Lab 2
Acoustical Waves, Electronic Measurements

Learning Goals

- To generate time varying voltage with a vibrating conducting wire in a stationary magnetic field.
- To produce a standing wave on a stretched wire
- To observe a the standing wave on an oscilloscope: its voltage, time, wave shape and phase.
- To use the electronic circuits controlling the oscilloscope beam so that the real time position of the beam on the screen accurately represents the voltage and the time indicated by the controls.
- To observe and hear the effects of combining two different sound waves; with the same amplitude and/or frequency (i.e., standing waves)
- To observe and hear the effects of combining two different sound waves; unlike in amplitude and/or frequency (i.e., beats)
- To hear and measure with a sound level meter the inference effects (standing wave) of two sound waves of equal amplitude and frequency emanating from two loudspeakers (i.e., maxima, minima).
- To use a wave simulator to study the properties of waves and their superposition.\

Apparatus:

Gram weights with weight hanger, pulley, wire, cord, alligator clips, meter stick, permanent magnet, microphone with amplifier, two loud speakers

INSTRUMENT	INSTRUMENTAL ERROR (of full scale)	INSTRUMENTAL RESOLUTION
Data Studio Software		
Two GLX data loggers	± 1.0%	Decibels; sec
STOPWATCH	± 0.10%	0.01 SEC
TWO SIGNAL/FUNCTION GENERATORS	± 1.0%	SEE OSCILLOSCOPE
OSCILLOSCOPE	± 3.O%	0.001 MILLIVOLT 0.1 MICROSEC
750 interface, microphone, speakers, voltage probe	± 3.O%	
Power amplifier		

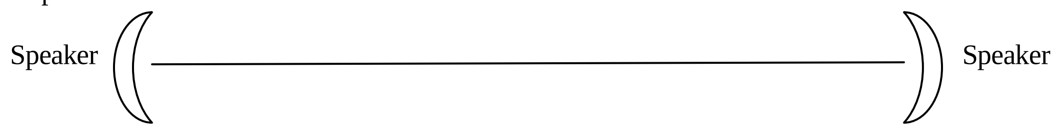
Theory:

When a moving conductor moves back and forth through a magnetic field **B** with a velocity **v** perpendicular to the direction of the field, an electromotive force or voltage is induced in the wire. This voltage is a force acting on charges (electrons) in the wire that are free to move. This time-varying voltage can be observed with an oscilloscope. Its appearance on the oscilloscope screen is that of a standing wave but it actually is a wave of electromagnetic energy traveling back and forth through the wire.

Just as standing waves represent energy of displacement of a string that travels along the string, sound waves can be generated electrically by the compression of air by a loudspeaker. When two or more sound waves intersect, the have a combined effect that is predicted from their original amplitude and frequency. Sound waves can be detected using the human ear or a microphone attached to an electronic measuring device (oscilloscope or sound meter).

Standing waves can be created on a stretched string by sending waves from one end that travel the length of the string, reflect from the other end, and then interfere with the oncoming waves. In the same way, a standing sound wave can be created in the air space between two speakers facing each other by sending waves that travel through the air toward and through each other. For any particular sound wave frequency coming from each speaker, a standing wave of a particular length is formed when the distance L between the speakers is in a particular relationship to the wavelength of the wave. (recall L = n λ/2). Regions of maximum amplitude called antinodes (large volume) and points that appear to ‘stand still’ called nodes (no volume) characterize the standing wave pattern.

This superposition of sound waves can be observed with the oscilloscope mode of the data logger. Waveport software can simulate waves and their superposition. (See CA 6787, 53 Wave Properties.ds)
See below diagram of a standing sound wave of mode n = 7 established between two speakers emitting waves of equal frequency and amplitude:



Prelab:

1. Draw a standing wave of 10 nodes on the 10 cm stretched wire below.

2. Draw a set of horizontal arrows perpendicular to the wire at one of its points of maximum amplitude (i.e., 0.5 cm) representing the magnetic filed through which the moving wire moves vertically.

3. The stretched wire at its point of maximum amplitude …(circle one choice) a) remains stationary in b) moves at a constant speed through c) moves at a changing speed through… the magnetic filed as the traveling wave vibrates on it.

4. Draw on the line below a sound wave of length 10.0 cm traveling through the air at a speed of 350 m/sec. (The sound wave is longitudinal but can be pictured as a transverse sine wave)

5. Draw on the line below a sound wave of length 0.000286 seconds traveling at a speed of 350 m/sec. (The sound wave is longitudinal but can be pictured as a transverse sine wave)

6. Draw a speaker at each end on the line below with a mode 2 standing sound wave of length 10.0 cm traveling through the air between the speakers at a speed of 350 m/sec. (The standing sound wave is longitudinal but can be pictured as a standing transverse sine wave)

7. From the drawing of 6. Above, if a microphone were placed at the 5.0 cm location, would the microphone detect the most loud sound or the most quiet sound?

8. From the drawing of question 6., if the microphone detects two adjacent quiet sounds that are 5.0 cm apart, what is the wavelength of the sound wave coming from each speaker?
   Ans.: ______ cm.

PART I: Measure the Conversion from Wave Energy to Electrical Energy:

Induce a Voltage Along a Wire Vibrating in a Standing Wave.

Procedure (**demonstration**)

a. The instructor will set up a standing wave on a metal wire and place a horseshoe magnet arrangement of two small permanent magnets over the wire at a location of maximum amplitude.
b. The instructor will connect two alligator clips at the nodes of this standing wave which border the magnets' arrangement. Attach the alligators to an oscilloscope and measure the voltage and frequency of the induced electric wave.

