Lesson Plan: Simple Harmonic Motion and Simple Harmonic Oscillators

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

As a **High School** or **Undergraduate Physics** teacher, you can use this set of computer-based tools to teach about **Simple Harmonic Motion (SHM)** and **Simple Harmonic Oscillators**.

This lesson plan will allow you to teach your students about Simple Harmonic Motion (SHM) and simple harmonic oscillators and engage them in a hands-on activity to explore these concepts. Simple harmonic oscillations, that occur in stratified fluids due to the **Archimedes' principle of buoyancy**, can affect the flow of energy within large scale systems such as the Earth's atmosphere and the oceans by the displacement of parcels of air/water. This lesson plan will thus, explain how natural oscillations in the atmosphere/oceans with the **Brunt–Väisälä frequency** affect cloud formation, occurrence of thunderstorms, and internal waves within oceans and thus, affect the climate.

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

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

1. What is Simple Harmonic Motion (SHM)?
2. What are simple harmonic oscillators? Discuss an example.
3. What is the Brunt–Väisälä frequency and how can it be used to predict cloud formations and the occurrence of thunderstorms?
4. How can simple harmonic oscillations in the Earth's atmosphere and oceans be responsible for influencing the climate?

About the Lesson Plan

Grade Level: High School, Undergraduate

Discipline: Physics

Topic(s) in Discipline: Simple Harmonic Motion (SHM), Simple Harmonic Oscillators, Brunt–Väisälä Frequency, Archimedes' Principle of Buoyancy in Fluids, Stratified Fluids, Density Gradient.

Climate Topic: Climate and the Atmosphere, Climate and the Hydrosphere

Location: Global

Access: Online, Offline

Language(s): English

Approximate Time Required: 50-60 min

1 Contents

1. Reading (25 min)

An introduction to simple harmonic motion and simple harmonic oscillators.

This can be accessed at:

https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/Map%3A_University_Physics_I_-_Mechanics%2C_Sound%2C_Oscillations%2C_and_Waves_(OpenStax)/15%3A_Oscillations/15.1%3A_Simple_Harmonic_Motion

2. Classroom/Laboratory Activity (20 min)

A hands-on laboratory activity (Dancing Test Tubes) to demonstrate simple harmonic oscillation in a stratified fluid.

3. Video (~4.5 min)

A video micro-lecture that describes how oscillations with the Brunt–Väisälä frequency in the atmosphere and oceans cause many natural phenomena that can influence Earth's climate.

This can be accessed at:

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

4. Suggested questions/assignments for learning evaluation

- What is Simple Harmonic Motion (SHM)?
- What are simple harmonic oscillators? Discuss an example.
- What is the Brunt–Väisälä frequency and how can it be used to predict cloud formations and the occurrence of thunderstorms?
- How can simple harmonic oscillations in the Earth's atmosphere and oceans be responsible for influencing the climate?

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

Use the reading, 'Simple Harmonic Motion' by LibreTexts™ to introduce the concept of Simple Harmonic Motion (SHM) and its characteristics. Use the text to define terms such as period, frequency, amplitude and equilibrium in oscillations and to describe a simple harmonic oscillator. Introduce the concept of non-uniform force directed towards the resting position of an object using the simple system of an object tied to a spring tethered to a wall. Explain that when you pull the object, there is a force acting on it which pulls it towards its resting position and if you then release the object, it will accelerate towards its resting position. Discuss how the object oscillates in SHM around its equilibrium position with the opposing forces acting on it. Use the text and a solved example to also discuss the equations of motion for the SHM.

This can be accessed at:

https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/Map%3A_University_Physics_I_-_Mechanics%2C_Sound%2C_Oscillations%2C_and_Waves_(OpenStax)/15%3A_Oscillations/15.1%3A_Simple_Harmonic_Motion

2. A Laboratory Activity to demonstrate Simple Harmonic Motion in stratified fluids- Dancing Test Tubes Experiment.

Use this suggested activity to allow your students to visualize how a parcel of water/air can perform SHM in the presence of a density gradient.

- Take a large beaker (volume ~4 liters).
- Fill it with 2 liters of regular water.
- Prepare a saturated salt solution by dissolving ~0.5 kg of table salt in another container with 2 liters of regular water.
- Dip a glass rod into the beaker.
- Pour the saturated salt solution along the glass rod into the beaker. This is done so that the salt solution reaches the bottom of the beaker with minimal mixing with the regular water
- Now the beaker contains the heavier salty water at the bottom and the lighter regular water at the top.
- Fill 2-3 test tubes with regular water. Leave ~10% of the test tube volume unfilled.
- Invert the test tubes and insert them into the large beaker. They should sink to the bottom of the beaker. They should also have a small air bubble.
- Adjust the unfilled amounts in the test tubes so that all the test tubes do not sink to the bottom.
- Heat the beaker using a hot plate.
- After some time, the test tubes start oscillating within the beaker.

