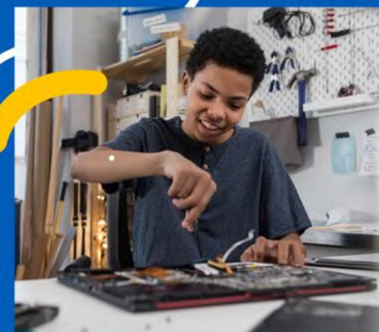
NEXT ENGINEERS



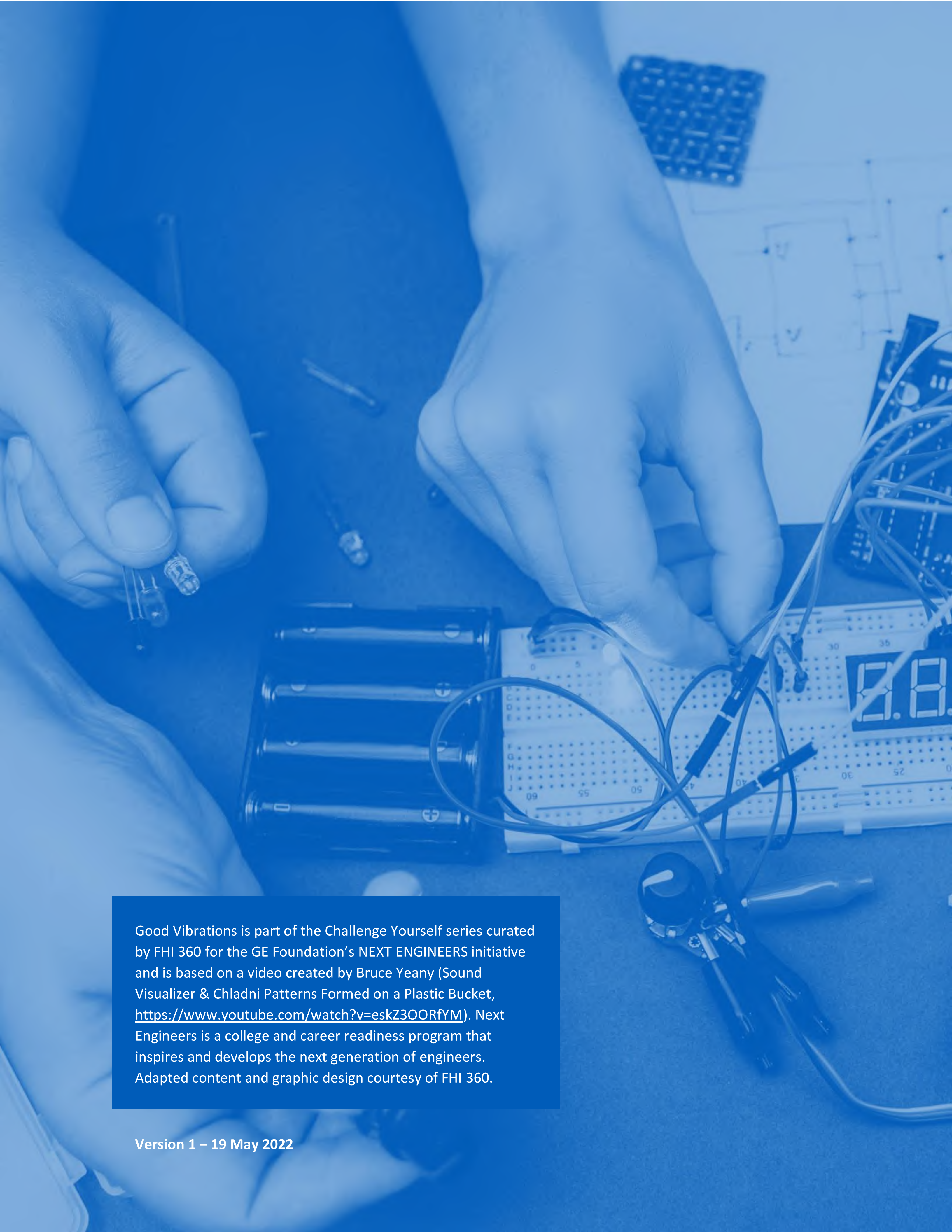
CHALLENGE YOURSELF

Good Vibrations

Audio Engineering

Sound

GE Foundation



Good Vibrations is part of the Challenge Yourself series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS initiative and is based on a video created by Bruce Yeany (Sound Visualizer & Chladni Patterns Formed on a Plastic Bucket, https://www.youtube.com/watch?v=eskZ3OORfYM). Next Engineers is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

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Good Vibrations

EXPERIMENT & EXPLORE

Ages	Cost	Time
14+	Low - Medium	60 minutes (or more)
Engineering Areas		
• Acoustic Engineering	• Sound	

Introduction

Do you like listening to music and talking to your friends? These activities involve you listening to sounds. But what really is sound and what does it look like?

