SeaGlide_TEAM	Ocean Currents & Temperature	Lesson #1 (60 minutes)

Description:

You are to take the role of a sailor and oceanographer in the Atlantic Ocean. Recently, a storm came through your hometown after meteorologists predicted the opposite. The town newspaper is blaming the meteorologists for incorrectly predicting the weather. Using your knowledge of ocean currents, you will defend the meteorologists and address the real culprit: the Coriolis effect.

This lesson was adapted from the Motion in the Ocean lesson by the National Ocean and Atmospheric Administration (NOAA).

Students will be able to:

- Describe how naval travel is important and relevant in today's society
- Explain the movement of water in the ocean due to temperature, density, and planetary movement
- Use mathematical models to predict the impact of the Coriolis Effect
- Connect their understanding of ocean currents and phenomenon to everyday occurrences like weather

Students will understand:

The cause of ocean currents and their impact on ocean movement are discovered through this lesson. In naval experiments and studies, the movement of the ocean water is key in analyzing and predicting data pertaining to the chemical composition and chemical levels within ocean water dependent on location. In the use of a SeaGlide, the ocean and its currents are important topics to discuss because of the direct impact on its function.

Key Definitions & Concepts: [1]

- **Oceanography**: the branch of science that deals with the physical and the biological properties along with other phenomena of the sea.
- **Coriolis Effect:** an effect whereby a mass moving in a rotating system experiences a force (the *Coriolis force*) acting perpendicular to the direction of motion and to the axis of rotation. On the earth, the effect tends to deflect moving objects to the right in the northern hemisphere and to the left in the southern. This is important in the formation of cyclonic weather systems.
- **Current:** any cyclical movement of a given body of water which are generated from the forces acting upon the water like the earth's rotation, the wind, the temperature and salinity differences and the gravitation of the moon.

Standards: [Copied from: 2]

MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

- Students will be learning about how the Earth's movement around the sun affects its processes. These processes include: thermoclines, currents, and the Coriolis effect. These events can affect the movement and function of their SeaGlide, and are necessary in understanding naval travel.

Background Information

Prior Knowledge:

- Basic understanding of weather conditions and weather reporting
- Basic understanding of ocean currents (i.e. movements of the tides, etc.)
- Basic understanding of naval importance (i.e. military uses, transportation, etc.)

Science Practices: [Copied from: 3]	Core Ideas: Copied from: 4]	Cross Cutting Concepts: [Copied from: 5]
• Developing & Using Models	• The Roles of Water in Earth's Surface Processes • Weather & Climate	• Systems & Systems Models

Possible Preconceptions/Misconceptions:

This lesson is designed to be an introduction to Ocean Conditions, so mistakes and misconceptions are to be expected. This lesson is meant to serve as a foundation for students to build their understanding of the ocean through vocabulary, important ideas, and concepts. Students may experience difficulty using the formula provided for answer the questions on *The Math of the Coriolis Effect*. However, this worksheet is listed as homework for the students to take home and complete. Hence, the students are expected to have access to internet resources other other forms of aid to complete the worksheet successfully.

Lesson Plan - 5E(+) Model

Engage:

Ask students to comment on the present-day importance of marine navigation. It is recommended that the instructor utilizes the *Present-Day Marine Navigation* answer key as a discussion guide for this section. As the instructor leads the whole class discussion, students will be following along and filling in the *Present-Day Marine Navigation* half sheet. Students should realize that, despite the prevalence of air travel and advances in aerospace technology, Earth's oceans are still vital to transportation, energy production, and recreation. Discuss the importance of real-time information for 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 some basic facts about "ocean motion," and use this information to solve problems dealing with winds, ocean waves, and currents. The instructor should also notify students that this information is relevant to the usage of their SeaGlide. This discussion should take 5 - 10 minutes.

Explore:

Part I: Introduction [1], [6]

The instructor will distribute the worksheets *Ocean Current Terminology* and *Currents*. These worksheets will be used throughout the rest of the lesson and topic. Students should work on the terminology worksheet individually.

Part II: *Benchmark Lesson*: Ocean Current Terminology [1], [6]

Students will work individually through this portion of the lesson. They should be instructed to read and to utilize the document *Currents* to complete the worksheet *Ocean Current Terminology.* The *Currents* reading introduces key vocabulary that will be used throughout the major topic of Ocean Conditions. The *Currents* reading also serves as an introduction to the the topic of Ocean Currents and how temperature impacts these currents. As an introduction to ocean conditions, this activity is important to establish a foundational vocabulary schema for students' understanding moving forward. It is recommended that the *Ocean Current Terminology* worksheet be collected immediately for grading as students finish, but allow them to hold onto the *Currents* reading for utilization later on in the lesson. This activity should take 10 - 15 minutes to complete.

