

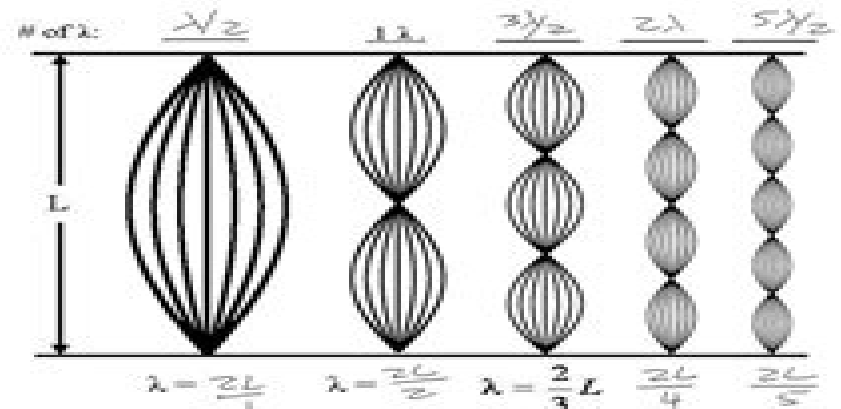
Harmonics on Strings and in Pipes

We will use the Socratic Method to derive equations for harmonics on strings and in pipes. "Sit and learn, Aristotle."

Harmonics on Strings

- 1) Fill in the equation at the right for how many antinodes (AN) equals 1 λ .
- 2) How many AN does the fundamental have?
- 3) Above the diagram, write how many wavelength each harmonic is (H_1 is already done).
- 4) So, how many L's is the wavelength of the fundamental?
- 5) Under each harmonic, write its wavelength in terms of "L". (H_1 is already done).
- 6) You probably have the wavelength of the fundamental as a whole number, not a fraction. Make it a fraction, over 1.
- 7) Notice the denominators of harmonics 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.
- 8) So, these changing denominators are the number of:
- 9) Calling the denominator "n" (the number of antinodes). Now write a formula for finding the wavelength of a particular harmonic on a fixed string of length "L".

$$\underline{2} \text{ AN} = \lambda$$



$$\lambda_{\text{string}} = 2L$$

- 10) * On a 2.5 m string, what is the wavelength of the 8th harmonic?
 $\lambda_1 = 2.5(2) = 5\text{m}$
 $\text{so } \lambda_8 = \frac{5}{8} = .625\text{m}$ or $\lambda_8 = \frac{2L}{n} = \frac{2(2.5)}{8} = .625\text{m}$
- 11) If a mechanical vibrator is vibrating 460 times per second to produce the 8th harmonic you just found, find the speed of the wave in the string.
 $v = f\lambda$
 $= 460(.625) = 287.5\text{ m/s}$

One other thing to notice: on a string it is possible to have every harmonic. There are no "missing harmonics".

Transfer of Waves Between Mediums

The speed of the wave is different in different mediums, so the speed of the wave is different in the string than in air.

- 12) The speed of sound in air varies between 330 Hz and 444 Hz. Let's use $v_{\text{sound}} = 340\text{ m/s}$.
- 13) If you tighten the string, will the wavelength of the harmonics change (is the string longer)? No
- 14) * When I tighten a string on my guitar what does change (music-wise)? pitch or note
- 15) When the string vibrates, it beats against the air, making the air molecules vibrate, too. Every time the string pushes, the air moves, too. So, what is the same in air as in a string: the wavelength of the vibration or the frequency of the vibration?
 $v = f\lambda$
- 16) What frequency sound will we hear from the string in Q11?
- 17) Is this audible to us (see "Sound" notes)? yes audible: 20 Hz $\rightarrow$ 20,000 Hz
- 18) What would be the wavelength of that sound in air? (You have speed and frequency...)

$$v = f\lambda$$

$$340 = 460\lambda \quad \lambda = .739\text{m}$$

Notice in Q10: wavelength on string was 0.625m and $v = 287.5\text{ m/s}$. f is same, but v is faster (340m/s), so wavelength increased: 0.739m

Ancillary Sound Topics Answer Sheet Stephen Murray

Kathleen Armour



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Table of Contents Ancillary Sound Topics Answer Sheet Stephen Murray

1. Understanding the eBook Ancillary Sound Topics Answer Sheet Stephen Murray
 - The Rise of Digital Reading Ancillary Sound Topics Answer Sheet Stephen Murray
 - Advantages of eBooks Over Traditional Books
2. Identifying Ancillary Sound Topics Answer Sheet Stephen Murray
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Ancillary Sound Topics Answer Sheet Stephen Murray
 - User-Friendly Interface
4. Exploring eBook Recommendations from Ancillary Sound Topics Answer Sheet Stephen Murray
 - Personalized Recommendations
 - Ancillary Sound Topics Answer Sheet Stephen Murray User Reviews and Ratings
 - Ancillary Sound Topics Answer Sheet Stephen Murray and Bestseller Lists

5. Accessing Ancillary Sound Topics Answer Sheet Stephen Murray Free and Paid eBooks
 - Ancillary Sound Topics Answer Sheet Stephen Murray Public Domain eBooks
 - Ancillary Sound Topics Answer Sheet Stephen Murray eBook Subscription Services
 - Ancillary Sound Topics Answer Sheet Stephen Murray Budget-Friendly Options
6. Navigating Ancillary Sound Topics Answer Sheet Stephen Murray eBook Formats
 - ePub, PDF, MOBI, and More
 - Ancillary Sound Topics Answer Sheet Stephen Murray Compatibility with Devices
 - Ancillary Sound Topics Answer Sheet Stephen Murray Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Ancillary Sound Topics Answer Sheet Stephen Murray
 - Highlighting and Note-Taking Ancillary Sound Topics Answer Sheet Stephen Murray
 - Interactive Elements Ancillary Sound Topics Answer Sheet Stephen Murray
8. Staying Engaged with Ancillary Sound Topics Answer Sheet Stephen Murray
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Ancillary Sound Topics Answer Sheet Stephen Murray
9. Balancing eBooks and Physical Books Ancillary Sound Topics Answer Sheet Stephen Murray
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Ancillary Sound Topics Answer Sheet Stephen Murray
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Ancillary Sound Topics Answer Sheet Stephen Murray
 - Setting Reading Goals Ancillary Sound Topics Answer Sheet Stephen Murray
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Ancillary Sound Topics Answer Sheet Stephen Murray
 - Fact-Checking eBook Content of Ancillary Sound Topics Answer Sheet Stephen Murray
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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