gravity DISCOVERY CENTRE

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Area of study ENERGY AND CHANGE and WORKING SCIENTIFICALLY
Target Level 6 or bright year 10 or 11 and 12 Physics students

SPEED OF SOUND

Use the coiled pipes to investigate some properties of sound.

Exhibits Numbers 26 and 27

This activity is targeted to the serious science students It investigates in a sequential way the factors that effect the speed of sound in a pipe. Wave interference and developing some lateral thinking to investigate scientifically means this unit can be used to clearly demonstrate that the student is working at level 6.
Background information of this unit can be found in the unit **Time Travel** if the students don't have any prior knowledge in sound transmission.

The external sound coil at the GDC

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These sheets are to provide information to teachers in order that they will be able to stimulate interest and discussion amongst their students.

Thanks to ***http://www.physicsclassroom.com*** for some of the material used in this Background.

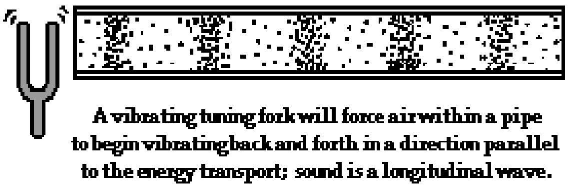
Sound and music are parts of our everyday sensory experience. Just as humans have eyes for the detection of light and color, so we are equipped with ears for the detection of sound. We seldom take the time to ponder the characteristics and behaviors of sound and the mechanisms by which sounds are produced, propagated, and detected. The basis for an understanding of sound, music and hearing is the physics of waves. Sound is a wave that is created by vibrating objects and propagated through a medium from one location to another.

A ***wave*** can be described as a disturbance that travels through a medium from one location to another location. A ***pulse*** is a single disturbance moving through a medium from one location to another location. But what is meant by the word *medium*? A ***medium*** is a substance or material which carries the wave. You have perhaps heard of the phrase *news medium*. The news media refers to the various institutions (newspaper offices, television stations, radio stations, etc.) within our society which carry the news from one location to another. The news move through the media. The media doesn't make the news and the media isn't the same as the news. The news media is merely the *thing* that carries the news from its source to various locations. In a similar manner, a wave medium is the substance which carries a wave (or disturbance) from one location to another. The wave medium is not the wave and it doesn't make the wave; it merely carries or transports the wave from its source to other locations.

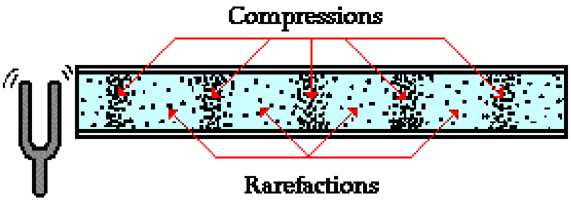
Waves are said to be an ***energy transport phenomenon***. As a disturbance moves through a medium from one particle to its adjacent particle, energy is being transported from one end of the medium to the other. Waves are seen to move through an ocean or lake; yet the water always returns to its rest position. Energy is transported through the medium, yet the water molecules are not transported. Proof of this is the fact that there is still water in the middle of the ocean. The water has not moved from the middle of the ocean to the shore. If we were to observe a gull or duck at rest on the water, it would merely bob up-and-down in a somewhat circular fashion as the disturbance moves through the water; the gull or duck always returning to its original position. The gull or duck is not transported to the shore because the water on which it rests is not transported to the shore. In a water wave, energy is transported without the transport of water.

The same thing can be said about a stadium wave. In a ***stadium wave***, the fans do not get out of their seats and walk around the stadium. We all recognize that it would be ludicrous for any fan to even contemplate such a thought. In a stadium wave, each fan rises up and returns to the original seat. The disturbance moves through the stadium, yet the fans are not transported. Waves involve the transport of energy without the transport of matter.

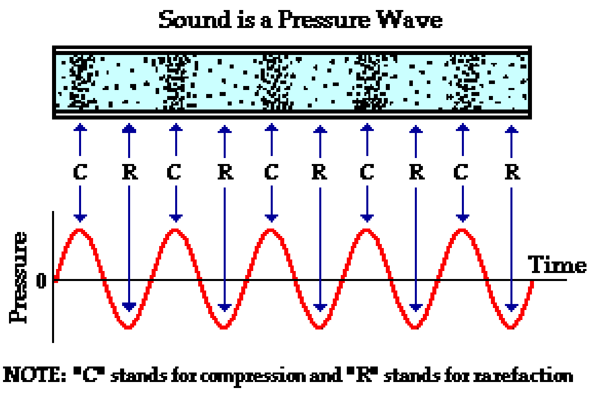
A ***longitudinal wave*** is a wave in which particles of the medium move in a direction parallel to the direction which the wave moves. Sound is a longitudinal wave.



