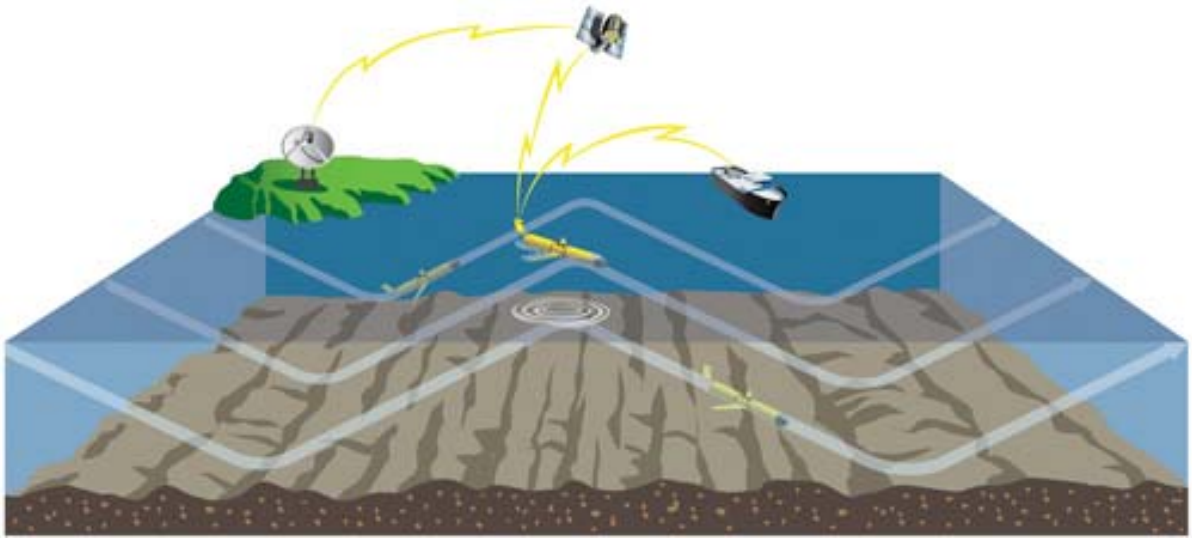
How to Pilot a Glider:
Ocean Robot Navigation Using Vectors and Dead Reckoning

GLIDER BACKGROUND

A glider is a robot used by ocean scientists to study physical and chemical properties in the ocean. Without engine or propeller, a glider slips through the water simply by changing its buoyancy. BIOS researcher Ruth Curry uses her glider (named Anna) to study currents around the island of Bermuda. When Anna surfaces, it communicates with Mrs. Curry via satellite phone. Anna tells Mrs. Curry where it is, and Mrs. Curry tells Anna the next direction to steer.

http://www.biosmagic.com/ BIOS's webpage on gliders

http://rucool.marine.rutgers.edu/ Rutger's University Coastal Ocean Observation Lab



VOCABULARY

Fix:	estimated current location
Bearing:	compass direction towards destination
Heading:	compass direction to which the glider points
Drift:	effect of a current on bearing
Vector:	an arrow with direction and magnitude

COMMON CORE AND NEXT GENERATION SCIENCE STANDARDS CORRELATION

Common Core

This lesson requires students to access and read several non-fiction articles to gain background information. Additionally, students will access information on current scientific research and obtain data online.

Next Generation Science Standards

While this lesson mainly reinforces mathematics standard, there is a significant emphasis on Engineering Design. The story line of the High School Engineering Design standard explains;

"…students are expected to engage with major global issues at the interface of science, technology, society and the environment… Defining the problem … requires both qualitative and quantitative analysis. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering."

