2019 weSTEM Conference Workshop

Seeing Sound with Lasers

Summary

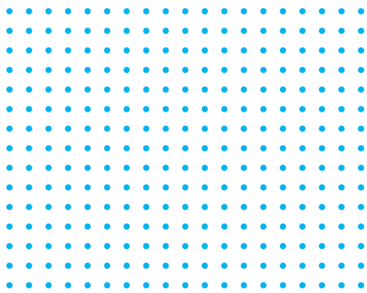
Hey! Let's learn how to do Engineering through science. We are going to **create** a device that will **reflect light** in such a way so as to project a **unique light pattern** for every note that you'll play in your piano.

You will learn how to think like an **Engineer**, by examining and assessing the available resources and making an educated decision of what to use. You will further explore how to use engineering principles to examine a **Scientific Idea** and experiment.

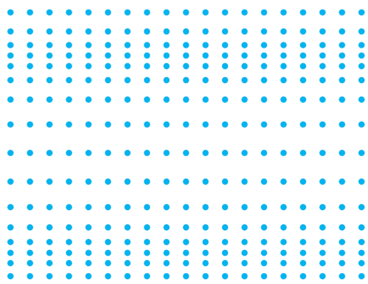
A brief background theory

Sound Waves

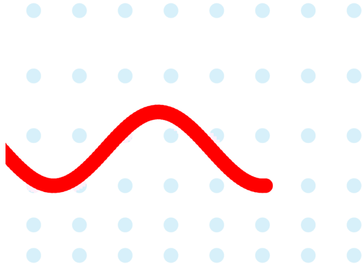
What is indeed a sound wave? Think of air as a **group of molecules** arranged in a **grid**. When the air is **undisturbed** the grid should look something like the picture on the left.



Wait! What's that going on in the left picture? It seems like parts of the grid is **bunched up together**, while others are **spread apart**. That means that somehow the air **moved**. The air could have moved by having a plate at the bottom, moving up and down. That motion will push the air and create areas where there are more particles at some points, and less at others.

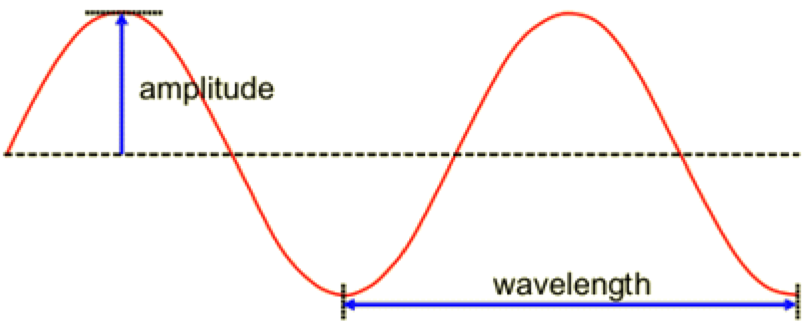


Infact, if we **zoom in** out particle grid and isolate the movement of **just one** air particle in the grid, and graph it. Let's see what happens... The position of the particle over time looks like a wave. We can see that the particle is **not moving forward overall**. It is just **oscillating**. Just like a **wave!**



Pro Tip: Try that by yourself with the QR Code below

We're getting there, hang on! Let's examine this wave looking picture. In **physics** we give certain **names** to certain aspects of it. More specifically you can see that the **distance between two peaks** is called **Wavelength,** it is symbolised with the greek letter **λ** (lamda: [λάμδα]) and measured in **meters (m)**. **Half the height between a trough and a peak**, is called **Amplitude**, it is symbolised with a **capital A** and also measured in **meters (m)**. Finally, the **time** it takes for the particle to travel **1 wavelength** is called the **period** of the wave. The **Period** is symbolised with a **capital T**, and measured in **seconds (s).** The **inverse of the period** (how many oscillations per seconds) is called the **frequency**, it is symbolised with **lowercase f**, and measured in **Hertz (Hz = 1/s).**



Adapted from:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/wave_model/whatarewavesrev3.shtml

