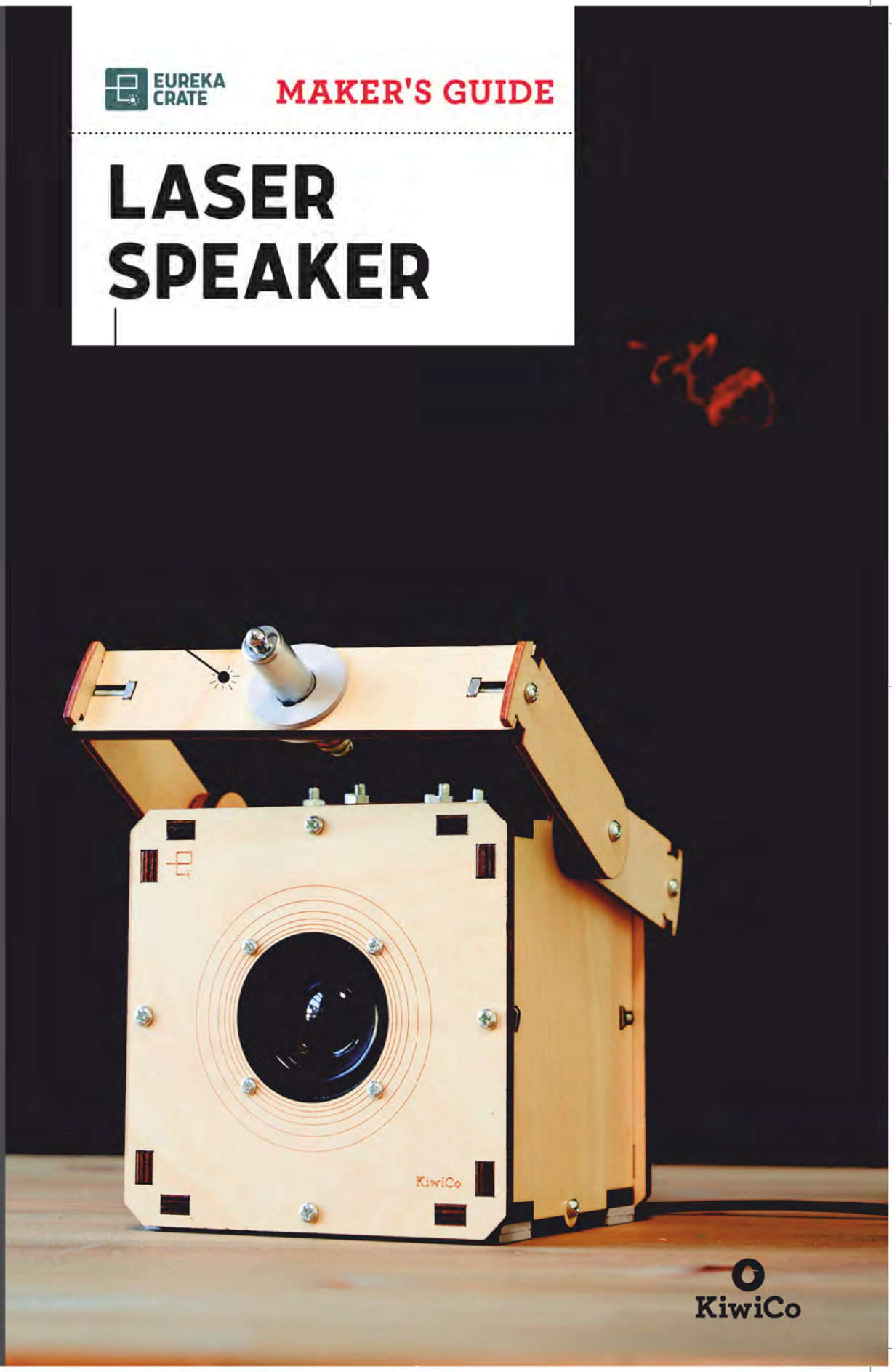
EUREKA CRATE

MAKER'S GUIDE

LASER SPEAKER



KiwiCo

WHAT'S IN THIS BOOKLET?

Step-by-step instructions to build a laser speaker, plus explorations of the **science**, **engineering**, and **history** behind the design.

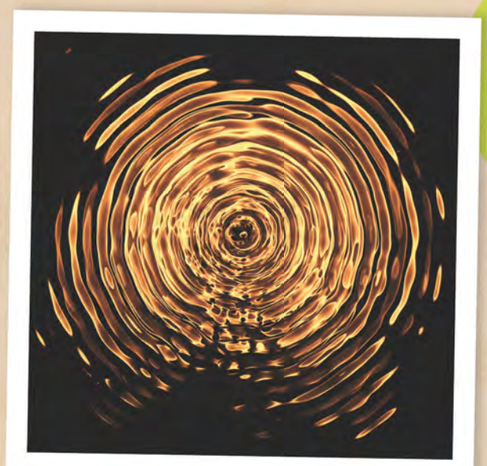


photo by Jordi Torrents via Wikimedia Commons (CC BY-SA 4.0)

DID YOU KNOW?

This is what water looks like when exposed to sound waves at a frequency of 11 hertz.

Music isn't just good vibes — it's *literally* **vibrations**! Your laser speaker makes music by vibrating the air around it, sending sound waves to your ear. It turns out that when air vibrates, it can cause *other* things to vibrate too — like the water in the photo above.

One of the world's loudest speakers, the **WAS-3000**, can generate up to 165 decibels (dB) of sound. In comparison, 130 dB is around the point at which a sound causes pain, and 150 dB is what a space shuttle produces when taking off. Thankfully, no one's using the WAS-3000 to blast groovy tunes. Instead, it's used to make a racket during simulations of battlefields *(used for military training)* and even rocket launches.

Source: United States Patent and Trademark Office, www.uspto.gov

U.S. Patent Dec. 16, 1975 3,927,402

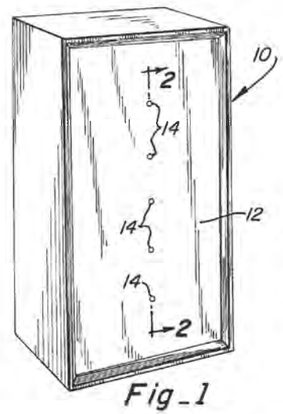


Fig_1

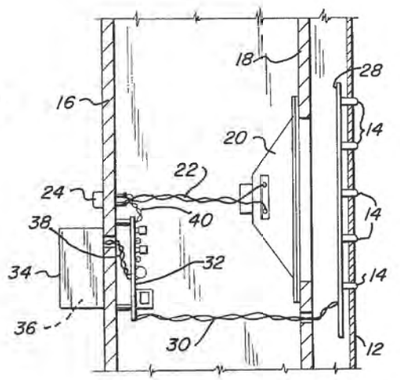


Fig_2

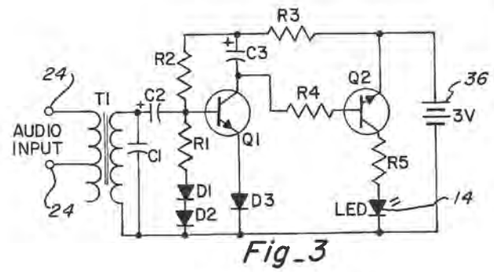


Fig_3

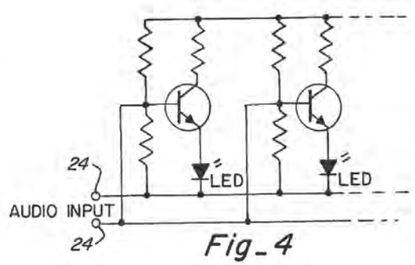


Fig_4

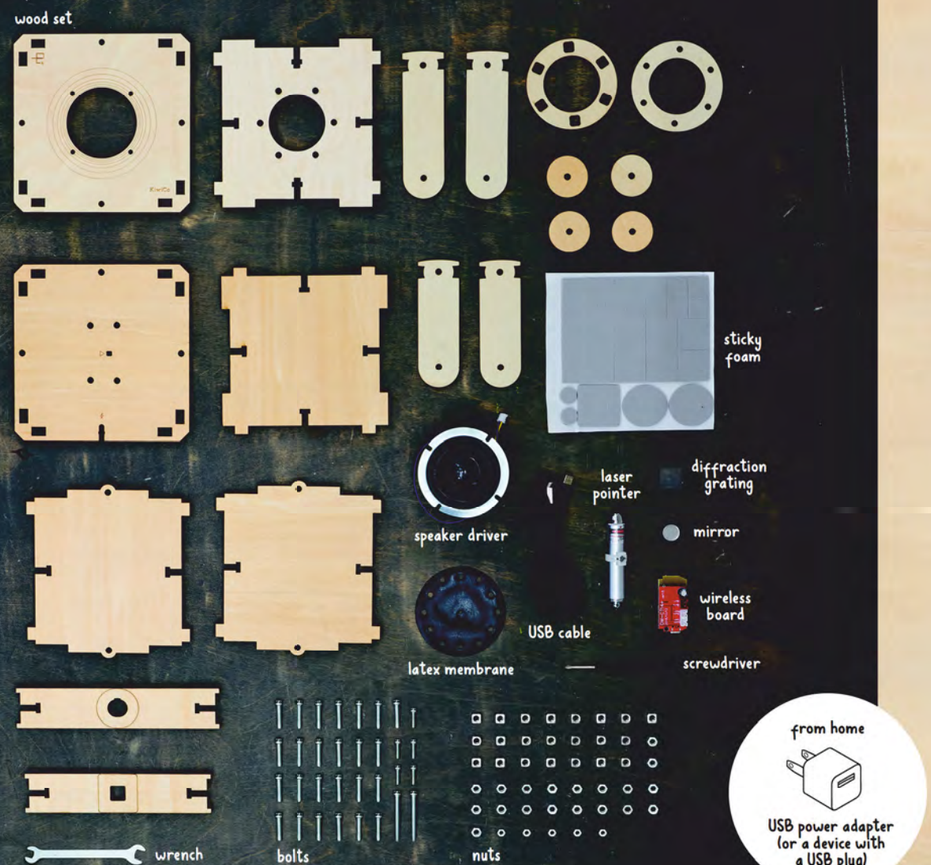
This 1975 patent features a light-up speaker, in which LEDs flash in time with the music. The brightness of the light corresponds to the volume of the speaker — so you can check if your sound is too high without having to wake up your neighbors to do it!

