Experiment 8
Vibrations

SAFETY

Make sure that you have read the **General Safety Notes**, in the Introductory section of this manual, before you begin.

Do not, **under any circumstances,** attempt to repair or dismantle any of the equipment. If you suspect equipment to be faulty, turn it off at the power point and talk to your demonstrator.

ADDITIONAL HAZARDS

Keep noise levels to a minimum. Some frequencies may cause discomfort and even nausea for some people. If this is the case, you may request ear plugs and please see your demonstrator immediately if you are unwell.

Outline of Experiment

Today you will be looking at **standing waves** of sound in pipes. The most common use of this phenomena is in musical instruments such as the clarinet and flute.

In this experiment you will observe and compare standing waves in a pipe (open at both ends) with standing waves in another pipe (closed at one end). You will explore the resonant frequencies (also known as 'modes of vibration') of the waves in each pipe and learn about harmonics. Finally, you will calculate the speed of sound in air using pipes both closed at one end and open at both ends.

This experiment is divided into two sections. In the first section you will measure the characteristics of standing waves. In the second part, you will aim to accurately determine the speed of sound.

✓***Pre-lab exercises:*** *Read the laboratory exercise, complete the questions below, then submit the pre-lab task online (LMS or http://fyl.ph.unimelb.edu.au/prelabs) for this experiment. [Your marks for the pre-lab will be based on the answers to the online questions, which are taken from the pre-lab work in the manual]*

Learning Goals

- To work well as a team completing the experiment and analysis efficiently and accurately.
- To demonstrate competency in the use of a digital oscilloscope and signal generator.
- To use different methods to confirm resonances and minimise false data.
- To demonstrate the behaviour of standing waves in pipes and determine the speed of sound in air.

Introduction

Before Starting the lab please visit these pages on harmonics in an air column. http://hyperphysics.phy-astr.gsu.edu/hbase/waves/opecol.html

http://hyperphysics.phy-astr.gsu.edu/hbase/waves/clocol.html

We will use the signal generator in the Scope Program connected to a loudspeaker to produce sound waves. The frequency of any sound wave (f) is determined by its source, and it will not change as the sound wave propagates through the air. The frequency is the 'rate' at which the wave repeats (so it is in units of Hertz – which is just inverse seconds). The time between 'peaks' (or troughs) at a fixed point in space, is called the period (T).

✓ **Pre-lab question 1**

Write down the equation relating frequency and the period.

$f = \frac{1}{T}$

The **wavelength** of a sound wave (written as **λ**) is the length of a complete wave. This will be the distance between maxima (or minima) if you consider a sound wave frozen in time.

The **speed** (just as it is normally) is the rate at which the wave moves. We could calculate it in the usual way, by dividing the distance travelled by the time taken.

✓ **Pre-lab question 2**

Write down an expression for the speed (v) in terms of the wavelength (λ) and the frequency (f).

$v = \lambda f$

This relation is true not only for sound waves but for **any** kind of wave, including water waves, radio waves and light.

Standing Waves in Pipes

A continuous sound wave moving along a pipe will be reflected at both ends of the pipe, whether the ends are open or closed (see appendix C). This means that after a very short time the pipe will contain **two** travelling waves, one moving along the pipe in one direction and the other moving in the opposite direction. These two waves will have equal speeds (as speed is determined by the properties of the air) and the same frequency (as determined by the source of the wave), and they will therefore also have the same wavelengths.

We can simply add the disturbance of air due to each of these two separate waves at each point in the pipe to produce a 'net' disturbance. The two travelling waves combine together to form a **standing wave**. Because the end point of a pipe defines a fixed maximum or minimum position (depending on if it is open or closed, and whether you are referring to the displacement or pressure) for a standing wave to form, the wavelength of the sound applied needs to relate to the length of the tube in a specific way.

✓ **Pre-lab question 3**

In terms of pipe length L and wavelength λ, write down a formula for the resonant frequencies of open and closed pipes.