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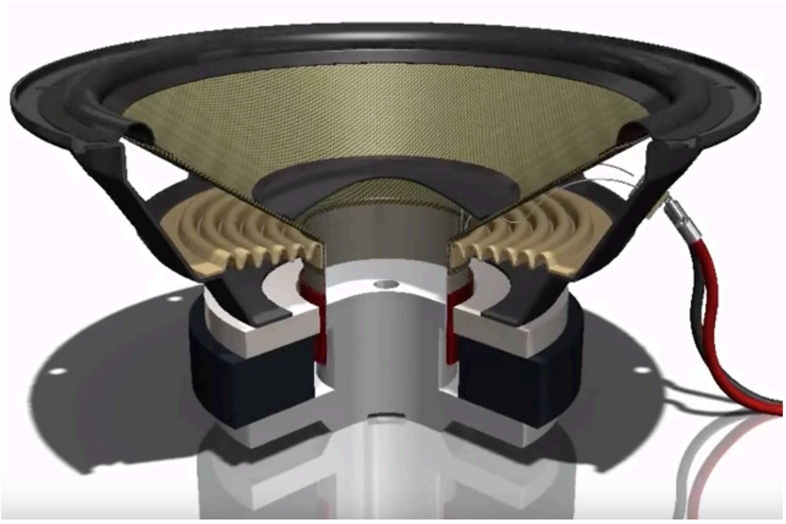
Interactive!
See how different notes on the piano make different sound waves!
This is a **Chrome Experiment,** just click the piano notes and see how the different notes correspond to different sound waves

Speakers

Remember when we said that a for a sound wave to be produced the **air must be pushed back and forth** from a stationary point? Well, the speaker is a device that does just that. The Speaker has a cone that is pushed back and forth according to the electric current passing through it. Therefore it is able to move back and forth, moving the air accordingly, **creating a sound**.

But **how** does it move back and forth? When **electric current** passess through a coil of wire it produces a **magnetic field.** That phenomenon is called **electromagnetic induction.** The speaker cone at its bottom has a **permanent magnet**, right underneath that, mounted on the speaker, there is a **coil.** So when current passes through the coil; the coil it becomes **magnetised**. As a result the cone is repelled and therefore **moved upwards.** When current stops flowing in the coil, it becomes **demagnetised**, and the cone **falls back down** due to gravity. If we provide the current in a smart way, we can move the cone back and forth in such a way so as to make notes, familiar tones, even speech!



Adapted from: https://www.youtube.com/watch?v=3ZQqCyRQFB4

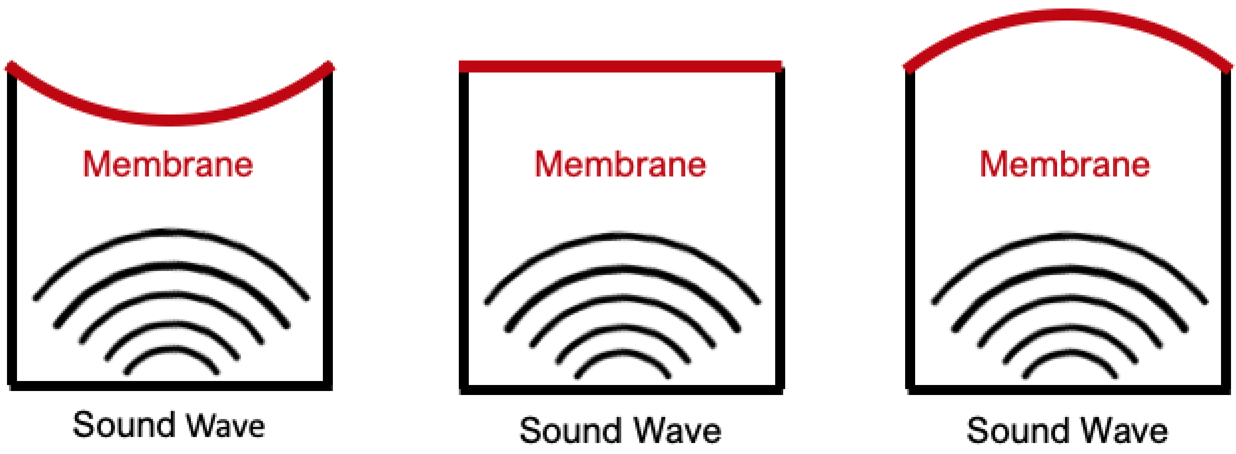
Interactive!
See the speaker move back and forth, while having all of its different parts explained in this 3D animation.

The Challenge

Today we are going to create a device that is going to allow us to **see those sound waves**. But how can we possibly see sound waves? Well, let's start from the very basics.

