

A Teaching Module On Antimatter

This is the first in a projected series of teaching resources from CERN whose overall aim is to stimulate interest in science by introducing themes in modern physics at earlier stages than is the practice in most national curricula. They are aimed at students aged 14-15 years (corresponding to the 9th and 10th year of schooling in most countries).

This module contains 8 lesson plans on the topic of antimatter, together with background materials and topics for extension. The lessons have been designed so that they can be integrated with science topics that are common across most national curricula for students aged 14 to 15 years. In this respect, the teacher need not feel that the material covered in the lesson plan is supplementary, but rather that it can serve as a vehicle to deliver topics in science that are already required by their syllabus, and to do so in a more modern and, we hope, more interesting way. These include: the building blocks of matter (fundamental particles), energy transformations, conservation of energy, kinetic energy, electric charge, and the evolution of the universe.

Care has been taken to ensure that the mathematical knowledge required for students to successfully complete these lesson plans harmonizes with that which is expected of students in the 9th and 10th forms, according to a representative sample of national curricula. For some of the more calculation-intensive lesson plans, teachers may find the Background Materials helpful. Teachers may also discover that the required calculations can provide an opportunity for training in the use of calculators and/or computer graphing programs.

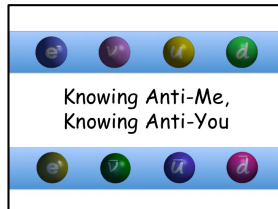


The information on the following pages provides a summary of the general content, aims and learning objectives of the materials included in the module.

Each of the lessons has been designed to have a duration of approximately thirty minutes, although this will vary depending upon how the teacher wishes to use the material. The order of the lesson plans is to a certain extent based upon pedagogical considerations, but remains a suggested order only. Teachers will most likely pick and choose which lessons they feel are most appropriate for their students, and at which point in their science syllabus they can be best integrated.

The lesson plans are presented as PowerPoint slides, allowing teachers a greater flexibility in the way the lesson is delivered. Teachers are free to create their own lessons by incorporating slides from various lesson plans.

Lessons Plans and Extension Topics



Lesson 1



Lesson 2



Lesson 3



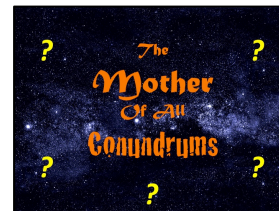
Lesson 4



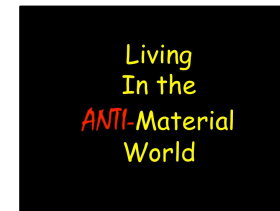
Lesson 5



Lesson 6



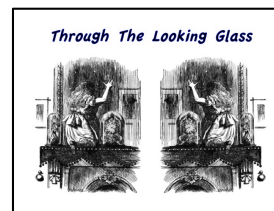
Lesson 7



Lesson 8



***Extension
Topic 1***



***Extension
Topic 2***

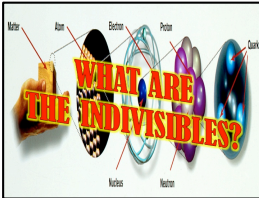
On the following pages you will find tables giving an overview of the content (together with detailed learning objectives) for each lesson and extension topic...

| LESSON | OVERVIEW | LEARNING OBJECTIVES |
|--|--|--|
| | | <i>Upon the completion of this lesson, the student shall:</i> |
| KNOWING ANTI-ME/ KNOWING ANTI-YOU | <p><i>This lesson is meant as an introduction to antimatter. It sets the scene by giving students an idea of what antimatter is and how it differs from ordinary matter.</i></p> | <p><i>Be aware that for each and every particle of matter there is a corresponding antimatter particle.</i></p> <p><i>Understand that antiparticles have the same mass as particles but have opposite electromagnetic properties such as charge.</i></p> <p><i>Be able to distinguish between the constituents of an atom of hydrogen and an atom of antihydrogen.</i></p> |
| OPERATION: ANNIHILATE! | <p><i>This lesson gives the students an understanding of what happens when matter meets antimatter. Some simple calculations enable students to get a quantitative idea of how much energy is produced when matter and antimatter annihilate each other. It is meant to be used in tandem with “Energy’s Spawn”.</i></p> | <p><i>Be aware that energy and mass are interchangeable quantities (that they can be transformed into each other).</i></p> <p><i>Understand that energy is also quantized in particles called photons.</i></p> <p><i>Be able to perform calculations involving the conversion of mass to energy using the formula $E = mc^2$.</i></p> <p><i>Understand that an enormous amount of energy can be obtained by the annihilation of matter with antimatter, and that the energy produced is in the form of gamma radiation.</i></p> |
| ENERGY’S SPAWN | <p><i>In “Operation: Annihilate”, the students learn that the annihilation of matter by antimatter produces energy. This lesson gives students a look at the reverse process: the transformation of energy into matter and antimatter.</i></p> | <p><i>Be aware that energy and mass are interchangeable quantities (that they can be transformed into each other).</i></p> <p><i>Understand that when energy is converted to mass, it always does so by producing 50% matter particles and 50% antimatter particles.</i></p> <p><i>Be able to perform calculations involving the conversion of energy to mass using the formula $E = mc^2$.</i></p> |

