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Using a smartphone application to measure the properties of water waves in the DIY Ripple Tank experiment set

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Abstract

The teaching of wave physics has developed over the years, including devices that demonstrate water waves being used effectively for a long time. However, it was not easy to select and display the wave frequencies. This research had developed a DIY Ripple Tank experiment set using a smartphone application to measure the properties of water waves. The vibrations of the source characterized by points and bars with a speaker and a small amplifier (model GF1002) connecting to the source with a wave ball displayed on the screen. The apparatus controlled the wave source by adjusting the frequency ranging from 10–30 Hertz via the PhyPhox application on a smartphone. Waves then were created in two types of liquid: water and a salt solution. Images of waves appearing on the receiver were adjusted to a standstill by the Strobe Light Tachometer application on the smartphone which allows us to adjust flashing light frequencies to match the frequency of the wave and the frequency of the sound source. As a result, we found that this research shows the relationship according to the equation of speed of a sinusoidal wave at different viscosity coefficients of the liquid. The speed of the wave in water and salt solution were found to be 0.079 ± 0.003 m s^{-1} and 0.074 ± 0.005 m s^{-1}, respectively. This research can be applied in school as a demonstration showing that physics of the wave is easy and interesting.

1. Introduction

At present, physics is one of the most important subjects of science, studying the truth of nature both inside and outside the world [1, 2]. In the 21st century, students can learn and understand physics better [3, 4] by using technologies such as various applications in smartphones and technology teaching materials [5–8]. Technology allows students to have a more scientific imagination [9]. It helps students understand physics quickly from direct and virtual experience [10]. So, students can imagine the physics that are linked to other sciences and current technology.

In physics, oscillations and waves are one of the more interesting natural phenomena that have been studied for a long time [2]. However, students usually have difficulty understanding the content since most of the waves in daily life cannot be seen with the naked eye, such as sound and electromagnetic waves [2]. To understand waves, one must use his imagination to draw the image. Therefore, it is difficult for most students. Thus, the study of simple wave physics should begin with those waves visible to the naked eye, such as water waves.

Besides, students should have experience in experimenting with various properties of water waves. When students understand physics in visible waves, they can understand that of the invisible ones, such as sound and electromagnetic waves, as well. Properties of water waves that students need to understand include frequency, speed, and wavelength [2]. However, measuring the properties of direct water waves is difficult because the water waves that are being tested in the Ripple Tank appear continuously and not stable [11]. Therefore, the properties can be measured only when the water waves are stopped by using a stroboscope. Moreover, typical stroboscopes are not only expensive but also large and may not be suitable for use teaching in a school with the Ripple Tank. The solution comes when students and teachers nowadays have smartphones. In this paper, we have developed a set of adjustable wave frequency generator using applications in the smartphone and applied the stroboscope apps in the smartphone that are used to measure the properties of water waves in a DIY [1] Ripple Tank (DRT) experiment set.

2. Experimental setup and procedures

The DRT experiment set was created and consists of three main components, so called system 1, system 2, and system 3 as shown in figure 1. System 1 was the Ripple Tank making a square tray with an area of 3.6 m^2, which had a sloping edge tray 45° around all four sides. The floor plate of the tray was an acrylic sheet that was transparent and had a thickness of 3 mm. The tray was installed on the base frame which was made from 1 inch diameter PVC water pipe. The lamp was mounted on the top of the tray, where it was about 50 cm high from the tray and was equipped with an area 2.5 m^2 water wave reception area under the wave tray where it was located from the 40 cm tray as shown in figure 1(a).

System 2 was the source of mechanical waves from the sound frequency created by a DIY model. The wave generator material was made of two types of plastic, which were a 2.5 cm diameter sphere and 12 cm long parallel bars. They were installed in the center of the 10 cm diameter subwoofer speaker, which provided bass frequencies in the range of 10 Hz–50 Hz. The speaker was connected to the GF1002 Audio and Amplifier Modules. It was connected to the smartphone and was controlled by various frequencies with the Phyphox application on smartphone A as shown in figure 1(b). The Phyphox application on smartphone A was an application developed by RWTHAACHEN University [12] and can be downloaded for free from the Google Play and App Store.

