Grade Level: 6-8
Time Estimate: 3-5 days

INTRODUCTION TO VECTORS / INSTRUCTOR INFO

Summary

This lesson includes vocabulary, content, examples, and activities to help students learn and understand vectors, vector addition, and vector subtraction. Using data collected from the OCEARCH Global Shark Tracker™, students will be able to work with real-life data to achieve the goals and objectives of this lesson.

Part 1. Vector and Scalar Basics
Part 2. Vector Equality
Part 3. Vector Diagrams
Part 4. Adding and Subtracting Vectors
Part 5. Adding Force Vectors
Activity: Shark Travel Vectors

Goals and Objectives

The students will:

- learn the difference between a vector quantity and a scalar quantity;
- draw vector diagrams;
- add and subtract vectors;
- calculate resultant vectors;
- calculate vectors using real life shark data.

// STANDARDS

This lesson aligns with the following TEKS:
Grade 6 Math: 2A, 2C, 2D, 2E, 3A, 3C, 4A
Grade 7 Math: 2A, 2C, 2D, 2E, 3A, 3C, 4A
Grade 8 Math: 2A, 2C, 2D, 2E, 3A, 3C, 4A

This lesson aligns with the following Next Generation Science Standards:

Framework

1. Asking questions and defining problems
2. Developing and using models
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
8. Obtaining, evaluating, and communicating information

MS. Forces and Interactions – MS-PS2-1; MS-PS2-2

Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions – such as inputs, processes and outputs – and energy and matter flows within systems (MS-PS2-1)

MS. Energy – MS-PS3-4

Crosscutting Concepts

Scale, Proportion, and Quantity

- Proportional relationships among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-4)

Helpful Tips

1) The content in this lesson is related to OCEARCH and the Global Shark Tracker. Spend a few minutes getting familiar with the website and the tracker if you have not done so already. The Global Shark Tracker is also available as an app for iPhone and Android.
2) This lesson plan is designed to be adaptable to suit your specific needs. Use the entire lesson plan or just parts of it. This material can be expanded to be an entire unit or condensed for just one day in the classroom.
3) Vocabulary words will be underlined as they appear in the lesson plan. A complete list of vocabulary words is included as well.
4) Answers to questions and prompts for discussions will appear in *italics*.
5) Optional activities and content (side notes) will appear in a box. Use these to enhance your lesson and adapt it to suit your needs!
6) Have questions for OCEARCH Expedition Leader, Chris Fischer? Email info@OCEARCH.org to schedule a Skype session and let your students/child talk directly to Chris and the OCEARCH crew!
7) Email all questions about this lesson to info@OCEARCH.org.

Vocabulary

Cardinal directions – The directions of north, south, east, and west.
Displacement – The change in the position of an object.
Force –Any influence that causes an object to undergo a change in speed, a change in direction, or a change in shape. Force is measured in Newtons (N). N = 1 kg * m/s^2.
Force vector – Describes a specific amount of force and the direction in which the force is applied.
Free-body diagram – Diagram or illustration of an object with all the forces acting on the object. Free-body diagrams are used to show relative magnitude and direction of all forces action upon an object.
Intercardinal directions – The directions of northeast, southeast, southwest, and northwest.
Magnitude – Magnitude is the numerical component of a value.
Net force – The vector sum of all the forces, or the overall force acting on an object.
Newton's First Law of Motion – An object at rest stays at rest and an object in motion stays in motion with constant speed and same direction unless acted upon by an unbalanced force.
Newton's Third Law of Motion – For every action, there is an equal and opposite reaction.
Resultant – The sum of two or more vectors.
Scalar – A quantity that is fully described by its magnitude.
Scale – A proportion between two sets of dimensions.
Vector – A quantity that has both magnitude and direction.

Grade Level: 6-8
Time Estimate: 5-15 mins

INTRODUCTION TO VECTORS / PRE-LESSON ASSESSMENT

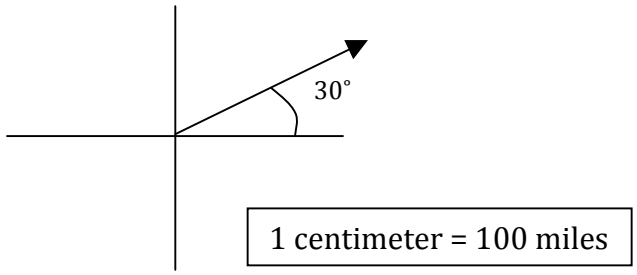
Use the following true/false, short answer, fill in the blank, and multiple choice questions as an introduction/warm-up to the lesson topics. You can do this in a verbal or written format, as a game, individually, in groups, or as a whole class! A handout is provided if you wish to hand the questions out in a quiz format.

1. True or False A vector has both magnitude and direction.
   Answer: *True*

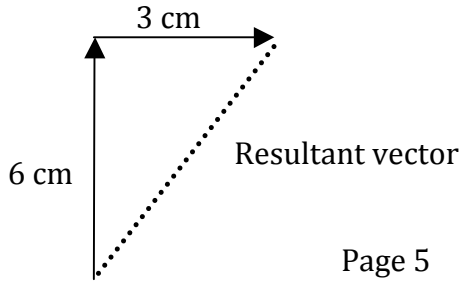
2. True or False A scalar quantity is fully described by its magnitude.
   Answer: *True*

3. True or False The magnitude is the length component of the vector and the direction of the vector is the direction of movement depicted by an arrow.
   Answer: *True*

4. Draw a vector diagram for a shark that has traveled 300 miles 30° North of East.
   Your drawing should look similar to this



5. Use the Pythagorean Theorem to find the resultant vector in the following vector diagram.



Answer: *6.7 cm*

Student handout on next page.

