallel rule (or drafting triangles) with the origin along a
bearing of 030°, then "walk" the rule (or triangles) until its
edge is aligned with the head of the ship's velocity vector
(if you aren't familiar with walking a parallel rule (or tri-
angles, see Figures 4a and 4b). Draw a line from the head
of the ship's velocity vector in the direction of the 030°
bearing, to a distance of 5 nm (which on our scale is equal
to the distance from the origin to the first concentric circle).
You can use a ruler or pair of dividers to transfer the length
of the current vector.

(d) Draw the resultant vector from the origin to the head of
the current vector. The bearing of the resultant vector can
be read from the outer scale, and is the course over the
ground; about 052°. The speed over the ground is equal to
the length of the resultant vector; about 18 nm. The small
graduations on the right side of the horizontal line can be
used to estimate fractions; in this case, the interval between
the small graduations is equal to 0.5 nm.

Now let's use your data retrieval and Maneuvering Board
skills to solve some "real world" problems.

1. Early in the morning of September 18, 2005, your vessel
passed under the Golden Gate Bridge, and at 6 am (Pacific
Daylight Time) you are steering a course of 065° with a
speed through the water of 8 knots. Using current data
from the Richmond, CA station, what is your course over
the ground and speed over the ground?

2. Suppose you are navigating a vessel into the harbor at
Bolivar Roads, Texas (near longitude 95° W), on April 12,
2005 at 0400 UTC (if you aren't familiar with UTC, see the
Note below). What course should you steer for a course
over the ground of 020° if your speed through the water
is 6 knots? What is your speed over the ground? (Hints:
a. Use the "Currents" button in the "Data Type" list. b. It
is easier to find the exact set and drift from tabular data
rather than trying to estimate these from a graph, so click
on "View Tabular Data" after you have set the data range in
the Station Data window).

3. Recreational fishermen along the U.S. Atlantic coast often find that they are most successful when they fish near the entrance to tidal creeks on a falling (ebb) tide. Suppose you are fishing in the upper portions of the Chesapeake Bay near Chesapeake City on July 3, 2004. When will there be an ebb tide during daylight hours? [Note: Chesapeake City is near Havre de Grace near the Maryland/Delaware border]

4. The Bay of Fundy is famous for its extreme tides, which expose large tidal flats that are the preferred habitat for softshell clams. Suppose you want to collect some clams for Christmas dinner near Eastport, ME, on December 23 or 24, 2005. For safety reasons (you don't want to get caught by the rising tide) you decide to limit your clamming to a four hour period spanning two hours before and after low tide. What times on December 23 and 24 would correspond to this interval?

5. After several days' celebration of the beginning of the year 2003, a guest falls off of a yacht anchored in Bolivar Roads, Texas. The merrymaker hit the water at 6:40 am on the morning of January 3, and was not recovered for several hours; fortunately, he was wearing a PFD (personal floatation device, or "life jacket"). How far would you expect him to have drifted from the yacht after two hours, and in what direction?

6. On the east coast of Florida, inlets connecting the Intracoastal Waterway with the Atlantic Ocean are notoriously dangerous, particularly when an ebb tide coincides with winds blowing toward the shore, since these conditions cause water to "pile up" in narrow inlets. Suppose you are contacted by a recreational boater who wants to go through one of these inlets on April 12, 2006 at 11:30 am (EDT). Using data from Trident Pier, FL, what advice would you offer? Why? [Hint: Remember that the direction of winds is reported as the direction FROM which they blow, in contrast to the direction of currents, which is reported at the direction TOWARD which they flow.]

