GENERAL PHYSICS LAB

Wave Experiment

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Purpose

The purpose of this experiment was to study the relationship between wavelength and tension in a stretched wire or string when you produce waves in it and to determine the frequency of vibration. Also it was to study the standing wave and find out the resonance condition.

Introduction

The introduction aptly sets the stage for investigating the intricate relationship between wavelength and tension in a stretched wire or string, particularly when generating waves. The overarching goal of our experiment was to delve into the dynamics of standing waves, elucidating their resonance conditions and unraveling the frequency of vibration.

A standing wave, often referred to as a stationary wave, emerges from the combination of two waves moving in opposite directions, each possessing identical amplitude and frequency. The experiment focused on observing the resultant interference pattern when waves propagate along a tightly bound rope, embodying the principle of superimposition. This principle dictates that the algebraic sum of individual wave functions gives rise to the resultant wave, a phenomenon explored in detail throughout the experiment.

As vibrations can be categorized into free and forced, our experiment concentrated on the former—free vibrations occurring when a system is momentarily disturbed and allowed to move without restraint. This aligns with the classic example of a weight suspended from a spring, demonstrating the oscillatory response of the system.

The materials and methods employed in this experiment aimed to create a comprehensive understanding of standing waves. By studying the interference patterns, the relationship between wavelength and tension, and exploring the resonance conditions, we sought to contribute to the broader understanding of wave behavior. This experimental journey, undertaken by Group B on December 8, 2023, holds the promise of shedding light on the subtle intricacies of standing waves and their fundamental characteristics.

Materials/methods

Principle:

If we create two waves by a tightly bounded rope then two waves superimposed on each other and produce displacement in its equilibrium position. The combination of separate waves in the space producing resultant waves is known as interference.

(a) Standing wave:

To understand this consider following figure.

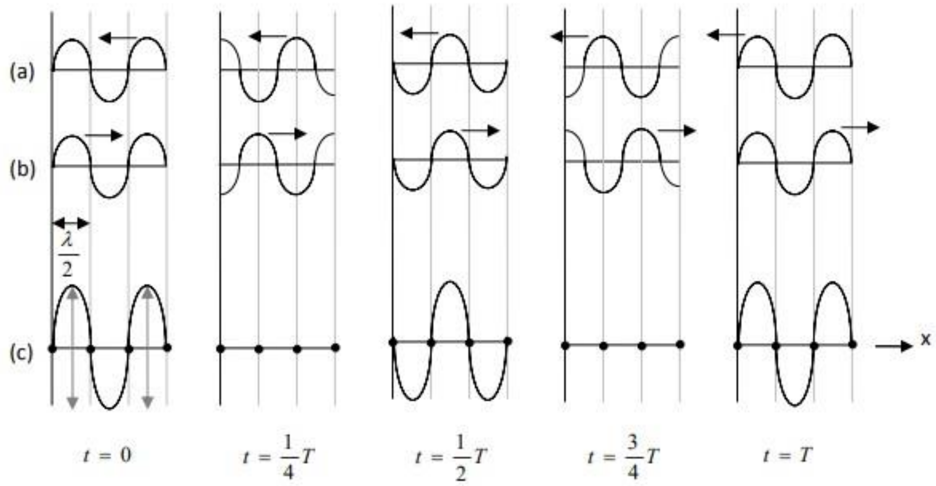


Figure 1. Waves at various times

In figure 1, (a) and (b) showing that two waves are moving towards left and right respectively, opposite to each other. The resultant interference pattern of these two waves is shown in figure (c) (Observe the wave patterns given in above figure and discuss among yourselves about it). The resultant wave is algebraic sum of the two individual wave functions and is known as principle of superimposition of waves. Assuming that the two waves of described as,

$$y_1(x,t) = y_m \sin(kx - wt) \qquad (1)$$

$$y_2(x,t) = y_m \sin(kx + wt) \qquad (2)$$

By the principle of superimposition the resultant wave will be,

$$y'(x,t) = y_1(x,t) + y_2(x,t) = y_m \sin(kx - wt) + y_m \sin(kx - wt)$$

by using trigonometric relation

$$\sin A + \sin B = 2\sin\frac{1}{2}(A + B)\cos\frac{1}{2}(A - B)$$

We can write it as

$$y'(x,t) = [2y_m \sin kx]\cos wt \qquad (3)$$

Eq. (3) has several significant features. The resultant wave function y' is also sinusoidal. Amplitude of the resultant wave is $|2y_m \sin kx|$. The minimum value of *sin kx* is zero implying that amplitude has minimum value of zero when x satisfies the condition, $\sin kx = 0$, therefore,

