Moire Patterns

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Date Created: June 2023

Subject: Physics

Grade Level: 9-12

Standards: Next Generation Science Standards (www.nextgenscience.org)

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

Schedule: 3-45 minute classes

CCMR Lending Library Connected Activities:

Objectives:	**Vocabulary:**
Students will learn about Moire patterns and how they are created.	- Frequency - Pitch - Moire Pattern - Interference - Lattice Period
Students Will: - Understand how frequency and pitch are related. - Learn how a beat pattern is created with interference from two sound waves. - Collect data and calculate the beat frequency. - Learn about about 2D Moire patterns and how they are connected to beat frequency. - Create Moire patterns and look at the effect of changing the lattice and angles. - Collect, calculate, graph, and analyze data on the effects of lattice size and angles in Moire patterns.	**Materials:** **Activity 1 (Provided by Teacher or Students)** ___ Two phones or one computer ___ Stopwatch **Activity 2 (For Each Group of 2-4 students)** ___ Transparent paper with hexagon lattice and reference period ___ 3 pieces of paper with hexagon lattice with periods 0.8, 1.1 and 1.2 ___ Paper clip ___ Ruler ___ Transparent paper with pink hexagon lattice with a period of 1 ___ Paper with blue hexagon lattice with a period of 1 ___ Pin and Cardboard
Safety	There are no safety concerns for this activity.

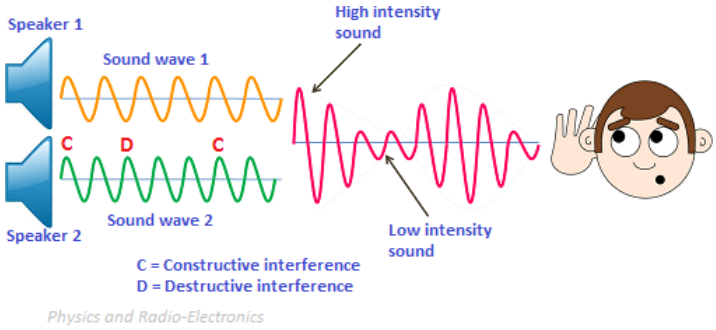
Science Content for the Teacher:

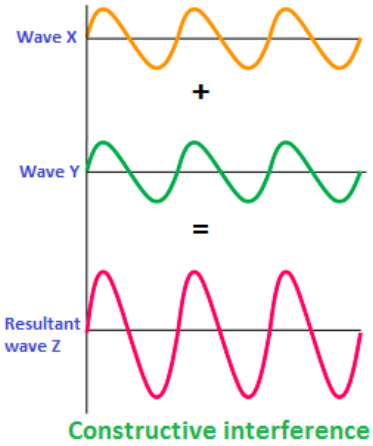
Background:

Beat Frequency:
When two objects vibrate with different frequencies, you hear a fluctuating sound (soft and loud sound alternatively). This phenomenon is known as beats or beats frequency of sound.

or

When two sound waves of slightly different frequencies approach your ear, you hear a fluctuating sound (soft and loud sound alternatively). This phenomenon is known as beats. The loud sound is caused by the constructive interference and the soft sound is caused by the destructive interference.

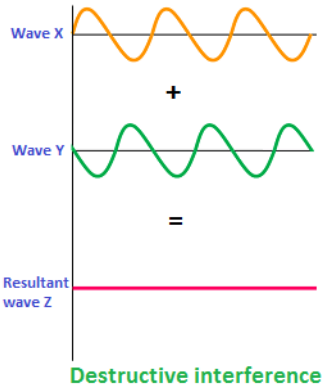




Constructive interference

The interference is said to be a constructive interference if two waves having the same frequency meet in such a way that the crest of a wave meets the crest of another wave.

When two sound waves having the same frequency meet in such a way that the crest of a wave meets the crest of another wave, the amplitude of sound waves are added. Therefore, the resultant sound is much louder than that of the original sound.



Destructive interference

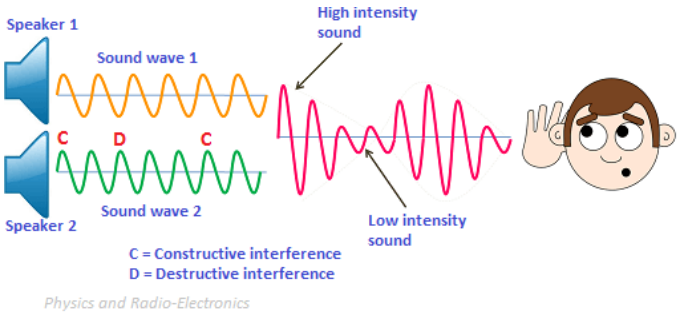
The interference is said to be a destructive interference if two waves having the same frequency meet in such a way that the crest of a wave meets the trough of another wave.

When two sound waves having the same frequency meet in such a way that the crest of a wave meets the trough of another wave, the amplitude of the sound waves are subtracted. Therefore, the resultant sound is much weaker than that of the original sound.

What is beats frequency?

