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Research Article

SPREADSHEET FOR PHYSICS: LISSAJOUS CURVE

Himawan Putranta[1] and *Heru Kuswanto[2]

[1]Postgraduate Student in Physics Education, Yogyakarta State University, Yogyakarta, Indonesia
[2]Doctor, Associate Professor at Physics Education Study Program, Yogyakarta State University, Yogyakarta, Indonesia

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ABSTRACT

In this research the researchers wanted to illustrate the physical materials about the Lissajous curve which is often taught by teachers in physics learning. This Lissajous curve is illustrated using a spreadsheet program on a computer or laptop. The advantages of spreadsheet programs that researchers use has a function as a program to process data in the form of numbers and can also be used to display graphics or curves more dynamic. Therefore, by using a program in a computer or laptop that is a spreadsheet program, it can easily and effectively process and display data in the form of numbers and graphic images simultaneously. Meanwhile, the result of this research is that the shape of the Lissajous curve is strongly influenced by the magnitude of the wave number (k) or in other words the wave number (k) is the component that has a major role in forming the Lissajous curve. By illustrating the Lissajous curve illustrated using this spreadsheet program, it is expected to facilitate students in understanding the wave matter especially about the Lissajous curve with active and enthusiastic participation..

INTRODUCTION

Technological advances have penetrated in all aspects of human life, both economic, social, health, defense and security, as well as the most fundamental technological advances in education (Ogunsola, 2005). One of the things that concerns in the advancement of education is the learning of physics by utilizing technological advances that exist (Lazzaro, 2015). Physical learning can be done by utilizing the progress of existing technologies such as computers, smart phones, or education video. It provide opportunities for students to focus on reasoning skills, understanding, critical thinking, and problem solving (Artigues, 2010). However, one of the most important things that must be done to maximize the potential of technological progress in physics learning is what device is in accordance with the stages of the development of students to support their learning activities (Oliveira & Napoles, 2017).

Nevertheless, most physics learning done by teachers or lecturers in teaching materials to students using computer assistance so that students during the learning activities take place will be more interesting, so that the material is learned more easily understood (Blas & Fernandez, 2008).One of the software in computer devices used by teachers or lecturers in teaching the material to students is to use software from spreadsheet program (Benacka, 2007). Therefore, through this article researchers will present and discuss the benefits of using a spreadsheet in describing or illustrating the Lissajous curve in physics learning.Through spreadsheet program, Lissajous curves are formed more subtle, dynamic, and can be modified curvanya shape in accordance with the value of the given quantity. Therefore, by simulating the Lissajous curve using this spreadsheet program, students are expected to be helped in understanding the wave material especially about the Lissajous curve because of the ease of operating this Lissajous curve simulation.

Spreadsheet programs have been used in managing and developing students' learning plans since 1985 (Hsiao, 1985). Research conducted by researchers especially computer-aided educational practitioners is focused on the goal of helping and improving the quality of learning activities and programming skills especially for novice students (Benacka, 2013). Around the nineties, a variety of studies have been conducted to apply computer science into constructivism of students' learning, software programs that support the easy application of constructivism in computer science are the spreadsheet program (Ben-Ari, 1998; Dybdahl, Sutinen, Tarhio, 1998; Benacka, 2012). Through spreadsheets, teachers can use

Corresponding author:* **Heru Kuswanto
Doctor, Associate Professor at Physics Education Study Program, Yogyakarta State University, Yogyakarta, Indonesia

problem-solving and heuristic methods in their learning execution. Therefore, students become accustomed to operating the spreadsheet program in supporting the understanding of the material in the learning activities, so that the teacher can focus on the activities of learning guidance and the preparation of learning activity planning (Benacka, 2013).

