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Creating Waves by Clapping

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ABSTRACT:
Physics is everywhere in this world. To make Physics enjoyable, it is important to find some interesting examples of activities that everyone does in their daily life, precisely when you are happy or appreciate someone and cheer for them by clapping shows Physics.
Waves are one of the important concepts in Physics. A wave is a disturbance in the medium that is produced by a repeated back-and-forth motion and carries energy from one place to another. Waves are everywhere. In this paper, we are using clapping to perform some experiments to find out how waves can be created with it. To understand what Physics is behind clapping, it is important to know how waves are created by clapping. In this paper, it is shown how types of waves e.g. sine waves, and cosine waves can be created by clapping. How loudness and fast clapping can show properties of amplitude and frequency. How interference can be explained by clapping. These are fascinating ways to study the concept of waves by clapping.
KEYWORDS: *Physics, Waves, Experiments, Clapping, Data Analysis.*

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I. INTRODUCTION:

What is a wave? It is a question that always comes to my mind. I searched on the internet and found some answers. The answer to this question that I like most is "A wave is a disturbance that travels through a medium from one location to another location like a slinky wave as an example of a wave [1-2] or water waves or sound waves. In my opinion, any back-and-forth repeated motion can create a wave.

Based on concepts of Waves, waves are created by continuous or repeated motion. The concept of waves is taught in schools and colleges and can be seen on various websites and textbooks. [2-5] Waves can create sound too. Sound is a mechanical wave created in the medium by repeated motion. For example: singing, speaking, or clapping. [6]

The frequency and amplitude of the waves are an important part and can be controlled by their time and loudness. [7] How clapping can create waves that have higher or lower frequencies, how their frequencies can be related to their periods, or how the loudness of clapping can be related to their amplitudes can be seen in this project as described below. Interference of the waves is also an important phenomenon that is taught in schools. [8]

How interference phenomena can be studied and how sine and cosine waves are formed by clapping are also interesting tasks of this project work. Physics has been one of the interesting subjects since middle school. I have conducted several experiments in high school and published them in scientific journals so far. All these publications can be seen in the references. [9-15]

STATEMENT: Can you create waves by clapping?
HYPOTHESIS:

1. If you clap, then you create a wave.
2. If you clap fast, then you can create higher-frequency waves.
3. If your claps are louder, then you can create higher amplitude waves.
4. If two people clap at the same time with the same frequency, then interference in waves can be seen.

RESEARCH QUESTIONS:

1. Can you create waves by clapping?
2. How can you change the frequency of waves created by clapping?
3. How can you change the amplitude of waves created by clapping?
4. Can you create interference by clapping?

VARIABLES:
Independent: Time of clapping (t)
Dependent: Frequency (f), Angular Frequency (ω), Amplitude (A), and Speed of clapping (v)
Constant: Environment
Control: The shortest amplitude (A1)
Repetitions: Each experiment was repeated three times.

MATERIALS AND EQUIPMENT:
Two people, Clap your hands, stopwatch, ruler, notebook, pencil, computer, M.S. office, data analysis software, Logger Pro, calculator, Wi-Fi.

PROCEDURE:
Experimentation:
1. Get ready with a stopwatch, ruler, notebook, pencil, and clapping.
2. Pick a distance "d" for clapping on a ruler e.g. 5 cm.
3. Place one hand at zero cm and the other at 5 cm.
4. Then start the stopwatch, start clapping at normal speed for 10 times, and record the time for clapping. Let's call it "t". Now calculate its Period, T = t/10.
5. Then record the Amplitude of clapping as A = d/2.
6. Calculate angular frequency, w = 2pi/T. Calculate frequency, f = 1/T.
7. Now apply them in the equation of waves, Y = A Sin wt.
8. Use Logger Pro and plot this Wave.
9. Now repeat steps 2-10 for the same d for two more times to see if the results are the same as before. Take the average t and then calculate the final T for waves.
10. Now repeat steps 2-10 for four different d's as 10 cm, 15 cm, 20 cm, and 30 cm.
11. Repeat each experiment with different d's for two more times and find out the average t for each of them.
12. Now repeat steps from 2-10 with two people who clap together with the same frequency, and period but have two different amplitudes and d's as 5 cm and 3 cm. Then plot graphs show how constructive and destructive interference can take place.
13. Now repeat steps 2-10 with two people who clap together with the same ds but have two different frequencies, and d = 5 cm to see how these waves look different.
14. Plot two waves with two different frequencies and amplitudes and see how they look different.
15. Plot Sine and Cosine waves with the same frequencies and amplitudes to show how they are different.

THEORY:
In physics, mathematics, engineering, and related fields, a wave is a propagating dynamic disturbance (change from equilibrium) of one or more quantities. Periodic waves oscillate repeatedly about an equilibrium (resting) value at some frequency. When the entire waveform moves in one direction, it is said to be a traveling wave; by contrast, a pair of superimposed periodic waves traveling in opposite directions makes a standing wave. Some examples are waves in a rope, water waves, sound waves, guitar waves, and surface waves. [16]

Figure 1: Surface waves in water showing water ripples. [16]

Waves can move in the form of crests and troughs that look similar to up and down peaks if plotted on the X-Y plane as displacement and time functions.
A general equation of the wave can be given as:
$Y = A*\sin \omega t$ (1)
Where Y is displacement, A is amplitude, ω is angular frequency and t is the time of propagation of waves.

