Subject Area(s) **measurement, physics, problem solving**

Associated Unit

Associated Lesson

Activity Title **What's a wavelength?**

Grade Level 11 (10-12)

Time Required **30 minutes**

Group Size 28

Expendable Cost per Group US$0

Summary

In this activity students measure the wavelength of sound. It covers basic vocabulary associated with waves. As a class students brainstorm what the difference is between two tuning forks and the sound they produce. They are then allowed to come up with a way to measure that difference. Using a pipe in a graduated cylinder filled with water volunteer students measure the wavelength of various tuning forks by finding the height the pipe must be held at to produce the loudest note. After calculating the wavelength and comparing it to the pitch of each tuning fork, students decide what the relationship is between wavelength and pitch.

Engineering Connection

Acoustical engineers use their understanding of the physics of sound to create products that maximize the sound output with good quality. Noise-canceling headphones are designed to cancel out wavelengths that come from outside the headphones. Engineers use the properties of sound when designing auditoriums and theaters to ensure that the whole room can hear the sound well.

Engineering Category

Choose the category that best describes this activity's amount/depth of engineering content: (#1) relates science concept to engineering, (#2) relates math concept to engineering,

Keywords

music, sound, pitch, wavelength

Educational Standards

Texas, Chapter 112. Texas Essential Knowledge and Skills for Science, Amended 2009, 1998, C Physics (7) Science concepts. The student knows the characteristics and behavior of waves. The student is expected to: (B) investigate and analyze characteristics of waves, including velocity, frequency, amplitude, and wavelength, and calculate using the relationship between wavespeed, frequency, and wavelength.

Pre-Requisite Knowledge

Students should be able to do simple mathematical calculations and know how to use a meter stick. A previous knowledge of waves can be helpful, but is not necessary.

Learning Objectives

After this activity, students should be able to:

- **Define wavelength, frequency, amplitude, pitch, and node.**
- **Calculate wavelength and frequency from a formula**

- **Relate the wavelength to pitch and frequency**

Materials List

Each class needs:

- large (2 L) graduated cylinder
- 1 3cm diameter tube (glass or plastic) the length of the gradated cylinder
- 1 meter stick
- at least 2 tuning forks of different pitches

Introduction / Motivation

How do we measure sound? We use a volume knob to adjust how loud it is, but what is the difference between these two sounds? (Strike 2 different tuning forks and allow students to listen to each. Students should say one is higher than the other) What do you mean when you say a sound is higher or lower? (Wait for answers and incorporate them into the definition of pitch) What you mean when you say a sound is high is that it sounds to you like it has a high frequency. Pitch is your perception of the frequency of a sound. But what is frequency? Frequency is something we can measure. Frequency is how fast the sound is traveling. Which fork has a higher pitch or a faster frequency? The faster the frequency the higher we think the pitch sounds. (Reason with students until they say the larger tuning fork has the lower pitch and the lower frequency. Ask students if someone will draw a wave on the board. Then ask how you measure the frequency from what they have drawn. Draw a second wave with many more crests and troughs) Which wave has a greater frequency of repetitions? (Answer: the one you drew) Which would have the higher pitch? (Answer: the one you drew) So how do we measure the frequency of these two waves? How many times does each wave repeat? (possible answers: 4 & 8) We measure frequency in Hertz which is another way of saying reciprocal seconds which is a fancy way for saying 1/seconds. If I told you that it takes each of these waves 1 second to get from the left side of the drawing to the right side, how many times does each repeat per second? (possible answers: 4 & 8) So the first wave has a frequency of 4 Hz and the second wave has a frequency of 8 Hz. But how do I measure how many repetitions this wave (strike the tuning fork) does in one second? It is going way faster than 4 Hz. Let's look back at our waves we have drawn up here. We can get more information from what we have drawn. How long is each wave? (Answer: same distance) So the length of the wave doesn't change the sound but what distances do change? (Answer: the distance between the peaks/valleys) We call those highest points crests and the lowest points troughs. The distance from one peak to one peak is called 1 wavelength. That distance is the same as the distance from one trough to one trough. What about the point in between the crest and the trough? Is the distance between two of those the same as well? (Answer: Yes) We call the point that is in between a node. The high point is positive and the low point is negative but the point in the middle is 0. So what can you tell me about the wavelength of each of these waves? (Answer: the 1^{st} one has a longer wavelength and the 2^{nd} has a shorter wavelength) So having a longer wavelength means that it will have a higher or lower pitch? Higher or lower frequency? (Answers: lower pitch lower frequency). Wavelength is inversely proportional to both pitch and frequency. We have a formula that relates wavelength to frequency using the speed of sound (Write $c=\lambda\upsilon$). Here c is the speed of sound and for our purposes it will be the speed in air, 343 m/s because it will travel at different speeds in water or space. We use λ to represent wavelength and it is measured in meters and υ is frequency which