A Note About Time Zones

The worldwide standard for time is "coordinated universal time," abbreviated UTC. (formerly known as Greenwich mean time; also called "Zulu time", "universal time," and "world time.") UTC uses 24-hour time notation in which "1:00 am" is expressed as 0100 (pronounced "zero one hundred"). To convert UTC to local time, you have to add or subtract hours from it. West of the zero meridian to the international date line (which includes all of North America), hours are subtracted from UTC to convert to local time. Following is a table showing the number of hours to subtract from UTC to convert to North American time zones:

Local Time Zone	Hours to Subtract from UTC:
Atlantic Standard Time (AST)	4
Atlantic Daylight Time (ADT)	3
Eastern Standard Time (EST)	5
Eastern Daylight Time (EDT)	4
Central Standard Time (CST)	6
Central Daylight Time (CDT)	5
Mountain Standard Time (MST)	7
Mountain Daylight Time (MDT)	6
Pacific Standard Time (PST)	8
Pacific Daylight Time (PDT)	7
Alaskan Standard Time (AST)	9
Alaskan Daylight Time (ADT)	8
Hawaiian Standard Time (HST)	10

Figure 1. Effect of Current Setting 90° to a Ship's Heading

Course Steered = 090°

A ——————————————→ B

Set = 180°
Drift = 3 kn

Speed Over Ground = 12.36 kn

C
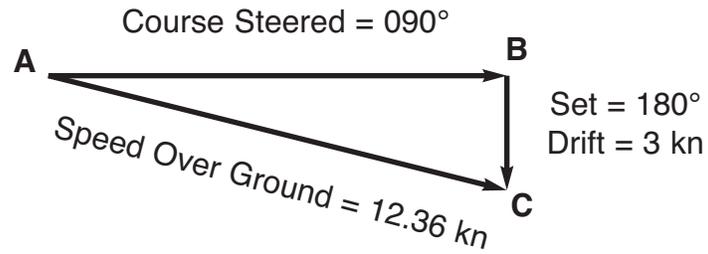
Figure 2. A Simplified Maneuvering Board
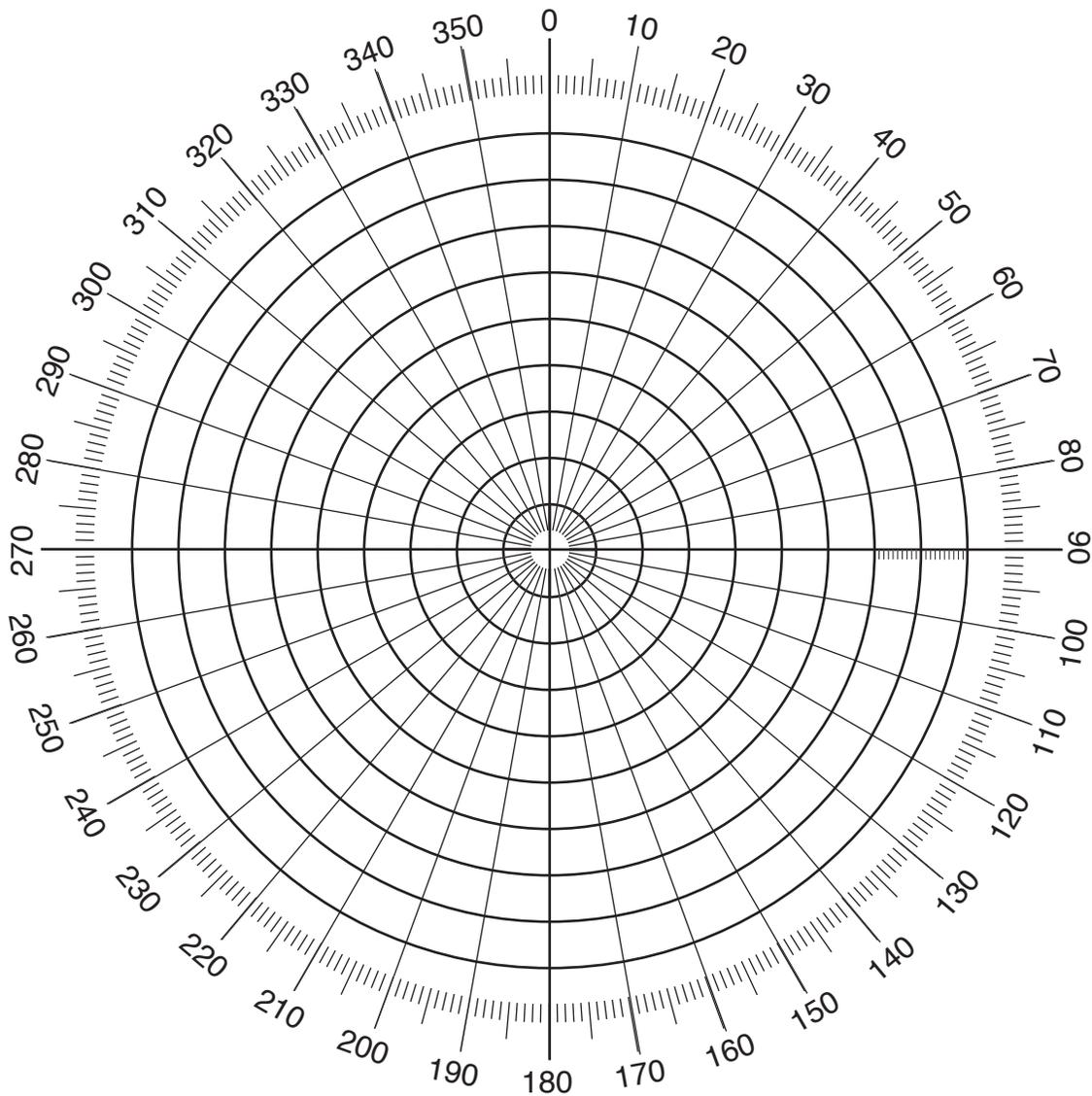
Figure 3. Using an M Board to find the effect of current on
course over the ground and speed over the ground

