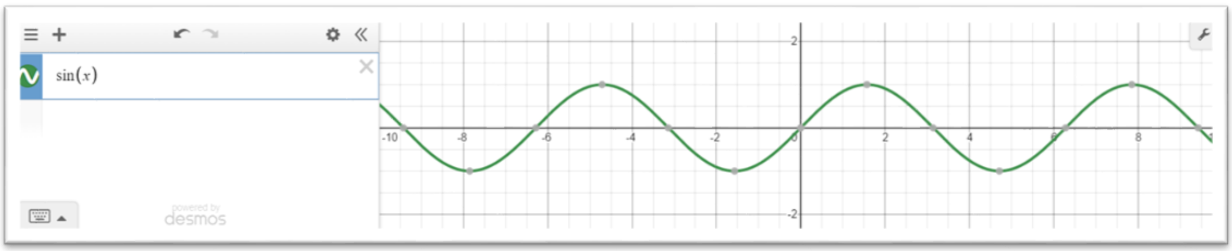
Sound Waves Lab – Sines and Cosines in Action

Introduction

Trigonometry is – in part – a study of sinusoids. A sinusoid is a function that has the form of a sine wave. You can see a sine wave plotted here:



We see a value x as input to a sine function. As x increases in value from negative to zero to positive, the value of sin(x) goes up and down and up and down bounded between 1 and -1.

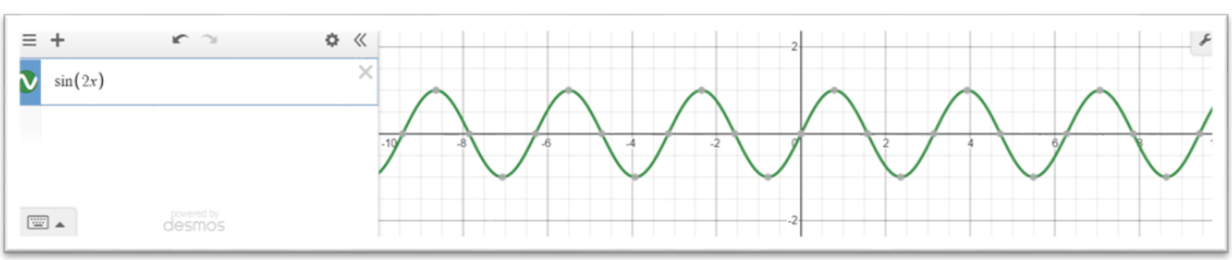
This can be considered a *mapping* from x to the output by the function sin(x). You can see that when x is equal to π, the sine function is back to 0. …and when x is equal to 2π, the sine function is back to zero again. This continues forever. This is very important.

Task 1: Plot sin(x) in desmos to see sin(x) for yourself.

You should see the plot above. Now, let's make some changes!

Ask yourself… what would the sine function do if x changed at a faster rate? What if x got to π and 2π and 3π twice as fast? Shouldn't sin(x) vary between -1 and 1 faster, as well? Let's see.

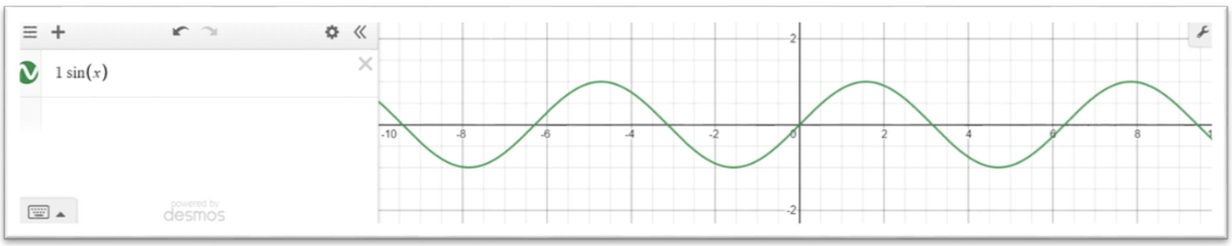
Task 2: Plot sin(2x) in desmos.



It's true! If x increases in value twice as fast, sin(x) varies between -1 and 1 twice as fast, as well! We call the rate at which the sinusoidal function changes the frequency.

The speed at which x changes is not the only thing that we can change. We can also change the range over which the sinusoidal function changes. Our current sinusoid is changing over a range of -1 to 1. From this, we say that our sinusoid has an amplitude of 1.