Sound Waves move Air Particles

As a result, particles that are moving back and forth, will move other materials back and forth at the same rate due to collisions between the material and air particles. Therefore what would happen if we were to place a membrane somewhere where a sound wave passes through? Well the membrane will obviously move! It will bulge and contract according to the frequency of the sound wave, as seen in the pictures below.

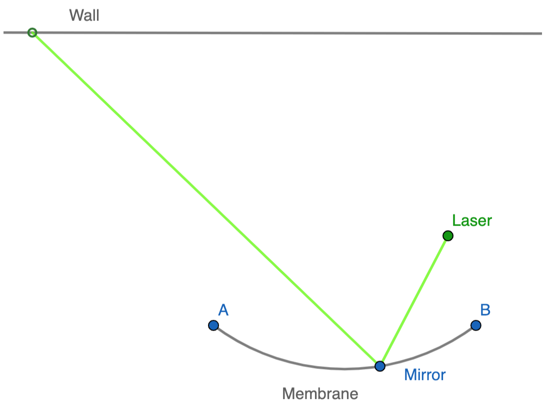


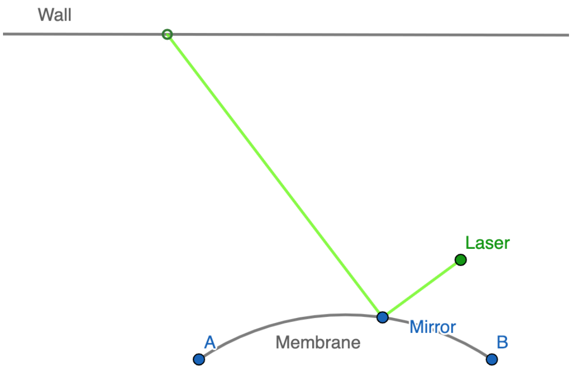
Therefore, putting a speaker at the bottom can produce a sound wave that moves the membrane accordingly.

The question remains… How can we see the sound wave?

Using Lasers to see sound

Let's put a small mirror on the membrane. If we shine a laser to the mirror, it will bounce back at an **angle that depends on the curvature of the membrane**. As a result, while the membrane moves, the laser moves as well. Since it is moving very fast, you might start to see certain shapes appearing on the wall... In the figures below you can see in 2 dimensions how the laser reflects on the wall, with different angles of curvature.





Interactive!
Play with the membrane curve, laser position, and mirror position and see what happens! What if you make the wall slanted? What else can you change?

Minimal Tutorial

Now we know everything we need to get started! Therefore, let's get started on building our experimental apparatus. Look at your **toolbox**. It contains everything you **may or may not** need to set up our experiment. It has the necessary **protection gear, tools, and materials** to get you started. **Let's go!**

I am **not** going to give you **exact step by step** instructions. **BE AN ENGINEER!** Solve problems and challenges by **yourself**! Therefore, You'll be called to solve a series of tasks with the materials and tools in your disposal right now.

Task #1

Mount the **balloon membrane** on top of the **PVC Pipe.**

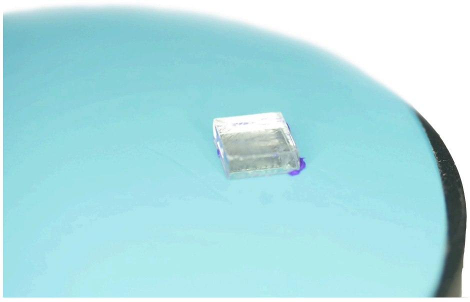
Materials
PVC Pipe ∅10 cm
Balloon
Glue? Tape?

Take out the **PVC Pipe** and try to secure the **balloon** on top of it, as seen in the picture on the right. **Think... How can you do that?** Maybe blow the balloon and place it on top of the pipe? Or cut the balloon and stretch it over? How are you going to ensure it stays taught?

Task #2

Secure the **mirror fragment** on the **balloon membrane**. And pace the apparatus on top of the **speaker.**

Materials
Mirror Fragment
Speaker
Tape? Glue?



Place and secure the **mirror fragment** on the membrane. You can use tape, glue, whatever you want. **Think... Where in the membrane should you place the mirror?** Then place and secure (with tape?) the pipe to the speaker.

Task #3

Point the **Laser** to the **mirror**.