Spreadsheets is an important program for teachers and educators to design learning activities, as this spreadsheet program can complete complex math, statistics, and graphics tasks without the need for complicated software programs (Petersdinh & Beaumont, 2017). In mathematics and physics learning, a spreadsheet program can help students to understand polynomial functions and other functional forms (Alagic & Palenz, 2006; Sadri, 2015). Spreadsheets are used to speed up calculations, one of which is the computation of complex numbers that can't be solved on calculators and standard graphs (Petersdinh & Beaumont, 2017). Spreadsheet programs have also been used to model many phenomena or natural events that appear in the realm of science and engineering, one of which uses VisiCalc software to create two-dimensional heat flow animations (Arganbright, 1985). In addition, Orvis (1997) also uses a spread sheet program to discuss materials about heat flow. Similar to that of Mohamed (2016) which states that the use of spreadsheet programs in learning especially physics learning strongly supports the learning process because the program is used to simulate basic analysis related to thermal fluid system material by presenting three related examples of the subject of heat transfer, fluid dynamics, and thermodynamics.

Agreeing with previous opinion, spreadsheet program can be used as a learning media that can support students to understand learning materials especially physics materials and interests of students more easily and interesting (Robinson, 2011). Through the use of this spreadsheet program in the learning activities is also expected to be one of the choices of various learning media used, this is because the spreadsheet itself is able to be used to develop the potential possessed by students and teachers as well as stimulate the physics learning material becomes easier understood, interesting, and varied and also challenged the curiosity in students (Shabrina & Kuswanto, 2018). The results of research conducted by Miller and Sugden (2009) show that through the use of spreadsheet programs in learning activities, students can acquire new ideas and mathematically strong conceptual understanding of the material taught by teachers, students' ability in terms of image and mathematical representation of a phenomenon can develop well, and students' mathematical abilities grow rapidly.

In this article the researchers present an illustration of the Lissajous curve formed through the speadsheet program and provide a brief summary of the codes used in spreadsheet program to illustrate the Lissajous curve. Based on what the researcher did about the lustration presentation of the Lissajous curve formed through the speadsheet program, there are also similar research results with the presentation of curves or graphs using a spreadsheet. Based on the results of research Gebeily & Yushau (2007) shows how the curves in the graphs are displayed through a spreadsheet program in rectangular and parametric forms.

MATERIALS AND METHODS

All waves have some distinctive characteristics that can be used to describe them, as in Figure 1 below which shows that periodic waves that appear to be frozen in time (Edwards, Dick, Callcott, Brown, Geddis, Gue, James, McCaul, & McGuire, 2003: 354). The horizontal line through the center is the position of rest or equilibrium with the highest point on the wave is the peak and the lowest point is the trough (Edwards *et al.*, 2003: 355). Amplitude (A) is the distance between the rest position and the symbol or the trough. The wavelength (λ, Greek lambda) is the shortest distance between two points in the medium in phase. Therefore, two adjacent peaks separate one wavelength. Similarly, two adjacent troughs are one separate wavelength.

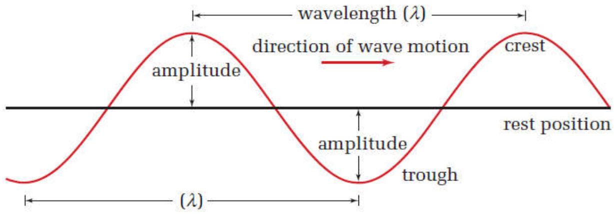

Figure 1 Characteristics of Wave in General (Edwards *et al.*, 2003: 355)

If the waves are no longer frozen in time but are in motion, the wave frequency (f) is the sum of the complete wavelengths passing through a point in a given amount of time with the unit of hertz, the frequency of the wave is the same as the source frequency that produces it, so it is independent of the propagation medium (Edwards *et al.*, 2003: 355). When the particles of the medium vibrate perpendicular to the direction of wave motion, the wave is called a transverse wave, for example a rope is vibrated one end. However, when the medium particles vibrate parallel to the direction of wave motion, they are called longitudinal waves, for example sound waves. Provided that limit ourselves to a one-dimensional non dispersive wave (a wave whose shape does not change as the wave progresses), any function, g, of the form

