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THE RELATIONSHIP BETWEEN WAVE PROPAGATION SPEED AND TENSION OF BOUND END STATIONARY WAVES

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ABSTRACT

Waves are vibrations that move energy from one place to another without being aware of what passes through them. The waves observed in this experiment are mechanical waves, namely standing waves on a rope. The purpose of this experiment is to determine the size of the wave length on the rope, the relationship between the speed of propagation and the tension in the rope, and the factors that affect the speed of waves on the rope. The tools and materials used in this experiment were a 220 Volt AC vibration source, ropes, weights, fixed pulleys, balances, and rulers. In this experiment, we use a frequency value of 11.61 Hz, a period of 0.08 seconds, and three weight variations of 0.02 kg, 0.024 kg and 0.05 kg respectively. After that, the value of the rope tension has also been obtained, each of which has changed, namely 0.2 kg.m/s^2, 0.24 kg.m/s^2, and 0.5 kg.m/s^2. While the values of the speed of propagation are 0.0361 m/s, 0.0441 m/s, and 0.09 m/s. So, the experimental results show that the greater the mass of the load used in this experiment, the greater the wavelength. This causes the wave propagation speed and rope tension to increase. Thus, the speed of wave propagation is directly proportional to the tension in the rope. Then the size of the stationary wavelength on the rope (λ) is 0.53 m. In addition, from this experiment we can find out the factors that affect the speed of wave propagation on the rope, namely the rope tension (F) and the mass density of the rope (μ).

***Keywords*—** Stationary wave, Tension force, Velocity

I. INTRODUCTION

Waves are disturbances or disturbances that originate somewhere and are propagated. Thus, it is clear that to cause waves, an energy source is needed that can cause disturbances (Z. J. Hadi,2020). Waves can be differentiated based on their physical properties, namely based on

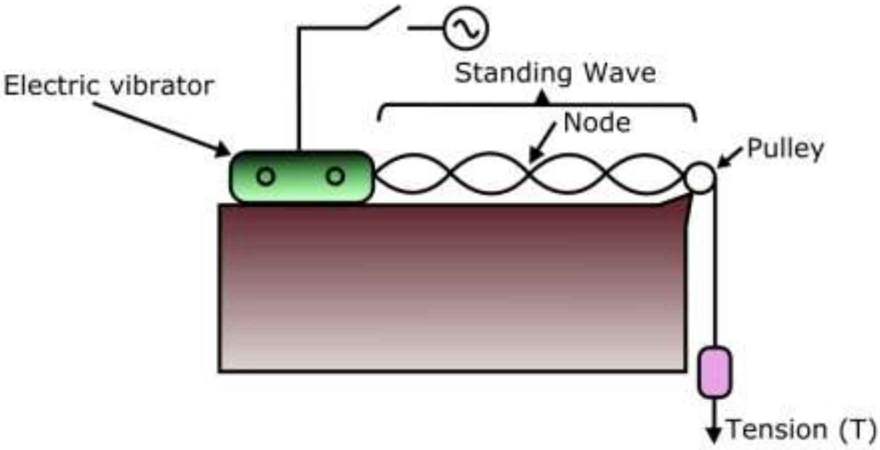

Figure 1. Melde's Law Series (R. A. Shavira,2018).

the medium, based on the direction of vibration and based on the amplitude (Septi Budi Sartika,2020). In contrast to Harmonic Motion which only vibrates (oscillates) in one place, waves are vibrations that propagate through a medium from one point (location) spreading to other points(H. Pain,2005).

Waves are vibrations that propagate. Every moving object is characterized by having speed. The speed of a wave depends on the nature of the medium in which it propagates (P. K. Pertiwi,2016). The speed of the wave in a stretched string, as well as the wave in the string, depends on the tension in the string and the mass of the string per unit length (W. Widayanti,2018)(A. K. Umam,2020). This speed will influence certain frequencies whose superposition produces a stationary vibration pattern called a standing wave (M. G. Nugraha,2018). After a stationary wave is formed, the wavelength that occurs can be measured (λ) (D. Halliday,2018)(Young and Freedman,2008).

