



8. G

(jyu@phya.snu.ac.kr)



http://phya.snu.ac.kr/~mi_ma/

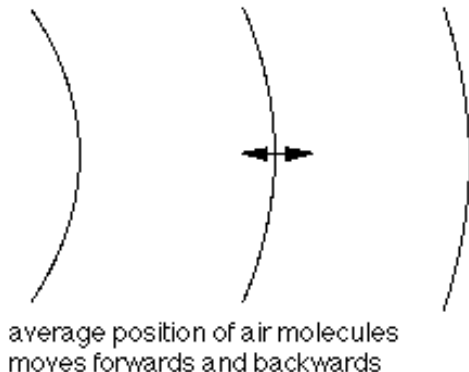
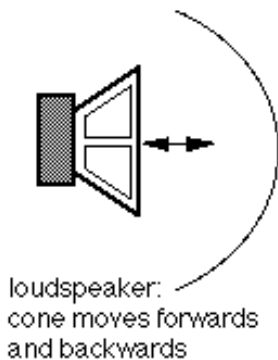


Orchestral Suite No.3 ('Air on G String')

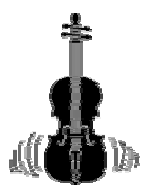


Johann Sebastian BACH (1685-1750)





- : $v = 331.5 \text{ m/s}$ (, 0.6 m/s 가)
- : $20 \text{ Hz} \sim 16,000 \text{ Hz}$



4 : E → A → D → G

- →
-
-
-
-
-
- A-

$$f = \frac{v}{\lambda}$$

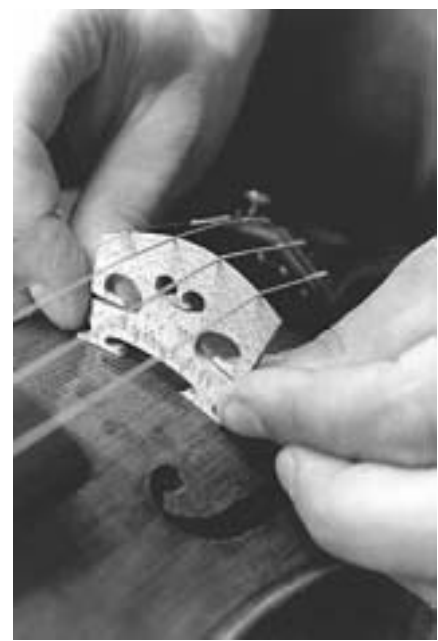
$$f' = \frac{v}{\lambda'}$$

$$\therefore \frac{f}{f'} = \frac{\lambda'}{\lambda}$$

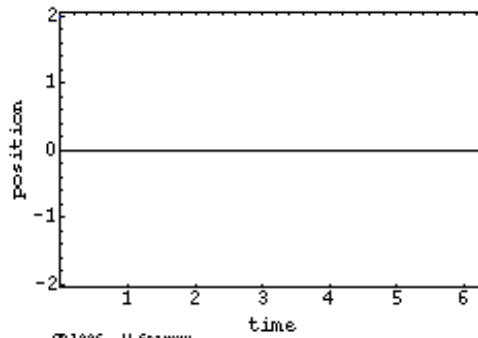
$$\therefore \frac{f}{f'} = \frac{\sqrt{F}}{\sqrt{F'}}$$

$$\therefore \frac{f}{f'} = \frac{\sqrt{D'}}{\sqrt{D}}$$

440 Hz



$$m \frac{d^2 x}{dt^2} + kx = 0 \quad \rightarrow \quad \frac{d^2 x}{dt^2} + \frac{k}{m}x = 0 \quad \rightarrow \quad \frac{d^2 x}{dt^2} + \omega_0^2 x = 0$$