$$y(x,t) = g(x \pm vt + \phi). \quad (1)$$

Equation 1 above is the equation for traveling wave (transversal), equation 1 is the wave equation moving in the direction of $\mp x$with velocity v and arbitrary phase ϕ (Robinson &Jovanoski, 2011).An important point in this material is that the position variable x, and the time variable t, must occur in the combination of $x \pm vt$as the equation describing the current wave. Propagation or phase v velocity relates to wavelengthλ, frequency f, angular frequency ω, and the wave number k, whose relation can be written like the following equation 2 (Robinson & Jovanoski, 2011),

$$v = \lambda f = \frac{\omega}{k} \quad (2)$$

where $\omega = 2\pi f$and $k = \frac{2\pi}{\lambda}$. (3)

A very important principle in wave motion, and an important point for the simulations presented here, is the principle of linear superposition. Thus, if the medium is subject to two sine waves, travelling in opposite directions, of amplitudes $A_1$and A_2respectively, with different angular wave numbers, angular frequencies and phases, the resultant wave amplitude which can be written like equation 4, but if there is only one wave and no superposition, then the equation is like in equation 5 below(Robinson & Jovanoski, 2011),

$$y(x,t) = A_1\, sin(k_1x - \omega_1 t + \phi_1) + A_2\, sin(k_2x - \omega_2 t + \phi_2) \quad (4)$$

$$y(x,t) = A\, sin(kx - \omega t + \phi) \quad (5)$$

One application of the current wave in the matter of physics is the wave or Lissajous curve. Lissajous figures or curves arise when oscillations at right angles are combined, and are usually displayed on cathode ray oscilloscopes and Lissajous figure formed by the two waves (Robinson & Jovanoski, 2011).

In this research, researchers discuss about illustration or depiction of superposition wave equation as in equation 4 and 5 to find out Lissajous curve using spreadsheet program. For example, $t = 0\, s$to $t = 5\, s$and $x = 0\, m$to $x = 10\, m$. In conducting this research using a spreadsheet program, in cell (A1) the researcher writes the value of *x,* the (F1) cell of the researcher writes the value of *t*, and the (J) cell writes the principal values contained in the wave equation as shown in Figure 2 below.

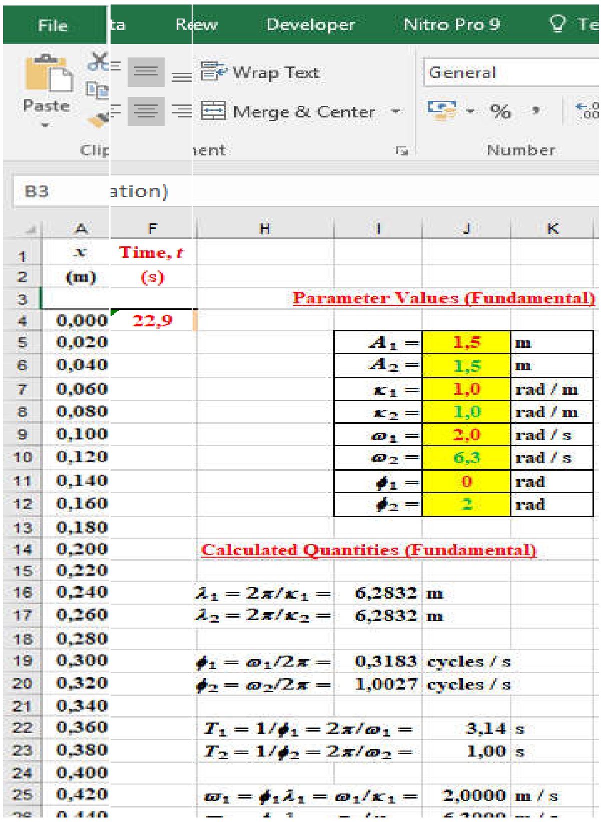

Figure 2 Input for the Value $t = 0\, s, x = 0\, m$ to $x = 10\, m$, and Principal Values Contained in Wave Equation

Meanwhile, in Figure 3 the following guidelines are provided for designing illustrations or drawings of the Lissajous curve. In this case on cell B1 the researcher writes y1 or the first wave, the researcher C1 cells write y2 or the second wave, and the researchers write the speradsheet formula on cell B4 for the first wave and in cell C4 for the second wave adjusted in Equations 4 and 5.