Part III: *Investigation Lesson*: Problems on Wind, Waves, & Current [7]

Students will test their knowledge of currents to answer questions on the *Problems on Wind, Waves, & Currents* about the movement of objects that have been drifted out at sea. Students will need to think critically and use online mariner resources to determine things such as: distance travelled by the drifter, the velocity of the drifter, and the location of the drifter. These questions are meant to have students make connections with the material and their SeaGlide, which may experience occurrences like the ones in the questions. This activity should take between 15 and 20 minutes to complete.

Explain:

Throughout the exploration of this lesson, students will engage in discussions and activities that seek to discover their understanding of the topic at-hand as it relates to ocean currents and temperature. Instructors should informally ask questions to promote thoughtful discussion that is designed to aid in addressing any questions or concerns that some students may have. Students are expected to formalize their answers throughout the entirety of the lesson via the worksheets and the evaluation.

Elaborate: [9]

This lesson is the introductory lesson to Ocean Conditions, which directly correlates to a SeaGlide's development and function within water. Although the lesson focus on the water within the ocean, the same principles of currents and temperatures affect any water that the SeaGlide will be present in. Ocean Conditions also impact the everyday lives of students, like impacting weather patterns and transportation. This is shown in the *Sailor Letter* activity, where the students are actively relating their acquired knowledge of ocean conditions to weather patterns in the United States. Reference the Evaluate section of this lesson plan for specific details regarding the *Sailor Letter* activity. Allow the remaining 15 minutes of class time to be dedicated to the *Sailor Letter* activity, and expect to collect the activity for grading at the end of the class period.

NOTES FOR THE TEACHER
Below is an additional activity that would engage students in thinking critically about ocean currents' applicability in mathematics. It is not included in the lesson because of timing purposes, but it is recommended to be used as an at-home assignment that is due during the next class meeting. See activity below:

The Math of the Coriolis Effect worksheet is designed to extend students' understanding of the ocean currents by using mathematics to predict its effects on everyday life. This is important for students to understand because the Coriolis Effect is a major contributor to wind patterns and ocean currents, which combine and affect weather patterns. Students will be required to use critical-thinking skills in order to predict what their answers should be, then use a formula to calculate the answer.

<u>Evaluate:</u>

Students take the role of a sailor and oceanographer in the Atlantic Ocean by working through the *Sailor Letter* activity. Recently, a storm came through their hometown after meteorologists predicted the opposite. The town newspaper is blaming the meteorologists for incorrectly predicting the weather. Using their knowledge of ocean currents, students will defend the meteorologists and address the real culprit: the Coriolis Effect. This activity prompts students to apply their newly-acquired knowledge of ocean currents and temperature to weather patterns. Students already learned and discussed how the Coriolis Effect impacts ocean currents, but now they are actively verbalizing and extending their understanding. This activity should take between 15 and 20 minutes to complete.

Throughout the entirety of this lesson, there will be both formal and informal evaluations. The informal evaluations occur throughout the exploration via leading and open-ended questioning, as well as through the open class discussions. The informal evaluations will allow for the teacher to gauge surface-level understanding of the students. By surveying the students during completion of the worksheets and activities, teachers will be able to hear and to address any misconceptions or misunderstandings as necessary. The formal evaluations of this lesson are the *Ocean Current Terminology* and *Problems on Wind, Waves, & Current* worksheets and the *Sailor Letter* activity.

<u>Enrich:</u>

This lesson can be differentiated by expanding on the impact that ocean currents and movement of water affect ocean ecology. Because of the movement of hot and cold water, microclimates within parts of the ocean can dramatically impact the ocean wildlife. This is most frequently seen in coastal biomes, where organisms are adapted to the warmer water. If the ocean current causes cold water to move in, then the organisms are at risk of dying. The instructor may also choose to focus on ecological and environmental impacts of the ocean currents since the Coriolis Effect worksheet provides priming to mathematical applications of environmental impacts, specifically those affecting ocean currents.

All associated documents are attached below

Reference *Annotated Bibliography* on the very last page of this packet

Name: ____ Date: ________________

Present-Day Marine Navigation

1. What is the importance of real-time information for safe naval navigation?

2. Devise some types of information that would be useful to a present-day mariner.

Name: ____ Date: ________________

Present-Day Marine Navigation

1. What is the importance of real-time information for safe naval navigation?

2. Devise some types of information that would be useful to a present-day mariner.

Name: ____ Date: _________________

Ocean Currents Terminology [1]

1. The __________ of currents includes speed and directional components.
2. Three factors that drive ocean currents are __________, ___________, and _________.
3. When a coastal tidal current __________, it moves toward the land and away from the sea. When a coastal tidal current __________, it moves toward the sea and away from the land.
4. As a coastal tidal current moves from ebbing to flooding (and vice versa), there is a period during which there is no current velocity. This period is called __________.
5. Tidal currents are most strongly influenced by motions of the __________.
6. When the moon is at full or new phases, the tidal current velocities are __________ and are called __________. When the moon is at first or third quarter phases, tidal current velocities are __________ and are called __________.
7. "__________ currents" occur when the moon and Earth are closest to each other. "__________ currents" occur when the moon and Earth are farthest from each other.
8. Wave height is affected by wind __________, wind ________, and __________.
9. Breaking waves are caused by __________.
10. A localized current that flows toward the ocean and that flows perpendicular, or nearly perpendicular, to the shoreline is called a __________.
11. __________ occurs when winds blowing across the ocean's surface push water away from an area, causing subsurface water to come up from beneath the surface to replace the diverging surface water.
12. Earth's rotation causes air circulating in the atmosphere to deflect toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. This deflection is called __________ .
13. Global winds drag on the ocean's surface, causing the water to move in the direction that the wind is blowing and thus create surface ocean currents. Deflection of these currents by Earth's rotation produces spiral currents called _________.