Engineering Design
MS – ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
HS – ETS - 1

HS – ETS1 – 2
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

NAVIGATION BACKGROUND

"Dead Reckoning" is a navigation technique used on ships and in airplanes. A navigator can work out the correct "heading" to steer, if they know:

1. Their present "fix" (where they are)
2. The "bearing" to their destination
3. Their speed
4. The "drift" (speed and direction of any current)

A simple example:

If…

1. I am in a plane in Bermuda (my "fix")
2. I want to get to Hamden High School, which is at a bearing of 330º
3. I travel at 200 miles per hour
4. There is no current

… my heading should be exactly 330º.

HOWEVER … if there is a side current, I must adjust my heading.

http://www.intmath.com/vectors/4-adding-vectors-2-dimensions.php

Dead Reckoning is not usually very accurate, as errors can be made in each of the 4 components. However, with repeated checks on measurements, a high degree of accuracy can be obtained. Glider pilots can use Dead Reckoning to plot their glider's course.

Glider Piloting – Problem #1

Anna surfaces at the Bermuda Atlantic Time-series Study (BATS) site, calls Mrs. Curry to give the present coordinates and asks, "Where do you want me to go?" Mrs. Curry wants Anna to go to Hydrostation S. What bearing should she tell Anna to steer?

Data: (use Google Earth's Measurement Tool to get bearings and distances)

- Bearing from BATS site to Hydrostation S = 330º
- Distance from BATS site to Hydrostation S = 65k
- Glider Speed = 5 k/h
- Current = 1 k/h at 240º (i.e. flowing approximately SW)

NOTE:
For simple examples and computation,
choose a current at right angles to the intended bearing.

Step 1:

Draw a bearing vector on graph paper indicating a direction of 330º and a magnitude of 65km.

Remember; A VECTOR has DIRECTION and MAGNITUDE!

Step 2:

Compute the length of time the glider will take to travel 64 km and reach its destination.

Speed = Distance / Time

5 k/h = 64 k / q hours

q = 65 / 5 + 13 hours

Step 3:

Compute the "drift" of the current over this time.

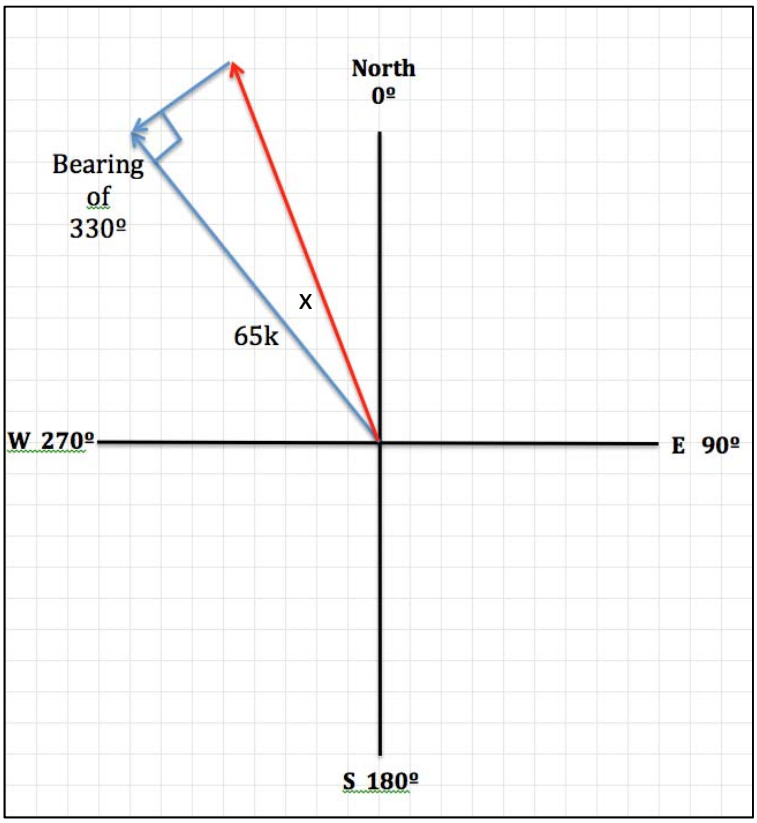
Speed = Distance / Time

1 k/h = p k / 13 hours

p = 13 km

Step 4:

Draw a second vector indicating the current, with a direction of 240º and a magnitude of 13 km. Draw this current vector so the arrow touches the arrow of the first vector. Draw a third line to complete a triangle. Label the diagram with distances and mark the right angle where the current vector meets the bearing vector.



