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From the Research Laboratories

ON THE SOUND, PRODUCED BY A COIN, ROLLING IN A BALLOON

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Abstract. Balloons may be a thing children love playing with, but they also have different interesting physical properties such as the sound that is produced when something is put inside a balloon. The phenomenon of interest of this article is the one of gently rolling a coin in a balloon and exploration of the sound produced by this movement. It turns out that when a coin with edges is put in a balloon and is being rolled a buzzing sound is produced which varies in frequencies depending on the count of edges of the coin. This can be observed in non-laboratory conditions. Not many experiments have been conducted to explore this phenomenon.

Keywords: IYNT; buzzing sound; coin; balloon; frequency; velocity

1. Introduction

In this study, we will investigate the behavior of the sound of a coin rolling in a balloon. It has been observed that when a coin rolls in a balloon a specific buzzing sound is produced. The aim of this investigation, inspired by Problem 1 of the International Young Naturalists Tournament 2021, is to theoretically explain the phenomenon trough the frequency of the produced sound and the speed of the coin, as well as to check our understanding of the problem and explore different parameters experimentally, using high-speed camera, directional microphone and sound analyzing program.

2. Experimental method

2.1. Experimental setup for sound capture and analysis

In this study, we will consider two different methods of finding the origin of the produced sound – trough sound analysis and using a high-speed camera. As known in physics, sound is a vibration in the form of a wave which we will analyze using the program Audacity (figure 4).

In our experiments, we used coins with different number of edges (figure 3) and transparent balloons (figure 1) so that the phenomena could be visible and we could be able to photograph it with a high-speed 1000fps camera (figure 2). For conducting our experiment, we put the balloon over a directional microphone (figure 1) and gently moved it as the coin started rolling on its edges.

We record the sound right under the balloon to omit the influence of the Doppler Effect[1] which may affect the results of our experiment even though the relative frequency shift induced by it is $\Delta f/f = v/c$ where v is the speed of the rolling coin and c is the speed of sound in air. We consider it negligible for $\Delta f/f < 0.01$ gives us $v < 3ms^{-1}$ Typical speed ranges in our experiments are $2 - 3ms^{-1}$.

As we gently move the balloon[2], we take a video of it with the high-speed camera and later analyze the coin's movements frame-by-frame so we can take direct velocity measurements.

While taking measurements we vary the balloon's circumference and the coin's radius and number of edges while changing one variable at a time. For our results, we decided to use a 50 pence coin and a 20 pence coin as the have the same number of edges but different radiuses and we compare their results when balloons have the same circumference.

Figure 1. Balloon and directional microphone

Figure 2. High-speed camera

Figure 3. Coin with a continuous edge; 50 and 20 pence coins with seven edges

Figure 4. Audacity

2.2. Velocity Derivation from Measured Audio Frequency

After taking the measurements of our experiment we analyze the recorded sound and determine its' fundamental frequency. We believe that the sound is produced by each hit of a coin's edge with the surface of the balloon and that gives us the opportunity to calculate the speed of the coin's movements using the formula:

$$coin\ velocity = \frac{fundamental\ frequency}{number\ of\ coin\ edges} * coin\ circumference$$

Trough it we obtain the results of the speed for our 20 pence and 50 pence coins (figure 6).