14. Each of the major ocean-wide gyres is flanked by a strong and narrow “western boundary current,” and a weak and broad “eastern boundary current.” The western boundary current of the North Atlantic gyre is called __________, and the eastern boundary current of this gyre is known as __________.
15. When surface water molecules move by the force of the wind, friction between water molecules causes movement of deeper water layers. However, deeper layers move more slowly than shallower layers, and all layers are deflected by Earth’s rotation (to the right in the Northern Hemisphere and to the left in the Southern Hemisphere). These forces create a spiral effect called __________.
16. Deep-ocean currents below 100 meters are driven by ___________________________, in a process known as __________.
17. The global-scale system of deep-ocean currents is sometimes called the __________.
18. Ocean and coastal current velocities are typically are measured in __________, which is equal to about ________standard (or “statute”) miles per hour, or about __________ kilometers per hour.

Currents [6]

Tidal currents occur in conjunction with the rise and fall of the tide. The vertical motion of the tides near the shore causes the water to move horizontally, creating currents. When a tidal current moves toward the land and away from the sea, it “floods.” When it moves toward the sea away from the land, it “ebbs.” These tidal currents that ebb and flood in opposite directions are called “rectilinear” or “reversing” currents.

Rectilinear tidal currents, which typically are found in coastal rivers and estuaries, experience a “slack water” period of no velocity as they move from the ebbing to flooding stage, and vice versa. After a brief slack period, which can range from seconds to several minutes and generally coincides with high or low tide, the current switches direction and increases in velocity.

Tidal currents are the only type of current affected by the interactions of the Earth, sun, and moon. The moon’s force is much greater than that of the sun because it is 389 times closer to the Earth than the sun is. Tidal currents, just like tides, are affected by the different phases of the moon. When the moon is at full or new phases, tidal current velocities are strong and are called “spring currents.” When the moon is at first or third quarter phases, tidal current velocities are weak and are called “neap currents.”

Also similar to tides, tidal currents are affected by the relative positions of the moon and Earth. When the moon and Earth are positioned nearest to each other (perigee), the currents are stronger than average and are called “perigean currents.” When the moon and Earth are at their farthest distance from each other (apogee), the currents are weaker and are called “apogean currents.”

Coastal currents are intricately tied to winds, waves, and land formations. Winds that blow along the shoreline—longshore winds—affect waves and, therefore, currents.

Before one can understand any type of surface current, one must understand how wind and waves operate. Wave height is affected by wind speed, wind duration (or how long the wind blows), and fetch, which is the distance over water that the wind blows in a single direction. If wind speed is slow, only small waves result, regardless of wind duration or fetch. If the wind speed is great but it only blows for a few minutes, no large waves will result even if the wind speed is strong and fetch is unlimited. Also, if strong winds blow for a long period of time but over a short fetch, no large waves form. Large waves occur only when all three factors combine (Duxbury, et al, 2002.)

As wind-driven waves approach the shore, friction between the seafloor and the water causes the water to form increasingly steep angles. Waves that become too steep and unstable are termed “breakers” or “breaking waves.”

Winds blowing across the ocean surface often push water away from an area. When this occurs, water rises up from beneath the surface to replace the diverging surface water. This process is known as “upwelling.” Upwelling occurs in the open ocean and along coastlines. The reverse process, called downwelling, also occurs when wind causes surface water to build up along a coastline. The surface water eventually sinks toward the bottom.

Coastal currents are affected by local winds. Surface ocean currents, which occur on the open ocean, are driven by a complex global wind system. To understand the effects of winds on ocean currents, one first needs to understand the Coriolis force and the Ekman spiral.

If the Earth did not rotate and remained stationary, the atmosphere would circulate between the poles (high pressure areas) and the equator (a low pressure area) in a simple back-and-forth pattern. But because the Earth rotates, circulating air is deflected. Instead of circulating in a straight pattern, the air deflects toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere, resulting in curved paths. This deflection is called the Coriolis effect. It is named after the French mathematician Gaspard Gustave de Coriolis (1792-1843), who studied the transfer of energy in rotating systems like waterwheels. (Ross, 1995).

