IB Physics Internal Assessment
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Investigating the Relationship Between Water Depth and Ripple Velocity

Contents

Introduction: .:. Top

As far back as I can remember, I have always had a fascination with water. I would examine the ocean and its behaviors, further increasing my curiosity. As I grew older, I began to learn about the physics of water. I've since had a lingering curiosity of how water behaves under certain conditions. This led me to research what the scientists of the past had learned about the experiment I was going to conduct.

Background: .:. Top

Ancient scholars like Leonardo da Vinci and Galileo Galilei were among the first to observe and document the behavior of waves in water. Da Vinci especially dedicated time to studying water and its behaviors. Leonardo made hundreds of observations on the movement of water at this time, and although certain themes recur - in particular his astute analyses of complex motions in terms of linear and circular components - the superabundance of particular cases prevented him from ever realising a set of generally applicable laws[1].

In the 19th century, Lord Rayleigh made substantial contributions to the study of waves, having a wave named after him. The Rayleigh wave is a compressional-transverse coupled wave propagating along the free surface of a semi-infinite elastic material, where the compression takes place in the propagation direction[2].

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[1] Roberts, Jane. 2003. Royal Treasures: A Golden Jubilee Celebration. London: Thames & Hudson. https://www.rct.uk/collection/912660/studies-of-water

[2] Hadj-Larbi, Fayçal. n.d. "Sezawa SAW devices: Review of numerical-experimental studies and recent applications." Elsevier 292 (2019): 1-216. https://www.sciencedirect.com/topics/physics-and-astronomy/rayleigh-waves

Albert Einstein's contributions to the understanding of water waves came through his work on general relativity and his investigations into the nature of light. Although not primarily focused on water ripples, his theories and equations related to wave-particle duality and the behavior of light waves contributed indirectly to the broader understanding of wave phenomena.

Water waves propagate along the surface through a complex motion that can be likened to a circular pattern. Near the water's surface, molecules move in circular orbits as the wave passes, imparting energy horizontally. However, as you descend deeper, this circular motion diminishes, and the wave's influence becomes less pronounced.

The motion near the bottom is constrained to be primarily horizontal. This horizontal movement is due to the friction between the water and the seabed, restricting vertical motion. Consequently, the wave energy is concentrated in a more confined, horizontal space.

Statement of the Problem: .:. Top

The purpose of this investigation is to determine the relationship, if any, that water depth has on the speed of ripples. Depth is defined as the distance between the surface and the bottom of the sink, and wave speed is defined as the linear speed of the leading edge of the ripple. The controlled variables include the frequency of the wave, and the temperature and purity of the water.

Related Links:

https://en.wikipedia.org/wiki/Ripple_tank - This wikepedia discusses the basics of ripple physics. It discusses the origins and the experiments conducted.

https://www.physicsclassroom.com/class/waves/Lesson-3/Reflection,-Refraction,-and-Diffraction - This article explains the refraction and reflection of waves

https://spark.iop.org/estimating-wavelength-frequency-and-velocity-ripples - This article discusses the velocity of ripples

https://scienceinprek.si.edu/science-water - This article gives a very brief description of the physics of water in general. A basic overview of its properties and behaviors.