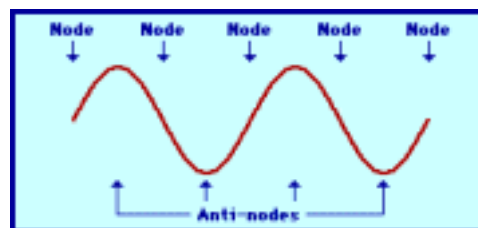
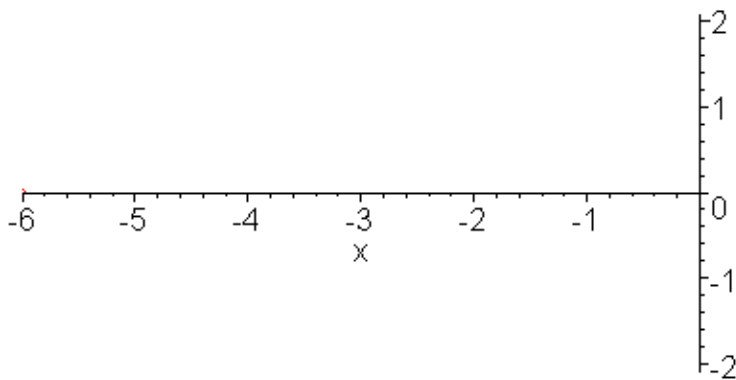


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modified by D. Russell, 1997

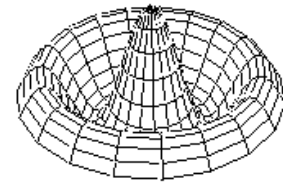
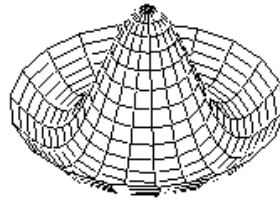
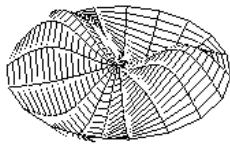
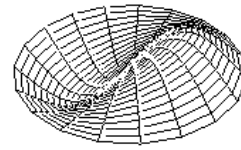
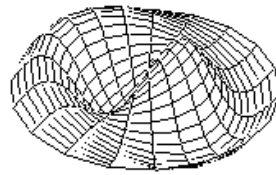
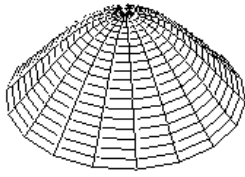
$$\omega_0 = 2\pi f_0 = \sqrt{\frac{\text{elasticity}}{\text{inertia}}}$$

$$\omega_0 = \sqrt{k/m}$$

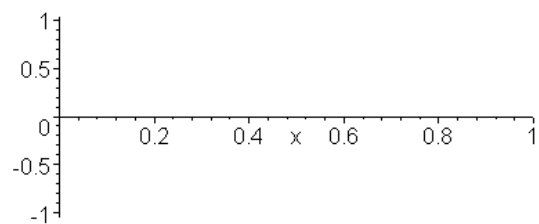
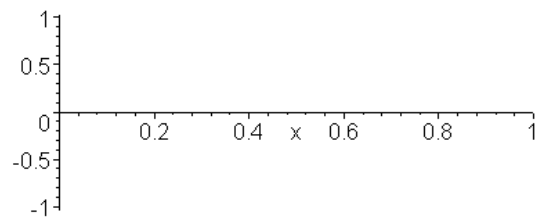
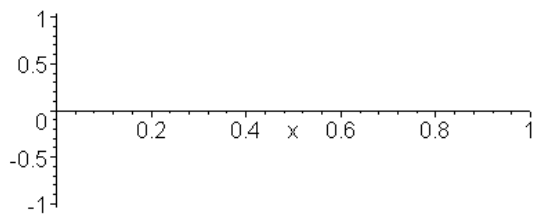
(standing waves)

