Co-funded by the
Erasmus+ Programme
of the European Union

Science Bridging Course
Unit P3 – 21st century physics, quantum physics essence

In this chapter you will find out:

- **Special and general relativity theory**
- **Quantum mechanics**
- **Microparticle variety**
- **The Big-Bang theory**

Why do we perceive the world? We perceive the world because body interaction takes place. Interaction is defined by forces. The reasons of forces are very different. How forces act – is a riddle about riddles and a physics science problem. Bodies are various therefore interactions are also various. Four interactions are found and described. Two are best known for us: gravitational and electromagnetic.

In universal gravitation law (Newton) asserts that all bodies attract each other with the force directly proportional to their masses, and inversely proportional to the square of their distance.

The law defining electromagnetic interaction states that electrical bodies affect each other by the force directly proportional to their electrical charges and inversely proportional to the square of their distance. This interaction guarantees the existence of the substances and atoms.

Einstein discovered stimulated emission law: if the light can stimulate the substance and atoms, then the same wave will make the system radiate equally the same wave, if it disturbs already stimulated system. So, mazers were found (Basov, Taunsa, and others) later lasers.

The other interactions act as well: the stronger and the weaker. These are interactions of micro-world.

Thus, nature does not like emptiness, and if it is so, then:

- all bodies move, and they can change the movement, or stop in respect of one another only a force acting on them – the first and the second Newton's laws;
- if a supplementary force does not act on bodies, they try to spread in space – diffusion process;
- if a body cannot move, then it has at least not to be calm in one place, it has to vibrate in its state of equilibrium. It means that bodies have to have wave properties. This confirms Heisenberg uncertainty principle and de Broil waves. E.g., electronic microscope).

Anarchy – mother of order. A similar law was proved by N. Prigožin. He received a Nobel prize for this. He proved that if a system is in a stimulated state, very far from thermodynamic equilibrium, then a new order can appear in it. This theory includes chaos theory, otherwise called non-equilibrium thermodynamics and instability theory. E.g., oil convection in an overheated frying pan, whirls in channels, substance self-organisation, coffee grounds fortune telling and so on.

Special and general relativity theory

Special relativity theory was created in 1905 – 1908 m. (Lorenz, Poitou- Charentes, Einstein). According to Galileo-Newtonian mechanics, the motions of body movement in respect of each other are added up /summed/ algebraically. Michelson's experiments in 1880 showed that electromagnetic waves propagating, velocities are not summed. It appears that propagation speed of light signal does not depend on the speed of movement of the light source. This contradicted to Galileo's theses. However, this theory was developed. In Galileo-

Newtonian mechanics, only speed was relative. In classical mechanics, space and time were independent, in the theory of relativity, it is a unified whole.

General relativity theory was created about 10 years later. In this theory, such concepts as space and time finite-infinity problem, the relationship between matter, movement, space, and time were introduced.

Development of the principle of relativity

From a philosophical point of view, relativity of any phenomena means that there are no absolute, insurmountable boundaries between them. Galileo was the first to establish relativity of mechanical motion with respect to rest. The essence of such a principle is that the laws of mechanics are of the same forms in all inertial systems, in other words, all mechanical processes take place equally in such systems. In Einstein's theory it is differently – not only mechanical but also all physical processes in inertial systems take place equally. Relativity principle takes place unanimously with other principles – the principle of the speed of light in vacuum consistency, the principle of the speed of light independence of the light source, and other. Transferring from one reference system to another, relative are also body dimensions, and the duration of their existence, the time of events, and so on.

The general theory of relativity states that natural laws act equally in inertial and non-inertial reference systems. Euclidean geometry can no longer use such theory but uses one which says that space is crooked under the action of gravity forces, slowing down of time flow in strong gravitational fields. All this leads to a deeper cognition of the world.

Modern science and mysticism

The rapid development of 20th century science is associated with the spread of mysticism, irrationalism, occultism, esotericism. Mystical consciousness always combines in itself belief in supernatural. Historically mysticism has manifested itself strongest in the cult of shamanism. A shaman is a man, who performs a role of an oracle, fortune teller, and so on, in the way of meditation able to travel to another world. It is thought that during meditation (ecstasy) those sensory organ signals are fixed, which usually "pass" close to consciousness. Any monotonically repetitive sounds can cause disconnection of specific brain centres and cause hallucinations. Visions can give the impression that it is actually visible. Researchers think that this is a penetration into the depth of consciousness. Such penetration can be achieved in a variety of ways, e.g., drugs.