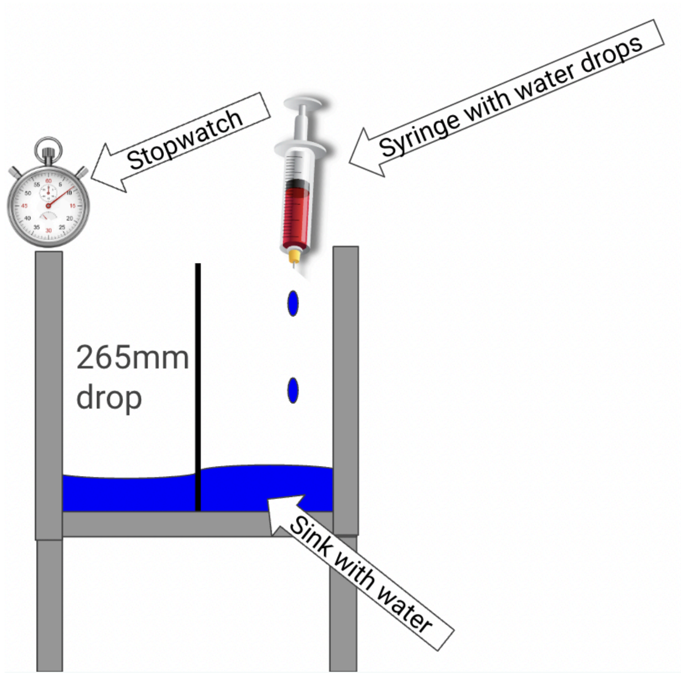
Hypothesis: .:. Top

I believe that gradually, the speed of the ripples will decrease with increased depth due to the force of impact having more space to exert force, rather than just horizontally. I will strive to find which depth has the greatest impact on velocity.

Materials: .:. Top

A kitchen sink was used as the container for the water, with the drain blocked. A syringe was used to release the water droplets. A stopwatch was used to record the time the ripples took to reach the desired distance.

Diagram: .:. Top



Method: .:. Top

In order to gather the most accurate data possible, I made sure to follow the same procedure for every data point collected. To be sure the water droplets hit the same spot in the sink, I made sure to mark that spot for the best accuracy. I made sure to measure the drop distance and the distance from the marked spot to the final distance I would measure. The drop distance was 265 millimeters, while the distance measured was 600 millimeters. The depth of the water started off at 10 millimeters, increasing by 10 millimeters each data point. A stopwatch was necessary to record the time of the trials. Each trial consisted of 15 variations ranging from 10-150 millimeters. By conducting 5 trials, I was able to gather a sufficient amount of data, which I was confident in doing a proper analysis for.

Safety Concerns: .:. Top

In this experiment, there were no visible risks or safety concerns that needed to be taken into account. The syringe used had no needle, so one would not have to worry about piercing their skin with it.

Data and Analysis: Data File

Raw Data: .:. Top

(+/- 0.05)	Time to travel 600mm (s)						
Depth in mm	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	average	uncty
10.0	3.07	3.17	3.27	2.80	3.15	3.09	0.24
20.0	3.48	3.54	3.50	3.66	3.51	3.54	0.09
30.0	3.43	3.40	3.65	3.84	3.55	3.57	0.22
40.0	3.32	3.50	3.50	3.39	3.52	3.45	0.10
50.0	3.59	3.50	4.01	3.64	3.72	3.69	0.26
60.0	3.42	3.41	3.51	3.62	3.58	3.51	0.11
70.0	4.04	3.72	3.04	3.54	3.47	3.56	0.50
80.0	3.73	3.77	3.62	3.75	3.81	3.74	0.10
90.0	3.72	3.80	3.56	3.89	4.09	3.81	0.27
100.0	3.93	4.21	4.11	4.11	4.17	4.11	0.14
110.0	3.90	3.90	3.96	3.98	3.48	3.84	0.25
120.0	4.41	3.72	3.94	3.89	4.02	4.00	0.35
130.0	4.01	4.14	3.95	3.71	3.98	3.96	0.22
140.0	3.28	4.05	3.85	3.91	3.86	3.79	0.39
150.0	3.53	4.30	3.85	3.91	3.86	3.89	0.39

Table 1: Raw data illustrating depth(mm) and time(s)

Data Processing: [.:. Top]

Once the data was gathered for each variation, I calculated the velocity for all five trials. This was done by dividing the distance used to measure the ripples by the times of each trial.

Velocity of one trial: 600mm/3.53s=169.97mm/s

Once I calculated the velocity for each trial, I calculated the average of all variations. This was done by adding all 5 trials, then dividing by the amount of trials done.

Average of one variation: 195.44+189.27+183.49+214.29+190.48=972.97mm/s

972.97/5=194.59

I then calculated the uncertainty of each variation. This was done by subtracting the lowest number from one of the five trials from the highest number. Then all that was needed was to divide by 2.

