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Original Article

Can Waves be Created by Body Movements?

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Abstract *- Waves are found everywhere, and you can notice them if you know how they are formed. According to the Physics of Waves, any repetitive motion can create a wave. Wave can be created in any medium, no matter if it is water or air. The repetitive movement of any part of the human body can also create waves. This is the goal of this research project on how to create waves with some types of body movement. For the experiments, one hand, half arm, full arm, and both hands and legs were used for a repetitive motion to generate waves. Body movements created several waves, and it was observed that when the amplitude is kept constant, the height of the wave in the graph becomes constant, and when the time period of the wave is constant, then the frequency of the wave is found to be constant. Details of each wave can be seen in the paper. The graphs of waves were plotted using Logger Pro. These movements show how concepts of Waves be applied to daily life activities to visualize and understand the concepts of waves in Physics.*

Keywords *- Waves, Sine wave, Amplitude, Frequency, Angular speed, Time period, Repetitive movement.*

1. Introduction

Every movement has more than one meaning, depending on the moment and what you are looking for. Taking the fact that an audience applauds after a concert, speech, or play as a sign of approval and enjoyment. Meanwhile, any repeating motion can create a wave. So, what is a wave? [1-4] A wave is any form of motion that can transfer energy from place to place without a net movement of particles. It is back and forth repetitive movement of particles from their mean position. The energy is transferred from particle to particle, and it creates waves. Swimmers and divers are producing waves in the water. When you speak, you also create waves, whether in the air or trying to speak underwater, because the air molecules or water molecules are moving back and forth. Even when you ripple when you go to the beach or play the drums in the water, there can be several examples and applications of waves. Some can be seen in these references as sound waves, music waves, body waves, ocean waves, Earth waves, water waves, etc. [5-8]. All of these waves involve Physics behind them.

A sine wave or cosine wave can be created by any repetitive motion. The Physics of waves involves amplitude, frequency, time period, speed, and energy of the wave. [1, 9-11] My interest in this project work is doing different types of body movement and seeing how I can create waves and how they look when following concepts of Physics. To understand concepts of Physics, I will use the data analysis software Logger Pro to see what waves look like. [12]. Waves can also be plotted using Desmos online tool. [13] I have tried both during experiments.

I learned concepts of Physics when I took Physics I and II courses. I feel it is more fun to use these concepts in the real world and daily life to see how Physics is happening around me. Hands-on experiments that can be done at home are the best way of working on any experimental project work as due to COVID issues, it is possible that someone has limited access to lab facilities, but using your own home and material at home can lead you to do what you can. Some of these publications show these types of hands-on experiments done during COVID, when everything was closed, and all classes were online. People still like to do experiments and are able to find good results to publish in journals and give other motivations not to stop learning and experimenting even though they live in very narrow and limited circumstances. [14-18] Some examples of publications can be seen here that talk about experiment-based research and project-based learning done by college students as honour projects showing how Physics can be applied to daily life activities. [25-26]

2. Materials and Methods

For this experiment, I had to constantly use a ruler and my phone to record the amplitude and time taken in a certain amount of movement and a calculator to calculate. I had to use a bucket, water, thread, books, and a notebook with a pen to record my data. Adhesive tape to secure the ruler on the wall.

First, this experiment has three parts. 1) Movement of the hand and arm in water and air (four waves of the same

amplitude). 2) Clapping movement (four waves of different amplitude). 3) Jumping movement (two waves of different amplitude). To do it, I counted from zero to 10 oscillation; in the first part, I used a bucket and poured water in it, held a ruler with my right hand, and put my other hand with the middle of my finger into 5cm going down 0cm and up 10cm slowly when my hand goes down someone starts the timer for me. When my hand goes to 5cm again after going 1 oscillation, I start counting. For the second wave, the same process was followed. The difference was I used my hand and waist together, which made it become a flying faster movement. In creating the third wave, which was the movement of the forearm with the wrist in the air at a faster speed, where I stuck the ruler in the wall and used adhesive tape to secure it, we used 5cm as our mean. For the fourth wave, in the first part, I use my full arm in the air at a regular speed to repeat the same process.

For the second part of this experiment, which also has the creation of waves with different amplitudes, I started by doing small clapping hands in repeating motion with a mean of 10cm by going to 8cm of distance with the middle finger of both hands open to 8cm and 12cm for 10 times as oscillation, where the amplitude is 0.02m. For the second wave in this part, I use a regular clapping hand in repeating motion with the mean of 10cm by going to 5cm of distance with both hands, one going to 5cm and the other going to 15 cm 10 times as oscillation. The third wave was a big clapping hand with a mean of 15cm where one hand went to zero, and the other one went to 30 for 10 times oscillation. For the last wave in this part, I had fully opened my arm to Clapp it and my back in the wall, where the center of my chest was the amplitude 1.0125m and opened it up where my elbow touched the wall. I used a thread and a ruler to get the measurement.

In the last part, the third part, I try to figure out that besides my hands, there is another way I can try to create waves. I first started to jump low, straight, without bending my knees in a room where I put some books on the floor to do the same jump for 10times; then, I got 0.064m as my amplitude. Then I realized why not go higher where I can bend my knees to get balance. I first jumped to get a distance, and I asked someone to observe my movement to see if I was repeating the same movement for 10times. I ended up with 0.309m as my final amplitude for the 2nd type of jump.

3. Theory Used

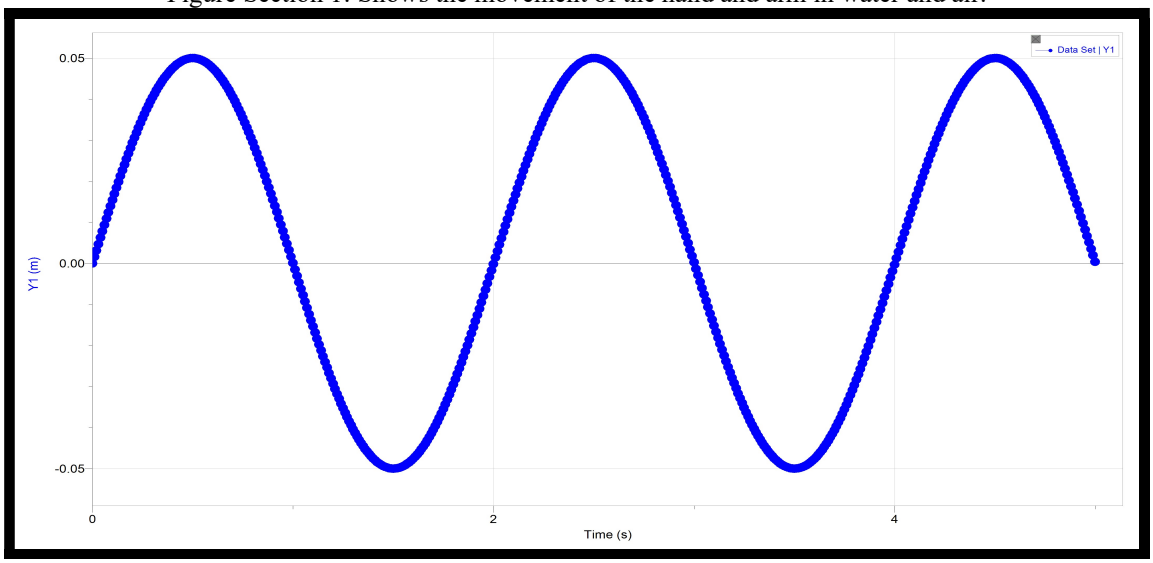
I use the equation of the wave Y=A sin ω t where Y is the displacement. Sin was used in this equation because of the existence of the sine wave, and it starts from zero. Small t is the time (s) recorded, a variable, while doing each experiment. Meanwhile, the big T is the time period (s) calculated with small t and n(oscillation). A is the amplitude (m) of the distance traveled from the mean position to the endpoint. The ω omega (rad/s) is equal to $2*\pi$ *f. The f represents frequency (Hz). Small n is the number of oscillations used for every experiment.

