**Introduction:** Sound waves consist of a series of air pressure variations. A Microphone diaphragm records these variations by moving in response to the pressure changes. The diaphragm motion is then converted to an electrical signal. Using a Microphone and a computer interface, one can explore the properties of common sounds.

We can study this phenomenon with a Microphone, lab interface, and computer. You are going to measure is the period \( T \) and frequency \( f \) of a tuning fork from both the number of cycles, from a sinusoidal curve fit, and also by using Fourier’s transformation technique, which gives power spectrum from frequency data. Recall that \( T \) is defined as the time for one complete cycle of repetition. Since period is a time measurement, it is usually written as \( T \). The reciprocal of the period \( (1/T) \) is called the frequency, \( f \), and the number of complete cycles per second. Frequency is measured in hertz (Hz). \( 1 \text{ Hz} = 1 \text{ s}^{-1} \)

When two sound waves overlap, their air pressure variations will combine. For sound waves, this combination is additive. We say that sound follows the principle of linear superposition. Beats are an example of superposition. Two sound waves of nearly the same frequency will create a distinctive variation of sound amplitude (loud and faint), which we call beats. The beat frequency is the difference between the two wave frequencies.

You will also determine the periods and frequencies of flute sounds/tones produced on the lab electronic keyboard’s keys: lowest C, C-sharp (C#), and D.

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\begin{align*}
 f_B &= |f_2 - f_1 | \\
 f_{ave} &= \frac{f_2 + f_1}{2}
\end{align*}
\]

**Objectives**
- Measure the frequency and period of sound waves from several objects and instruments.
- Observe beats between the sound of two different frequencies and determine beat frequency

**Apparatus:** Vernier LabPro unit, LoggerPro, electronic keyboard, microphone, tuning fork and banger.
**Procedure**

1. Connect the Vernier Microphone to Channel 1 of the LabPro.

2. Open the LoggerPro data collecting file. The computer will display a graph of sound wave pressure versus time. It will collect data for just about 0.03 to 0.05 s to display the rapid pressure variations of sound waves. The vertical axis corresponds to the variation in air pressure and the units are arbitrary.

3. Open a word document for your lab report. Make a data table. Make sure you have the data and graphs for each sound together. Label appropriately as Tuning Fork, Noise, etc.

4. Strike a tuning fork with a banger and collect the sound. Keep trying until a nice wave form is made with at least 10 periods of oscillation shown. Find the time for 10 cycles and then for one cycle. Calculate the frequency and compare (% error) with what is found on the fork. Copy and paste the LabPro graph into your report. Is the waveform what you expect for a tuning fork? Why or why not? Enter this in your data table.

5. Find the frequency using a sinusoidal fit and calculating the frequency in Hz from the angular frequency. Calculate the % error from what is found on the fork. Enter this in your data table.

6. Click on the Fast Fourier Transform (FFT) graph. Select the “Examine” option on the LoggerPro tool bar. A box will now open just above the FFT plot. Put the cursor on the tallest bar/peak and read the peak/dominant frequency of the sound signal. This is displayed in the box. This is the frequency of your fork obtained by using power spectrum (FFT technique). Obtain the values of any secondary frequencies present (overtones). Again record these data below the Data table. Compare your value of the frequency obtained here with the value obtained above and also with the actual frequency. Report these results in your lab report.

7. Now digitize 5 more sounds of your choosing such as: 1) Noise (such as jingling keys) 2) Singing letter “A” with one voice 3) Singing letter A for more than one voice 4) Say “I love physics!” over and over and over again! 5) Something from your phone. Copy and paste the LabPro graphs into your report for each sound, labeling each clearly. If possible, determine the period and frequency of each sound. Is the waveform what you expect? Why or why not? Type your findings and comments under each graph.

8. Select the flute sound on the keyboard, capture the wave pattern on the screen for the lowest C (fifth white key from the left end on the keyboard), hold it close to the microphone, and click [Collect]. The data should be sinusoidal in form. If it is not, repeat this step. Note the appearance of the graph. Count and record the total time for ten complete cycles and determine the period and fundamental frequency for the sound wave. To do this, click the Examine button, [Examine]. Calculate the frequency in hertz (Hz) and record it in your data table. Copy and paste your wave form into your lab report.

9. Repeat the above procedure for the C-sharp - C# (the black key to the right of the lowest C – it is often called C-sharp) on the keyboard and for the lowest D (the white key to the right of the lowest C, which is then 5th white key from the left end of the keyboard). Copy and paste your wave form into your lab report.
10. Adjust the maximum time on the horizontal axis to 0.2 s and change the data collection length (under menu item Experiment) to 0.2 s. Capture the wave pattern on the screen when the lowest C and C# are played together on the keyboard, and copy and paste it into your lab report. Determine the time for one beat and the beat frequency using \( f = \frac{1}{T} \). Compare (\% difference) with the expected beat frequency using the values of frequencies found in part 6 & 7.

11. Repeat the above procedures for the lowest C and D played together on the keyboard.

12. Write a brief summary of your observations and results.