Uncertainty of one variation: 214.29-183.49=30.8

30.8/2=15.40

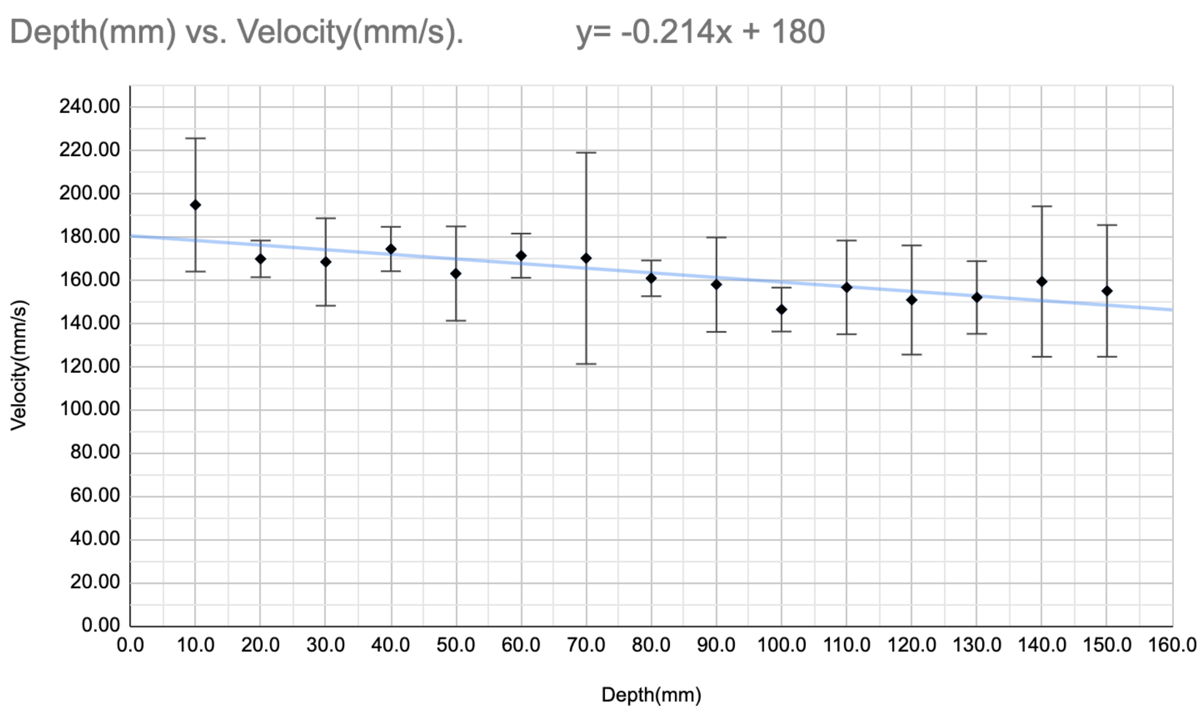
Raw Data: [.:. Top]

(+/- 0.05)	Velocity of ripples (mm/s)						
Depth in mm	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	average	uncty
10.0	195.44	189.27	183.49	214.29	190.48	194.59	15.40
20.0	172.41	169.49	171.43	163.93	170.94	169.64	4.24
30.0	174.93	176.47	164.38	156.25	169.01	168.21	10.11
40.0	180.72	171.43	171.43	176.99	170.45	174.21	5.13
50.0	167.13	171.43	149.63	164.84	161.29	162.86	10.90
60.0	175.44	175.95	170.94	165.75	167.60	171.14	5.10
70.0	148.51	161.29	197.37	169.49	172.91	169.92	24.43
80.0	160.86	159.15	165.75	160.00	157.48	160.65	4.13
90.0	161.29	157.89	168.54	154.24	146.70	157.73	10.92
100.0	152.67	142.52	145.99	145.99	143.88	146.21	5.08
110.0	153.85	153.85	151.52	150.75	172.41	156.48	10.83

120.0	136.05	161.29	152.28	154.24	149.25	150.62	12.62
130.0	149.63	144.93	151.90	161.73	150.75	151.79	8.40
140.0	182.93	148.15	155.84	153.45	155.44	159.16	17.39
150.0	169.97	139.53	155.84	153.45	155.44	154.85	15.22

Table 2: Processed data illustrating the depth(mm) and velocity

Graph 1: The data from Graph 1 was taken from the processed data from Table 2.