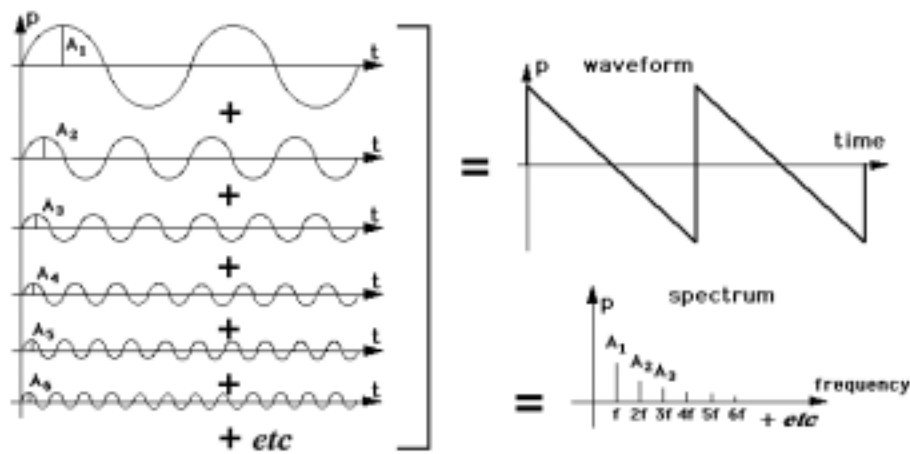



(drum)




(harmonics)





 wav The first six harmonics of a sawtooth wave, sounded one at a time.

 wav Sequential synthesis using the first six harmonics, then a melody using that spectrum.

(pitch)

A4/5
 440; 880

C5/6
 523; 1047

B4/5
 494; 988

A4/5
 440; 880

A#4/5
 466; 932

G4/5
 392; 784

E4/5
 330; 659

F4/5
 349; 698

F#4/5
 370; 740

D4
 294

D#4
 311

C4
 262

C#4
 277

1 2 3 4 5 6 7 8 9 10 11 12

- (가)
- → 1:2
- 5 → 2:3

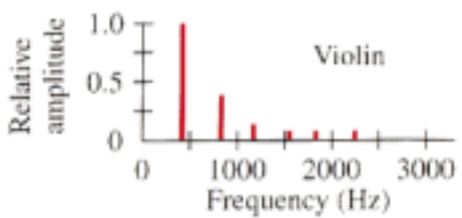
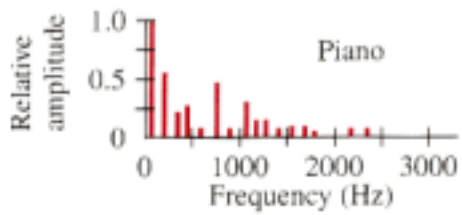
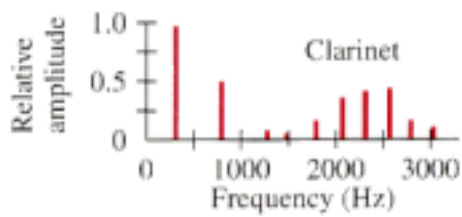
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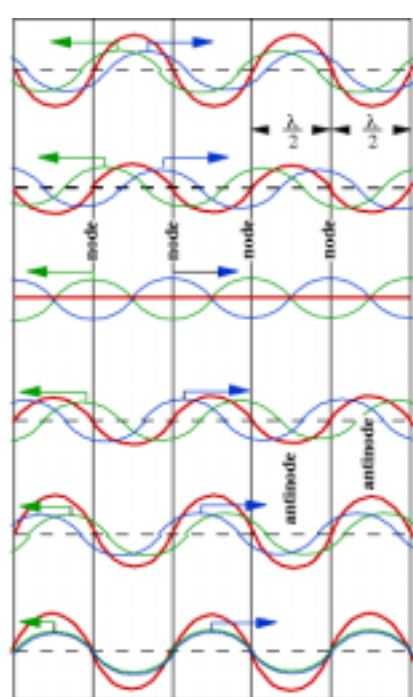
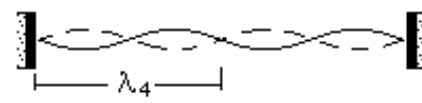
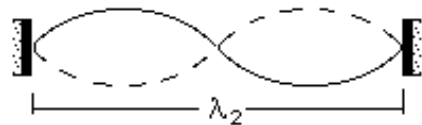
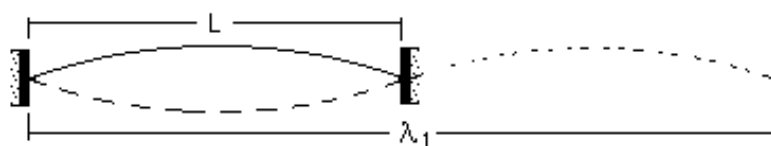
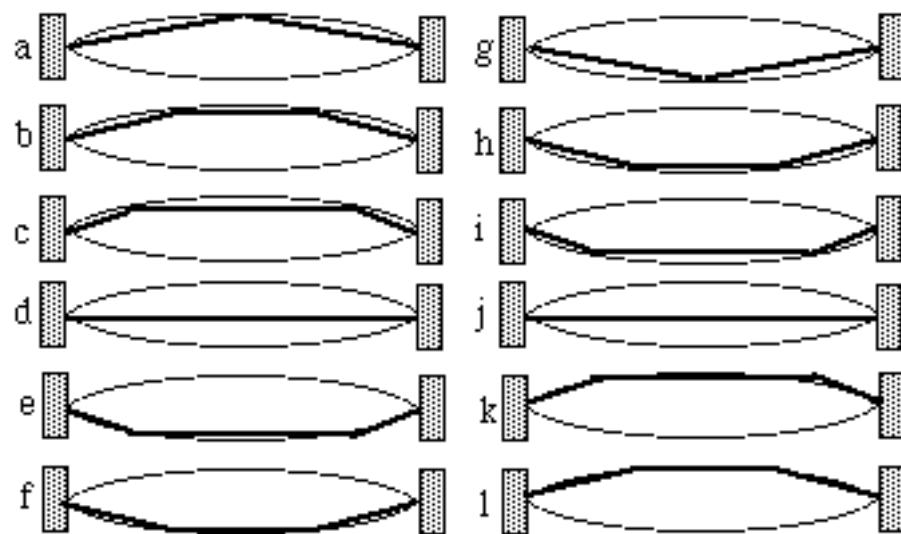


