AT Learning ScEnario

# Title

The power of protons

# Author(s)

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# Summary

This learning scenario shows the importance of elementary particles in science today and the principle on which particle accelerators work. The proton, which has enormous energy in the particle accelerator, stands out in particular. It shows the advantages of using protons in radiation therapy for cancer patients.

# Keywords

Acceleration, scattering, radiation, particles, proton

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# Overview

|  |  |
| --- | --- |
| *Subject(s)* | Chemistry, physics |
| *Topic(s)* | Proton Scattering  Acceleration  Energy |
| *Age of students* | 16-19 years old |
| *Preparation time* | 45 min |
| *Teaching time* | 2 hour and 30 minutes |
| *Online teaching material* | Videos:   * <https://www.youtube.com/watch?v=GvJ4afrkgDM> * **<https://www.youtube.com/watch?v=1wANXKjur-I>** * <https://www.youtube.com/watch?v=HX2GBOPnLbc> |
| *Offline teaching material* | Laser pointer, glass with clear water, milk |
| *Resources used* | Videos:   * <https://www.youtube.com/watch?v=GvJ4afrkgDM> * **<https://www.youtube.com/watch?v=1wANXKjur-I>** * <https://www.youtube.com/watch?v=HX2GBOPnLbc> * <https://www.classhook.com/resources/4006-star-wars-episode-iv-a-new-hope-destruction-of-the-death-star>   Internet resource:   * <https://www.tportal.hr/vijesti/clanak/sve-zablude-i-mitovi-o-lhc-u-20100404> * <https://www.sciencefocus.com/space/how-the-science-of-star-wars-is-turning-fiction-into-fact> * <https://omlc.org/classroom/scat_demo/> * <https://www.scienceinschool.org/article/2008/lhchow/> |

# Aim of the lesson

Explain what is achieved by accelerating particles and how protons gain energy in a particle accelerator. State the advantages of using proton radiation in comparison to x-radiation in medicine.

# Trends

1. Project-Based Learning: students get fact-based tasks, problems to solve and they work in groups. This kind of learning usually transcends traditional subjects.
2. Collaborative learning: students will complete tasks in groups.
3. Visual Search & Learning: images and multimedia are more powerful than verbal stimuli.

# 21st century skills

This learning scenario supports the following 21st century Learning and innovation skills:

Critical thinking – through problem solving

Students develop self-direction and self-motivation as they engage in hands-on experiments, and complete assignments. They also adapt to new concepts and information as they explore physics concepts and apply them to real-world scenarios.

# STEM Strategy Criteria

In this Learning Scenario, the following STEM elements and criteria are addressed:

|  |  |
| --- | --- |
| Elements and criteria | How is this criterion addressed in the learning scenario |
| Instruction | |
| Problem and project-based learning (PBL) | Students explore the topics by solving problems/tasks |
| Inquiry-Based Science Education (IBSE) | Students explore the construction of a particle accelerator |
| Curriculum implementation | |
| Emphasis on STEM topics and competencies | STEM topics are at the centre of this learning scenario. |
| Interdisciplinary instruction | The lesson plan encourages the use of 21st century skills and competences that are also relevant for other subjects. It would be possible to cooperate with an Chemistry teacher. |
| Contextualization of STEM teaching | A learning scenario provides an entry point for moving on  discussions of particle accelerators, how they are built,  to include high energy particles (sometimes referred to as radiation). The importance of accelerators in society and science. |
| Assessment | |
| Continuous assessment | Continuous assessment Continuous assessment strategies are used to monitor |
| Professionalization of staff | |
| Professional development | Diverse opportunities for staff to develop a greater understanding and knowledge regarding the topic. |
| School leadership and culture | |
| School leadership | School leadership supports innovative approaches in the classroom. |
| High level of cooperation among staff | Diverse opportunities for staff to develop a greater understanding and knowledge regarding the topic. By introducing these topics first in a professional development course for teachers, the teacher can first improve their own understanding of both how accelerators work and the contextualisation of physics in contemporary research facilities. This can increase the likelihood of the teacher using the activitiy in the classroom and of providing background and context to the students when introducing it in a lesson |
| Connections | |
| With other schools and/or educational platforms | <https://www.scienceinschool.org/> |
| With universities and/or research centers | Proton beam-this is the type of scattering which plays the major role in medical applications. In tissues the light is scattered at cells or their components |
| School infrastructure | |
| Access to technology and equipment | School is equipped with internet access, as well as laptops, tablets and one projector per classroom. |