In the early years of laser technology, the power of a laser was measured in **Gillettes** — i.e. the number of Gillette razor blades it could burn through! Today, scientists in California are working on a laser system that can produce 2.5 megajoules of energy, meaning it could theoretically cut through *1.6 million* razors.

TIME TO START MAKING.

Clear your workspace and gather your materials — here's what you get.

You have enough materials to build your speaker, plus a few extras!



BUILD STATS

KEY COMPONENTS: mirror, speaker driver, laser pointer

SKILLS: wood assembly, electronics, music taste

COMPLEXITY: low

TIME: 1 hour

THE MAKER'S GUIDE TO THE

LASER SPEAKER

5 THINGS YOU DIDN'T KNOW ABOUT

SOUND VISUALIZERS

1. LASER LIGHT, LASER BRIGHT

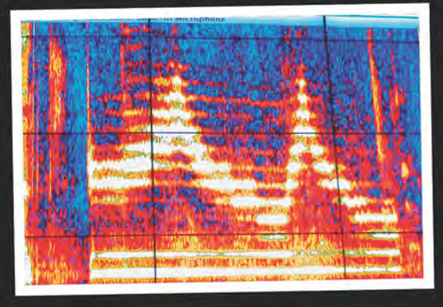
In the 1960s, the company Sonovision introduced the first **laser light show** technology. When a laser beam was directed at a reflective membrane stretched over a booming loudspeaker, it cast patterns over the ceiling and walls — all in sync with the sound.

just like your laser speaker

The patterns looked a lot like this!

2. PICTURE PERFECT

Spectrograms visualize the loudness and pitch of audio over time. Which means they're a great audio editing tool — you can just delete unwanted background blips as if you're editing the background of a photo. Some musicians even "draw" pictures onto spectrograms, creating sounds that otherwise wouldn't exist!



3. THIS SONG IS FIRE

A **Rubens' tube** consists of a sealed tube with holes at the top, packed full of flammable gas that's set on fire. When sound waves pass through the tube, the flames escape through the holes, leaping to the beat! Uh, don't try this at home.

4. VIOLIN VIBES

Way back in the 18th century, scientist Ernst Chladni invented a bold new way to visualize vibrations — **Chladni plates**. Sprinkle a metal plate with sand, salt, or flour, then draw a violin bow against the edge of the plate.

The sand will rearrange itself into jazzy geometric patterns!

The sand bounces off the parts of the plate that vibrate more, collecting in the parts that vibrate less. Turn to page 44 to try it for yourself!

5. DRUM ROLL, PLEASE

Not all sound visualizers involve lasers, fancy software, or flammable gases. Performance art crew Blue Man Group is famous for its **paint drumming** performances. The performers cover their drumheads with colorful paint, so it splashes and splatters with every beat.

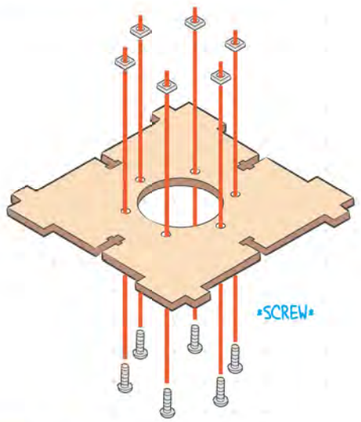
Colorful powders work too! That's what people use during Holi, a festival of colors celebrated in many parts of India.

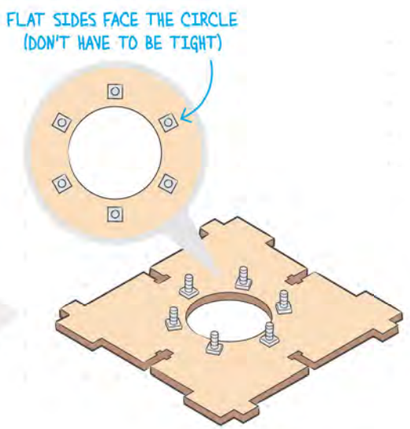
PART A

Start the Speaker Box

THIS IS THE SPEAKER'S BODY,
PLUS THE PART THAT MOVES THE LASER BEAM.

Step 1





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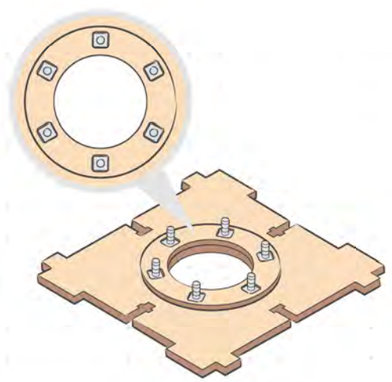

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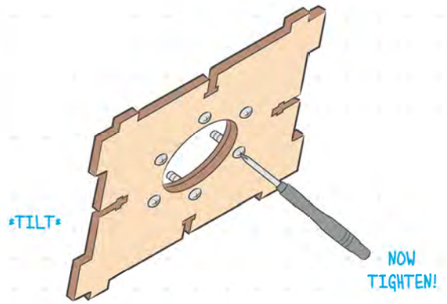

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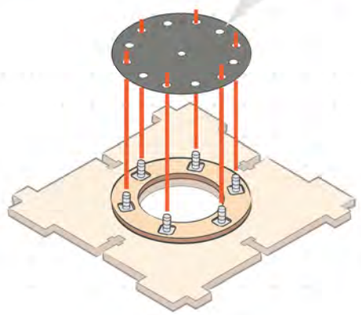
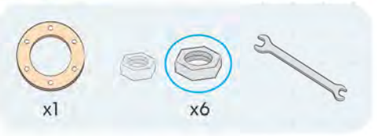
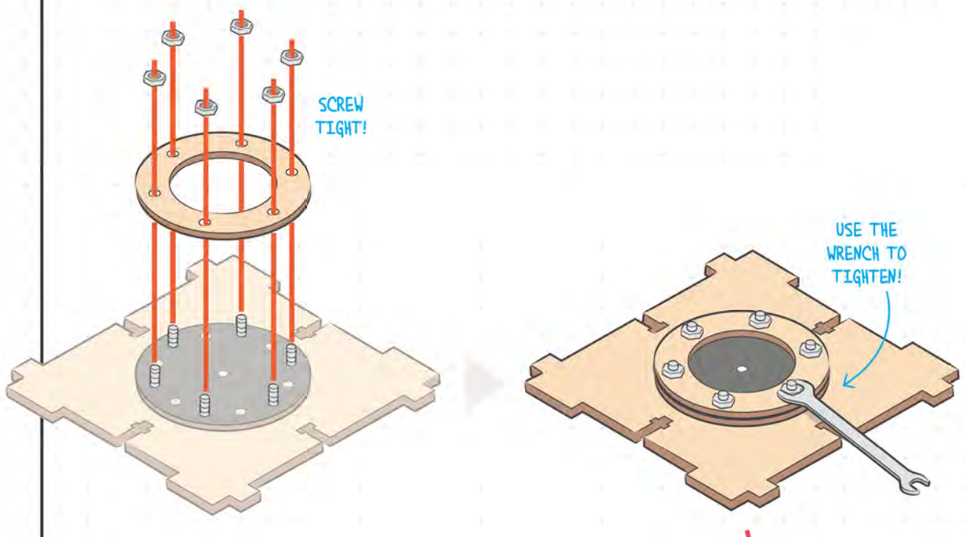


THE HOLES YOU USE AFFECT THE LASER PATTERN. SEE PAGE 33 FOR HOW TO SWITCH HOLES LATER!

Step 5





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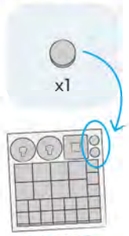

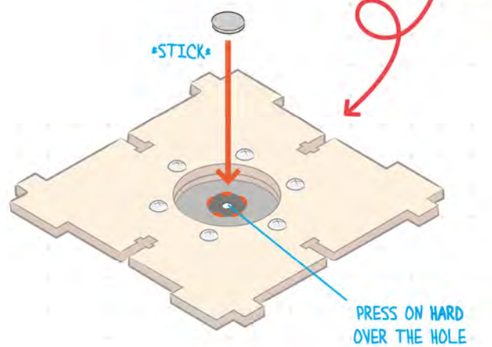

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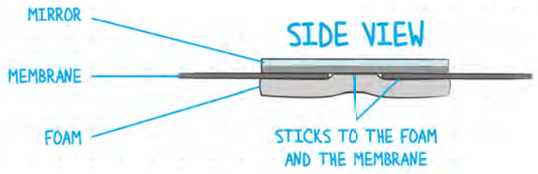

