

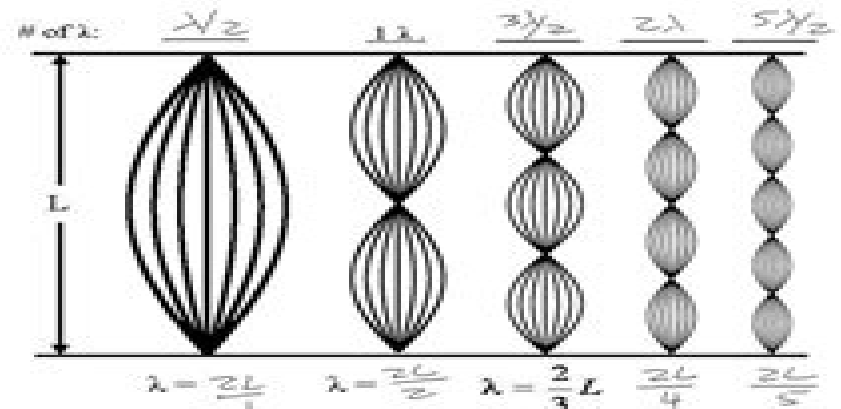
Harmonics on Strings and in Pipes

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

Magnetic Fields Cstephenmurray Answers

Huangqi Zhang



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Table of Contents Magnetic Fields Cstephenmurray Answers

1. Understanding the eBook Magnetic Fields Cstephenmurray Answers
 - The Rise of Digital Reading Magnetic Fields Cstephenmurray Answers
 - Advantages of eBooks Over Traditional Books
2. Identifying Magnetic Fields Cstephenmurray Answers
 - 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 Magnetic Fields Cstephenmurray Answers
 - User-Friendly Interface
4. Exploring eBook Recommendations from Magnetic Fields Cstephenmurray Answers
 - Personalized Recommendations
 - Magnetic Fields Cstephenmurray Answers User Reviews and Ratings
 - Magnetic Fields Cstephenmurray Answers and Bestseller Lists
5. Accessing Magnetic Fields Cstephenmurray Answers Free and Paid eBooks
 - Magnetic Fields Cstephenmurray Answers Public Domain eBooks
 - Magnetic Fields Cstephenmurray Answers eBook Subscription Services
 - Magnetic Fields Cstephenmurray Answers Budget-Friendly Options
6. Navigating Magnetic Fields Cstephenmurray Answers eBook Formats

- ePub, PDF, MOBI, and More
- Magnetic Fields Cstephenmurray Answers Compatibility with Devices
- Magnetic Fields Cstephenmurray Answers Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Magnetic Fields Cstephenmurray Answers
 - Highlighting and Note-Taking Magnetic Fields Cstephenmurray Answers
 - Interactive Elements Magnetic Fields Cstephenmurray Answers
- 8. Staying Engaged with Magnetic Fields Cstephenmurray Answers
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Magnetic Fields Cstephenmurray Answers
- 9. Balancing eBooks and Physical Books Magnetic Fields Cstephenmurray Answers
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Magnetic Fields Cstephenmurray Answers
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Magnetic Fields Cstephenmurray Answers
 - Setting Reading Goals Magnetic Fields Cstephenmurray Answers
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Magnetic Fields Cstephenmurray Answers
 - Fact-Checking eBook Content of Magnetic Fields Cstephenmurray Answers
 - 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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