1	9/8	5/4	4/3	3/2	5/3	15/8	2
24	27	30	32	36	40	45	48

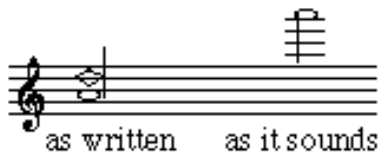
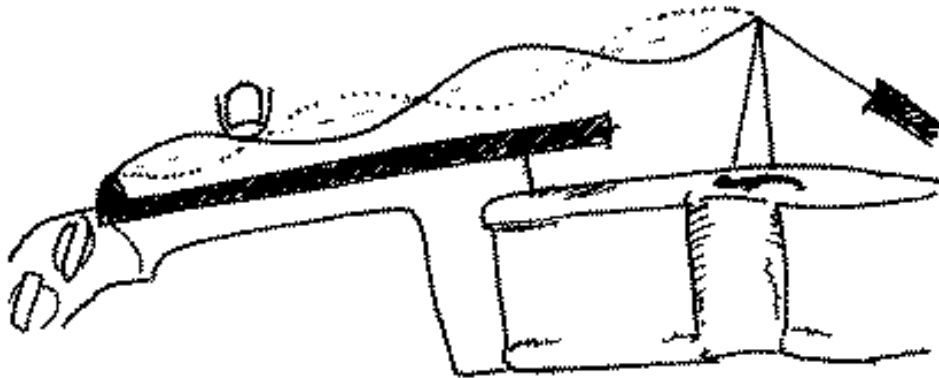
(tone; timbre)

The shapes of the spectra change as the instruments play different notes.