Equations used for Wave: T=t/n, f=1/T, $\omega=2*\pi$ *f, Y=A sin ω t

4. Results

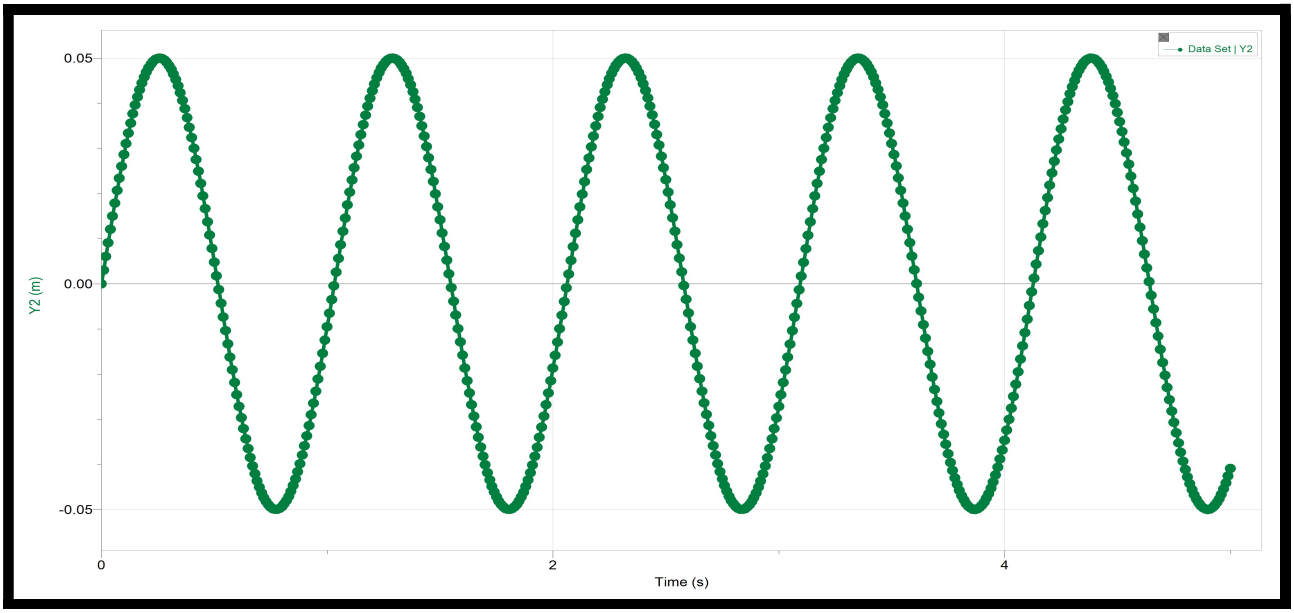
The waves created by different parts of the body are shown below in the form of the graphs plotted in Logger Pro in three different sections of Figures, and later data tables are shown for them too. These sections are Section 1) one hand and arm movement in water and air, Section 2) two hands movement for clapping, and Section 3) jumping with two legs.

Figure Section 1: Shows the movement of the hand and arm in water and air.



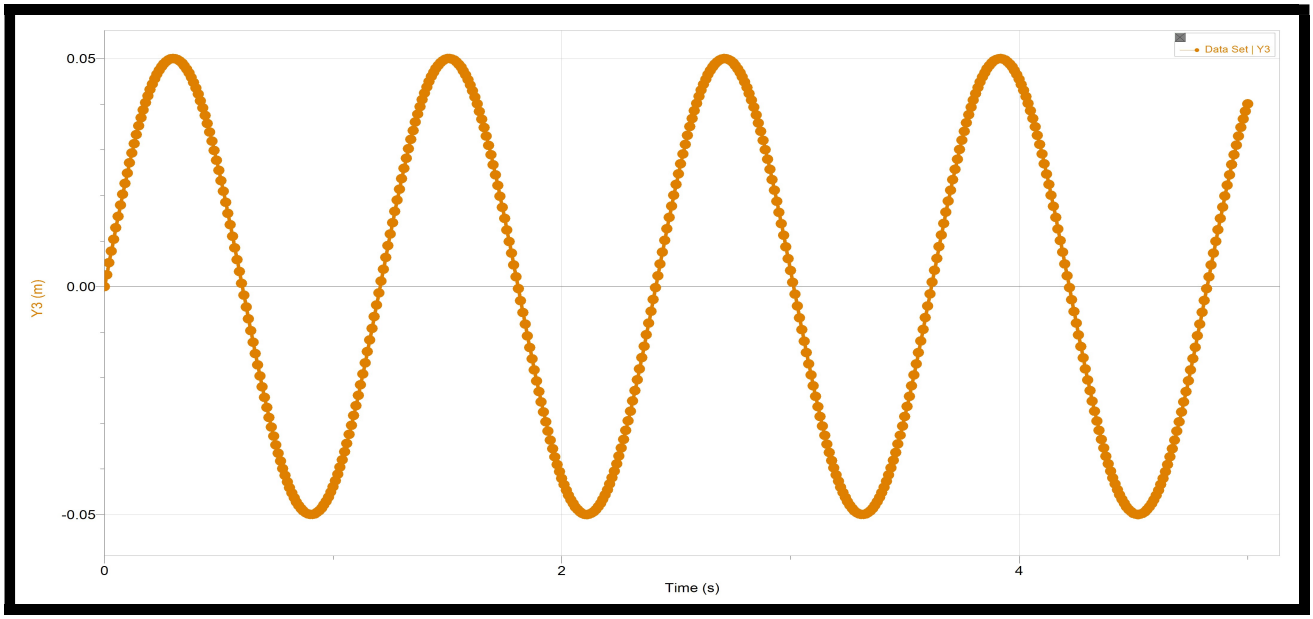
Graph 1(a). Waves generated by the movement of a hand in the water for a shorter distance.