Name: _____ Date: _____

Vectors

Select the correct answer(s) to each of the following questions

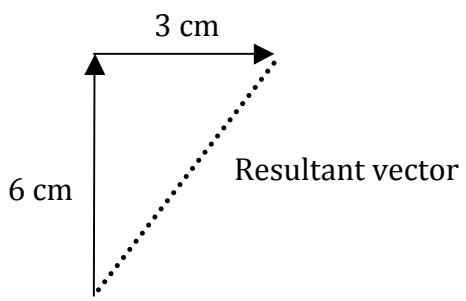
1. True or False — A vector both magnitude and direction.

2. True or False — A scalar quantity is fully described by its magnitude.

3. True or False — The magnitude is the length component of the vector and the direction of the vector is the direction of movement depicted by an arrow.

4. Draw a vector diagram for a shark that has traveled 300 miles 30° North of East.

5. Use the Pythagorean Theorem to find the resultant vector in the following vector diagram.



Answer: d

INTRODUCTION TO VECTORS / LESSON PLAN

INTRODUCTION **3-5 mins**

Part 1. Vector and Scalar Basics (30 – 45 minutes)

A vector is a value or quantity that has both magnitude and direction. Magnitude is the amount of force, acceleration, velocity, and displacement an object contains. Vectors are a measurement of displacement, or position change, and are only complete when both the magnitude, or distance, and the direction of the vector are communicated.

A scalar is a quantity that has magnitude *without* direction. Examples of scalar quantities are temperature, time, and density.

What is the difference between a vector and a scalar? A vector has a direction and a magnitude. A scalar only has magnitude. You can tell the difference between the two by determining if direction is associated with it.

Vector Quantities	Scalar Quantities
Displacement	Length
Velocity	Area
Acceleration	Temperature
Momentum	Pressure
Force	Energy

Lift	Speed
Drag	Volume
Thrust	Mass
Weight	Density

<u>Vector or Scalar?</u>

(5 minutes; optional)

Read the following examples aloud to the class. Students should decide if it is an example of a vector or scalar.

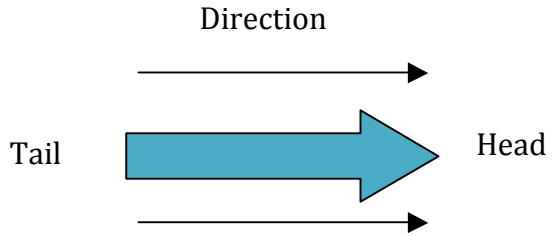
1. A tiger shark is cruising at 5 mph towards the coastline.
   Answer: *This is an example of a vector because it represents a magnitude (5 mph) and a direction (towards coastline).*

2. The area of the boat deck is 850 m^2.
   Answer: *This is an example of a scalar. Area has a magnitude of 850 m^2.*

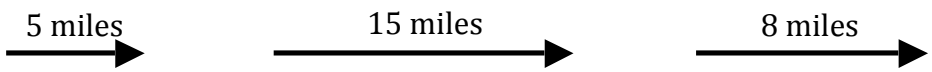
3. The temperature of the water is 45°F.

How are vectors and magnitude drawn?

Vectors are drawn as arrows with a tail and head. The direction of the arrow is the direction of the vector.



The length of the arrow depends on the magnitude of the vector. For example:



How are vectors and magnitude written?

Vectors are written as $\overrightarrow{\mathbf{AB}}$, or sometimes simply '**a**'. **A** is the initial point (starting point) and B is the terminal point (ending point).

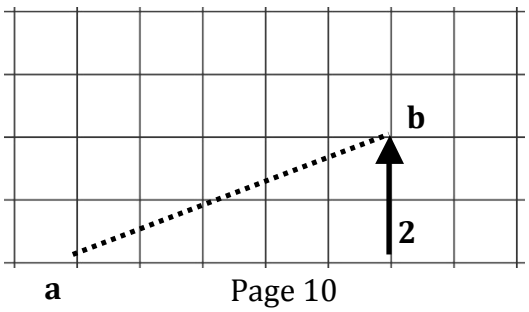
The magnitude of vector 'a' is written as |**a**|.

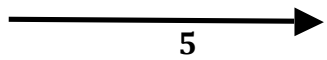
The magnitude of vector $\overrightarrow{\mathbf{AB}}$ is written as |**AB**|.

Another way of writing a vector is by the size and direction of the vector, which can be shown by giving the horizontal units over the vertical units. In the example below, 5 is the horizontal unit and 2 is the vertical unit.

$$\begin{bmatrix} 5 \\ 2 \end{bmatrix}$$

Both values in the above equation are positive values. This tells us that we move 5 units to the right and 2 units up. "**a**" represents the start point and "**b**" represents the end point. The dotted line represents the resultant distance.

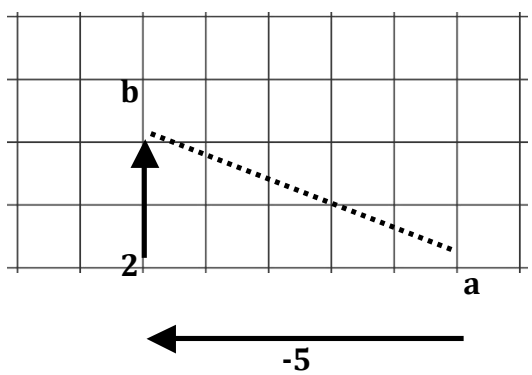




What about vectors in different directions? For example,

$$\begin{pmatrix} -5 \\ 2 \end{pmatrix}$$

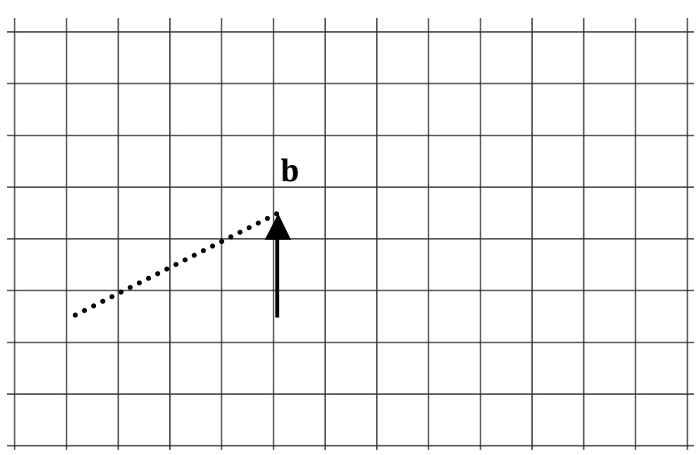
This movement has a vector negative horizontal units and positive vertical units. In other words, move 5 units to the left and 2 units up.

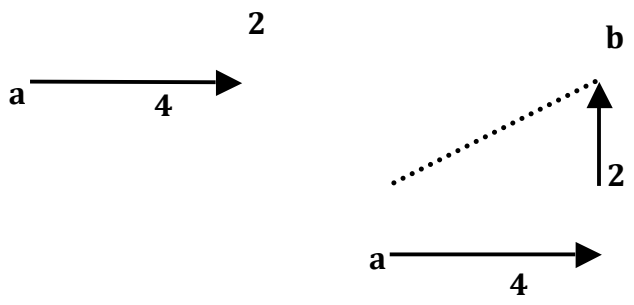


Part 2. Vector Equality (10 minutes)

If two vectors have the same magnitude and direction, they are said to be equal. Vectors can even be equal if they are in different positions on a grid as long as the vectors are in equal directions (see figure below).

Consider the vector $\begin{pmatrix} 4 \\ 2 \end{pmatrix}$



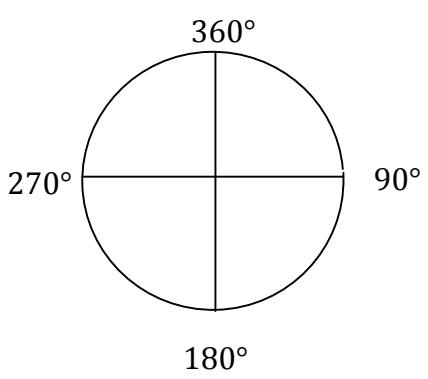


Both go 4 units to the right and 2 units up. Therefore, both vectors are equal.

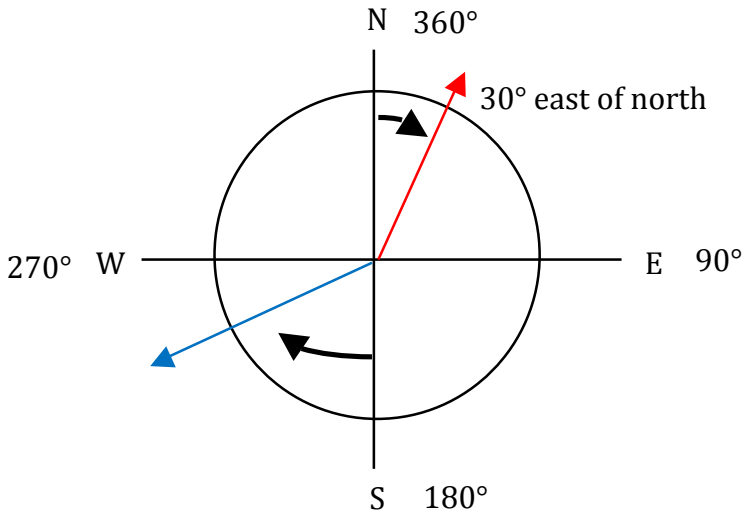
Part 3. Vector Diagrams (30 – 45 minutes)

The direction of a vector can be described in different ways. The four cardinal directions include north, south, east, and west. The four 'intercardinal' directions include northwest, southwest, northeast, southeast. If described as a degree, the direction is always measured counterclockwise from the east.

When measuring an angle in degrees, we use the circumference of a circle divided into 360 equal parts. Each of those equal parts is called a "degree."



Now let's look at a compass in relation to the 360° circle. Say you want to plot N 30° east, or in other words, 30° to the east of north (red arrow). In another example, say you want to plot S 60° west, or 60° to the west of due south (blue arrow).

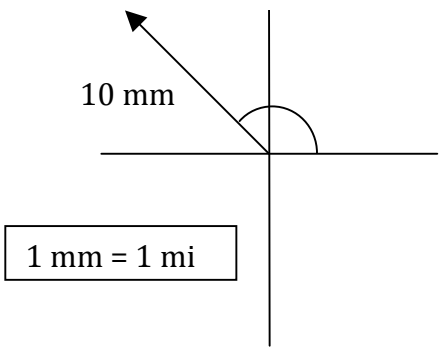


60° west of south

Examples.

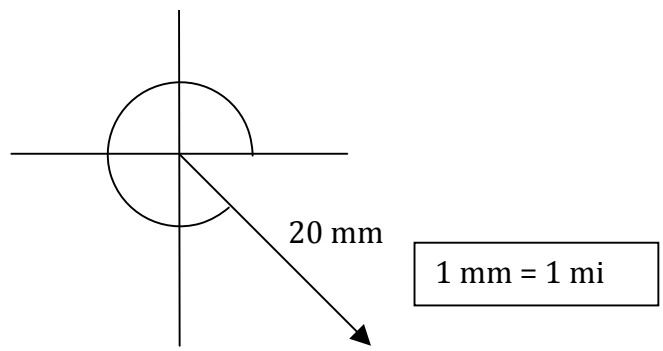
130° Counter-Clockwise rotation measured from the east