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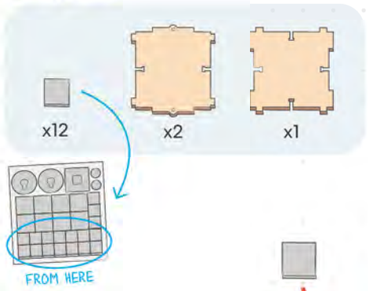
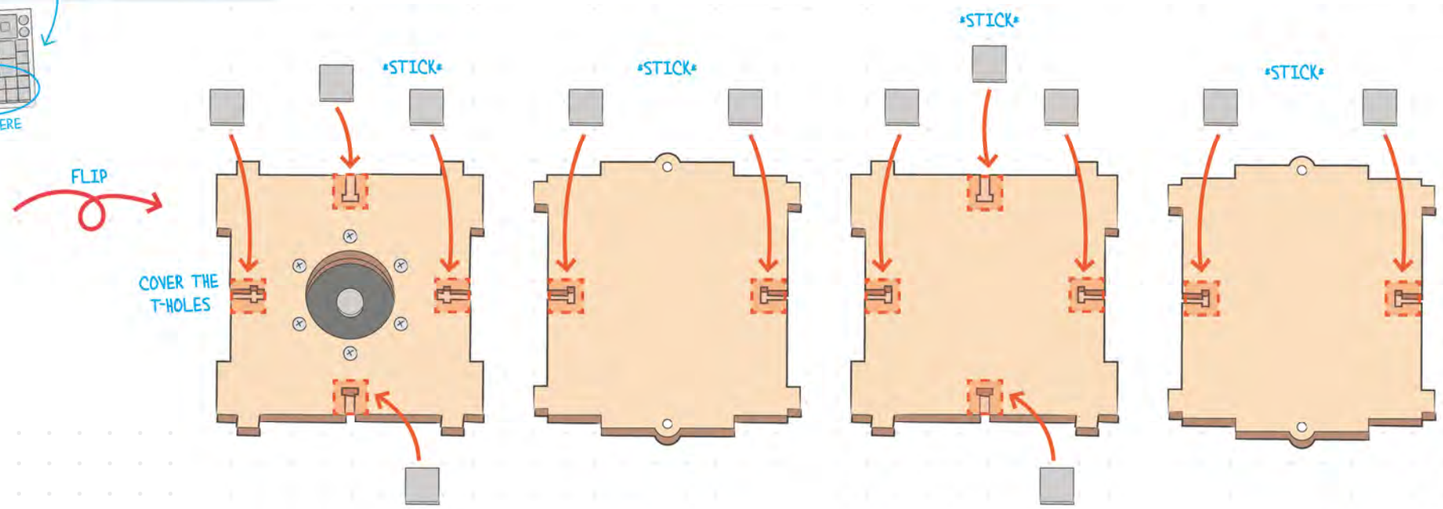
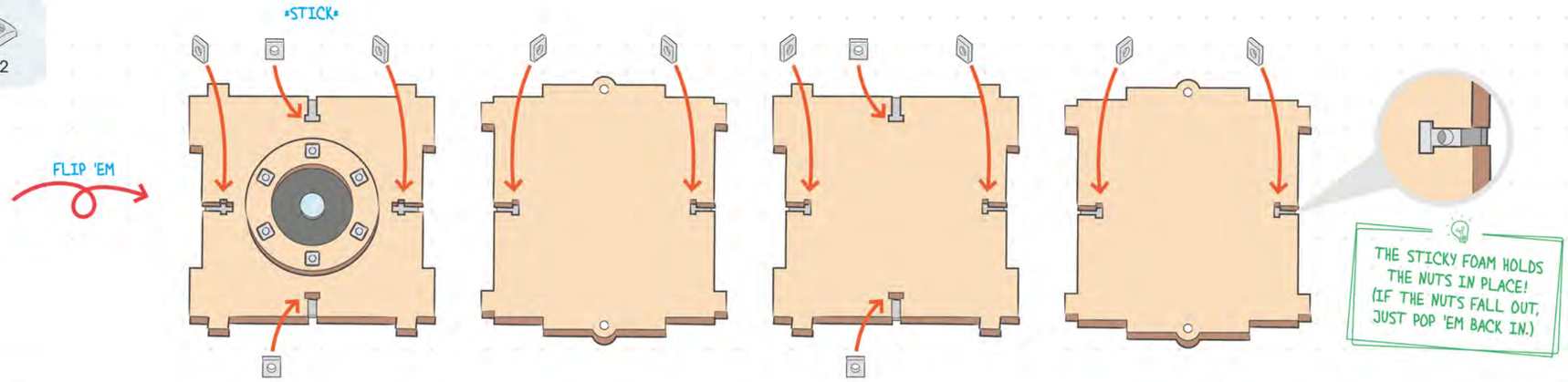

x12
x2
x1
FROM HERE

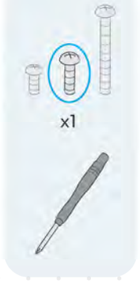

FLIP
COVER THE T-HOLES
"STICK"
"STICK"
"STICK"
"STICK"

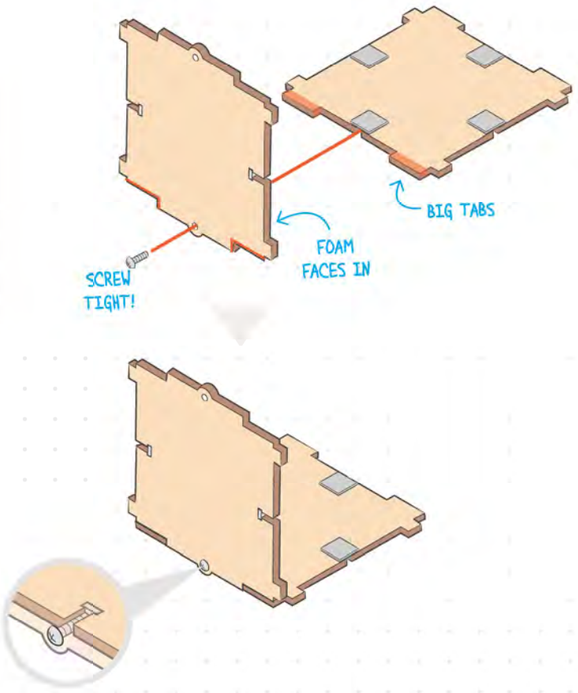
Step 9


x12


"STICK"
FLIP 'EM
THE STICKY FOAM HOLDS THE NUTS IN PLACE! (IF THE NUTS FALL OUT, JUST POP 'EM BACK IN.)

Step 10





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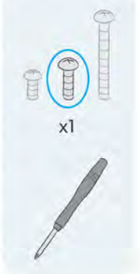

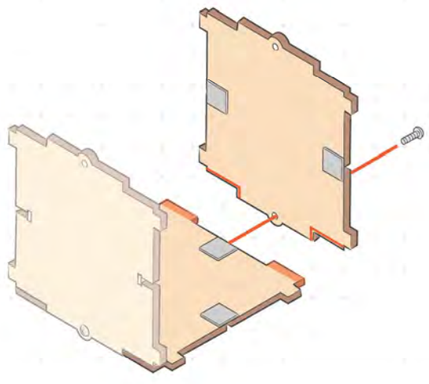

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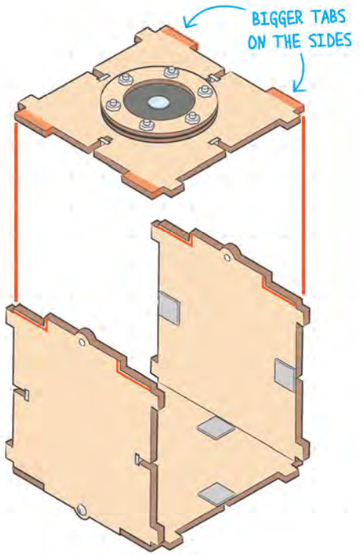
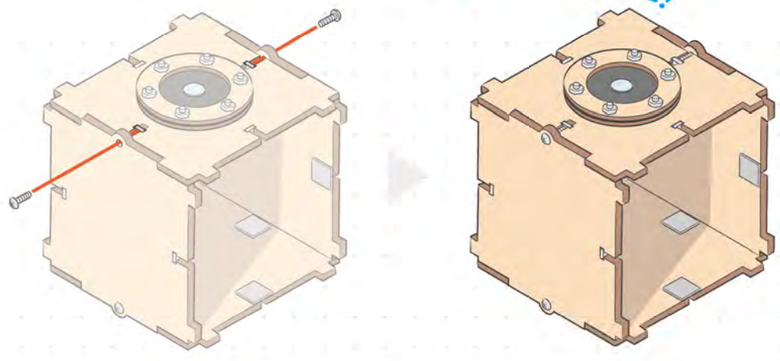


Step 13

THESE DON'T HAVE TO BE TOO TIGHT. YOU'LL REPLACE THEM IN PART C!



PART B

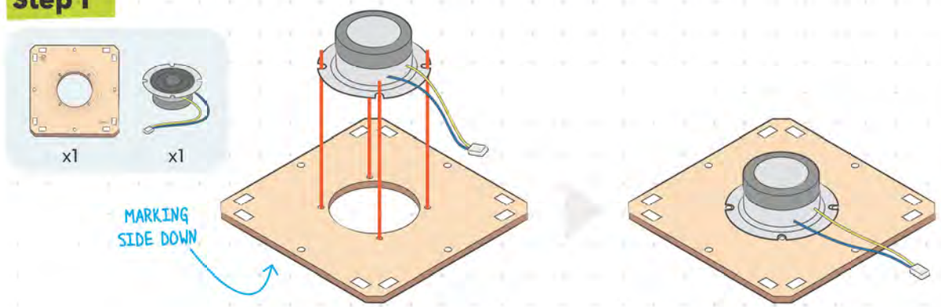
Add the Electronics

THIS IS HOW YOU CONNECT TO THE SPEAKER AND PLAY MUSIC.

Before you start

Be careful when handling the speaker driver.
The membrane on the front is super thin and very fragile, so avoid touching it.

Step 1



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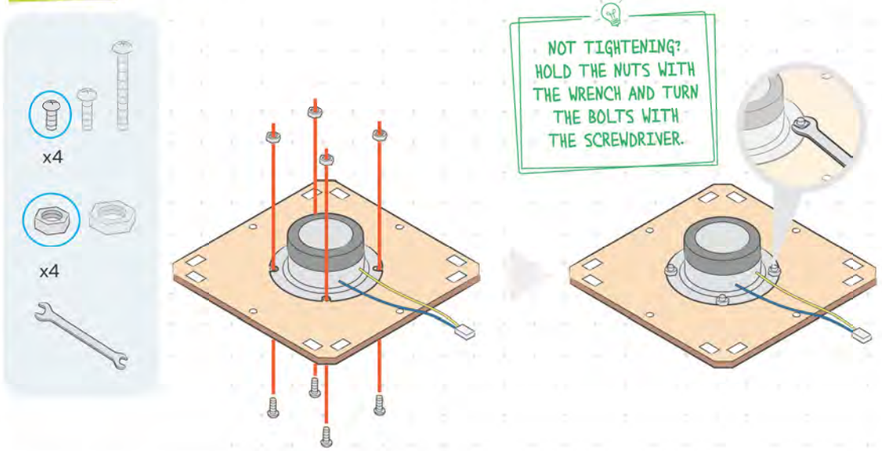

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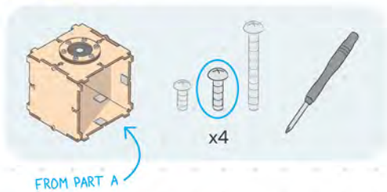

