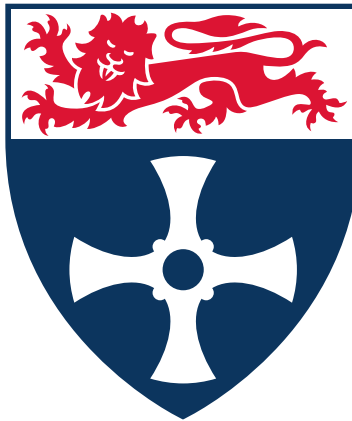


# Newcastle University

School of Maths, Stats, and Physics



Instructions for students

## Introduction

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By this point, you should have seen the presentation on standing waves, in which we discussed how waves propagate and interact to form standing waves. Most of the concepts discussed were framed as an oscillating string, but the same principles apply to any wave, including ripples on a pond, light (electromagnetic waves), and sound waves. Sound waves differ from the other examples mentioned in that they are longitudinal waves, rather than transverse waves. This means that the oscillations are parallel to the direction of travel of the wave, rather than perpendicular to it.

Since sound is also a wave, some conditions can set up standing waves in air. The clearest example of this is wind instruments: in general, a wind instrument in its simplest form is a pipe, open at one end. A standing wave can be set up within that pipe, and just like before the allowed frequency is determined by the length of the pipe. We hear different frequencies as different pitches, so the length of the pipe determines the pitch of the note played. There's then three ways in which wind instruments change the note played. The simplest is by having multiple pipes of different length, like a church organ. Alternatively, they might physically change the length of the pipe, like a trombone. Finally, they might cover and uncover holes in the pipe, like a clarinet or recorder. This forces the standing wave to have a node at the hole, changing which frequencies are allowed.

## Sheet Music

As part of this activity, you'll be reading sheet music, which looks a bit like this:



You can think of this as a bit like a graph: the  $y$ -axis represents pitch, and the  $x$  axis represents time. Then, the shape of the notes themselves tell you how long each note should be played, and any markings (like the  $\sharp$  and  $\flat$  symbols) indicate some modification to how the note would normally sound.

We'll break down the example above, but first a short primer on the notes in the 12-note scale<sup>1</sup>. We divide the range of all possible pitches into sections called octaves. These are defined such that one octave starts at exactly double the frequency of the previous octave. Because of this nice relationship between the frequencies, notes that are one octave apart sound good together, and also fulfil similar roles in music. This makes it quite logical to name the notes in each octave the same, and use a number to indicate the octave. For example, the note A in the 4<sup>th</sup> octave has frequency 440 Hz<sup>2</sup>, while the note A in the 5<sup>th</sup> octave has frequency 880 Hz.

It's worth emphasising that frequency and perceived pitch don't have a linear relationship; we hear the jump between 220 Hz and 440 Hz as the same as the jump from 880 Hz to 1760 Hz. The difference between the two is not the same, but the ratio is.

Within each octave, we define 12 notes. Exactly how these are defined is not actually very straight forward, but for the purposes of this activity we'll just assume we're using something called equal temperament. This means that the ratio between any two adjacent notes is always the same, and is the 12<sup>th</sup> root of 2 ( $\sqrt[12]{2} \approx 1.059463$ ). To go from the first note of an octave to the second, we multiply the frequency by  $\sqrt[12]{2}$ . This means to go from the first note of one octave to the first note of the next, we multiply the frequency by  $\sqrt[12]{2}$  12 times, which is the same as multiplying by 2. We usually call the jump from one note to the next a half-step or a semitone. Jumping up two notes is called a whole-step or a tone.

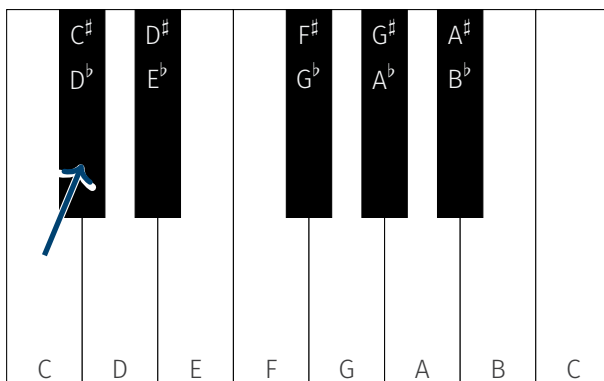
When writing music, we don't usually use all 12 notes in a given octave. In western music, we usually use a subset of 7<sup>3</sup>. This is called a key. The simplest key is called C major (you can safely ignore the "major" for this activity), in which the 7 keys used are labeled with the letters A to G. The notes in between are then labelled with what are called accidentals: a sharp ( $\sharp$ ) raises the pitch by a semitone, while a flat ( $\flat$ ) lowers the pitch by a semitone.

<sup>1</sup>A 12-note scale is most common in western music, but is far from the only scale used. For example, Indian classical music uses a 22-note scale, which contains pitches which sit between the notes in the 12-note scale.

<sup>2</sup>The frequency of A<sub>4</sub> is actually used to define the tuning; A-440 is the standard tuning for orchestras, but other tunings are used in other contexts.

<sup>3</sup>This is why it is called an octave; with a 7-note scale, the 8<sup>th</sup> note is the same as the first but an octave higher. "Oct" is a prefix from Greek that means 8.

The easiest way to show this is with a piano keyboard:



The 7 notes used in C major are given white keys, while the 5 other notes sit between those as black keys<sup>4</sup>.

<sup>4</sup>Until relatively recently, this was inverted; harpsichords and other keyboard instruments used to have a large row of black keys and a small upper row of white keys