Measuring Pin Drop Silence

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Introduction / Statement of the Problem / Purpose

Parents, teachers, even authors have used the statement “pin drop silence,” to create an environment in which you could supposedly hear a pin drop. After repeatedly hearing the statement one would start to wonder, is there a degree of silence so quiet in which you could hear a pin drop? That is what this experiment will find out. There is a current lack of any scientific measurements of “Pin Drop Silence.” This project will be measuring the sound produced by dropping several pins of varied materials from different heights onto the surface of varied materials. The project will then develop a direct association between each combination (Material of pin, material of surfaces, and height) of variables and the sound produced by a pin dropped.

There is no established equation or correlation of variables involved in dropping an object to the sound it produces. This project will measure the sound produced by a pin when dropped from some variable heights. This action, while it sounds trivial, incorporates multiple laws and principles of physics such as, the Law of Conservation of Energy, Law of Momentum Conservation, and the principles of both potential and kinetic energy. The importance of not only the material of the pin being dropped, but also the material of the surface the pin is being dropped onto, are shown in this series of tests.

This experiment was designed to measure and develop a direct association between each combination (Material of pin, material of surfaces, and height) of variables and the sound produced by pin dropped.

Previous Experiments

In an amazing experiment conducted by Massimo Grassi, at the University of Padua, Italy, titled “Do we hear size or sound? Balls dropped on plates”, examined whether it is possible to correlate directly the size of an object from the sound of an impact. Specifically, the study was designed to investigate whether listeners can tell the size of a ball from the sound when it is dropped on plates of different diameters (on one, two, or three plates in three Experiments). In this paradigm, most of the sound produced is from the plate rather than the ball. Listeners were told neither how many different balls or plates were used nor the materials of the balls and plates. Although listeners provided reasonable ball size estimates, their judgments were influenced by the size of the plate: Balls were judged to be larger when dropped on larger plates. Moreover, listeners were generally unable to recognize either ball and plate materials or the number of plates used in Experiments. Finally, various acoustic properties of the sounds are shown to be correlated with listeners’ judgments.

In another experiment by Roberta L. Klatzky, Dinesh K. Pai and Eric P. Krotkov, titled “Perception of Material from Contact Sounds”, they investigated the relation between material perception and variables that govern the synthesis of contact sounds. Subjects judged the similarity of synthesized sounds with respect to material (Experiment 1 and 2) or length (Experiment 3). The sounds corresponded to modal frequencies of clamped bars struck at an intermediate point, and they varied in fundamental frequency and frequency-dependent rate of decay. The latter parameter has been proposed as reflecting a shape-invariant material property: damping. Differences between sounds in both decay and frequency affected similarity judgments (magnitude of similarity and judgment duration), with decay playing a substantially larger role. Experiment 2, which varied the initial sound amplitude, showed that decay rate---rather than total energy or sound duration---was the critical factor in determining similarity. Experiment 3 demonstrated that similarity judgments in the first two studies were specific to instructions to judge material. Experiment 4, in which subjects assigned the sounds to one of four material categories, showed an influence of frequency and decay, but confirmed the greater importance of decay. Decay parameters associated with each category were estimated and found to correlate with physical measures of damping. The results support the use of a simplified model of material in virtual auditory environments.

Core Science

Sound is a vibration that propagates as a wave of pressure and displacement. The sound source creates vibrations in the surrounding medium, usually air particles. The vibrations propagate away from the source at the speed of sound, creating a sound wave. Even though the vibrations propagate in the air, the air particles do not travel with the sound wave. The dropping of a pin incorporates multiple laws and principles of physics such as, the Law of Conservation of Energy, Law of Momentum Conservation, and the principles of both potential and kinetic energy. The Core Science of these principles is described below.

When the pin is dropped from a height it has potential energy that is converted in to kinetic energy. An object can store energy as the result of its height above the zero height position. Kinetic energy is energy possessed by an object due to its movement. Any object that is moving has momentum. The law of Conservation of Momentum states that the momentum/energy of an object colliding with another object is the same before and after the collision hence, the momentum of the pin (when collided with the surface) is transferred to the surface. The new momentum in the surface causes the surface vibrate thus creating a sound.