Based on their propagation, waves are divided into two, namely transverse waves and longitudinal waves. The relationship between waves and Melde's law is that Melde's law discusses quantities that influence the speed of propagation of transverse waves on a string(H. Pain,2005).

In the Melde law experiment, the type of wave produced is a transverse wave or also called a mechanical wave because the propagation process requires a medium (R. A. Shavira,2018). Transverse waves have amplitude. The amplitude of a wave will remain constant if the given frequency is constant (M. G. Nugraha,2019). In waves there is the term standing wave. Standing waves can occur when two waves formed interfere with each other(A. K. Umam,2020). When one end of the rope is tied and the other end is vibrated, the incoming wave will be the same as the reflected wave so it will be seen that the wave remains as if it is not traveling, only oscillating from top to bottom until it forms a destructive and constructive (W. Widayanti,2018).

The phenomenon of Melde's Law occurs when a string is tensed and vibrated so that one end oscillates, creating waves whose direction of vibration is perpendicular to the direction of propagation, commonly known as transverse waves [4]. If both ends of the rope are locked so that they do not move, a knot and a stationary wave will be created, as in Figure 1.

Melde's law states in the following equation:

$$v = F\mu \qquad (1)$$

which

v : wave propagation speed (m/s)

F : rope tension force (N)

μ : linear mass density of the rope (mass of the rope/length of the rope) (kg/m) (D. Halliday,2018)

II. METHOD

In carrying out this experiment, the first thing to do is:

(a) Determine the Harmonic Frequency by measuring the length and mass of ropes A, B and C to determine the mass per unit length and record it in Table 1. Then measure the mass of the load used, record it in Table 2, assemble the tool as in Figure 1, turn on the vibrator by turning the ON button, adjust the frequency by turning the vibrator frequency button until it produces the first harmonic (2λ), namely the amplitude largest in the middle and knots at the ends (P. K. Pertiwi,2016). When approaching the optimal frequency, make adjustments gradually and wait a few seconds after making the adjustment for the system to stabilize. Record the frequency as f1 and calculate the frequency value [4]. After that, increase the frequency gradually so that you get the second harmonic (f2,($-\frac{2}{2}$ λ)), the third harmonic (f3($\frac{3}{2}$ λ).

Record the frequencies as f2 and f3 and calculate frequency value. describe the wave shape and record the frequency value, maximum amplitude and wavelength at each harmonic frequency without changing the length of the rope and mass of the load, then calculate the value of the wave propagation speed of each harmonic frequency. also calculate the average wave propagation speed and standard deviation of the data obtained from each rope. Record it in Table 4. Finally, repeat steps 1-8 using a different type of rope.

(b) Factors that influence the speed of standing waves on the rope, by repeating experiment 4a, do steps 1-6 in experiment 4a until you get a harmonic frequency that is easily observable. Then add or vary the load, then record the mass and λ values without changing the frequency value. Determine the value of string tension (F) and wave propagation speed (v), record the experimental results data in Table 4. Make a linear regression graph of F against v^2, F (x-axis) with v^2 (y-axis). repeat steps 1-4 with a different type of rope

III. RESULT AND DISCUSSION

A stationary wave with both ends tied is a type of stationary wave, namely, an incident wave (yd) moving to the right. When it hits an obstacle, the wave will be reflected to the left (yp). Because the ends of the rope are tied tightly, the reflected wave will experience a change in phase angle. The phase of the reflected wave is the opposite of the phase of the incident wave so it can form a knot.

The results of the practicum that has been carried out in Table 3 show that, if the greater the wavelength used, the more nodes there will be on the wave. Meanwhile, in Table 4. with load variations, it can be seen that the wavelength obtained is always the same even though the mass of the load is greater, because the wavelength is only influenced by the length of the rope. However, the greater the load mass, the higher the rope tension and speed, so that different knots are obtained for each different load mass.