System 3 was the apparatus used to make shadows of the water wave that were stagnated on the screen by controlling the flashing of the light using the Strobe Light Tachometer application on smartphone B as shown in figure 1(b). The Strobe Light Tachometer application on smartphone B was only available from the App Store for iOS devices and can be downloaded for free. The DRT experiment set was tested to identify the properties of the waves in 2.25 l of two types of liquid medium including water and a salt solution (with concentration of 26.23% by weight) on the wave tray. The studied frequencies released from the Phyphox application on smartphone A were 10 Hz, 15 Hz, 20 Hz, 25 Hz, and 30 Hz. The sound frequency signal was sent into the board amplifier, entered the speaker and was adjusted to vibrate down the wave generator. Water waves occurred on the DRT as a result. Water waves could be observed with the naked eye and display dark bands and bright bands on the screen. Then the Strobe Light the application on smartphone B was an application developed by Motionics LLC [13] and adjusted to match the light flashing frequency to that of the water wave. Images of the wave appearing on the screen are stopped as a result. Finally, the wavelength of the water wave was measured from the distance between two dark bands and was analyzed for the speed of water waves in equation (1). We note here some precautions while using smartphones A and

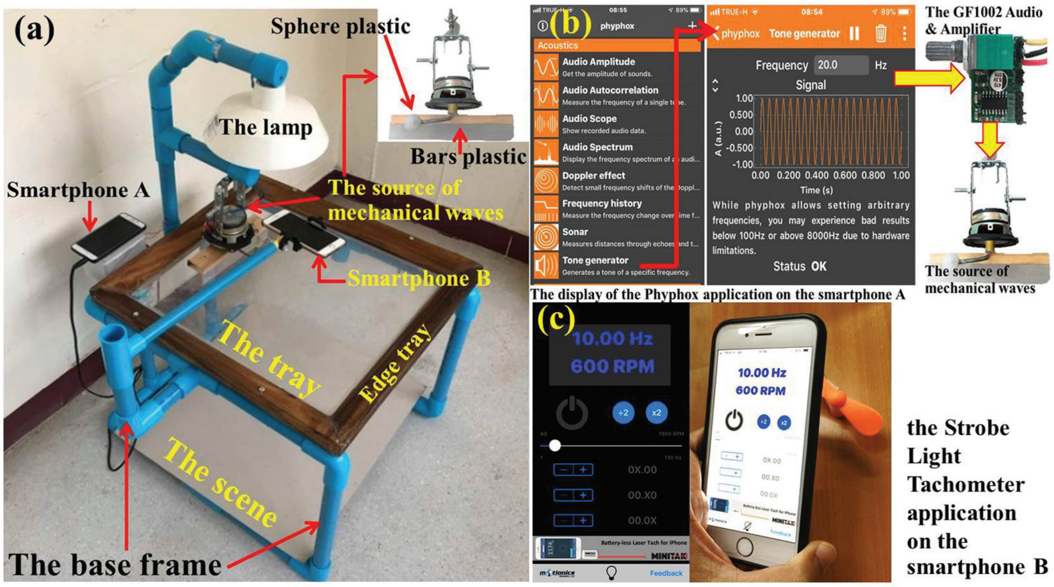

Figure 1. The DIY Ripple Tank (DRT) experiment set (a) was controlled and measured by the source of mechanical waves from the sound frequency created by a DIY model (b) and the Strobe Light Tachometer application on smartphone B (c). (© Copyright 2019: Motionics LLC).

B near the water in The Ripple Tank experiment set: (1) smartphone A and B must be fixed to the base; (2) water and salt in the tray must be handled carefully; (3) water and salt water are used in an appropriate amount for the wave tray capacity; (4) the DIY Ripple Tank experiment set must have a short circuit protection system in which electrical systems are stored in separate electrical insulation boxes.

3. Theoretical background

Some waves that were observed in nature represent a combination of transverse and longitudinal displacements. The study of waves should start with surface-water waves for a good example that can be seen by with the naked eye. Elements of water at the surface move in an almost circular path when water waves travel on the surface of deep water as shown in figure 2(a). The following equations represent the analysis mathematical model of a traveling wave. This model is used in situations in which a wave moves through space without interacting with other waves or particles. Figure 2(b) shows a snapshot of a traveling wave moving through a medium. Figure 2(c) is a graph of the position of one element of the medium as a function of time. The crest of the wave representing as a point in figure 2(b) is where the displacement of the element from its normal position is highest. The trough is the lowest point. The wavelength (λ) is the distance from one crest to the next. Generally, the wavelength is the minimum distance between any two identical points on adjacent waves as shown in figure 2(b) [2].