The Ekman spiral, named after Swedish scientist Vagn Walfrid Ekman (1874-1954) who first theorized it in 1902, is a consequence of the Coriolis effect. When surface water molecules move by the force of the wind, they, in turn, drag deeper layers of water molecules below them. Each layer of water molecules is moved by friction from the shallower layer, and each deeper layer moves more slowly than the layer above it, until the movement ceases at a depth of about 100 meters (330 feet). Like the surface water, however, the deeper water is deflected by the Coriolis effect—to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. As a result, each successively deeper layer of water moves more slowly to the right or left, creating a spiral effect. Because the deeper layers of water move more slowly than the shallower layers, they tend to “twist around” and flow opposite to the surface current.Winds drive ocean currents in the upper 100 meters of the ocean’s surface. However, ocean currents also flow thousands of meters below the surface. These deep-ocean currents are driven by differences in the water’s density, which is controlled by temperature (*thermo*) and salinity (*haline*). This process is known as thermohaline circulation.

In the Earth's polar regions ocean water gets very cold, forming sea ice. As a consequence the surrounding seawater gets saltier, because when sea ice forms, the salt is left behind. As the seawater gets saltier, its density increases, and it starts to sink. Surface water is pulled in to replace the sinking water, which in turn eventually becomes cold and salty enough to sink. This initiates the deep-ocean currents driving the global conveyor belt.

The term “knot”, in reference to currents, is defined as one nautical mile per hour and is used to measure speed. A nautical mile is slightly more than a standard mile.

1 nautical mile = 1.15 miles = 1.85 kilometers

1 knot = 1.15 miles per hour = 1.85 kilometers per hour

1 knot = 20.251969 inches per second = 51.44 centimeters per second

The term knot dates from the 17th Century, when sailors measured the speed of their ship by the use of a device called a “common log.” This device was a coil of rope with uniformly spaced knots tied in it, attached to a piece of wood shaped like a slice of pie. The piece of wood was lowered from the back of the ship and allowed to float behind it. The line was allowed to pay out freely from the coil as the piece of wood fell behind the ship for a specific amount of time. When the specified time had passed, the line was pulled in and the number of knots on the rope between the ship and the wood were counted. The speed of the ship was said to be the number of knots counted (Bowditch, 1984).

Current measurements are important to shipping, commercial fishing, recreational boating, and safety. By using predicted, real-time and short-term forecasted currents, people can safely dock and undock ships, maneuver them in confined waterways and safely navigate through coastal waters. With this information, merchandise and people can arrive on schedule. Lack of this knowledge can lead to collisions and delayed arrivals.

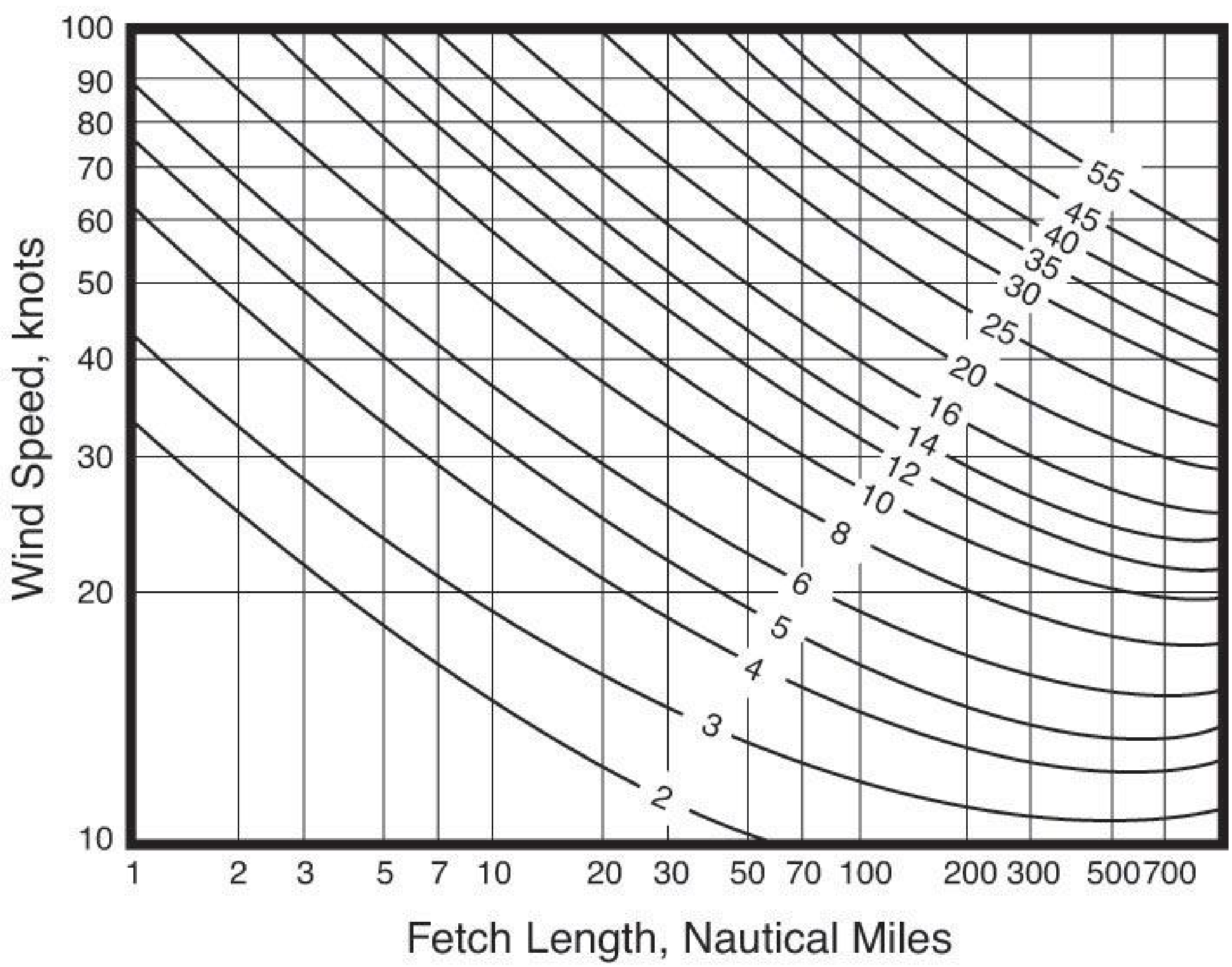
Search-and-rescue personnel can use real-time and predicted current patterns to determine where the water may carry a missing person or floating object(s). Geographic Information Systems (GIS) programs are used to assist in search-and-rescue efforts as well. These programs use the last-known position of the lost person or item(s), predicted and real-time current and weather data, and drift patterns to estimate the location of the person or item(s).

