Einstein versus Water Flea
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Background, Purpose, and Hypothesis

During a class tour at The Perimeter Institute, " The (De)mystifying of Einstein's Speed of Light Postulate"[1] was presented with an analogy using waves on a pond. Water waves are also frequently used to describe other properties of light waves, such as interference and diffraction. The purpose of this project is to investigate if water waves could also (de)mystify Einstein's other postulates. We believe that *The Special Theory of Relativity* can be developed analogous to waves in a pond.

Procedure

This project involves five experiments, models, and a thought experiment. The pattern shown in ***Figure 1*** was marked on the bottom of a water tank measuring 80 X 40 X 20 cm which was filled with water at room temperature. Points **CBDA** formed a diamond with all sides equal to 25 cm. Water Fleas Alice and Bob, constructed of sponge were anchored at positions A and B. Golf balls and a ramp provided the source of water waves.

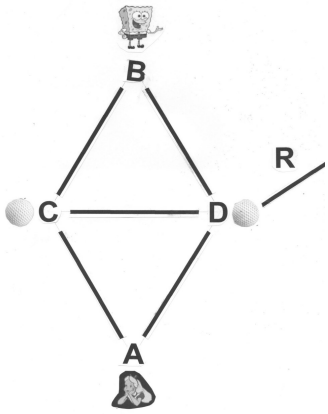

Figure 1

Experiment 1: One golf ball was dropped into the water at point D. A stopwatch was used to measure the time for the wave pulse to reach Alice and to reach Bob.

[1] http://www.perimeterinstitute.ca/activities/community/teachers/lightpostulate.pdf

Experiment 2: The golf ball was rolled down Ramp R and dropped at point D. The time required for the wave pulse to reach Alice and Bob was recorded.

Experiment 3. Golf ball G1, was dropped at point D and golf ball G2, was dropped simultaneously at point C. The times when the wave pulses from both balls reached Alice and Bob were recorded.

Experiment 4: Experiment 3 was repeated but Bob was put into motion at various speeds moving from the left of B and parallel to C and D. When the moving Bob was at position B, both golf balls were simultaneously dropped at C and D. The times when the wave pulse from C and D reached Alice and Bob were recorded.

Experiment 5. A smaller tank, with dimensions of 40 X 20 X 10 cm, was placed parallel to points C and D with points C' and D' mirrored in the smaller tank. With the smaller tank stationary, four golf balls G1, G2, G3 and G4 were simultaneously dropped at points C, C', D and D'. This was repeated with the smaller tank in motion parallel to C and D. The times when the wave pulses from C, C',D and D' reached Alice and Bob were recorded. All experimental results were statistically analysed.

Experimental Results

Experiments 1, 2, and 3 all showed an average time of 1 second to travel 25 cm.

Experiment 4 resulted in Alice receiving simultaneous wave pulses from C and D after 1 s. However, Bob received the D wave pulse first, before 1 s, and received the second wave pulse from C after 1 s.

Experiment 5 resulted in simultaneous wave pulses from C' and D' for Bob and simultaneous wave pulses from C and D for Alice. When the tank was in motion, Bob also recorded non-simultaneous pulses from C and D.

Simultaneity Box : Materials and Results

In order to study the similarities between water and light waves, a simultaneity box (***Figure 2***) was constructed. Using a cassette box with two movable arms secured by a dowel, simultaneity measurements were made by moving the dowel (Einstein or Water Flea) at different speeds sideways. The freely moving ends of the arms measured the times of each wave pulse. The simultaneity box was calibrated using our experimental data and manual calculations of both light and water wave speeds and their associated times. Since the measurements are based on wave speeds, the instrument was scaled so that 10 cm on the arm measured the distance that a wave would travel in 1s. For the water wave, 10 cm on the arm would represent 25 cm and for the light wave, 10 cm would represent 30 billion cm. Measurements showed that when the velocity of the observer was expressed as a ratio of the wave speed, the observer recorded similar non-simultaneous times for both water and light waves.