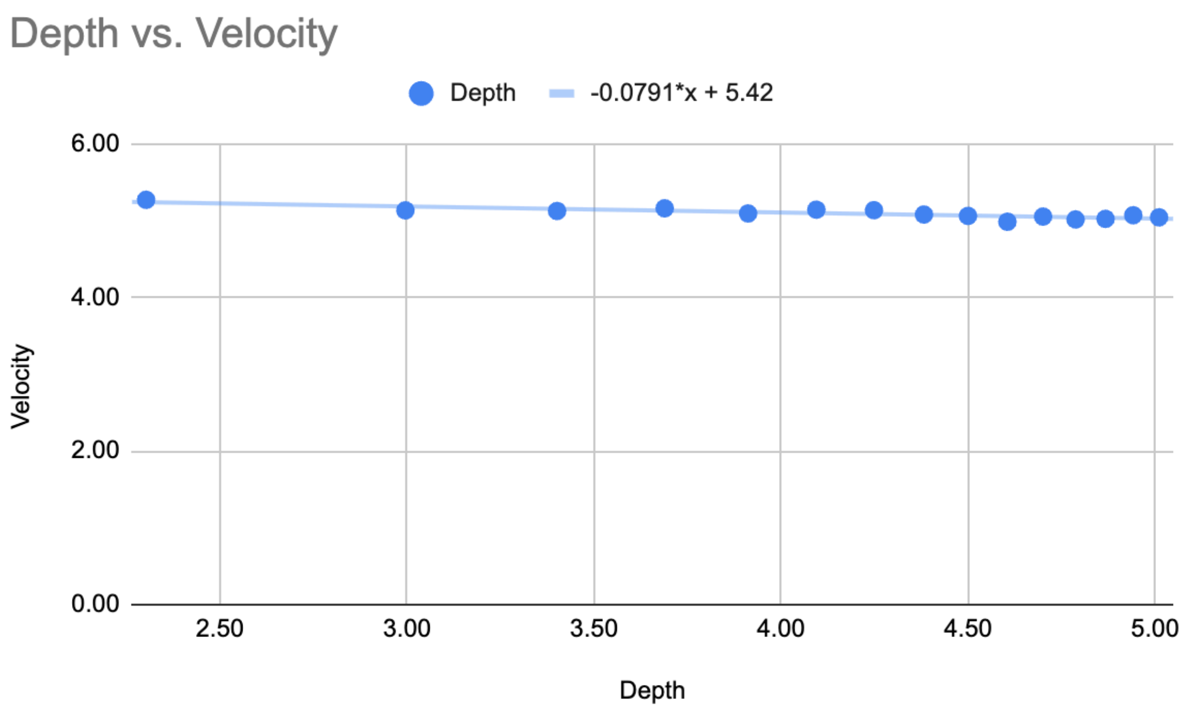


Each of the error bars were calculated individually by subtracting the minimum value for a variation from the maximum value from that same variation

214.29-183.49=30.8

Log-Log Graph:

This log-log graph was completed by calculating the log base for each average of all the variations.