Based on the graph in the image above, the result is that the greater the mass of the load used, the greater the propagation speed and tension of the rope. Based on the experiments that have been carried out, we use a frequency value of 11.61 Hz, a period of 0.08 seconds, and 3 variations in load mass, namely 0.02 kg, 0.024 kg, and 0.05 kg, respectively. After that, the rope tension values were also obtained, with each hose experiencing a change, namely 0.2 kg.m/s2, 0.24 kg.m/s2, and 0.5 kg.m/s2. Meanwhile, the propagation speed values are 0.0361 m/s, 0.0441 m/s, and 0.09 m/s.

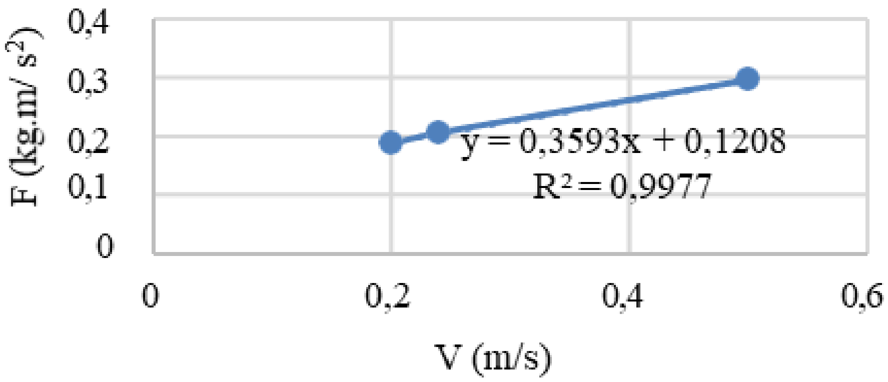

Figure 1. Graph of the relationship between string tension and wave speed

Table 1 Data Measurement of Mass and Length of Rope

Rope Type	Rope mass (kg)	Rope length (m)	μ (kg/m)
A	0,00028	0,53	$5{,}28 \times 10^{-4}$

Table 2 Load Measurement Data

Rope Type	Rope mass (kg)
A	0,020
B	0,024
C	0,050

Table 3 Harmonic Frequency Measurement Data

Harmonic Frequency to	f1	f2	f3
f (Hz)	5,80	11,61	17,41
T (s)	0,17	0,08	0,05
λ (m)	1,06	0,53	0,79
V (m/s)	1,04	1,48	0,19

Table 4 Data Measuring Rope Tension Force and Wave Speed

Frequency (Hz)	T (s)	Mass (kg)	λ (m)	F (kg. m/s2)	v (m/s)	v 2 (m/s2)
11,61	0,08	0,02	0,53	0,2	0,19	0,0361
		0,024	0,53	0,24	0,21	0,0441
		0,05	0,53	0,5	0,30	0,09
		0,02	0,53	0,2	0,19	0,0361

So, the experimental results show that the greater the load mass used in this experiment, the greater the wavelength. This causes the speed of wave propagation to increase and so does the tension in the rope to increase. Thus, the wave propagation speed is directly proportional to the tension force in the rope.

In addition, it was found that the higher the value (λ) used, the more nodes the wave will form. Then, in this experiment, variations in the mass of the load do not affect the resulting value (λ), but the greater the mass of the load, the greater the wave propagation speed and rope tension, so that for each different variation of the load mass, different knots will be formed according to the mass load used.

IV. CONCLUSION

From the data and discussion of practical results, it can be concluded that: First, the size of the stationary wavelength on the string (λ) in this experiment is 0.53 m. Second, the relationship between the tension in the rope and the speed of wave propagation in the rope is directly proportional, so the greater the tension in the rope, the greater the speed of wave propagation. Thus, the speed of wave propagation in the rope depends on the length of the rope and the mass of the load used. Lastly, the factors that influence the speed of wave propagation in a rope are the tension in the rope (F) and the mass density in the rope (μ).

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