Equation of Graph 1(a): Y(t)=A sin ω t ⇒ 0.05 sin 3.135 t



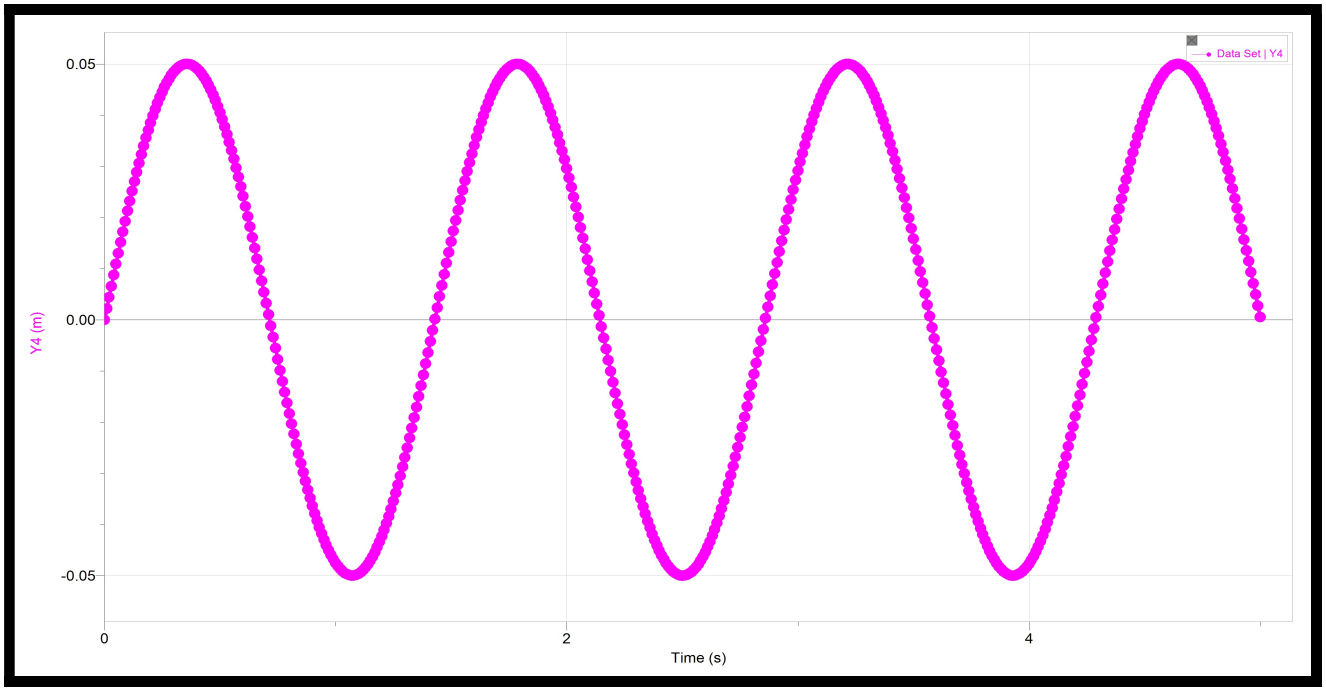
Graph 1(b). Waves generated by the movement of a hand for a longer distance

Equation of Graph 1(b): Y(t)=A sin ω t ⇒ 0.05 sin 6.088 t



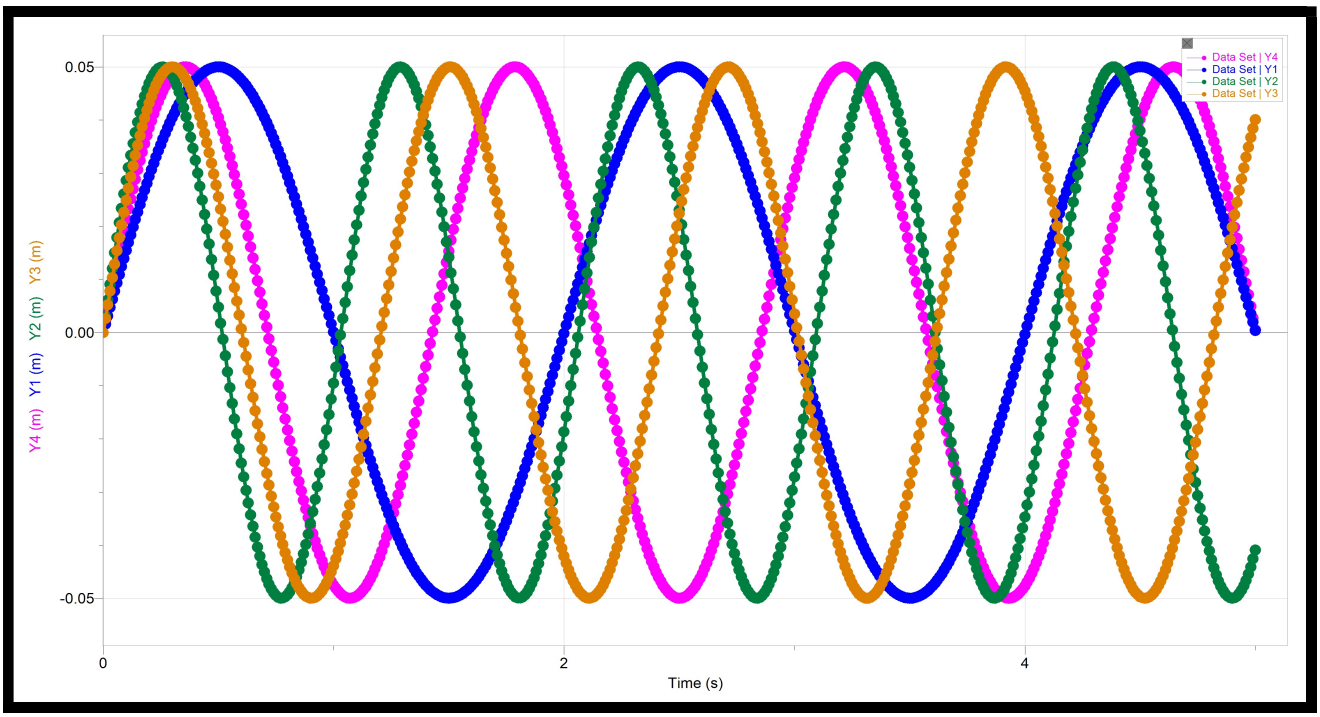
Graph 1(c). Waves generated by the movement of a hand for a longer distance in the air.