Waves can be a sine wave or cosine wave. If it is a cosine wave, then it can be written as:
$Y = A*\cos \omega t$ (2)
To create a sine or cosine wave, it is important to think of the origin where a wave starts. If a wave starts from a zero, then it is a Sine wave and if the wave starts from its highest/maximum displacement then it is a cosine wave.[17]

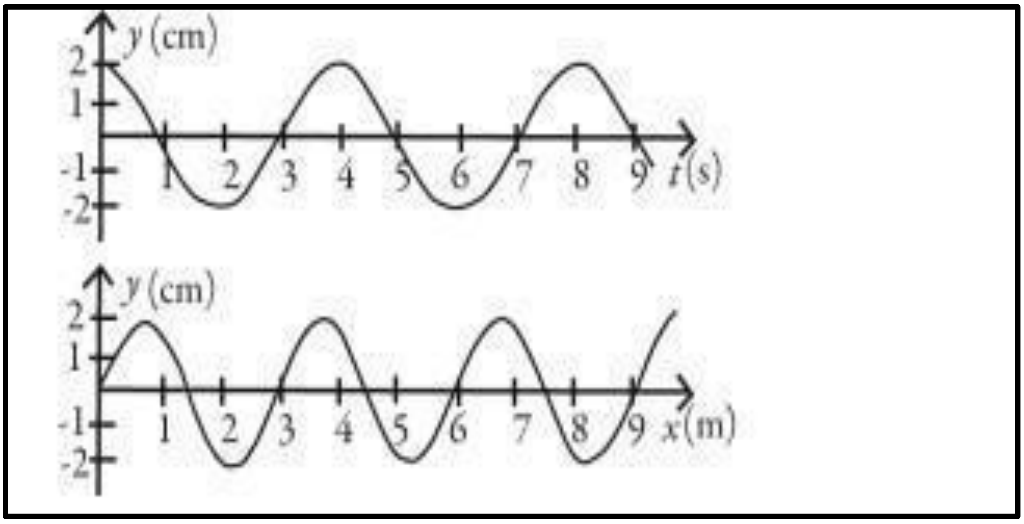

Figure 2: A sketch of waves that is plotted as a Sine wave (upper) and as a Cosine wave (lower).[17]

A wave can be plotted as a function of displacement and time or as a function of displacement and distance of the wave as it is moving forward from the place it begins.
The details of a wave can be seen below:[18]
Wavelength (**λ**) is the horizontal distance along a wave between similar particles of the wave.
Displacement (d) is the distance of a particle of the wave from its equilibrium position at any particular time.
Amplitude (**A**) is the maximum displacement of a particle of the wave from its equilibrium position.
Period (**T**) is the time for one complete oscillation of the wave.
Frequency (**f**) is the number of waves produced per second.
Velocity (**v**) is the velocity of a particle of a wave in the direction the wave is traveling.

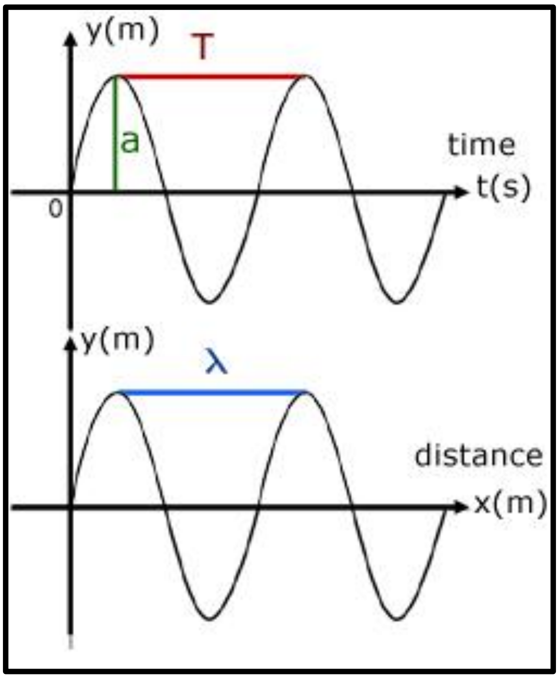

Figure 3: A sketch of waves that is plotted as Y vs t, (upper) and as Y vs d (lower).[18]

The time period (T), frequency (f), angular frequency (ω) of the wave can be given as:
T = t/n (3)
Where t is any time for n repeated motions.
f = 1/T (4)
ω = 2 pi/T (5)
The wave speed (v) can be given as:
V = λ/T (6)
The modified version of the wave speed for clapping can be given as:
V = d/T (7)
Interference: When two waves meet together with the same frequency and period, they can create constructive and destructive interference. When they meet at the same phase, they create constructive interference and when they meet in the opposite phase, they create destructive interference. Interference is a phenomenon of waves when two waves interfere with each other.
Here are some illustrations that can be seen here. [19]