Step 5:

Compute for the angle x.

tan x = 13 / 65

tan x = 0.2

x = $\tan^{-1}$ (0.2) = 11.3º

https://www.google.com/search?q=logarithm+calculator&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a&channel=nts

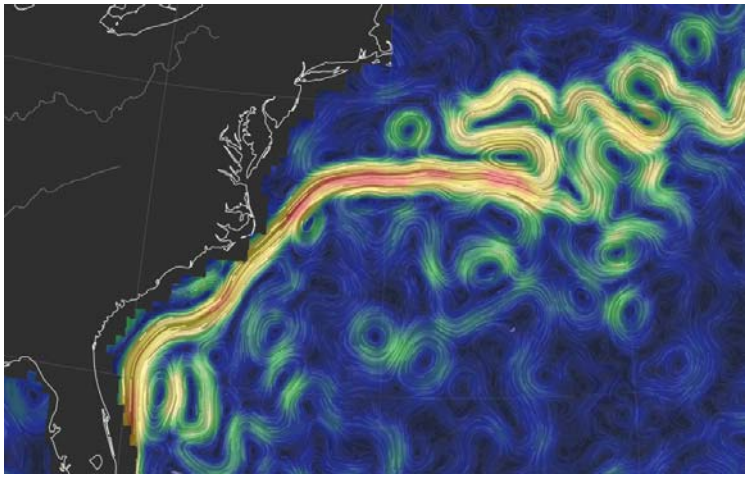
Step 6:

Compute the correct heading to accommodate for the cross current.

The bearing is 330º
The drift is 11.3º
*The correct heading is 330 + 11.3 = **341.3º***

So although the bearing to the destination is at 330º, Anna must head 341.3º because of the current.

Glider Piloting – Problem #2



Mrs. Curry wants to know the strength of the Gulf Stream near Cape Hatteras. She launches Anna off the coast and tells her to glide at a heading of 100º. Anna surfaces 3 hours later and reports her location. Refer to Google Earth and use the following data to calculate the strength of the current.

Data:

- Heading at which Anna is launched = 100º
- Coordinates from which Anna is launched = N 35º 19' W 75º 20'
- Length of dive = 3 hours
- Glider speed = 5k/h
- Coordinates where Anna surfaces = N 35º 21' W 75º 09'
- Distance from launch to surface = 16.45k

Step 1:

Compute the distance Anna *should* travel on her dive

Speed = Distance / Time
5 k/h = q k / 3 hours
q = 15 X 3
q = 15 k

Step 2:

Draw a bearing vector on graph paper indicating a direction of 100º and a magnitude of 15 k.

Step 3:

Draw a second vector indicating the actual course, with a magnitude of 16.45k (assuming the North flowing Gulf Stream pushes Anna to the North of her original

heading). Draw a third line to complete a triangle. Label the diagram with distances and mark the right angle where the current vector meets the bearing vector.

Step 4:

Compute the magnitude of the current vector using Pythagoras' theorem:

$$Actual\ course^2 = Intended\ course^2 + Current^2$$

$$(16.45)^2 = (15)^2 + Current^2$$
$$Current^2 = 270.6 - 225 = 45.6$$
$$Current = 6.8k$$

Step 5:

Calculate the current speed:

Speed = Distance / Time

Speed = 6.8k / 3h = 2.3 k/h

Step 6:

Calculate the current direction:

Current is flowing -90º from the original bearing.

100º - 90º = 10º

The current is flowing at 10º or NNW.