Equation of Graph 1(c): Y(t)=A sin ω t ⇒ 0.05 sin 5.190 t



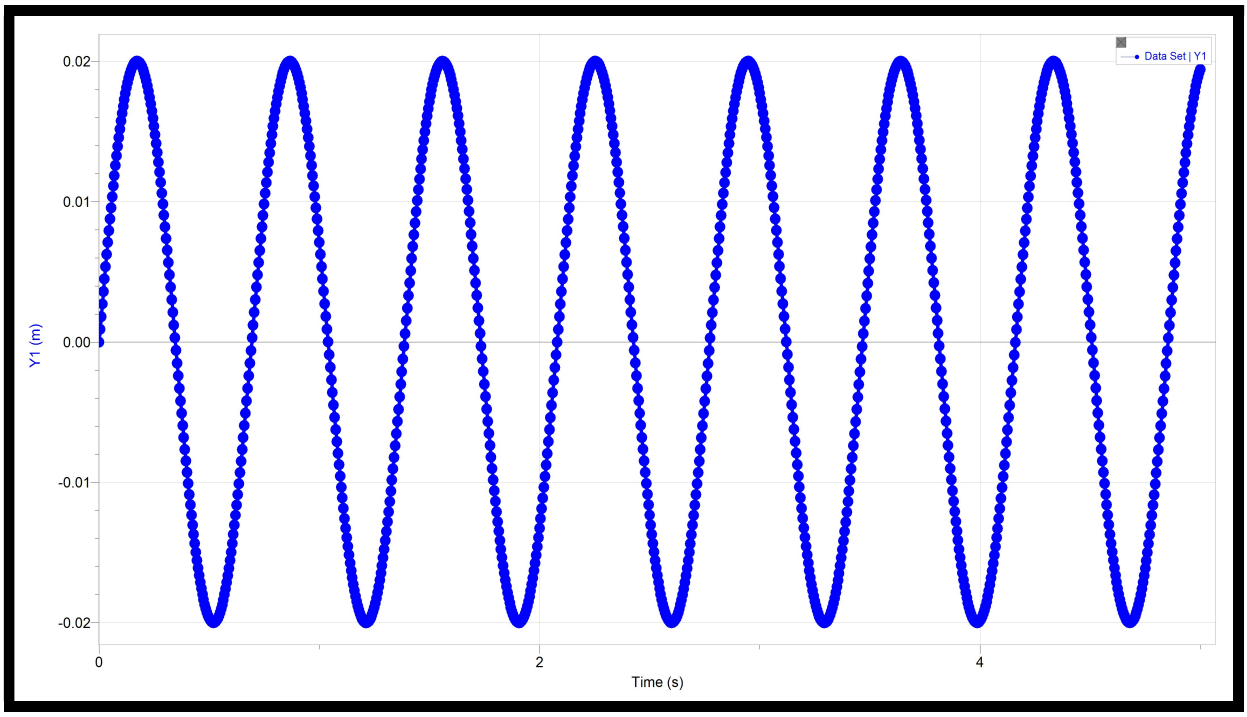
Graph 1(d). Waves generated by the movement of a hand for a regular distance in the air.

Equation of Graph 1(d): $Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 4.392 t$



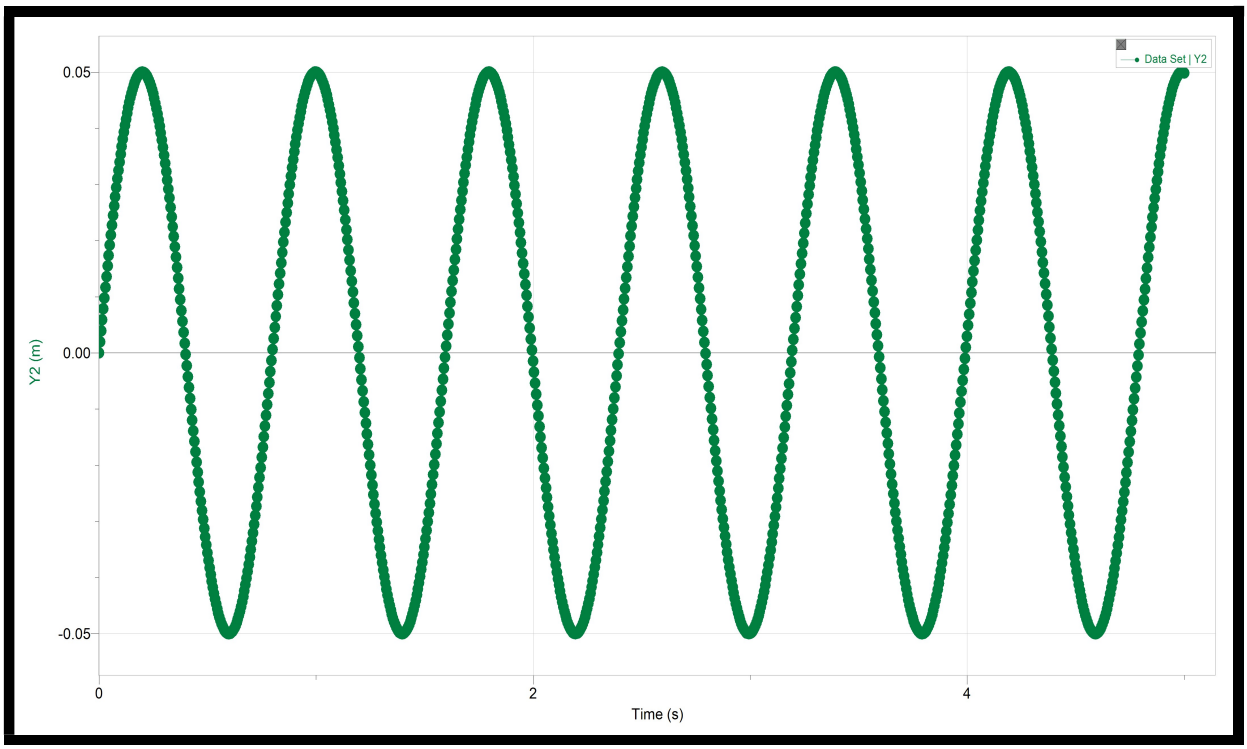
Graph 1(e). Showing all waves formed by the hand and arm movement in water and air, keeping A same.

Figure Section 2. Shows clapping movement



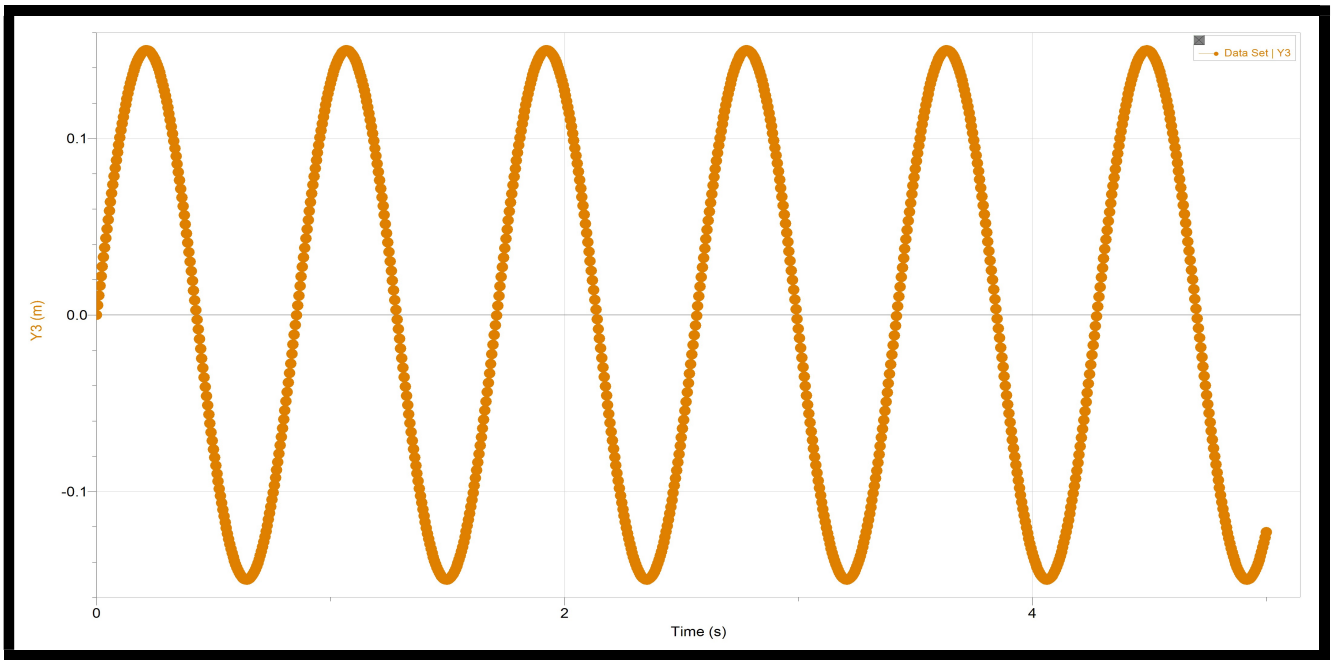
Graph 2(a). Waves generated by the movement of both hands for a shorter distance in the air.