Name: ____ Date: ________________

Problems on Wind, Waves, & Currents [7]

Surface ocean waves are produced by winds. The height of these waves depends upon wind speed, the length of time the wind blows (duration) and the distance over which the wind blows (fetch). In 1952, Charles Bretschneider created a diagram that describes the relationship between these parameters and provides an easy way to predict the height of a wave produced by specific wind conditions. Figure 1 is an example of this kind of diagram (usually called a “Sverdrup-Munk-Bretschneider nomogram”). The y-axis describes Wind Speed; the x-axis describes Fetch Length; solid curved lines in the middle of the diagram show the Wave Height in feet (most Sverdrup-Munk-Bretschneider nomograms also include lines showing wave period and wind duration; these have been omitted from Figure 1 for clarity). When using the nomogram, be sure to match these lines with the correct labels!

Figure 1:



Questions:

1. If a wind blows over a 10 nautical mile fetch at 21 knots, what would the resulting wave height be?

2. What would cause the larger increase in wave height for conditions in the preceding question: increasing the wind speed by 60 knots or increasing the fetch length by 60 nautical miles?

3. What would be the minimum fetch over which a 60 knot wind would have to blow to produce a wave 10 feet high?

4. There are a variety of ways to measure the velocity of a current. One of the oldest and simplest methods is to use a “drifter,” which can be any floating object (an ideal drifter is one that is not affected by wind; glass bottles partially filled with sand are a traditional type of drifter). To measure current velocity, an observer places the drifter into the water, measures the amount of time the drifter takes to move a known distance, and notes the direction of the drifter’s motion (since velocity is a vector quantity, and has dimensions of direction as well as speed). Next, the observer finds the speed of the current by dividing the distance the drifter traveled by the time it took to travel that distance. The speed of the drifter combined with the direction in which it moved is the current’s velocity.

   Suppose a drifter is released near Charleston, SC from a research vessel whose position is 32°23’15” North latitude, 79°12’33” West longitude, at 0915 eastern standard time (EST) on May 11, 2004. A sailing yacht recovers the drifter at 1930 EST on May 17, 2004 in position 39°56’23” North latitude, 73°44’35” West longitude.

   What is the estimated velocity and direction of the current that transported this drifter?

   Note:

   In this case, it is sufficient to describe the direction component of the velocity vector as north, northeast, east, southeast, south, southwest, west, or northwest. State the speed component of the vector in knots (nautical miles per hour). [Hint: You can use the calculator at Chemical Ecology | Latitude & Longitude to find the distance between two points whose latitude and longitude are known.]

   If you would like to have a map of the area covered by the drifter, visit the Marine Geoscience Data System Web site (Marine Geo | Map Grids). Enter the latitude and longitude boundaries for the area you want the map to cover, then click on the “Map” button. In this case you would enter 40° as the northern boundary; -80° as the western boundary (note that longitudes west of the prime meridian are assigned a negative value, while longitudes east of the prime meridian are positive); -73° as the eastern boundary; and 32° as the southern boundary. The map will show the elevation (or depth) of Earth’s surface in the included area.

