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Experiment 2: Waves

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Date of Experiment: September 19, 2003
Due Date: October 03, 2003
Section 221-006
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Statement of Objectives

The purpose of this experiment was, in part A, to measure the harmonic frequencies of standing waves on a string and, in part B, to use Thomas Young's double slit experiment to study the relationship between wavelength of sound waves, distance between sources, and the angle of emission.

Theory

Part A: Standing Waves in a Wire

For a string stretched between two fixed points, it vibrates in fundamental mode if it consists of a single segment with nodes at each end of the string. This driving frequency is called the fundamental frequency. Standing waves form when the driving frequency is any integer multiple of the fundamental frequency called harmonics. The frequency can be expressed in terms of the length of the string and its velocity. The velocity of the wave on the wire can be determined by graphing the frequency versus the number of the harmonics.

$$v = \frac{2Lf}{n}, \qquad (1)$$

Where f is the frequency
v is the velocity
L is the length
n is the harmonic

This can be written:

$$f = n\frac{v}{2L} \qquad (2)$$

The velocity can be found in terms of tension and the linear mass density as shown:

$$v = \sqrt{\frac{T}{\mu}} \qquad (3)$$

Where v is the velocity
T is the tension
μ is the linear mass density

Part B: Sound Wave Interference

When two sound sources are emitting sound waves in phase an interference pattern occurs at the points where the sound waves meet. The interference produced depends on the path length difference of the two sources from the receiving point. If the path length difference is a multiple of the wavelength of the sound wave, constructive interference occurs at the receiving point. If the path length difference is a half-multiple of the wavelength of the sound wave, destructive interference occurs at the receiving point. Using the following equation:

$$\sin\theta = \frac{\lambda}{d} m \tag{4}$$

Where λ is the wavelength
d is the distance
m= 1, 2, 3, …

A graph of sin(θ) versus an integer of wavelengths will yield the slope:

$$slope = \frac{\lambda}{d} \tag{5}$$

The wavelength can also be expressed in terms of velocity and frequency as shown:

$$\lambda = \frac{v}{f} \tag{6}$$

Also, in calculating the theoretical value for the speed of sound we must use the equation:

$$v = 20.05\sqrt{T} \tag{7}$$

Where v is the velocity
T is the temperature in Kelvins

Equipment List

- Magnet
- Transistor
- Calibrated Weight
- String
- Meter Stick
- AC Power Supply
- Ammeter
- Audio Generator
- Counter
- Two (2) Sound Emitters
- Sound Receiver
- Oscilloscope

Procedure

Part A: Standing Waves in a Wire

An AC current was sent through a wire that ran through a magnet. A mass was hung from the end of the wire so that the wire was taught. The value of the mass was recorded. The length of the wire between the anchor and the top of the pulley was measured. With these values the frequencies for the harmonics 1, 2, 3, 4, 5, and 6 were calculated. Using the frequencies we calculated standing waves were visible. We then fine tuned the frequencies and repositioned the magnet until maximum amplitude was found and recorded.

Part B: Sound Wave Interference

Two speakers attached to the same frequency generator were set a small distance apart on a track and the distance between them recorded. A microphone was aligned on a track parallel to the track the speakers are on. The distance between the two tracks was measured. The microphone was set at its center position. The microphone was slid along the track until maximum amplitude of the signal was obtained. The distance from the center position was recorded. The microphone was moved along the track obtaining subsequent maxima and the distance from the center position was recorded for each of the maxima. The microphone was moved to the other side of the center position and the maxima were measured again. The same procedure was repeated for a different distance between the speakers.

Data

Part A: Standing Waves in a Wire

The power supply along with the ammeter was used to find the frequencies at which the first 6 harmonics occurred. The calculated frequencies were used as a starting point to find the actual frequencies. Standard values of tension, velocity, mass density, and length are also listed below.

Part A: Data Table

Wave Number	Calculated Frequencies (s^{-1})	Experimental Frequencies (s^{-1})
1	18.0172	18.35
2	36.0345	36.20
3	54.0517	56.35
4	72.0689	73.80
5	90.0861	92.40
6	108.103	109.40

Table 1-A

Standard Values

τ (tension)	0.981 N
v (velocity)	36.575 m/s
μ (mass density)	0.0007333 kg/m
L (length)	1.015 m

Table 1-B

Part B: Sound Wave Interference

The two sources of sound produced constructive interference at various distances along a track; the first 8 are recorded below along with the standard values of temperature, speed of sound, sound frequency, distance between sound sources, and length between tracks.