A

B

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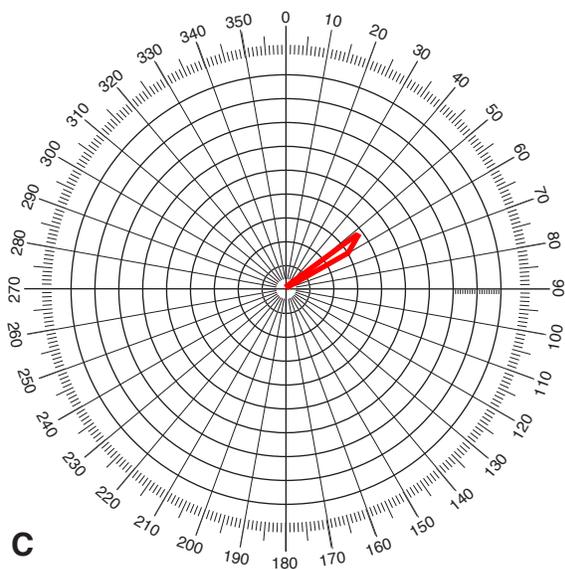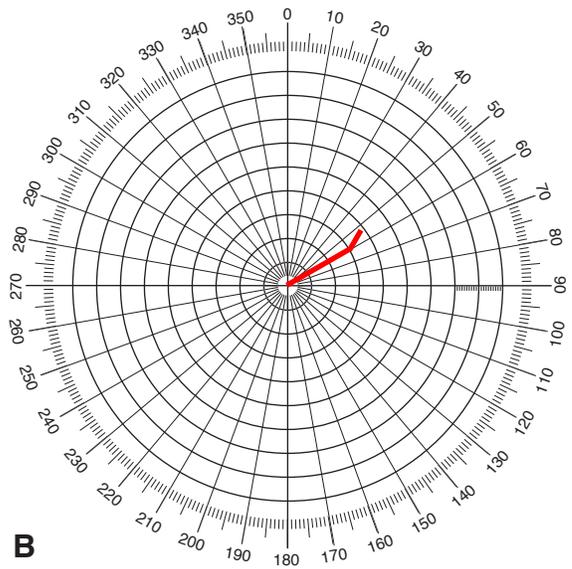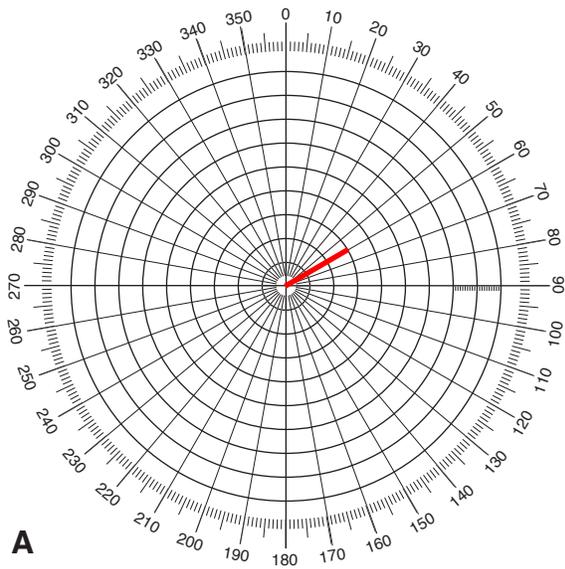
Figure 4a. How to Transfer the Angle of a Line to Another Point Using Parallel Rules

