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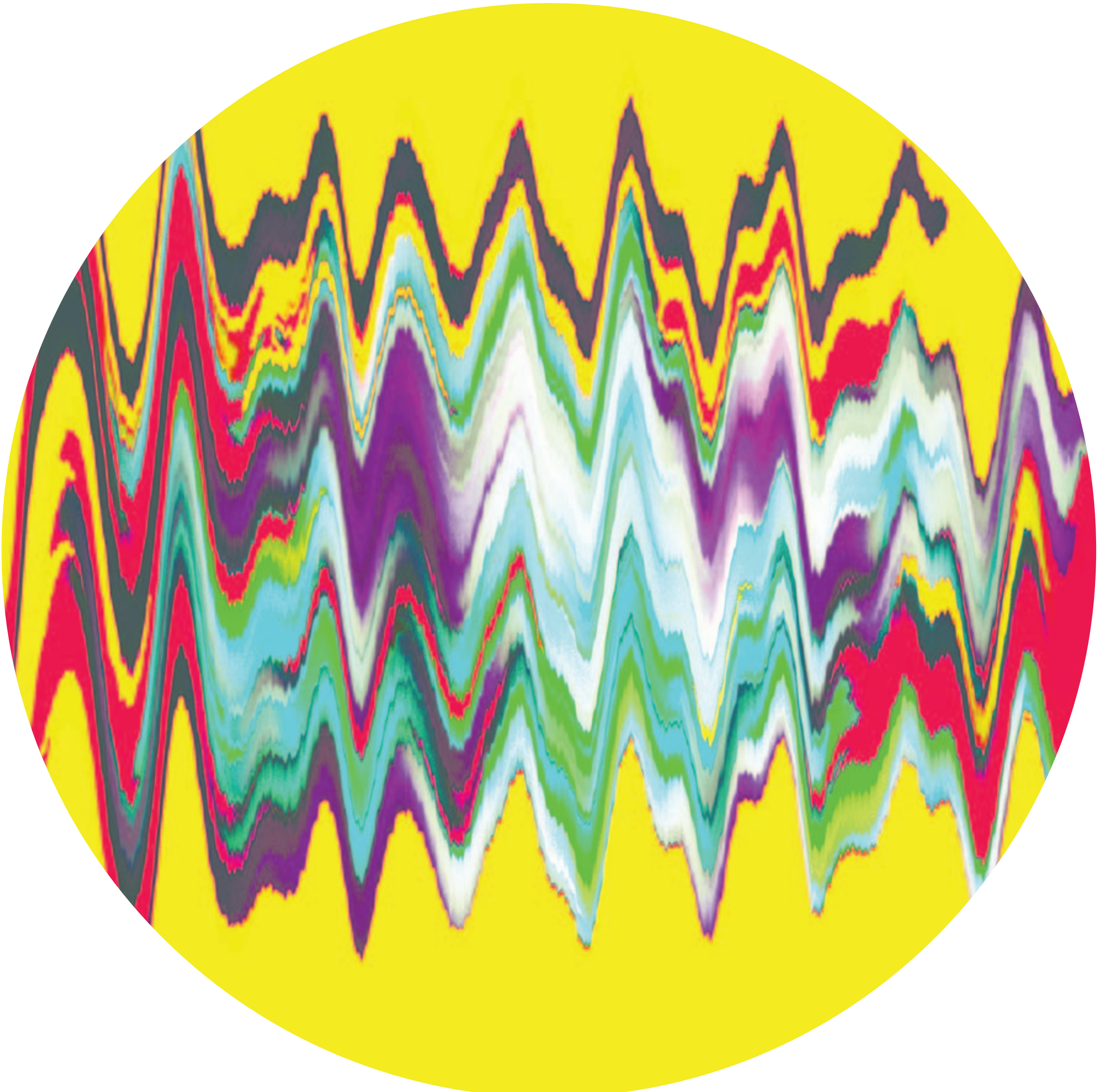
Resonating Wine Glass



hear it!

Resonating Wine Glass

What's it all about then?

This experiment is about resonance. In this experiment you will be making a wine glass vibrate at its resonant frequency before slowing the vibrations down using a strobe light.

It's a great experiment which allows the students to really get to grips with the concepts of sound and resonance.

What you can explore through this experiment:

- Sound is vibration
- Longitudinal waves
- Resonant frequency

How to present this:

This is a guideline of how to present the experiment to the students. You do not have to follow it exactly, as long as you allow the students to explore the concepts outlined above. You can expand or shorten this experiment as necessary to fill the time allocated.