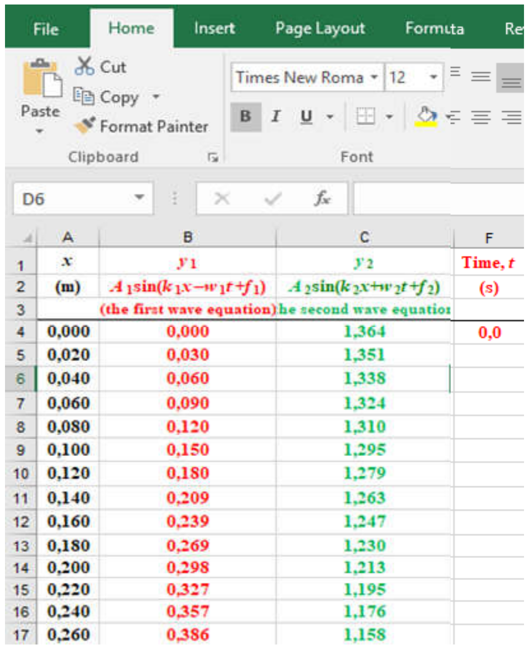

Figure 3 Input to Design Illustrations of Lissajous Curve

The sperasheet formula written by researchers on B4 cells to illustrate the first wave can be written as follows=$J$5*($N$18*SIN($J$7*A4$J$9*$F$4+$J$11)+$N$19*1/3*SIN(3*($J$7*A4$J$9*$F$4+$J$11))+$N$20*1/5*SIN(5*($J$7*A4$J$9*$F$4+$J$11))+$N$21*1/7*SIN(7*($J$7*A4$J$9*$F$4+$J$11))+$N$22*1/9*SIN(9*($J$7*A4-$J$9*$F$4+$J$11)))and the sperasheet formula written on cell C4 for the second wave can be written as follows=$J$6*($O$18*SIN($J$8*A4+$J$10*$F$4+$J$12)+$O$19*1/3*SIN(3*($J$8*A4+$J$10*$F$4+$J$12))+$O$20*1/5*SIN(5*($J$8*A4+$J$10*$F$4+$J$12))+$O$21*1/7*SIN(7*($J$8*A4+$J$10*$F$4+$J$12))+$O$22*1/9*SIN(9*($J$8*A4+$J$10*$F$4+$J$12))).

Meanwhile, Fig. 4 shows all the components as well as the first and second wave equations to form or illustrate the Lissajous Curve.

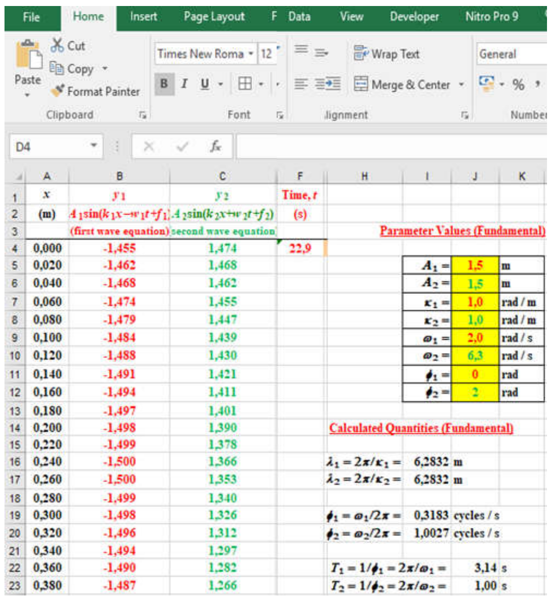

Figure 4 The Components to Illustrate Lissajous Curve

Then, to formulate a Lissajous graph or curve, then columns B and C must be blocked. The next step is to select the Insert option on the Menu Bar, select Scatter, and select Smooth Lines and Markers as shown in Figure 5 below.