or

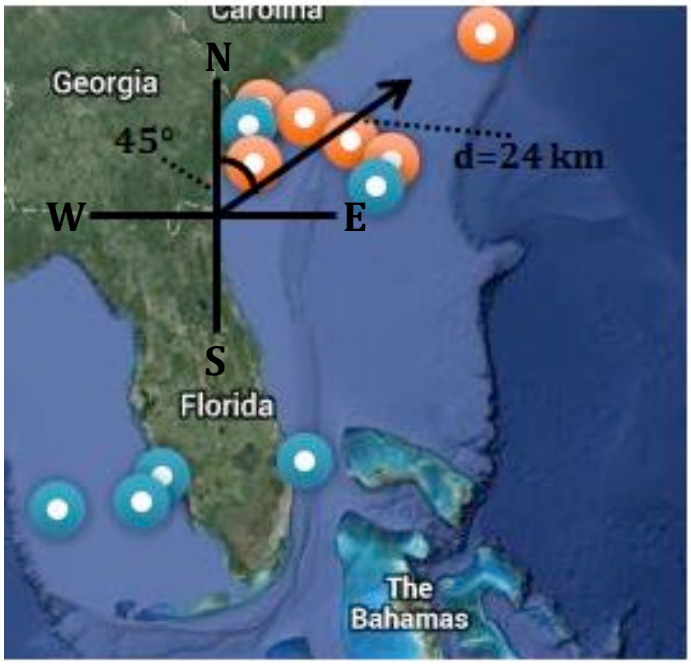


315° Counter-Clockwise rotation measured from the east

or



Vectors are often represented by vector diagrams such as the one shown below. Below is a section of the Global Shark Tracker™. Orange dots represent sharks that have pinged in, or have reported in, within the last 30 days. Blue dots are sharks that have pinged in over 30 days ago. Four sharks have pinged in within 45° east of north.

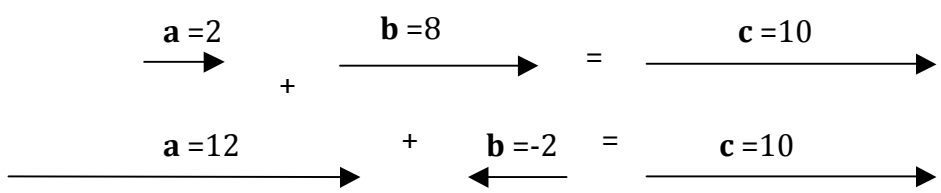


To create a vector diagram, you must have the following components:

1. A determined **<u>scale</u>** such that a small measurable unit within the diagram can be used to define a larger magnitude in a real – life situation.
2. A **vector arrow**, with a tail and head, drawn in a specific direction. The tail of the vector arrow should begin at a defined starting point, usually the intersection of the 'X' and 'Y' axis. The length of the arrow should represent the magnitude of the vector. Use the scale to accurately represent magnitude.
3. A clearly labeled **magnitude and direction**.

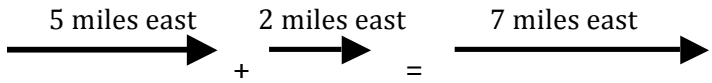
Part 4. Adding and Subtracting Vectors (30 – 45 minutes)

When scientists have many vectors to examine, they first draw a vector diagram. Vectors can then be added or subtracted using the head to tail method.

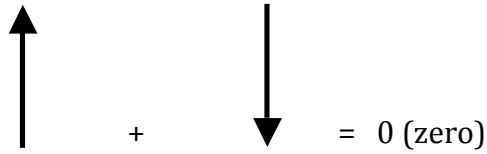


Example 1. (A) If a shark traveled five miles east and then two more miles in the same direction, the sum of those two vectors would be seven miles in an eastern direction. (B) However, if a shark travels three miles north, then three miles south, the sum of those two vectors would be zero.

Answer: for part A



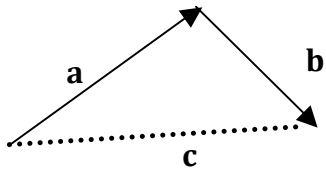
Answer for part B



3 miles north 3 miles south

So how do you add vectors in *different* directions? There are two methods you can use. The easiest way to add these types of vectors is by using the head-to-tail method. The tail of the additional vectors is placed at the end of the head of the previous vectors. The resultant vector is the vector drawn from the tail of the first vector to the head of the last vector.

For example:



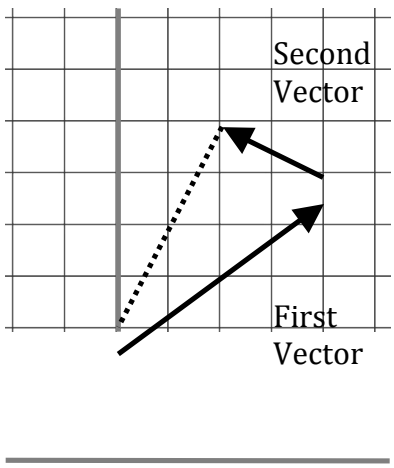
The second method is to use the written numbers to add or subtract the horizontal and vertical values.

$$\begin{bmatrix} 4 \\ \\ \end{bmatrix} \quad \begin{bmatrix} -2 \\ \\ \end{bmatrix}$$

Example 2. 3 + 1 = ?

<u>Method 1</u>

Plot the vectors:



Resultant Vector = $\begin{pmatrix} 2 \\ 4 \end{pmatrix}$

<u>Method 2</u>

$$\begin{pmatrix} 4 \\ 3 \end{pmatrix} + \begin{pmatrix} -2 \\ 1 \end{pmatrix} = \begin{pmatrix} 2 \\ 4 \end{pmatrix}$$

Simply add the top, horizontal numbers, together. Then add the bottom, vertical numbers, together.