When two sound waves of different frequencies meet each other, the amplitude of sound waves are added and subtracted alternatively over a given period. Therefore, the resultant sound intensity fluctuates (becomes louder and softer) over a given period.

Consider two sound waves: sound wave 1 and sound wave 2 of different frequencies but same amplitude traveling in the same medium.



When these sound waves meet each other, a fluctuating sound is produced. For some time, the crest of sound wave 1 meets the crest of sound wave 2. This results in constructive interference. Therefore, the intensity of sound rises for some period.

However, after some time, the crest of sound wave 2 meets the trough of sound wave 1. This results in destructive interference. Therefore, the intensity of sound falls for some period.

Likewise, the intensity of sound rises and falls regularly with time. As a result, you hear a soft and loud sound alternatively.

Unlike the original sound waves, the amplitude of the resultant sound wave is not constant; it varies with respect to time.

When the intensity of sound rises to maximum, we call it as waxing of sound. When the intensity of sound falls to minimum, we call it as waning of sound.

The phenomenon of periodic waxing and waning of sound, when two sound waves of nearly equal frequencies meet each other is called beats.

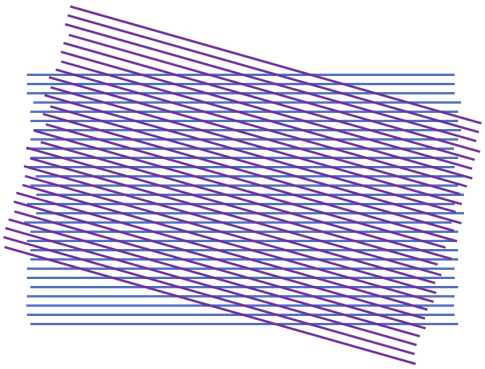
The number of beats produced per second is called beat frequency, which is equal to the difference in frequencies of two waves.

I.e. $f_b = |f_1 - f_2|$ Where, f_b = beats frequency
f_1 = frequency of sound wave 1
f_2 = frequency of sound wave 2
$|f_1 - f_2|$ = positive (+) value of the difference

Applications of beats
The various applications of beats are:

- Police radar
- Doppler pulse detection
- Subjective tones
- Multiphonics

Moire Patterns:
A moiré pattern is a two dimensional interference pattern produced by overlaying two periodic patterns with either slightly different periods or with the same period but placed at a small angle to one another. Solid state materials consist of atoms arranged in a periodic lattice. By fabricating thin films of solids, researchers can create two dimensional patterns at the nanoscale. Placing two thin films on top of one another weaves moiré patterns of atoms.



Other Resources:

Beat Frequency & Wave Interference

"8.6: Beats." *Physics LibreTexts*, Libretexts, 12 Jan. 2023 phys.libretexts.org/Courses/University_of_California_Davis/UCD%3A_Physics_7C_-_General_Physics/8%3A_Waves/8.6%3A_Beats

"Wave Interference Using Sound: Beat Frequency for Two Sine Waves with Similar Frequencies." *YouTube*, YouTube, 19 Oct. 2021, www.youtube.com/watch?v=2eBW3NOqQiQ.

Shaik, Asif. "Beats." *Physics*, www.physics-and-radio-electronics.com/physics/beats-waves-physics.html.

Moire Patterns

"Moiré Pattern." *Wikipedia*, Wikimedia Foundation, 2 Sept. 2023, en.wikipedia.org/wiki/Moir%C3%A9_pattern

Classroom Procedure:

Pre-Activity:
Introduce the concept of patterns in nature. The first types of patterns are sounds. For this activity, you can introduce frequency, pitch, constructive interference, and destructive interference either before or after the beats frequency activity.

Activity: Beat Frequency
This will work best as a class activity. You can play the sounds on two phones or the best way is to play them on one computer, with each sound on a different tab. Have the students count the beats and calculate the beat frequency for when the difference is 1Hz and 0.5Hz

Activity: Lattice Periods and Angles
Introduce Moire patterns and make connection with Beat frequency. Have students perform activities where they see how the lattice size and angles affect the Moire pattern.

Class Discussion:
Summarize results. Watch the video "A Science Love Story" to find out why these patterns interest scientists.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

4= exceeds expectations
3= meets expectations consistently
2= meets expectations occasionally
1= not meeting expectations

	Engage	Explore	Explain
4	Shows leadership in the discussion and an in depth understanding of beat frequency and Moire patterns.	Completes work accurately while providing an explanation for what is observed. Works very well with partners.	Provides an in-depth explanation of findings. Fills out worksheets clearly.
3	Participates in the activities and shows an understanding of beat frequency and Moire patterns.	Completes work accurately and works cooperatively with partners.	Provides a clear explanation of findings. Fills out the worksheet clearly.
2	Contributes to the discussion, but shows little understanding of beat frequency and Moire patterns.	Works cooperatively with partners, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Fills out some of the worksheet.
1	Does not participate in discussion. Shows no understanding of beat frequency and Moire patterns.	Has trouble working with partners. Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out the worksheet.