Teaching Activity: Using Sound Waves to Study Climate Change

Introduction: Sound is produced when matter vibrates, and like light, travels through a medium in the form of waves. Sound waves are composed of a series of high and low points, much like the crest and trough of an ocean wave. The distance from one wave crest to the next is known as wavelength. The rate at which a sound wave travels depends upon the type of medium (air, water, rock, etc.) that it is moving through. In air, sound travels approximately 1000 feet (330 m) per second; in water it travels at about 4800 feet (1500 m) per second. A good example of how fast sound travels in the air can be observed during a thunderstorm. If you see a flash of lightning, the distance from the lightning to you can be calculated by counting the seconds until you hear the thunder and multiplying by 1000. For example, if you see lightning and count to five before you hear the thunder (5 x 1000= 5000) then the lightning was about 5000 feet, about 1 mile away when you first saw it.

Objectives:

- To describe the characteristics of sound waves and their movement through different mediums;
- To apply the use of sound waves to map the ocean floor;
- To analyze the relationship between the speed of sound in water and temperature;
- To illustrate the uses of acoustic monitoring in global change research;

Important Terms: Sound, waves, wavelength, geologist, topography echo sounding, speed of sound, elasticity, acoustic monitoring scheme, heat flux, Fram Strait, Arctic Ocean, Spitzbergen Island, frequency;

Materials: **Student Activity Sheets,** calculator, paper/pencil, ruler, dictionary/Earth Science text, world atlas, graph paper;

Procedure:

Activity #1: Math Application: Students should try the problems below using the information in the Introduction.

1. **You see a lightning flash and count to 15 before you hear the thunder. How far away was the lightning? ______________________________**

2. **If you see a flash of lightning and count to one before you hear the thunder, how far away was the lightning strike?______________________**

3. **How long would it take to hear the thunder accompanying a lightning strike 5 miles away?___________________________**

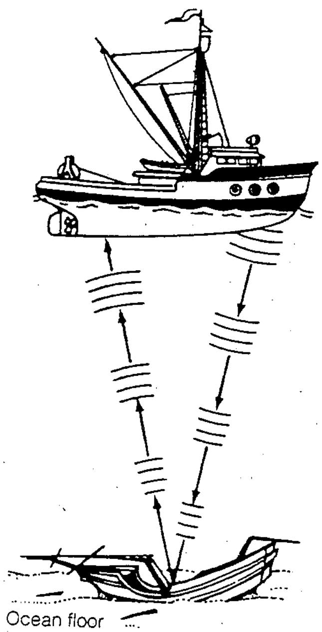
4. **A boy throws a rock at the window of a building about 200 feet away. His friend is standing next to him. How long would it take for his friend to hear the window break?** ______________________________

5. **How many time faster does sound travel in air than in water?** __________

6. **An orca emits a "ping" that locates a seal 2 miles away. About how long should it take the sound to travel to the seal and the echo to be received by the orca? (HINT: 1 mile =5280 ft)** ________________

Activity #2: Using Sound Waves to Map the Ocean Floor:

Background: In the past 50 years, marine geologists have been able to learn about the topography of the ocean by using sound. An echo sounding is made to measure the depth of the ocean. It includes a series of "pings" from an instrument aboard a ship. When the sound wave hits the ocean floor, an echo is reflected back and received by the ship. The amount of time between the transmission of the "ping" and the receiving of the echo give a measure of the depth. The speed of sound in water is about 4800 ft (1500 m) per second (ft/sec). Scientists use the following formula to determine the depth of the ocean from the echo sounding:



Ocean Depth (in feet) = Time elapsed (seconds) ÷ 2 x 4800 ft/sec

NOTE:

- **Ocean depth is what they are trying to determine at various points along the ocean floor. It is measure in feet or meters.**
- **Time elapsed is the time measured between the transmitting of the "ping" and the receiving of the echo. However, since the sound travels to the ocean floor and bounces back, this equation must be divided by 2.**
- **4800 ft/sec is the speed of sound in water;**

TASK: You have just completed an oceanographic voyage in the Atlantic Ocean that followed the track along the 45 ° N latitude from Halifax, Nova Scotia, Canada to the Bay of Biscay, France. Your job is to map the ocean floor from the sounding taken during the voyage.

1. The depth chart below gives the location of the ship (longitude) and the amount of time it took the echo sounding to be transmitted and received.
   - Students should use the formula for determining depth to complete the chart below. (Depth = Time ÷ 2 x 4800)

2. Once all the depths are calculated, students should plot them on the graph of the ocean floor.
   - Look up the depth for a specific longitude.