$$f = \frac{1}{T}. \tag{1}$$

In general, the period (T) is the time interval required for two identical points of adjacent waves to pass by a point as shown in figure 2(c). The period of the wave is the same as the period of the simple harmonic oscillation of one element of the medium. The corresponding unit for T is seconds (s). The same information is more often given by the inverse of the period that is called the frequency. In general, the frequency (f) of a periodic wave is the number of crests (or troughs, or any other point on the wave) that passes a given point in a unit time interval. The frequency of a sinusoidal wave is related to the period by the expression. The most common unit for frequency is s^{-1}, or hertz (Hz). The amplitude (A) is the maximum position of an element of the medium relative to its equilibrium position of the wave as indicated in figure 2. Waves travel with a specific

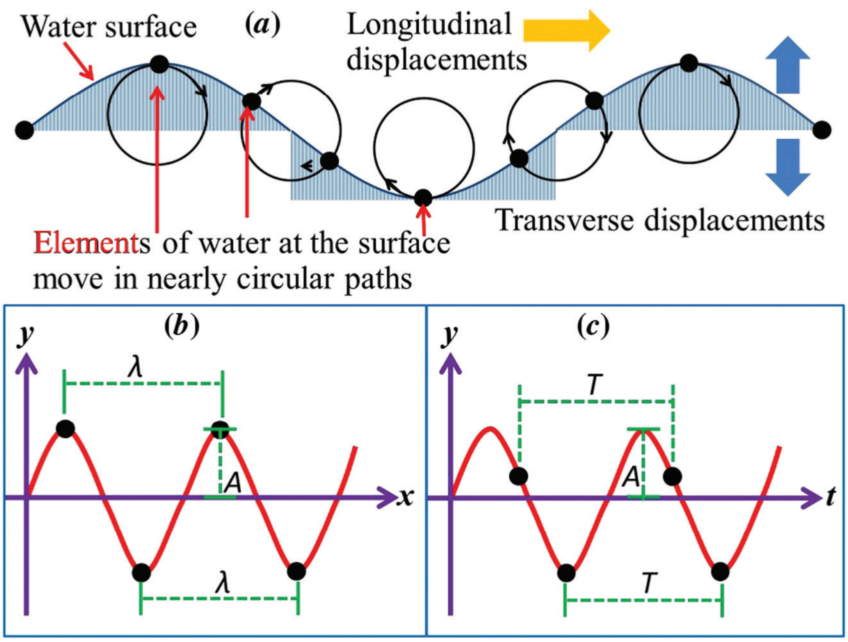

Figure 2. Diagrams of a wave propagating is a combination of transverse and longitudinal displacements in the model for explaining the motion of water elements on the surface of deep water (a). A snapshot of a sinusoidal wave and the wavelength (b). Function of time at the position of one element of the medium (c).

speed, and this speed depends on the properties of the medium being disturbed. For instance, sound waves travel through room-temperature air with a speed of about 343 m s^{-1}, whereas they travel through most solids with a speed greater than 343 m s^{-1}. The wave speed, wavelength, and period are related by the expression [2].

$$v = \frac{\lambda}{T}. \tag{2}$$

We can express the wave function in a convenient form by defining two other quantities, the angular wavenumber (k) and the angular frequency (ω) [2]:

$$k = \frac{2\pi}{\lambda} \tag{3}$$

$$\omega = \frac{2\pi}{T} = 2\pi f. \tag{4}$$

Using these definitions, the wave function equation for a sinusoidal wave can be written in the more compact form [2]

$$y = A\sin\left(kx - \omega t\right). \tag{5}$$

Using equations (1), (3) and (4), the wave speed v originally given in equation (2) can be expressed in the following alternative forms speed of a sinusoidal wave [2]:

$$v = \frac{\omega}{k} \tag{6}$$

$$v = \lambda f. \tag{7}$$

4. Experimental results

The image of the sample wave on the screen was frozen by the flashlight from the smartphone, where the frequency was equal to the frequency from the wave source equal to 10 Hz as shown in figure 3(a). The image of the wave on the screen moves away from the source of the wave when the flashlight was adjusted with decreasing frequencies, meanwhile, it moves towards the wave source when the flashlight was adjusted with increasing frequencies as shown in figures 3(b)–(d). Wave images from other frequencies were adjusted to the frequency of the light using the Strobe Light Tachometer application