Equation of Graph 2(a): Y(t)=A sin ω t ⇒ 0.02 sin 9.067 t



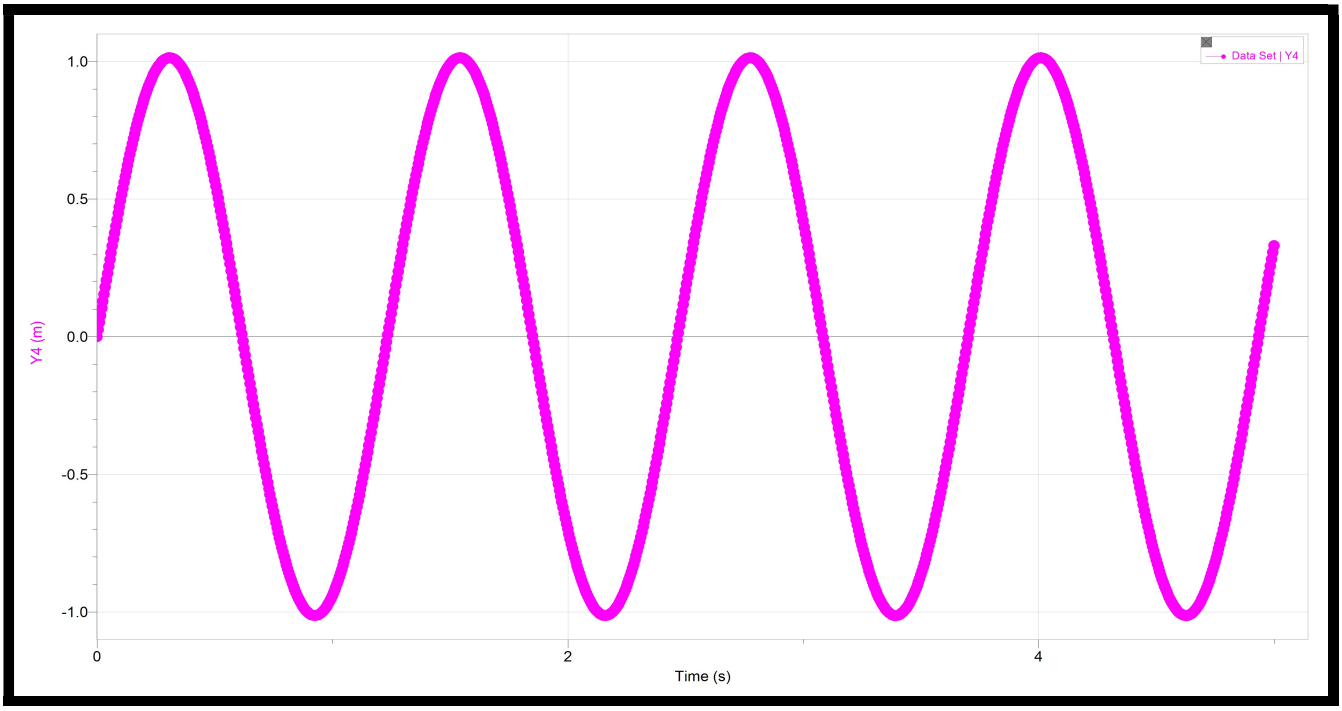
Graph 2(b). Waves generated by the movement of both hands for a regular distance in the air.

Equation of Graph 2(b): Y(t)=A sin ω t ⇒ 0.05 sin 7.873 t



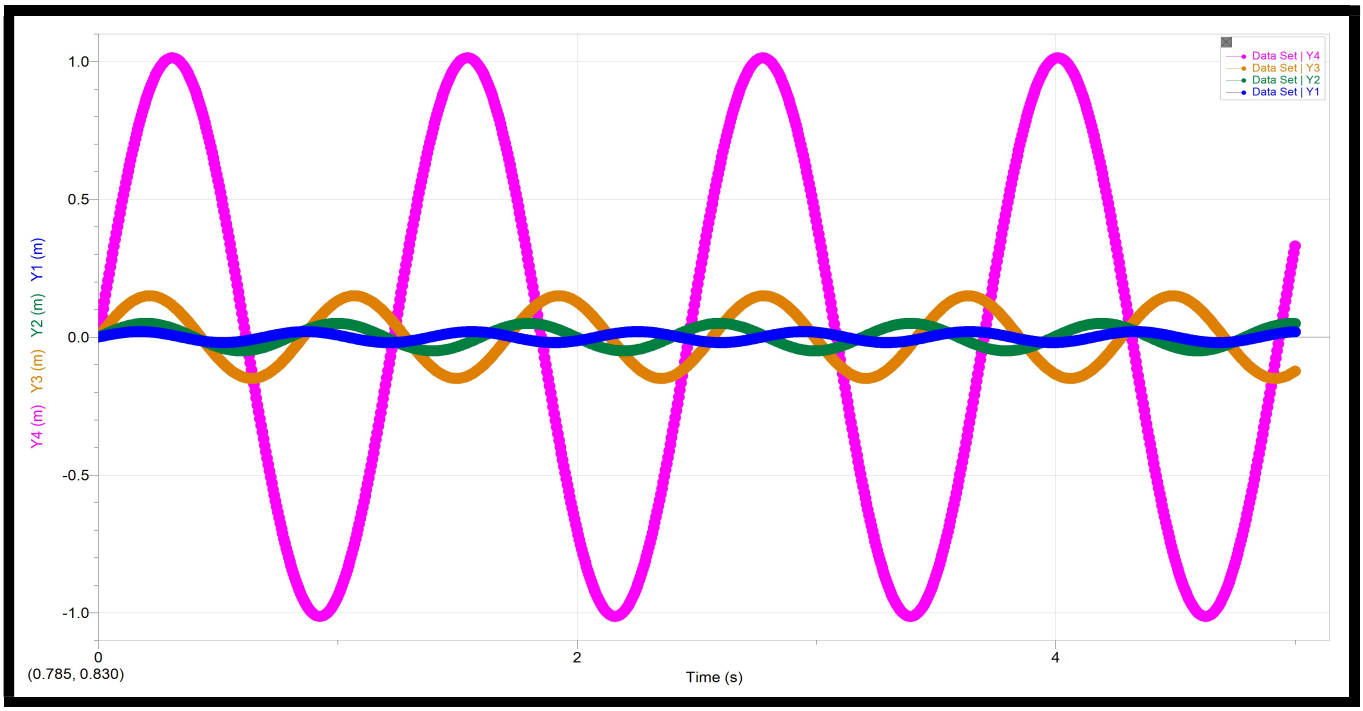
Graph 2(c). Waves generated by the movement of both hands for a longer distance in the air.

