SPACE VOYAGE

Fundamental particles and interactions

Extract from "The world of particles", by Brian Southworth and Geoges Boixader

1) Introduction du document:

I) The zoo of particles (p 1, 2, 3, 4):

- What is the document?
It is a comic strip.
-Who are the main characters?
There are a magician (wizard), small imaginary fellows (balls, characters), scientists, a man, a woman.
-What does the comic strip deal with?
It deals with the structure of atoms and other particles.
- What have we discovered so far in the chronological order?
We have discovered first the electrons, then the nucleus, then protons and neutrons, after other particles with charge and spin and finally quarks.
- What are the electrons responsible for? Same question for the nucleus.
The electron is responsible for light, electricity, electronics, chemistry and mechanical properties.
The nucleus is responsible for the nuclear energy, used in medicine, industry and agriculture.
-What are the questions which are not answered till now?
Why do we have particles among quarks which we do not need to build matter?
Do the quarks have something inside them? What about electrons?

Conclusion: Scientists in CERN have discovered lots of particles by accelerating them and making them collide in very powerful accelerators.
By destroying electrons or protons, they found new particles. At the beginning, they could not understand why there were so many and how to classify them.
Just as Mendeleeïv did with chemical elements, they tried to classify them according to their properties. And as Mendeleeïv found, they found empty spaces where more particles must be…

2) Aborder le document par morceau et sélectionner les informations principales :

II) Interactions between particles (p 5, 6, 7, 8):

Choose the right title to each page:
- *Weak interaction and neutrino*
- *The three interactions at the microscopic scale*
- *The particularities for the strong force and gravity*
- *The electromagnetic interaction mechanism*

Fill in the table with the characteristics of the interactions:

Interactions	particles concerned	effects
Gravity	*massive particles*	*governs the Universe, holds all the celestial bodies together.*
Electromagnetic interaction	*charged particles*	*holds atoms and molecules together, responsible for the unity of matter.*
Strong interaction	*neutrons and protons*	*holds the nucleons together, responsible for the unity of nuclei.*
Weak interaction	*neutrons*	*beta radioactivity, responsible for the decay of neutrons.*

The beta decay is a nuclear reaction in which neutrons (n) break up into protons (p), electrons (e) and neutrinos (ν):

The nuclear reaction has the following equation: $^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + {}^{0}_{0}\nu$

- **the number at the bottom is the number of charge : Z (expressed in elementary charges)**
- **the number at the top is the number of mass : A (expressed in nucleons)**

In nuclear reactions, the number of charge (Z) and the number of mass (A) are conserved:

1 = 1 + 0 + 0

0 = 1 + (-1) + 0

The neutrino is an elusive (which we cannot hold of) particle without charge and mass (or so tiny that we cannot detect it).

<u>Interactions between particles (p9):</u>

What was the main discovery in 1970?

- *The unification of electromagnetic force and weak force.*

Why was it so surprising?

- *Because the weak interaction is much weaker than the electromagnetic force.*

How was the new theory confirmed?

- *By discovering the messenger particles of the weak interaction: W and Z particles.*

What is the messenger particle of the strong interaction?

- *This is the gluon.*

Which messenger particle is missing up to now to complete the whole theory?

- *The graviton…or the Higgs' boson…*

3) Prolongement et recherche documentaire :

Homework: search for the CERN's scientists who won the Nobel Prize in 1984 and for the scientist who is responsible for the diagrams p9.

4) Activités interactives sur le web :

III) Fundamental questions **Activities on the web:**

1. **Go to the website of the CERN : http://public.web.cern.ch/Public/Welcome.html and then, click on the CERN's flagship project : the LHC**

   What is the LHC?
   The LHC is the Large Hadron Collide: this is a particle accelerator.

   What is it for?
   *It will collide beams of protons at an energy of 14 **TeV**, in order to explore deeper into matter.*

   *A **TeV** is a unit of energy used in particle physics. 1 TeV is about the energy of motion of a flying mosquito. What makes the LHC so extraordinary is that it squeezes energy into a space about a million million times smaller than a mosquito…*

   ***The threshold**: **the entrance** (le seuil)*

2. **At the bottom of the page, click on one of the three following questions:**

   (Les élèves, par binôme, ont tiré au sort une des trois questions)

- **Why do physicists want to study particles?**
- **How do physicists study particles?**
- **Is particle research useful?**

3. **Read the introduction and choose one of the sub articles given in the part "more about it".**

4. **For the sub article you have chosen,**

- **Quote the key words.**
- **Write the words you do not understand, search for the meaning, using a dictionary on the web.**
- **Write it down.**
- **Prepare 5 questions about the article.**
- **Write the answers you are waiting for.**

5. **Prepare a form with:**

- The question you have been working on.
- The title of the sub article you have chosen.
- A vocabulary box for help.
- Your 5 questions.