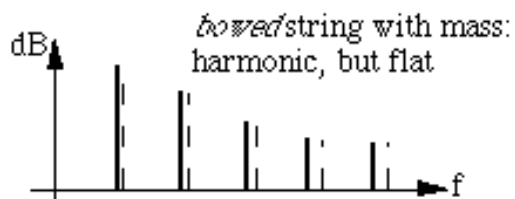
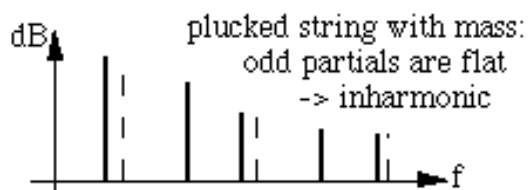
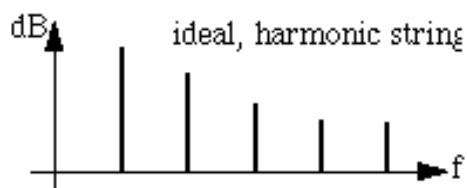


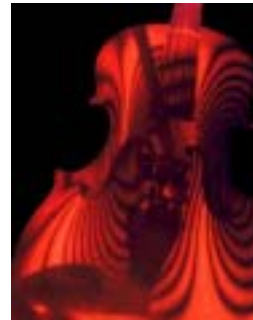
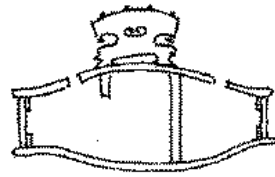
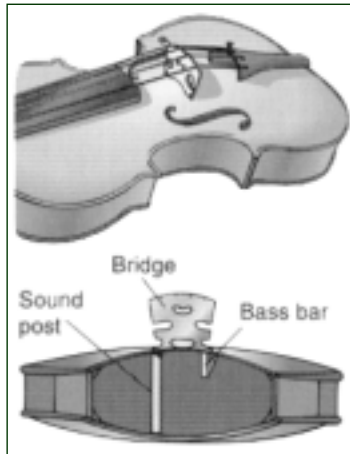
(overtones)



?

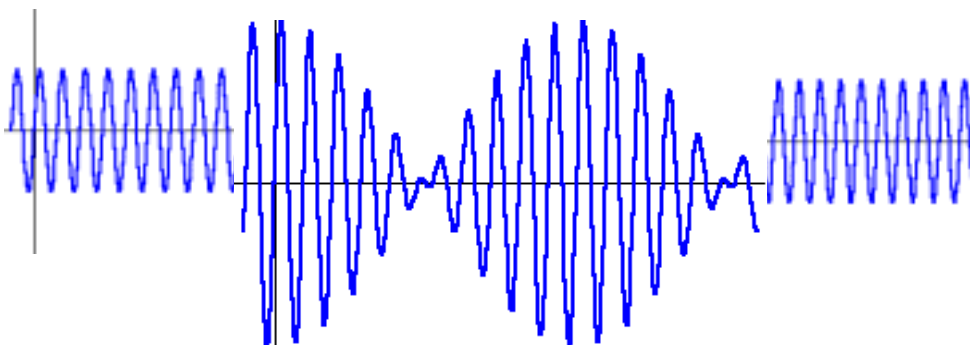
(How harmonic are harmonics?)