- Find the depth on the graph.
- Place their ruler across the graph at that depth.
- Find the specific longitude and make an imaginary vertical line to the ruler.
- Plot the point where the vertical liner and the ruler meet.
- Plot all the remaining depths the same way.

3. Students should then connect all of the points. The line that develops is a profile of the ocean floor from Canada to France.

4. Students should then look up the following terms of ocean floor features and label them on your graph: Continental Shelf, Abyssal Plain, Continental Slope, Mid Ocean Ridge.

Part III: Temperature and the Speed of Sound

Background: Scientists know that in addition to the type of medium, its elasticity and density, the speed of sound in also determined by temperature. Lowering the temperature of a substance makes the motion of the particles more sluggish. The particles are more difficult to move and slow to return to their original positions. Therefore, sound travels faster at higher temperatures and slower at lower temperatures. Solids are much more elastic that either liquids or gases, and allow sound waves to travel through them very quickly, at about 600 feet (2000 m) per second. Liquids, because of their looser particle arrangement are not very elastic and so they are not good transmitters of sound.

Activity #3: Making a Temperature/Sound Graph: Using the following data, students should plot a line graph showing how the speed of sound in air varies with temperature. They should then answer the **Analysis** questions for this section.

TEMPERATURE (in ° Celsius)	SPEED (in meters per second)
-50	301
-40	307
-30	313
-20	319
-10	325
0	331
10	337
20	343
30	349
40	355
50	361

PART IV: Acoustic Monitoring for Ocean Climate Studies

Background: Climatologists and oceanographers know that if global warming actually happens, the warming effect in the Arctic region will probably be 2-4 times greater than at lower latitudes. This would cause the polar ice packs to melt, adding water to the ocean basins and raising global sea levels significantly. One way to estimate if and how much global warming is actually occurring is to monitor the temperature in the northern ocean.

The basic idea is simple and based on the fact that sound travels faster in warm water than in cold water. The travel time of a sound signal from a ship to a land based receiver will decrease if the ocean water in between warms up, and increase if the ocean cools down. National Oceanic and Atmospheric Administration (NOAA) scientists have designed and implemented an *acoustic monitoring scheme* between the Atlantic Ocean and the Arctic Ocean through the Fram Strait, where about 80% of the heat flux into the Arctic Ocean occurs. Fram Strait is located in the North Atlantic between the coast of Greenland and Spitzbergen Island. Low frequency, "whale safe" sound is transmitted across the Strait to measure the average temperature of ocean water to a depth of about 3.5 m. The travel time is a direct measure of the average temperature between the source and the receiver. It is hoped that measurements of this region of the ocean will provide important information for reducing the uncertainty in global climate models and answers to many questions, especially those regarding global warming as a result of the enhanced greenhouse effect.

Activity #4: Plotting Depth, Velocity and Temperature: Using the data in the Table below, create a graph showing the relationship between depth, velocity and temperature in Fram Strait.

1. Instruct students to round the numbers in the **Depth** column (A) and record them in Column B.

2. Instruct students to round the number **Velocity** column (C) to the nearest whole number and record them in column D.

3. Instruct students to complete Column E in the **Data Table** using the following procedure:
   - Refer to the Temperature given for 44.60 m depth (5 C)
   - Using the following information and calculate the water temperature for each depth based on the sound velocities.

     "Water temperature increases 5 C for every 23 m/sec increase in the sound velocity."
   - Record your computations in the column E of the Data Table.

4. After all computations are completed, students should create a 3-axes line graph of the information:
    - Left Y-axis: DEPTH (m)
    - Right Y-axis : Sound Velocity (m/s)
    - X-axis: Temperature (° C)

5. Students should format the unit measurements for each axis as necessary:
    - Left Y-axis : meters
    - Right Y-axis: meters/sec
    - X-axis: ° C

6. Instruct students to choose three different colored pencils and plot the points for each set of data.
    - *Connect the dots with the same color when all the points have been plotted.*
    - *Create a color key at the bottom of the graph.*

7. When all computations are completed students should answer the questions in the **ANALYSIS** section.

Student Activity Sheet: Using Sound Waves to Study Climate Change

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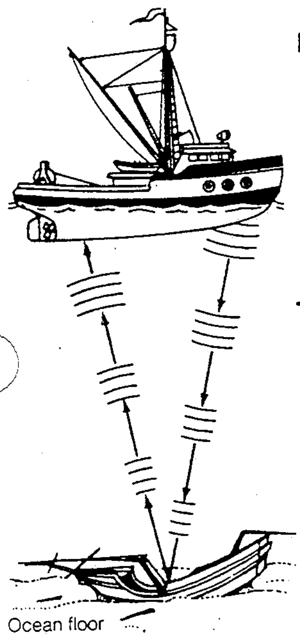

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5. Format the unit measurements for each axis as necessary:
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6. Choose three different colored pencils and plot the points for each set of data.
   - Connect the dots with the same color when all the points have been plotted.
   - Create a color key at the bottom of the graph.