is in 1/seconds. So is it possible to measure wavelength easier than it is to measure frequency? We are going to try and measure the wavelength of a few of these tuning forks today.

Vocabulary / Definitions

Word	Definition
wavelength	The distance over which the wave's shape repeats.
frequency	The number of waves that pass a point per second.
amplitude	The height of a wave measured from the origin perpendicular to the motion of the wave.
pitch	The perceived frequency of a sound.
node	The point at which a wave has 0 amplitude.
crest	The point at which a wave has it's maximum amplitude.
trough	The point at which a wave has it's minimum amplitude.

Procedure

Background

It is possible to measure the wavelength of sound using a tube closed at one end. By using a tube submerged in water you can adjust the length of the tube to match the frequency of the sound wave being measured. At the point at which the sound is the loudest the length of the tube above the water is ¼ the wavelength. As sound travels down the tube and back out nodes are created and to assure the crest of the wave is at the mouth of the tube you want to align the node at the bottom of the tube or the top of the water.

Wavelength = 4 x the distance from the top of the water to the top of the tube

Frequency = speed of sound / wavelength

Speed of sound in air = 343 meter/sec

Before the Activity

- Place tube inside of graduated cylinder and fill with water
- Practice with different tuning forks to find which would be best to let the students test

With the Students

1. Tell them the materials they have and show what happens when you strike the fork and hold it above the pipe.
2. Ask them how they would use this to find out more about the wavelength.
3. Get volunteers to come up and test their theories.
4. After discovering that at some height the pitch is the loudest tell them what they have discovered. The amplitude is largest and the sound is loudest when the distance from the water to the top of the pipe is ¼ the wavelength. Have all students independently calculate the wavelength of the chose tuning fork. Once they have calculated the wavelength of the first have them try others.
5. Have them formulate opinions as to the relationship of pitch and wavelength and record that along with the calculations they have done.
6. Provide the formula to relate frequency and wavelength and have students convert each of the wavelengths they calculated to frequency
7. Provide a list of musical notes with their associated wavelengths and frequencies (from Notes List) and ask students to assign notes to each of the forks. Have them compare the

"calculated" note to the actual note of the fork and comment on the results. Students should provide reasons if the notes do not agree.

8. Given a tuning fork with a specific note tell the students to predict the height at which the tube must be held and have a volunteer demonstrate when all students have finished calculating.
9. Redefine all keywords and reemphasize all important formulas.
10. Ask how they could use what they learned today. Have students offer as many applications as possible before suggesting real engineering concepts. Touch on familiar ways they see sound waves and wavelengths in their lives and how engineering brought those devices to them.

Attachments

Notes List (xls)

Safety Issues

- If using glass graduated cylinder or tubing warn students to be delicate with them so they do not break.
- Only strike tuning forks with a rubber mallet or on the sole of a shoe

Troubleshooting Tips

It is important to test all tuning forks before you start. Some will have frequencies too low and the students will not be able to hold the tube high enough. If students find multiple points at which the sound is louder discussion may turn to harmonics. If they find a multiple of the wavelength the calculations will give them the wrong result but you can remind those that are familiar with music that notes repeat on a scale.