The loudness we hear depends on the ratio of the area of our sound collector to the total area of the sphere surrounding the sound source. The intensity of a sound wave is the amount of power in the wave per unit area and has units of W/m2. Both sound pressure level and sound intensity level measure the same thing: the loudness of a sound that we hear. Here are a few equations to characterize the relationship:

sound intensity = sound power / (4 pi R squared)

sound pressure level = Lp = 20 log (p / p0) = 10 log (p2 / p02)

The law of conservation of energy says that the total energy of an object remains constant .As Albert Einstein said “Energy cannot be created or destroyed, it can only be changed from one form to another.” In the case of a pin dropping, kinetic energy can be changed into sound energy which is what we are measuring in this experiment.

Hypothesis and Materials

The sound produced by a pin drop is based off of multiple variables and has many possible results. Using multiple laws and principles of physics (the Law of Conservation of Energy, Law of Momentum Conservation, and the principles of both potential and kinetic energy), and the previous experiments of sound/sound waves, the hypothesis estimates below were created:

1. **The sound produced by a regular metal pin on a metal surface when dropped from a height of 25 inches will produce a sound of 98 dBSPL (15 dBFS).**

2. **It is also predicted that the sound produced by a regular metal pin on a metal surface will be the loudest.**

3. **All pins dropped from the height of 25 in. will be louder than any pin dropped from a lower height.**

1. Anechoic Chamber measuring at least 10ft. x 8ft.

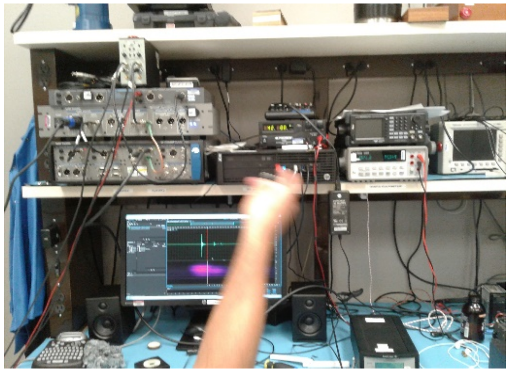
2. 4 pins consisting of at least 2 different Pin Materials (Plastic and Metal) and at least 2 assorted sizes (Small, Medium or Large).

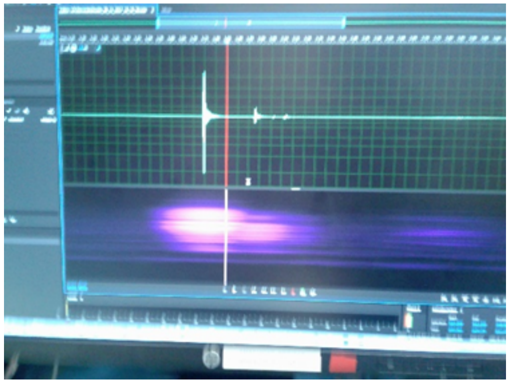
3. At least 3 different landing pad materials (rubber, plastic, and metal) on which the pin will land on.

4. Adjustable stand for pin dropping at a specified height.

5. Multiple microphones and other appropriate equipment to collect sound data.

6. Computer with compatible software for sound recording, observations and results





Procedure

Part I: Preparation for Testing

1. Set up Excel Document ready to convert dBfs (the units of sound the microphone uses) to dbSPL (the units of measurement that this experiment uses)

2. Identify an Anechoic Chamber that you can use for testing.

3. Get a sound expert, Ricardo Bernal, to help review the data analysis when testing is complete

Part II: During Testing

1. Select Pin (P) one

2. Select landing pad(LP) material one

3. Drop pin from heights 5-25 in with intervals of ten.

4. Measure Sound produced in dBfs using Microphones (See materials)

5. Repeat steps 3-4 with P1 LP2

6. Repeat steps 3-4 with P1 LP3

7. Repeat steps 3-4 with P2 LP1

8. Repeat steps 3-4 with P2 LP2

9. Repeat steps 3-4 with P2 LP3

10. Repeat steps 3-4 with P3 LP1

11. Repeat steps 3-4 with P3 LP2

12. Repeat steps 3-4 with P3 LP3

13. Repeat steps 3-4 with P4 LP1

14. Repeat steps 3-4 with P4 LP2

15. Repeat steps 3-4 with P4 LP3

Part III: After Testing

1. Analyze the data to find trends in the sound

2. Develop several different Excel graphs based on the data collected

3. Review data analysis and results with mentor

Observations and Results

Sound produced by a pin depends on several variables such as Material of pin, material of surface, and the height from which the pin is dropped. After multiple sets of experiments using a combination of variables, the following observations were made:

- The sound produced by a wood surface is always louder than sounds produced by a metal or rubber surface.
- On a wooden surface, the height of the pin drop does not impact the sound.
- The sound produced by a large metal pin when dropped on a wood landing pad produces the largest sound irrespective of the height of the pin. However, the sound produced follows a similar pattern of being the quietist at 5 inches, the loudest at 15 inches and in-between at 25 inches.
- There is an impact of height on the sound produced when using a rubber landing pad. A plastic pin when dropped on a rubber pad creates an outlier effect with the sound produce increasing at a height of 25 inches. (note: this last observation was checked multiple times to ensure that it was not a flaw)
- The sound produced from a height of 5 inches has a uniform decrease of sound as the size of the pin (weight) decreases. The largest sound is still produced by the metal on wood combination.

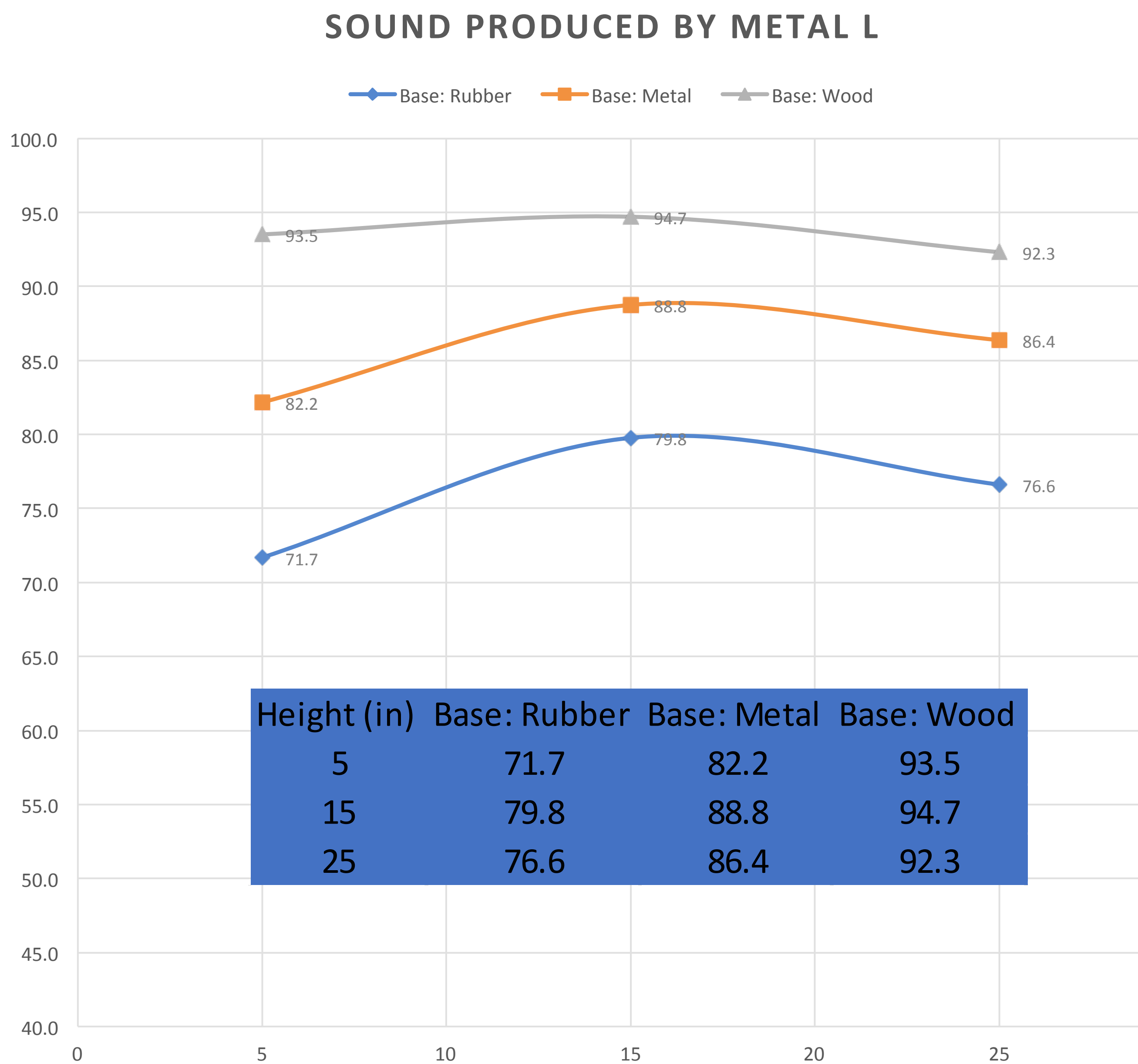
The following results were computed in consideration of the hypothesis:

- **All metal pins were louder than the plastic pin at most heights**
- **The wooden surface created the loudest sound when a metal pin was dropped on it**
- **In most cases Plastic created the smallest sound except on the rubber surface**
- **The range of the data was from 47.85 – 98.53 resulting in an average of 73.2 dBSPL**
- **82.98 dBSPL was the measurement of a metal pin falling on a metal surface from a height of 25 in.**

Graph and Data Table I- Pin Material: Metal Large

This set of data shows that:

- The sound produced by a large metal pin when dropped on a wood landing pad produces the largest sound irrespective of the height of the pin.
- The different arcs of this graph are follow a similar pattern of being the quietist at 5 inches, the loudest at 15 inches and in-between at 25 inches.

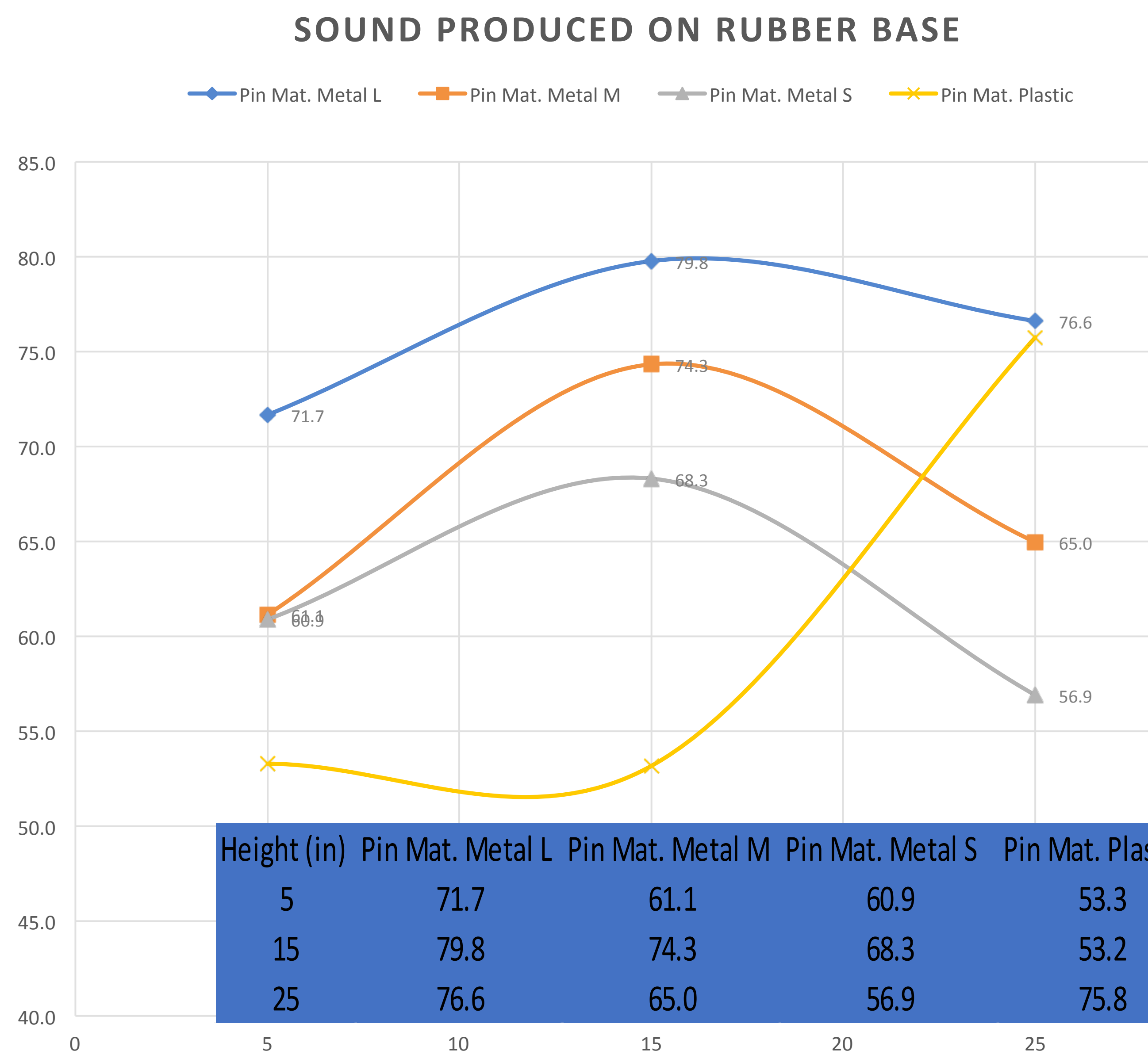


Height (in)	Base: Rubber	Base: Metal	Base: Wood
5	71.7	82.2	93.5
15	79.8	88.8	94.7
25	76.6	86.4	92.3

Graph and Data Table II-Landing Surface Material: Rubber

This set of data shows:

- That there is an impact of height on the sound produced when using a rubber landing pad.
- A plastic pin when dropped on a rubber pad creates an outlier effect with the sound produce increasing at a height of 25 inches. (note: this last observation was checked multiple times to ensure that it was not a flaw)