Part B: Data Table Trial 1

Order of Interference	Distance Left of Center (m)	Distance Right of Center (m)	Average Distance (m)	Angle θ (°)	Sin θ
m = 1	.013	.016	.0145	2.05045	.035780
m = 2	.031	.036	.0335	4.72852	.082435
m = 3	.049	.051	.0500	7.03794	.122527
m = 4	.063	.055	.0590	8.28849	.144157
m = 5	.083	.070	.0715	10.0120	.173855
m = 6	.096	.087	.0900	12.5288	.216930
m = 7	.114	.109	.1115	15.3927	.265433
m = 8	.130	.149	.1395	19.0060	.325667

Table 2-A

Part B: Data Table Trial 2

Order of Interference	Distance Left of Center (m)	Distance Right of Center (m)	Average Distance (m)	Angle θ (°)	Sin θ
m = 1	.025	.020	.0225	3.17983	.055470
m = 2	.051	.050	.0505	7.10760	.123733
m = 3	.076	.070	.0730	10.2177	.177388
m = 4	.100	.098	.0990	13.7363	.237453
m = 5	.128	.124	.1260	17.2815	.297067
m = 6	.154	.148	.1510	20.4474	.349348
m = 7	.186	.183	.1845	24.4919	.414565
m = 8	.218	.209	.2135	27.7964	.466331

Table 2-B

Standard Values

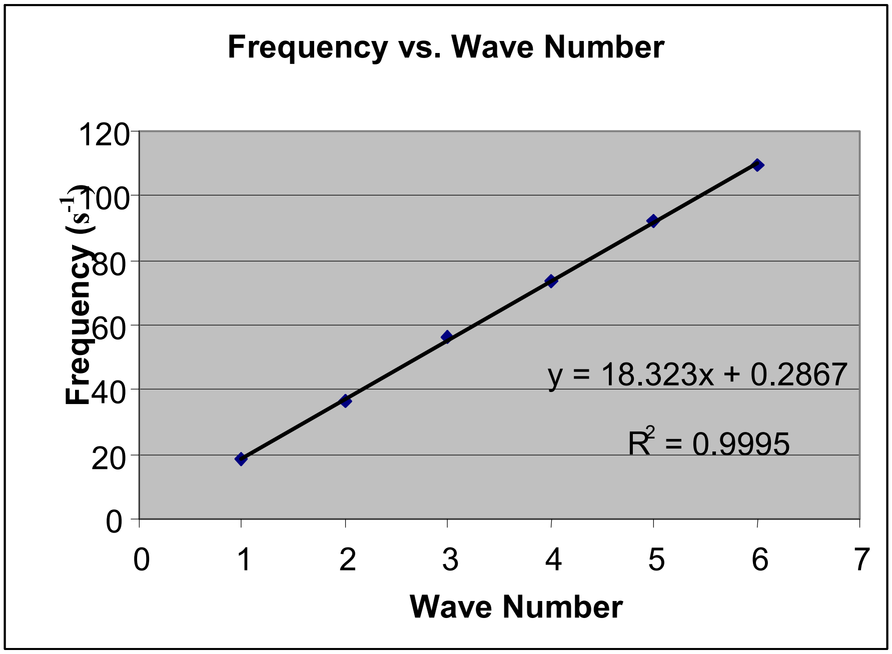
Room Temperature	298 K
Speed of Sound	346.117 m/s
Distance Trial 1	.215 m
Distance Trial 2	.145 m
Length	.405 m
Frequency	40005 Hz

Table 2-C

Analysis

Part A: Standing Waves in a Wire

Using equation 3, we calculated the theoretical value of velocity to be 36.575 m/s. After collecting the data in Table 1-A, a graph of frequency versus n was made.

