INTRODUCTION TO SOUND

The objectives of this experiment are:

- To study some basic features of simple and complex sounds and to investigate the relationships among the frequencies of notes on the chromatic scale
- To learn how to use two software programs

APPARATUS: Computer, microphone, and speakers.

INTRODUCTION

In this experiment you will learn how to use the computer to produce, collect and analyze sound wave data. We will use one program (MouseKeyboard) to produce sounds from the speakers attached to the computer and then we will use another program (fftscope) to analyze the sounds being picked up by the microphone. A microphone is a transducer; that is, it converts energy from one form to another. In this case the energy of the sound wave is converted into electrical energy, i.e. a voltage, by the microphone. (Note that a speaker works in the opposite sense: converting electrical energy into sound.) The voltage from the microphone, in turn, is sampled by fftscope, which can display the data as a graph in different ways.

An oscilloscope is a very useful device in physics that allows one to see how an input voltage varies with time. In today's lab you will use a computer program that does this. The same program can also be used to analyze the time variation of voltage, by doing what's called a Fast Fourier Transform (FFT) on the input signal. Later in the course we will study Fourier Transforms, but for now all you need to know is that an FFT tells you the amount of power in the input sound wave as a function of frequency. If you have a pure sine wave input to the FFT it will produce a spike in the FFT plot – this is telling you that all of the power in the input signal occurs as one single frequency. The FFT is extremely useful for analyzing sounds.

There are many possible musical scales. Western music uses a 12-note *chromatic* scale. There is also the *diatonic* scale (seven primary notes) with which even non-musicians are familiar as "do-re-me-fa-so-la-ti-do." This scale can be played with the white keys on a piano keyboard, starting with *C*. As you go though a diatonic scale it is eight steps from *do* back to *do* again. For this reason, this range of notes is called an *octave*. The black keys on the piano form yet another scale called *pentatonic*. Together the *diatonic* and *pentatonic* scales make up the *chromatic* scale.

Musical scales are tied closely to mathematics. You will use a computer-interfaced Microphone to record the waveform of the sound that is produced and use an FFT to determine the fundamental frequency of the sound. Your challenge is to measure the frequencies of all the notes of a chromatic scale and then to determine a mathematical pattern.

PROCEDURE AND TECHNIQUES

1. Plug the microphone into the lower Labtec speaker input, if it isn't already plugged in.

2. Turn speakers on. Open the Lab Softwares folder on Desktop. Open FFTScope and MouseKeyboard. MK should be set to program 80, Chords = None, Pitch and Modulation wheels = 0. MK has a volume control; the speaker volume control will affect both the FFT Function generator and the MK amplitudes together. Point and click a MK key; use left Ctrl to lock tone. Click again to unlock. If no lock, run program up, then reset to 80. If no MouseKey sound, check that "MIDI Out" is not set to None.

Be sure there are not two FFTScope windows open at the same time – bad things can happen to data.

EXPERIMENTS

(1) Pure tone: Produce middle C (faint dot, freq approximately 262 Hz.) with MK; lock note. Hold the microphone close to the speaker. Set FFTScope in Oscilloscope mode (button toggles between FFT and OSC modes) and select 0.1 or 0.2 seconds for Time (this sets the sampling rate – larger values mean longer integration times and higher frequency resolution in FFT mode). Be sure Silent is selected under Function Generator. A plot of voltage vs. time should appear. Increase speaker volume to get as clean a sin curve as possible, but avoid clipping (flat-topped sines). Acquire data for a number of samples. Expand the horizontal scale of the graph appropriately using the mouse (click and drag, to reset look under View). Find the time difference for a number of cycles (10 or so), calculate the period T and then the frequency f.

Switch FFTscope to FFT mode with FFT averaging on (View menu). Signal/noise improves as the square root of observation time - the random noise involves some cancellation so it accumulates only as the square root. (Stop data acquisition before, or soon after, signal stops; noise will not stop when signal does, so the signal/noise advantage of averaging can be diluted.) Expand the horizontal scale and read the frequency corresponding to the peak power of the note. To improve accuracy, try increasing the sampling rate (i.e., set Time to a value between 1 and 10 s).

(2) Ambient Room Noise: With MK and FFTScope Function Generator signals off, observe the FFT frequency spectra of the ambient noise in the room. Note and record the frequencies of several narrow peaks in the power spectrum.

(3) Voice Analysis: Hold the microphone away from the speaker and speak, sing or whistle into it. (Don't blow at it.) Observe the Oscilloscope time patterns and the FFT frequency patterns for vowels and consonants. Can you make nice sine waves (pure tones)? If so, for what type of sounds? Compare the FFT frequency patterns for a spoken vowel and consonant. Which of these sounds has more overtones (i.e., a larger number of peaks in the power spectrum)?

