Waves kit

In this kit you will have the following experiments:

1. Wild Water Waves

   Designed by: Jonathan Rustad, Noah Mock, and Houssam Ennoura
2. Speed of light/sound experiment

   Desinged by: Noah Tibben-Lembke and Jake Markowskit
3. Through the looking glass

   Desinged by: Derk Lyford and Ethan Niles

These kits are designed to explore the properties of waves and how they travel. This include measuring wavelength and observing resonance. It

This kit contains some of the materials needed, but we highly encourage you to explore how you can use the stuff around your house. Be creative, be curious, and have fun!

Kit Contents

- 3 Cups for Wild Water Waves these cups are also used for Though The Looking Glass
- Ruler for measuring melty distances.

Wild Water Waves

Have you ever wondered why some objects are harder to carry water in? When you walk with these the water sloshes, splishes, and splashes all over the place. How can we avoid these waves causing us to spill all over the place? With this experiment we hope you'll learn about waves in liquids in different containers.

What you want them to observe.

Materials:

- Bowl
- Mug
- Vase
- Cornstarch

Instructions

To keep this experiment fun and novel, we will be conducting a series of races using a variety of vessel sizes to see which is the easiest to manage.

The first race will be with the wide and short vessel. Fill this vessel so that water is roughly 2 cm from the top rim of the vessel. Race across an approximately 10m distance, but make sure you try not to spill any water! The first person to the finish line is the winner!

Now conduct the race again, this time using the moderate width and moderate height vessel. Fill this vessel with the same volume of water used for the wide and short vessel. See who can go the fastest across the 10m with this vessel.

Conduct the race a third time, this time with the tall and narrow vessel. Again fill with the same volume of water from the previous two trials and race across the 10m distance.

If there is just one person completing the experiment, they can do timed trials with each vessel, but if there are more than one experimenters, have them go head to head in the races!

Variation #1 - Disqualify anyone if they spill any water at all!
Variation #2 - Change up the liquids in each container so there is a variety of viscosities (this can be done by adding cornstarch to water) and see how this affects the results. To compare how the viscosities affect the created waves, you should use the same container and change the viscosity, but afterwards it would be fun to compare different viscosities in different containers! (i.e., what is easier to run with, a high viscosity liquid in a wide container or a low viscosity liquid in a narrow container)

Parents/Teachers

- In this experiment we want kids to gain insight into how waves form and propagate in different vessels and mediums.
- We want kids to see which vessels and liquids they can run the fastest without spilling. By seeing which combinations of vessels and liquids are the hardest to spill we hope they will learn how the properties of waves in water will change based on the medium and container.
- When we walk, we are driving an oscillating the container. If this oscillation matches the frequency of the waves splashing back and forth the water waves will get bigger until the water spills everywhere! We call this the resonant frequency.
- The resonant frequency changes with the size of the container. If you use a larger container the waves take longer to bounce back and forth of the sides of the container.

Measuring The Fastest Speed In The Universe!

You've probably heard of the speed of light before, and with good reason, it's one of the most important constants in all of physics! Today you are going to find it using just marshmallows and a microwave!

Materials:

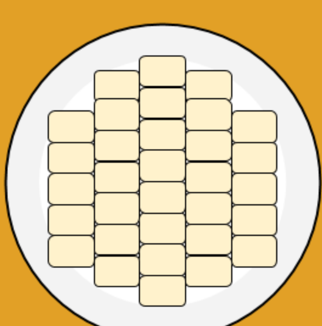
Mini Marshmallows, or Chocolate chips
Microwave
Paper Plate
Ruler

Experiment:

- Before beginning the experiment, remove the rotating table from the microwave and find and record the frequency of your microwave (It will likely be either on the back or the side of the microwave and be given in Hz). Next put the mini marshmallows on a plate in a way that there is a consistent 1 marshmallow deep covering on the entire plate, like in the picture!
- Microwave the marshmallows for 10 seconds. There should now be several spots where the marshmallows are more melted than the marshmallows around them. Measure and write down the distance between the center of two melted points using meters (1 cm = .01m). Multiply this answer by 2 and you have just calculated the wavelength inside of your microwave!
- Since frequency is a measure of how many wavelengths pass in a second, if we multiply the frequency of our microwave by the wavelength we found, we will find the speed of the waves inside your microwave! This is shown in the following equation where v is the velocity, or speed of the wave, f is the frequency, and λ is the wavelength.