6) Évaluation à chaud : le professeur passe vérifier la formulation des questions posées par les élèves.

5) Travail croisé:

Les fiches préparées par les élèves sont ramassées, rassemblées en tas et classées par sujet.
Un élève de chaque binôme vient tirer au sort une fiche parmi les sujets qu'il n'a pas étudiés.
Chaque binôme doit lire son nouvel article et répondre aux questions préparées par les autres élèves.
Il peut s'aider du vocabulaire préparé par le binôme qui a réalisé les questions.

IV) Why do physicists want to study particles?

Scientists have found that everything in the Universe is made up from a small number of basic building blocks called elementary particles, governed by a few fundamental forces.

Some of these particles are stable and form the normal matter; the others live for fractions of a second and then decay to the stable ones. All of them coexisted for a few instants after the Big Bang.

Since then, only the enormous concentration of energy that can be reached in an accelerator at CERN can bring them back to life. Therefore, studying particle collisions is like "looking back in time", recreating the environment present at the origin of our Universe.

What for? To understand the formation of stars, Earth, trees, everything you see around and, finally, us!

http://public.web.cern.ch/Public/Content/Chapters/AboutCERN/WhyStudyPrtcles/WhyStudyPrtcles-en.html

1) Antimatter:

- Keywords: particle, antiparticle, perfect opposites, electric charge reversed, "annihilate" = mutually destroy, where did the antimatter go?

- Vocabulary: whilst = whereas ; amount = quantity ; beside = apart from

- Questions & answers:

  - What is the antiparticle of the electron?
    - The antiparticle of the electron is the positron.
  - What happens when matter and antimatter meet?
    - When matter and antimatter meet, they annihilate e.g. they mutually destroy and the energy released is converted into photons or other particles.
  - What is the difference between particle and antiparticle?
    - Particle and antiparticle have opposite charge.
  - When was an equal amount of matter and antimatter created?
    - An equal amount of matter and antimatter was created when the Universe was formed, e.g. 13,7 billion years ago.
  - How can we produce antimatter?
    - We can produce antimatter by colliding particles of high energy in powerful accelerators for example.

2) Nature's glue - what holds matter together?

- Keywords: 4 basic interactions; electromagnetic; gravity; weak force; strong force.

- Vocabulary: bind = join, attach; in bulk = in mass, in large quantity; decay = disintegration

- Questions & answers:

  - What is the most familiar basic force?
    - The most familiar basic force is gravity.
  - What is the stronger fundamental force?

- The stronger fundamental force is the electromagnetic one.

➢ What does the weak force do?
- The weak force causes the neutrons to decay.

➢ What does the strong force do?
- The strong force holds quarks together within protons, neutrons and other particles.

➢ Why is the strong force so special?
- This force becomes stronger with the distance unlike gravity and electromagnetic force which decrease with the distance.

V) How do physicists study particles?

Particles are extremely tiny, and to be able to see and study them, scientists need very special tools.

They need accelerators, huge machines able to speed up particles to very high energies before smashing them into other particles.

Around the points where the "smashing" occurs, scientists build experiments which allow them to observe and study the collisions. These are instruments, sometimes huge, made of several kinds of particle detectors.

By accelerating and smashing particles, physicists can identify their components or create new particles, revealing the nature of the interactions between them.

http://public.web.cern.ch/Public/Content/Chapters/AboutCERN/HowStudyPrtcles/HowStudyPrtcles-en.html

1) Accelerators: the ultimate microscope.

- Keywords: subatomic level, femtometre, wavelength, moving particles considered as waves, high energy, electron microscope, particle detectors.

- Vocabulary: to probe = to explore; to imply = to bring about; therefore = consequently; for instance = for example; among(st) = with, surrounded by; alloys = a substance composed of two or more metals; oddly = curiously.

- Questions & answers:

➢ Why do physicists need other tools than ordinary microscope to explore matter at subatomic level?
- To be able to investigate matter at a smaller scale than the wavelength of visible light.