In this Experiment & Explore activity, you will discover what sound is by looking at its effects. You will also experiment with its properties, explore the patterns that different kinds of sounds make, and discover ways engineers might put this knowledge to work to solve real-world problems.

What you will need

- An old round plastic container with a diameter of between 20 cm and 40 cm (8 in and 16 in) like a bucket, old drum, or a paint can
- A craft knife
- Plastic sheeting (you can use a heavy-duty garbage or rubbish bag)
- Scissors
- An old cardboard box like a breakfast cereal box (optional)
- Some electrical or adhesive tape
- About 125 g (4.5 oz) fine dry sand, fine salt, or couscous
- A mobile phone or computer
- A speaker (a small Bluetooth speaker would be ideal)
- A tone generator app (like the Multitone Generator app for Android or iOS. You can also search your mobile app store for 'free tone generator'.)

What to do

1. To start with, you need to make a homemade drum. Cut the bottom of your plastic container to create a cylindrical shape with two open ends. Try and cut the bottom off as straight as possible so that the cylinder sits level on a table. If you have a suitably sized drum already, you can skip to step 7.
2. Cut out a circular piece of your plastic sheeting to be a few centimeters or inches larger in diameter than the top of your cylinder.
3. Using a piece of tape, stick one edge of your piece of plastic sheeting to the side of your cylinder.

TOP TIP

Make sure that your plastic container is big enough to be able to fit your speaker inside without it touching the sides or top.

DID YOU KNOW?

A tone generator is a device that can produce a pure sound at a particular volume and pitch. Most sounds we hear are really many sounds of many volumes and pitches. A 'pure' sound is a sound of only one pitch or frequency.

4. Stretch the plastic sheeting tightly over the top of your cylinder and stick the opposite edge to the side of the cylinder.
5. Work your way around the cylinder, stretching and sticking the piece of plastic sheeting. You need to stretch the plastic sheeting as tightly and evenly as possible without tearing it.
6. To keep things from getting too messy later, make a collar for the top of your drum. Cut out a few strips of your piece of cardboard about 5 cm (2 in) wide and stick these end-to-end. Wrap this around the top of your 'drum' and fasten the ends with some tape.
7. Now we can start experimenting. What do you think will happen if you tap the top of your drum with your finger? Try it. What happens? Is this what you expected? What do you think makes the sound that you hear?
8. Now lift your drum up, holding your finger lightly on the plastic sheeting. What do you think you will feel if you shout into the bottom of the drum? Do this. What do you feel? What do you think is causing these vibrations? What happens if you shout louder or softer? What happens if you shout at a higher or lower pitch?
9. Place your drum on a table and sprinkle some sand, salt, or couscous onto the top. What do you think will happen if you sing a single note near the top of the drum? Do this and see if what you observe matches your predictions. What happens if you sing louder or softer? What happens if you sing lower or higher notes?
10. Connect your speaker to your mobile phone and open the tone generator app. A tone generator produces a 'pure' sound or tone of a single defined pitch and volume. Set the **frequency** to 200 Hz. Set the **amplitude** quite low. Play the sound. What do you think it will sound like if you increase the frequency? What do you think it will sound like if you increase the amplitude? Experiment for a bit with these two values to see how they affect the sound produced.

What's happening

Before starting this activity, you may have already known that sound is the result of vibrations that travel through the air (or liquids and solids) to our ears as **longitudinal (or pressure) waves**. These waves are caused by vibrating objects. When you hit a drum, you cause the velum (the stretched material) to vibrate which makes the air particles vibrate back and forth which creates a sound wave. The same is true for instruments like guitars where the strings vibrate.

PITCH

The 'highness' or 'lowness' of a musical note or sound is called its pitch. Birds tweet at a high pitch. Lions roar at a lower pitch.