One of the essential social mystical sources is fear. One man is powerless against the forces of society and nature. At social-psychological level, this has an expression of fear. Another source is belief. Belief is a natural human need. Some religions, e.g., Brahmanism, Hinduism and others are based on deep mysticism. Personality type of a human also has influence. Such types can be discerned:

1. An absurdist (life generally has no sense, so living in such a world means to live in an evil world).
2. Characters (see the meaning of life in the life itself, in the surrounding reality).
3. Creators (find the meaning of life by searching for that meaning, creating).
4. Fantasts (closest to mysticism, searching for the meaning of life in the unreal world, giving preference to the transcendent perception of the world).

Science itself has influence on the development of mysticism. In science, worldview and methodological relativism develops, the boundary between object and subject disappears,

holistic and holistic world perception, and so on. There are a number of scholars, who are looking for analogues between the image of the modern world and the mystical Ancient East world images. An interest in exo-psychology appears, holographic human thinking functioning conception is developed, relativistic quantum psychology, Galactic mind hypothesis, and so on. Classical European science considered such things to be schizophrenia, so at this moment it is thought that this requires serious analysis. It is even asserted that physics is only a branch of psychology. Still, it is necessary to distinguish objective cognitive content /facts, laws, principles, theories from their worldview interpretation (philosophical, religious, and so on). Consciousness is always active here. Again, we can derive three chains

Science **Intermediary chain** **Anti-science**

Quantum physics, the theory of relativity created very unusual things for us. We understand that the results of an experiment depend on the type of an experiment itself, the devices used, and the experimenter himself. Devices are not perceived as something separate but as an inseparable part of the researcher. An observer and an object of observation form an inseparable unity in the cognition sphere. There is a lot of evidence that human mind generates a certain energetic field, which affects /in a way as electromagnetic field distorts an image on a television screen/. Thus, consciousness generates a bio-gravitational field.

Quantum mechanics and quantum physics basically formed at the beginning of the 20th century. It was created by the most famous scientists of that time Planck, Einstein, Bohr, De Broil, Heisenberg, Schrodinger and other. The world seems to be described in a statistically probable way. If a continuous energy exchange takes place in the macro-world, then in the micro-world this takes place in a strictly established order – radiation taking place in portions.

Until the end of the 19th century, the smallest particle of matter was considered an atom. The periodic law formulated by Mendeleev in 1869 encouraged the researchers to think that the structure of atoms is determined by even finer particles. In 1897 an English physicist Thomson discovered an electron – the first elementary particle. When the neutron was found in1932, it seemed that the structure of matter was basically clarified. The particles known at that time – *proton, neutron and electron* – were enough to explain the structure and properties of matter.

Gradually a new structural level of the existence of matter was described. This formed conditions for the physics of the solid body to develop. The structure of metals, dielectrics, semiconductors, their thermodynamic, electrical, and magnetic properties were explained. Quantum mechanics explained that the source of stellar energy is nuclear reactions taking place at very high temperatures /hundreds of millions of degrees/.

Quantum mechanics was applied to physical field explanation. Photon is understood – a particle of electromagnetic field, not having a rest mass.

Quantum mechanics + special relativity theory = antiparticles

It was clarified that every particle has a "twin" (another particle, having a different charge, but the same mass). In 1934, an English physicist Dirac discovered a ***positron*** – an electron antiparticle.

A little bit later, a ***neutrino*** *was* discovered. It was ascertained that radioactive ß decay taking place, *electrons and protons*, having different energy are released from the atomic nucleus. But energy does not disappear anywhere and does not emerge from nowhere. Where

else is part of the energy? A Swiss physicist theoretic Pauli stated that with the electron /or positron/ one more small particle is released. It was called *neutrino*. If a positron is emitted, neutrino is emitted at the same time, if an electron – antineutrino is emitted.

