

Musical Notes, Scales, and Frequencies

- When musicians play a 1-octave scale, they play _____ notes, the first and last of which have the same note name.
- Frequency is a rate – cycles per second. For waves, it is the number of wave cycles per second. The unit for frequency is _____, which is equal to _____ wave per second.
- When two notes are separated by an octave, the higher note has a frequency that is _____ the frequency of the lower note. For example, a musical note with a frequency of 110Hz is an A. If we start singing at that pitch and move gradually upward, we will reach the next A when we get to _____ Hz. The next A after that will be heard at _____ Hz.
- Even though a one octave scale has 8 notes, the most common system actually divides each octave into _____ “equal” parts. Each of these equal parts is called a _____ or a _____. The musical system that divides an octave in this way is called 12-Tone Equal Temperament (or 12-TET). This is the system that applies to most of the music that you have heard (probably).

| Note Name | half steps up from starting note | Frequency (Hz) | Ratio: Current frequency / Previous frequency | Ratio of wavelength to starting note wavelength |
|------------|----------------------------------|----------------|---|---|
| A | 0 | 440 | NA | 1 |
| A# (or Bb) | 1 | 466 | 1.059 | 0.944 |
| B | 2 | 494 | 1.059 | 0.891 |
| C | 3 | 523 | 1.059 | 0.841 |
| C# (or Db) | 4 | 554 | 1.059 | 0.794 |
| D | 5 | 587 | 1.059 | 0.749 |
| D# (or Eb) | 6 | 622 | 1.059 | 0.707 |
| E | 7 | 659 | 1.059 | 0.667 |
| F | 8 | 698 | 1.059 | 0.630 |
| F# (or Gb) | 9 | 740 | 1.059 | 0.595 |
| G | 10 | 784 | 1.059 | 0.561 |
| G# (or Ab) | 11 | 831 | 1.059 | 0.530 |
| A | 12 | 880 | 1.059 | 0.5 |
| A# (or Bb) | 13 | 932 | 1.059 | 0.472 |
| B | 14 | 988 | 1.059 | 0.445 |
| C | 15 | 1047 | 1.059 | 0.420 |
| C# (or Db) | 16 | 1109 | 1.059 | 0.397 |
| D | 17 | 1175 | 1.059 | 0.375 |
| D# (or Eb) | 18 | 1245 | 1.059 | 0.354 |
| E | 19 | 1319 | 1.059 | 0.334 |
| F | 20 | 1397 | 1.059 | 0.315 |
| F# (or Gb) | 21 | 1480 | 1.059 | 0.297 |
| G | 22 | 1568 | 1.059 | 0.281 |
| G# (or Ab) | 23 | 1661 | 1.059 | 0.265 |
| A | 24 | 1760 | 1.059 | 0.25 |

Where does the 1.059 ratio come from?

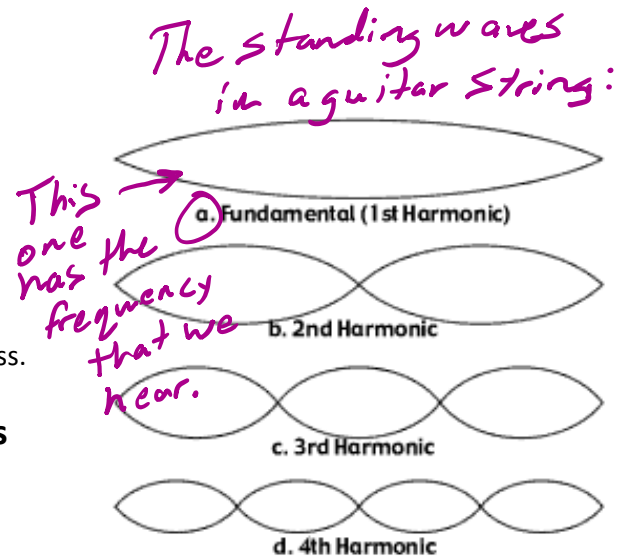
- A one octave jump in pitch represents a 2^1 increase of sound wave frequency.
- A two octave increase in pitch represents a 2^2 increase in frequency.
- A three octave increase in pitch represents a 2^3 increase in frequency.
- A four octave increase in pitch represents a 2^4 increase in frequency.
- A 1/12 octave increase in pitch (in other words, a half step) represents a $2^{(1/12)}$ increase in frequency. In other words, to raise the pitch of a sound by a half step its frequency must be multiplied by $2^{(1/12)} \approx 1.0595$.