(4) + (-2) = 2

(3) + (1) = 4

Once you understand how to add vectors, subtracting vectors is quite easy!

Example 3.

$$\begin{bmatrix} 4 \\ 3 \end{bmatrix} - \begin{bmatrix} -2 \\ 1 \end{bmatrix} = ?$$

Answer:

$$\begin{bmatrix} 4 \\ 3 \end{bmatrix} - \begin{bmatrix} -2 \\ 1 \end{bmatrix} = \begin{bmatrix} 6 \\ 2 \end{bmatrix}$$

(4) – (-2) = 4 + 2 = 6

(3) – (1) = 2

In order to add vectors with more complex directions than just horizontal and vertical, the "head to tail" method can also be used.

The "head to tail" method uses a scaled vector diagram:

Step 1. Choose an appropriate scale for the vector diagram.

Step 2. Draw the first vector to scale in the correct direction.

Step 3. Starting from the head of the first vector, draw the next vector to scale in the correct direction.

Step 4. Continue until all vectors are added to the diagram.

Step 5. Draw the resultant vector from the tail of the first vector to the head of the last vector and measure it with a ruler.

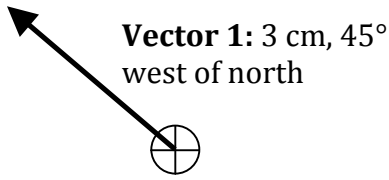
Step 6. Convert the units using the scale to determine the magnitude.

Step 7. Determine the direction of the resultant vector with a protractor.

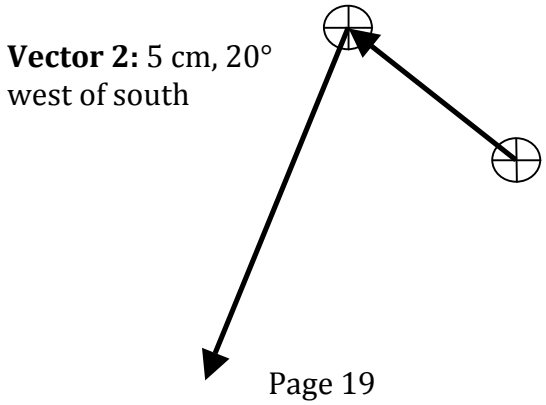
Example 4. If Lydia, a great white shark, travels 18 km at 45° west of north, then 30 km at 20° west of south, then 12 km due south, how far and in which direction has she traveled overall?

Step 1. Choose a scale. We will be using the scale 1 cm = 6 km.

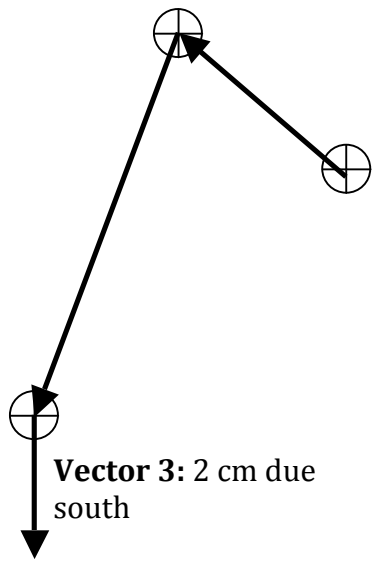
Step 2. Draw the first vector.



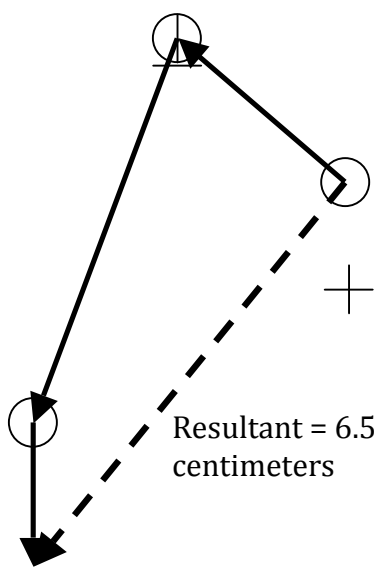
Step 3. Draw the second vector.



Step 4. Draw all remaining vectors.



Step 5. Draw the resultant vector and measure using a ruler.



Step 6. Convert the scale units, 6.5 centimeters multiplied by 6 kilometers/cm = 39 kilometers

Step 7. Determine the direction of the vector – this can be estimated or measured using a protractor. The direction of this vector is approximately 45° west of south.

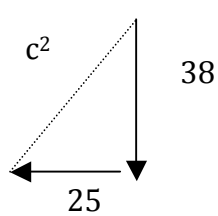
Adding Vectors at 90° Angles: Pythagorean Theorem

The Pythagorean Theorem can be used to find a resultant vector, **c**, if the vectors **a** and **b** form a 90° angle. In this scenario, the new equation is as follows:

$$a + b = c \rightarrow a^2 + b^2 = c^2$$

Example 5. A female bull shark swims 38 miles south and 25 miles west to its breeding ground. What is the resultant distance (c) if she swam a straight line?

The bull shark swam in two vectors, one to the south and one to the west. South and west are at 90 degree angles from each other, so we can use the Pythagorean Theorem to solve the question.



$a^2 + b^2 = c^2$

$38^2 + 25^2 = c^2$

$1{,}444 + 625 = c^2$

$2{,}069 = c^2$

$\sqrt{2{,}069} = 45.5$ *miles*

The distance is 45.5 miles.

Part 5. Adding Force Vectors (30 – 45 minutes)

Force is also a vector quantity, which means force has a magnitude and a direction. To fully understand the applied or resulting force, you must first describe both the magnitude and direction. For example, 5 N is not a descriptive explanation of a force. However, 5 N in an upward direction is a descriptive explanation of a force. This also describes the force as a vector!

Force is measured in Newtons (N). One N is the amount of force required to give a 1 kg mass an acceleration of 1 m/s^2.