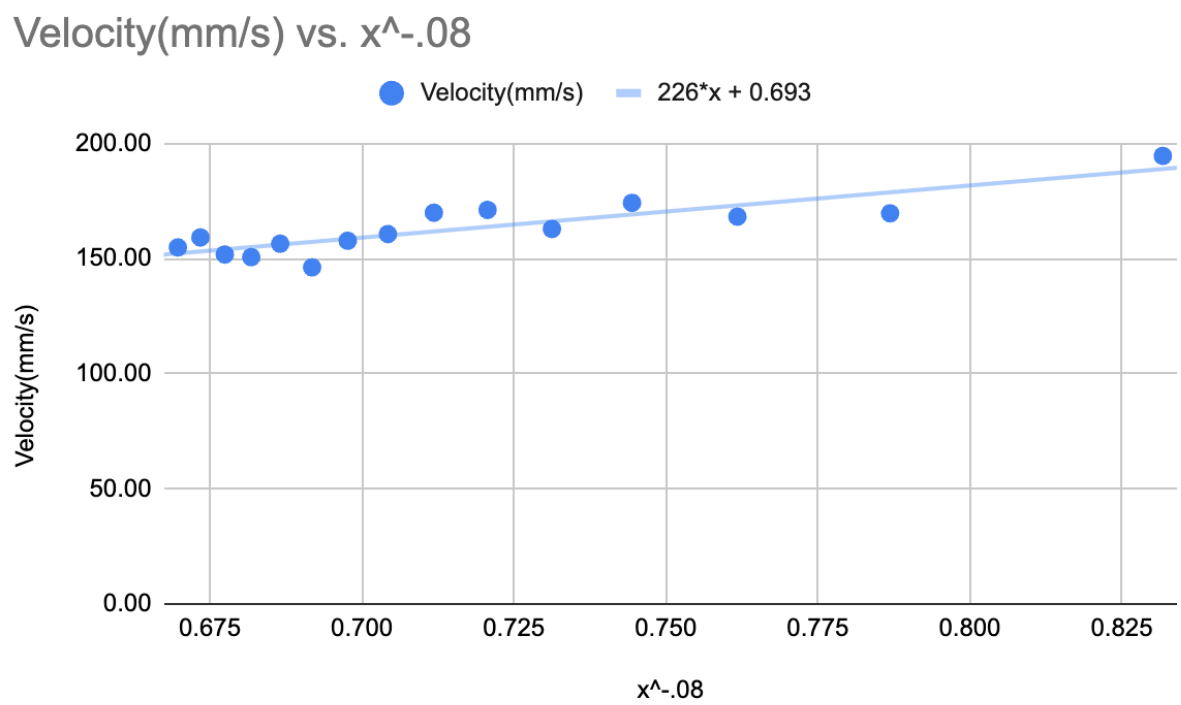


Once I created the log-log graph, I used the exponent to create a linearized graph. This was done by raising the depth of a variation to the power of the exponent.

10^-0.08=0.832

I did this for each trial, then created a graph with all of the average velocities and depth calculations.

Linearized Graph:



Conclusion: [.:. Top]

After analyzing the data, I concluded that there was a pattern between depth and velocity. As the graphs above show, there is a gradual decrease in velocity the more the depth increases. Although my hypothesis was correct, there was great error throughout the experiment. The cause of this was likely due to human error and accuracy.

One possible error is the depth of the water being inaccurate. The ruler used to measure the depth may have been viewed from an angle that could cause a mistake. Another possible error is the bottom of the sink may be slightly sloped, thus causing inconsistent measurements. The velocity(mm/s) was fairly inconsistent throughout each trial and variation. This may have caused my calculations to have inaccuracies, thus affecting my evaluation. If I were to do this experiment again, I would make sure the sink had no slope by using an inclinometer.

Along with the flaws of my setup, there were also human errors throughout. One possible error was the delayed or early start and ending of the stopwatch. Humans are imperfect, thus it’s reasonable to assume that the timer could be a great source of error.

Another potential error is the placement of the syringe. There's a chance that the syringe moved slightly with each trial. Despite being held in place by a gate over the sink, the angle of the syringe may have caused further errors. If I repeated this experiment a second time, I would have recorded each trial on video with the stopwatch present, so I could do flawless time recordings. There were additional tools I could have used to keep the syringe the same throughout every trial.

With any further experiments I conduct in the future, I would apply the solutions I thought about in my conclusion in the actual experiment. This way my future experiments will have little to no errors, whether human or setup.

Works Cited: .:. Top

Roberts, Jane. 2003. *Royal Treasures: A Golden Jubilee Celebration*. London: Thames & Hudson. https://www.rct.uk/collection/912660/studies-of-water

Hadj-Larbi, Fayçal. n.d. "Sezawa SAW devices: Review of numerical-experimental studies and recent applications." *Elsevier* 292 (2019): 1-216. https://www.sciencedirect.com/topics/physics-and-astronomy/rayleigh-waves