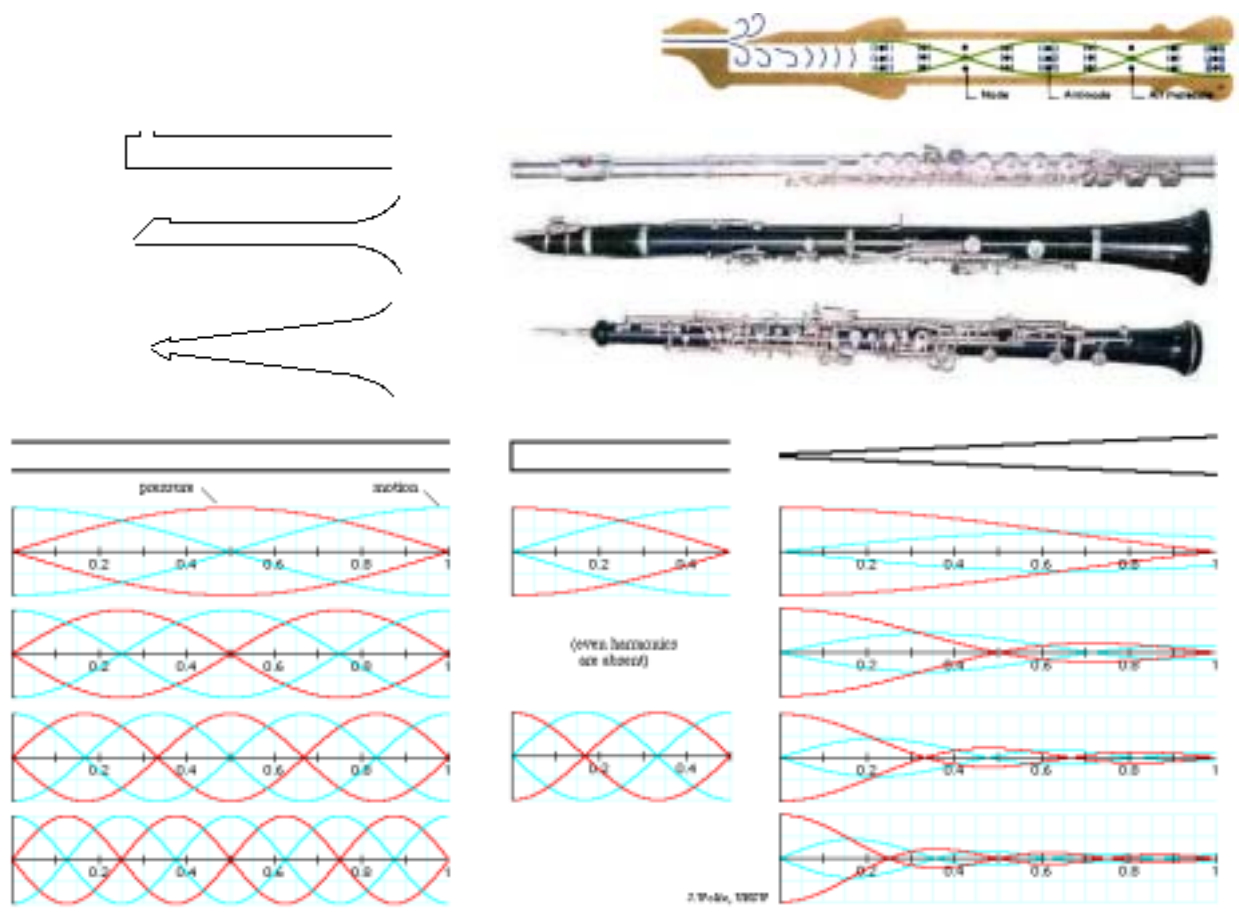




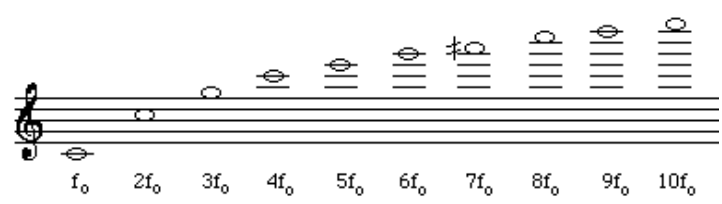
(Tuning)

- :
- Two notes separated by a perfect fifth have a frequency ratio of 3:2.
- Notice that 2nd and 3rd harmonic on string are perfect 5th
- (beating)

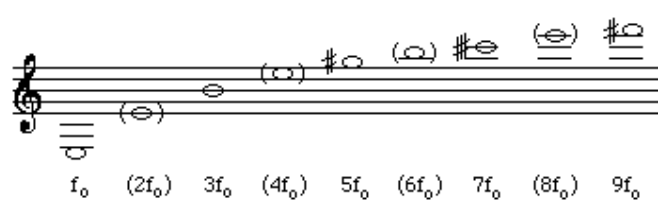




Flutes vs Clarinets



Eight harmonics of the lowest note on a flute.



Harmonics of the lowest (written) note on a clarinet.