Equation of Graph 2(c): $Y(t)=A \sin \omega t \Rightarrow 0.15 \sin 7.351 t$



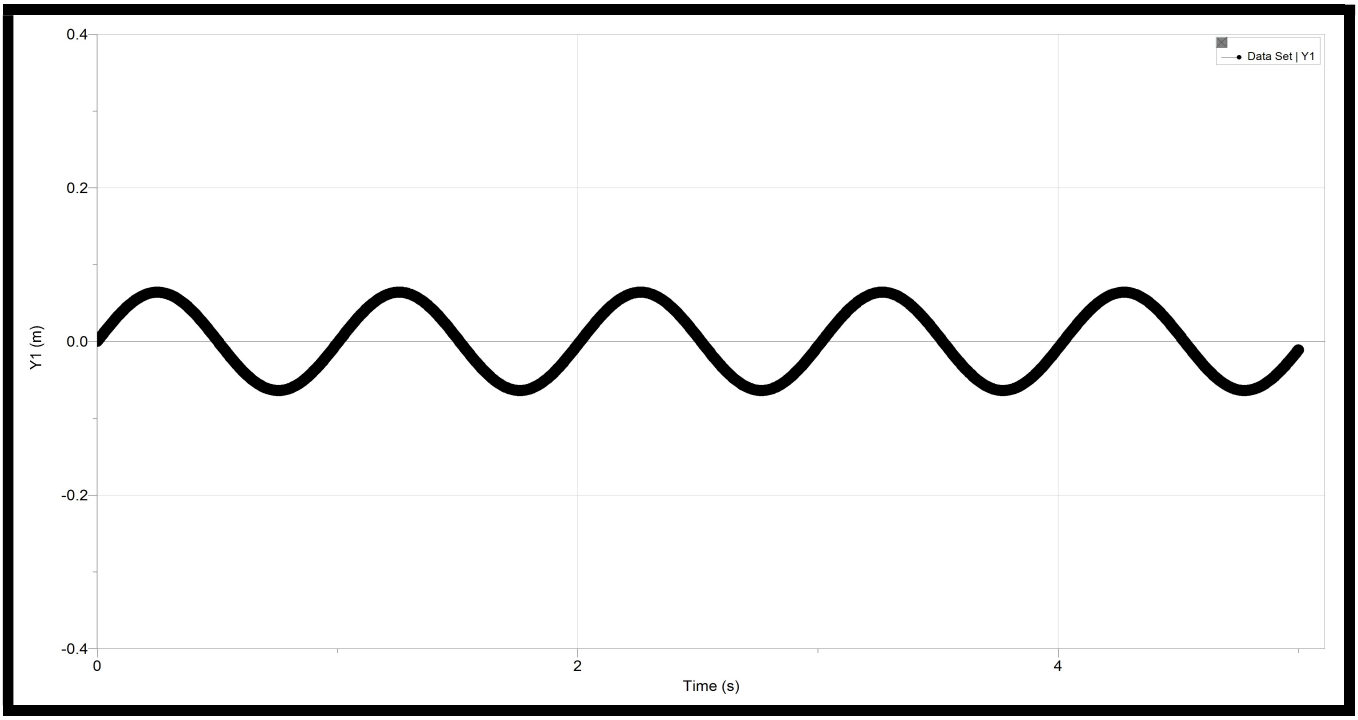
Graph 2(d). Waves generated by the movement of both hands for a much longer distance in the air.

Equation of Graph 2(c): $Y(t)=A \sin \omega t \Rightarrow 1.0125 \sin 5.096 t$



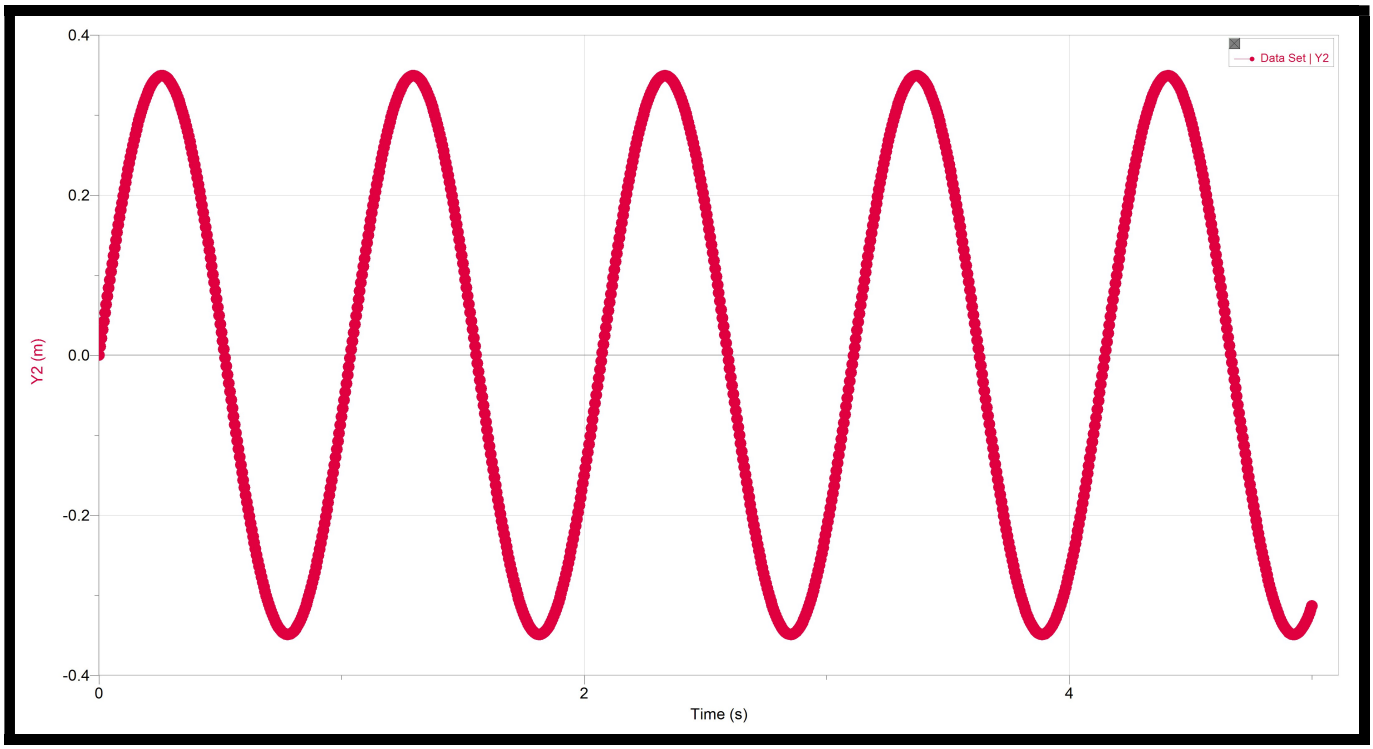
Graph 2(e). Showing all waves formed by clapping movement with different amplitude and frequencies.