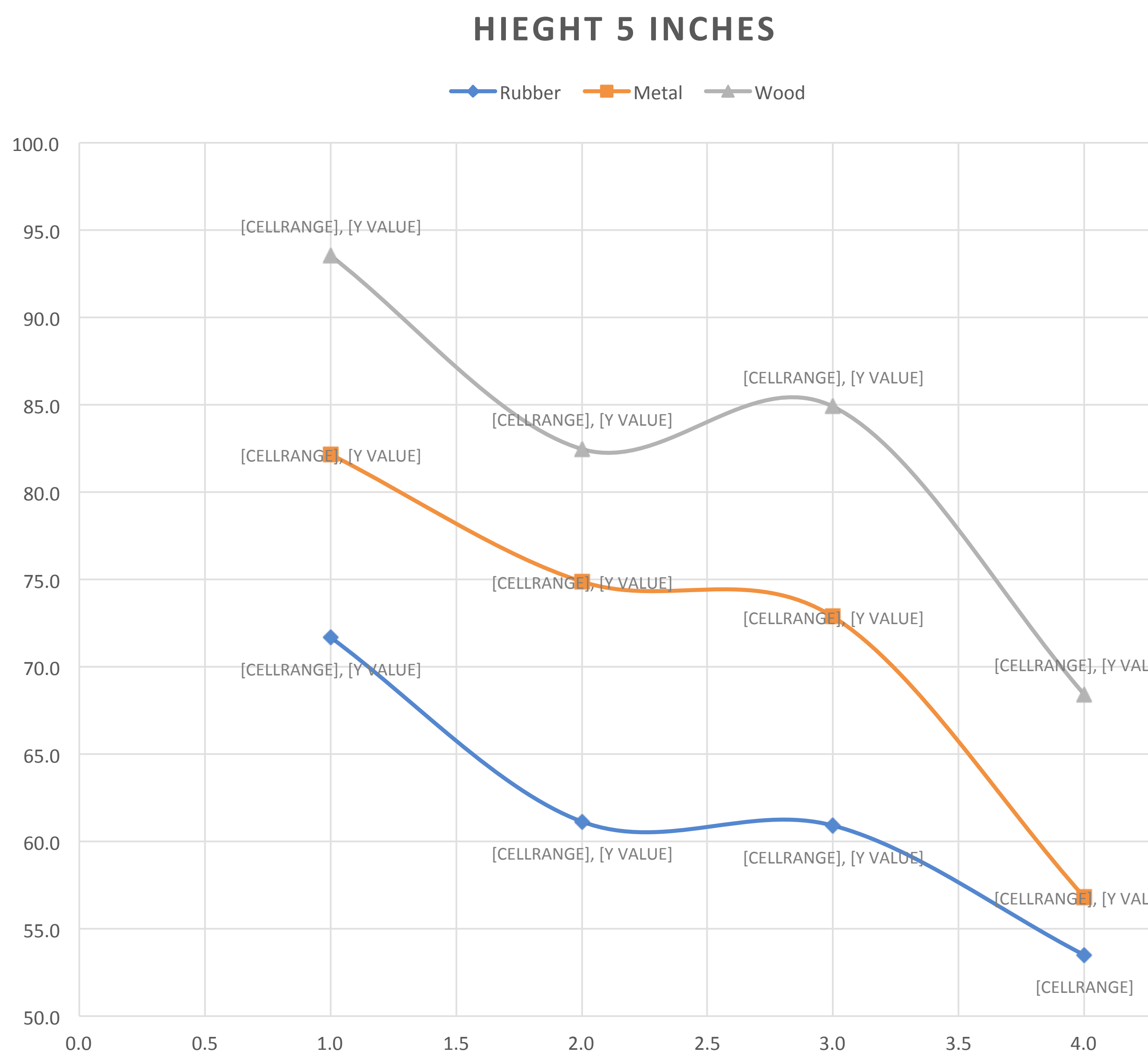


Height (in)	Pin Mat. Metal L	Pin Mat. Metal M	Pin Mat. Metal S	Pin Mat. Plas
5	71.7	61.1	60.9	53.3
15	79.8	74.3	68.3	53.2
25	76.6	65.0	56.9	75.8

Graph and Data Table III-Drop Height: 5 Inches

This set of data shows:

- That the sound produced from a height of 5 inches there is a uniform decrease of sound as the size of the pin (weight) decreases. The largest sound is still produced by the metal on wood combination.



Height (in)	Base: Rubber	Base: Metal	Base: Wood
5	71.7	82.2	93.5
15	79.8	88.8	94.7
25	76.6	86.4	92.3

Conclusions and Recommendations

Sound produced by a pin depends on several variables such as Material of pin, material of surface, and the height from which the pin is dropped. While there is no direct correlation between the sound produced and these variables universally, each combination (Material of pin, material of surfaces, and height) of variables can be directly associated. For example, the sound produced by a wood surface is always louder than sounds produced by a metal or rubber surface. On a wooden surface, the height of the pin drop does not impact the sound

This project measures the sound produced in dBSPL by pins of varied materials at 3 different heights. Previous experiments and key laws of physics were incorporated to serve as a reference or baseline for this experiment. Despite all the pins being relatively the same length, the sound produced varies largely from pin-pin.

In the experiments conducted, the measured sound produced by a pin (in the anechoic chamber) ranges between 47.85 dBSPL (Similar sound level to quiet conversation) to 98.53 dbSPL (Similar sound level to a diesel truck from 10 meters away) from over 15 different combinations between the variables of height, material of pin, and material of landing pad. This sound intensity is not what we hear when the same pin is dropped outside the anechoic chamber implying that a large amount of the sound energy is dissipated in the environment before it reaches the human ear. Hence the association of a pin drop and silence.

In order to improve the project, there are several recommendations:

- The use a human ear microphone to record the sound a human would hear and then compare that data to the existing graphs.
- Use smaller height increments. This would allow for deeper analysis of how height affects sound.
- Adding more materials such as a wood pin, or different types of metals. This would again allow for a deeper analysis of how material effects sound.
- Measuring the sound produced at the human ear, outside of an anechoic chamber
- Measure the energy lost due to the environment

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