1. The Problem: How to transfer the angle of Line AB to Point C?
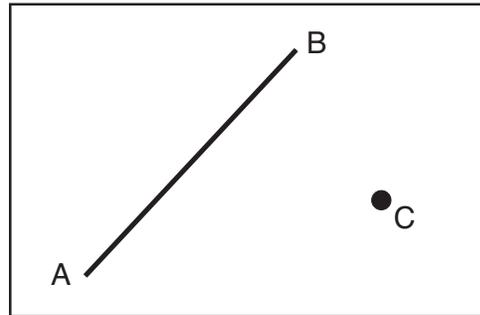
2. Align one edge of the parallel rules with Line AB.
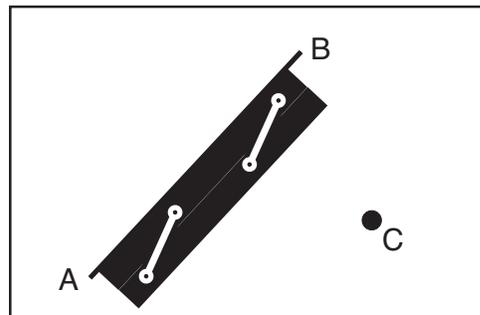
3. Hold the rule next to LineAB, and "walk" the other rule toward Point C.
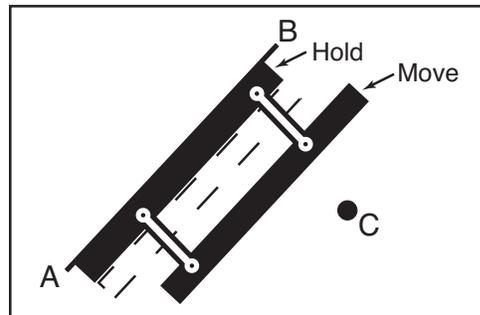
4. Hold the rule that was "walked," and move the other rule in the direction of Point C.
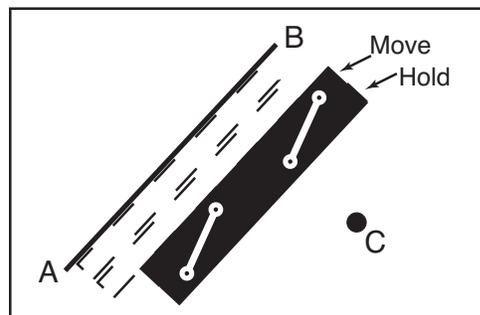
5. Continue "walking" the rules until Point C is reached. You can now draw a line through Point C that is parallel to Line AB.
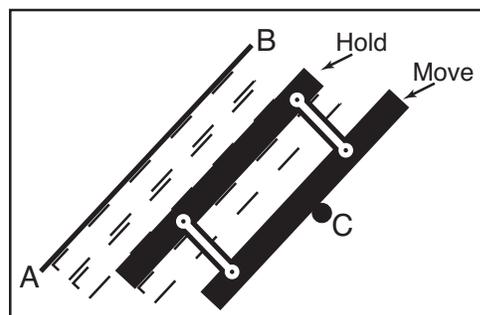
Figure 4b. How to "Walk" a Pair of Triangles

