# How loud is a string?

## Introduction

I enjoy playing songs on piano. However, I have noticed that while it is easy to play louder sound, playing quietly have always been a challenge. This turned me curious of the relationship between the loudness of the sound and the amount of force that I apply to it.

## Experimental variables

The loudness of a sound is determined by the intensity of the sound wave and the energy which it contains..

## The Experiment

## Predicting the relationship

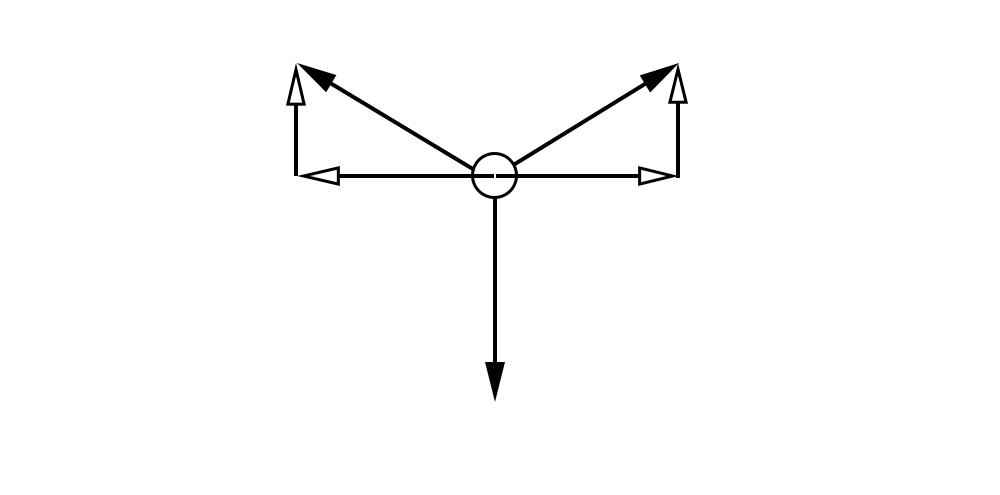
### Variables

|  |  |  |
| --- | --- | --- |
| Variable | Meaning | Unit |
|  | Intensity |  |
|  | Sound pressure |  |
|  | Particle velocity |  |
|  | Angular frequency |  |
|  | Amplitude (particle displacement) |  |
|  | Density of medium in which sound is traveling |  |
|  | Speed of wave (sound) |  |
|  | frequency |  |
|  | Ratio of circumference to diameter of a circle |  |
|  | Original tension of the string |  |
|  | Tension of the string at equilibrium |  |
|  | Force of the striking object |  |
|  | Vertical component of the tension of the string |  |
|  | Change in length of the string after tension is applied |  |
|  | Spring constant of the string |  |
|  | Original length of the string |  |
|  | Current length of the string |  |
|  | Power output of the microphone without gain |  |
|  | sensitivity |  |
|  | Actual output voltage of the microphone |  |
|  | Gain of the microphone |  |
|  | Measured output of microphone |  |

### Deriving the formula

The loudness of sound is dependent on its intensity, which can be expressed as:

Since angular frequency is just change in angle per second: ,

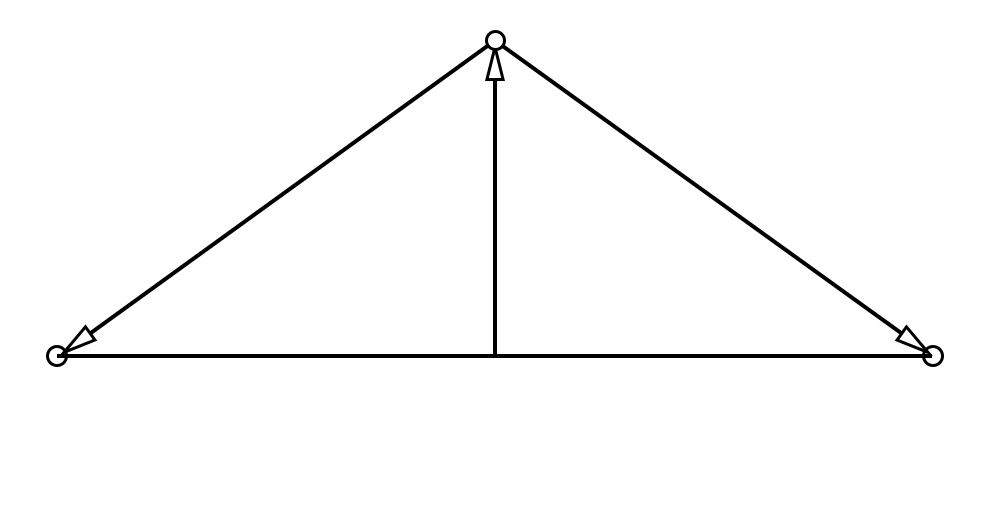


The amplitude is related to the tension force and the force pushing the string

Since at the maximum displacement, the system would be in equilibrium,

, which means that

Since will be the final force on the string, the string will extend m



=>

Therefore

The sound pressure level can be determined by the power that the microphone produced divided by the sensitivity

Also, as the measured power is in decibel =>

As , therefore:

Now, equal the two equations for intensity:

Canceling some terms: