VRIJE ASO-SCHOOL

Once More Back 2 the Future of Physics

Topics

1. Gravitational waves

This is a very "hot" topic, since the first gravitational waves were discovered just a few years back and already honoured by the Nobel Prize in 2017.

Make a historical survey of gravitational waves from the predictions of Einstein, via various attempts to measure them, to the first successful measurements. In addition, make a survey of experimental facilities and of some of the gravitational waves measured after the first discovery.

2. Black holes

This has been a fascinating topic ever since it was first proposed. Very recently it has regained attention since the first black hole was photographed in 2019, and 2020 the Nobel Prize was awarded for work on black holes.

Explain what black holes are and how they are formed. List how they are observed (indirectly and directly). Discuss the theoretical evidence of the existence of black holes and summarize how scientists succeeded in taking a picture of a black hole. You can also refer to Science Fiction films in which black holes appear.

3. The Standard Model

The Standard Model contains a description of the fundamental particles (quarks, leptons and more), their properties and their interactions.

List the fundamental particles and their properties (mass, charge and spin). Differentiate between mass-particles and force-particles. The Higgs boson is an elementary particle in the Standard Model. Explain its role in the Standard Model and summarize its discovery in 2012, as well as mentioning the Nobel Prize awarded in 2013. As an optional choice you can discuss the neutrino and the experimental difficulty to measure it.

4. CERN and LHC

The Large Hadron Collider (LHC) is the largest and most famous particle accelerator in the world.

Give a general overview of CERN and of LHC in particular. Discuss the experiments performed at LHC and give an overview of some famous results (e.g., the Higgs boson).

5. Antimatter

Antimatter has always been a hugely fascinating topic.

Describe in what way antimatter differs from ordinary matter. What happens when antimatter gets in contact with ordinary matter? Give a survey of experimental facts: How much (and what type of) antimatter is created in the laboratories? How long does it exist? Does antimatter have normal gravitation or anti-gravitation? How can you create a container for antimatter?

An initial sequence of the film *Angels and Demons* was filmed at CERN. In this sequence, some antimatter is created in an experiment and then stolen. Comment on the physical correctness of this sequence.

6. Nanotechnology

Nanotechnology is an extensive field of science including physics, chemistry and biology. Probably it is the most important field of modern physics with respect to how breakthrough developments in the imminent future will affect our lives.

Concentrating on the physics part, supply a general description of what nanotechnology is. Then choose a couple of topics within this field that in the near future could change our lives in a more or less dramatical way.

7. Nuclear physics in medicine

This is a very current topic. Examples are the injection of radioactive isotopes for diagnostics (finding tumours), the injection of radioactive isotopes for therapy (killing tumours), hadron therapy (killing tumours by radiating them by a beam of ions (protons or nuclei), PET (positron emission tomography).

Choose one or more of these examples and explain the physics behind them.

8. Photonics and spectral analysis

Today spectral analysis is used on the one hand to examine medicine, food, doping, etc. On the other hand, it is used in astronomy to identify astrophysical objects. Explain what spectral analysis is and discuss some current examples of its use.

By photonics one intends the interaction between light (or other parts of the electromagnetic spectrum) and matter, often by the use of lasers. Give some examples of such usage in technology, including also a physical description.

9. Complex Systems

All complex systems consist of many different interacting parts. They have been studied by physicists for a couple of centuries, and can be difficult to describe mathematically – they may have an enormous number of components or be governed by chance. They could also be chaotic, like the weather, where small deviations in initial values result in huge differences at a later stage.

There are many ways to study complex systems, for example this year the Nobel Prize was given partly for developing climate and weather models, and partly for the study of hidden patterns in disordered complex materials. These hidden patterns make it possible to understand and describe many different and apparently entirely random complex materials and phenomena, not only in physics but also in other, very different areas, such as mathematics, biology, neuroscience and machine learning.

Start by making a general survey of different fields in which complex systems play an important role. Continue by making a more in-depth analysis of climate models, concentrating on the physics part.