Classroom discussion:

- Ask your students to recall Archimedes' principle of buoyancy of fluids- the force acting on an object immersed in water is equal to the weight of the water displaced by the object. Explain to the students that this principle works in any fluid -air, water, and lava.
- Ask students how the weight of water can be changed by adding salts, by heating/cooling. Explain that as ocean water is saltier at the bottom than at the top, it is heavier at the deeper levels than near the surface of the oceans.
- Therefore, if you move a small 'parcel' of water to the top from the bottom it will be heavier and sink. Similarly, if you move a parcel of water from the top to the bottom, it will be lighter and rise.
- Explain that this sets the stage for simple harmonic motion – a force that is always acting in the opposite direction of the displacement.
- Remind the students that initially in the lab activity, the test tube filled with regular water is heavy enough to sink to the bottom. As the beaker is heated, the test tube also gets heated and the air expands just enough to make them lighter than the salty water around them. The test tube then rises until it reaches the regular water near the top. The test tube is now denser than the water surrounding it, and it starts sinking.

- Explain to your students that the test tubes represent water or air 'parcels' in the ocean and atmosphere. In this experiment, the test tubes are displaced by heating the beaker and they begin to oscillate. This is analogous to the displacement of water or air parcels in Earth's oceans and the atmosphere.
- Discuss how such a displacement can generate internal waves that result in the redistribution of energy within these systems.

3. Extend the understanding of the role of SHM in redistribution of energy within Earth's atmosphere and oceans.

Use the video micro-lecture, 'What causes stripey clouds?' by Professor Mike Merrifield, University of Nottingham, to explain how SHM in the atmosphere cause cloud patterns, cloud formations and results in thunderstorms. The air close to the earth's surface is denser than the air higher above - the reason why it is harder to breathe in the mountains. When parcels of air are displaced from their original position (maybe due to the presence of an obstacle like a mountain), they oscillate up and down. When they move upward, they become cooler and when they move downward, they heat up. If an upward moving air parcel contains water vapour, this water vapour condenses and forms clouds. The downward moving air heats up and does not form clouds. This forms a wave-like pattern of clouds that are visible quite often in the sky.

Use the video to describe the Brunt–Väisälä frequency in SHM. The oscillation of air/water parcels depends on the rate of change of density with height and acceleration due to gravity. If the density decreases with height, the force always points to the position of rest and parcels exhibit SHM. If the density decreases rapidly, the oscillation is faster (can you explain why?) and vice versa. This frequency of oscillation is called the Brunt–Väisälä Frequency. In such a situation, the atmosphere is said to be stable. If the density increases with height, then the parcel always experiences a force upward. In this case, no SHM is possible and the atmosphere is unstable. In such a situation cloud formation and thunderstorms occur.

Use this video to describe similar occurrences of SHM in the oceans where energy is obtained from the coasts, at the surface and from the ocean floor. Since the ocean is stratified, some of this energy is converted to SHM of water parcels. The energy contained in these movements results in the generation of internal waves that transport this energy to other parts of the ocean. These internal waves also transport plankton larvae from the deep ocean to the coasts.

Conclude with a discussion on how such a redistribution of energy within Earth's atmosphere and oceans, can impact its climate.

This video micro-lecture can be accessed at:

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

4. Questions/Assignments

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

- What is Simple Harmonic Motion (SHM)?
- What are simple harmonic oscillators? Discuss an example.
- What is the Brunt–Väisälä frequency and how can it be used to predict cloud formations and the occurrence of thunderstorms?
- How can simple harmonic oscillations in the Earth's atmosphere and oceans be responsible for influencing the climate?

3 Learning Outcomes

The tools in this lesson plan will enable students to:

- learn about Simple Harmonic Motion (SHM) and Simple Harmonic Oscillators
- demonstrate SHM in the laboratory
- explain how Archimedes' principle (buoyancy of objects in fluids) can cause parcels of air/water to oscillate in the atmosphere/ocean with the Brunt–Väisälä frequency
- how the Brunt–Väisälä frequency can be used to predict cloud formation and thunderstorms

4 Additional Resources

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

1. Video micro-lecture; 'Introduction to harmonic motion'

A video micro-lecture by Sal Khan, Khan Academy, that introduces the concept of harmonic motion.

This can be accessed at:

https://www.khanacademy.org/science/physics/mechanical-waves-and-sound/simple-harmonic-motion-with-calculus/v/introduction-to-harmonic-motion

2. Video; 'A Wave Tank Demonstration of Internal Tides'

A video by E.D. Zaron and A. Raitano, Portland State University, that demonstrates how internal waves are formed in the oceans, causing a redistribution of energy within these systems.

This can be accessed at:

https://www.youtube.com/watch?v=U2lq8TpLqR4

5 Credits/Copyrights

1. Reading; ‘Simple Harmonic Motion’

By LibreTexts™.

2. Video micro-lecture; ‘What causes stripey clouds?’

By Professor Mike Merrifield, University of Nottingham.

Hosted on Sixty Symbols YouTube Channel by Brady Haran.

3. Additional Resources

Khan Academy

E.D. Zaron and A. Raitano, Portland State University.