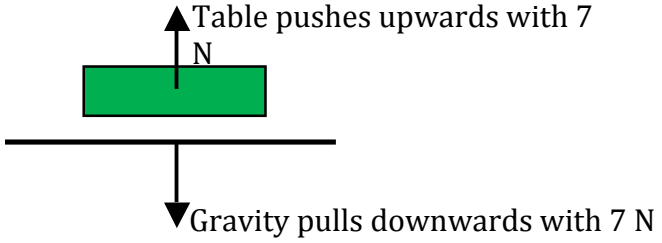
$$1\ N = 1\ kg * m/s^2$$

Newton's Laws of Motion

The free-body diagram below illustrates Newton's first law of motion. The first law states that an object at rest tends to stay at rest unless acted upon by an unbalanced force. The same goes with an object in motion. An object in motion tends to remain in motion at constant speed unless acted upon by an unbalanced force (e.g., friction). Newton's second law states the acceleration of an object is dependent upon the net force acting on the object and the mass of the object. Newton's third law states that

for every action, there is an equal and opposite reaction. This means forces come in pairs! These forces are called *action* and *reaction.*

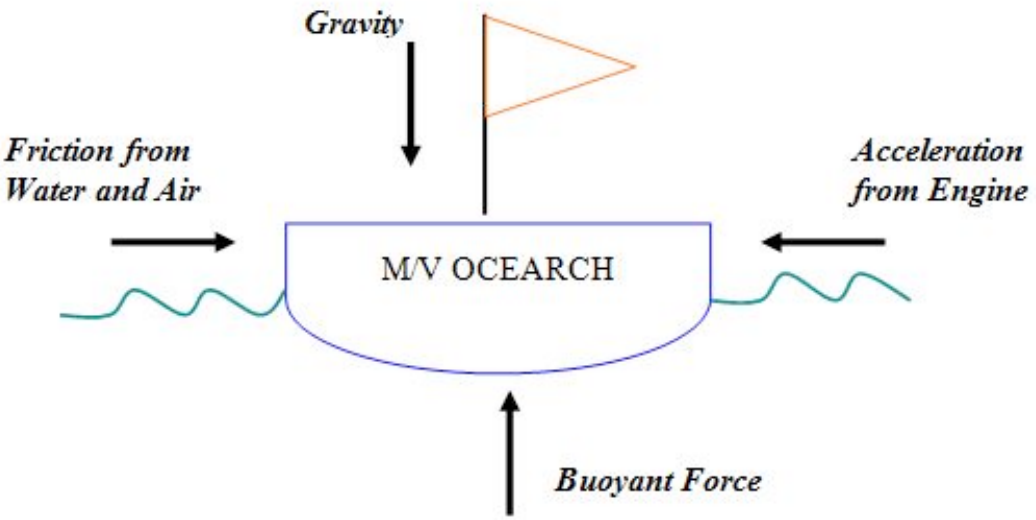
Individual forces can balance each other out (see image below). For example, if there is an upward 7 N force acting on a book sitting on a table, there is a downward 7 N force (caused by gravity) acting on the book.



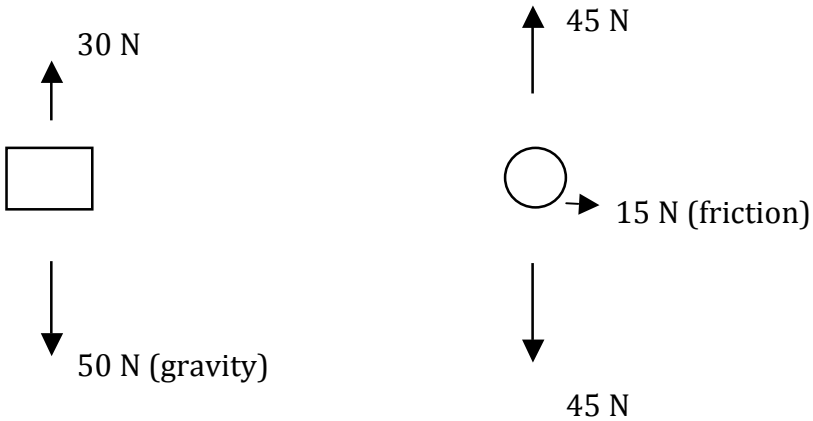
In another example, as you sit in your chair, your body exerts a downward force on the chair and the chair exerts an equal upward force on your body. There are two forces in this interaction, a force on your body and a force on the chair. The forces are equal because you are not moving up, down, or side-to-side.

Force Vectors

Vectors are used to describe the <u>forces</u> such as thrust, gravity, velocity, and acceleration which can be applied to an object.



A <u>force vector</u> describes a specific amount of force and the direction in which the force is applied. The free-body diagrams below illustrate objects experiencing unbalanced forces.