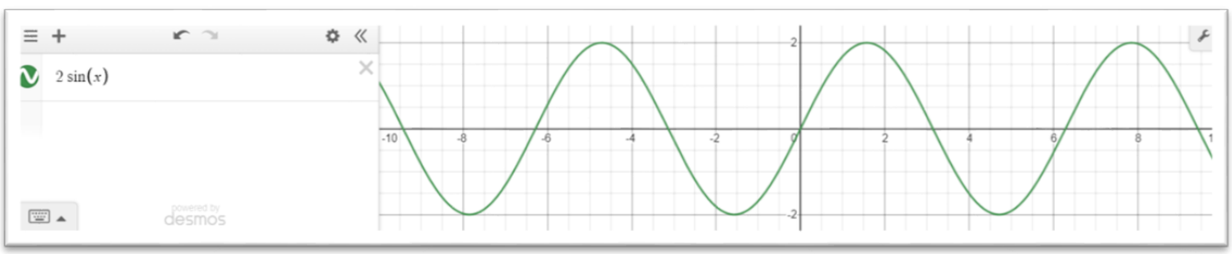
We didn't see it in our sinusoidal equation, but it is there. You can see it here:



Look at the equation to the left. Now you can see clearly that our sine wave has an amplitude of one. Let's change the amplitude.

Task 3: Plot 2 sin(x) in desmos.

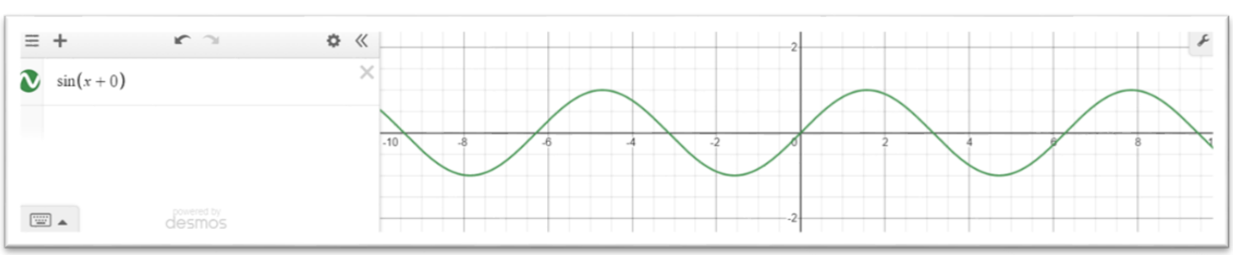
You should see this:



We have just doubled the range over which the sinusoidal output spans with an amplitude of 2.

The last characteristic that we will consider for a sinusoid is phase. Phase can be considered to be the starting point of our sinusoidal function. It gets added to x before the sine calculation.

The sinusoid with which we have been experimenting has had a phase of 0. Just like the amplitude characteristic, it was not explicitly included. We can include it here, though:

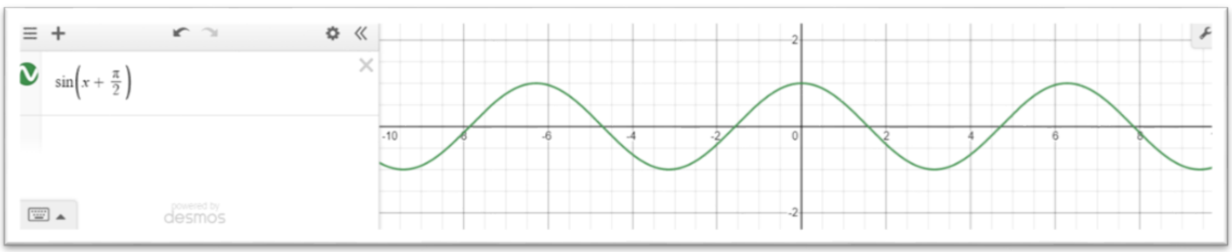


We see our exact original sinusoid because adding 0 to x before calculating the sine function doesn't change sin(x). …but what if we added a non-zero value?