Sound waves consist of rarefactions and compressions and a pulse is a single compression.



Since a sound wave consists of a repeating pattern of high pressure and low pressure regions moving through a medium, it is sometimes referred to as a ***pressure wave***. If a detector, whether it be the human ear or a man-made instrument, is used to detect a sound wave, it would detect fluctuations in pressure as the sound wave impinges upon the detecting device. At one instant in time, the detector would detect a high pressure; this would correspond to the arrival of a compression at the detector site. At the next instant in time, the detector might detect normal pressure. And then finally a low pressure would be detected, corresponding to the arrival of a rarefaction at the detector site. Since the fluctuations in pressure as detected by the detector occur at periodic and regular time intervals, a plot of pressure vs. time would appear as a sine curve. The crests of the sine curve correspond to compressions; the troughs correspond to rarefactions; and the "zero point" corresponds to the pressure which the air would have if there were no disturbance moving through it. The diagram below depicts the correspondence between the longitudinal nature of a sound wave and the pressure-time fluctuations which it creates.



Like any wave, the ***speed of sound*** refers to how fast the disturbance is passed from particle to particle. While ***frequency*** refers to the number of vibrations which an individual particle makes per unit of time, speed refers to the distance which the disturbance travels per unit of time.

The faster which a sound wave travels, the more distance it will cover in the same period of time. If a sound wave is observed to travel a distance of 700 meters in 2 seconds, then the speed of the wave would be 350 m/s. The speed of any wave depends **on the properties of the medium** through which the wave is traveling. Typically there are two essential types of properties which effect wave speed - inertial properties and elastic properties. The density of a medium is an example of an ***inertial property***. The greater the inertia (i.e., mass density) of individual particles of the medium, the less responsive they will be to the interactions between neighboring particles and the slower the wave. If all other factors are equal (and seldom is it that simple), a sound wave will travel faster in a less dense material than a more dense material. Thus, a sound wave will travel nearly three times faster in Helium as it will in air; this is mostly due to the lower mass of Helium particles as compared to air particles.

Elastic properties are those properties related to the tendency of a material to either maintain its shape and not deform whenever a force or stress is applied to it. A material such as steel will experience a very small deformation of shape (and dimension) when a stress is applied to it. Steel is a rigid material with a high elasticity. On the other hand, a material such as a rubber band is highly flexible; when a force is applied to stretch the rubber band, it deforms or changes its shape readily. A small stress on the rubber band causes a large deformation. Steel is considered to be a stiff or rigid material, whereas a rubber band is considered a flexible material. At the particle level, a stiff or rigid material is characterized by atoms and/or molecules with strong attractions for each other. When a force is applied in an attempt to stretch or deform the material, its strong particle interactions prevent this deformation and help the material maintain its shape. Rigid materials such as steel are considered to have a high elasticity (elastic modulus is the technical term). The phase of matter has a tremendous impact upon the elastic properties of the medium. In general, solids have the strongest interactions between particles, followed by liquids and then gases. For this reason, longitudinal sound waves travel faster in solids than they do in liquids than they do in gases. Even though the inertial factor may favor gases, the elastic factor has a greater influence on the speed (**v**) of a wave, thus yielding this general pattern:

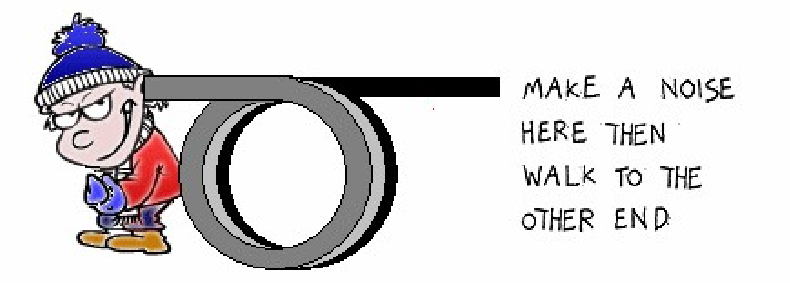
$$v_{solids} > v_{liquids} > v_{gases}$$

The speed of a sound wave in air depends upon the properties of the air, namely the temperature and the pressure. The pressure of air (like any gas) will effect the mass density of the air (an inertial property) and the temperature will effect the strength of the particle interactions (an elastic property). At normal atmospheric pressure, the temperature dependence of the speed of a sound wave through air is approximated by the following equation:

$$v = 331 \text{ m/s} + (0.6 \text{ m/s/C})*T$$

where T is the temperature of the air in degrees Celsius. Using this equation is used to determine the speed of a sound wave in air at any temperature.

