Lab 6: Speed of Sound

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Abstract

In this experiment, a closed end tube was used to determine the speed of sound in air. Sound waves at known frequency were sent into the closed end tube created a node and anti node and a microphone was used to determine the peak sound intensity at the anti node. Resonant frequency values were determined from this.

1 Objective

The objective of this lab is to determine the speed of sound in air.

2 Experimental Setup

A tube is filled with water near a point that will allow the formation of an anti node at the open end. A speaker and microphone are placed at the open and to send and receive sound waves. A frequency generator is used to determine what frequencies cause anti nodes and the microphone measures sound intensity on an oscilloscope to determine where the anti nodes are.

3 Theory

A waves speed (c) is given by equation 1:

$$c = \lambda * f \tag{1}$$

Where the wavelength is given by 2:

$$\lambda = 4 * L \tag{2}$$

As can be seen from figure 1 A harmonic value is found every third factor of

$$\frac{\lambda}{4} \tag{3}$$

In other words:

$$L = \frac{n\lambda}{4} \tag{4}$$

where $n = 1, 3, 5, 7...$ In the end:

$$f = \frac{nc}{4L} \tag{5}$$

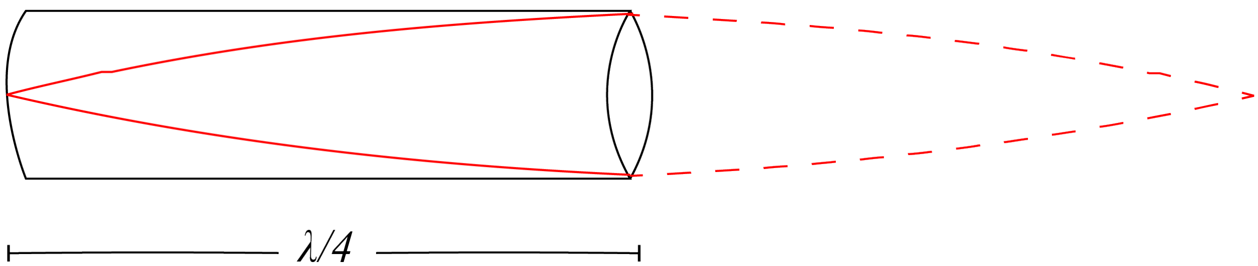

Figure 1: Closed end tube at first harmonic

4 Graphing

Resonant frequency values (Figure 2) were plotted versus harmonic values. A best fit line was constructed, the slope of which gives:

$$\frac{c}{4L} \tag{6}$$

A value for the speed of sound was determined to be $(330 \pm 15)\frac{m}{s}$ This is compared to the

Figure 2:

Harmonic (n)	Resonant Frequency (Hz)
3	791
5	1287
7	1683
9	2162
11	2653
13	3128
15	3597
17	4087
19	4554
21	5034

value determined from equation 7

$$V = 331 + (.6 * T_R) \tag{7}$$

where $T_R = 21.5$, yielding a speed of $334\frac{m}{s}$. This value for the speed of sound falls within the error margin of the determined speed.