$\mathbf{n \rightarrow p + e + \upsilon_e}$.
If a positron and neutrino are emitted, then a proton turns to neutron

$\mathbf{p \rightarrow n + e^+ + \upsilon_e}$.

These particles are not in the nucleus of the atom, they are born in the process of a neutron conversion to a proton or vice versa.

Quantum mechanics started to analyse matter and the field in a close relationship. Quantum mechanics seems to merge the corpuscular and wave concepts into one phenomenon. Heisenberg introduces the uncertainty principle, which says that the coordinates of pulse propagation remain uncertain. Bohr introduces complementarity principle, contrasting it with the causality principle. If we use an accurate device to measure the coordinates of the particles, then the pulse can be any, thus, causal relationship does not exist. Heisenberg proposed the principle of uncontrolled interaction /particles with the device/.

The principle of some concepts

The question arises "What is a proton made of?", Is an electron divided? Is a photon indivisible or a composite particle? And other. However, analysing basically such questions lose their meaning. When we say that the system is made up of elements, it is as if we perceive that it is made of smaller independent units. In the micro-world it is different, we say that particles turn into one another in a variety of interaction processes. Even when a particle decomposes, we cannot assert that the particles obtained in the process are simpler, that they have entered the decomposing particle composition. In quantum decays the "born" particles have a bigger mass than the "mother" particle. E.g., when a pi meson decomposes into *proton + neutron*, the particle mass of this pair far exceeds the mass of pi meson itself. Therefore, we call many of these particles not ordinary, but elementary. However, they manifest themselves also in their own internal structure. A free, not interacting particle is just a mathematical abstraction. Real physical particles always interact with vacuum fields, giving up or absorbing virtual particles. A "cloud" of virtual particles forms around each micro-particle.

Microparticle variety

More than 400 elementary particles are known at this moment. Some of them exist for a very short time. Some turn into others e.g., during their lifetime are able to cover a distance equal to the radius of the atom, 10^{-12} cm. Some elementary particles turned out to be heavier than some atoms.

By classifying particles, it is possible to discern certain regularities of the micro-world, to perceive relations between the forms of interaction: *gravitational, electromagnetic, strong, and weak*. The radius of weak interaction is less than 10^{-15} cm. Even the weak interaction many times exceeds the gravitational interaction. Coulomb's repulsive force of two electrons is 10^{42}

times bigger than their gravitational attraction. In any case, the radius of the interaction force depends on the mass of particles. Electromagnetic interaction carries photons (rest mass=0), gravitational – gravitons (particles have not been experimentally determined yet), a rest mass of which has also be =0). Gravitational interaction causes attraction effect between equal particles, the other interactions cause repulsion between equal particles. The carriers of strong interaction in atomic nuclei are gluons.

Micro-world variety realises its unity through particle and field changeability.

Particle + antiparticle = new particle.

Hadrons are heavy particles, made up of three particles – quark, antiquark and the gluon connecting them. There also exist light particles leptons.

Micro-world is infinite for cognition. And what is next? Anything can be next.

- Science hardly ever will really tell who and what a micro-world is;
- alchemy → chemistry → quantum physics (Rutherford – I am the last alchemic because for sure one atom can be converted by another). E.g., gold can be made from mercury.
- The proton is unstable, after some time decomposes to leptons. Over the time all atom nuclei will turn into electrons, neutrinos, and photons – and this means that organised matter will disappear. Now it is thought that the lifespan of proton is about 10^{32} years. The material is likely to disappear in future. All particles made of quarks are unstable, only the fact of proton's decay has not been confirmed yet. All of this is **the front line of cognition**.

Fundamental force, also called **fundamental interaction**, in physics, any of the four basic forces—gravitational, electromagnetic, strong, and weak—that govern how objects or particles interact and how certain particles decay. All the known forces of nature can be traced to these fundamental forces. The fundamental forces are characterized on the basis of the following four criteria: the types of particles that experience the force, the relative strength of the force, the range over which the force is effective, and the nature of the particles that mediate the force.
The current physical description of the fundamental forces is embodied within the Standard Model of particle physics, which outlines the properties of all the fundamental particles and their forces. Graphical representations of the effect of fundamental forces on the behaviour of elementary subatomic particles are incorporated in Feynman diagrams.

