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Sound Intensity of a Drum

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Abstract

A small steel ball was dropped onto the center of a bongo drum. The relationship between impact energy and the maximum amplitude of the sound produced upon impact was determined using release heights ranging from 5 to 70 cm. It was found that there was a power relation between the impact energy and the maximum amplitude of the sound, indicating that the partitioning of energy in the system is dependent on impact energy.

Introduction

When an object strikes a drum, the energy of the object is transferred into stretching the circular membrane of the drum. This sets up an oscillation of some amplitude. Striking the drum with an object of greater energy will transfer more energy into the oscillation of the drumhead, increasing the energy of the oscillation of the membrane, leading to an increase in the intensity of the sound produced.

The amplitude of the air oscillation is expected to be directly related to the amplitude of the drumhead oscillation. For small oscillations, the energy of the oscillating drumhead is proportional to its amplitude squared[1]. In the case of this investigation, when a falling ball impacts a drum, the energy of the object is transferred into the energy required to oscillate the drumhead. For relatively small oscillations of the drumhead, the energy of the oscillating circular membrane can expressed as

$$U = \frac{1}{2}kx^2 \qquad \text{(Equation 1)}$$

where U is the elastic potential energy stored in the drum oscillation, k is the effective spring constant of the drumhead (for small amplitudes) and x is the maximum displacement of the center of the drumhead from its equilibrium position[1].

A portion of the drumhead energy is converted into sound energy, while another portion of the energy is dissipated as heat. If the proportion of the partitioning of the sound and heat energy is constant, the relationship between the energy of impact, the energy of the oscillating drumhead, and the maximum sound amplitude squared (proportional to maximum sound intensity) can be expressed as

$$\frac{1}{2}mv^2 \propto \frac{1}{2}kx^2 \propto A_{max}^2 \, . \qquad \text{(Equation 2)}$$

This also assumes that the partitioning of the impact energy onto the drumhead energy and the rebound kinetic energy of the ball is constant.

If these assumptions are correct, the energy upon impact is predicted to be directly proportional to the maximum sound amplitude squared. However, the partitioning of the sound and heat energy may not be constant, and may depend on the energy of the oscillating drumhead. Additionally, the partitioning of the kinetic energy of impact into the elastic potential energy of the drumhead and kinetic rebound energy may also be dependent on impact energy. It cannot be assumed that there would be a proportional relationship between amplitude squared and the energy upon impact of the drum, as the partitioning of sound energy and heat energy is uncertain. Due to the complex nature of the energy conversions it is necessary for the actual relationship between the kinetic energy of the ball on impact and the maximum amplitude of sound to be determined experimentally.

Methods

A bongo drum and a metal ball of mass 11.96 ± 0.01 g were used in this experiment. An apparatus for releasing the ball was constructed from an electromagnet. The microphone was situated 70.0 ± 0.1 cm away from the point of impact. The drum was placed below the electromagnet. A plumb bob was used to ensure that the ball was released directly above the center of the drum. The microphone was set to collect data at 15,000 samples/second. The ball was held in place by the electromagnet. After ensuring that the room was generally free of background noise, the data collection was started and the ball was released from its position by disconnecting the electromagnetic circuit.

Release heights ranging from 5.0 to 70.0 ± 0.1 cm between the surface of the drum and the base of the electromagnet were tested, with three trials for each height.

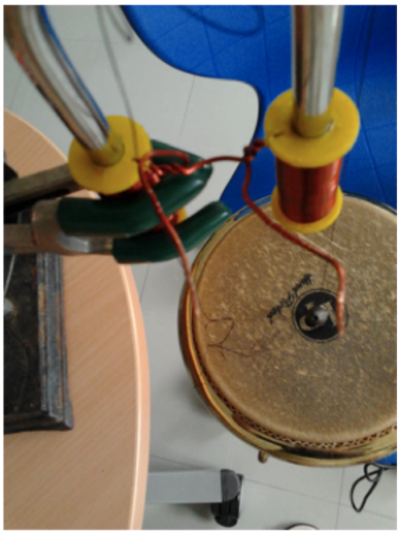

Figure 1 Experimental setup

Results and Discussion

It can be seen that the first few data points suggest that for small impact energies, the sound amplitude squared, or sound intensity, is proportional to the impact energy,

$$A^2 = 10x \qquad \text{(Equation 3)}$$

where x is impact energy. This indicates that the partitioning of the energy remains constant for low energies. It is apparent from figure 2 that this relationship no longer holds at greater impact energies. The proportional relationship between maximum sound amplitude squared and the impact energy appears to be applicable only for small impact energies.

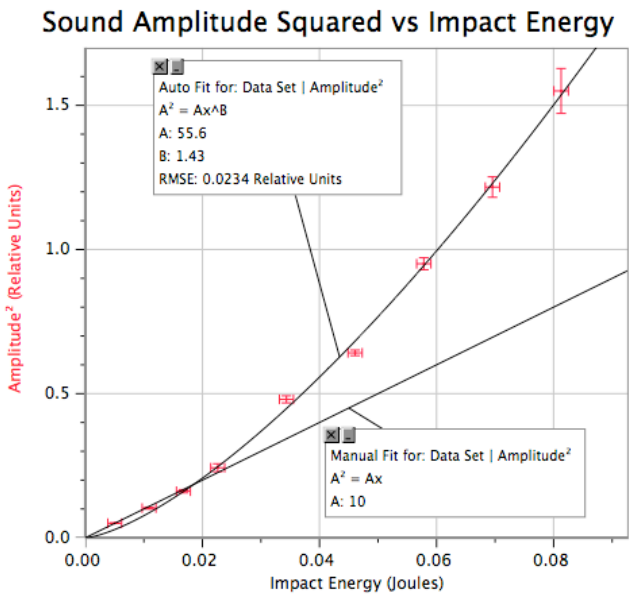

Figure 2 The sound intensity is proportional to impact energy for small impact energies, but for larger energies, a power function better describes the relationship.

For the range of impact energies tested, the relationship between sound intensity and impact energy is more accurately modeled as

$$A^2 = 56x^{1.4} \quad \text{(Equation 4)}$$

This shows that the relationship between the amplitude squared and the kinetic energy upon impact is a power relationship. Since sound intensity is proportional to maximum sound amplitude squared, the partitioning of the impact energy into drumhead energy, rebound energy, thermal energy, and sound energy is not constant. As impact energy increases, a greater proportion of the energy is converted into sound energy. The range over which this relationship applies is uncertain. It is expected that there will be an impact energy limit above which this relationship no longer applies, given that the drumhead approaches a limit to how much sound it can produce. Further measurements need to be done to determine the relationship at high impact energies. Further research is also suggested using balls of different mass, and with different types of drums.

Conclusion

Within the range of impact energies tested, an increase in the impact energy of the metal ball will increase the maximum intensity of the sound produced by the drum upon impact with a power relationship. These results may not be applicable to all types of drums and a greater range of impact energies, as the production of sound produced by each drum approaches a limit as impact energy increases.

References

[1] Raichel, D. R. (2006). *The Science and Application of Acoustics*. (2 ed.). Springer Science Business Media. Retrieved from http://maji.utsi.edu/courses/08_aeroacoustics/ref_ac2_Science_and_Applications_of_Acoustics_2e_Raichel.pdf