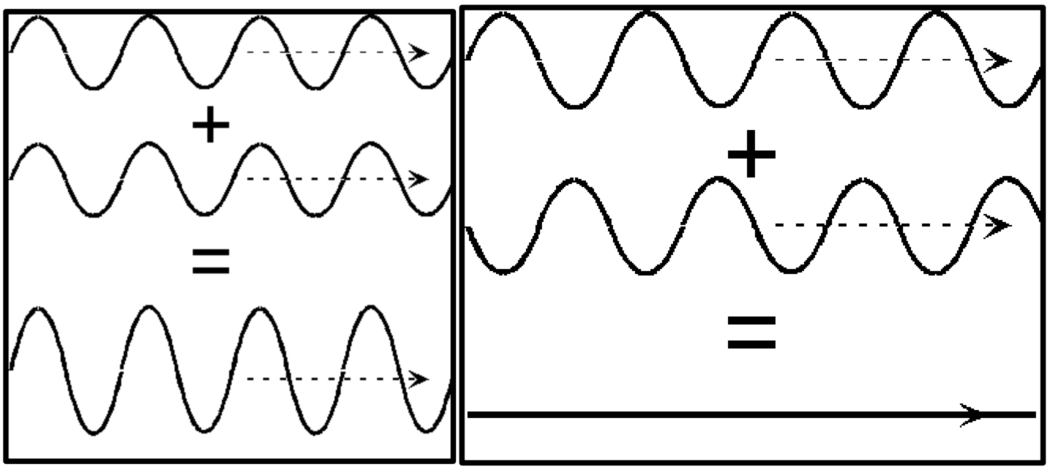

Figure 4: A sketch of constructive interference left: (Yt = Y1+Y2), and destructive interference of two waves, right: (Yt = Y1-Y2). [19]

II. RESULTS AND DATA ANALYSIS:

Based on the Methods mentioned in the Procedure section, experiments were conducted to obtain data on types of clapping and then plotted them using Logger Pro. A data table is shown below for data collected for clapping.

Data Table 1: Details of waves created with five different Amplitudes.

Data collection for five different Amplitudes				T = t/n	f=1/T	ω =2pif	v=2A/T	λ = v*T
	A(m)	t(s)	n	T(s)	f(Hz)	ω (rad/s)	v(m/s)	λ (m)
A1	0.025	6.94	10	0.694	1.440922	9.048991	0.072046	0.05
A2	0.05	7.05	10	0.705	1.41844	8.907801	0.141844	0.1
A3	0.075	7.19	10	0.719	1.390821	8.734353	0.208623	0.15
A4	0.1	8	10	0.8	1.25	7.85	0.25	0.2
A5	0.15	9.02	10	0.902	1.108647	6.962306	0.332594	0.3

Data Table 2: Showing three trials of each type of clapping and their average.

Time for three trials					
A1(s)	A2(s)	A3(s)	A4(s)	A5(s)	
6.73	6.75	7.21	8.01	8.94	
6.94	6.95	7.38	8.12	9.28	
7.15	7.04	6.99	7.88	8.84	
6.94	**7.05**	**7.19**	**8.00**	**9.02**	**Avg**

Data Table 3: Showing two waves with the same amplitude but different Periods.

Same A					
A(m)	**t(s)**	**n**	**T(s)**	**f(Hz)**	**ω (rad/s)**
0.025	6.94	10	0.694	1.441	9.049
0.025	2.31	10	0.231	4.329	27.186

Data Table 4: Showing two waves with the same Periods but different Amplitudes.

Same T					
A(m)	**t(s)**	**n**	**T(s)**	**f(Hz)**	**ω (rad/s)**
0.025	6.94	10	0.694	1.440922	9.048991
0.01	6.94	10	0.694	1.440922	9.048991