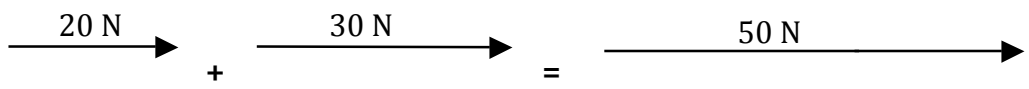


Adding and Subtracting Force Vectors

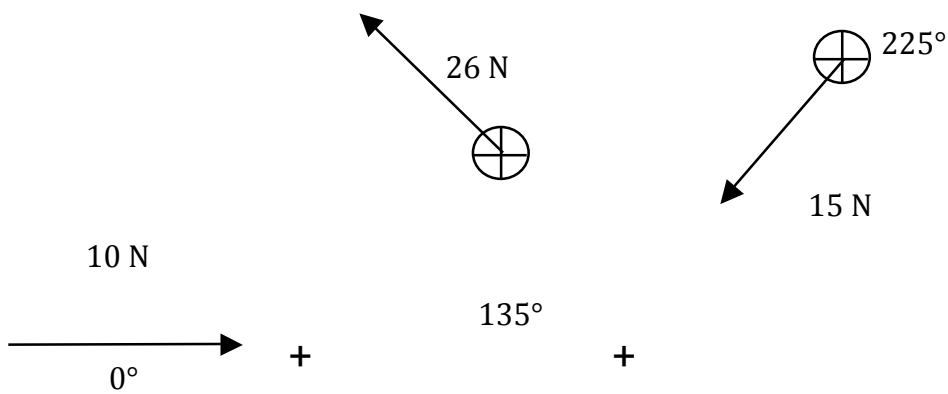
You learned how to use the head-to-tail method to add vectors. Now we will use the same method to add force vectors. With the head-to-tail method, vectors are first drawn to scale where the head of one vector is lined up to the tail of the second vector. Just as you have seen in previous examples, the resultant force is determined by drawing a vector from the tail of the first vector (starting point) to the head of the last vector (ending point). The purpose of adding these force vectors is to find the <u>net force</u> acting on an object. The net force is the vector sum of all the forces, or the overall force acting on an object.

A + B + C

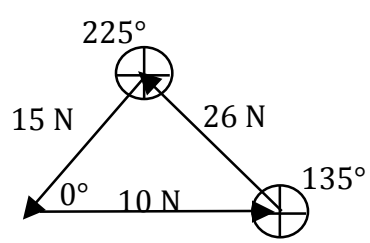
Example 6. Add the vectors below.



Example 7. Add the vectors below.



First, use the head-to-tail method and draw a diagram of all 3 vectors.
Remember, where the head of one vector ends, the tail of the next vector begins.



Now that all of the vectors are placed accurately in a diagram, the resultant (or vector sum) can be calculated by drawing a vector from the tail of the first vector to the head of the last vector. Since the vectors start and end at the same point, there is no resultant vector, the vector force is 0 N.

For further explanation and more practice problems on vector forces, please view *OCEARCH Physics Part 1 – Forces*.

Introduction to Vectors: Practice Problems

Name: _____

Date: _____

Instructions

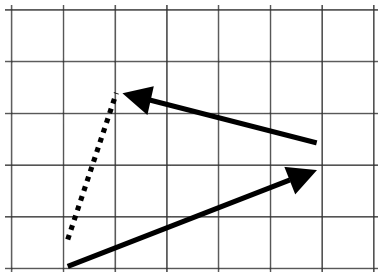
Add or subtract the following vectors problems.

1. A tiger shark tagged in Florida swam 22 miles north and 13 miles west. What is the resultant distance (c) if she swam a straight line? Hint: it's a 90° angle.

2. $\begin{bmatrix} 8 \\ 4 \end{bmatrix} - \begin{bmatrix} 6 \\ 1 \end{bmatrix} = ?$

3. $\begin{bmatrix} 12 \\ 4 \end{bmatrix} + \begin{bmatrix} 2 \\ 3 \end{bmatrix} = ?$

4. Find the resultant vector.



5. Caroline, a hamm ıf due south. Draw a vector diagram f s 15° to the west of due south. Don't ram.

6. Of the following quantities, which are vectors and which are scalar?

   a.) Great white shark population along east coast of U.S.

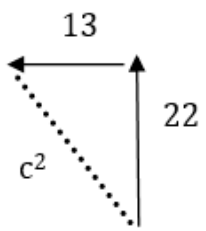
   b.) Migratory pathway of Lydia.

   c.) Speed of the M/V OCEARCH.

   d.) Velocity of a tiger shark swimming.

Introduction to Vectors-Practice Problems KEY

1. A tiger shark tagged in Florida swam 22 miles north and 13 miles west. What is the resultant distance (c) if she swam a straight line? Hint: it's a 90° angle.



$a^2 + b^2 = c^2$

$22^2 + 13^2 = c^2$

$484 + 169 = c^2$

$653 = c^2$

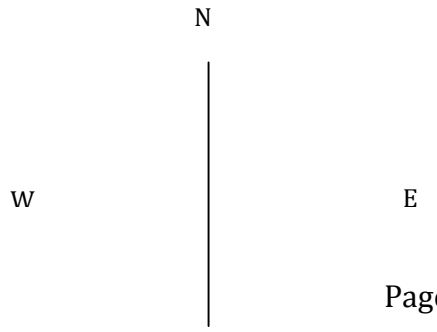
$\sqrt{653} = c$

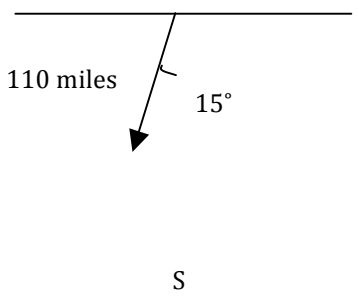
2. $\begin{bmatrix} 8 \\ 4 \end{bmatrix} - \begin{bmatrix} 6 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 3 \end{bmatrix}$

3. $\begin{bmatrix} 12 \\ 4 \end{bmatrix} + \begin{bmatrix} 2 \\ 3 \end{bmatrix} = \begin{bmatrix} 14 \\ 7 \end{bmatrix}$

4. Resulting Vector = $\begin{bmatrix} 1 \\ 3 \end{bmatrix}$

5.





6. Of the following quantities, which are vectors and which are scalar?
    a. Great white shark population along east coast of U.S.
    Answer: scalar

    b. Migratory pathway of Lydia.
    Answer: vector

    c. Speed of the M/V OCEARCH.
    Answer: scalar

    d. Velocity of a tiger shark swimming.
    Answer: vector

ACTIVITY 1. Shark Travel Vectors (60 minutes or take home)

Introduction

Students will create vector diagrams using data collected from the OCEARCH Global Shark Tracker™. Each student will choose three sharks, observe their migration patterns, and record three consecutive vectors from any point in time for each shark. The students will then calculate the resultant vector for each shark using the "head to tail method".