1. The Problem: How to draw a line parallel to Line AB through Point C?
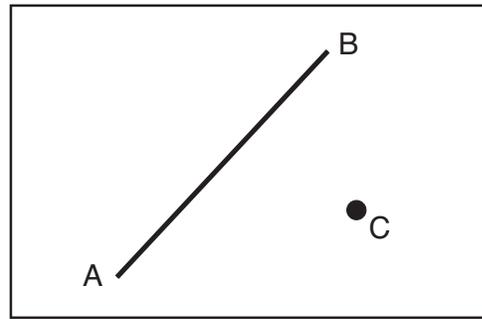
2. Place the hypotenuse of one traangle next to the hypotenuse of the other and align the triangles with Line AB.
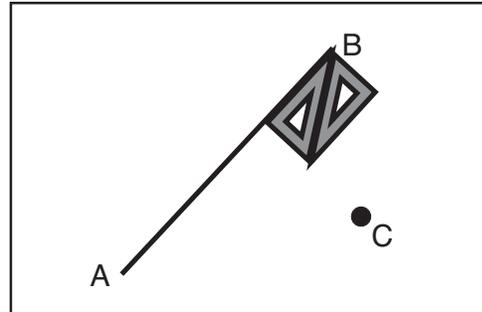
3. Hold one triangle, and slide the other triangle toward Point C.
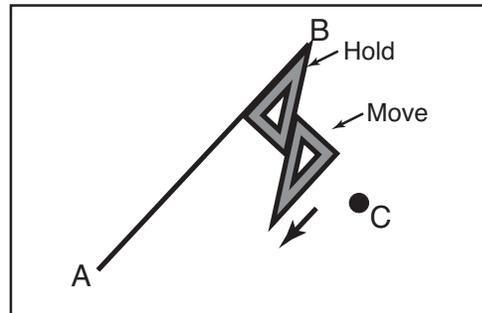