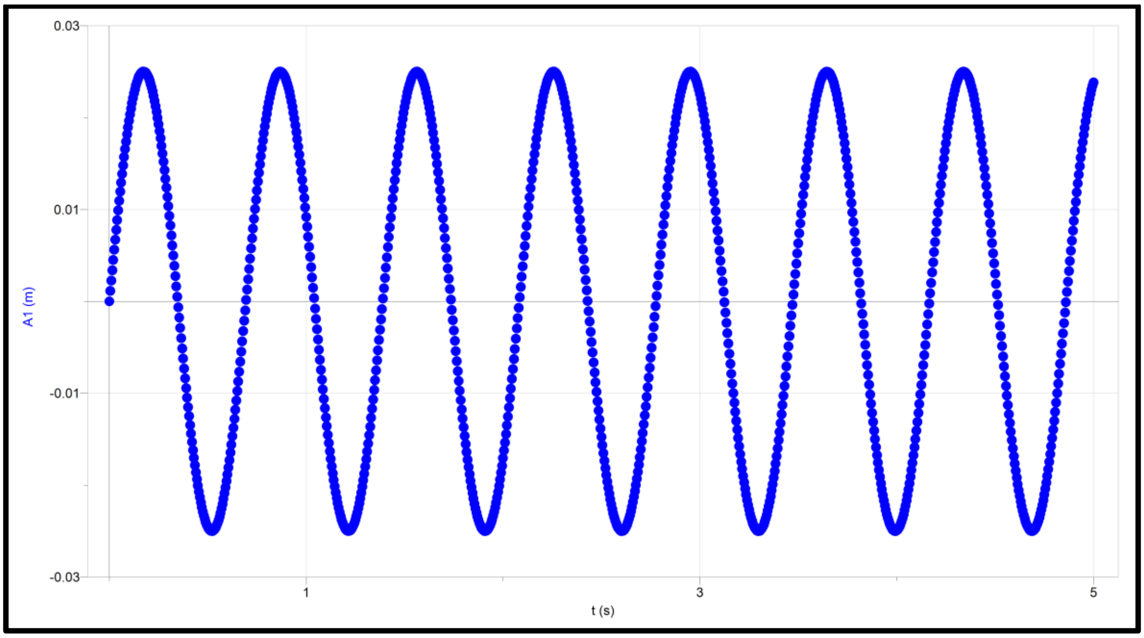

Figure 5: A wave is created from clapping with an initial amplitude (A1) of 2.5 cm and T = 0.694s. Y = A Sin ωt or Y = A Sin (2pi/T)t.

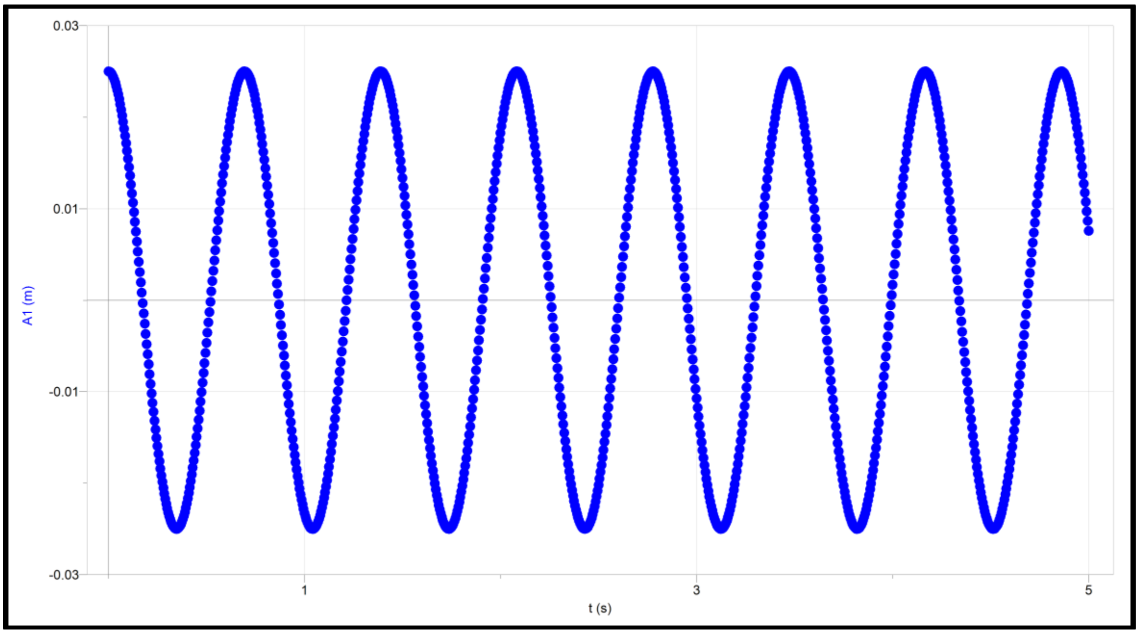

Figure 6: The same wave created by clapping for A1 of 2.5 cm as a Cosine wave. Y = A Cos ωt.