Name: ____ Date: ________________

The Math of the Coriolis Effect [7]

1. The deflection of moving objects caused by Earth's rotation is called the Coriolis effect. Acceleration due to the Coriolis effect always acts at right angles to the direction of the velocity vector, and has a magnitude of

   $$(2 \cdot w \cdot v \cdot \sin f)\ \text{cm/sec}^2$$

   where w is the angular velocity of Earth, v is the velocity of the moving object, and f is the latitude in degrees. Since the angular velocity of Earth is about 7.29 x 10-5 radians/sec, acceleration due to the Coriolis effect is about

   $$(1.5 \times 10^{-4} \cdot v \cdot \sin f)\ \text{cm/sec}^2$$

   (note that radians have no units). What does this equation suggest about the magnitude of the Coriolis acceleration at the equator?

2. Suppose a soccer player in Tijuana, Mexico kicks a soccer ball with a velocity of 10 meters per second. What is the effect of the Coriolis acceleration on the ball?

3. Given the results of the preceding question, why is Coriolis acceleration significant to the circulation is the atmosphere and ocean?

Name: ____ Date: ________________

Sailor Letter

Introduction:

You are a sailor and oceanographer with experience on the Atlantic Ocean. Recently, a storm came through your hometown after meteorologists predicted the opposite. The meteorologists' computer systems mistakenly placed the town in the Southern Hemisphere instead of the Northern Hemisphere. The town newspaper is blaming the meteorologists for incorrectly predicting the weather, stating that the location of the town in the Northern or Southern Hemispheres does not affect the weather prediction. Using your knowledge of ocean currents and systems and of the Coriolis Effect, defend the meteorologists and address the real culprit. Hint: discuss the significance between the location of the storm based on the hemisphere.

Rubric:

Points	0	1 - 2	3 - 4
Explanation of Why Hemisphere Matters / What Caused the Incorrect Prediction	The student does not explain the phenomenon that caused the weather prediction to be wrong.	The student states what caused the weather prediction as an error, but does not explain how it affects the weather prediction.	The student clearly explains the cause of the weather prediction error and how it affected the weather prediction.
Correctness of Science	The student does not use any factual scientific evidence to support their explanation.	The student provides little to no scientific evidence to support their explanation.	The student provides adequate scientific evidence to support their explanations.
Grammar / Format	The letter is full of grammatical and spelling mistakes. There is no direction or progression in the writing.	The letter has several grammatical and spelling mistakes. The letter has some direction and progression.	The letter has little to no grammatical or spelling mistakes. The letter has a clear direction and progression.
Creativity (BONUS)	The student does not show any clear creativity in the letter.	The personality of the writer is shown through providing analogies or jokes, etc.	

Grade:

Points	0	1 - 2	3 - 4
Explanation of Why Hemisphere Matters / What Caused the Incorrect Prediction			
Correctness of Science			
Grammar / Format			
Creativity (BONUS)			

Total Score: ____________ / 12

____________ / 2 (Bonus)

Overall: ______________

Comments:

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Name: ____ Date: _________________

Present-Day Marine Navigation

1. What is the importance of real-time information for safe marine navigation?

   Answers are dependent on student response.

   Expect the following: Real-time information is important in marine navigation because the ocean is an ever-changing system. Because it is ever-changing, marine navigation cannot solely rely on information from a previous time. If marine navigation were to use old information, sailors could potentially drift off course, sail into a storm system, lose precious cargo due to turbulent water, and/or even sink. Real-time information allows marine navigation to adjust their course and plan on-demand based on the data that they are collecting.

2. Devise some types of information that would be useful to a present-day mariner.

   Answers are dependent on student response.

   Expect some of the following: ocean temperature, weather forecast, water salinity, ocean current velocity, and wind velocity. All of these conditions directly impact the water in which the marine navigation is occurring. For reasoning explaining why this information is important, see the above explanation.

Name: ___________________ANSWER_KEY___________________Date: ________________

Ocean Currents Terminology [1]

1. The velocity of currents includes speed and directional components.
2. Three factors that drive ocean currents are tidal motion, wind, and thermohaline circulation.
3. When a coastal tidal current floods, it moves toward the land and away from the sea. When a coastal tidal current ebbs, it moves toward the sea and away from the land.
4. As a coastal tidal current moves from ebbing to flooding (and vice versa), there is a period during which there is no current velocity. This period is called slack water.
5. Tidal currents are most strongly influenced by motions of the moon.
6. When the moon is at full or new phases, the tidal current velocities are strong and are called spring currents. When the moon is at first or third quarter phases, tidal current velocities are weak and are called neap currents.
7. "Perigean currents" occur when the moon and Earth are closest to each other. "Apogean currents" occur when the moon and Earth are farthest from each other.
8. Wave height is affected by wind speed, wind duration, and fetch.
9. Breaking waves are caused by friction between the seafloor and the water.
10. A localized current that flows toward the ocean, perpendicular or nearly perpendicular to the shoreline is called a rip current.
11. Upwelling occurs when winds blowing across the ocean's surface push water away from an area, causing subsurface water to come up from beneath the surface to replace the diverging surface water.
12. Earth's rotation causes air circulating in the atmosphere to deflect toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. This deflection is called Coriolis effect.