(4) Chromatic Scale: For each of the notes listed in the Table (page 6), find and record its frequency from either the Oscilloscope time plot or the FFT frequency plot as done above for the pure tone. Notes 1 – 12 are the notes of one octave. Notes 13, 17, 20, and 25 are in higher octaves. Use the diagram as a reference point to locate the different notes on a keyboard. The musical notes are also listed in the table, with a subscript number indicating what octave they are in, such as C_4 (middle C).

Note: The same black key note may sometimes be written as a sharp, or as the flat of the next higher white key. The choice depends on the ascending or descending context in the musical composition.

1. Calculate the difference in frequency between each note (except the first and the last three) to the previous one. Record your result in the column labeled Delta f (Hz) in the data table.
2. Calculate the ratio of each frequency (except the first and the last three) to the previous one. Record your result in the data table.
3. Fill in the unshaded cells of the last column by calculating the ratio of the frequency of the note to the frequency of the C_4 note.
4. Study your data on the white keys (the diatonic scale). These notes are listed in bold in the data table. Try to identify a pattern to these frequencies and ratios. Can the ratios in the last column be converted into ratios of small whole numbers? What would those whole-number ratios be? [Example: ratio = 1.33; small whole number ratio = 4:3]
5. Considering all the notes, what patterns exists between successive notes? Explain, citing specific evidence from your lab work.

Graphing Standards

In this lab course you will be making many graphs which is a powerful technique in displaying and comprehending experimental results. You will be evaluated on your graphical representation of data. So, keep in mind the following definitions and techniques for two dimensional graphs:

A) The quantity that can be changed is called the independent variable which is normally plotted on the horizontal axis called the abscissa. This is also called the x-axis.

B) The quantity that changes because the independent variable changed is the dependent variable which is usually plotted on the vertical y-axis called the ordinate.

C) The origin is where the abscissa and ordinate are both zero. Some graphs do not plot the origin because the information is better portrayed without it. Remember that there is an artistic aspect to graphs: there are several ways to maximize the portrayal of information.

D) All graphs must have a title. Different sets of data can be plotted, but they must be identified with symbols, different line-types, etc. A legend defines these data sets.

E) Measurements taken from graphs must be shown. Superpose your measurement lines and identify the parameters and measured values.

F) The axes must be labeled. The numerals should be plotted at several intervals without creating a confusing, congested mess. Numbers less than zero should be preceded by a zero: the decimal point should not be first. Any scale (multiplier) must be shown.

G) Straight lines are always drawn with a straight edge or ruler. In this lab curves can be sketched in pencil.

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LAB REPORT FORM

NAME: ____________________________________ DATE: _____________

PARTNER(S): ____

FREQUENCY AND PERIOD:

(1) Pure tone:

Record your values and do not forget the units!

Frequency of middle C (C_4)	
Number of Waves Counted:	
Time Duration for these Waves:	
Period of One Wave:	
Calculated Frequency:	
% Difference:	
Frequency from FFT:	
Estimated Uncertainty on Freq. from FFT:	
% Difference:	

(2) Ambient room noise:

Frequencies of power peaks: ____

(3) Voice analysis:

Record your observations of the quality of the sound produced by your voice.

Were you able to make a pure sin curve? __________If so, how? ______________________

____

Describe your spoken vowel: ____

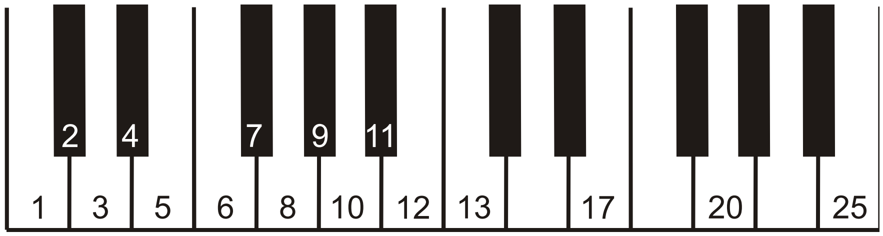
____

Describe consonant: ____

____

Which has more overtones? ____

CHROMATIC SCALE:



Figure

Key #	*Note*	*Frequency (Hz)*	*Delta f (Hz)*	*Ratio to previous note*	*Ratio to C4*
1	*C4*				*1.0*
2	***C4#***				
3	*D4*				
4	***E4*b**				
5	*E4*				
6	*F4*				
7	***F4#***				
8	*G4*				
9	***A4*b**				
10	*A4*				
11	***B4*b**				
12	*B4*				
13	*C5*				
17	*E5*				
20	*G5*				
25	*C6*				

= sharp, b = flat

Describe any patterns: ____

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