Figure Section 3. Showing Jumping movement



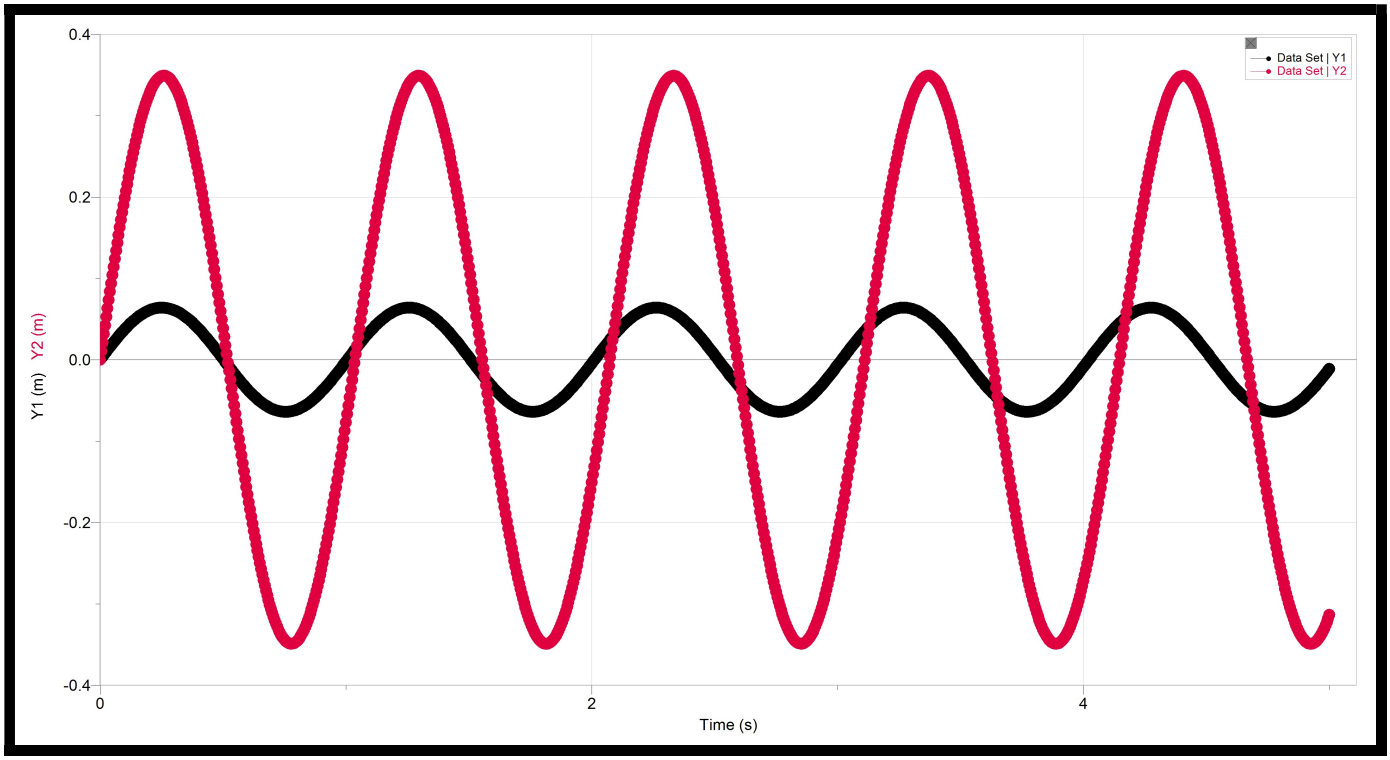
Graph 3(a). Waves generated by the movement of jumping for a lower distance in the air

Equation of Graph 3(a): $Y(t)=A \sin \omega t \Rightarrow 0.0635 \sin 6.252t$

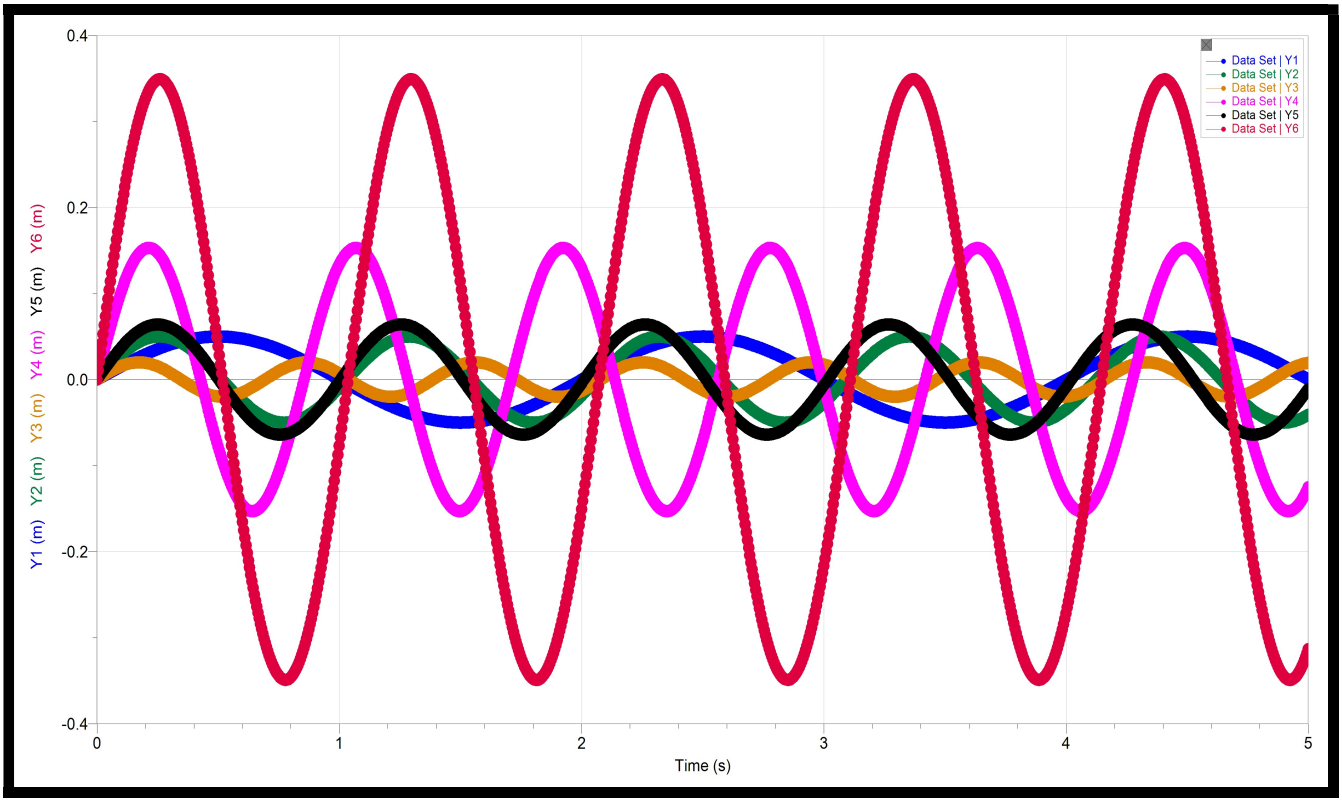


Graph 3(b). Waves generated by the movement of jumping for a higher distance in the air.