13. Global winds drag on the ocean's surface, causing the water to move in the direction that the wind is blowing and thus create surface ocean currents. Deflection of these currents by Earth's rotation produces spiral currents called gyres.
14. Each of the major ocean-wide gyres is flanked by a strong and narrow "western boundary current," and a weak and broad "eastern boundary current." The western boundary current of the North Atlantic gyre is called the Gulf Stream, and the eastern boundary current of this gyre is known as the Canary Current.
15. When surface water molecules move by the force of the wind, friction between water molecules causes movement of deeper water layers. However, deeper layers move more slowly than shallower layers, and all layers are deflected by Earth's rotation (to the right in the Northern Hemisphere and to the left in the Southern Hemisphere). These forces create a spiral effect called Eckman spiral.
16. Deep-ocean currents below 100 meters are driven by differences in water density, in a process known as thermohaline circulation.
17. The global-scale system of deep-ocean currents is sometimes called the global conveyor belt.
18. Ocean and coastal current velocities are typically are measured in knots, which is equal to about 1.15 standard (or "statute") miles per hour, or about 1.85 kilometers per hour.

Name: ___________________ANSWER KEY___________________ Date: _______________

Problems on Wind, Waves, & Currents [7]

Questions:

1. If a wind blows over a 10 nautical mile fetch at 21 knots, what would the resulting wave height be?

   3 feet

2. What would cause the larger increase in wave height for conditions in the preceding question: increasing the wind speed by 60 knots or increasing the fetch length by 60 nautical miles?

   Increasing the wind speed by 60 knots would increase the wave height to approximately 12 feet, while increasing the fetch length by 60 nautical miles (nm) would increase the wave height to less than 6 feet.

3. What would be the minimum fetch over which a 60 knot wind would have to blow to produce a wave 10 feet high?

   A 60 knot wind would have to blow over a fetch of about 9 miles to produce a wave 10 feet high.

4. There are a variety of ways to measure the velocity of a current. One of the oldest and simplest methods is to use a “drifter,” which can be any floating object (an ideal drifter is one that is not affected by wind; glass bottles partially filled with sand are a traditional type of drifter). To measure current velocity, an observer places the drifter into the water, measures the amount of time the drifter takes to move a known distance, and notes the direction of the drifter’s motion (since velocity is a vector quantity, and has dimensions of direction as well as speed). Next, the observer finds the speed of the current by dividing the distance the drifter traveled by the time it took to travel that distance. The speed of the drifter combined with the direction in which it moved is the current’s velocity.

   Suppose a drifter is released near Charleston, SC from a research vessel whose position is 32°23’15” North latitude, 79°12’33”West longitude, at 0915 eastern standard time (EST) on May 11, 2004. A sailing yacht recovers the drifter at 1930 EST on May 17, 2004 in position 39°56’23” North latitude, 73°44’35” West longitude.

   What is the estimated velocity and direction of the current that transported this drifter?

   The distance between the points is 524.6 nautical miles.The total time elapsed is 6 days, 10.25 hours = 154.25 hours. So the estimated current speed is:

   524.6 nm ÷ 154.25 hr = 3.40 nm/hr = 3.40 knots

   The estimated direction of the current is northeast.

Name: ___________________ANSWER KEY___________________ Date: ________________

The Math of the Coriolis Effect [7]

1. The deflection of moving objects caused by Earth's rotation is called the Coriolis effect. Acceleration due to the Coriolis effect always acts at right angles to the direction of the velocity vector, and has a magnitude of

   $$(2 \cdot w \cdot v \cdot \sin f)\ \text{cm/sec}^2$$

   where w is the angular velocity of Earth, v is the velocity of the moving object, and f is the latitude in degrees. Since the angular velocity of Earth is about 7.29 x 10-5 radians/sec, acceleration due to the Coriolis effect is about

   $$(1.5 \times 10^{-4} \cdot v \cdot \sin f)\ \text{cm/sec}^2$$

   (note that radians have no units). What does this equation suggest about the magnitude of the Coriolis acceleration at the equator?

   Since the latitude at the equator is zero, the formula for Coriolis acceleration suggests that the magnitude of this acceleration at the equator is zero.

2. Suppose a soccer player in Tijuana, Mexico kicks a soccer ball with a velocity of 10 meters per second. What is the effect of the Coriolis acceleration on the ball?

   The latitude of Tijuanaisabout 32.5°N. A velocity of 10 meters/second is equal to 1,000 centimeters/second. So, the magnitude of the Coriolis acceleration is

   $(\sin 32.5° \cdot 1.5 \times 10^{-4} \cdot 1{,}000)\ \text{cm/sec}^2 = 0.537 \cdot 1.5 \times 10^{-4} \cdot 1{,}000 = 0.081\ \text{cm/sec}^2$

   The effect is very small.