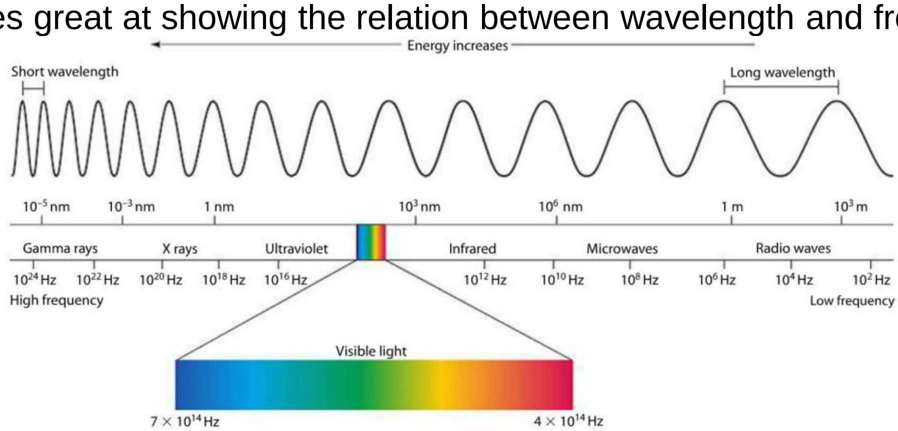
$$v = f \times \lambda$$

- Plug your values for frequency and wavelength into the equation. What do you find the speed of the microwaves to be? This is the same speed that all light travels at!



Parents/Teachers

- Frequency will likely be either on the back or the side of the microwave and will likely be given in terms of Hz. If you cannot find your microwave's frequency, assume it is 2.45 GHz or $2.45 \times 10\text{^}9$ or 2,450,000,000 Hz.
- The unit Hz is called Hertz and $1\text{Hz} = (\frac{1}{second})$ which means if the waves in the microwave have a frequency of 2.45 billion Hz then 2.45 billion complete waves will pass by each second!
- The most melted points are where the wave intensity is strongest, at a peak of a wave. Help your student understand what a peak is based on the wave at the bottom of this page.
- Help your student understand how the wavelength (in meters) times the frequency (1Hz=$\frac{1}{s}$) results in a velocity (in meters/second). Tell them that speed is measured in terms of distance traveled divided by the time traveled (think miles per hour).
- The actual value for speed of light is $2.998 \times 10^8 \frac{m}{s}$ or 299,800,000m/s. Try to help your student understand the magnitude of this; light travels 299,800,000 meters, or 983,583,840 feet every single second! That's fast enough to go all the way around the earth in less than one-fourth of a second! There are more questions to put this value into perspective in the additional exploration section.
- A note on electromagnetic waves: There are many types of electromagnetic waves including gamma rays, microwaves, radio waves, and light itself. All electromagnetic waves travel at the same speed, the speed of light. The following picture does great at showing the relation between wavelength and frequency for each wave



Answers to exploratory questions: 1. Depends on results 2. 8 minutes 20 seconds 3. $9.45 \times 10^{15} m$ 4. .0308 m 5. V= 7.50×10^{14} B= 6.66×10^{14} G= 6.00×10^{14} Y= 5.451×10^{14} O= 4.61×10^{14} R= 4.61×10^{14}

Measuring the Speed of Sound!

In this segment, you will explore how fast sound travels through air and compare that speed to the speed of light!

What you Need:

Large outside space   A Friend   Tape Measure

Experiment:

Tell your partner to stand a long distance away from you, preferably more than 100 feet because a longer distance will make it easier to measure! Use your tape measure to measure the distance between you and your friend. If you can use a football field, the distance between the two end zones on a football field is 100 yards (91.5 meters). Hold your hands out to your sides and clap above your head. Your partner should start the stopwatch as soon as they see their hands connect and stop it whenever they hear the sound. It'll be a very small time for sound to travel that distance, so take at least 10 trials and find the average time to improve the accuracy of your results! Record the times on a separate piece of paper.

With the times you measured, you can find the speed of sound! Start by converting the distance measured in between you and your partner to meters. Next, find the average time. Divide the distance between you and your partner by the average time. Congratulations! You've found the speed of sound.

Believe it or not, temperature affects the speed of sound. Heat, like sound, is a form of kinetic energy. Molecules at higher temperatures have more energy, meaning they can vibrate faster, and sound waves can travel quicker. Work with an adult to find the temperature by using your speed of sound! What did you find the temperature to be? How accurate is your estimate? The commonly used value for the speed of sound is 343m/s (at 20 degrees C in the air). Think about that for a second; sound travels 343 meters, or 1125 feet every second! How does this compare to the speed of light from the previous experiment?

$$\gamma = 1.4,\ R = 8.314\ J/molK,\ and\ M = 0.02897\ kg/mol,$$

$$v = \sqrt{\frac{\gamma R(T+273)}{M}} \quad T(^{\circ}C) = \frac{v^2 M}{\gamma R} - 273$$

Parents/Teachers

Help your students work through the data collection, ensuring that they take accurate distance measurements and checking their calculations. You can help them convert feet to meters by dividing their measurement by 3.281. For example, 100 feet equals 30.48 meters. Once they have obtained a value for the speed of sound, help them use their value to compute the temperature:

Molecules at higher temperatures have more energy, meaning they can vibrate faster, and sound waves can travel more quickly. This is shown in the following equation, where and R are constants, T is the absolute temperature, and M is the molecular mass of the gas. Use this equation to solve for temperature with your student.

