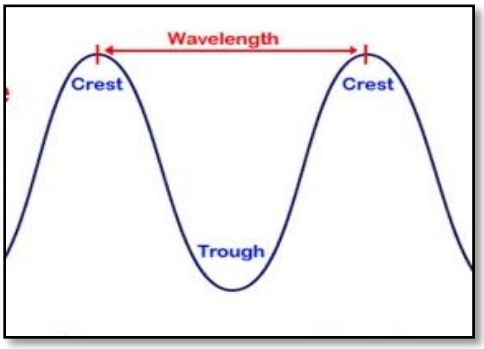
Student Sheet 1

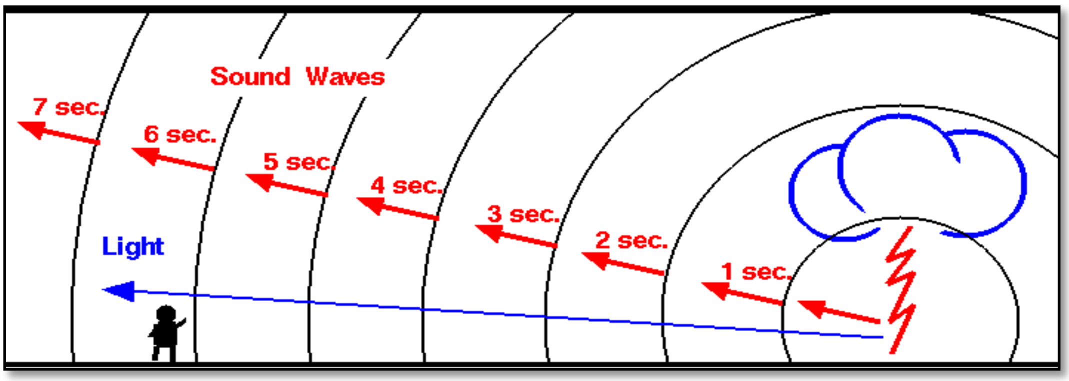
MATH APPLICATION ACTIVITY:
Using Sound Waves to Study Climate Change



Sound is produced when matter vibrates, and like light, travels 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 the *wavelength*.

The speed of sound is not always the same. Sound is a vibration of ***energy*** passed from molecule to molecule. The closer the molecules are to each other and the tighter their bonds, the less time it takes for them to pass the sound to each other and the faster the sound can travel. The speed of sound is faster in solid materials and slower in liquids or gases. 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 about 1000 feet (330 m) per second; in water it travels at about 4800 feet (1500 m) per second.

The speed of sound is slower than the speed of light. Lightning and thunder both happen at the same timed during a thunderstorm. We see the lightning almost immediately, but it takes longer to hear the thunder. Based on how much longer it takes to hear thunder tells us how far away the storm is. The longer it takes to hear the thunder, the farther the distance its sound had to travel and the farther away the storm is.



Light travels at about 186,000 miles per second
Sounds travels through air at a speed of about 1100 ft. per second.

This is why we see lightning so much sooner than we hear thunder. If lightning occurs a mile away, the light arrives almost immediately (1/186,000 of a second), but it takes sound nearly 3 seconds to arrive. Next time you see lightning, count the number of seconds before the thunder arrives, then divide this number by 5 to find how far away the lightning is.

Temperature is another condition that affects the speed of sound. Heat, like sound, is a form of ***kinetic energy***. Molecules at higher temperatures have more energy and can vibrate faster and allow sound waves to travel more quickly. The speed of sound at room temperature air is 346 meters per second. This is faster than 331 meters per second, which is the speed of sound in air at freezing temperatures. The speed of sound is also affected by other factors such as humidity and air pressure.

Climatologists and oceanographers predict that the warming effect in the Arctic region will probably be 2-4 times greater than at lower latitudes. As a result, the polar ice packs will melt, adding water to the ocean basins and raising global sea levels significantly. To help scientists understand how much warming is actually taking place, the temperature in the northern ocean is being monitored using sound waves.

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 designed an ***acoustic monitoring program*** *measure temperature changes* between the Atlantic Ocean and the Arctic Ocean. The system was set up in the Fram Strait, located in the North Atlantic between the coast of Greenland and Spitzbergen Island. Fram Strait was chosen as the monitoring site because it is where about 80% of the heat exchange between the Arctic Ocean and the Atlantic Ocean occurs.

Student Sheet 3

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 these measurements will provide important information for improving global climate models and answer many questions about global warming resulting from the enhanced greenhouse effect.

ACTIVITY #1: MATH APPLICATION: Try the problems below using the information from page 3. Show your work in the spaces provided.

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 times 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?

Student Sheet 4

ACTIVITY 2: TEMPERATURE AND THE SPEED OF SOUND

DATA TABLE 1: RELATIONSHIP BETWEEN SPEED OF SOUND AND TEMPERATURE

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

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?

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 heard 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?

Student Sheet 5

ACTIVITY 3: PLOTTING DEPTH, VELOCITY AND TEMPERATURE

DATA TABLE 2: OCEAN DEPTH, TEMPERATURE AND SOUND VELOCITY AT FRAM STRAIT

A	B	C	D	E
DEPTH (m^2)	DEPTH (r)	VELOCITY (cm/s)	VELOCITY (cm/s)	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 Sheet 6

ANALYSIS:

1. What information is provided by the data table and 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?
5. Where on the globe is global warming expected to have the greatest impact?
6. What will be the direct effect if this happens?
7. Describe one technique for investigating this event.
8. What scientific fact is this procedure based on?
9. How will water temperature affect sound traveling from Point A to Point B in a global warming world?
10. What is acoustic monitoring? Who developed it?
11. Where on the globe is this process being tried out? Why?
12. How deep into Fram Strait will this process be used?
13. What benefit do scientists hope to get from the *AMFS?*
14. What could be one detrimental effect of such a program?