$$kx = n\pi \qquad n = 0,\ 1,\ 2,\ 3,\cdots$$

Because, $k = \dfrac{2\pi}{\lambda}$, it gives

$$x = n\frac{\lambda}{2} \qquad n = 0,\ 1,\ 2,\ 3,\cdots \qquad (4)$$

the maximum value of the *sin kx* is 1 therefore amplitude has max. value of $2y_m$ therefore,

$$kx = (n+\frac{1}{2})\pi \qquad n = 0,\ 1,\ 2,\ 3,\cdots$$

because $k = \dfrac{2\pi}{\lambda}$, it gives

$$x = (n+\frac{1}{2})\frac{\lambda}{2} \qquad n = 0,\ 1,\ 2,\ 3,\cdots \qquad (5)$$

(b) Speed of the waves on ropes:

Consider a small element of the rope of length Δl as shown in figure 2. It forms an approximate an arc of a circle of radius R. This element has centripetal acceleration V^2/R , which is due to components of the force known as radial force and it is given by for small angle θ as,

$$F_c = 2\tau \sin\theta \approx \tau(2\theta) = \tau\frac{\Delta l}{R} \qquad (6)$$

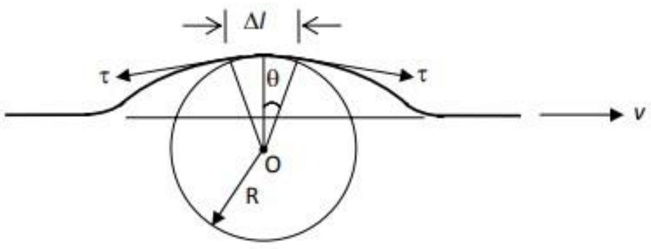


Figure 2

The element has mass $m = \mu\Delta l$ where, μ is linear mass density i.e. mass per unit length. Now from Newton's second law of motion $F=ma$

$$F_c = ma = \mu \cdot \Delta l \cdot \frac{v^2}{R} \tag{7}$$

Equation (6) and (7) will gives us $\mu \cdot \Delta l \cdot \frac{v^2}{R} = \tau \frac{\Delta l}{R}$, Therefore the speed of waves on rope will be

$$v = \sqrt{\frac{\tau}{\mu}} \tag{8}$$

(b) Standing waves in a rope fixed at both ends:

Consider a rope of length L fixed at both ends as shown in figure 3. Standing waves are setup in oscillation with frequency f in the rope due to continuous superposition of two waves. The vibration in the rope will have different modes. In some of the frequencies the left and right waves will give interference pattern and produces a wave as a result of resonance of the two waves. The modes of oscillation in the rope are shown in figure 3. The normal frequencies associated with these modes of vibration are given by the relation $f = v/\lambda$. In general the various modes of oscillation for the rope with length L is given as,

$$\lambda = \frac{2L}{n} \qquad n = 1,\ 2,\ 3, \cdots \tag{9}$$

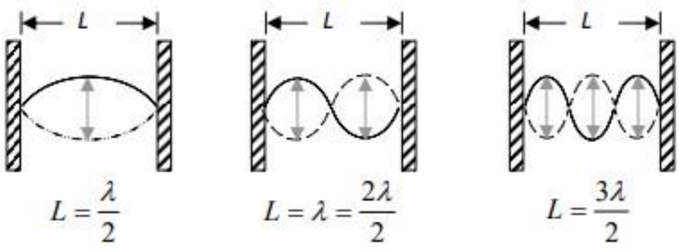


Figure 3.

because, $v=\sqrt{T/\mu}$ where, T is the tension in the string and μ is its liner mass density. Therefore we can express frequencies of the string as

$$f=\frac{v}{\lambda}=\frac{1}{\lambda}\sqrt{\frac{\tau}{\mu}}=\frac{n}{2L}\sqrt{\frac{\tau}{\mu}} \qquad n=1,\ 2,\ 3,\cdots \tag{10}$$

Instruments:

Mechanical Wave Driver, Function Generator, Precision scales, pulleys, weights, Weight Lifting Plate.