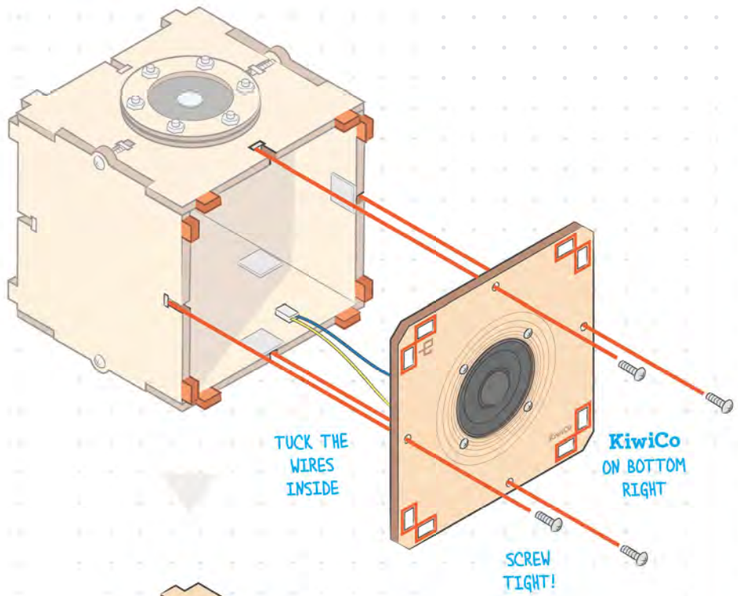

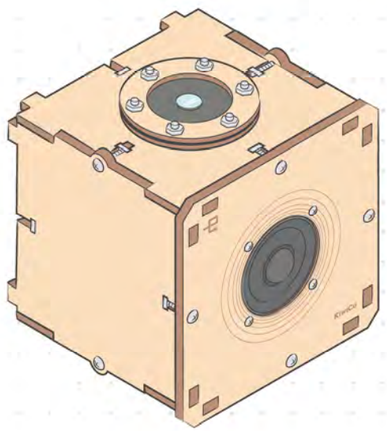

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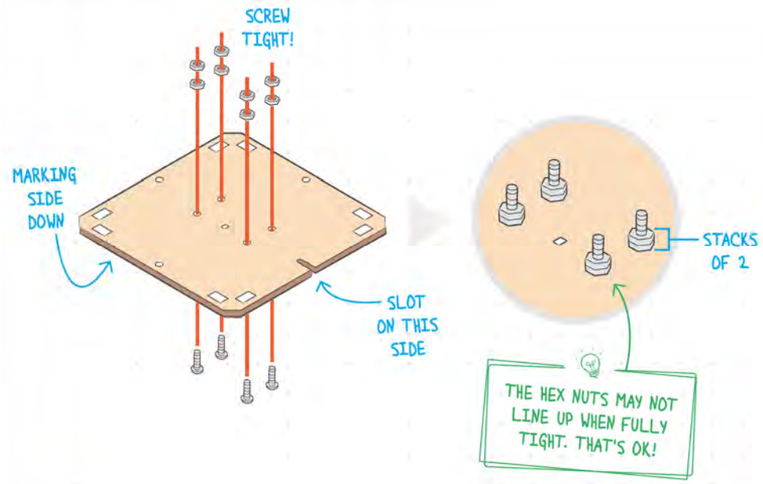

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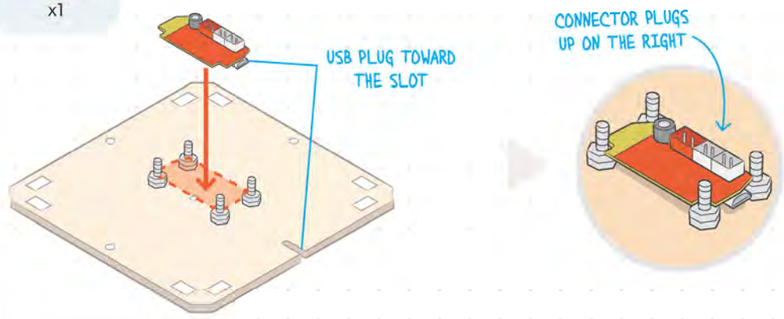

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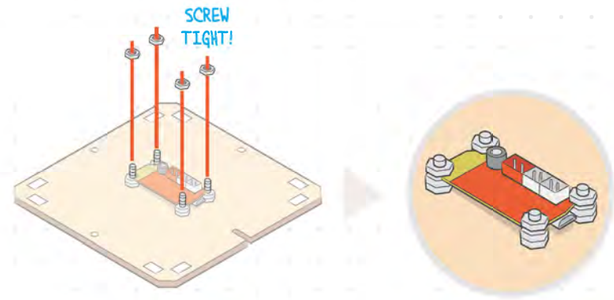

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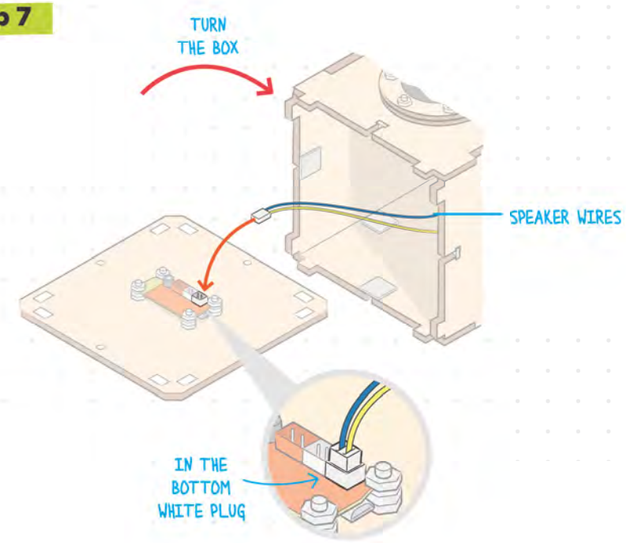

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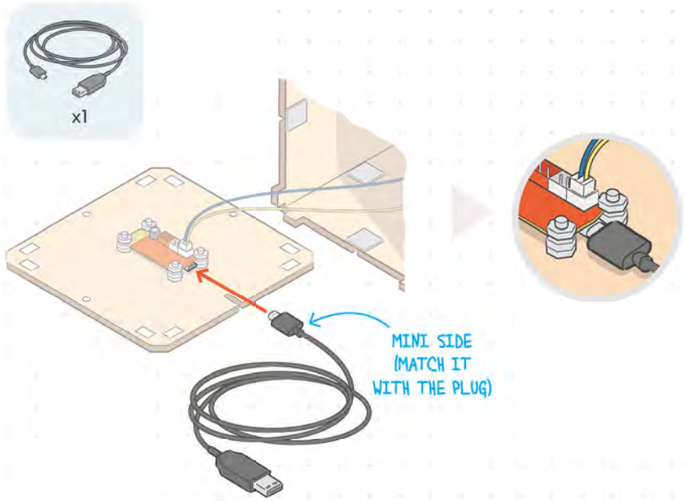


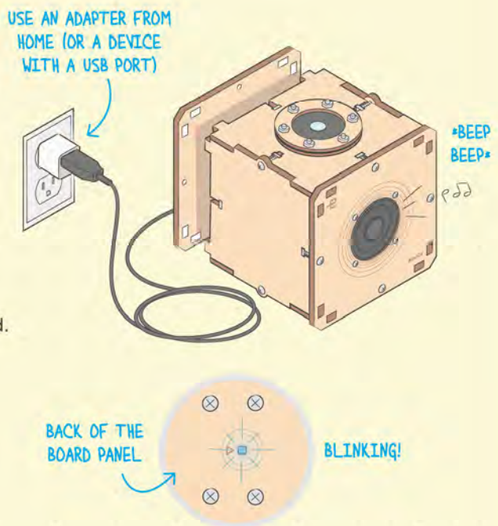
Stop & Check

Plug the USB cable into a power source. The speaker will beep, and the blue light on the wireless board will start to blink!

If the board doesn't power up, make sure the USB cable is plugged all the way into the board and the power source.

If the speaker doesn't beep, make sure the connector is plugged all the way into the board.

Unplug from the power source when you're done checking!



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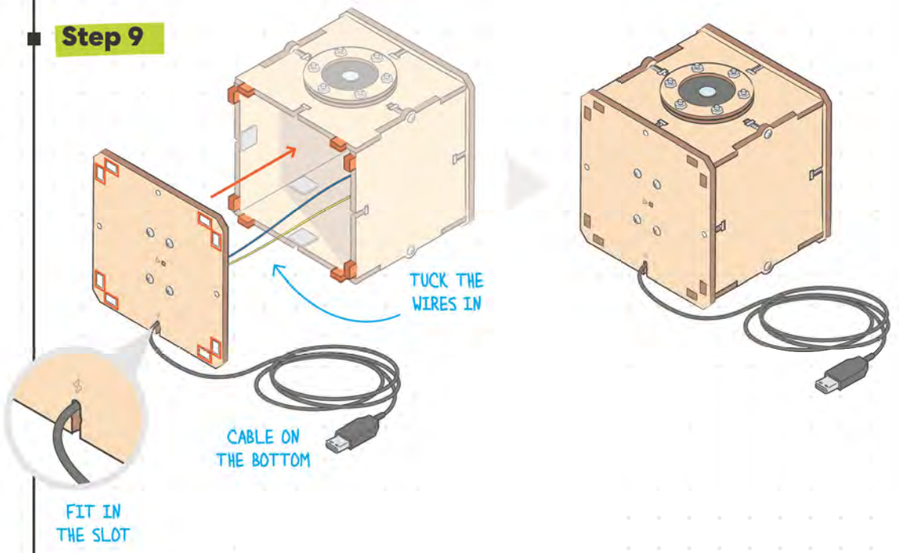

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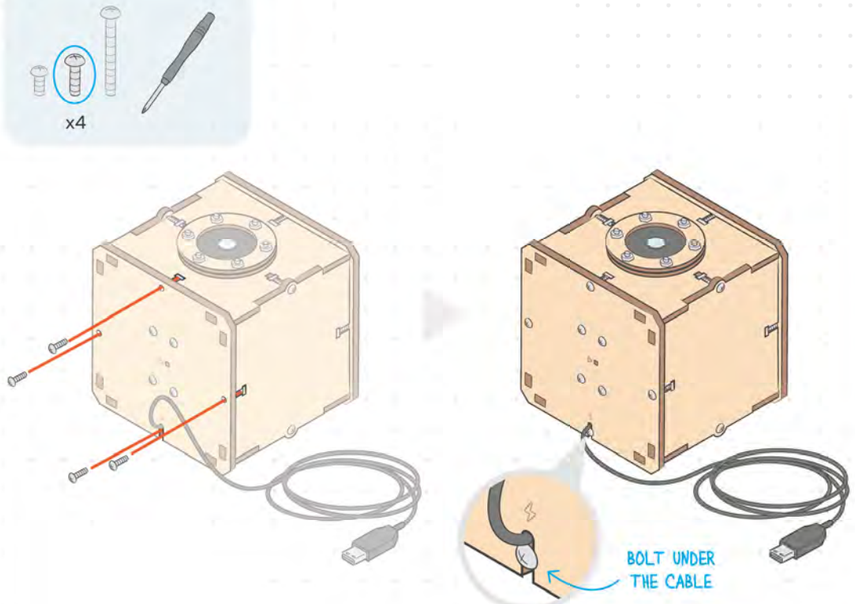