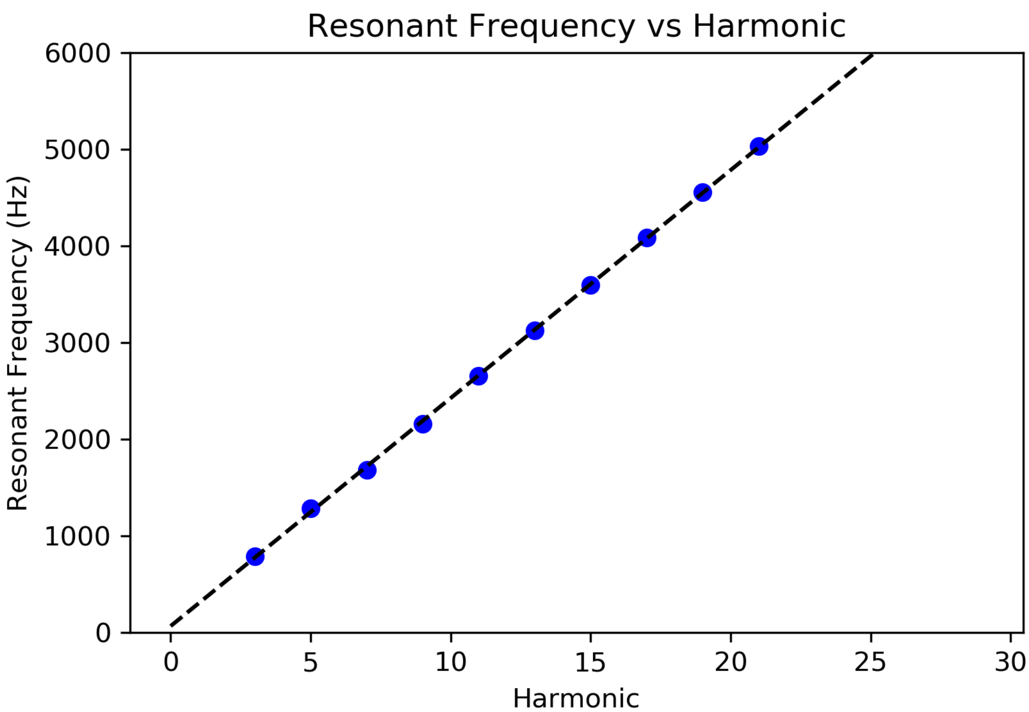

Figure 3: Resonant frequencies vs harmonic values

5 Conclusion

This experiment was designed to allow the determining the speed of sound in air by using the physical properties of a closed end tube and resonant frequencies. Using the closed end of the tube with water as a node allowed the speed of sound to be calculated.

References

[1] L. E. Kinsler, A. R. Frey, A. B Coppens, J. V. Sanders, *Fundamentals of Acoustics*, (Hamilton Press, New York, 2000).

```python
# -*- coding: utf-8 -*-
"""
Created on Tue Sep 25 15:28:59 2018

@author: maxhu
"""

import matplotlib.pyplot as plt
import numpy as np
L = .349

x_vals = [3,5,7,9,11,13,15,17,19,21]
y_vals = [791,1287,1683,2162,2653,3128,3597,4087,4554,5034]

N = len(x_vals)

sum_y = 0
sum_x = 0
sum_xy = 0
sum_x_squared = 0

for i in range(0,N):
    sum_y = sum_y + y_vals[i]
    sum_x = sum_x + x_vals[i]
    sum_xy = sum_xy + x_vals[i]*y_vals[i]
    sum_x_squared = sum_x_squared + x_vals[i]**2

Delta = N*sum_x_squared - (sum_x)**2
A = (sum_x_squared*sum_y - sum_x*sum_xy) / Delta
B = (N*sum_xy - sum_x*sum_y) / Delta

deviation = 0
for i in range (0,N):
    deviation = deviation + (y_vals[i] - A - B*x_vals[i])**2

sigma_y = np.sqrt(deviation / (N-2))

sigma_A = sigma_y*np.sqrt(sum_x_squared/Delta)
sigma_B = sigma_y*np.sqrt(N/Delta)

```

```python
print('The best estimate for A is: ', A)
print("The best estimate for the uncertainty in A is: ", sigma_A)

print('The best estimate for B is: ', B)
print("The best estimate for the uncertainty in B is: ", sigma_B)

x_plot = np.arange(0,30)
plt.ylim(0,6000)

def my_fit(x):
    return A + B*x

fig = plt.figure(1)

plt.scatter(x_vals,y_vals, color = 'b', marker='o')
plt.plot(x_plot,my_fit(x_plot), color ='black', linestyle = '--')
plt.ylabel('Resonant Frequency (Hz)')
plt.xlabel('Harmonic')
plt.title('Resonant Frequency vs Harmonic')
plt.savefig('lab 6 plot.png', dpi=300)

#Speed of Sound
SOS = B*L*4
print('The determined speed of sound is:')
print (SOS)

#####################################
#Calculating Error in slope (A) for Speed of sound
efreqabs = 12
sumyerr = np.sqrt(10*efreqabs**2)
sumxyerr = sumyerr*10
AbsErrB = np.sqrt((sum_x*sumyerr)**2+(19*sumxyerr)**2)/Delta
#Calculating Error in Speed of Sound
errmeter = .001
ErrSOS = SOS*4*np.sqrt((errmeter/L)**2+(AbsErrB/B)**2)
print ('The error in the speed of sound is:')
print(ErrSOS)
```