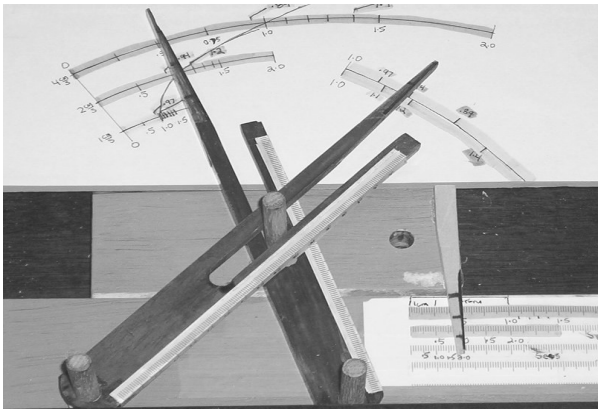

Figure 2

Conclusions

1. "The principle of the constancy of the velocity of light" [2] is one of the postulates of the Special Theory of Relativity. Experiment 1 and 2 concluded that the speed of a water wave is constant and is independent of the velocity of the source .

[2] Einstein's Theory of Relativity, pg. 232, Max Born, Dover publications, 1965

2. Einstein (using a train and lightning) in describing the principle of simultaneity said, "Events which are simultaneous with reference to the [embankment] are not simultaneous with respect to the [train], and vice versa (relativity of simultaneity)" [3]. Experiment 3 and 4 showed that a simultaneous event being observed by two motionless observers equidistant from the event were simultaneous. However a simultaneous event relative to one observer was not necessarily simultaneous to another observer in motion.

3. "The principle of Relativity assumes that all physical laws apply equally to any frame of reference" [4]. Experiment 5 illustrated that the laws of physics were equal for either observer in their respective frames of reference. It can be concluded that water waves are a good model for Einstein's Theory of Special Relativity.

Thought Experiment and Areas for Further Study

Experiment 5 did show some puzzling observations. The area of the time triangle for Bob in the moving tank remained the same as Alice's. In Einstein's original "*train and lightning*" thought experiment the lightning struck the embankment only. What if the lightning struck the ends of the train only (***Figure 3***)? An observer M midway between A and B will conclude that the strikes of lightning and an increase in temperature from A and B were simultaneous. With the train and observer M, now at high velocity, he will observe the lightning flash from A before he sees the

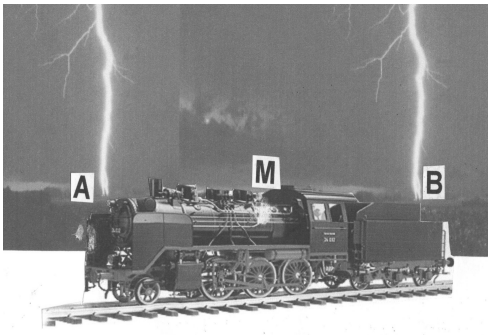

Figure 3

[3] Relativity, pg 30-31, Albert Einstein, Three Rivers Press, 1952, NY, NY

[4] Einstein's Theory of Relativity, pg. 232, Max Born, Dover publications, 1965

lightning flash from B, *principle of simultaneity.* What about the rise in temperature from A and B? The ends of the train are in M's frame of reference and M has to observe the rise in temperature from A and B as simultaneous, *principle of relativity*. The sequence recorded by M in the moving train would be; flash from A first, then the heat from A and B simultaneously and later the flash from B. This is essentially part 2 of Experiment 5. Using a wooden boat filled with water and the simultaneity box the same results were observed. When Bob was in a wooden boat, his time-area was the same as Alice's. Replacing the wooden boat with a sponge boat it was observed that the length of the sponge boat and Bob's time-area contracted with motion. These results need to be investigated further.

Einstein in1928 said, "According to the general theory of relativity, space with out ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time. But this ether may not be thought of as endowed with the quality characteristics of matter, as consisting of parts ('particles") which may be tracked through time"[5]. The quantum world permits virtual particles that posses no characteristics of matter and may not be tracked through time. These virtual particles could be the elusive "***windless"*** ether that Einstein is talking about.

Acknowledgements

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[5] http://www.spaceandmotion.com/

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