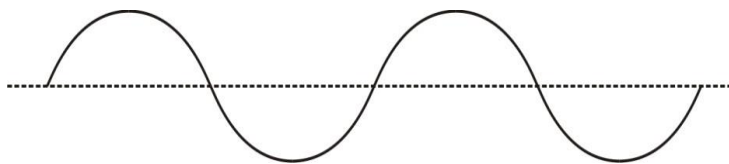


**Notes - Waves, Standing Waves, Division of The Octave, and Fret Calculations**

Show these parts of a transverse wave: crest, trough, wavelength, amplitude

Wavelength Symbol: \_\_\_\_\_

Frequency:



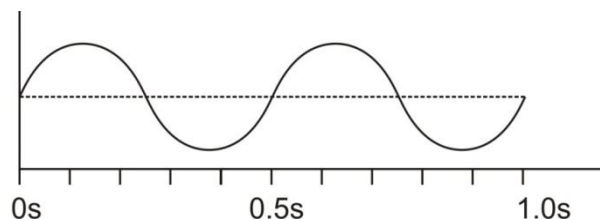
Frequency Symbol: \_\_\_\_\_

Units: \_\_\_\_\_

Frequency Formula:

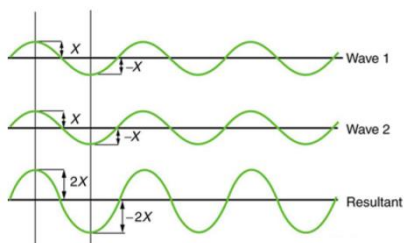
Wave speed Formula:  $v =$

Calculate the frequency of the series of waves on the right.

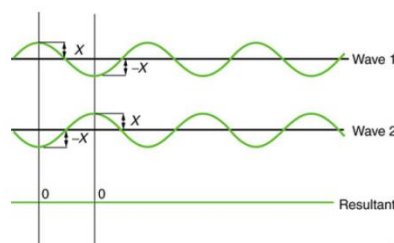


Assuming that  $\lambda=10\text{m}$  for the waves on the right, what is the wave speed?

2. When two or more waves arrive at the same point, the resulting wave is the \_\_\_\_\_ of the individual waves. This is a phenomenon called \_\_\_\_\_. If the disturbance corresponds to a force, then the forces add. Whatever the disturbance, the resulting wave is a simple addition of the disturbances of the individual waves. That is, their amplitudes add.

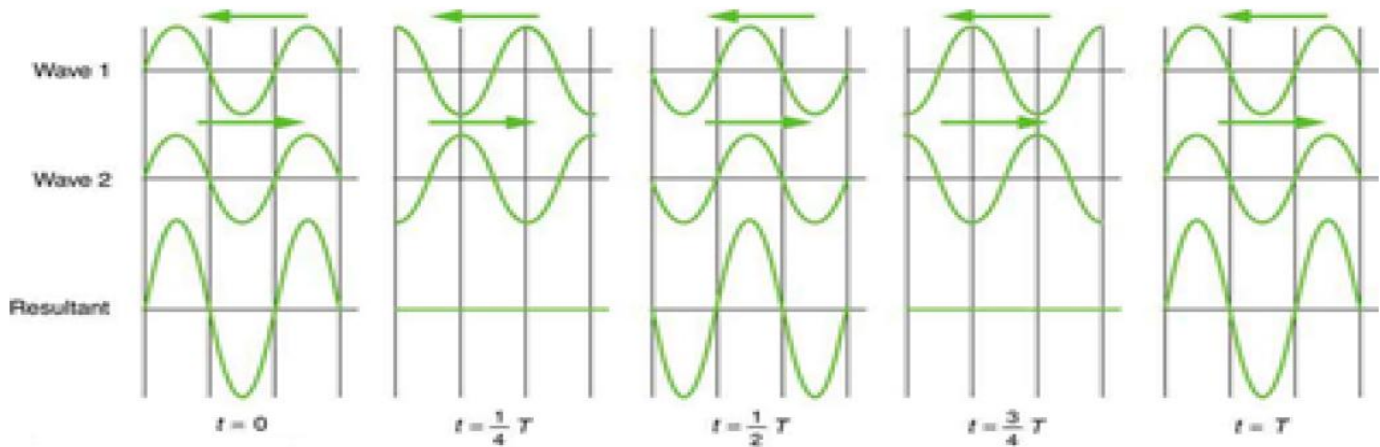


Pure \_\_\_\_\_ Interference



Pure \_\_\_\_\_ Interference

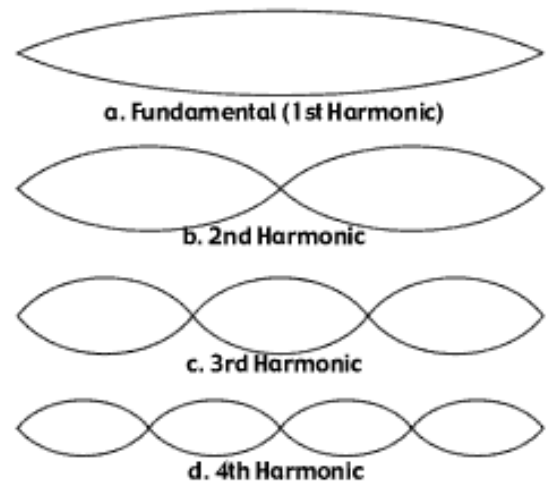
3. In the diagram below, two waves pass through each other moving in opposite directions, and their disturbances add as they go by. Since the two waves have the same \_\_\_\_\_ and \_\_\_\_\_, then they alternate between constructive and destructive interference. The resultant looks like a wave standing in place. This is called a \_\_\_\_\_.



