

Let's use the Socratic method to derive equations for harmonics on strings and in pipes. "Sit and learn, Aristotle."

- 1) How many antinodes (AN) equals 1λ ? $2AN = \lambda$
(Circle this equation.)
- 2) How many AN does the fundamental have? $1AN = \lambda$
- 3) Using "L" as the length of a fixed string find and label the wavelengths for the harmonics shown on this graphic (do it at the bottom of each harmonic).
- 4) You probably have the fundamental as a whole number (not a fraction). Make it a fraction; write it with its denominator (this is obvious; don't make it hard).
- 5) Notice the denominators of harmonic 1, 3, and 5. You should see a pattern. Change the fractions of the other harmonics (2 and 4) so that the pattern is the same for all of them.
- 6) So, these changing denominators are the number of? AN
- 7) Let's call this "n". Now write a formula for finding the wavelength of a particular harmonic on a fixed string of length "L" (Circle this equation): $\lambda = \frac{2L}{n}$

$$\lambda = \frac{2L}{n}$$

- 8) On a 2.5 m string, what is the wavelength of the 8th harmonic?

$$\lambda = \frac{2L}{n} = \frac{2(2.5)}{8} = \frac{5}{4} \text{ m}$$

- 9) If a mechanical vibrator is vibrating 460 times per second to produce the 8th harmonic, find the speed of the wave in the string.

$$v = f\lambda = 460(.625) = 287.5 \text{ m/s}$$

- 10) The speed of the wave is different in different mediums, so the speed of the wave is different in the string than in air. What is the speed of sound in air? $\lambda f = \frac{343 \text{ m/s}}{1} = 343 \text{ m/s}$

$$V = 340 \text{ m/s}$$

- 11) If you tighten the string, will the wavelength of the harmonics change? *no*
 12) When I tighten a string on my guitar what changes (music-wise)? *pitch*
 13) So, what is the same in air as in a fixed string: the wavelength of the vibration or the frequency of the vibration? *frequency*
 14) What frequency sound will we hear from the string in Q8? *460 Hz*
 15) Is this audible to us? *yes*
 16) What would be the wavelength of that sound in air? *$340 \text{ m/s} = 460(\lambda) \quad \lambda = .752 \text{ m}$*

$$340 \text{ nm} = 460(\lambda) \quad \lambda = .752 \mu\text{m}$$

- 17) Using the equation for λ for a string and $v = f\lambda$, write an equation for f .

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

Let's switch now to silver.

- 18) In an open end of a pipe is there a node or antinode? *AN* *★*
 19) At the closed end of a pipe is there a node or antinode? *N* *★*
 20) On the graphic at the right, let's pretend we have a pipe with one end closed. We'll put that at the bottom of the graphic. For the fundamental draw a pipe that starts at the bottom. (*Don't be fancy, just use a rectangle with one side open, being sure to follow the rules in Q17 and 18.*)
 21) Draw this same length pipe around each of the harmonics.
 22) Which harmonics can be produced in this pipe? *1, 3, 5, 7, 9,*
 23) So, for a pipe closed on one end (closed pipe), give the sequence of what harmonics can be present. *$n = 1, 3, 5, \dots$*

$$\lambda = \frac{4L}{n}$$

- 24) For the first harmonic, how many antinodes (AN) are present in the closed pipe you drew? 1/2 AN

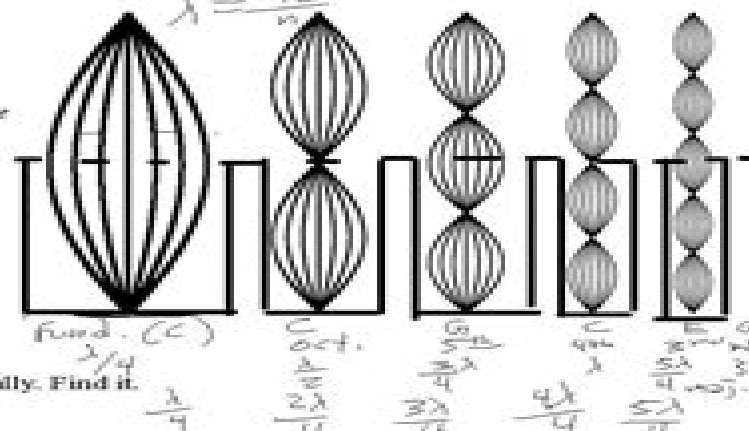
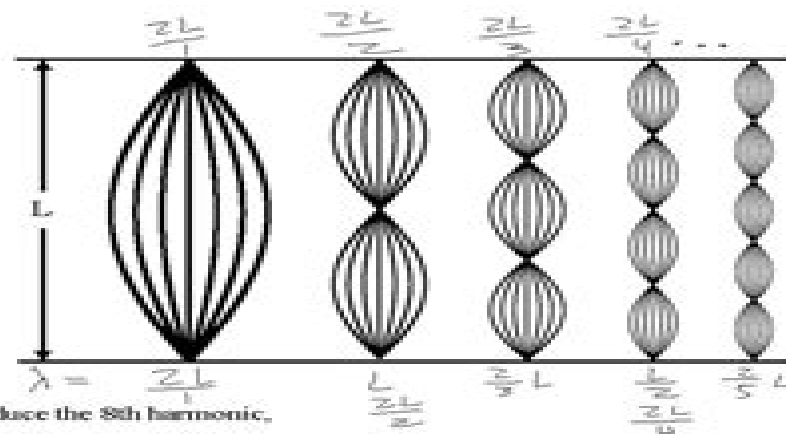
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- 25) How many λ is that? $1/24$
26) Write the wavelengths under the harmonics (even the ones that can't really exist).

H₂ and H₃ should be obvious.

- 27) Remembering Q7: there must be a pattern that includes "n" sequentially. Find it.

- 28) But n can only = 1, 3, 5



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JL Elias



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