Investigating Questions

What instruments produce the highest/lowest notes? Why?
How do you make a sound louder/softer/higher/lower?

Assessment

Pre-Activity Assessment

Asking students questions to begin the activity determines prior knowledge

Activity Embedded Assessment

Since students provide the momentum of the lesson they should be providing answers to your questions throughout which are embedded in the lesson.

Post-Activity Assessment

The individual work they do during the lesson should be turned in so that you can see if they can do the calculations and form relationships between the concepts as well as define them

References

Suits, B.H. Physics of Music – Notes. 8 Apr 2010. Physics Department, Michigan Technological University. 9 Apr 2010. http://www.phy.mtu.edu/~suits/notefreqs.html

Supporting Program

GK-12 Program, College of Engineering University of Houston

Note	Frequency (H	Wavelength (cm)
C0	16.35	2100
C#0/Db0	17.32	1990
D0	18.35	1870
D#0/Eb0	19.45	1770
E0	20.6	1670
F0	21.83	1580
F#0/Gb0	23.12	1490
G0	24.5	1400
G#0/Ab0	25.96	1320
A0	27.5	1250
A#0/Bb0	29.14	1180
B0	30.87	1110
C1	32.7	1050
C#1/Db1	34.65	996
D1	36.71	940
D#1/Eb1	38.89	887
E1	41.2	837
F1	43.65	790
F#1/Gb1	46.25	746
G1	49	704
G#1/Ab1	51.91	665
A1	55	627
A#1/Bb1	58.27	592
B1	61.74	559
C2	65.41	527
C#2/Db2	69.3	498
D2	73.42	470
D#2/Eb2	77.78	444
E2	82.41	419
F2	87.31	395
F#2/Gb2	92.5	373
G2	98	352
G#2/Ab2	103.83	332
A2	110	314
A#2/Bb2	116.54	296
B2	123.47	279
C3	130.81	264
C#3/Db3	138.59	249

D3	146.83	235
D#3/Eb3	155.56	222
E3	164.81	209
F3	174.61	198
F#3/Gb3	185	186
G3	196	176
G#3/Ab3	207.65	166
A3	220	157
A#3/Bb3	233.08	148
B3	246.94	140
C4	261.63	132
C#4/Db4	277.18	124
D4	293.66	117
D#4/Eb4	311.13	111
E4	329.63	105
F4	349.23	98.8
F#4/Gb4	369.99	93.2
G4	392	88
G#4/Ab4	415.3	83.1
A4	440	78.4
A#4/Bb4	466.16	74
B4	493.88	69.9
C5	523.25	65.9
C#5/Db5	554.37	62.2
D5	587.33	58.7
D#5/Eb5	622.25	55.4
E5	659.26	52.3
F5	698.46	49.4
F#5/Gb5	739.99	46.6
G5	783.99	44
G#5/Ab5	830.61	41.5
A5	880	39.2
A#5/Bb5	932.33	37
B5	987.77	34.9
C6	1046.5	33
C#6/Db6	1108.73	31.1
D6	1174.66	29.4
D#6/Eb6	1244.51	27.7
E6	1318.51	26.2

F6	1396.91	24.7
F#6/Gb6	1479.98	23.3
G6	1567.98	22
G#6/Ab6	1661.22	20.8
A6	1760	19.6
A#6/Bb6	1864.66	18.5
B6	1975.53	17.5
C7	2093	16.5
C#7/Db7	2217.46	15.6
D7	2349.32	14.7
D#7/Eb7	2489.02	13.9
E7	2637.02	13.1
F7	2793.83	12.3
F#7/Gb7	2959.96	11.7
G7	3135.96	11
G#7/Ab7	3322.44	10.4
A7	3520	9.8
A#7/Bb7	3729.31	9.3
B7	3951.07	8.7
C8	4186.01	8.2
C#8/Db8	4434.92	7.8
D8	4698.64	7.3
D#8/Eb8	4978.03	6.9