PART I: Data (record in notebook)

1. Record the voltage ______volts and frequency ______Hz of the induced electric wave.
2. A typical value for the voltage of this standing wave is 30 millivolts at a frequency of 120 Hz.
3. The equation which predicts the voltage ***E*** induced on the stretched wire of length ***l*** moving vertically with velocity ***v*** through a magnetic field of intensity ***B*** due to the presence of the standing wave is ***vlB***. Calculate the expected value of an induced voltage ***E*** if a wire of length ***l*** of 2 cm is moving through a magnetic field ***B*** of 5 Tesla with velocity ***v*** of $-0.60\pi[\sin 100\pi x][\sin 20\pi t]$ when x = 0.005 m and t = 1 second. ***E*** = -0.006 volts = - 6 mv.

PART II: Measure the Amplitude and Wavelength of a Sound Wave

Procedure

c. The instructor will set up one GLX data logger to act as a continuous 1,750 Hz tone Generator: Home: Files, delete files; Home, Output, √; Wave Form :Sine, Step 100, Frequency: 1,750 Hertz, Volume: full, On.
d. Each group will set up one GLX data logger on graphing mode to act as a receiver: Home: files, delete files; Home, Sensors, microphone, sound sensor; Home, Graph, Scope mode, Auto scale
e. Each group will present its data logger to face the tone generator GLX while pressing ►on the GLX in graphing mode to collect several seconds of sound, then pressing ► again to stop collecting data.
f. Each group will then select auto scale and select scale and press > repeatedly to display a sample of one complete wave.
g. Each group will use the smart tool to record enough points (at least ten) in the data able below **to sketch one complete wave** in the laboratory notebook. The y-axis is the sound wave's amplitude and the x-axis is the time.
h. Each group will use the graph to calculate and record the sound wave's period and frequency.
i. Compare this calculated value of frequency with the 1,750 Hz wave produced by the tone generator with a percent difference.

Part II Data (record in notebook)

4.

Point #	1	2	3	4	5	6	7	8	9	10
Amplitude (db)										
Time (sec)										

4. Graph of 1,750 HZ sound wave using data table above. Indicate time and voltage scales on the margins of the graph axes.

[redacted]

6. Experimental value of the length of the wave $\lambda_{experimental}$ = __________ m
7. Calculated wave period T= ______ sec , Calculated frequency f = ______ Hz ,
8. Per cent difference ______ %

PART III (demonstration) Producing a Standing Sound Wave Using Two Speakers

Procedure:

a. The instructor will measure the amplitude and wavelength of a sound wave using two loud speakers facing each other by connecting one speaker to the Pasco 750 sound generator and the other speaker to the Pasco 750 voltage input; then he will…
b. Set the data studio to display both the output and the input simultaneously.
c. Adjust the generator to produce a 1,750 Hz sound wave of sufficient amplitude to be audible.
d. Move the speakers toward each other so that the wave received by one of the loud speakers move through one cycle.
e. Measure the distance the speakers moved relative to each other with a meterstick and this value in meters will be the length of the sound wave. Record this value in the data table as the experimental value of the length of the 1,750 Hz sound wave in air.
f. Compare the experimental value of the sound wave with the theoretical value predicted by dividing the speed of sound in air (350 m/sec) by the frequency of the sound wave (1,750 Hz) and record this value in the data table.
g. Compare these values of the wavelength with the value determined in part II Data item #5.

PART III Data (record in notebook)

9. $\lambda_{experimental}$ = ________ m 10. $\lambda_{theoretical}$ = ________ m 11. (5.) $\lambda_{experimental}$ = ________ m

PART IV: (**demonstration**) Measuring the amplitude and wavelength of a standing sound wave using a microphone

Procedure:

h. The instructor will connect one tone generator to one speaker and to the input of an oscilloscope and then will… adjust the frequency of the generator to be 1,750 Hz at an amplitude of 1.0 volt peak-to-peak. Disconnect the connection to the oscilloscope. The loud speaker should produce an audible sound with a wavelength of approximately 0.2 meters. Does it?
i. Connect the other tone generator to the other speaker and to the input of the oscilloscope. Adjust the frequency of the generator to be 1,750 Hz at an amplitude of 1.0 volt peak-to-peak. Disconnect the connection to the oscilloscope. The loud speaker should produce an audible sound.
j. Estimate the distance between the speakers if the length λ of one sound wave is theoretically 350/1,750 = 0.200 meters. If the standing wave is in the seventh mode,
$L = n\lambda/2 = 7\lambda/2 = 0.700$ meters.

k. Sketch the two speakers facing each other 0.700 meters apart with the seventh mode standing wave vibrating between them. Note that the antinode of the sound wave occurs at the open end of each speaker.
l. Place the speakers as described in d) above. Using the sketch in d) as a guide, try to measure location of the seven nodes and the location and amplitude of the six antinodes with a meterstick and sound level meter. If the sound level is too low, increase the voltage output of the tone generators to larger, equal values and repeat e)
m. Record the measured values in e) in the data table below.
n. Examine the data table and predict the length λ of the standing wave (which is also the length of the 1,750 Hz sound wave) by using the distances between nodes. This distance between any two consecutive nodes is equal to half the length of the 1,750 HZ sound wave or 0.100 meters.

o. Compare the experimental and theoretical values of the 1, 750 Hz standing sound wave produced by the two speakers.

p. Calculate the velocity of the standing wave using $v = f\lambda$ and compare it with 350m/sec.

Data PART IV (record in notebook)

12. 1,750 Hz standing wave data

Location of node (cm)						
Location of antinode (cm)						
Amplitude (db) of anti node						

13. $\lambda_{experimental}$ = __________m 14. $\lambda_{theoretical}$ = _________m 15. % difference ________ .

16. $v_{experimental}$ = _________m/sec 17. $v_{experimental}$ = ________m/sec 18. % difference _______ .