➢ What can moving particles be considered as?
- Moving particles can be considered as waves.

➢ What is an electron microscope like?
- An electron microscope is a sort of accelerator which provides electrons with enough energy to reach very a short wavelength.

➢ What is an electron microscope used for?
- It can be used for biology or metallography.

➢ Why do we have to build even larger machine?
- The larger the machine, the most powerful, the higher the energy, the smaller the wavelength, the smaller the detail we can look at.

2) How does an accelerator work?

- Keywords: vacuum chamber, magnets, radio frequency cavities, particles accelerated by electric fields, curving the beam's path by dipole magnets, quadrupole magnets to focus the beam.

- Vocabulary: vacuum = empty space; a particle beam = a ray of particles; to constrain = to force; a lens = an optical device which curves the rays of light; merely = just, simply; the behaviour = the manner of acting.

- Questions & answers:

  - What does an accelerator consist of?
    - An accelerator consists of a vacuum chamber surrounded by a long sequence of vacuum pumps, magnets, radio-frequency cavities, high voltage instruments and electronic circuits.
  - What are the particles accelerated with?
    - The particles are accelerated with electric fields.
  - What provides energy to particles in motion?
    - The Radio-Frequency (RF) cavities provide radio energy which is converted into kinetic energy to accelerate the particles.
  - Why do most accelerators look roughly circular?
    - To make the acceleration more effective, accelerator designers force the particle beam to go through the RF cavities many times, by curving its trajectory into a closed loop thank to magnetic fields.
  - Which device allows focusing the beam?
    - Quadrupole magnets, which act on the beam as a lens would on the light allow focusing the beam.

VI) Is particle research useful?

CERN's accelerators and detectors require the leading edge in technology. For this, CERN works in close collaboration with industries, to the benefits of both partners. Related spin-offs in all kinds of other domains are now incorporated in our daily lives.

Cancer therapy, medical and industrial imaging, radiation processing, electronics, measuring instruments, new manufacturing processes and materials, the WWW, these are just some of the many technologies developed at CERN during research in particle physics.

http://public.web.cern.ch/Public/Content/Chapters/AboutCERN/ResearchUseful/ResearchUseful-en.html

leading edge = the top ***spin-off = by-product***

1) Particles for medicine: cancer therapy and much more

- Keywords: 17 000 particle accelerators in the world, imaging, therapy, radiopharmaceuticals, high-intensity proton beams, Positron Emission Tomography, scalpel replaced by a tiny particle, radiotherapy with X-rays, electrons, neutrons and hadrons, cyclotrons, hadrontherapy.

- Vocabulary: to target = to point; a particle beam = a ray of particles; a span = a duration; to owe = to be in debt, to be obliged to pay; forerunner = precursor; surgery = operation.

- Questions & answers:

  - What are the main applications of particle accelerators?
    - The main applications of particle accelerators are imaging and radiotherapy.
  - What is a radiopharmaceutical?
    - A radiopharmaceutical is a substance that contains radioactive atoms which can yet be safely used in humans.
  - Once in the human body, what is the aim of radiopharmaceuticals?
    - Their aim is to give information about the body's metabolism by fixing to specific tissues or organs and then, decaying.
  - What does the radiotherapy consist in?
    - Radiotherapy is a form of biological surgery using very little particles capable of sterilizing malignant cells.
  - Where do X-rays or electron beams used in radiotherapy come from?
    - They come from linear accelerators.

2) Technology transfer at CERN

- Keywords: Collaboration between CERN and industrial partners, technology Transfer policy, royalty, to encourage competitive tendering, market surveys.

- Vocabulary: know-how = knowledge and skill required to do something, procurement = acquisition, a patent = *brevet*; a royalty = *redevance*; a tendering = an offer; a bidder = someone who makes an offer; market survey = *enquête de marché*; to foster = to encourage.

- Questions & answers:

  - What are the different forms of collaboration between CERN and industrial partners?
    - Collaboration takes the form of common development contracts, licensing of know-how and designs and consultancy.
  - What has the CERN developed for more than 10 years?
    - The CERN has developed a technology transfer policy.
  - What does the CERN request in case of commercial exploitation?
    - The CERN requests a royalty.
  - What is CERN policy?
    - CERN's policy is to encourage competitive tendering among Member State firms that are technically and financially qualified.
  - Who does the CERN file contracts with?
    - After market surveys, CERN files contracts with the lowest bidder.