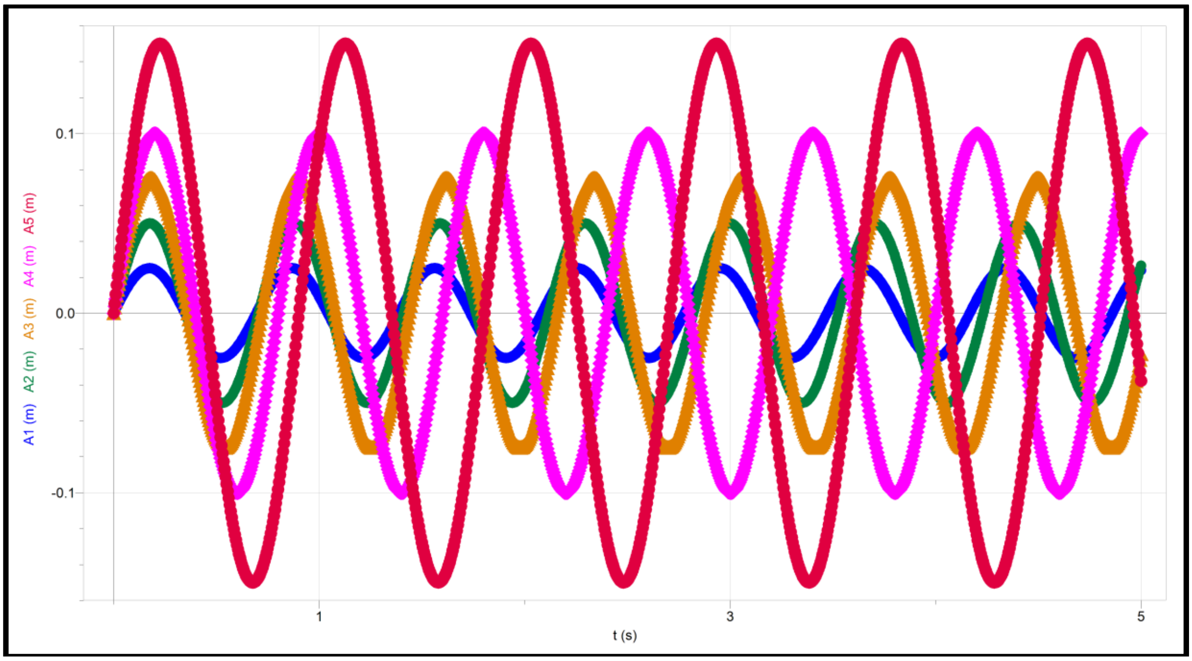

Figure 7: All Sine waves created by clapping with different Amplitudes from A1 to A5 and T1 to T5 are shown in Table 1.

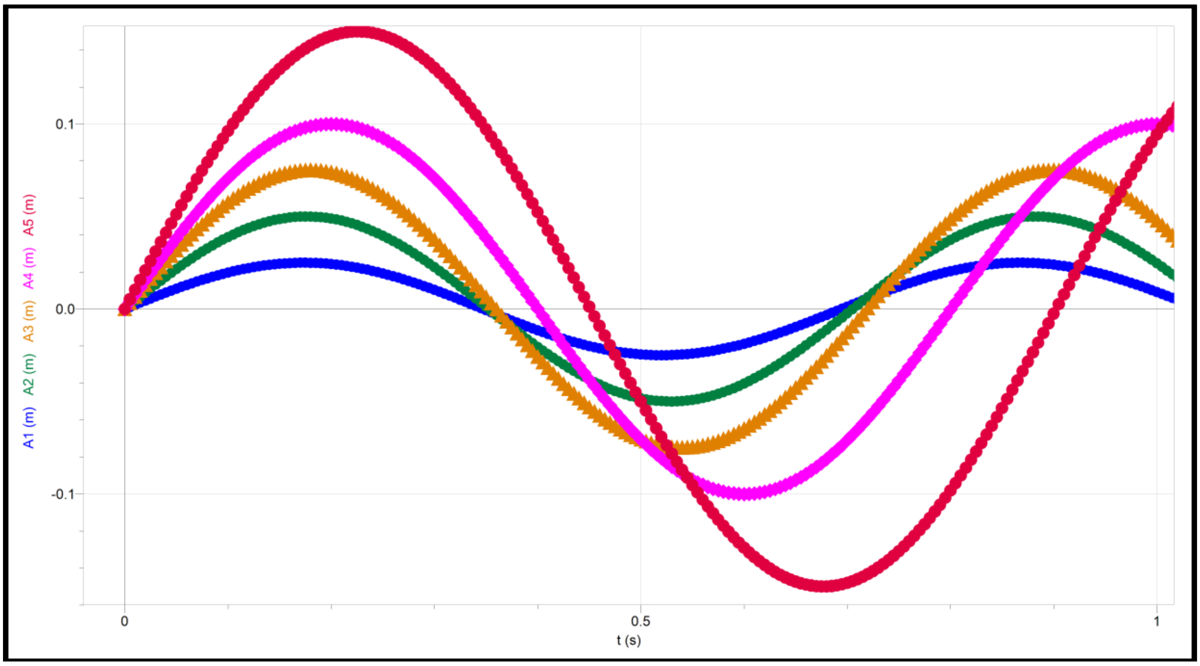

Figure 8: Zoomed in part of all waves created by clapping with different Amplitudes from A1 to A5 from Figure 6.