The kit:

- Signal generator
- Spectrum analyser Software called "gram12" set up on laptop. Username is: *lial* and the password is: *password*.
- Speakers
- Wine glasses
- Strobe light
- Retort stand and clamps
- Sound-proof box
- Slinky spring
- Ping pong ball
- Amplifier

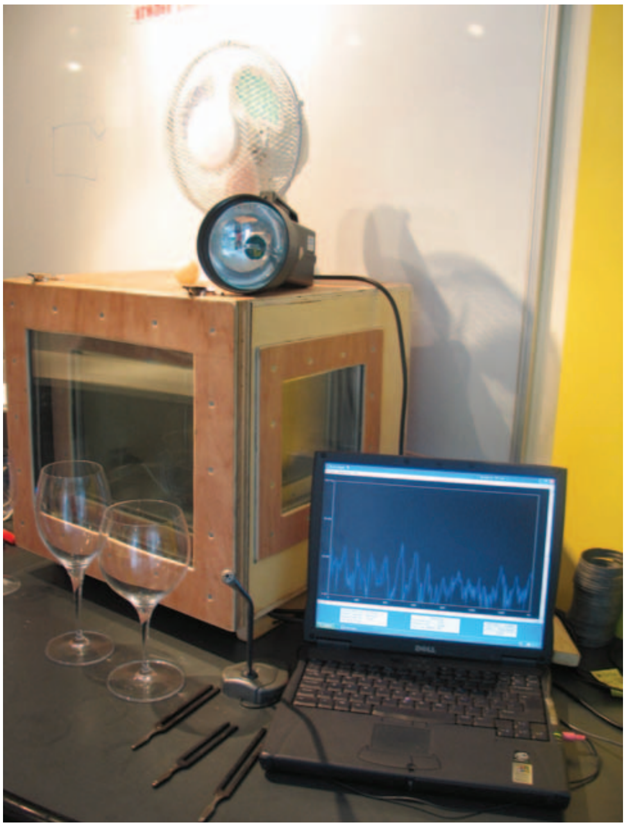


Image of equipment

Resonating Wine Glass

Introduction

Start by asking the students what sound is. Get them to hum and feel the vibrations in their throat. Sound is vibration but how does sound travel? Can sound travel through solids, liquids and gases?

You could use a slinky spring to demonstrate how sound travels through the air as a longitudinal wave. When an object is vibrating, it is flexing in and out. As the vibrating object flexes out it pushes the surrounding air molecules causing them to collide with the ones in front of them (compression). As the vibrating object flexes in it pulls in on the air molecules which creates and drop in pressure which pulls in surrounding air molecules (rarefaction). These pushes and pulls travel through the air to reach your ears where you hear the sound.

Part 1: Test the resonant frequencies of different wine glasses

1.1 Every object has a natural frequency that it likes to vibrate at – its resonant frequency. Introduce this by asking one the students to try to make different wine glasses ‘sing’ by rubbing their finger around the rim. Ask the students why they think that the wine glasses sound different – what is it that’s making the noise?

1.2 Introduce the spectrum analyser. The spectrum analyser is a computer programme that analyses and displays the frequency of sounds received by a microphone. The display shows the frequency as Hertz, discuss with the students what they think the word Hertz refers to. Ask the students to find the different frequencies of the singing wine glasses.

1.3 Discuss why some sounds are low and some are high – you could ask a student to sing into the microphone to see the frequency of different notes. It may help to use the ‘peak hold’ button on the spectrum analyser which freezes the screen and helps you identify the most prominent peak in frequency.

1.4 Introduce the signal generator which is connected to an amplifier and speaker. Ask one of the students to change the frequency of the signal generator and listen to the noise that is produced by the speaker. Drop the frequency down very low and see how the speaker is very slowly moving in and out – you can relate this back to sound being a longitudinal wave pushing and pulling the air molecules.

Image of the signal generator

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Part 2: Make the wine glass resonate visibly

2.1 Unplug the speaker and connect the speaker in the sound box. Ask a student to take a wine glass and find its resonant frequency. Then place the wine glass in the sound box and ask the students for their suggestions on how to make the wine glass vibrate without touching it. Place a ping pong ball in the bowl of the glass, close the sound box and ask one of the students to tune the signal generator to the resonant frequency of the wine glass.

2.2 Once the resonant frequency is found the glass will vibrate and the ping pong ball will start to bounce around. You can emphasise at this point that the speakers are moving the air molecules at a frequency which the glass likes to vibrate at and in turn is making the glass vibrate a lot!