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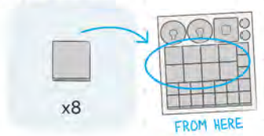
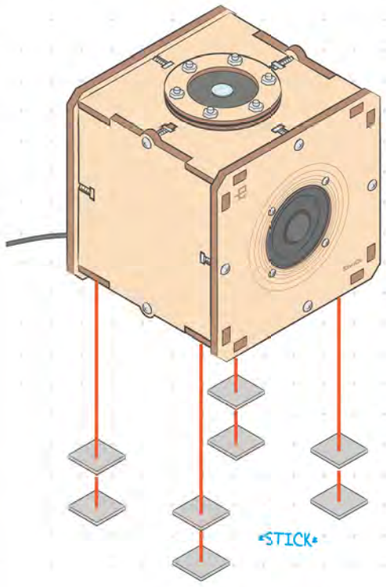
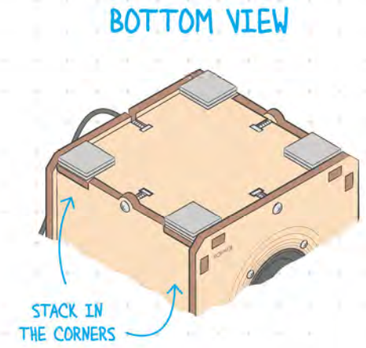
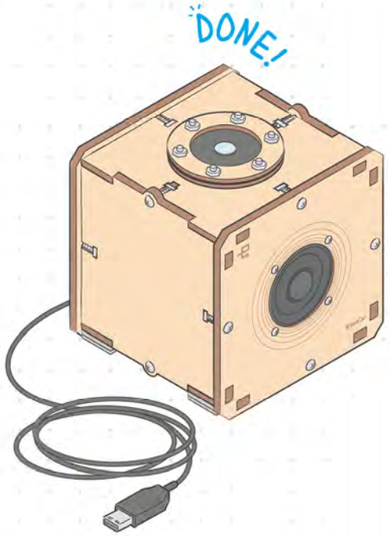








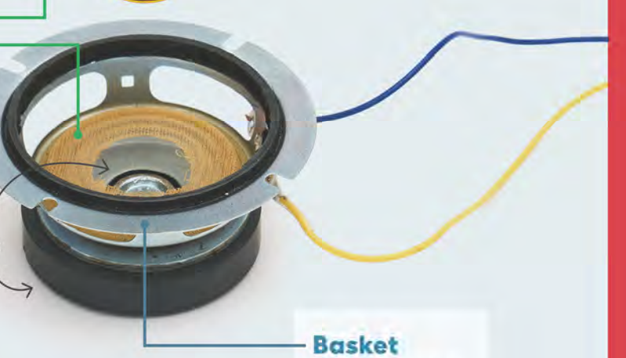
LOOK INSIDE

Speaker Cone

Sounds are waves in the air caused by vibrating objects — like your speaker cone! Let's look at the parts that make it work.

Voice coil
Electrical signals from the wireless receiver pass through a copper wire coil. The signals create a magnetic field that pushes the coil away from the magnets.

Diaphragm
The voice coil pushes the front of the speaker, which pushes against the air. The area of compression moves away from the speaker as a sound wave!



Suspension and Spider
Flexible membranes let the voice coil and diaphragm slide back and forth smoothly.

Basket
The frame holds all the pieces together

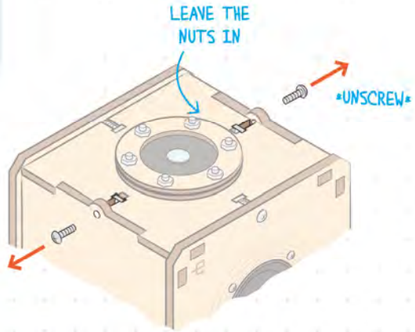
WARNING:
Don't take your speaker apart like this!
It won't work anymore. (We sacrificed this one for a good cause.)

PART C

Add the Arms

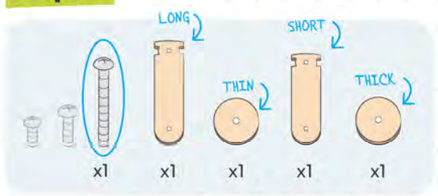
THESE HOLD THE LASER AND DIFFRACTION GRATING SO YOU CAN PUT ON A SHOW.

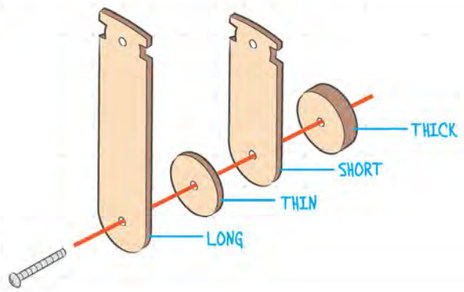
Step 1



YOU CAN SET THESE BOLTS ASIDE. YOU WON'T NEED THEM.

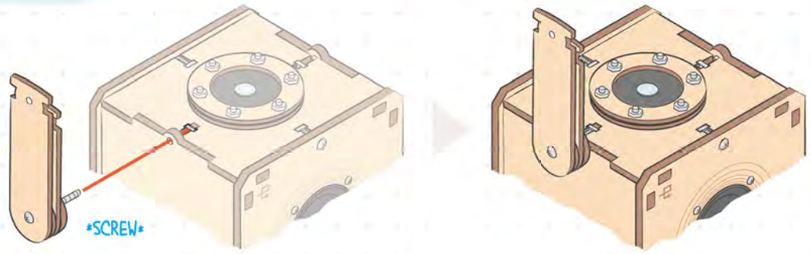
Step 2



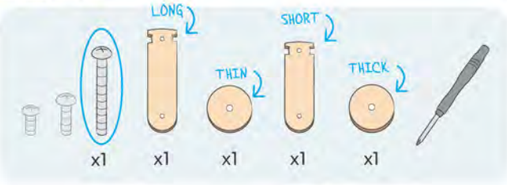


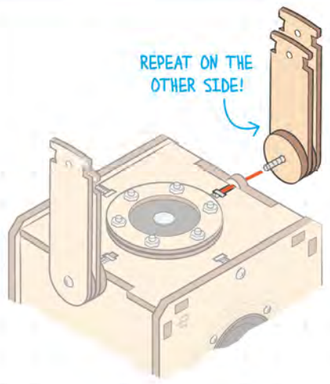
Step 3

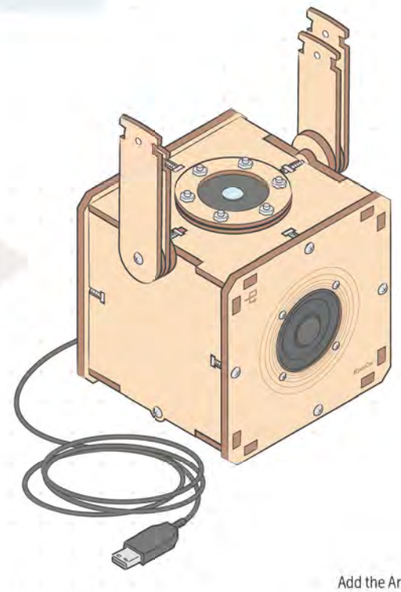
THE ARMS SHOULD BE LOOSE ENOUGH TO TURN BUT TIGHT ENOUGH TO STAY IN PLACE.



Step 4







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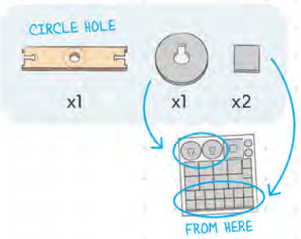
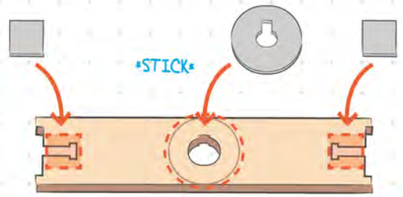
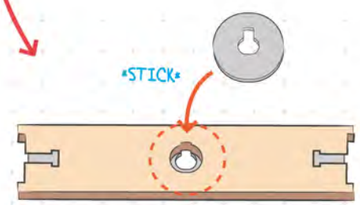




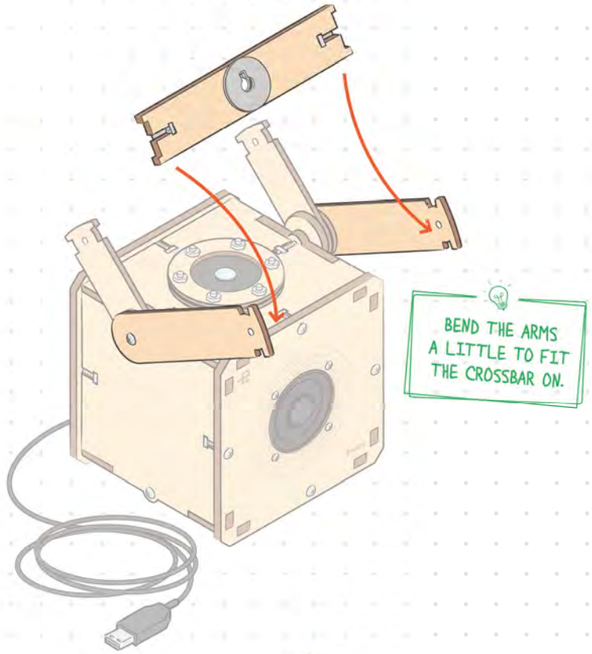
FLIP

Step 6



Step 7

Step 8



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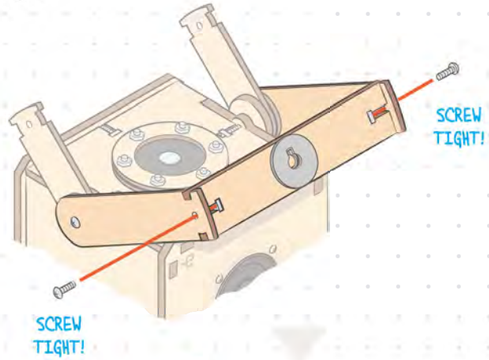