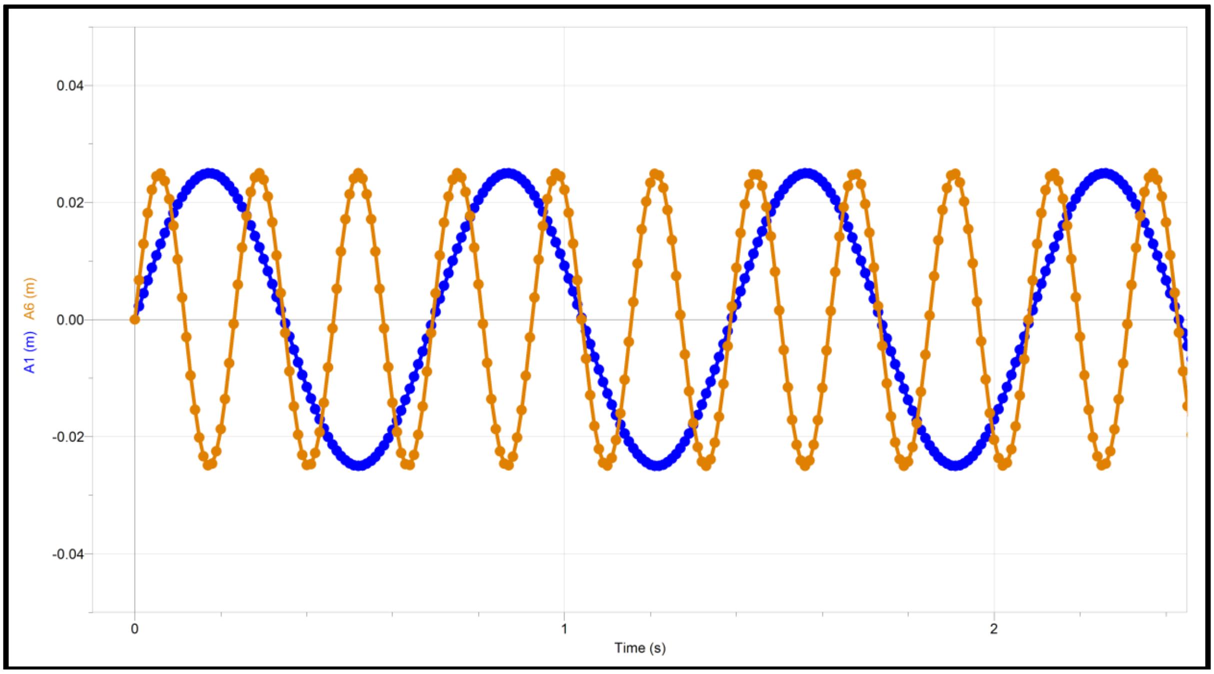

Figure 9: Two waves created by clapping keeping Amplitude the same but period and frequency different as shown in Table 3. ***This figure shows the effect of frequency increasing pitch but keeping amplitude the same.***

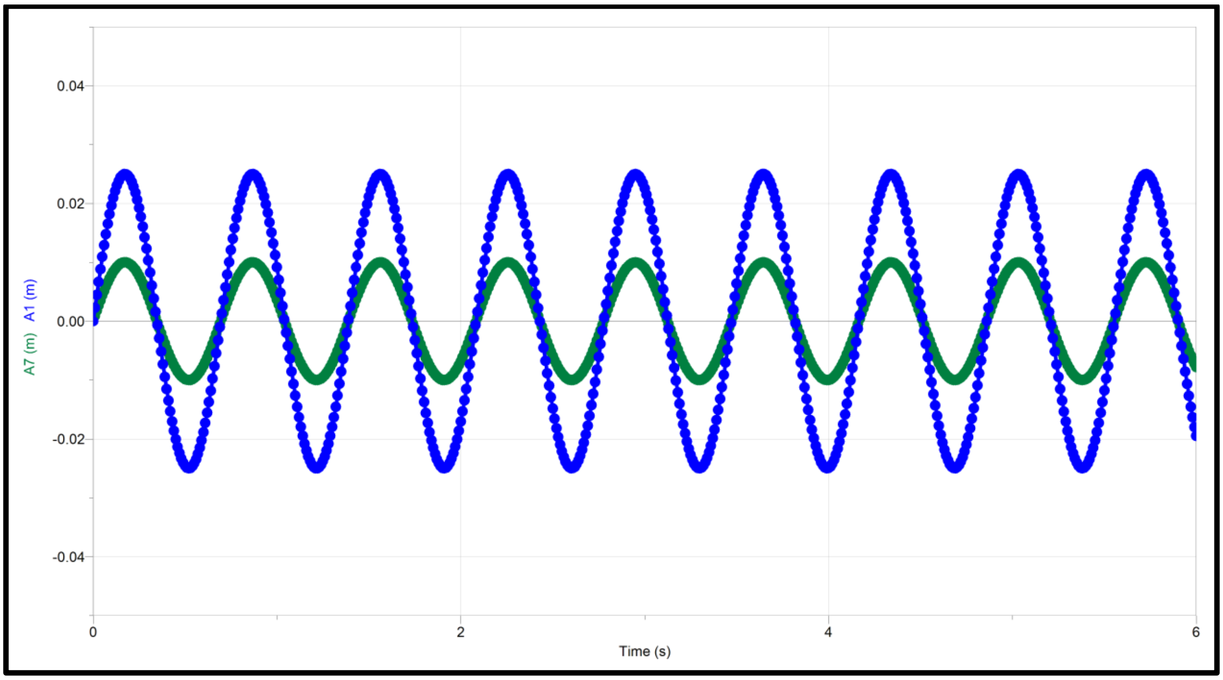

Figure 10: Two waves created by clapping keeping the Period same but Amplitude different as shown in Table 4. ***This figure shows the effect of loudness with an increase in amplitude keeping frequency the same.***