$$\gamma = 1.4,\ R = 8.314\ J/molK,\ and\ M = 0.02897\ kg/mol,$$

$$v = \sqrt{\frac{\gamma R(T+273)}{M}} \qquad T(°C) = \frac{v^2 M}{\gamma R} - 273$$

You can convert the temp from Celsius to Fahrenheit with the following equation: $F = \left(\frac{9}{5}\right)C + 32$

Solutions to exploration questions:
1) Answers will vary 2)Sound is faster on a warm summer day 3) 343 meters/second x 60 seconds/minute x 60 minutes/hour = 1,234,800 meters 4) 300,000,000 m/s - 343 m/s = 299999657 m/s 5) Sound travels slowest in air, faster in a liquid, and fastest in a solid. 6) t_{hear} = (20,000m) / (343 m/s) = 58.309 seconds. t_{see} = (20,000m) / (300,000,000 m/s) = 0.000067 seconds 7) 343 = .5 t^2 -> t=26.19 seconds

Exploratory Questions for Speed of Light Experiment

1. The equation for percent error is $\% \, Error = \frac{|experimental\ result - expected\ result|}{Expected\ Result} \times 100\%$. What is the Percent error for this experiment? Don't worry if the percent error is high! It can be difficult measuring the exact distance between nodes.
2. The average distance between Earth and the Sun is $1.5 \times 10^{11} m$, how long does it take for light from the sun to reach Earth?
3. Using the speed of light, calculate the distance of one light-year, or the distance light could travel in one year. The closest star from the earth is called Proxima Centauri and is 4.24 light-years from Earth, how many miles (1 mile is approximately 1610 meters) away is that?
4. Take a minute and think about that with your student, the light you see from stars at night has traveled for many years before it reached your eyes. Or conversely, if an alien 65 million light-years away had a strong telescope pointed at the Earth, they would be able to see the dinosaurs right now!
5. If you turn an FM radio on to 97.1, it is playing at a frequency of 97.1×10^8 Hz. What is the wavelength for this radio wave?
6. The colors you see are also electromagnetic waves, meaning they travel at the speed of light (c), and fit the equation $c = f\lambda$. Listed below are a selection of colors and their wavelengths. Can you calculate the frequency of your favorite color?

Color	Violet	Blue	Green	Yellow	Orange	Red
Wavelength (m)	4.00×10	4.50×10^{-7}	5.00×10^{-7}	5.50×10^{-7}	6.00×10^{-7}	6.50×10^{-7}

Answers on Parent / Teacher Sheet

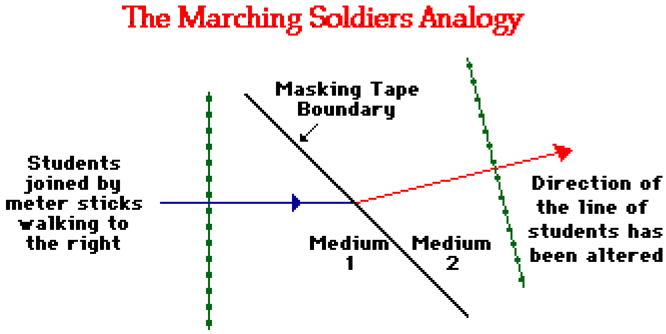
Exploratory Questions for Speed of Sound Experiment

1.Using the equation for percent error from the first experiment, find your percent error. Don't worry if the percent error is high! It can be difficult to measure the time between such short events.
2.Is the speed of sound faster on a warm summer day or a freezing winter night?
3.If you could travel at the speed of sound, how far could you travel in one hour?
4.How much faster is the speed of light than the speed of sound you found?
5.Thinking about how close particles are to each other, how do you think the speed of sound compares in different materials? Would sound travel fastest through a solid, liquid, or gas?
6.If there was an extremely loud explosion 20 kilometers away when the temperature outside is 20℃, how long would it be until you can see the explosion? How long would it be until you could hear it?
7.A sonic boom occurs when an object travels faster than the speed of sound, if our physics department allowed us to include a supersonic jet in this kit that travels at a velocity given by the function, $v(t) = \frac{1}{2}t^2$, at what time will the jet surpass the speed of sound creating a sonic boom? At what time will our jet break physics and surpass the speed of light?

Answers on Parent / Teacher Sheet

Parents/Teachers

- Refraction of light occurs because light travels at different speeds in different substances. When light strikes a surface with a higher index of refraction, it will change the direction of its path. An intuitive analogy involves a line of students. The students are told to walk at a normal pace in a line holding hands. When they reach a chalk line on the ground, they are instructed to walk much slower. As the line of students goes over the chalk line, their direction changes.



- The cups act use refraction as a lens to focus the objects, but there are only certain locations were images can be in focus, where all the rays come back together.

- Approximate distances for an object 3m away
  - Medium->large: 9cm apart
  - Small -> Medium: 7 cm apart
  - Small-> Large: 10cm apart
  - Small-> Medium->Large: 12cm from the small to the medium, 25cm from the small to the large