

### Alleluia and Fugue, Op. 40b and Prayer of Saint Gregory

## Chapter 6 - Outline

Standing waves
Basics
Frequencies and wavelengths
Longitudinal waves
Complex Waves
Timbre



Produced when incident and reflected waves <u>interfere.</u>

Principle of superposition.

# Standing Wave

There is no apparent motion along the direction in which the two individual waves move.









# Harmonic Series

A series of frequencies in which all members are an integral multiple of the lowest frequency



The lowest frequency is called the <u>fundamental frequency</u> or <u>first harmonic.</u>



The higher frequencies are called the second harmonic, third harmonic, fourth harmonic, etc.



 $f_2 = 2f_1$  $f_3 = 3f_1$  $f_4 = 4f_1$ 





Harmonics above the first are also called **Overtones**.

#### Tube Open at Both Ends



(a)

 $\lambda_1 = 2L$  $f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$ 

 $\lambda_2 = L$ 

First harmonic

Second harmonic

Third harmonic

### Tube Open at Both Ends:

# $\lambda_n = 2L/n$ $f_n = nf_1$



### Tube Closed at Both Ends: (same as rope - fixed ends)

# $\lambda_n = 2L/n$ $f_n = nf_1$



Tube Closed at One End:

# $\lambda_n = 4L/(2n-1)$ $f_n = (2n-1)(v/4L)$

# Standing Sound Waves Tube Closed at One End: $f_2 = 3 f_1$ $f_3 = 5 f_1$ $f_A = 7 f_1$



### Resonance in tubes

Complex Waves

Created when frequencies which are members of a harmonic series are added.











### Complex Waves

When waves whose frequencies are members of a harmonic series are added, the frequency of the resultant wave is **always** the same as that of the fundamental.



Missing Fundamental (virtual pitch) Track 37.

Virtual Pitch with Random Harmonics Track 43-45

### Fourier Synthesis

Any periodic wave of frequency f<sub>1</sub> can be produced by adding together sine waves of frequency f<sub>1</sub>, 2f<sub>1</sub>, 3f<sub>1</sub>, 4f<sub>1</sub>, 5f<sub>1</sub>, etc.















### Fourier Synthesis

Demo with Fourier Synthesizer and Oscilloscope

### Fourier Analysis

Any periodic wave of frequency f<sub>1</sub>, no matter how complex, can be broken down into sine waves of frequency  $f_1$ ,  $2f_1$ , 3f<sub>1</sub>, 4f<sub>1</sub>, 5f<sub>1</sub>, etc.

### Fourier Analysis

The set of sine waves that make up a complex wave are called the complex wave's Fourier Components. Fourier Spectrum or Harmonic Spectrum

A listing of the amplitudes of each component in either tabular or graphical form





Timbre

The different combinations of harmonics gives different qualities or timbers to sounds.



#### Flute (few harmonics)





#### Oboe (many harmonics)





#### Violin (intense harmonics)





### *The Effect of spectrum on timbre Track 53*



### III-6 Vibrations on a Guitar String

III-7 Fourier Analysis and Synthesis

Summary

Any periodic wave of frequency f<sub>1</sub> can be produced by adding together sine waves of frequency f<sub>1</sub>, 2f<sub>1</sub>, 3f<sub>1</sub>, 4f<sub>1</sub>, 5f<sub>1</sub>, etc.

Summary

Any periodic wave of frequency f<sub>1</sub>, no matter how complex, can be broken down into sine waves of frequency  $f_1$ ,  $2f_1$ , 3f<sub>1</sub>, 4f<sub>1</sub>, 5f<sub>1</sub>, etc.

Summary

The pitch we hear always corresponds to that of the fundamental frequency.