SOUND SCIENCE
EXHIBIT 26



There is an approximate 0.89km length of plastic pipe that has been coiled for you. If you make a sound at one end of the pipe .by hitting the membrane can hear the sound travelling down the pipe by the imbedded microphones. This coil of pipe is what you walked through at the entrance.

SOME FACTS ABOUT SOUND AND ITS VELOCITY

- Waves transfer **energy** from one place to another but require a medium. (Such as air, water, rock)
- There is no transfer of **matter** as the energy is transferred from one point to another.
- Sound waves are **pressure** waves.
- We hear because our eardrums move back and forth when the sound wave reaches it.
- The speed of sound in air is given by $\mathbf{v=331+0.6T_c}$
- It is effected by **temperature, pressure** and to a much smaller extent by the pipe diameter.

How many microphones are there in the pipe? Explain how you got your answer.

YOU ARE HEARING THE PAST!

What do we mean by hearing the past?

What do light and sound have in common?

Complete the following.

Looking at a star means we are…………………the past.

You know that the speed of sound waves travelling through the air can be calculated by timing how long it takes to travel through the tube. Your task is to calculate the speed of sound in air given the length of the tube is 0.89 km and you have a stopwatch.(use yours) You are to give your answer in both km/h and m/s ***REMEMBER*** ***v=s/t***

What we did and the result.

Did you do the experiment more than once, if so why/why not

Record the temperature of the area and workout what the speed of sound should be today given the speed of sound in air at 0^oC is 331m/s and the speed of sound in air is given by

$\mathbf{v=331+0.6T_c}$

How does this compare with your result?

Speculate on what may cause the difference in the speed of sound at different temperatures?

You have seen the coil outside Guess what the temperature of the air may be inside the tube. (yes go and feel it)

How accurate do you thinks your estimate is. (Express as a %) Explain how you can justify this number.

BRAINSTORM

With your group brainstorm how you could use **only the pipe and a stopwatch** to measure the temperature of the air in the sound coil pipe. (Note you have the method hidden in the previous pages.)

Brainstorming space

Description of how you will do it.

Set out neatly and clearly all your assumptions and calculation and give the temperature of the air in the pipe.

WHAT EFFECTS THE INTENSITY OF THE RETURNED SOUND

Hit the membrane with varying levels of force and listen to the intensity of the returned sound. Record your results.

Try to explain your results. In terms of energy inputs and losses and other concepts that you have an understanding of.

COLLIDING WAVES WHAT DO YOU THINK HAPPENS EXHIBIT 27

This coil is a miniature version of the first telephone. You can use it like a telephone, talk into one end and listen to yourself in delay. You are to carry out a number of activities with this sound coil.

Think laterally and workout the length of the sound coil. You must state how you did this and your estimated length.

Use this estimate to calculate the time delay you experience between talking and hearing your voice. (use the speed of sound for the temperature of the pipe.)

SOLVE A PUZZLE ABOUT COLLIDING WAVES

What happens to colliding sound waves? Write a testable hypothesis below.

You can get sound waves colliding by having two people make two very short, sharp and different sounds at exactly the same time so that the sound waves pass in the pipe. Then IMMEDIATLEY move the pipe end to your ear.

What was the result of your test?

Compare it to water waves meeting.

Name as many wave types as your group knows.

Make a generalisation about all waves as they pass though waves of the same kind as themselves.

Go outside and use the ***Di Candilo wave cable*** and test your generalisation in a cable. You can do this by putting a pulse in the cable then another to pass thought the first one that is being reflected. What did you find out?

These sheets are for teachers and students to help in the levelling of student work in this module.

Overarching Major Learning Outcomes

There are opportunities to assess students in the following outcomes when taking part in this program.

OLO 7: Students understand and appreciate the physical, biological and technological world and have the knowledge and skills to make decisions in relation to it.

OLO 5: Students describe and reason about patterns, structures and relationships in order to understand, interpret, justify and make predictions.

