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# Designing an antimatter MOOC

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In this report, we describe our work on designing an antimatter MOOC that is aimed at first-year university students or even second/third-year students that are not studying physics. In particular, we discuss the MOOC's presentation slides, handouts, tasks and animations. The MOOC is planned to be taught by a series of short presentations followed by quizzes.

## 1. Introduction

Undoubtedly, learning is essential for personal, national and international development. Therefore, it is of great importance to improve the quality of education and make it easily accessible for learners through the Internet. Some learners, however, may not be able to pay the fees for online courses or ebooks. A massive open online course (MOOC), which is a free open online course, is a possible solution.

In this report, we discuss the antimatter MOOC that we designed during the CERN summer internship. The idea was to design a MOOC that is aimed at freshmen about antimatter but second/third-year students that are not majoring in physics may take the course as well. Therefore, it was necessary to ensure that the MOOC is at the right level of difficulty. In particular, we tried to avoid, for example, including complicated mathematical equations.

### 1.1. MOOC's content

Brainstorming the MOOC's syllabus is the first step after selecting a topic for the MOOC. Although an obvious step, it is one of the first things that the learner may look at to decide whether to enrol in the MOOC. Several important aspects should be considered in this step. First, the course designer should have an answer in mind for the question, *why this piece of information is of interest to the learner?* Second, excessive stating of facts without explaining the governing concept should be avoided since this may make the MOOC more like a newscast. Instead, explaining the basic physics principles briefly might be more interesting for the course-takers. Third, avoiding jargon, which may not be understood by the students, in the sections' titles of the MOOC.

The MOOC covers the concept of antimatter, some experimental techniques used for antimatter, recent research in the field and some applications of antimatter. FIG. 1 shows the contents of our part of the MOOC in more detail, covering five study weeks and each node shows the title of each week's material.

In the antimatter theory section, we answer the question *what are the fundamental building blocks of matter around us?* and introduce the concept of antimatter. We then discuss briefly some of the conventions used in the field and about Feynman diagrams. In the second section, we move to particle detectors and how these can be used to study the fundamental building blocks discussed in the previous section. Additionally, we present some of the mechanisms of particles interactions with matter. In the experimental methods section, we discuss some of the methods of confining charged particles. After this, we move to the frontier of antimatter research, in which we discuss some of the important concepts, machines and experiments in the field of antimatter. Also, we demonstrate why these results are important in physics. Further, we discuss the particle-wave duality of matter and antimatter. We also present an experiment comparing protons and antiprotons.

## 2. MOOC's structure and some samples

The contents are divided into, approximately, eight study weeks[2], five of these are presented in 1 1.1. The MOOC's design involved preparing presentation slides, handouts and tasks. Furthermore, when studying the MOOC, students should first watch the short videos[3] and then read the associated handout at the end of each week. Then, students need to complete the weekly tasks.

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[2] Assuming students will spend about three to five hours weekly on the MOOC.

[3] This is not done in this project but only some draft videos were recorded.


FIG. 1. A mind-map of the antimatter MOOC's contents, containing four sections. Each section represents a topic for one study week.

Also, the experimental methods section involves some simulations. Below is a more detailed description of the structure along with samples from the MOOC.

### 2.1. The presentation slides

The slides were written in LaTeX, using a document class called *Bemear*. The total number of slides was approximately 170. FIG. 2 shows two slides from the MOOC. The 3D figures inside the slides (see FIG. 2) were designed using *Paint 3D* software, designing such figures may be useful because of several reasons. First, some of the diagrams available online or in research papers may be under a license that is incompatible with the open access policy of the MOOC. Second, the customizability of the design. Third, the high resolution and quality of the designed figures.

### 2.2. The handouts

These were also written in LaTeX. The handouts refer to and build upon the materials delivered in the short videos and may discuss the topics in more detail. They are not intended to be bare summaries and thus some parts may include some new materials. In each section of the handout, a red box containing some text is used to capture the reader's attention. For example, quoting from the handout,

*"The simplest atom is not so simple!"*.

This refers to the fact that even the hydrogen atom, which consists of a proton and an electron, is not so simple partly because the internal structure of the proton is non-trivial, which is described by the so-called *parton distribution function*. See Appendix A for a sample from the handout.