Equation of Graph 3(b): $Y(t)=A \sin \omega t \Rightarrow 0.349 \sin 6.063 t$



Graph 3(c). Showing waves generated by all Jumping movements with different amplitudes and almost similar frequencies



Graph 4. Showing a comparison between waves formed by all types of body movements. Blue and Green are hand movements in water and air with the same amplitude, Orange and Magenta are clapping with different amplitudes and different frequencies, and Black and Red are jumping with almost similar frequencies.

5. Data Tables and Calculations

Section 1: I have performed experiments moving my hand for the shorter and longer distance with my half arm and full arm in the water and in the air for the data in Table number one.

Table 1. Show the movement of the hand and arm in water and air.

# of waves	Types of waves	Amplitude, A, (m)	Time, t, (s)	Time period, T, (s)	Frequency, f, (Hz)	Omega, ω, (rad/s)
1	movement of the hand in water (Slower)	0.05	20.06	2.006	0.499	3.135
2	movement of the hand with the wrist in water (flying faster)	0.05	10.32	1.032	0.969	6.088
3	movement of the forearm with the wrist in the air (faster)	0.05	12.10	1.210	0.826	5.190
4	movement of the full arm in the air (regular speed)	0.05	14.30	1.430	0.699	4.392

In the first table of the experiment, I intentionally keep my amplitude constant.

Section 2: In this table number two, I have recorded the data of clapping with the smaller distance and middle distance to the larger distance

Table 2. Show clapping movement.

# of waves	Types of waves	Amplitude, A, (m)	Time, t, (s)	Time period, T, (s)	Frequency, f, (Hz)	Omega, ω, (rad/s)
1	Small Clapping hands in repeating motion with the mean of 10cm by going to 5cm of distance with both hands(8,12) 10 times	0.02	06.93	0.693	1.443	9.067
2	regular Clapping hands in repeating motion with the mean of 10cm by going to 10cm of distance with both hands (5,15) 10 times	0.05	07.98	0.798	1.253	7.873
3	Big Clapping hands in repeating motion with the mean of 15cm by going to 30cm of distance with both hands (0,30) 10 times	0.15	8.55	0.855	1.170	7.351
4	Full arm Clapping hands with the mean in the middle of my chest 10 times	1.0125	12.33	1.233	0.811	5.096

In this part of the experiment, I did not keep my amplitude constant; amplitude varies.

Section 3: In this table number 3, I have recorded the lowest jumping data to the highest jumping movement.

Table 3. Show Jumping movement.

# of waves	Types of waves	Amplitude, A, (m)	Time, t, (s)	Time period, T, (s)	Frequency, f, (Hz)	Omega, ω, (rad/s)
1	Low jump straight without bending the Knees	0.064	10.05	1.005	0.995	6.252
2	High jump straight with bending the knees	0.349	10.36	1.036	0.965	6.063

In the last table of the experiment, the amplitude and time period both varied.

Here is one calculation shown for Graph 1a as an example of the way it is done. All calculations are performed in the same way.

Everything starts with the value of Amplitude(A)=0.05m and small (t) time= 20.06s and n= the number of times I repeat the experiment 10 oscillation. To get time period (T)=t/n ⇒ 20.06/10=2.006 s. The frequency(f) formula=1/ 2.006=0.499Hz. To get my omega (ω), I plug my known data into this formula $2*\pi*f \Rightarrow 2*\pi*0.499=3.135$rad/s. All these calculations are necessary to plug the data into the equation of wave; $Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 3.135\ t$.

The same method was followed to calculate the rest of the nine waves.

6. Discussion

After performing these three sets of body movements and collecting their data, repetitive body movements can create waves, and the waves can have the same or different

amplitudes and the same or different frequencies as well. As described in this paper, all of the body movements followed the concepts of waves. This section shows only waves with the lowest and highest frequency from each part of the three parts of each experiment. A comparison between types of waves generated by body parts can be seen in Graph 4. A summary table is shown below as Table 4, with some waves that have either the least frequency or highest frequency.

Table 4. Summary table that shows only waves that have the lowest and highest frequency.

Waves with the lowest frequency					Waves with the highest frequency				
Table #'s of waves	Amplitude, A, (m)	Time period, T, (s)	Frequency, f, (Hz)	Omega, ω, (rad/s)	Table #'s of waves	Amplitude, A, (m)	Time period, T, (s)	Frequency, f (Hz)	Omega, ω, (rad/s)
1	0.05	2.006	0.499	3.135	1	0.05	1.032	0.969	6.088
2	1.0125	1.233	0.811	5.096	2	0.02	9.693	1.443	9.067
3	0.349	1.036	0.965	6.063	3	0.064	1.005	0.995	6.252

Table 5. Summary table that shows when you move your body, you can create waves

Number of waves	Waves equations
1	$Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 3.135 t$
2	$Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 6.088 t$
3	$Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 5.190 t$
4	$Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 4.392 t$
5	$Y(t)=A \sin \omega t \Rightarrow 0.02 \sin 9.067 t$
6	$Y(t)=A \sin \omega t \Rightarrow 0.05 \sin 7.873 t$
7	$Y(t)=A \sin \omega t \Rightarrow 0.15 \sin 7.351 t$
8	$Y(t)=A \sin \omega t \Rightarrow 1.0125 \sin 5.096 t$
9	$Y(t)=A \sin \omega t \Rightarrow 0.0635 \sin 6.252 t$
10	$Y(t)=A \sin \omega t \Rightarrow 0.349 \sin 6.063 t$

For the first two pairs of numbers, one wave, I noticed that the movement of the hand in water with a slower speed had the lowest frequency among all of them, and the highest frequency came from the low jump straight without bending the knees movement.

In this table, I have used three different colors to separate the three types of waves that I had looked for. Where the color red is the movement of the hand and arm in water and air yellow is the clapping movement. Meanwhile, blue represents the jumping movement.

7. Conclusion

In conclusion, 10 experiments were done to check if waves can be created by body movement. Among these experiments, four were pretty much the same. I used one hand for two experiments in water and one hand for two in the air. Another four experiments where I used both hands by clapping with different movements, and two experiments where I jumped. All was done with different body parts by using the repeating motion to check my theory. After doing all of these experiments and calculating, I have concluded yes! Body movements can create waves, and the types of waves created along the way of this experiment are cited in the results part and the rest of the tables.

Acknowledgments

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