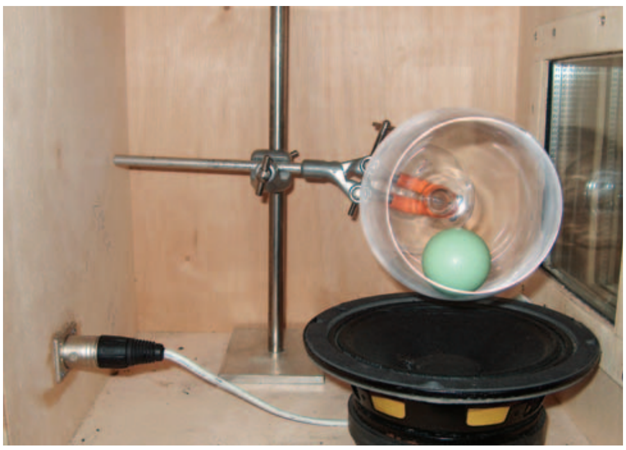


Image of a wine glass and speaker in the sound box'

Part 3: Using the stroboscope

3.1 To see this vibration in slow motion use the strobe light. To explain how a strobe works ask one of the students to turn on the fan. Then ask another student to adjust the frequency of the strobe until the fan looks like it is motionless. Ask why they think this is.

3.2 Take the ping pong ball out of the glass and make sure that the signal generator is set to the resonant frequency of the glass in the sound box. Then ask one of the students to hold the stroboscope to the sound box side window and adjust the frequency of the strobe. Do check before you use the strobe if anyone is epileptic. Once the correct frequency on the strobe is achieved the glass will appear to vibrate in slow motion.

3.3 Ask the students how we can make the wine glass break. What is it that will make it shatter? Try increasing the amplitude and see if you can get the wine glass to break.

Resonating Wine Glass

Some questions you may be asked:

What is resonance?
Resonance can be a hard concept for students and the analogy of resonance working like pushing someone on a swing can be helpful.

Imagine someone sitting on a swing that is already swinging. Without putting in any energy that person will slow down. However, if you keep putting in a little bit of energy at just the right time in the swing you can keep the swing going for longer without too much effort. Something will keep vibrating easily at its natural frequency if you put in a small amount of energy at just the right time.

To help with this explanation we have a rod with three pendulums. Ask one of the students to twist the rod back and forth to make one of the pendulums swing. They will find that they can only get one of the pendulums swinging well at one time. This is because you are putting in a small amount of energy at just the right time to keep one of the pendulums swinging. The other pendulums have different frequencies at which they swing so need the energy putting in at different intervals.

What does the spectrum analyser show?
The spectrum analyser shows the vibrations per second measured in Hertz. Ask a student to sing into the microphone. You can then point out to them that their vocal chords are vibrating a certain number of times a second. If they want some sort of gauge to understand this by then you can tell them that a mosquito's wings beat 600 times a second which is what makes that high pitched whine.

What is white noise?
White noise does not vibrate at one specific frequency but covers a range of frequencies. White noise is often used as sirens by the emergency services as it cuts through background noise and does not echo so it is easier to perceive the direction the vehicle is travelling.

Can everyone hear all frequencies?
No. As you get older your ability to hear high pitched frequencies decreases. When working with students you can set the signal generator on a very high frequency and ask who can hear it – the younger the group the higher the frequency they will be able to hear.

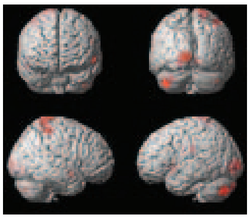
Can all glasses vibrate?
Everything has a resonant frequency that it likes to vibrate at, but to make glasses "sing" they have to have a stem for you to hold – it does not work with a tumbler!

Resonating Wine Glass

Where else can you see resonance in action?

Magnetic Resonance Imaging (MRI)

Even the cells in your body have a frequency that they like to vibrate at. An MRI scan takes advantage of this to build up a picture of inside your body. MRI scanners use very strong magnets (strong enough to pick up a car) to line up all the hydrogen atoms in your body. A radio frequency (RF) pulse is then used to make the protons of the atoms resonate and change direction that they are lined up in. This pulse gives the atoms energy. When the RF pulse is switched off the atoms release this energy, and this gives off a signal that can be turned into an image.



http://www.teachingmedicalphysics.org.uk/

Tacoma Narrows Bridge collapse

There is a DVD of the Tacoma Narrows bridge collapse that you can show the students if you have time. The bridge was built in 1940 in Seattle, America and was the longest suspension bridge of its time. However, the bridge would twist violently in winds which would cause an aeroelastic flutter. On the day of the collapse a 42 mph wind hit the bridge from the side causing the angle of attack (the angle between the wind and the bridge) to increase and in turn causing a torsional twisting in the bridge until the angle of attack increased to the point of stall and the bridge began to twist in the opposite direction. As the wind continued to blow it pumped in more energy than the twisting structure dissipated and so increasing the amplitude with each cycle. Eventually the amplitude of the motion increase beyond the strength of the bridge and the suspender cables failed and eventually the bridge collapsed into the ravine.