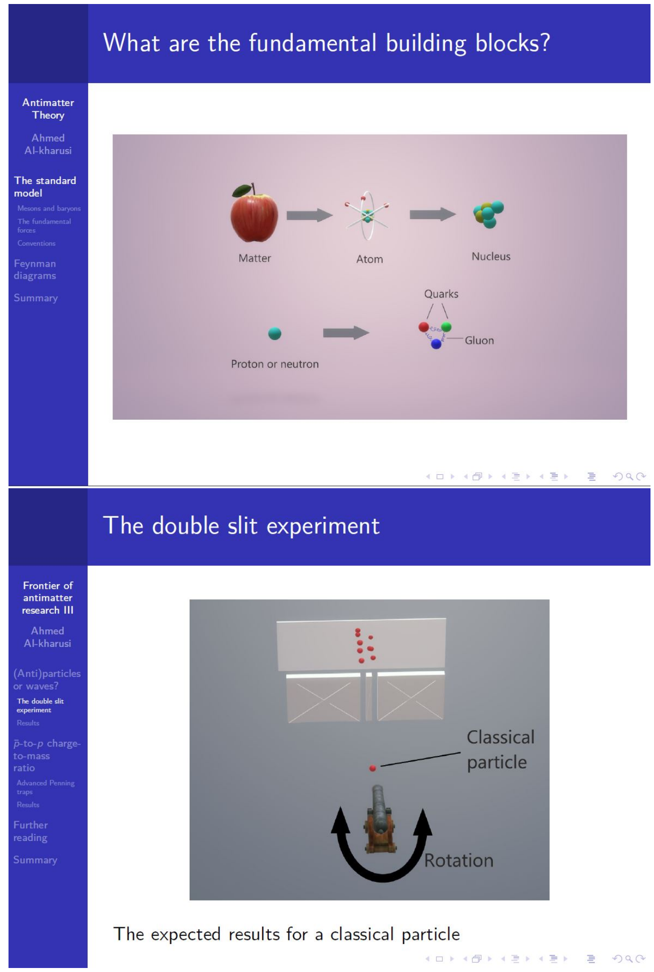


FIG. 2. Example screenshots of the MOOC slides.

### 2.3. The weekly tasks

At the end of each section in the handout, the weekly tasks are included. These test the learners' understanding of the subject and may ask them to search for a piece of information or complete a reading assignment. Also, these are useful for the discussion boards that many MOOC's have. Some tasks are marked as optional, while others are marked as a challenge. The optional label can be used, for example, if only some of the MOOC-takers are expected to complete the task. In contrast, the challenge tasks should be suitable for all the MOOC-takers, although they are harder, in general. Below we quote an example task,

*"(Challenge) Calculations, similar to that in the question above, indicate that the transition frequency of the hydrogen atom occurs at a specific value. However, for example, in the* $1S-2S$ *transition data (see the slides*

*on laser cooling), we see a distribution of frequencies corresponding to a particular transition ($1S - 2S$). Explain how the Doppler effect may cause this distribution of frequencies.*
*You may assume that atoms in the trap move in random directions and have a distribution of velocities."*

### 2.4. The simulations

The section on experimental methods contains three simulations written in the Python programming language[1] which were used to produce video animations for the MOOC. All of these are implemented using the *fourth-order Runge–Kutta method* also known as the RK4 method. The three simulations are

#### 1. Demonstration of Earnshaw's theorem

For this simulation, there are eight fixed charges at the vertices of a cube and a free charge at the centre of the cube. The code simulates the motion of the free charge that is caused by the electrostatic forces from the fixed charges. In particular, the code demonstrates the concepts of stable and unstable equilibrium (See Appendix A).

#### 2. Simulating a charged particle in a Penning trap

This code simulates the motion of a charged particle inside an ideal Penning trap. The simulation was used to illustrate the different patterns that may arise from the particle's motion. It also shows how such simulations are useful for scientists.

#### 3. Simulating a charged particle in a Paul trap

Similar to the one above but for a Paul trap. FIG. 3 depicts an example of the resulting particle's trajectory.

Moreover, students can download the codes[1] and investigate the simulations by changing the parameters in the code. No programming knowledge is required for this. For instance, for 2 2.4 1, students can easily enter the new locations of the fixed charges and investigate how the corresponding motion of the free charge changes.

### 3. Conclusion

In conclusion, we presented the antimatter MOOC's aims, contents and design strategy. We discussed how the presentation slides, handouts, weekly tasks and simulations were used in the MOOC, and how were they designed. Samples of these were presented as well.