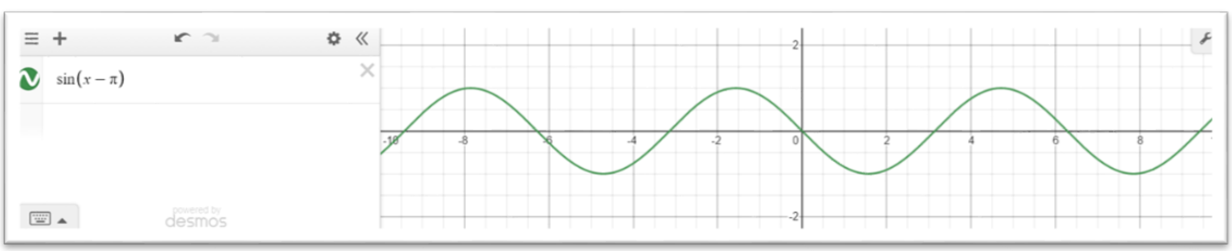
Before we change the phase, take another look at theplot of sin(x+0). We can see that sin(x)=1 at π/2. sin(x)=0 at π. sin(x)=-1 at 3π/2. What if we added π/2 to x? Wouldn't that shift the sine curve?

Task 4: Plot sin(x+π/2) in desmos.

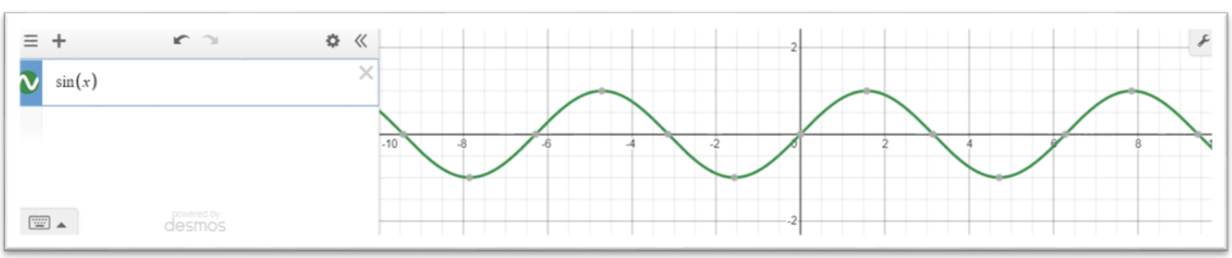
Mission accomplished! We have shifted the sin(x) curve ahead by π/2! This is – in fact – a cosine function now. Freaky!



We can shift back, too. Let's shift the sine curve back by π.



Look closely compared to what we started with:



The original sine function started at 0 at x=0 but was rising to 1. The function is still starting at 0 at x=0 but is falling to -1. We can also see from this that sin(x+π/2) = - sin(x).

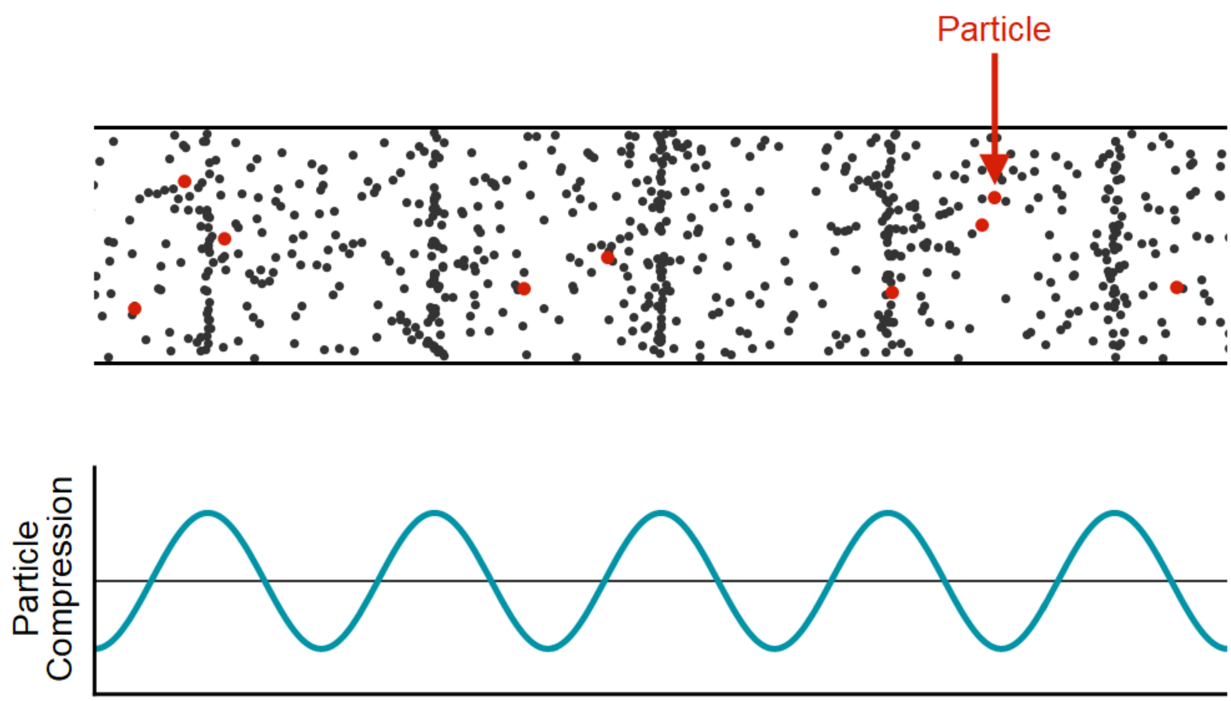
So, now we can change the frequency, amplitude, and phase of a sinusoid. But, why do we care? We care because sinusoids are used to model the world around us!