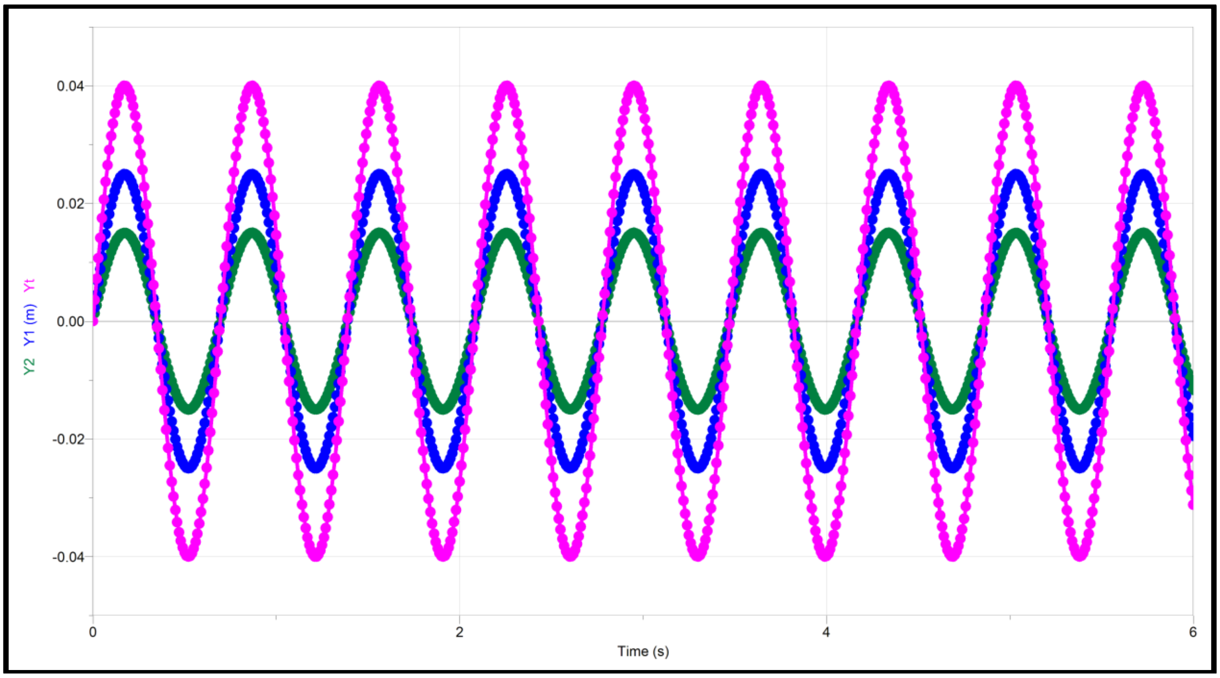

Figure 11: Two waves interfered constructively giving resultant amplitude as Yt for Y1 and Y2 as Yt = Y1 + Y2. ***This figure shows constructive Interference.***

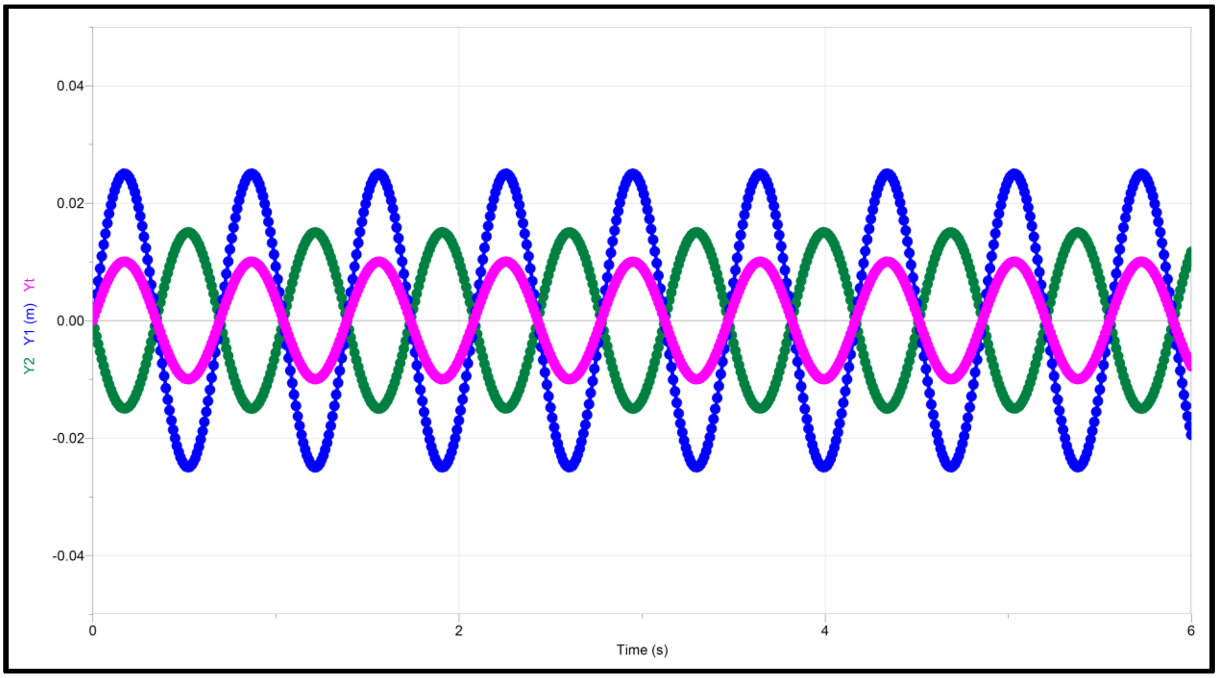

Figure 12: Two waves interfered destructively giving the resultant amplitude as Yt for Y1 and Y2 as Yt = Y1- Y2. ***This figure shows destructive Interference.***