What's Really Going On In Instrument Strings:

12. A plucked string seems to be simply vibrating back and forth, perpendicularly to the length of the string. In actuality, the vibration can be understood as a standing wave pattern produced by the interference of waves traveling parallel to the string length.

The vibrations of a string actually comprise several different standing wave patterns superimposed over one another. This is why, if you zoom in on the graph of an instrument's waveform, it looks like a mess.

The important thing to understand here is that waves travel back and forth down a guitar string, and their frequencies determine the pitch we hear.



Fret Placement:

When a string is plucked or bowed, many types of waves travel along it, producing a variety of standing waves. The dominant (loudest) standing wave is called the fundamental. There are also other harmonics (a.k.a. overtones), which have higher frequencies and pitch.

13. Suppose an instrument string is **50cm** long. When the open string is plucked, its frequency is **400hz**.

a. For purposes of tuning, we care about the *fundamental* vibration of the string. Draw a diagram in the space below showing a guitar's nut and saddle. Draw the string vibrating in its fundamental mode (the most important one that we hear) How many wavelengths does the vibrating string represent?

b. What is the full wavelength of the waves that are traveling down the string?

c. What is the relationship between string length and the wavelength of the string's fundamental standing wave?

$$1 \text{ string length} = \text{wavelength} \times \underline{\hspace{2cm}}$$

d. What is the speed of the waves traveling along the guitar string? [use the wave speed formula].

- e. The first fret (closest to the nut) on a finger board needs to correspond to a note that is one half-step higher than the open string. What is the frequency of a note one half step higher than the 400hz open string?
- f. In order to produce that note, what wavelength must the string have? [hint: you know the string's wave speed. Use the wave speed formula.]
- g. How long must the vibrating portion of the string be in order to produce that wavelength? [Use the formula you created in part c.]
- h. How far from the nut should the first fret be located? In other words, by what distance must you shorten your string in order to raise your instrument's pitch by one half step? [Hint: you know the full string length, and you know the length of string that provides the correct new frequency for the first fret.]

Frets on String Instruments

14. Each fret on a fretted string instrument is separated from the next fret by 1 _____ step.
15. Two half-steps is called a _____ step.
16. Most of the music that you have heard is played in either a *major key* or a *minor key*. Each type of key uses different notes within the range of an octave. In general, more songs are written in major keys. **Marking your frets to indicate major and minor key notes will make it easier to play scales and songs.**

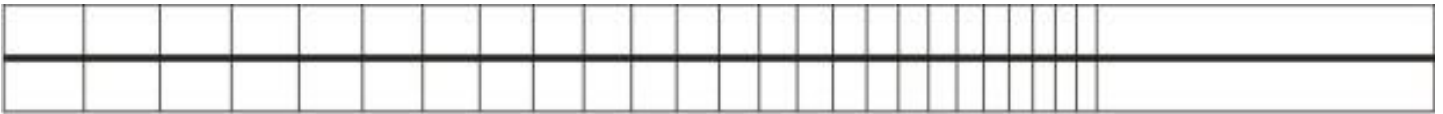
The pattern of whole steps (W) and half steps (H) for a **major key**, one octave scale is **WWHWWWH**

The pattern for a **minor key**, one octave scale is **WHWWW**

You can start anywhere on the fingerboard and play these scales using this pattern.

17. On the top half of the finger board, below, label frets with the numbers 1-7, representing the notes of a **major** scale. You can start wherever you want, but make sure that you go as far as you can in both directions.
18. On the bottom half of the finger board, label the frets with the numbers 1-7, representing the notes of a **minor** scale. You can start wherever you want, but make sure that you go as far as you can in both directions.

Major key notes (1-7)



Minor key notes (1-7)

19. If you want to play a one octave, major key scale, what numbers should you play?
20. Each key (black or white) has a frequency one half step from the next key.
- Which **major** key scale can be played on the piano without using any of the black keys?
 - Which **minor** key scale can be played on the piano without using any of the black keys?