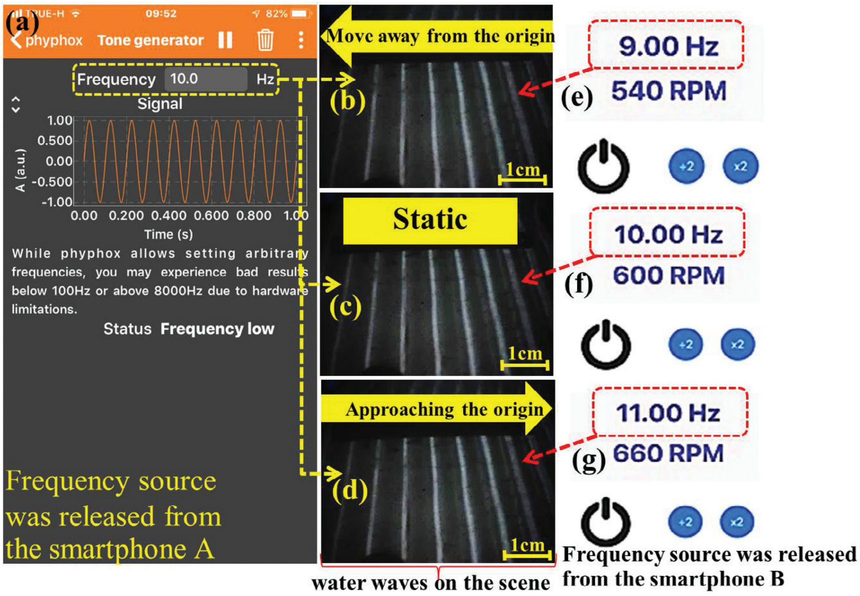

Figure 3. The results showing the source frequency was released from smartphone A (a), the image of water waves on the screen (b)–(d). The source frequencies released from smartphone B that match with that of the water wave released from smartphone A to make the image on the screen, which were found to be 9 Hz (e), 10 Hz (f) and 11 Hz (g).

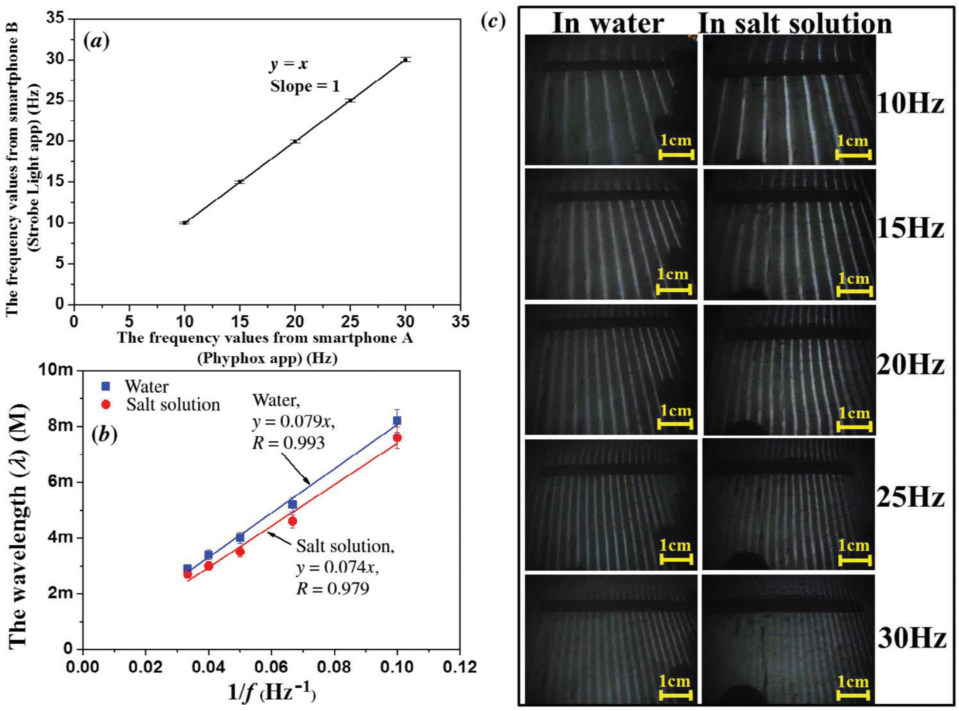

Figure 4. A comparison between the frequencies of the source released from smartphone A and those released from smartphone B (a). A comparison graph of frequencies versus wavelengths in water wave and in a salt solution (b). A comparison images of a water wave in a salt solution at various $(1/f)$values (c).

on smartphone B in figures 3(e)–(g), as in this example.