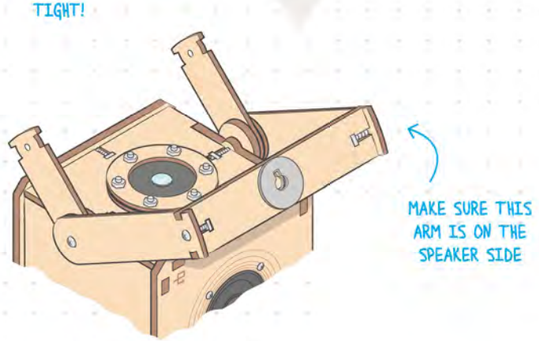

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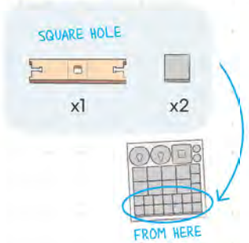

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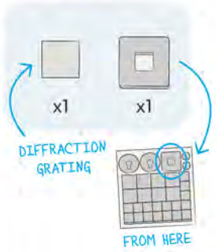

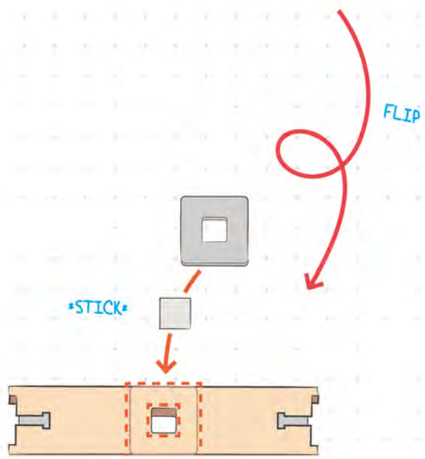

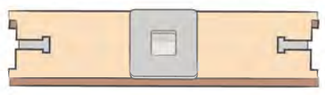

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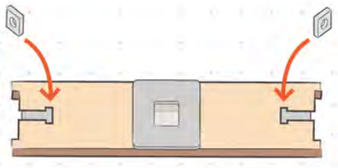

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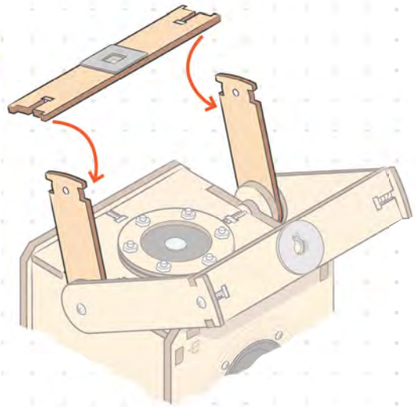
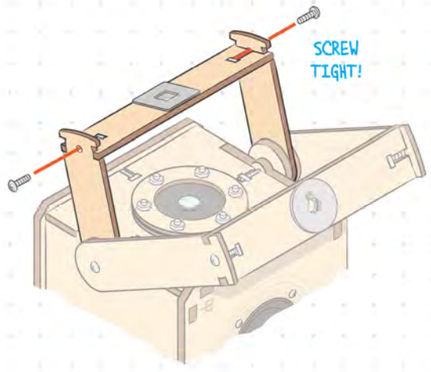
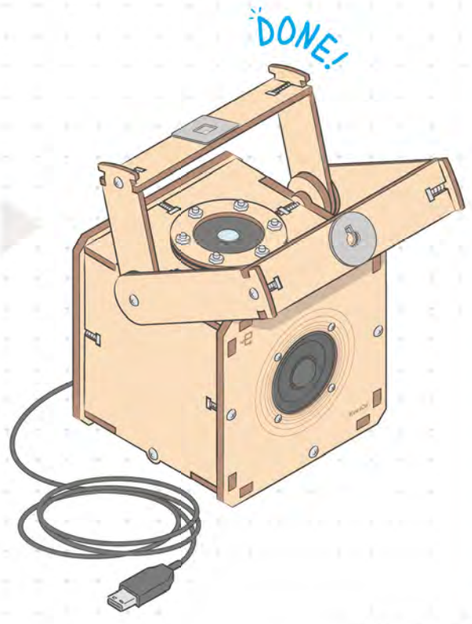


Step 14

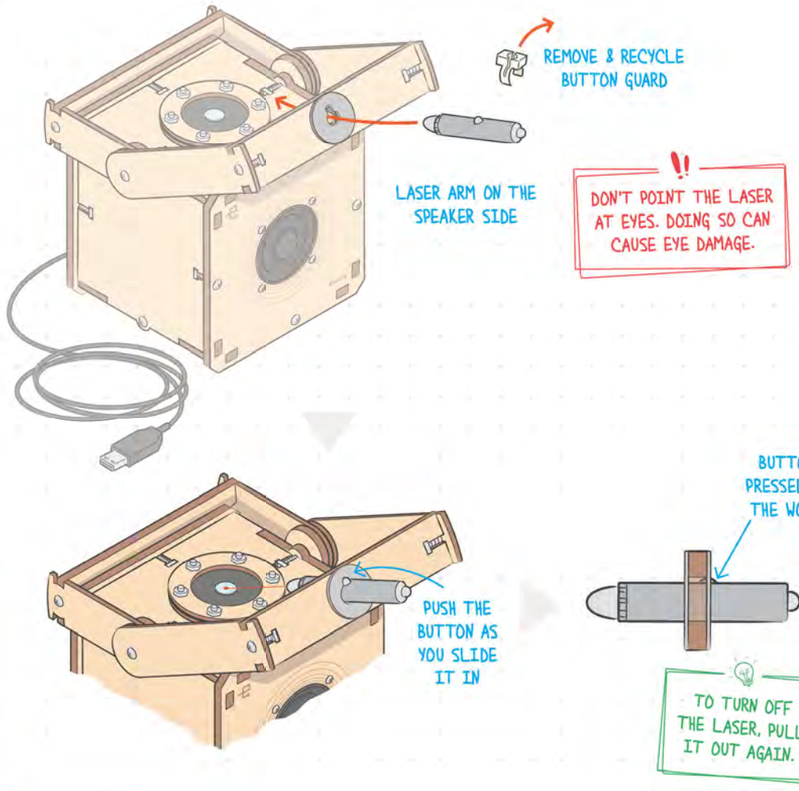




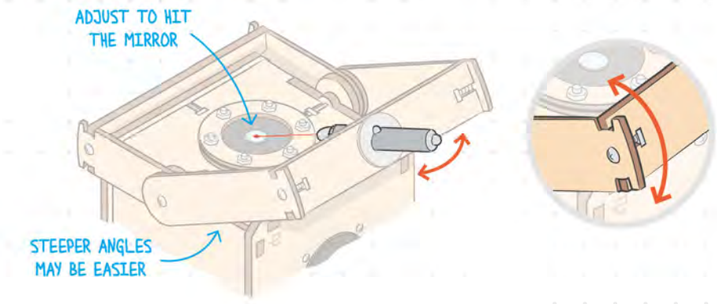
HOW TO LINE UP THE LASER

Your **laser speaker** works best in low light. Go someplace dark to try it out!

1 Place the **speaker** on a flat surface, facing away from a wall. Push the **laser pointer** through the hole in the laser arm so the button gets pressed down.

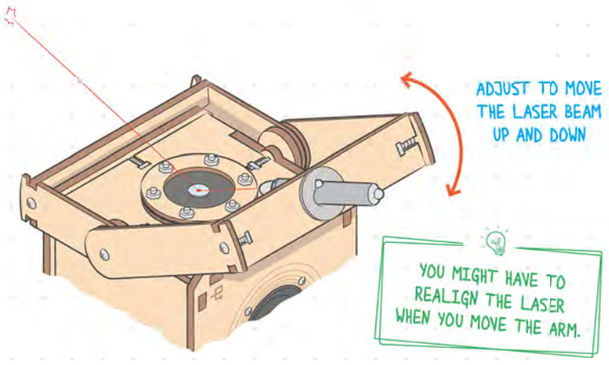


2 Tilt the laser, arm, and crossbar so the beam hits the mirror.



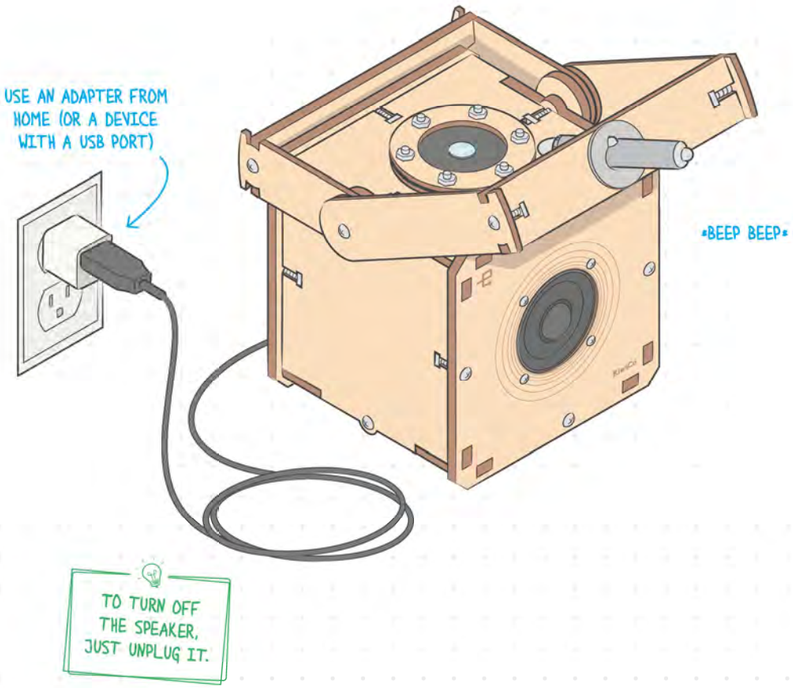
3 When the laser hits the mirror, the beam will bounce onto the wall behind the speaker!

To adjust the beam's position on the wall, move the arm up or down.



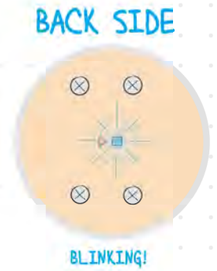
HOW TO CONNECT THE SPEAKER

1 Plug the **USB cable** into a **power source**. The speaker will beep!



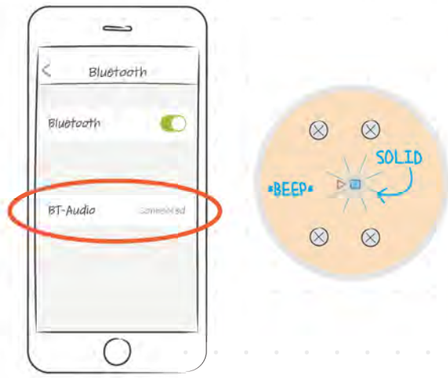
2 Check the back of the speaker. The blue light should be blinking! That means the speaker is ready to connect.