Standing Waves in Vibrating Strings fixed at both ends (e.g. a guitar string)

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 set of complex interactions between waves that are traveling parallel to the string length, interfering with one another as they reflect back and forth, and producing standing wave patterns.

The vibrations of a string actually comprise several different standing wave patterns superimposed over one another. The loudest wave pattern is the **fundamental** (a.k.a. **1<sup>st</sup> harmonic**). All of these wave patterns are called **harmonics**, and they only occur at integer multiples of the fundamental frequency. For example, if the fundamental frequency is 10Hz, the 2nd harmonic would have a frequency of 20Hz; the 3rd harmonic would be 30Hz; the 4th harmonic = 40Hz. For wavelength, this relationship is inverted. The wavelength of the 2<sup>nd</sup> harmonic is 1/2 the fundamental wavelength. The 3<sup>rd</sup> harmonic's wavelength is 1/3 the fundamental wavelength



4. For the figure on the top right, give the wavelength for each harmonic, in terms of the vibrating string length.

Fundamental Wavelength = \_\_\_\_\_ string length

2<sup>nd</sup> harmonic Wavelength = \_\_\_\_\_ string length

3<sup>rd</sup> Harmonic Wavelength = \_\_\_\_\_ string length

4<sup>th</sup> Harmonic Wavelength = \_\_\_\_\_ string length

**12 TET (12 Tone Equal Temperament) Division of the Octave**

1. When musicians play a 1-octave scale, they play \_\_\_\_\_ notes. When we hear the musical notes at the bottom and top of a 1-octave scale, our ears perceive those notes as being the same notes, even though one sounds “higher” and one sounds “lower.”

2. 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.

3. In an 8 note, one octave scale, not every note on the instrument gets played. The music that most of us listen to 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

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

\_\_\_\_\_. This is the system that applies to most of the music that you have heard (probably).

4. A one octave jump in pitch represents a \_\_\_\_\_ of sound wave frequency.

5. A two octave increase in pitch represents a  $2^{\quad}$  increase in frequency.

6. A three octave increase in pitch represents a  $2^{\quad}$  increase in frequency.

7. A four octave increase in pitch represents a  $2^{\quad}$  increase in frequency.

8. A 1/12 octave increase in pitch (in other words, a half step) represents a  $2^{\quad}$  increase in frequency. In other words, to raise the pitch of a sound by a half step its frequency must be multiplied by  $2^{(1/12)} \approx 1.0595$ .

9. To raise pitch by n half steps, one must multiply the current frequency by  $2^{\quad}$ .

10.  $2^{(1/12)} \approx 1.0595$

**String Instruments:**

11. The frequency of sound produced by a string is affected by the string's \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and other characteristics.

12. The vibrating portion of a string extends from an instrument's \_\_\_\_\_ to its \_\_\_\_\_.

13. Label the *nut*, *bridge*, *body*, *neck*, *frets*, *saddle*, and *tuners* on the string instrument to the right.



14. The purpose of frets is to allow the musician to precisely control \_\_\_\_\_  
\_\_\_\_\_

15. The purpose of the body is to \_\_\_\_\_  
\_\_\_\_\_

16. The purpose of the bridge is to \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

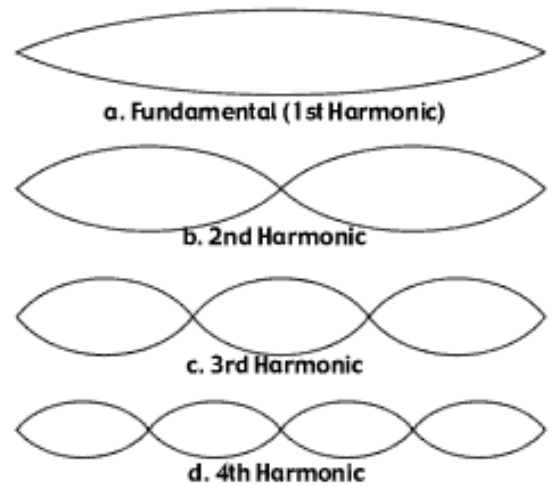
17. The purpose of the saddle is to \_\_\_\_\_  
\_\_\_\_\_

18. The purpose of the tuners is to \_\_\_\_\_  
\_\_\_\_\_

### 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.

19. Suppose an instrument string is **50cm** long, and when the open string is plucked, its frequency is **400hz**.
- a. For purposes of tuning, we care about the *fundamental* vibration of the string. On the diagram to the right, label the position of the bridge and the nut. In this case, 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?
- d. What is the speed of those waves? Note: This speed is constant for a given string as long as the string's tension remains constant.
- 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]
- g. How long must the vibrating portion of the string be in order to produce that wavelength?
- 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?

**Practice Problem:**

20. Suppose an instrument string is **68 cm** long, and when the open string is plucked, its frequency is **220 Hz**.

- a. Considering only the *fundamental* vibration of the string how many wavelengths of that vibration are equal to the length of the vibrating string?

L =

- b. What is the full wavelength (in **centimeters**) of the waves that are traveling down the string?
- c. What is the speed of those waves? Note: This speed is constant for a given string as long as the string's tension remains constant.
- d. 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?
- e. In order to produce that note, what wavelength must the string have? [hint: you know the string's wave speed]
- f. How long must the vibrating portion of the string be in order to produce that wavelength?
- g. 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?