LONGITUDINAL WAVE

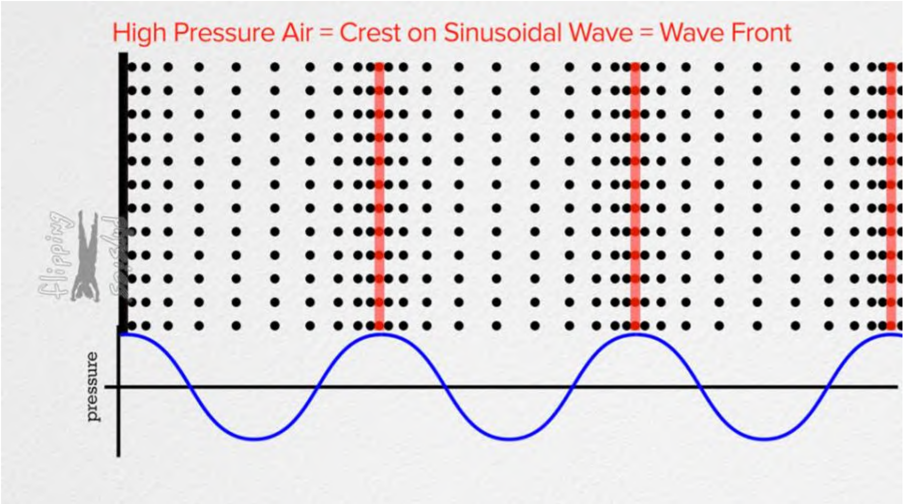
A longitudinal wave is a wave where the particles vibrate back and forth in the same direction as the direction in which the wave travels. Longitudinal waves have repeating areas of high pressure (compressions) and low pressure (rarefactions).

FREQUENCY

Frequency is a measure of how often something happens. With waves (e.g., sound waves), it is a measure of how many waves pass a fixed point per second. We experience the frequency of a sound as its pitch. We hear low frequency waves as low-pitched sounds and high frequency waves as high-pitched sounds.

AMPLITUDE

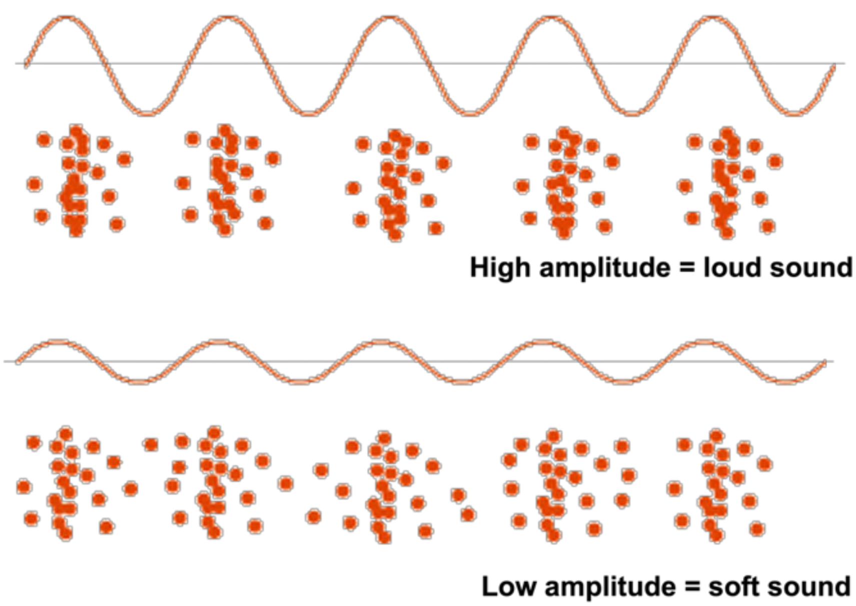
Amplitude is a measure of the maximum distance a particle in a wave moves from its rest point. The greater the amplitude of a sound wave, the more the air particles vibrate and the louder the sound we hear.



Comparison of a longitudinal wave (top) and transverse wave (bottom)
See the animated gif at
https://www.flippingphysics.com/uploads/2/1/1/0/21103672/0327-animated-gif-6_2.gif

You may have discovered that the reverse is also true - sound waves produced by you (or a speaker) cause the velum to vibrate. If you sprinkle grains of sand, salt, or couscous onto the drum, you can see these vibrations quite clearly. You can also see that sound is a form of energy transfer: it is able to make these grains move.

The sounds we hear are distinguished by their volume and their pitch, which you can see reflected in how the grains vibrate in response to different sounds. A larger amplitude (louder sound) makes the grains vibrate more vigorously. The greater the amplitude of the sound, the greater the energy it transfers.