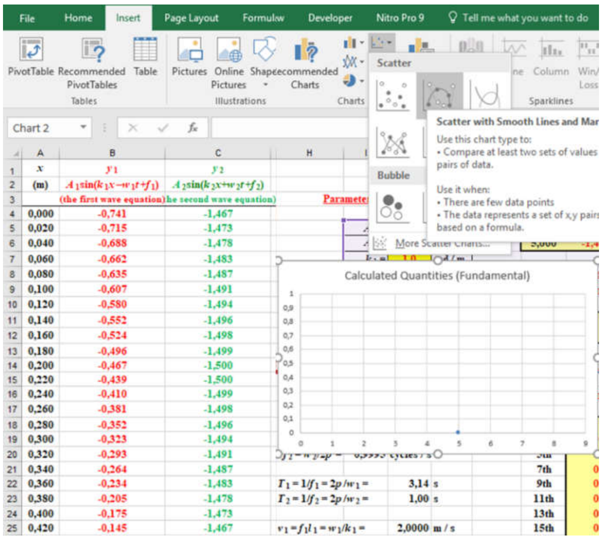

Figure 5 Designing Graphs to Illustrate Lissajous Curve

RESULT AND DISCUSSION

After formulating a Lissajous chart or curve by selecting the Insert option on the Menu Bar, select Scatter, and select Smooth Lines and Markers, then the next step will form the Lissajous curve in accordance with the given input or desired quantity.In accordance with the components or magnitudes affecting the resulting Lissajous curve shown in Figure 4, the Lissajous curve formed can be shown as in Figure 6 as follows.

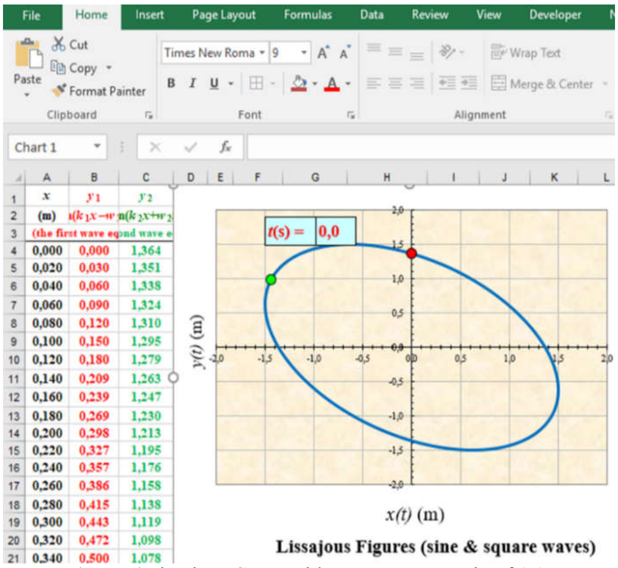

Figure 6 Lissajous Curve with a Frequency Ratio of 1:1

Based on Figure 6 above, it can be explained that the Lissajous curve is in a circle or in other words the Lissajous curve with a frequency ratio of 1:1. This is caused by the quantities or components of the first and second wave equations, namely Amplitude (A), frequency (f), and its wave number (k) are the same between the first and second wave, as follows$A_1 = A_2$of 1,5 m, $f_1 = f_2$ of 1 Hz, and $k_1 = k_2$ of 1,0 rad/s. The Lissajous curve formed as in Figure 6 is a representation of the Lissajous curve with a phase difference of 90° which has the same frequency and amplitude between wave one and the second wave. However, if the wave number (k) and frequency (f) between the first wave and the second wave is changed to not equal, then the shape of the Lissajous curve will not form a circle, but form the superposition of the sine wave as shown in Figure 7 as follows.