# Activities

Describe here the activities your students will follow, adding all the necessary steps, details, and duration (in minutes / hours) for each activity.

|  |  |  |
| --- | --- | --- |
| Name of activity | Procedure | Duration |
| *KWL table* | **I use the KWL table to test how much students know about particle accelerators.**  It serves the student for:   * motivation * correcting misconceptions * developing scientific expression * encouraging respect for other people's opinions * learning by asking "good" questions * creation of mental maps  |  |  |  | | --- | --- | --- | | What do I know? | What do I want to know? | What did I learn? | |  |  |  | | 10 min |
| *Task 1: Explore the construction of a particle accelerator* | After we comment on the answers from the KWL table, I direct the students to use the tablets to visit the website <https://www.scienceinschool.org/article/2008/lhchow/>  and to investigate the structure of the particle accelerator.  When they become familiar with the structure of the particle accelerator, they should answer the following questions.   1. How many particle accelerators are there in the world? 2. What are the three main parts of a particle accelerator? 3. What part of the accelerator accelerates the particles? 4. Can speeds greater than the speed of light be achieved in a particle accelerator? | 30 min |
| *Video and discussion* | **Watch a video showing how accelerators are used in medicine:**  **<https://www.youtube.com/watch?v=1wANXKjur-I>**  This is the type of scattering which plays the major role in medical applications. In tissues the light is scattered at cells or their components.  What do you see?  You should see a color change after the particles pass through the liquid disinfectant. This means that the particles are accelerated.  What happened?  The yellowish color is seen due to the scattering of light through the tiny particles present in the water which are the same size as the yellow color...that's why they can only scatter the yellow color | 10 min |
| *Task 2.:* *Experiment with Light Scattering* | It is quite easy to demonstrate the effect of scattering with simple equipment. If you have a laser pointer you can do it by yourself like this:  laser_pointer-1.gif (48k)   1. A simple glass instead of our fancy tank will be just fine. Because the camera we used was to insensitive we actually used a stronger laser for the pictures below. However, if you dim the light you should see the same effects using your laser pointer, only better. 2. Fill the glass with clear water and place a white sheet of paper behind the glass. 3. Shine with the laser pointer through the water (see picture a) below). Depending on how many small air bubbles (or other particles like dust) you have in the water you might see a dim red line where the laser beam goes through the water. The bright spot on the paper is actually just red, the white spot in our picture is caused by overexposure. 4. Add a small amount of milk and still until it is mixed. If you hold the laser so that the beam passes right below the surface you should be able to see where the beam goes. We had 600 cc water (little more than 1/2 Gallon), and added 1 cc of vitamin D milk (see picture b)). You will probably have less water, so be very carefull and start by adding only a few drops! If you add too much milk you will not see the dim spot (see arrow in picture b)) on the screen anymore. 5. Add more milk and see how the light pattern changes. In pictures c) to f) you can see how the light beam eventually becomes a glowing ball. (In the last picture the level is so low because I ran out of milk.)   pure_water-3.gif (22k) 1cc-3.gif (21k) 4cc-3.gif (21k) 10cc-3.gif (21k) 20cc-3.gif (20k) pure_milk-3.gif (21k) | 30min |
| *Video and discussion* | **Use of particle accelerators in medicine. How is cancer treated?**  <https://www.youtube.com/watch?v=HX2GBOPnLbc>  Questions:   1. What does and what does not scatter light?   X-ray scattering is essential to obtain atomic and molecular information on materials. Although the light emitted by a laser is different from synchrotron light, this experiment helps demonstrate how we achieve experiments involving scattering of X-rays, which have a 'significantly' smaller wavelength than the visible lasers. Synchrotron light is a very powerful form of electromagnetic radiation that can be generated across a wide range of wavelengths. When studying minuscule structures like molecules, our primary focus is to produce electromagnetic radiation with short wavelengths, namely in the X-ray range. | 30 min |
| *Task 4.: Killing cancers* | **Students explore physics concepts in this video and apply them to real-world scenarios.**  **[Star Wars example: Destruction of the Death Star](https://www.google.com/search?q=Star+Wars+example%3A+Destruction+of+the+Death+Star&rlz=1C1GCEA_enHR866HR866&oq=Star+Wars+example%3A+Destruction+of+the+Death+Star&gs_lcrp=EgZjaHJvbWUyBggAEEUYOdIBCTI5MjBqMGoxNagCALACAA&sourceid=chrome&ie=UTF-8" \l "fpstate=ive&vld=cid:d5a8e639,vid:6H0vFP_jXN4,st:0)**  In the original Star Wars film, the rebels have to destroy the Death Star (the giant space station that destroys planets) by firing their proton torpedoes into an exhaust port in a trench, as this would initiate a damaging chain reaction, leading to its destruction. To do this, Luke Skywalker needed to pilot his X-wing fighter into the gap and fire a proton torpedo, then use the Force to guide the missile to the target.  **Real science: Proton-beam therapy**  Proton radiation therapy offers many benefits over conventional X-ray photon radiotherapy in targeting and killing cancers. The proton beams pass through healthy tissue and then deliver a dose of radiation at the target, a process determined by the Bragg peak. Current research is directed at accurate monitoring of the beam. | 15 min |
| *Task 5.: Read a science story* | **Proton torpedoes**  In 1977’s A New Hope, the very first Star Wars movie, the Rebels Alliance used proton torpedoes to destroy the Death Star as their lasers couldn’t penetrate the space station’s shields. The nearest thing to this in the real world is our use of ‘proton torpedoes’ in cancer therapy.  Within the pan-European [OMA (Optimization of Medical Accelerators) project](https://www.liverpool.ac.uk/oma-project/) we are using proton beams to target something that is hidden very deep inside the body and very difficult to target and destroy.  The most common form of radiotherapy uses X-rays. The main issue with this method is that for a deep-seated tumors, X-rays deliver a significant entrance and exit dose that damages healthy tissue. This is because the dose deposition follows an exponential decay and it is difficult to target the rays accurately.  An alternative is to use a proton beam. Protons are positively charged particles, created when a hydrogen atom loses its electron in an ‘atom smasher’ such as cyclotron – one of the earlier types of particle accelerator.  Questions:  1. What are protons?  2. Why is it better to use a proton beam than x-rays in cancer treatment? | 15 min |
| *Task 6.: I hand out a card called Myths and Misconceptions about LHC to the students* | Circle the correct answer  The LHC cannot repeat the Big Bang T F  Higgs boson is not the 'God particle' T F  A black hole will be created in the LHC that will  devour the Earth T F  After they answer the questions, I give them a link where they can check their answers  <https://www.tportal.hr/vijesti/clanak/sve-zablude-i-mitovi-o-lhc-u-20100404> | 10 min |