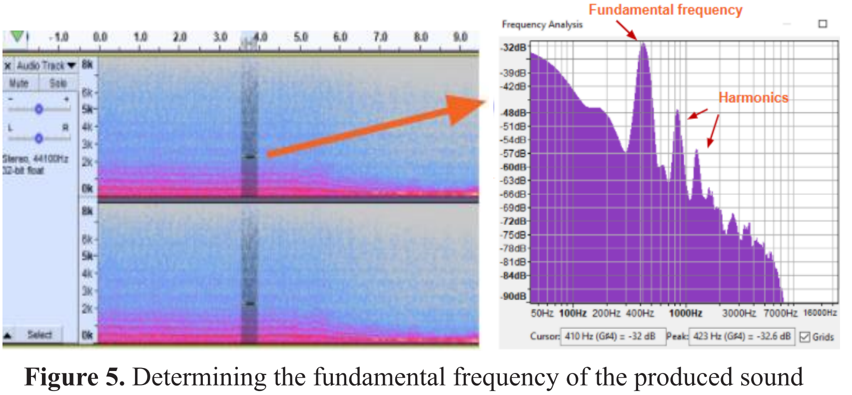


Figure 5. Determining the fundamental frequency of the produced sound

Table 1. Results for the 20 pence and 50 pence coins

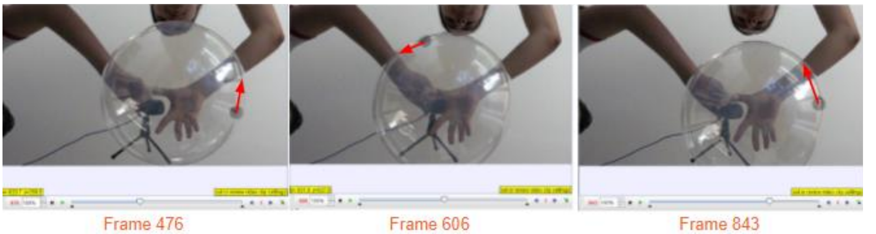
Coin	Coin Circumference [m]	Balloon Circumference [m]	Frequency [Hz]	Calculated Velocity [m/s]
50 pence	0.084	0.71	278	3.336
50 pence	0.084	0.7	320	3.84
50 pence	0.084	0.68	292	3.504
50 pence	0.084	0.68	302	3.624
20 pence	0.065	0.73	370	3.436
20 pence	0.065	0.72	454	4.216
20 pence	0.065	0.71	276	2.563
20 pence	0.065	0.69	332	3.083

2.3. Direct Velocity Measurement

For confirming our source of sound, we use another method of calculating the speed of the coin. We record a video with the high-speed camera and then analyze frame-by-frame the time it takes for the coin to make one whole circle in the balloon (figure 7). Then we calculate the speed of the coin using the formula:

$$Coin\,Velocity = \frac{Balloon\,Circumference}{Time\ for\ a\ Full\ Rotation\ Around\ the\ Balloon}$$

Trough it we obtain the results of the speed for our 20 pence and 50 pence coins (figure 8).



Frame 476 Frame 606 Frame 843

Figure 6. Frame-by-frame analysis

Table 2. Results for the 20 pence and 50 pence coins

Coin	Calculated Velocity from Direct Measurement [m/s]	Calculated Velocity from Frequency Derivation [m/s]	Difference [%]
50 pence	2.84	3.336	12.8
50 pence	3.5	3.84	9.7
50 pence	3.238	3.504	8.2
50 pence	3.469	3.624	4.5
20 pence	3.493	3.436	-1.6
20 pence	3.886	4.216	8.5
20 pence	2.136	2.563	20
20 pence	2.708	3.083	13.9
		Average Difference:	**9.48**

Results

3.1. Comparison between Velocities from Frequency Derivation and Direct Measurement

After putting our results in a table (Table 3) the difference between the calculated speed of the coin with both approaches is about 9.48% and the results form a trend line with $R^2 = 0.927 \approx 1$ (figure 8). That means both of our approaches produce comparable results, hence, the initial hypothesis has been confirmed by using two different coins and two different ways of calculating the coin velocity. The source of sound was thus successfully identified.

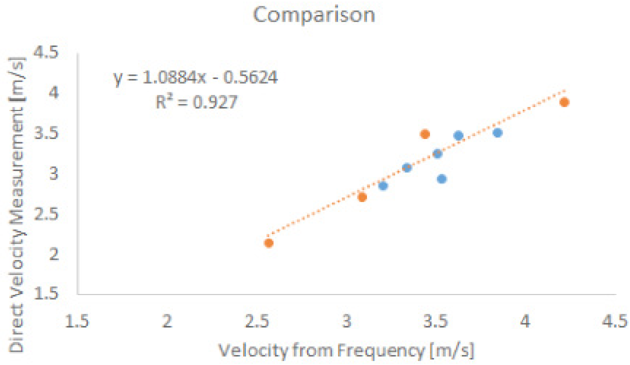


Figure 7. 20 pence coin in red and 50 pence coin in blue

3.2. Decelerating Motion of the Coin as It Slows Down

Now, after confirming the source of sound we can observe the decelerating motion of the coin by using the fundamental frequency of the sound alone in a colored non-transparent balloon. The decrease of the velocity follows a polynomial trend line (figure 9), which allows us to predict future results for different coins and circumferences of the balloon.