Sinusoids and Sound

Have you ever wondered what is sound? Sound is pressure variations that are detected by our ears. Much of it is sinusoidal. Yes, sinusoidal! A moving speaker is shown here. You can see that the speaker is pushing on air molecules in a sinusoidal fashion.

If you increase the frequency of a sound, it gets higher in pitch. That is the speaker moving in and out at a faster rate. If you increase the amplitude of a sound, it gets louder. That is the speaker moving in and out farther. You can even change the phase of a sound. We will look at all of this.

What do these sinusoidal pressure variations look like? Here is an excellent depiction of the sound of single frequency tone such as a whistle or long beep:



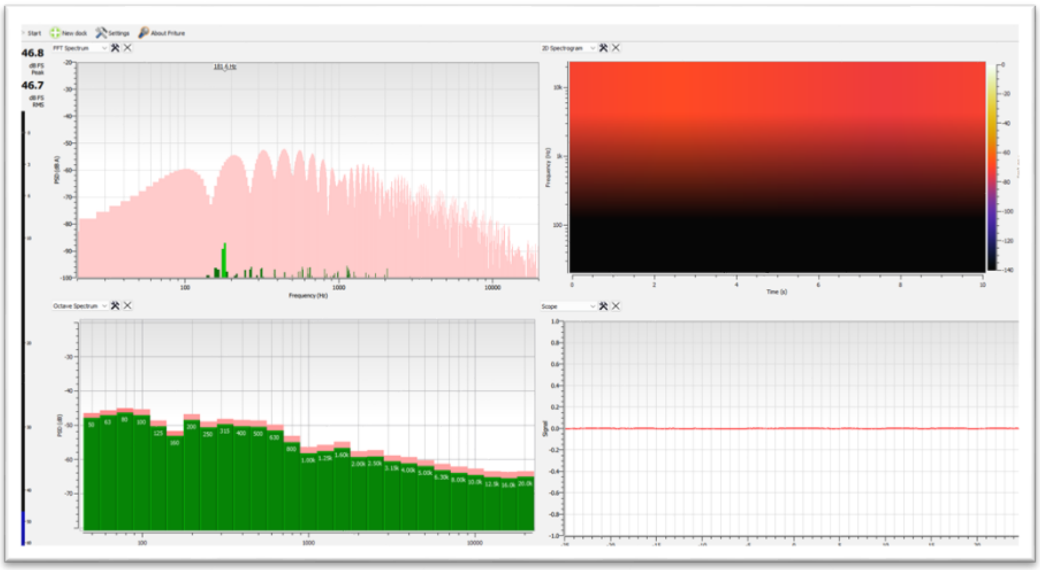
It might surprise you to know that the air particles that transfer sound don't move that much. If I am talking with you, the particles near my mouth stay very near my mouth. The particles that are near your ear stay there, as well. …but, the way in which they push against each other conveys sound.

The amount of particle compression is shown at the bottom of the figure. That is the sound pressure. For a tone, it is a sinusoid! More complicated sounds such as speech or music are just combinations of simple sounds.

<u>More Complicated Sounds</u>

Your voice is one of the best examples of a complicated sound. Interestingly, you can use it to make the simple sounds at which we have been looking. Let's try.