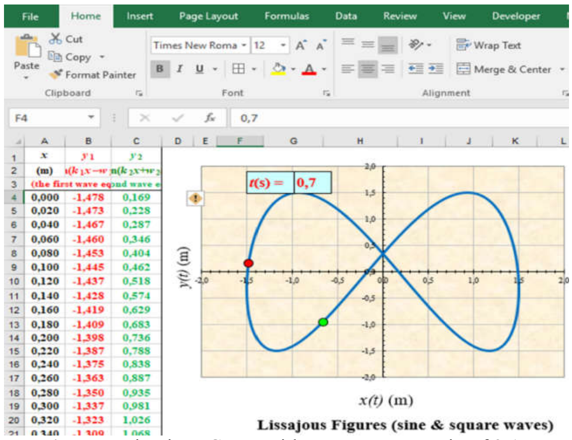

Figure 7 Lissajous Curve with a Frequency Ratio of 2:1

Based on Figure 7, the Lissajous curve formed is not like the one formed in Figure 6 which makes the circle, but since the wavelength between the two waves is not the same, the Lissajous curve formed forms sinusoidal waves.As shown in Figure 7 above, the magnitude of the wave number (k) and frequency (f) for the first wave and the second wave are not the same, $k_1 = 1$ rad/mand $k_2 = 2$ rad/m and $f_1 = 1$ Hzand $f_2 = 2$ Hz, but the amplitude for the two waves is of equal magnitude, that is equal to $A_1 = A_2$ of 1,5 m. Therefore, the Lissajous curve formed will not form a circle or in other words the Lissajous curve with a frequency ratio of 2:1.The Lissajous curve formed as shown in Figure 7 is a Lissajous curve representation with a phase difference of 90° which has different frequency and wave numbers between the first wave with the second wave and the same amplitude between wave one and second wave.

Meanwhile, if the physics quantities affecting the Lissajous curve illustrated by the speradsheet program are similar in magnitude to the same amplitude between the two waves, the wavelength and frequency of the two waves are different, the Lissajous curve illustrated can be shown as in Figure 8 below.

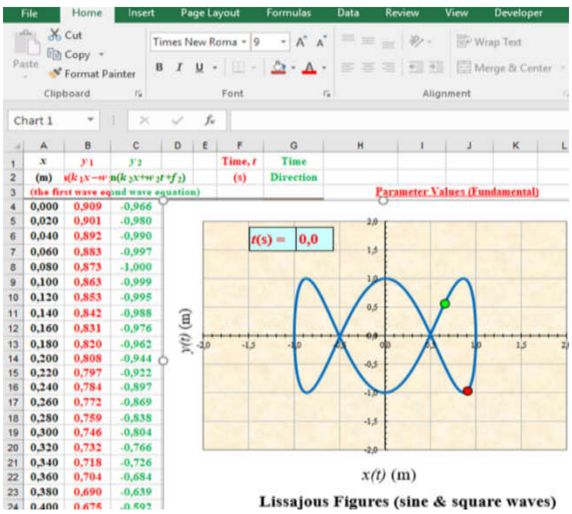

Figure 8 Lissajous Curve with a Frequency Ratio of 3:1

Based on Figure 8, it can be argued that the Lissajous curve formed does not form a circle as shown in Figure 6, but forms a Lissajous curve formed from the combination of two sinusoidal waves. As shown in Figure 8, the magnitude of the wave number (k) and frequency (f) for the first wave and the second wave are not the same, $k_1 = 1$ rad/mand $k_2 = 3$ rad/m and $f_1 = 1$ Hz and $f_2 = 3$Hz, but the amplitude for the two waves is of equal magnitude, that is equal to $A_1 = A_2$ of 1,5 m. Therefore, the Lissajous curve formed will not form a circle or in other words the Lissajous curve with a frequency ratio of 3:1.The Lissajous curve formed as shown in Figure 8 is a Lissajous curve representation with a phase difference of 90° which has different frequency and wave numbers between the first wave with the second wave with the frequency and the second wave number three times the frequency and the first wave number. The Lissajous curve formed in Figure 8 above can be represented in a vertical or horizontal position depending on the frequency ratio and the wave number between the two waves.