Materials

- Computer with internet access
- Paper (lined, blank, or graphing)
- Writing utensil
- Ruler or straight-edge
- Colored pencils, crayons, or markers
- Protractor optional
- Worksheet provided

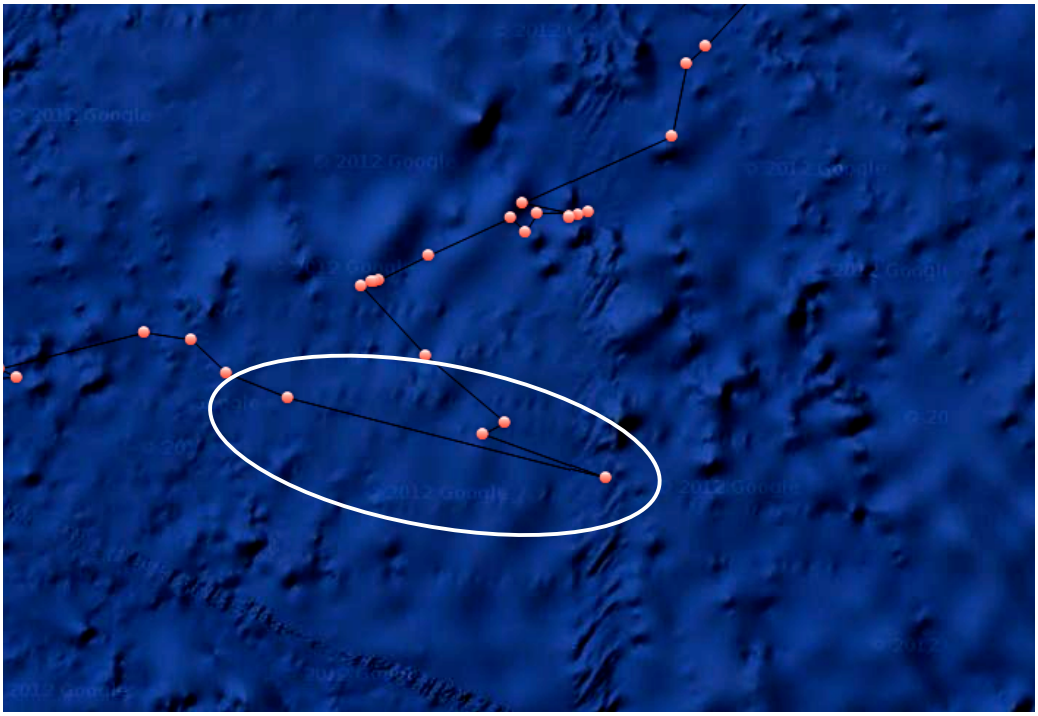
Instructions

1. Give students time to familiarize themselves with the OCEARCH website.
2. Find three sharks and record their names and species in Table 1.
3. Students should then choose three pings for each shark, from any point in time as long as they are consecutive.
4. Trace the location of the pings (relative to each other) on the provided worksheet. The pings of the vectors can be traced from the computer screen onto the worksheet. Or, students can measure the distance from each point on the computer with a ruler, and recreate the pings on the worksheet. Protractors can be used to accurately measure the angles. Whichever method chosen, the exact length and direction of each vector should be conveyed in a vector diagram. The vectors should be placed head –to- tail as stated in the "head to tail method".

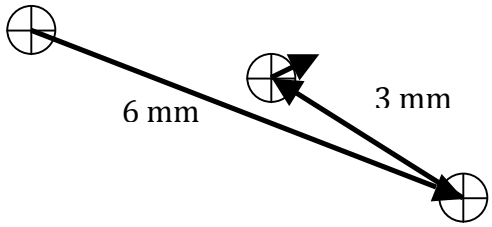
5. Once the vectors are transferred to the worksheet, write down the scale of the map. This is very important! For example, if the scale says "1 mm = 1 mile", and the resultant vector is 3 mm long, then the shark traveled 3 miles.
6. Repeat these steps two more times per shark.

See the example below

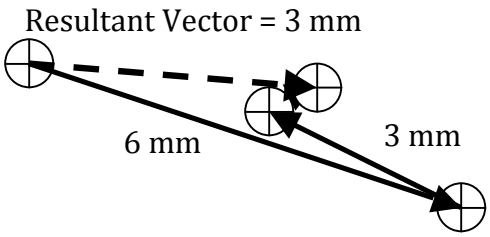
Example.



First, pick the three vectors to be added and copy them exactly communicating the proper magnitude and direction. Remember to use rulers and protractors.



Using a straight edge, draw the resultant vector. Measure the resultant vector and convert the measured units to match the scale. For example, if the scale says “1 mm = 1 mile”, and the resultant vector is 3 mm long, then the shark traveled 3 miles.



Date: _____

Instructions

1. Pick three of your favorite sharks on the Global Shark Tracker™.
2. Record the names and species of your sharks.
3. On pages 2 & 3, record three consecutive vectors from any point in time for each shark.
4. Then calculate the resultant vector for each set of vector diagrams using the "head to tail method".
5. Remember to convert your ruler measurements to the map scale measurements (e.g., mm to km).
6. Record your results in the table below.

Table 1. Resultant forces for migratory sharks.

Shark Name	Species	Resultant Force 1	Resultant Force 2	Resultant Force 3

Vector 3

Shark #1_____

Vector 1

Vector 2

Shark #2_____

Vector 1

Vector 3

Vector 2

Shark #3_____

Vector 1

Vector 3

Vector 2

Activity 1. Shark Travel Vectors.
Student Worksheet Page 3 of 3