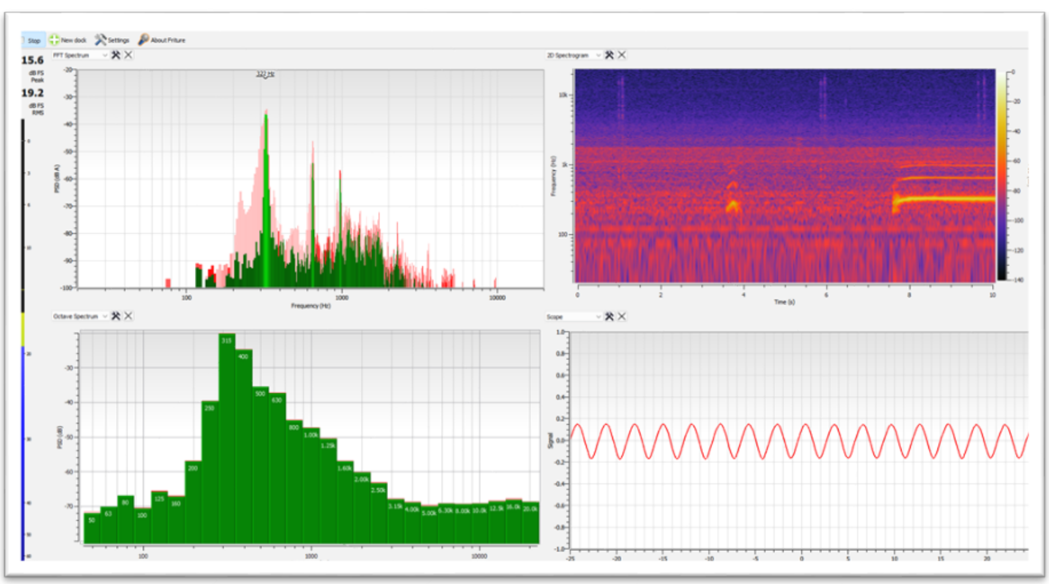
Open the program *friture*. Friture analyzes the sounds measured by a computer microphone. We can use it to analyze the sounds of your voice. When you open friture, it should look something like this:



For now, we will only concern ourselves with the lower right window. This is a time window very much like what we were using in desmos.

Task 5: Make a "whooooooo" sound.

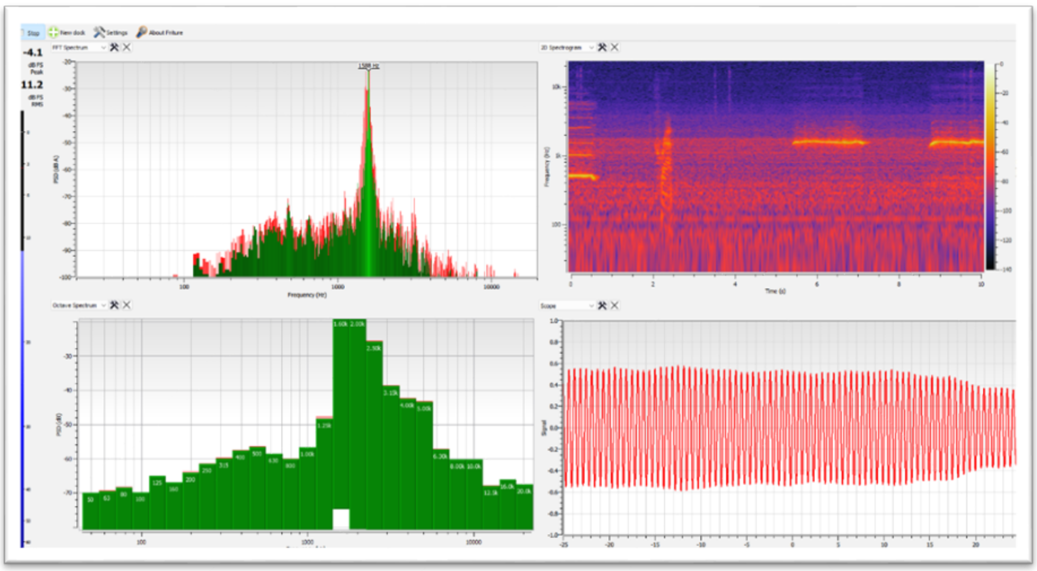
You should see something like this:



Do you notice how the “whoooooo” sound in the lower right window resembles a sinusoid from desmos? That is the sinusoidal air pressure variations coming from your mouth being measured by the microphone. …and just like in desmos, we can change the frequency and amplitude! [We can change phase, too, but that comes later.]

Task 6: Make a “whoooooo” sound at a higher loudness and pitch.

It is not as easy as it might seem. You should see something like this:



Wow! We changed both the frequency and amplitude!