7. Answer the questions in the **ANALYSIS** section.

Student Activity Sheet #1

Activity II:

DEPTH CHART

LONGITUDE	TIME (SECONDS)	DEPTH (FEET)
64 W	0	
60 W	0.125	
55 W	0.18	
50 W	0.1	
48 W	4.8	
45 W	5.5	
40 W	5.2	
35 W	5.7	
33 W	4.7	
30 W	4.2	
28 W	2.4	
27 W	3.0	
25 W	4.3	
20 W	5.8	
15 W	6.3	
10 W	6.8	
05 W	5.9	
04W	0.2	
01W	0	

ANALYSIS:

1. What relationship is illustrated by the slope of the graph?__________________________

____

2. From your graph, determine the speed of sound in air at 18 and 25 ° C. By how much does the speed of sound change for every degree of change in temperature?

____

3. How much faster does sound travel at 80 ° C than at -20 C? ________________________

Student Activity Sheet # 1

4. The water temperature in the North Atlantic in winter can reach -15 degrees C. The water temperature around the equator generally stays around 80 degrees. Where would an underwater volcanic eruption be hear sooner, in the North Atlantic or in the region around the equator? Why? ______________________

____

____

5. Sound travels faster in liquids than in gases and faster in solids than in liquids. Explain why a worker who puts one ear against a long metal pipe would hear two sounds if another worker struck the pipe only once at some distance away.

