Lesson Plan: Thermodynamic Processes in the Atmosphere

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

As an **undergraduate Physics** teacher, you can use this set of computer-based tools to help you in teaching the principle of thermodynamics and about thermodynamic processes.

A fundamental notion in Thermodynamics is a '**Thermodynamic System**'. A thermodynamic system is a part of the universe that is under study; the rest of the universe is considered the 'environment' for this system. The separation between the system and the environment may be real (like a wall) or imaginary. Every thermodynamic system has certain measurable quantities called **state variables** such as pressure, volume, temperature, density, internal energy, entropy, and enthalpy. In this lesson plan, students will learn about **thermodynamics processes** and their examples in the atmosphere that determine the vertical temperature structure of the atmosphere. This lesson plan will also describe how the thermodynamic stability of the atmosphere changes and how **adiabatic** processes affect cloud formation, a component of climate. It also includes an interactive simulation tool to enable students to explore the different types of **thermodynamic processes** in a gaseous system.

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:

- What is a thermodynamic system?
- What are the thermodynamic state variables?
- Describe the different kinds of thermodynamic processes.
- Explain how atmospheric stability and cloud formation are affected by thermodynamic adiabatic processes.

About the Lesson Plan

Grade Level: Undergraduate

Discipline: Physics

Topic(s) in Discipline: Thermodynamics, Thermodynamic Systems, Thermodynamic Processes- Isothermic, Isobaric, Isovolumetric, and Adiabatic, Lapse Rates.

Climate Topic: Climate and the Atmosphere

Location: Global

Access: Online, Offline

Language(s): English, An interactive tool available in several languages

Approximate Time Required: 45-60 min

1 Contents

1. Reading (20 min)

A reading that introduces various thermodynamic processes and provides a few exercises to understand them.

This can be accessed at:

https://opentextbc.ca/physicstestbook2/chapter/the-first-law-of-thermodynamics-and-some-simple-processes/

2. Video (11 min)

A video lecture that explains how adiabatic processes and lapse rates determine the stability of the atmosphere and in turn, influence cloud formation.

This can be accessed at:

https://www.youtube.com/watch?v=ObnWb7yspxA

3. Simulation (20 min)

An interactive simulation to explore thermodynamic processes in a gaseous system. This tool is available in several languages.

This can be accessed at:

https://phet.colorado.edu/en/simulation/legacy/gas-properties

4. Suggested questions/assignments for learning evaluation

- What is a thermodynamic system?
- What are the thermodynamic state variables?
- Describe the different kinds of thermodynamic processes.
- Explain how atmospheric stability and cloud formation are affected by thermodynamic adiabatic processes.

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, 'First Law of Thermodynamics and some Simple Processes' by OpenStaxCollege, BCCampus Open Education, to introduce your students to common thermodynamic processes like isobaric, isovolumetric (or isochoric), isothermal and adiabatic processes. Thermodynamic processes are representation of the change of the state variables of a system. They are usually plotted using any two state variables as the x and y axes. The most commonly used plot is the P-V diagram, where Pressure and Volume are the two axes. However, any two thermodynamic state variables can be used as axes in a 'Thermodynamic diagram'. Use the examples given in text to enable your students to understand these processes and their variables better.

This can be accessed at:

https://opentextbc.ca/physicstestbook2/chapter/the-first-law-of-thermodynamics-and-some-simple-processes/

2. Extend understanding using the example of atmospheric thermodynamic processes

In atmospheric sciences, the basic thermodynamic system studied is called the 'air parcel'. As the name suggests, it is simply a volume of air with an imaginary boundary which separates it from the rest of the atmosphere. Vertical motion in the atmosphere is usually faster than the rate at which the air parcel can exchange heat with the surrounding air (environment). Therefore, most vertical motion in the atmosphere is approximately adiabatic. Using this approximation, we can estimate how much the air parcel cools as it rises in the atmosphere- known as the 'atmospheric lapse rate'. Use the video, 'Adiabatic Processes, Lapse Rates and Rising Air' by Stephan Becker, Lehman College CUNY to explain the lapse rate in the atmosphere. Emphasize to your students how this is changed in the absence or presence of water vapour and thereby, affects condensation and cloud formation.

This can be accessed at:

https://www.youtube.com/watch?v=ObnWb7yspxA

3. Classroom/Laboratory Activity

Use the interactive PhET simulation, 'Gas Properties' by University of Colorado Boulder to enable your students to explore the different state variables for a given gaseous system. This tool is available in several languages. Instruct your students to use the simulation to create scenarios for different thermodynamic processes ie. Isothermic, isobaric, isovolumetric or adiabatic. Use the video micro-lecture, 'Thermodynamics and P-V Diagrams' by Paul Andersen, Bozeman Science as a guide for design and analysis of your customized classroom activity to explain thermodynamic processes involved in this simulation.

The PhET simulation can be accessed at:

https://phet.colorado.edu/en/simulation/legacy/gas-properties

The Bozeman Science micro-lecture can be accessed at:

https://www.youtube.com/watch?v=qVAvmieRM1E

4. Questions/Assignments

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

- What is a thermodynamic system?
- What are the thermodynamic state variables?
- Describe the different kinds of thermodynamic processes.
- Explain how atmospheric stability and cloud formation are affected by thermodynamic adiabatic processes.

3 Learning Outcomes

The tools in this lesson plan will enable students to:

- understand thermodynamic systems and their state variables
- learn about the different thermodynamic processes
- describe thermodynamic adiabatic processes and lapse rates in the atmosphere
- explain how atmospheric thermodynamic processes influence cloud formation

4 Additional Resources

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

1. Video lecture; 'Macrostates and Microstates'

A video that introduces the concept of a thermodynamic system.

This can be accessed at:

https://www.khanacademy.org/science/physics/thermodynamics/laws-of-thermodynamics/v/macrostates-and-microstates

2. Reading; 'The Importance of Understanding Clouds'

A reading by NASA that explains how the thermodynamic stability of the atmosphere changes and affects cloud formation that influences the climate.

This can be accessed at:

https://www.nasa.gov/pdf/135641main_clouds_trifold21.pdf

5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided. We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

1. Reading; 'First Law of Thermodynamics and some Simple Processes'

By OpenStaxCollege, BCCampus Open Education.

2. Video; 'Adiabatic Processes, Lapse Rates and Rising Air'

By Stephan Becker, Lehman College CUNY.

3. Simulation; 'Gas Properties'

PhET simulation developed by University of Colorado Boulder.

4. Video micro-lecture; 'Thermodynamics and P-V Diagrams'

By Paul Andersen, Bozeman Science.

5. Additional Resources

Khan Academy

NASA