3. Given the results of the preceding question, why is Coriolis acceleration significant to the circulation is the atmosphere and ocean?

   Even though the effect of Coriolis acceleration on soccer balls, walking humans, etc. is practically negligible, when it acts on very large masses over very long distances, the acceleration becomes significant.

Name: ___________________ANSWER KEY___________________ Date: ________________

Sailor Letter

Introduction:

You are a sailor and oceanographer with experience on the Atlantic Ocean. Recently, a storm came through your hometown after meteorologists predicted the opposite. The meteorologists' computer systems mistakenly placed the town in the Southern Hemisphere instead of the Northern Hemisphere. The town newspaper is blaming the meteorologists for incorrectly predicting the weather, stating that the location of the town in the Northern or Southern Hemispheres does not affect the weather prediction. Using your knowledge of ocean currents and systems and of the Coriolis Effect, defend the meteorologists and address the real culprit. Hint: discuss the significance between the location of the storm based on the hemisphere.

Expectation:

Technically speaking, the weather report was correct because of the Coriolis Effect. The Coriolis Effect is a weather phenomenon that is caused by the spinning of the Earth. As the Earth spins, it generates a force on a given mass, in this case the air, causing it to move and behave oddly. This allows for winds in the Northern Hemisphere to blow towards the East and winds in the Southern Hemisphere to blow towards the West. The weather report's predictions were wrong by assuming that the Atlantic Ocean is located in the Southern Hemisphere. If the meteorologists' location assumptions were correct, then their report would also be correct. However, due to the incorrect location assumption, the weather affected a community in the Southern Hemisphere instead of in the Northern Hemisphere as reported. Hence, the misinterpretation of the storm's movement affected the community that was assumed to be safe. The weather station is not directly to blame; it's the Coriolis Effect.

Note:
The scientific evidence is stating the importance of the Coriolis Effect and explaining (accurately) what the Coriolis Effect is.

Annotated Bibliography

[1] NOAA, & Ocean Service Education. (n.d.). Currents Subject Review. Retrieved March, 2019, from https://aamboceanservice.blob.core.windows.net/oceanservice-prod/education/lessons/media/currents_review.pdf

This reference was used for excerption purposes within the lesson plan. This reference aided in the completion of the key concepts and definitions as well as the lesson's introduction activity. As stated, the worksheet and its content was directly used to establish necessary vocabulary for the students. It allowed students to not only develop literacy skills, but also the vocabulary of this module. Further, the Ocean Current Terminology worksheet was excerpted from this reference and extended into a 5E Plus lesson plan.

[2] Nsta. (n.d.). Access the Next Generation Science Standards by Topic. Retrieved January 18, 2019, from https://ngss.nsta.org/AccessStandardsByTopic.aspx

This website was used in each lesson in the Ocean Conditions module to select proper national set standards for science subjects that each lesson is centered around.

[3] Nsta. (n.d.). Science and Engineering Practices. Retrieved January 18, 2019, from https://ngss.nsta.org/PracticesFull.aspx

This website used in every lesson in the Ocean Conditions module to find Standards for Science and Engineering Practices that are applicable in each lesson.

[4] Nsta. (n.d.). Disciplinary Core Ideas. Retrieved from https://ngss.nsta.org/DisciplinaryCoreIdeasTop.aspx

This website was used in each lesson in the Ocean Conditions module to select appropriate disciplinary core ideas set forth by the NSTA that are at the center of each lesson.

[5] Nsta. (n.d.). Crosscutting Concepts. Retrieved from https://ngss.nsta.org/CrosscuttingConceptsFull.aspx

This website was used in each lesson in the Ocean Conditions module to selecting appropriate crosscutting concepts set forth by the NSTA that apply to each science lesson.

[6] US Department of Commerce, & National Oceanic and Atmospheric Administration. (n.d.). Motion in the Ocean. Retrieved from https://oceanservice.noaa.gov/education/lessons/ocean_motion.html

This was used for adaptation services within the lesson plan. This reference aided in the completion of the lesson activities and worksheets. Also, the NOAA lesson plan activities and worksheets were adapted. They were adapted to the 5E Model. The activities and worksheets were useful in illustrating ocean currents and their impact of ecosystems/life.

[7] US Department of Commerce, & National Oceanic and Atmospheric Administration. (2008, January 15). NOAA National Ocean Service Education: Motion in the Ocean | Lesson Plan: Student Worksheet. Retrieved March, 2019, from https://oceanservice.noaa.gov/education/lessons/ocean_motion_wksht.html

This resource was used for excerption purposes. This reference aided in the completion of the lesson exploration: part 3 investigation portion.. Also, the worksheet and its associated questions and image were excerpted for this activity. As stated, the worksheet and its content was directly used for the investigation lesson activity, but broken up into two seperate worksheets. This reference directly connects to work being done by the US Navy, establishing a concrete real-world application and connection to the SeaGlide. This lesson extends the worksheet to be used in a 5E lesson.