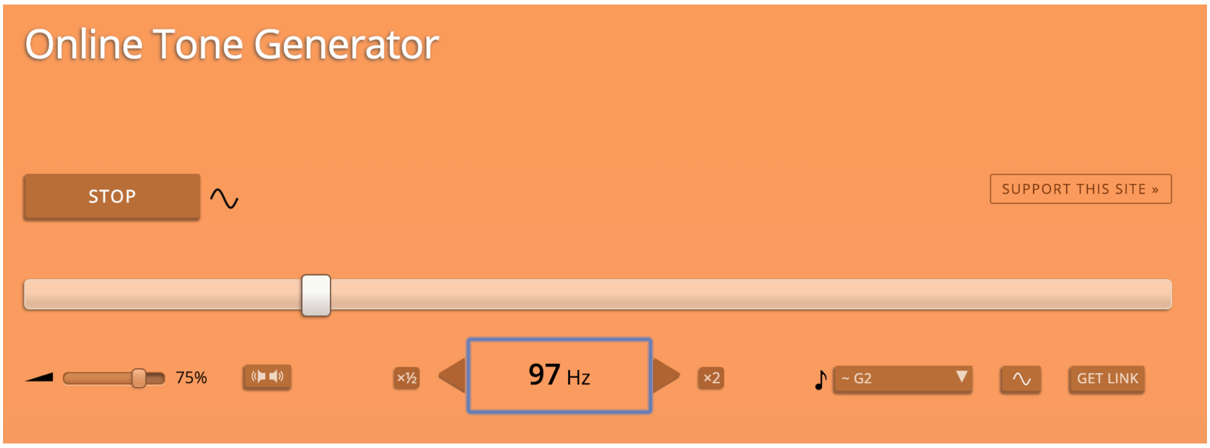
Materials
Laser Pointer
Clamp Stand

Secure the **laser** in one end of the **clamp stand**, and secure the other end to your **table.** Point the Laser to the mirror. **BE CAREFUL! The lasers you are handling are very bright! DON'T POINT THEM TO YOURS OR ANYBODY'S EYES!**

Experiment #1

Now that you managed to create the apparatus, let's run some experiments! Go to the **online tone generator** (http://www.szynalski.com/tone-generator/, see **QR Code below**). A **Tone Generator** is a tool that allows us to create sound at a **particular frequency**. We are going to use it to create different frequencies and see different shapes!

Set the sound frequency to something close to **97 Hz,** click **play**, and see what happens to the laser!



Interactive!
Now it's your turn! Go to the **online tone generator** and play with the frequency. **What do you observe?** Why do you think is the cause of the drastic shape size as you sweep through frequencies?

Works Cited

This handout is created so that you can take it home and reproduce the experiment. You can do it with household materials as well, and therefore examine the physical phenomena of sound by yourself. Look up **wave interference** and **standing waves** to see where these more advanced concepts fit in the overall complexity of what we did today! Congratulations on taking the initiative and interest in physics and engineering, now it's up to you to take it to the next level! **Happy Exploring!**

An explanation of wave phenomena includes information from **Physics for the IB Diploma, K. A. Tsokos**, and **University Physics, Young & Freeman**.

An Explanation of the structure of speakers was found in **Engineering Circuit Analysis by Hayt, Kemmerly, Durbin**.

The workshop's physical model for viewing sound waves was partly inspired by the work cited here: https://youtu.be/C-V1uXeyGmg

Special thanks to **Grace** and **Kevin** for helping to carry out the workshop.

Physics & Engineering

Workshop Cheat Sheet

Physical Quantities

Physical Quantity	Symbol	SI Unit	Description
Wavelength	λ (lamda, λάμδα)	m (meters)	The distance of a wave from peak to peak
Frequency	f (lowercase f) or ν (nu, νι)	Hz (Hertz $= s^{-1}$)	The number of oscillations of a wave per second
Period	T (uppercase T)	s (seconds)	The time required for a wave to travel one wavelength
Amplitude	A (uppercase A)	m (meters)	The maximum displacement of particles from equilibrium

Toolbox Tools

Epoxy	Superglue	2-Sided Tape	Marker	Computer
Scissors	Laser Pointer	Clamp Stand	Pipe clamp	Minijack Cable
Ruler	Box Cutters	Screwdriver Set	Eye Protection	Usb cable
Caliper	Mirror Fragments	Angle finder	Gloves	Midi Keyboard
Duct Tape	PVC Pipe	Notebook	Clamp	Graph paper

Notes