____

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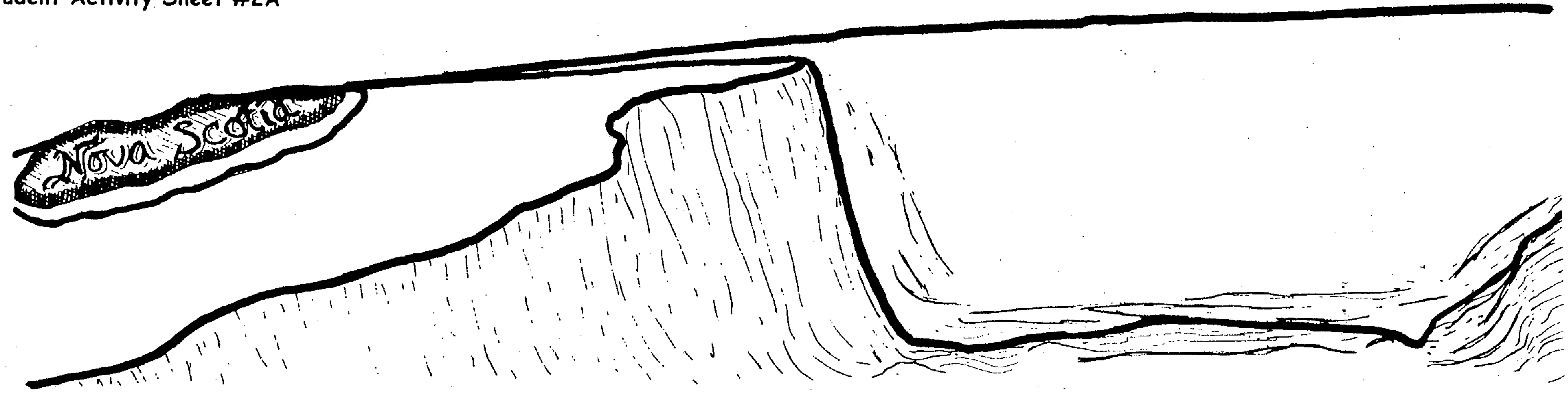
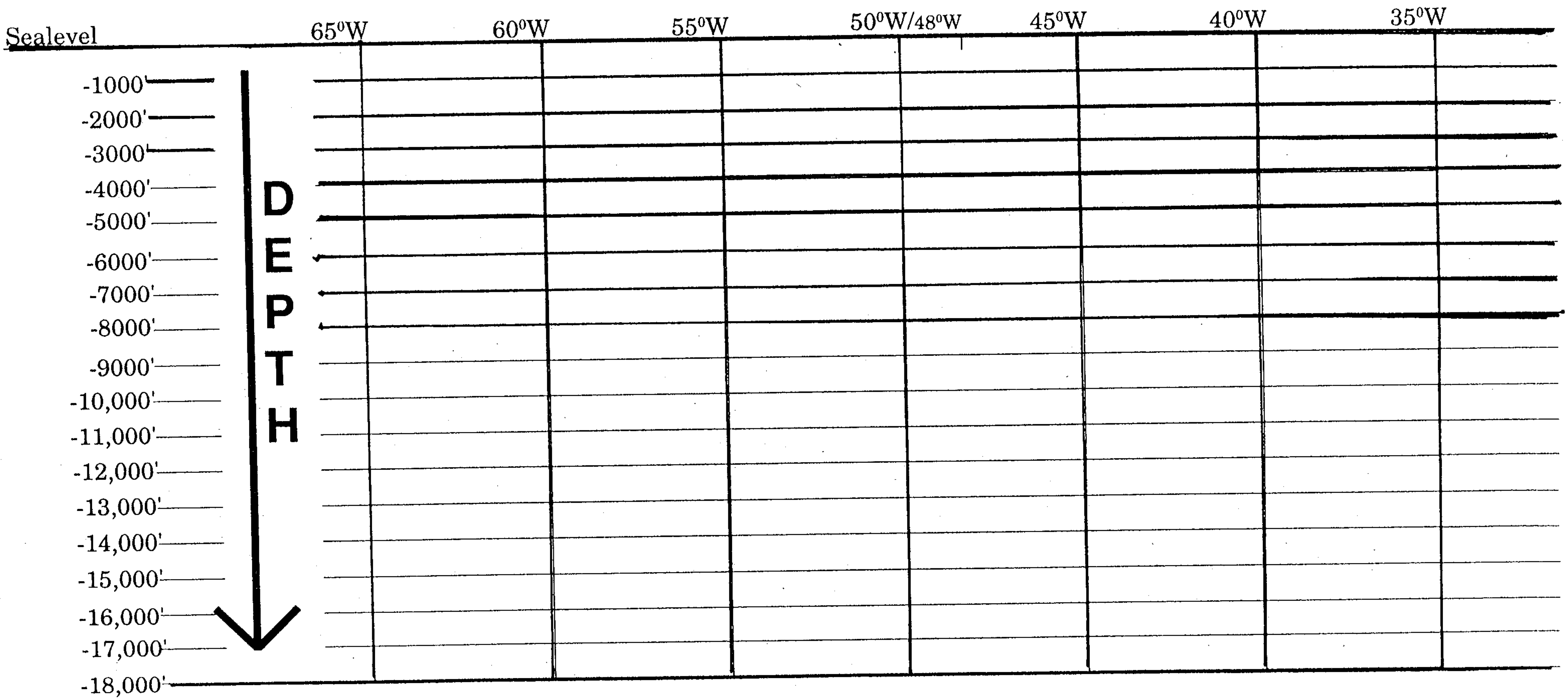
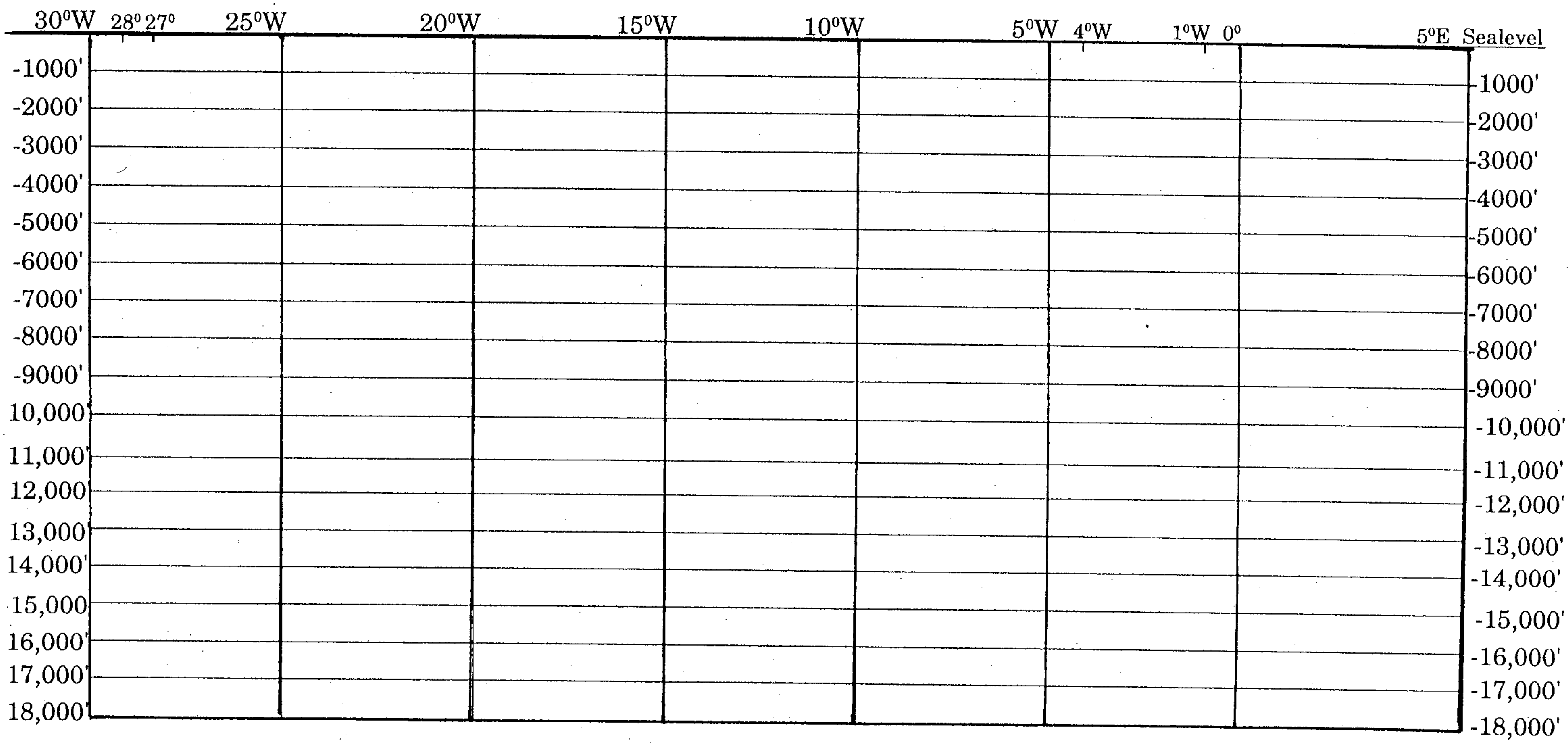
____