Attentions:

1. Unlock the drive arm by sliding the drive arm locking tab to the unlock position. If you do not switch to this state, when the oscillator starts, it will be very noisy.
2. Connect the drive arm to the string or experimental apparatus you need to lock the drive arm by sliding the drive arm locking tab to the Lock position.(This protects the speaker as you connect the drive arm to a string or to other apparatus.)

Procedure:

1. Set up the equipment as shown in Figure 4.
2. Record the density of the string μ.
3. Unlock the drive arm to the unlock position. And hang the mass of 300 g, then calculate the tension of the string.
4. Adjust the tension until the cord vibrates in 3 segments, and record he wavelength λ and the frequency f.
5. Repeat step 4, find out the wavelength λ and the frequency f of the cord vibrates in 4, 5, 6 segments.
6. Using the data you record and use the formula $v=f\lambda$ to calculate the velocity v. And also calculate the average value.
7. Repeat the steps 3~6 for 5 times, increase the weights about 50g for each times.
8. Draw the graphs to find out the relationship between v^2 and T. Using the

8. Draw the graphs to find out the relationship between v^ 2 and T. Using the formula

8, you can get the line densityμ. Compare with the result with step 2.

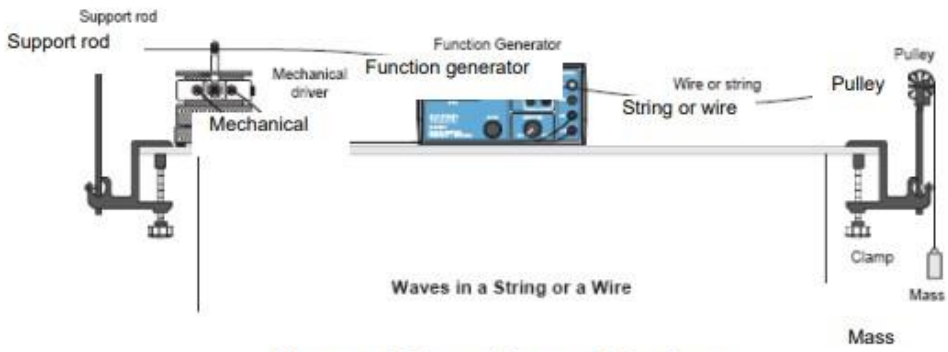


Figure 4. Experimental devices

Results

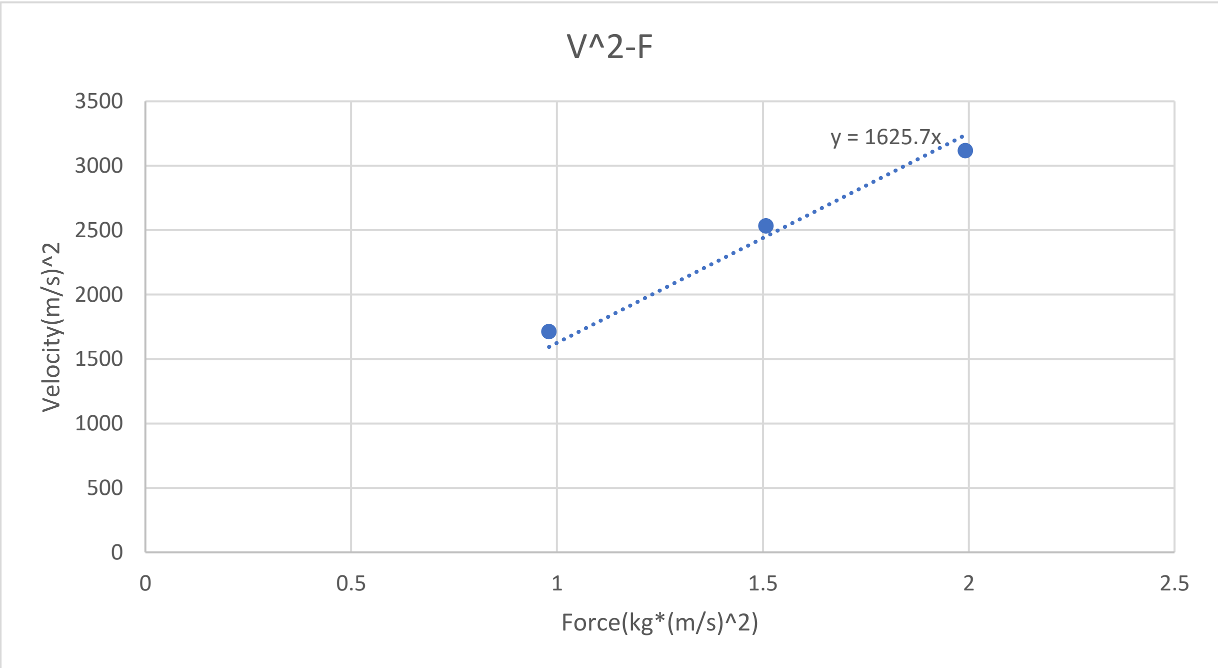
Experiment 1

0.10005	kg			
Wave	3	4	5	6
freqency(Hz)	35.85	45.8	61.2	73.33
halfwavelength(m)	0.57	0.45	0.34	0.285
wavelength(m)	1.14	0.9	0.68	0.57
Velocity(m/s)	40.869	41.22	41.616	41.7981
Average Velociy(m/s)	41.375775			
Velocity ^2(m^2/s^2)	1711.954757			
Force(kg*(ms)^2	0.98049			

0.1538	kg			
Wave	3	4	5	6
freqency(Hz)	43.1	59.32	73.8	87.98
halfwavelength(m)	0.58	0.43	0.34	0.285
wavelength(m)	1.16	0.86	0.68	0.57
Velocity(m/s)	49.996	51.0152	50.184	50.1486
average Velocity(m/s)	50.33595			
Velocity ^2(m^2/s^2)	2533.707862			
Force(kg*(ms)^2	1.50724			

0.20328	kg			
Wave	3	4	5	6
freqency(Hz)	47.75	67.13	83.82	99.47
halfwavelength(m)	0.55	0.425	0.343333333	0.2825
wavelength(m)	1.1	0.85	0.686666667	0.565
Velocity(m/s)	52.525	57.0605	57.5564	56.20055
average veloity(m/s)	55.8356125			
Velocity ^2(m^2/s^2)	3117.615623			
Force(kg*(ms)^2	1.992144			

a	1625.7			
Mass(string)	1.21		0.00121	kg
length(string) (m)	1.98			
density(g/cm3)	0.000611111			
slope	0.000615093			
error(%)	0.65%			



Discussion