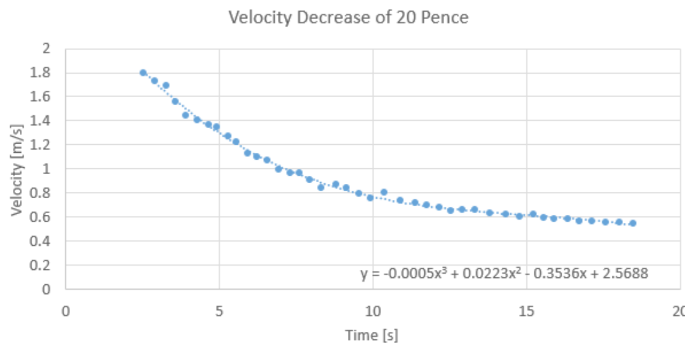


Figure 9. Velocity decrease analysis

3.3. No Buzzing Sound

While doing our experiments, we found a case when no buzzing sound is produced and that is linked to our hypothesis that the sound producing events are the hits of the coin's edges to the surface of the balloon. When using a coin with a continuous edge, there is no sound that differs from the background noise, and that confirms our hypothesis once again (figure 10). The number of edges is crucial for the results of our experiments as the higher it is, the more sound producing events happen for one whole circle of the coin around the balloon.

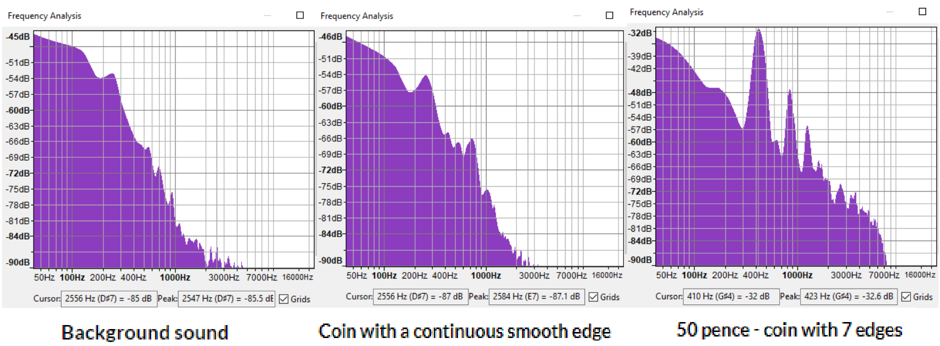


Figure 10. Comparison of sound spectrum

4. Conclusion

In this article, we discussed the vaguely explained phenomenon of the buzzing sound produced when a coin rolls inside a balloon. Two different methods were used for pointing out the sound producing events by calculating the velocity of the coin rolling inside the balloon and comparing the results. A set up for filming the coin's movements inside the transparent balloon and recording the sound was made and cleared of outside sources of error and multiple experiments were done. The frequency was linked to the number of edges and the radius of the coin and the circumference of the balloon. The decrease of velocity with time was discussed as well as the event when no sound is produced. The experiment lead to the conclusion that the fundamental frequency of the buzzing sound is generated by the vibrations of each side of the coin striking the sides of the balloon.

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NOTES

1. Sound of a nut rolling inside an elastic rubber balloon Amaury Barral, Quentin Louis, Clément Brochet1, Julie André, Anthony Guillen, Fang Goh, Angel Prieto and Thibault Guillet Sound of a nut rolling inside an elastic rubber balloon | Emergent Scientist (edp-open.org)

2. Science Experiment: Centripetal Force - Hex Nut Balloon Science Experiment: Centripetal Force –… | Indianapolis Public Library (indypl.org)

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