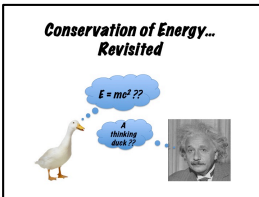
| LESSON | OVERVIEW | LEARNING OBJECTIVES |
|--------------------------------------|--|--|
| | | <i>Upon the completion of this lesson, the student shall:</i> |
| BOYS WITH TOYS | <i>This lesson provides a series of exercises that will enable students to assess popular claims regarding antimatter's use as a fuel source, and about the possibility of creating weapons using antimatter.</i> | <p><i>Be able to perform calculations using the formula $E = \gamma mc^2$. (Information on this formula is provided in Background Materials)</i></p> <p><i>Be able to critically assess claims of using antimatter as a future energy source to drive spacecraft.</i></p> <p><i>Be able to critically assess recent claims made about research into antimatter weapons.</i></p> |
| IT CAME FROM OUTER SPACE | <p><i>This lesson will give students an understanding of the nature of cosmic rays (in particular, how cosmic rays are related to antimatter).</i></p> <p><i>(The lesson also includes a half-day hands-on activity that allows the students to detect cosmic ray particles in the classroom).</i></p> | <p><i>Understand how antimatter is created by a natural process.</i></p> <p><i>Realize that antimatter was first discovered in cosmic rays.</i></p> <p><i>Be aware of the existence of two other types of particles: pions and muons.</i></p> <p><i>(Become familiar with the construction and use of a simple particle detector).</i></p> |
| MEDICINE: THE NEXT GENERATION | <i>This lesson uses a medical application of antimatter, the PET scan, as a way of introducing the concept of radioactive nuclei (in this case, positron-emitters) and their decay products.</i> | <p><i>Be aware that certain nuclei are unstable, and that they become stable through radioactive decay.</i></p> <p><i>Understand how antimatter (in the form of positrons) can be produced by the decay of certain radioactive nuclei.</i></p> <p><i>Understand how positrons are used in a PET scan.</i></p> |

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|---|--|--|
| | | <i>Upon the completion of this lesson, the student shall:</i> |
| THE MOTHER OF ALL CONUNDRUMS | <p><i>In this lesson, the students will learn about a mystery that has yet to be solved:</i></p> <p><i>Why is our Universe composed of matter rather than antimatter?</i></p> | <p><i>Understand how a small difference in the amount of matter and antimatter very early in the history of our Universe led to the disappearance of antimatter.</i></p> <p><i>Understand that Nature has a tiny preference for matter over antimatter.</i></p> <p><i>Become aware that the question of why our Universe is composed of matter is still one of science's unsolved mysteries.</i></p> |
| LIVING IN THE ANTI-MATERIAL WORLD | <p><i>This lesson takes the form of a thought-experiment about a world made of antimatter, and is meant to consolidate what the students have learned throughout the course of the module.</i></p> | <p><i>Have applied critical-thinking skills in an imaginary scenario, using the knowledge that has been learned thus far about antimatter.</i></p> |
| EXTENSION TOPIC 1: CONTAINING ANTIMATTER | <p><i>This lesson takes the students through an explanation of how antimatter (in the form of antiprotons) can be contained.</i></p> | <p><i>Understand a basic technique for containing charged antimatter particles using magnetic and electric fields.</i></p> <p><i>Understand that the containment of neutral atoms of antimatter such as antihydrogen has not yet been solved, and is an area of ongoing research.</i></p> |
| EXTENSION TOPIC 2: THROUGH THE LOOKING GLASS | <p><i>This lesson gives the students one possible solution to the problem introduced in "Living in the Anti-Material World" – how to tell the difference between matter and antimatter.</i></p> | <p><i>Become aware of another example of the underlying symmetry between matter and antimatter.</i></p> <p><i>Become aware of another form of radioactive decay (electron emission) and of the concept of nuclear spin.</i></p> <p><i>Understand how the decay of Cobalt-60 and anti-Cobalt-60 differs.</i></p> |

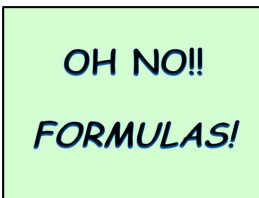
Background Materials



Here, the students will find information on the concept of a “fundamental particle”.



This gives students a simple way to understand the meaning behind the formula $E = mc^2$.



This material helps the students to understand two other formulae ($E = hf$, and the formula for relativistic kinetic energy). This material is meant to be used in connection with the lessons “Operation: Annihilate!” and “Boys With Toys”.



Here, the students will find some background information on electric charge as it pertains to the particles that are relevant to this module.



This material gives the students an understanding of how physicists can use units of energy for expressing the mass of particles.

You will also find links to information and other resources in the lesson plans themselves.

Acknowledgements

Thank you to Christian Cheung of the Norwegian University of Science and Technology (NTNU) for his design of the Big Bang expansion cone (based upon an earlier CERN poster), and for his animation of the Democritus wood chopping sequence.

And finally, thank you to the Leader of the CERN Education Group, Dr. Rolf Landua (aka “Mr. Antimatter”), for his support in the development of this teaching module.



*Will it be “...a blinding explosion equivalent to 5 kilotons”?
Terrence Baine and Rolf Landua with the antimatter trap from the film “Angels & Demons”.*