However, in contrast to Figure 8 which has a large difference in frequency and wave number of three times the magnitude of the first frequency and wave number. In Figure 9, the ratio of physical quantities affecting the Lissajous curve that is formed such as frequency and wave number is greater than the ratio of the physical quantities of frequency and the wave numbers that form the Lissajous curve in Figure 8.

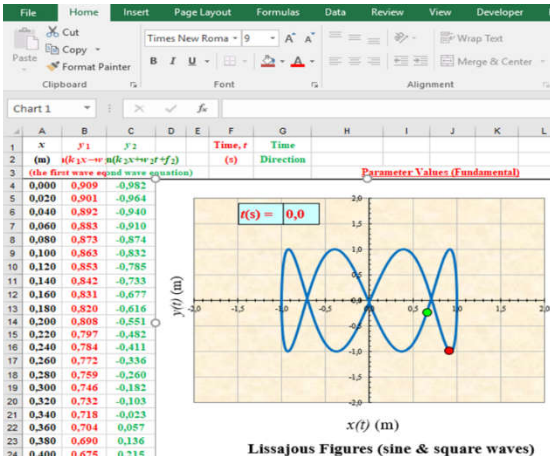

Figure 9 Lissajous Curve with a Frequency Ratio of 4:1

Based on Figure 9, it can be argued that the Lissajous curve formed does not form a circle as shown in Figure 6, but forms a Lissajous curve formed from the combination of two sinusoidal waves. As shown in Figure 9, the magnitude of the wave number (k) and frequency (f) for the first wave and the second wave are not the same, $k_1 = 1$ rad/mand $k_2 = 4$ rad/m and $f_1 = 1$ Hz and $f_2 = 4$Hz, but the amplitude for the two waves is of equal magnitude, that is equal to $A_1 = A_2$ of 1,5 m. Therefore, the Lissajous curve formed will not form a circle or in other words the Lissajous curve with a frequency ratio of 4:1.The Lissajous curve formed as shown in Figure 9 is a Lissajous curve representation with a phase difference of 90° which has different frequency and wave numbers between the first wave with the second wave with the frequency and the second wave number four times the frequency and the first wave number.

Meanwhile, for a Lissajous curve image that uses a physical quantity of a frequency and a wave number whose ratio of three to two between the first and second wave can be shown as in Figure 10 below.