4. Hold the triangle moved in Step 3, and slide the other triangle toward Point C.
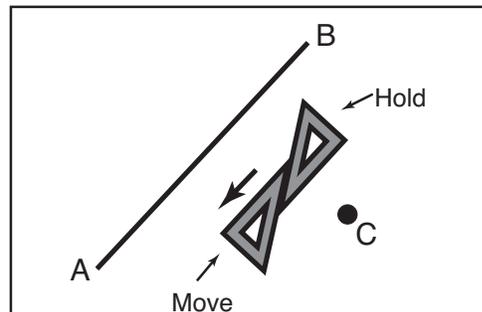
5. Continue alternately holding and sliding the triangles until Point C is reached. Now you can draw a line through Point C that will be parallel to Line AB.
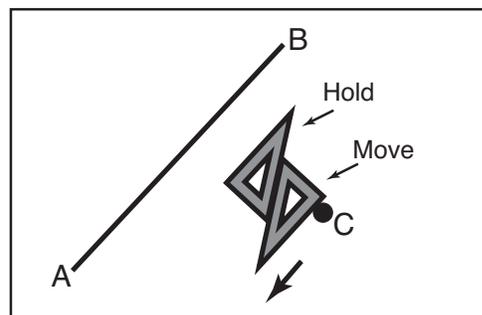
Figure 5. Solution to Problem 1
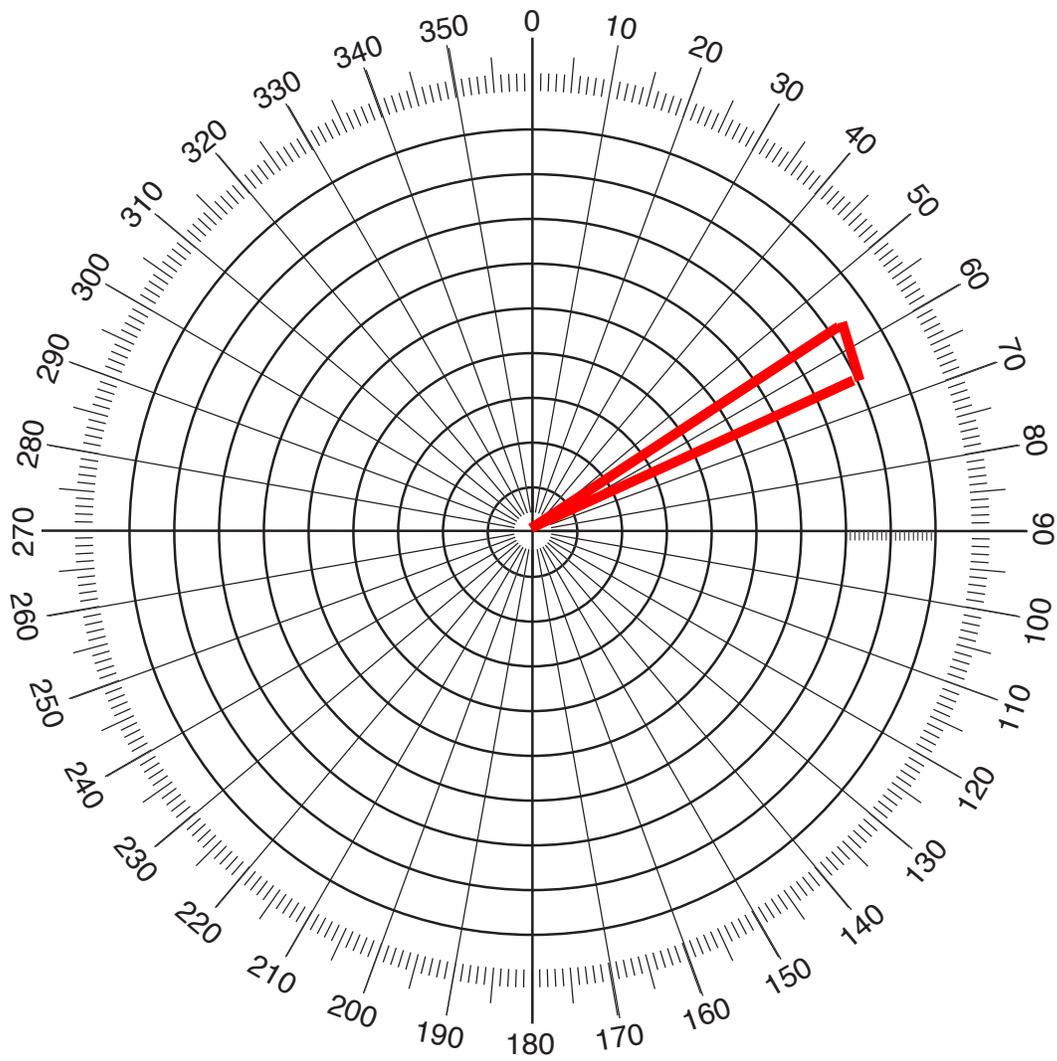
Figure 6. Solution to Problem 2