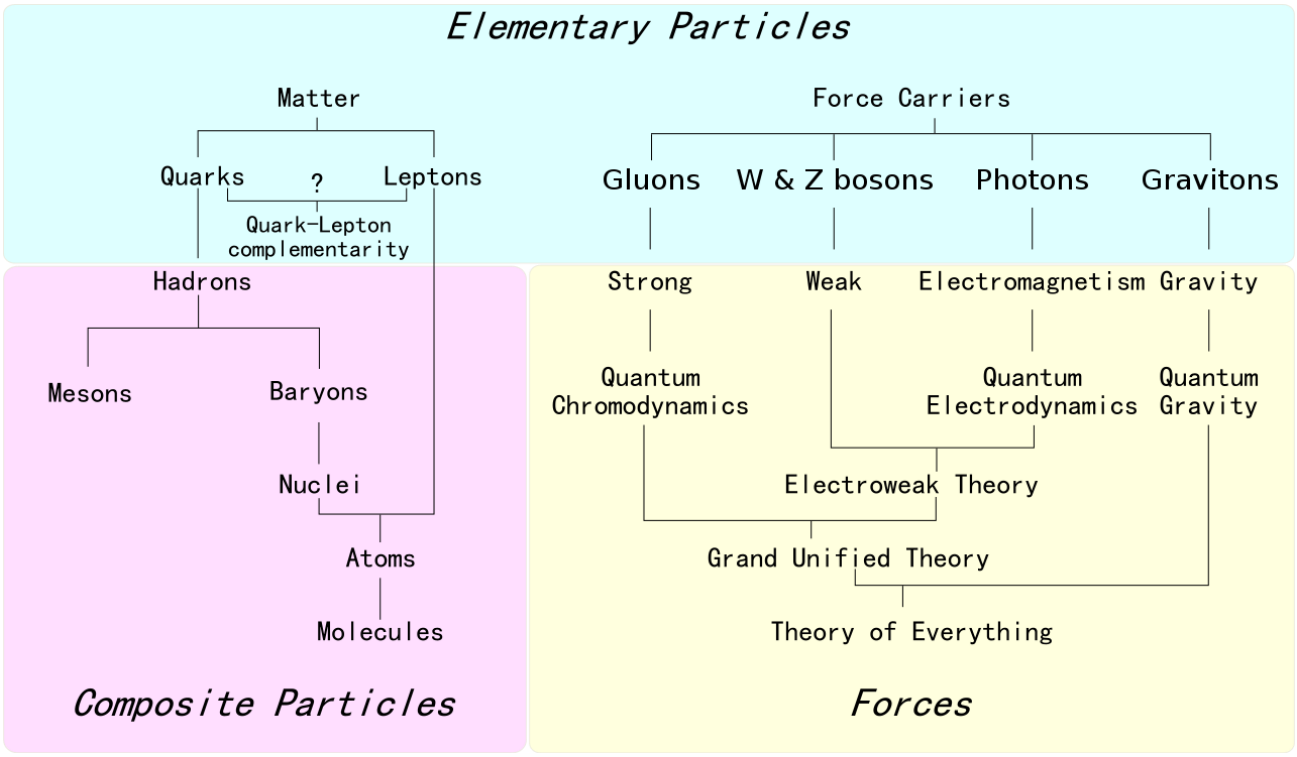

Fig. 5. Elementary particles
(https://en.wikipedia.org/wiki/Fundamental_interaction#/media/File:Particle_overview.svg)

Thus, atom is an overall nuclear electronic system. The most important component of an atom is – nucleus. In different energetic levels of atom's orbit, electrons are located. The essential atom interaction types are three:

1. Interaction with fields and particles, during which internal structure of atoms changes (e.g., radiation and light absorption).
2. Atom reciprocity, which determines aggregation state of matter.
3. Chemical interaction, when molecules and other chemical combinations form.

The more complex are atoms, the more complex is their interaction. Chemical interaction takes place only at atomic level, therefore atom can be treated as the most elementary chemical interaction particle. On the other hand, chemical interaction is not the other thing as interaction between atoms, and this means that atom features determine this interaction.