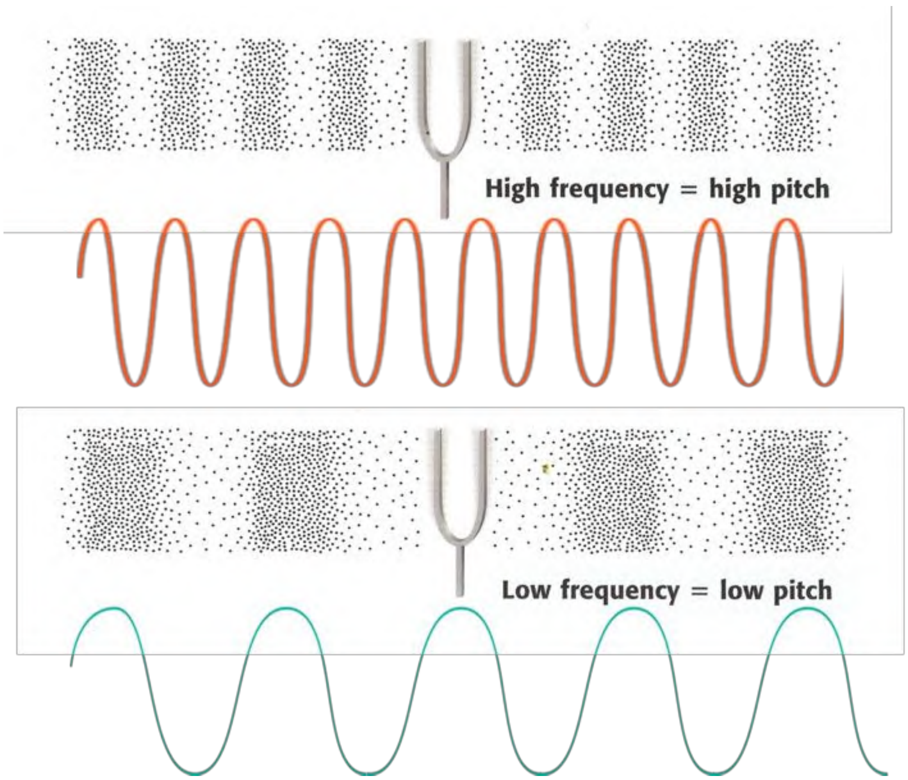


The greater the amplitude of the sound wave, the greater the volume of the sound

Think about it

So far, we have seen that a greater amplitude produces a louder sound and makes the grains vibrate more. But what about the frequency of the sound wave. How does it affect the grains?

A greater frequency sound wave results in a higher pitched sound. It turns out that different frequencies can make the grains vibrate in different patterns. The relationship between the frequency and the patterns produced is very complicated and is the result of **standing waves**. This relationship was first described by mathematician Sophie Germain.



The greater the frequency the higher the pitch

If you want to learn more about sound and its volume and pitch watch the video called *The Pitch and Loudness of Sound, and a Comparison of Audible Frequency Ranges* (7:13) (https://www.youtube.com/watch?v=wEL87lznGrg).

Let's investigate these patterns in more detail.

1. Place the drum over your speaker and sprinkle more grains evenly over the top. Play a tone with a frequency of 71 Hz. Set the amplitude so that the grains vibrate without flying off. What do you notice? Do grains all over the surface vibrate the same amount? Do grains in some areas not vibrate at all? Do the grains start to form a pattern? Can you draw a picture of this pattern?
2. Change the frequency of the tone to 88 Hz. What do you observe happening now? Do grains vibrate and not vibrate in the same areas as before? Does a different pattern start to emerge? Can you draw a picture of this new pattern?
3. Try the following frequencies – 120 Hz, 344 Hz and 787 Hz. Does every frequency form a clear and unique pattern? What sorts of patterns emerge?

Portrait of Sophie Germain by non lisible is in the public domain https://commons.wikimedia.org/wiki/File:Portrait_Sophie_Germain.jpg

LEARN MORE

Watch these videos to learn more about standing waves and how sounds of different frequencies create different patterns.

- *Chladni Figures - random couscous snaps into beautiful patterns* (3:50) https://www.youtube.com/watch?v=CR_XL192wXw
- *Singing plates - Standing Waves on Chladni plates* (4:19) https://www.youtube.com/watch?v=wYoxOJDrZzw

4. Starting with a frequency of 100 Hz, gradually increase the frequency to 1 700 Hz to see if you can find any other patterns. Draw pictures of any of the patterns that emerge.
5. How large can you make the frequency before the pitch of the sound is too high for you to hear? Do you think this is because of your ears or the quality of the sound that the speaker can produce?

Links to the real-world

Do you think we can put our understanding of sound to practical use? Consider these possibilities.

- How might you use your knowledge of sound waves to create a new musical instrument?
- How might you use your knowledge of sound waves to design a sound-proof room?
- How else might you engineer a use for sound waves to solve a real-world problem.

Share your ideas at **#nextengineersdiy**.