Today when engineers are designing bridges they include dampeners to stop this type of damage from resonance. Dampeners use a reservoir of oil that slows the movement of the bridge down.

When an army of soldiers are marching across bridges they "break step" which means that they do not march left right, but alternate the steps so that they do not cause resonance which may damage the bridge.

Musical instruments

Almost all musical instruments work by resonance. When you blow into a woodwind or brass instrument the air column inside vibrates and by pressing different keys the air column is changed which in turn changes the pitch of the note. When you pluck a string on a guitar the string, wooden case and air inside the case vibrates at a resonant frequency. You can change the pitch of the note by plucking shorter or longer strings.

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How does a stroboscope work?
The strobe is lighting up an object at regular intervals so we see snap shot images of that object. When using the strobe light on a moving object such as a fan you only see it when the fan blades are in a certain position. Our eyes then send these images to the brain which puts them together and perceives the fan as being slowed down.

Your television works as a strobe. Sometimes you may see cars driving on television where their wheels look like they are either staying still or going backwards. This is because the television is showing snap shot images of the wheels in certain positions and your brain puts the information together and perceives it as going backwards.

Glossary:

Vibration
Something that moves forwards and backwards, or side to side, or wobbles. Our ears can only hear vibrations between 25 and 20,000 vibrations per second. One vibration per second is 1 Hertz (Hz). One thousand vibrations per second is 1 kilohertz (kHz)

Longitudinal wave
A vibration where the wave motion is in the same plane as the travelling direction of the wave (demonstrate with a slinky). When you see sound waves drawn as transverse waves you are seeing a representation of the change in pressure against time, not a drawing of what the waves look like themselves. When you speak, sound waves don’t come out of your mouth and move up and down through the air!

Standing wave
When waves are contained in some way, either on a string when both ends are fixed, or in a pipe (which can be open or closed at the ends), then the waves being sent out get reflected back. The waves going out interfere with those coming in. At some frequencies the waves add up so that there are areas where they cancel each other out (nodes) and areas where they add up to maximum movement (antinodes). This is a standing wave, because it doesn’t seem to be moving one way or the other (can be shown with a slinky with some practice)

Resonance
When energy is put into an object at the same frequency that it like to vibrate at. Things with a large mass tend to have a low resonant frequency and things that likes to vibrate faster have a higher resonant frequency.

Loudness/ volume
Subjective terms for how intense you feel a sound to be.

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Sound intensity
A physical and objective property measured in decibels.

Amplitude
The scientific term for the height of a wave. If two sounds are the same distance away, the one with the largest amplitude will be the loudest.

Pitch
The musical term that relates to the frequency of the vibration. Subjective to the listener rather than objective (measurable). High frequency usually corresponds to high pitch. Low frequency sounds like a low pitch.

Wavelength
The distance from one peak of a wave to the next peak. Related to frequency by the relationship: speed of sound = frequency x wavelength. Assuming speed of sound stays the same, then this shows that as the frequency goes up (high frequency) the wavelength gets smaller and vice versa.

Harmonics
In a tube or fixed length of a string, there is more than one standing wave pattern that can be achieved. If the most simple (or fundamental) frequency is 10Hz then standing waves can also be formed at multiples of this number (i.e. 20Hz, 30 Hz etc). Each of these successive resonances is called a harmonic (1st harmonic, 2nd harmonic etc). Sounds from musical instruments are a mixture of each of these harmonics mixed together to give the instrument a unique sound quality, or “timbre”.

Medium
What the sound is travelling through. Sound generally travels more efficiently through solids and liquids than through gases

For more information about MRI scans go to:
http://www.netdoctor.co.uk/health_advice/examinations/mriscan.htm

For more information on resonance and swings
www.hk-phy.org/articles/swing/swing_e.html

For the video footage of the Tacoma Bridge collapse
www.camguys.com/bridgeclpse.html

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Notes

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