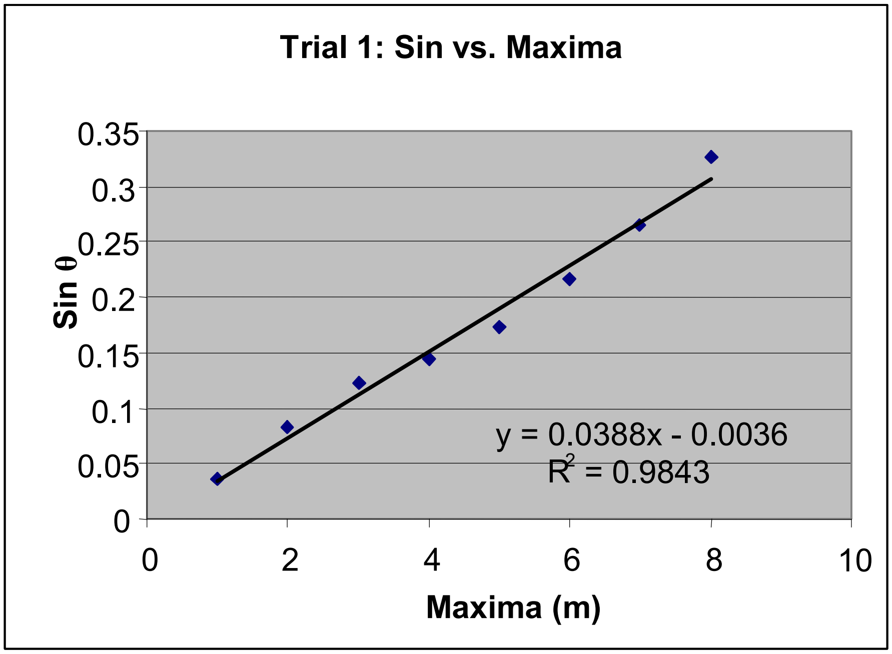


Graph 1

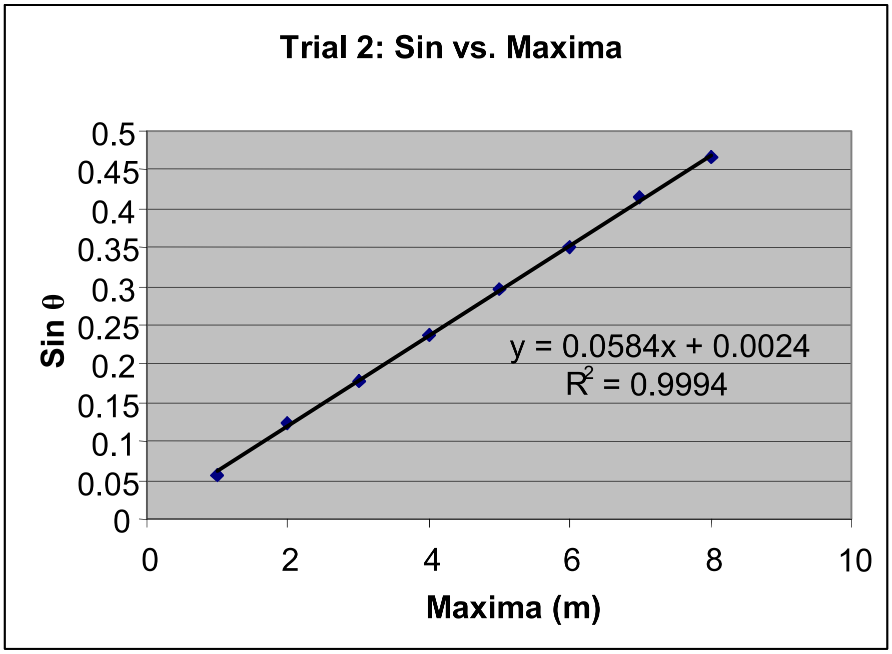
Using equation 2 and the slope of the best fit line for the graph, we can calculate the experimental velocity. Our experimental velocity turns out to be 37.1957 m/s. With this velocity, we know that our percent of error is equal to 1.669%.

Part B: Sound Wave Interference

After determining the room temperature to be 298 K, we were able to calculate the velocity of sound. Using equation 7, the velocity of sound in the room was found to be 347.276 m/s. After collecting the data in Tables 2-A and 2-B, we were able to produce graphs of Sin θ versus average distance.



Graph 2-A



Graph 2-B

Using equation 6, the theoretical value of the wavelength was calculated to be .008652 m. With this wavelength, our error in Trial 1 is 348% and for Trial 2 is 575%.

Discussion of Results

For the harmonics of the wire, the experimental value observed and the theoretical value computed differ by less than 1 m/s. The calculated error value of 1.669% is very accurate. In the second part, sound wave interference, our error values were enormous and our experimental findings differed by an order of magnitude from the calculated theoretical values. This is due to a number of reasons: Miscellaneous noise throughout the room, fluctuations in air temperature, and most importantly faulty equipment. We were not able to get a steady reading on the oscilloscope. Even after disconnecting and reconnecting the equipment on the second trial were we unable to get an accurate response from the oscilloscope. Poor speaker connections were also a problem seeing as the connections were loose during the testing phases.

Conclusion

With our experiments and testing in harmonics it is easy to see that the harmonics in the wire are multiples of the fundamental frequency. The sound wave interference testing does not show indication that the double slit method works for determining the wavelength of the sound wave. Since the procedure was successful back in the 19th Century for Thomas Young in determining the wavelength of light, and has been repeated throughout history, the equations we are concerned with are not in question of validity. Perhaps with newer equipment and an isolated room, the double slit experiment would have been successful.