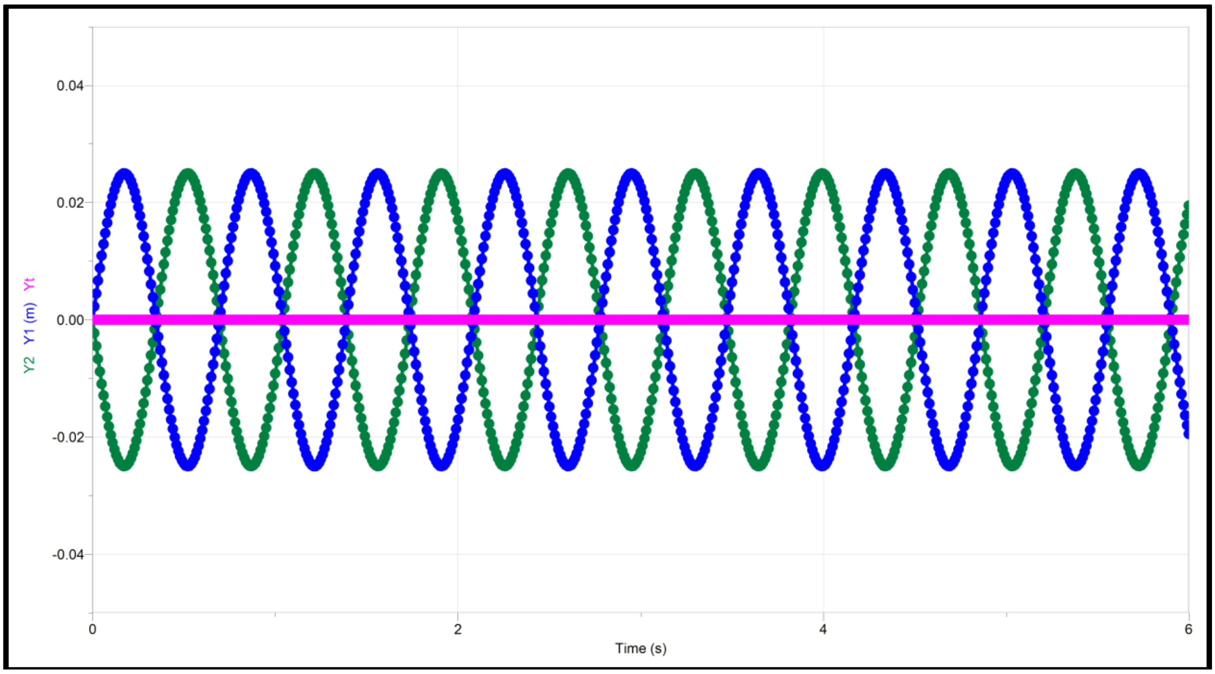

Figure 13: Two waves interfered destructively giving resultant amplitude as **zero** for Yt as Yt = Y1-Y2. ***This figure shows total destructive Interference.***

III. DISCUSSION:

Based on results and graphs plotted for waves created by clapping using Logger Pro, it can be seen that clapping can create waves. These waves can show most of the wave phenomena that are taught in high school and college. These waves show a sine and cosine waves can be created by clapping. It also shows that waves with different amplitudes can be created. It also shows that waves with different frequencies can be created. Different amplitudes represent changes in loudness. Higher amplitude means a louder sound of clapping. Whereas higher frequency means higher pitch.

Interference phenomena can also be seen in clapping when two people clap at the same time with the same frequency and in the same phase, constructive interference can be created which results in higher amplitude which also means louder claps. Destructive interference can also be created by clapping in opposite phases which can result in lower sound and volume. Whereas a total destructive interference can be created hypothetically thinking two waves meet opposite with the same amplitude and frequency, then the resultant will have zero amplitude and no sound at all.

From the period, frequency, and angular frequency can be calculated following wave theory. The speed of wave and wavelength can also be calculated following wave equations as shown in the theory section. All data and calculations are shown in Data Table 1.

IV. CONCLUSION:

In summary, it can be said that waves can be created by clapping. In fact, clapping is a good example of classroom activities to teach students the concepts of waves. It is also a good example to relate concepts of waves to the real world and daily life activities. It can be seen from the results that sine and cosine waves can be created by clapping. The phenomena of interference and the effect of pitch and amplitude can be seen in clapping. All hypotheses come true, and all research questions are answered. This work can be used for class projects or science fairs as well. This work has a connection between disciplines as it connects concepts of Physics, technology, software engineering, writing, reading, and real-world applications. In the future, if time permits, this type of work can also be done in water, for example in the swimming pool to see the effect of water waves that is created by clapping.

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