If the blue light is solid, your speaker is already connected to a device and you can skip Step 3.



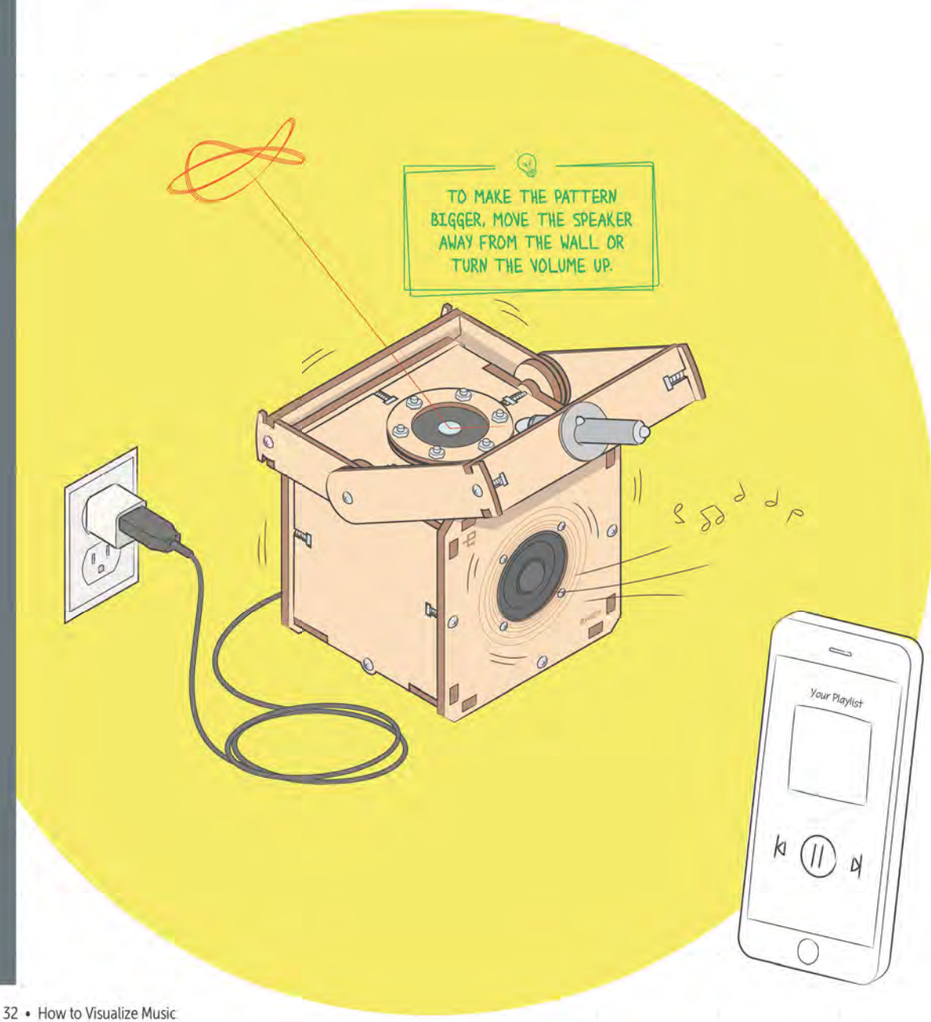
3 Grab a **Bluetooth-enabled device**, go to the Bluetooth settings, and enter pairing mode. Select **BT-Audio** or **DW-CT14+** to connect.

When paired, the speaker will beep again and the blue light will turn solid.



HOW TO VISUALIZE MUSIC

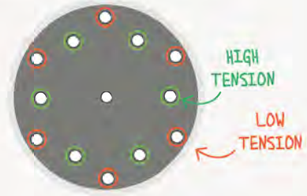
Pick out a favorite song on your device and hit play. As the speaker plays, **the laser beam will dance to the beat** and trace wild patterns on the wall!



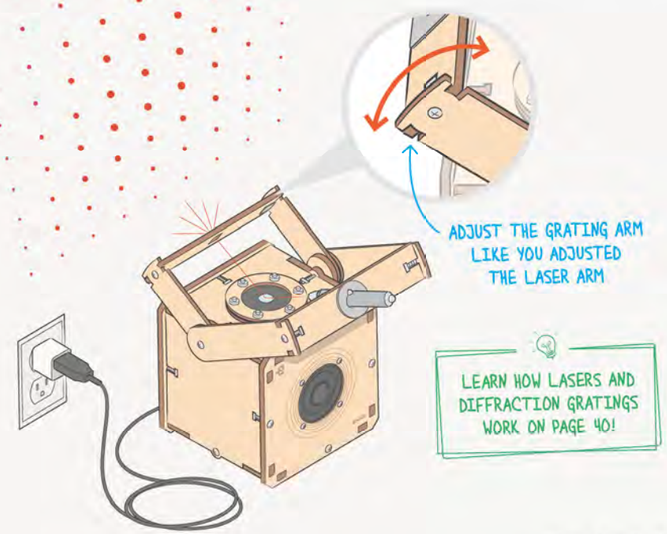
Try these tips:

Control the speaker's **volume** from your device.

The **membrane** has two settings: low tension and high tension. Try them out and see how the different tensions change the visualizer!



Ready to pump up the party? Move the **diffraction grating** into the path of the laser beam to split it into lots of patterns!



AUDIOVISUAL EXPERIMENTS

Visualizing Sound

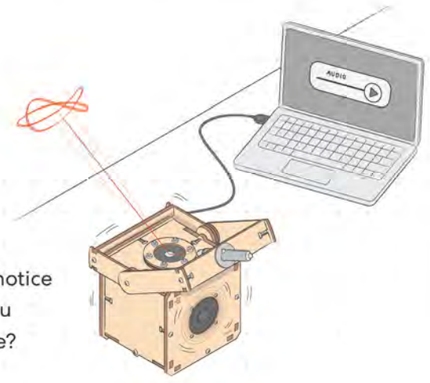
Your speaker doesn't let you just *hear* sound — it lets you *see* it, too!

To make sound, the speaker driver **vibrates**. That moves the air inside the speaker, which causes the membrane, and the stuck-on mirror, to vibrate too. So as the laser beam bounces off the moving mirror, its wild patterns are directly made by the music you hear!

But notice how the laser pattern changes when you play different sounds? That's because different sounds are caused by different **types of vibrations** — loud or soft, high or low, each sound has its own vibration pattern. Experiment and see (literally) what kinds of vibrations go with what sounds!

Step 1

Connect to your **speaker** with an **internet-enabled device**. Then go to eurekacrate.com/laserspeaker.



Step 2

Play the **test sounds**. What do you notice about how they sound? What do you notice about the patterns they make?

Step 3

Record your observations! Write down what each test sounds like and sketch the laser pattern (or film it).

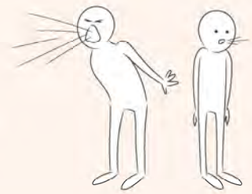
Try out these test sounds!

TEST SOUND 1

Volume

How does the same tone at different volumes affect the pattern?

***Volume** is how loud or soft a sound is. More powerful sound vibrations make a louder volume, and weaker vibrations are softer.*



TEST SOUND 2

Pitch

How do higher and lower pitches change the pattern?

***Pitch** is how high or low a sound is. Higher pitches come from faster vibrations, and lower pitches come from slower vibrations.*

TEST SOUND 3

Timbre

What changes with the same tone played on different instruments?

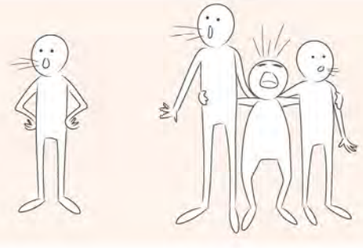
***Timbre** is the quality of a sound that makes it distinct, like what makes a trumpet sound different from a piano.*

TEST SOUND 4

Harmony

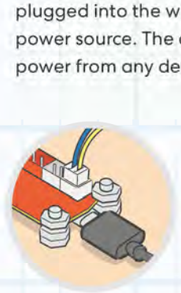
How do multiple tones compare to single tones?

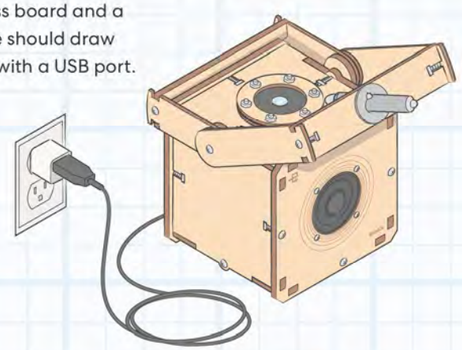
***Harmony** is when multiple tones are played at the same time.*



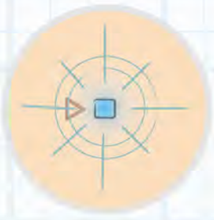
TROUBLESHOOTING

If the blue light isn't on,
make sure the USB cable is firmly plugged into the wireless board and a power source. The cable should draw power from any device with a USB port.

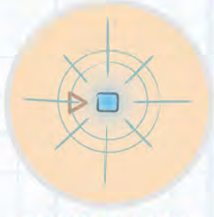




If the wireless board doesn't beep when you plug it in,
that's no problem. As long as the blue light is on (blinking or solid), the board is working!



If you can't find the speaker on your device,
make sure the speaker's light is blinking. If it's solid, the speaker is connected to another device. Turn off Bluetooth on that device for the speaker to enter pairing mode again.