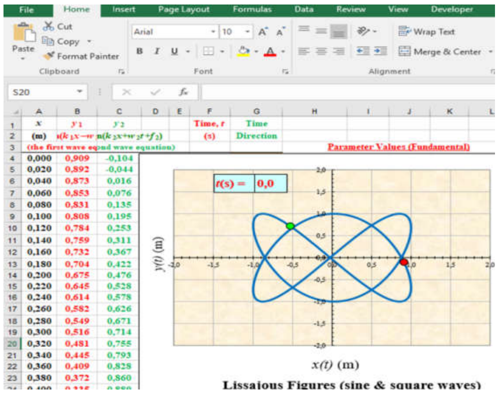

Figure 10 Lissajous Curve with a Frequency Ratio of 3:2

Based on Figure 10, it can be argued that the Lissajous curve formed does not form a circle as shown in Figure 6, but forms a Lissajous curve formed from the combination of two even more sinusoidal waves. As shown in Figure 10, the magnitude of the wave number (k) and frequency (f) for the first wave and the second wave are not the same, $k_1 = 2$rad/mand $k_2 = 3$ rad/m and $f_1 = 2$Hz and $f_2 = 3$ Hz, but the amplitude for the two waves is of equal magnitude, that is equal to $A_1 = A_2$ of 1,5 m. Therefore, the Lissajous curve formed will not form a circle or in other words the Lissajous curve with a frequency ratio of 3:2.The Lissajous curve formed as shown in Figure 10 is a Lissajous curve representation with a phase difference of 90° which has different frequency and wave numbers between the first wave with the second wave with the frequency and the second wave number three-by-two times the frequency and the first wave number. The Lissajous curve formed in Figure 10 above can be represented in a vertical or horizontal position depending on the frequency ratio and the wave number between the two waves.

Meanwhile, for a Lissajous curve image that uses a physical quantity of a frequency and a wave number whose ratio of four to three between the first and second wave can be shown as in Figure 11 below.

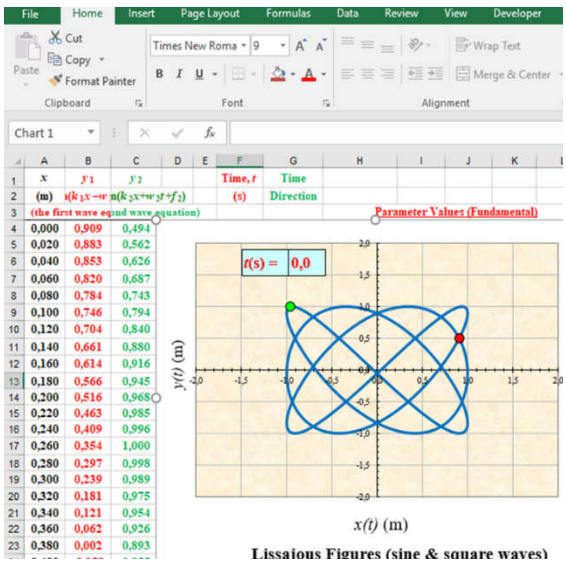

Figure 11 Lissajous Curve with a Frequency Ratio of 4:3

Based on Figure 11, it can be argued that the Lissajous curve formed does not form a circle as shown in Figure 6, but forms a Lissajous curve formed from the combination of two even more sinusoidal waves. As shown in Figure 11, the magnitude of the wave number (k) and frequency (f) for the first wave and the second wave are not the same, $k_1 = 3\text{rad/m}$and $k_2 = 4\text{ rad/m}$ and $f_1 = 3\text{Hz}$ and $f_2 = 4\text{Hz}$, but the amplitude for the two waves is of equal magnitude, that is equal to $A_1 = A_2$ of 1,5 m. Therefore, the Lissajous curve formed will not form a circle or in other words the Lissajous curve with a frequency ratio of 4:3. The Lissajous curve formed as shown in Figure 11 is a Lissajous curve representation with a phase difference of 90° which has different frequency and wave numbers between the first wave with the second wave with the frequency and the second wave number four-by-three times the frequency and the first wave number.

Therefore, based on the Lissajous curve formed in Figure 6to Figure 11, it can be discussed together that the quantity or component of wave number (k), frequency (f), and amplitude (A)are the components that have a major role in forming the Lissajous curve or in other words that wave number (k), frequency (f), and amplitude (A)greatly affect the shape of the waves that are formed.Thus, teachers should also be prosecuted by professionals in explaining the material of the Lissajous curve clearly to students by explaining the shape of the Lissajous curve formed by the change in the value of the wave number (k), frequency (f), and amplitude (A).

CONCLUSION

Based on results and discussion, it can be concluded that one spreadsheet program can be used to illustrate the Lissajous curve in physics learning. Through the illustration of the Lissajous curve illustrated using this spreadsheet program, it is expected to facilitate students in understanding the material of the Lissajous curve. In addition, the wave number (k), frequency (f), and amplitude (A) are the components that have a major role in forming the Lissajous curve or in other words that the wave number (k), frequency (f), and amplitude (A) greatly affects the waveform formed.

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