OLO 6: Students visualise consequences, think laterally, recognise potential patterns and are prepared to test options.

Science Major Learning Outcomes

Working Scientifically

1. Investigating skills
Students investigate and answer questions about the natural and technological world. They use the skills of scientific investigation, reflection and analysis to prepare a plan for their investigation; to collect, process and interpret data: to communicate their conclusions

2. Communicating Scientifically

Students communicate scientific understandings to different audiences for a range of purposes.

3. Applying Science in Daily Life
Students apply and evaluate scientific knowledge, skills and understanding across arrange of contexts.

Using Science in Society
Science understands that science is a human activity which influences all people as a part of their daily lives.

Understanding concepts

1. **Earth and Beyond**

Students understand the physical world around them and its impact on the way we live.

2. **Energy and Change**

Students understand the scientific concept of energy and explain that energy is vital to our existence and quality of life.

Student Outcome Statements

Students typically in years 8-10, will be performing at levels (3-6). The following examples demonstrate outcomes for levels 4 and 5

Investigating scientifically

Planning:

- Identifies the variables to be changed, the variable to be measured and at least one variable to be controlled. In a descriptive study plans are made for the necessary types of observations.
- Analyses problems, formulates a question or hypothesis for testing and plans an experiment in which several variables are controlled.

Conducting:

- Takes care with data collection so that data is accurate, uses repeated trials and uses independent variables that are usually continuous.
- Uses equipment that is appropriate for the task and uses preliminary trials of the investigative procedure to improve the procedure or measurement techniques.

Processing Data:

- Calculates averages from repeated trials, plots data as line graphs where appropriate and makes conclusions, which both summarise and explain the patterns in the data.

- Makes conclusions, which are consistent with the data and explains the patterns in the data in terms of scientific knowledge.

Evaluating:

- Makes general suggestions for improving the data
- Suggests a specific change that would improve the techniques used or the design of the investigation.

Earth and Beyond

- Understands processes that can explain and predict interactions and changes in physical systems and environments.
- Understands models and concepts that explain earth and space systems and that resource use are related to the geological and environmental history of the earth and universe

Energy and Change
1. Understands that energy interacts differently with different substances and this can affect the use and transfer of energy.
2. Understand models and concepts used to explain the transfer of energy in an energy equation.

General notes on levelling"

Level	Level Descriptors
2	**Describe**s a number of features but does not **relate** them
3	Describes **patterns** and makes **generalisations** from **concrete** experience
4	Describes **non observable** properties or events
5	Explains in terms of a **concept.**
6	**Choose apply** and **quantify** concepts and principals

Appendix 2: Questions and associated levels
Question Possible answers Level

What do we mean by hearing the past? Level 6 answers.

The sound wave that has travelled in the tube is carrying information about an event in the past. The information it carries can be used to determine what the event was and when it occurred.

Set out neatly and clearly all your assumptions and calculation and give the temperature of the air in the pipe. Level 6 answers

Since we know the relationship between speed and temperature and making the following assumptions we can calculate the temperature in the pipe.
Assumptions The length of the pipe is O.89km and the temperature of the air is constant in the pipe.

Measurements The time taken for the sound pulse to travel the length of the pipe.

$\mathbf{v=331+0.6T_c}$ now $\mathbf{v=s/t}$ **by substituting and rearranging you get the following**

$\mathbf{s/0.6t -331/0.6 = T_c}$

solve for $\mathbf{T_c}$ as **s**and **t** are known

What happens to colliding sound waves? Level 6

If I and another member of my group shout into both ends of the tube at the same time we would get colliding sound waves. If the sound arrives unaltered then we can say that they pass through each other without interference.

Some web based resources that may be helpful to teachers and students in preparing for the visit.

Web based resources
http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u11l2c.html

This is a great interactive site to lean the basics of physics of sound.

The Physics Classroom Tutorial is an online physics tutorial written for high school physics students. The tutorial was originally developed for Regular-level Physics students at Glenbrook South High School in Glenview, Illinois. These pages were once hosted on the Glenbrook South server. As the popularity of the pages grew, a decision was made to move them elsewhere in order to free up the burden placed upon the school's server by external traffic. Today the Tutorial pages and other original Glenbrook South resources are hosted by Study Works Online.

http://www.physicsclassroom.com/Class/sound/U11L2d.html

http://www.slcc.edu/schools/hum_sci/physics/tutor/2210/mechanical_waves/