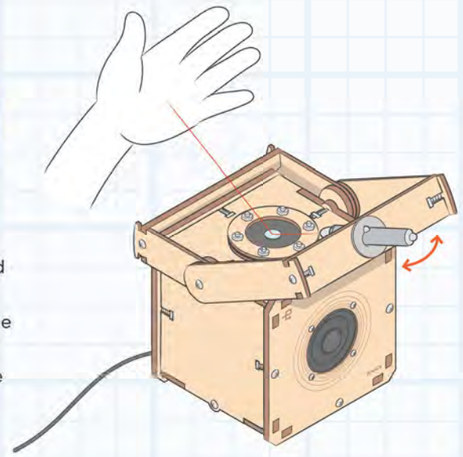


UNPAIRED = BLINKING

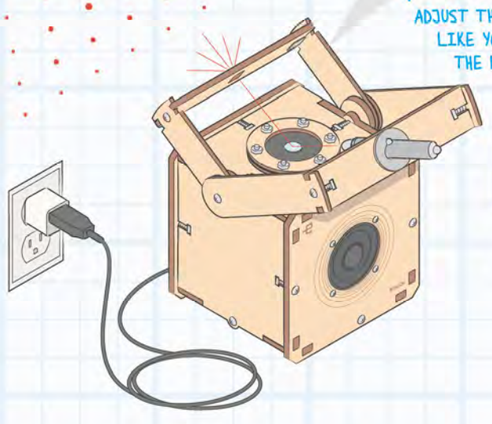
PAIRED = SOLID

IF YOUR DEVICE CAN SEE BT-AUDIO OR DW-CT14+, BUT CAN'T CONNECT, RESTART THE DEVICE.

If you can't see the laser beam,
use your hand to trace the path of the laser. If you can't see the beam before the mirror, make sure the button is pressed down. If you can't see it after the mirror, adjust the laser so it hits the mirror. Also make sure to use the speaker in a dark room.



ADJUST THE GRATING ARM LIKE YOU ADJUSTED THE LASER ARM



If the laser beam misses the diffraction grating,
you can adjust both the laser and the diffraction grating. Tilt the cross bars, or tilt the laser in the foam holder.

LASER SPEAKER

BEHIND THE DESIGN

Speaker Design

All speakers make sounds, but that **doesn't mean they're all alike**. We tried speakers with open holes, speakers with giant cones, and even one with a winding tunnel inside. We settled on the final **closed box design** because it was the best at vibrating the mirror membrane.

Wireless Board

To make the speaker **high-tech**, we added a wireless board for next generation connectivity. But in figuring out how to secure it without damaging any of the **delicate circuitry**, our best solution ended up pretty **low-tech** — we just used nuts and bolts to **grip the board directly**!

Testing Playlist

One of our favorite features of the laser speaker is that it doesn't just respond to single held notes like lots of other visualizers — it can visualize **all sorts of music**! To see just how much it could handle, we put the speaker to the test with a playlist of **dubstep hits**. If it can visualize Skrillex, it can visualize anything.

For calmer testing, we played *Mother Earth's Plantasia*, a 1976 album made for plants.

Diffraction Grating

In looking for a way to pump up the party with the laser speaker, we found that **diffraction gratings** were a quick and easy way to split a laser into **hundreds of beams**. The grating in your speaker is also used in **spectrographs**, scientific tools that let you see the individual colors of light in a light source.

Membrane Hole

Originally, we tried sticking the mirror right to the membrane, but with all the vibrating, it came **unstuck** easily — and even if it did stick, it was hard to **line it up with the laser**. We didn't have a total fix, but we figured adding a **target** to the membrane might help with alignment. The target hole turned out to be the perfect size for a **foam anchor** to stick the mirror to, fixing both issues!

BY THE NUMBERS

Hours of music testing: **60**

Speaker drivers tested: **35**

Wireless boards tested: **11**

Times asked to "turn it down": **25**

Explore online:

Check out **eurekacrate.com/laserspeaker** to learn more about the design behind your laser speaker!

PUTTING SCIENCE TO WORK

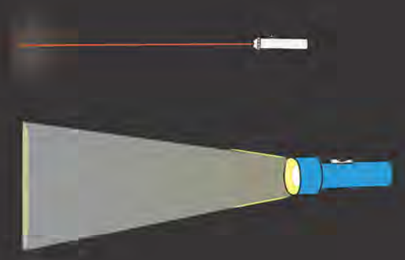
LASERS AND DIFFRACTION

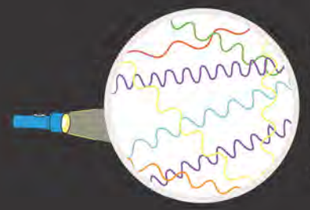
What do engineers, surgeons, astronomers, and cats have in common? They all love lasers — just like the one in your speaker.

Laser light is useful stuff. An engineer used a laser cutter to design the wood pieces for your speaker. An eye surgeon might use lasers to reshape someone's cornea so they can see better. Astronomers can point out stars and measure the distance from Earth to the Moon with super powerful lasers. And well... you know why cats love lasers.

WHAT MAKES LASERS SO SPECIAL?

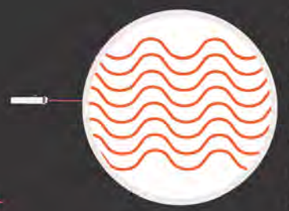
Grab a regular flashlight and shine it on a wall, then move it back a few feet and watch how the light changes. Now try the same thing with your laser pointer. See the difference? The flashlight's beam spreads and fades, but the laser beam stays the same shape, size, and intensity.





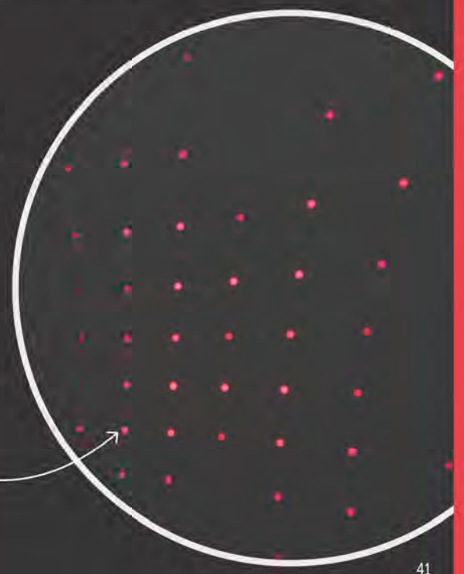
Light moves as a wave, and different sizes of wave *(or wavelengths)* are different colors. A white light bulb *(like the one in a flashlight)* sends out lots of different wavelengths in all directions.

A red LED *(or a white light with a red filter over it)* sends out only the waves that make red light — so the light is **monochromatic**. The waves still scatter in every direction, though.



A laser sends out identical waves that all travel in the exact same direction in perfect sync — so the light is **coherent** as well as monochromatic. That gives you a super narrow and precise beam, which can be used for anything from scanning barcodes to putting on a light-and-sound show!

But when you're rocking out, you might want to party with more than a single dot — even if it *is* dancing to the beat. That's where your **diffraction grating** comes in! When laser light passes through its tiny slits, the beam splits. The waves stay in sync, but go in different directions. The redirected waves collide and interfere, giving you a whole bunch of dots all dancing together. Now *that's* a party!



HISTORY OF DESIGN

WIRELESS COMMUNICATION

THE NEED:
a way to control an electronic device without wires

THE INVENTION:
frequency-hopping, a crucial part of wireless communication today


Hedy Lamarr

Wireless technology is everywhere — from Wi-Fi to cell phones to the receiver in your laser speaker. But none of it would be possible without one outside-the-box inventor: a glamorous Hollywood star named **Hedy Lamarr**.

Lamarr often holed up in her actor's trailer, tinkering and experimenting. Over the years, she invented a fluorescent dog collar, a mechanism that helped disabled people use the bath, a tablet that turned water into soda(!), and more.

So when World War II began, and news broke that Nazi forces had sunk a refugee ship, Hedy was ready to help. She knew that U.S. torpedoes were seriously inaccurate — up to *3 in 5* were no-gos.

What if, she thought, you could use radio signals to guide torpedos, so they'd hit their target more often? Of course, radio signals could be intercepted by the enemy, so the signals would need to randomly switch from frequency to frequency to evade interference. Lamarr called the idea **"frequency hopping."**

Lamarr teamed up with *another* outside-the-box inventor, composer George Antheil, to bring her idea to life. The inventors knew they needed a way to sync up the frequencies between the transmitter *(the ship trying to guide the torpedo)* and receiver *(the torpedo itself)*, or else the two wouldn't be able to communicate while hopping.

Their solution was, well, outside-the-box: **player piano rolls**! Self-playing pianos used paper rolls full of punched-out holes to play pre-programmed music. If you gave two player pianos matching piano rolls, they'd play the same music in tandem. Lamarr and Antheil decided to use a similar device — perforated ribbons with a sequence of radio frequencies punched into them. Install one in the torpedo and one on the ship, and they'd hop frequencies in tandem, like a beautiful symphony. But the enemy couldn't listen in on the signals, because they didn't know the frequency sequence!

Lamarr and Antheil presented their **"Secret Communication System"** to the Navy, but the Navy felt the technology was too "bulky," even though it was actually compact enough to fit inside a watch. Antheil later joked that the officers must've misunderstood and thought they'd suggested *putting actual pianos inside of torpedoes!*

It would be several decades before the Navy — and the world at large — realized the value of Lamarr's idea. If frequency hopping could stop intentional jamming, it could prevent accidental jamming, too, for all sorts of wireless signals. Thanks to her ideas, your phone can send signals to your speaker without them "bumping into" any of the other signals bouncing around you.

Sadly, Lamarr never received compensation for her innovation; her contribution wasn't even publicly recognized until late in her life. But our lives would be entirely different — and a lot less connected — without her.

Hedy Lamarr in The Heavenly Body (1944)

DESIGN CHALLENGE

VIBRATION PLATE

A laser isn't the only way to visualize vibrations.
Make your own vibration plate to see sounds!

You'll need...

a flat surface that can vibrate, like:
- a baking sheet or pie tin
- a sheet of cardboard
- a balloon or plastic bag you can stretch out

something that'll move around on top of the surface, like:
- fine sand
- salt or pepper
- a dish of water

Pick something you can see against the surface.

a way to hold up your surface, like:
- a large coffee can
- a bucket
- books or blocks

something that makes loud sounds, like:
- a speaker *(like your laser speaker)*
- loud instruments and noisemakers
- your voice

Experiment to find the right combination of materials!

Get inspired by these designs, or invent your own.

Cut out the bottom of a canister or bucket before stretching a membrane over the top.

If you have a big speaker, you can tip it sideways and put your plate directly on top of it.

Find a tone generator online and play different pure tones. Watch the patterns change! Do you see a difference between high and low notes?

Show off what you made!

Use **#EurekaCrate** to get featured!

Connect with us!

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⚠ WARNING

CHOKING HAZARD – Small parts.
Not for children under 3 years. Only for use by children aged 12 years and older.

KiwiCo

Inspiring young innovators with seriously fun and enriching hands-on experiences.

Keep the instruction sheet since it contains important information.