Section A: Modes of Vibration

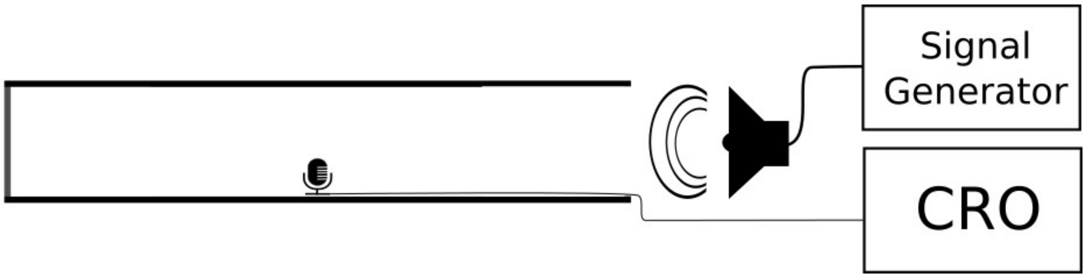
In the experiments below, we will use a loudspeaker to produce sound waves, and observe resonance in a tube/pipe. The motion loudspeaker is driven by a sinusoidal electrical signal, and therefore produces sinusoidal waves that move along (through) the pipe. When the wave reaches the other end of the pipe, some of it will be reflected, whether the end is open or closed. The reflected wave can then interfere with the original wave. Under certain conditions, a resonance can occur.

Experiment 1: Pipe open at one end

Procedure:

- ✓ Close one end of the cardboard tube (post pack) with lid provided and place the open end directly next to the loudspeaker above as shown in the diagram.

- ✓ Measure the length of your cardboard tube (post pack).



- ✓ Set the signal generator (use the Scope program) to SINE mode and a frequency of 150 Hz

- ✓ Adjust the output control so that you can hear the sound.

- ✓ Gradually increase the frequency until you hear a distinct increase in volume (i.e. loudness). You will also see an increase in amplitude of the signal on the oscilloscope. This point is called a resonance, and the frequency f_n at this point is called a resonant frequency of the pipe.

- ✓ By carefully varying the frequency, identify all resonances in the range 150-2000 Hz. You may like to use the sweeping function or make some predictions for the resonant frequencies you are looking for.

Data

✓ Record the resonance frequencies in your logbook.

Tips:

If you are unsure about hearing an increase in volume, move the pipe away from the speaker. If the sound doesn't become immediately less loud, it is not a resonance. You might find it useful to rapidly move the pipe in and out of line with the speaker.

Watch out for **false resonances**, which are due to the characteristics of the speaker rather than of the pipe. There is likely to be one at around 250 Hz. Again, the test is to check for a change in volume as you move the pipe away.

Experiment 2: Pipe open at both ends

Repeat the procedure as for experiment 1, this time using the same tube with the lid taken off so that it is open at both ends. (Be sure to replace the lid when you have finished this section.)

Analysis

✓ The lowest possible resonant frequency (where n = 1) is called the fundamental frequency of the pipe. In general, the resonances are called harmonics (or modes). For example, the standing wave corresponding to n = 3 is called the 'third harmonic' (or the 'n = 3 mode'). The integer n is sometimes called the harmonic number or the mode number. You now have enough data to interpret how sound waves interact with open and closed pipes. As a starting point, use the expressions you obtained in the Pre-lab exercise relating the resonant frequency series.

Section B: Speed of Sound in Air

✓ Using your equations derived in the pre-lab questions, calculate the speed of sound using both your closed and open pipe.

Consider these questions in your discussion:

- ✓ How do the resonant frequencies compare with the length of the tube?
- ✓ In measuring the length of the pipe did you include some confidence limits?
- ✓ Is the speed of sound in the lab 340 ms^{-1}? What might affect this?
- ✓ Look back at your table of measurements for the two pipes. How did you identify the fundamental frequency?
- ✓ How does the fundamental frequency of a pipe open at both ends compare with the fundamental frequency of a pipe open at one end, when the two pipes have the same length?
- ✓ Were all of the resonances you observed generated by the pipe?

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