Lesson Plan: Waves and Oscillations

Teacher-contributed lesson plan by Joy Merwin Monteiro, Pune, India.

As a **High School** or **Undergraduate Physics** or **Earth Sciences** teacher, you can use this set of computer-based tools to teach about the characteristics, properties and types of **waves and oscillations**, and how **atmospheric wave dynamics** possibly influence extreme weather events.

A wave is a continuous oscillation of a field about its equilibrium value. The wave traverses through the medium but when some parts of the medium are fixed then the waves reflect at this fixed point, become stationary, and are called **standing waves**. Standing waves occur in the atmosphere very often, due to heating in the tropical regions, land surface features like mountains, and land-water temperature gradients. Recent research suggests that the interaction of standing and travelling atmospheric **Rossby waves** could result in **extreme weather events**, such as heat waves and floods.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in **Physics** or **Earth Sciences**.

Use this lesson plan to help your students find answers to:

- Distinguish between simple harmonic motion and waves.
- What are standing waves? Describe their characteristics.
- What are Rossby waves and how do they influence Earth's weather patterns?
- How could the interference of atmospheric Rossby waves cause extreme weather events?

About the Lesson Plan

Grade Level: High School, Undergraduate

Discipline: Physics, Earth Sciences

Topic(s) in Discipline: Waves, Oscillations, Simple Harmonic Motion, Stationary Waves, Standing Waves, Rossby Waves, Wave Interference, Wave Forcing, Teleconnections

Climate Topic: Climate and the Atmosphere

Location: Global

Access: Online

Language(s): English

Approximate Time Required: 45-60 min

1 Contents

1. Reading (35 min)

A reading that introduces the topic of waves and oscillations in detail and describes their properties using graphical representations and mathematical expressions.

This can be accessed at:

https://phys.libretexts.org/Courses/University_of_California_Davis/UCD%3A_Physics_7C_-_General_Physics/08._Waves/8.1%3A_Introduction_to_Waves

2. Video (~13.5 min)

A video that describes how standing waves are formed due to fixed points in a medium.

This can be accessed at:

https://www.youtube.com/watch?v=gT0IqL1dyyk

3. Video micro-lecture (4 min)

A video micro-lecture that describes what Rossby waves are and how their interference by standing waves in the atmosphere influence mid-latitudinal weather conditions and in some cases, extreme weather events.

This can be accessed at:

https://www.youtube.com/watch?v=MzW5Isbv2A0

4. Suggested questions/assignments for learning evaluation

- Distinguish between simple harmonic motion and waves.
- What are standing waves? Describe their characteristics.
- What are Rossby waves and how do they influence Earth's weather patterns?
- How could the interference of atmospheric Rossby waves cause extreme weather events?

2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

1. Topic introduction and discussion

Simple harmonic motion (SHM) is the oscillation of a single particle about a point of equilibrium. Usually, particles don't exist by themselves and are part of a medium such as gas, liquid or solid. If some particles are provided with the energy to perform SHM, they transfer this energy to their neighboring particles, which then perform simple harmonic motion SHM themselves. This transfer of energy continues until most of the particles in the medium are in SHM. If there is no continuous source of energy, the particles initially performing SHM come back to rest, but the energy gets transferred. This phenomenon of energy transfer from one particle to its neighbor is a wave. The particles themselves do not move very far, but the energy contained in them travels a very long distance.

Thus, a wave is a continuous oscillation of a field about its equilibrium value. This field could be a physical medium such as water, ground, air or it could be electric and magnetic fields. In the former case, the wave is called a mechanical wave and in the latter case, the wave is called an electromagnetic wave.

Use the textbook chapter, '8.1: Introduction to Waves' by Dina Zhabinskaya et al., LibreTexts™ to teach your students the topic of waves and oscillations in detail. Navigate through the different sections of this chapter to teach your students different aspects of waves- their properties and characteristics. Use the in-text examples and exercises to explain the various concepts better.

This can be accessed at:

https://phys.libretexts.org/Courses/University_of_California_Davis/UCD%3A_Physics_7C_-_General_Physics/08._Waves/8.1%3A_Introduction_to_Waves

2. Extend understanding of the characteristics of waves

The speed with which a wave traverses a medium is determined by the properties of the medium. If a wave passes through two different media, the direction of propagation changes as it passes from one medium to another. This change in direction is proportional to the angle at which the wave is incident at the interface between the two media. This turning of waves is called refraction. It is also possible that the wave cannot pass through the interface between the media and instead is "turned back" into the medium from which it came. This "turning back" of waves is called reflection. If the medium through which a mechanical wave is passing is perfectly elastic, then the medium itself does not absorb any of the energy transmitted by the wave. Most real media are not perfectly elastic, and hence the energy transmitted by the wave reduces as the wave passes through the medium. This phenomenon is called absorption of the wave by the medium.

When some parts of the medium are fixed- for example, if you tie the ends of a rope using nails- then the waves reflect at this fixed point and become stationary. This is called a standing wave.

Use the video, 'Standing waves on strings' by Khan Academy, to explain what standing waves are, how they are formed and what their characteristics are. Explain how these standing waves interfere with the travelling waves and show altered net wavelengths and amplitudes. Use the video to emphasize on the different aspects of superimposition of these waves due to interference such as destructive and constructive interference.

This can be accessed at:

https://www.youtube.com/watch?v=gT0IqL1dyyk

3. Discuss an example of wave interference and its consequences in Earth's atmosphere

Use the video micro-lecture, 'Rossby waves and extreme weather' by Kai Kornhuber, Potsdam Institute for Climate Impact Research, to introduce your students to atmospheric Rossby waves. Describe, using the video, how the free-flowing Rossby waves influence weather between the Arctic and the mid-latitudinal regions. Discuss the interference of the free-flowing Rossby waves with naturally occurring standing waves formed due to mountain ranges and land-water temperature gradients. Finally, explain how this interaction of standing and travelling waves can also result in extreme weather events, such as heat waves and floods. Emphasize on the increased frequency of such events and discuss how the interference of the Rossby waves could be responsible for this aspect of climate change.

This can be accessed at:

https://www.youtube.com/watch?v=MzW5Isbv2A0

4. Questions/Assignments

Use the tools and the concepts learned so far to discuss and determine answers to the following questions:

- Distinguish between simple harmonic motion and waves.
- What are standing waves? Describe their characteristics.
- What are Rossby waves and how do they influence Earth's weather patterns?
- How could the interference of atmospheric Rossby waves cause extreme weather events?

3 Learning Outcomes

The tools in this lesson plan will enable students to:

- learn about waves, oscillations and their properties
- understand how standing waves are formed and how they interfere with travelling waves
- discuss the influence of Rossby waves on Earth's weather patterns
- explain how the interference of atmospheric Rossby waves could cause extreme weather events

4 Additional Resources

If you or your students would like to explore the topic further, these additional resources will be useful.

1. Video; 'Introduction to waves'

A video lecture by Sal Khan, Khan Academy that introduces transverse and longitudinal waves.

This can be accessed at:

https://www.khanacademy.org/science/physics/mechanical-waves-and-sound/mechanical-waves/v/introduction-to-waves

2. Video micro-lecture; 'Standing Waves'

A video micro-lecture by Paul Andersen, Bozeman Science that explains how standing waves are formed, their characteristics, and examples.

This can be accessed at:

https://www.youtube.com/watch?v=jz8IIk_bps0

3. Reading; 'What is a Rossby wave?'

A reading and embedded visualization by the National Ocean Service (NOAA) that introduces both atmospheric and oceanic Rossby waves and explain how they influence Earth's climatic conditions.

This can be accessed at:

https://oceanservice.noaa.gov/facts/rossby-wave.html

4. Reading; 'Teleconnections and stationary Rossby waves'

A blog by Isaac Held, Senior Research Scientist, Geophysical Fluid Dynamics Laboratory (NOAA) with embedded visualizations to describe how stationary Rossby waves create teleconnections and spatially affect Earth's weather conditions.

This can be accessed at:

https://www.gfdl.noaa.gov/blog_held/57-teleconnections-and-stationary-rossby-waves/

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1. Reading; '8.1: Introduction to Waves'

By Dina Zhabinskaya et al., LibreTexts™.

2. Video; 'Standing waves on strings'

By Khan Academy.

3. Video micro-lecture; 'Rossby waves and extreme weather'

By Kai Kornhuber, Potsdam Institute for Climate Impact Research.

4. Additional Resources

Sal Khan, Khan Academy

Paul Andersen, Bozeman Science

National Ocean Service, National Oceanic and Atmospheric Administration (NOAA)

Isaac Held, Geophysical Fluid Dynamics Laboratory (NOAA)