The experiment unfolded as anticipated, revealing valuable insights into the intricate interplay between wavelength, tension, and frequency within the realm of standing waves. A comprehensive examination of the experimental procedures illuminated key relationships, such as the direct correlation between increased frequency and the subsequent rise in the number of observed waves. Notably, this phenomenon coincided with a reduction in wavelength—a manifestation of the heightened force applied during the experiment.

The second segment of the experiment introduced variations in force and mass while maintaining other parameters. This deliberate manipulation allowed for a nuanced exploration of the interconnected variables. The systematic analysis exposed compelling correlations among force, wavelength, and velocity, enriching our understanding of the dynamic interrelationships governing standing waves.

In acknowledging the intricacies of the experimental process, the discussion turned its attention to the calculated errors, notably the slender 0.65% percentage error. This meticulous consideration underscores our commitment to precision while simultaneously prompting reflection on potential avenues for refinement. The proposal to expand the experiment on a larger scale emerges as a strategic move to enhance accuracy and capture a more comprehensive view of the relationships at play.

The conclusion synthesizes these findings, affirming the experiment's alignment with the initial hypothesis. However, it also recognizes the iterative nature of scientific inquiry and suggests that refinement and expansion could further elevate the experiment's robustness. The call for future experimentation on a broader scale echoes the scientific ethos of continuous improvement and exploration.

Conclusion

The experiment unfolded as planned, aligning with our initial hypothesis. However, to refine the precision of our results, conducting the experiment on a larger scale and repeating it multiple times could be beneficial. This expanded approach would offer a more comprehensive understanding of the relationship between wavelength, tension, and frequency in the context of standing waves.

The percentage error, albeit minimal at 0.65%, highlights the need for meticulous attention to detail and perhaps further calibration in future iterations. A nuanced exploration on a broader scale could unveil additional insights and contribute to the ongoing discourse on standing waves.

In conclusion, while our experiment provided valuable data and supported our hypothesis, there is always room for refinement and enhancement in scientific pursuits. This could involve scaling up the experiment, exploring variations, and scrutinizing the methodology to ensure a more exhaustive exploration of the intricate interplay between wave characteristics.

Reference

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