# Assessment

Student progress is evaluated through different formative evaluations (self-evaluation,

and peer evaluation). The teacher should encourage students to ask questions, form hypothesis

and check if their ideas are correct. Some examples below:

1. Through a group discussion, for example after watching the video :

What happened?, How would you explain from a physical point of view what happened? What does and what does not scatter light? What are protons? Why is it better to use a proton beam than x-rays in cancer treatment? How many particle accelerators are there in the world? What are the three main parts of a particle accelerator? What part of the accelerator accelerates the particles? Can speeds greater than the speed of light be achieved in a particle accelerator?

Or using an exit card to check students' misconceptions.

2) If the learning scenario is done as a demonstration, the teacher should ask questions

students to answer.

# Student feedback

# At the end of the lesson(s), students can ask questions, provide feedback, and share their overall

# About Accelerating Teaching and Scientix

**Accelerating Teaching**, has develop a joint MOOC-course aiming at professional development for science teachers in lower and upper secondary school. The MOOC comprise both the physics behind particle accelerators as well as learning scenarios to use in class and may thereby increase teachers’ agency in teaching about physics and state of-the-art research related to particle accelerators. Accelerating Teaching also explores teachers' experiences of using the learning scenarios in their classrooms.

**Scientix**, the community for Science Education in Europe, promotes and supports a Europe-wide collaboration among STEM (Science, Technology, Engineering and Mathematics) teachers, education researchers, policymakers, and other STEM education professionals. If you need more information, check the [Scientix portal](http://www.scientix.eu/home), or contact either the Scientix National Contact Point or Scientix Ambassadors [in your country](http://www.scientix.eu/in-your-country).

# Annex(es)

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| --- | --- | --- |
| First name |  | |
| Last name |  | |
| **Circle the correct answer** | | |
| The LHC cannot repeat the Big Bang | T | F |
| Higgs boson is not the 'God particle' | T | F |
| A black hole will be created in the LHC that will  devour the Earth | T | F |