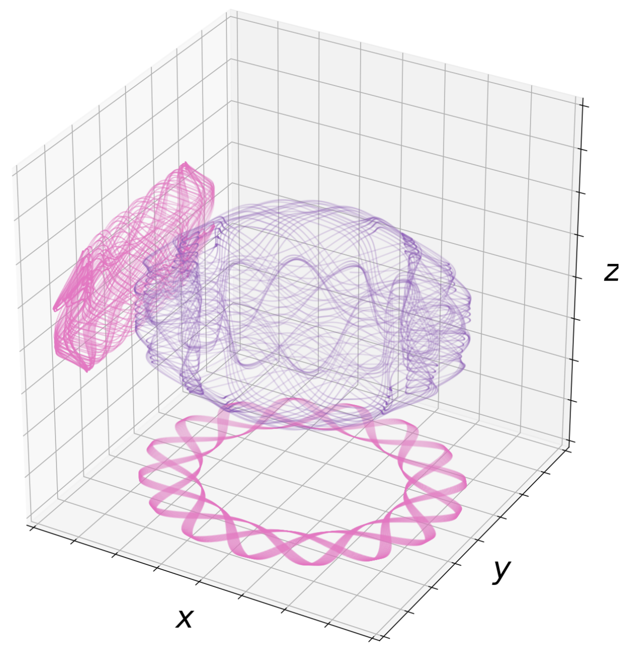


FIG. 3. One of the resulting patterns from the motion of a charged particle in a Paul trap. In pink, are the projections in the x-y and y-z planes

The work presented in this report may be useful for a general MOOC design.

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## Appendixes

### A. A preliminary sample from the handout

"Due to Earnshaw's theorem, an electrostatic field cannot be used to confine a charged particle in a stable equilibrium. We illustrate what is a stable/unstable equilibrium by the following examples. Consider a ball in a hill as shown in FIG. 4. In this case, if we move the ball a small distance from its current position, it will fall down the hill. This is an example of unstable equilibrium. In contrast, in FIG. 5, if we move the ball a small distance, the gravitational force acting on it will force the ball to return to the same position. This is an example of stable equilibrium. "

### B. Personal gain from the summer programme

I would like to summarize how I found this internship useful in the following points: First, the summer lecture series gave me a broad overview of the ongoing work at CERN. Second, from this project, I gained experience in designing a MOOC. Namely, how to select a MOOC's syllabus, how to use simulations to explain the related content in the MOOC and how to design/write a MOOC's slides, handouts and quizzes. Third, I learned about the antimatter research that is being done at CERN and its importance in physics by reading research articles and searching online when preparing the MOOC's content.

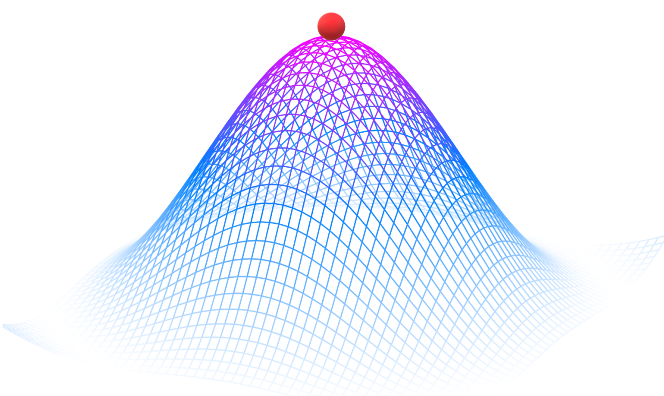

FIG. 4. A ball (in red) on a hill, representing an unstable equilibrium.

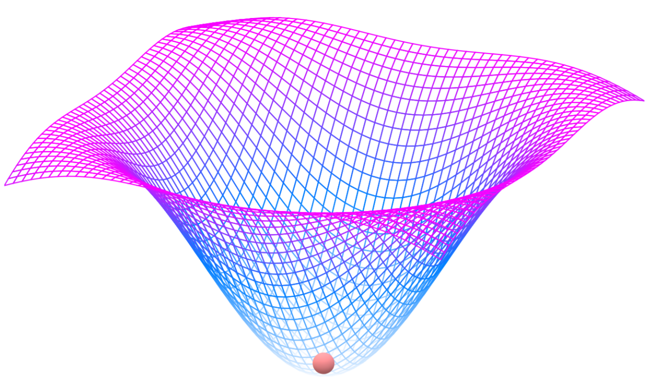

FIG. 5. A ball (in red) in a valley, representing a stable equilibrium.

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