The frequencies of water waves measured by the Strobe Light application were 10 Hz, 15 Hz, 20 Hz, 25 Hz, and 30 Hz. The frequency difference between that from the Phyphox application and the Strobe Light application represented as a straight linear graph with the slope was equal to 1 as shown in figure 4(a). Because the wave frequency on the surface was equal to the frequency from the Phyphox application, which signals the wave source speaker.

Waves were studied in two mediums including a water and salt solution. We found that the wave speed on the medium could be calculated from the slope of the graph showing the relationship between the frequency of the medium from the Strobe Light application and wavelengths by measuring static waves on the screen. After that, the term $(1/f)$and wavelengths in equation (7), which is written in the form of a linear equation$\lambda = v \times (1/f)$, were determined by carrying out the linear fitting curve to the graph.

We found that the speed of a wave in the water (0.079 ± 0.003 m s^{-1}) was greater than that in the salt solution (0.074 ± 0.005 m s^{-1}) due to the water the viscosity coefficient (20.86 Ns m^{-2}) which was less than that of the salt solution (22.43 Ns m^{-2}). The results are presented in figure 4(c). The image of standing waves clearly showed the relationship between frequency and wavelength according to equation (7). The 1/frequency of the wave varied with the wavelength, which show that increasing the frequency (from 10 Hz,15 Hz, 20 Hz, 25 Hz, and 30 Hz, respectively) resulted in a reduction in wavelength i.e. shorter distance between bright lines on the screen.

5. Conclusions

The DRT wave tray set was made up of a simple and cheap DIY process. The wave source was made of the bar and spherical plastics using the DIY process in combination with speakers, amplifiers and the Phyphox application. The wave properties of the medium including water and salt solution were measured using the Strobe Light application and calculated using equation (7). We found that the frequency of the wave varies with the wavelength, which show that increasing frequencies resulted in reducing wavelengths, agreeing well with the theory. The speed of a wave in water was greater than that in a salt solution since the water had a smaller viscosity coefficient than that in the salt solution. We believe this low-cost DIY wave tray set used with smartphones could be used in schools for teaching the physics of waves.

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References

[1] Thepnurat M, Saphet P and Tong-on A 2017 Low cost DIY lenses kit for high school teaching *J. Phys.: Conf. Ser.* **901** 012120
[2] Serway R A and Jewett J W 2013 *Physics for Scientists and Engineers with Modern Physics* 9th edn (Boston, MA: Brooks/Cole Cengage Learning) pp 449–91
[3] Mellema S 2001 A physics lecture for the 21st century *Phys. Educ.* **36** 306
[4] Putri D H, Risdianto E and Sutarno S 2017 Pre-service physics teachers' perception toward hands-on lab activity and 21st century skills *J. Phys.: Conf. Ser.* **895** 012015
[5] Ramos P M, Silva M R and Silva P S P 2017 Smartphones in the teaching of Physics Laws: projectile motion *RIED* **20** 213–31
[6] Monteiro M, Stari C, Cabeza C and Marti A C 2019 Physics experiments using simultaneously more than one smartphone sensors *J. Phys.: Conf. Ser.* **1287** 012058
[7] Sans J A, Manjón F J, Pereira A L J, Gomez-Tejedor J A and Monsoriu J A 2013 Oscillations studied with the smartphone ambient light sensor *Eur. J. Phys.* **34** 1349
[8] Pierratos T and Polatoglou H M 2018 Study of the conservation of mechanical energy in the

motion of a pendulum using a smartphone *Phys. Educ.* **53** 015021
[9] Stinner A 2003 Scientific method, imagination, and the teaching of physics *PiC* **59** 335–46
[10] Gutiérrez J M, Mora C E, Díazand B A and Marrero A G 2017 Virtual technologies trends in education Eurasia *J. Math. Sci. Technol. Educ.* **13** 469–86
[11] Yapo S, Seesomboon E, Chattrapiban N and Pussadee N 2018 Surface water wave topography construction using free surface synthetic Schlieren method for demonstration of ripple tank wave phenomena *J. Phys.: Conf. Ser.* **1144** 012119
[12] Staacks S, Hütz S, Heinke H and Stampfer C 2018 Advanced tools for smartphone-based experiments: phyphox *Phys. Educ.* **53** 045009
[13] Motionics LLC 2019 Strobe light tachometer (https://apps.apple.com/us/app/strobe-light-tachometer/id978182913)

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