Student Activity Sheet #2A





Student Activity Sheet #2B



DATA TABLE: Ocean Depth, Temperature and Sound Velocity at Fram Strait

A	B	C	D	E
DEPTH (m^2)	DEPTH (r)	VELOCITY (m/s)	VELOCITY (r)	TEMP. (□C)
13.07		1425.88		
16.07		1437.88		
19.07		1448.90		
24.74		1451.60		
34.31		1467.80		
44.60		1471.88		5
54.57		1482.50		
64.58		1490.60		
74.60		1494.20		
84.39		1506.30		
94.41		1512.90		
104.35		1517.20		
114.30		1530.00		
124.21		1533.60		
134.19		1540.50		
144.29		1556.20		
154.03		1558.90		
163.96		1563.50		
174.17		1571.90		
274.17		1580.50		
374.17		1583.50		
474.17		1586.50		
574.17		1592.10		
674.17		1599.30		
774.17		1609.20		

Student Activity Sheet #3

ACTIVITY #4: ANALYSIS

1. What information is provided by the Data Table /graph? ____________

____

____

2. What data is plotted along the left Y-axis? The right Y-axis? __________

____

____

3. What unit of measurement is used for the X-axis? ____________________

4. What is the relationship between the speed of sound in ocean water and the temperature of the water? ______________________________

____

____

____

4. Where on the globe is global warming expected to have the greatest impact? ______________________________________

5. What will be the direct effect if this happens? ______________________

____

6. Describe one technique for investigating this event. __________________

____

____

____

____

7. What scientific fact is this procedure based on? ____________________

____

____

____

8. How will water temperature affect sound traveling from Point A to Point B in a global warming world? ___________________________

____

____

Student Activity Sheet #3

Activity #4: ANALYSIS

9. What is acoustic monitoring? Who developed it? ____________________
____
____
____

10. Where on the globe is this process being tried out? Why? ___________
____
____
____

11. How deep into Fram Strait will this process be used? _______________

12. What benefit do scientists hope to get from the AMS?
____
____
____

13. What could be one detrimental effect of such a program?
____
____
____
____