Molecules – is another evolution level of matter. This is qualitatively another level. Modern natural science treats molecular movement as the movement of independent systems. In other words, the atoms forming a molecule move not chaotically, but submit to the internal molecular logic.

Modern chemistry knows plenty of chemical particles, which differ one from another in their structure, complexity, and so on. One can distinguish three levels of matter:

1) atom level (electrically neutral atoms, ions, isotopes and so on);
2) molecular level (molecules, radicals, molecular ions, ionic radicals, and other);
3) over molecular level/colloidal compositions – micelles, molecular complexes, and polymer macromolecules/.

In every of these levels chemical processes are getting more complex, the particles becoming more complex. In biological systems, a qualitative activity sphere of chemical movement form sort of finishes. Other complex transformations start.

From physics and chemistry towards geology and biology

Chemical and physical process and transformation consequence is – a biological movement form. It can be represented by the following scheme.

Physical interaction phenomena at the level of elementary particle and atomic nuclei	Chemical atom and molecule movement Physical atom-molecular processes	Life, biological proteinic-nucleic system movement form Geological processes

This reflects a complex development process. In atom-molecular level, processes are very complex, interdependent. In geological and biological systems, all movement forms are related by internal relations.

How did the Universe emerge? The works of Einstein, Friedman, Hubble and others showed that meta-galaxy is constantly expanding, galaxies are moving away from each other. Thus, it was a primary centre of something. This is called The Big Bang. Nobody knows what existed before the Big Bang. The energy generated during the explosion turned into atomic particles. After about 1 billion years after the Explosion, gravity pulled hydrogen and helium into the clouds, spinning gas balls formed, and the first galaxies and stars appeared.

The big Bang evidences

1. Light travels billions of years from the farthest galaxes to us therefore, we can see what they looked like before that time.
2. Galaxies are moving away from us which means that once upon a time everything was concentrated in one place.
3. In 1965, scientists found a relic heat radiation remaining after the explosion, which travels in all directions of space.

The future of the Universe is vague. Some think that it will expand, grow, and cool. Stars will disappear and the Universe will become cold and dark.

Others believe that after many years, gravity will stop galaxies so that they will stop to expand. Then gravity again will attract galaxies one to another. The Universe will shrink to one point, the material will get hotter and hotter until it compresses to a state called the Great Crisis. Everything will fall apart, and that will be the end of the Universe. Later, there may be another Big Bang and a new Universe may form.

However, the question remains, how the Universe emerged. It has been known since ancient times that nothing emerges from anything. Any object can emerge only from the other objects. Absolute emptiness does not exist. If there is no matter, it is a field, if there is no field, then there is its physical vacuum. Modern physics understands the vacuum as a special state of matter, and not as an absolute nothingness. E.g., a vacuum of electromagnetic field is its state, in which there are no photons.

Thus, the principle of non-creation and non-destruction of matter remains valid. Mass endurance, energy endurance, electric charge, pulse endurance, and other laws were known already at the beginning of the 20th century.

Today, it is popular to absolute the concept of “black hole”. However, today it is clear that they are not completely isolated and closed. It has been thought for a long time that black holes were only absorbing objects, the gravity of which was so big that it blocked even the radiation of the light. However, today it has been stated that black holes also emit fluxes of matter and antimatter, electromagnetic waves, etc. into the surrounding space.

The theory of the “thermal death” of the Universe

In 1960, a German physicist Clausius formulated the second thermodynamics law, which says that in the irreversible processes, entropy /disorder/ is constantly growing. A conclusion was drawn from this law that all forms of motion of matter will turn to thermal form and evenly will spread in the Universe. However, it is obvious that not only the process of decomposition of matter takes place, but also its concentration in space. It is thought that black holes are concentrators of matter and energy, which are able to return it to the surrounding space by explosions.

Thus, the mega-world is also rather complex. It turns out that it is not possible to create a complete theory that would explain all the different forms of the existence of matter. If such theory were developed, science would lose its meaning, everything would be explained. E.g., what is valid in the micro-world, appears to be invalid in the world of elementary particles. “Part less than the whole” is not valid for elementary particles.

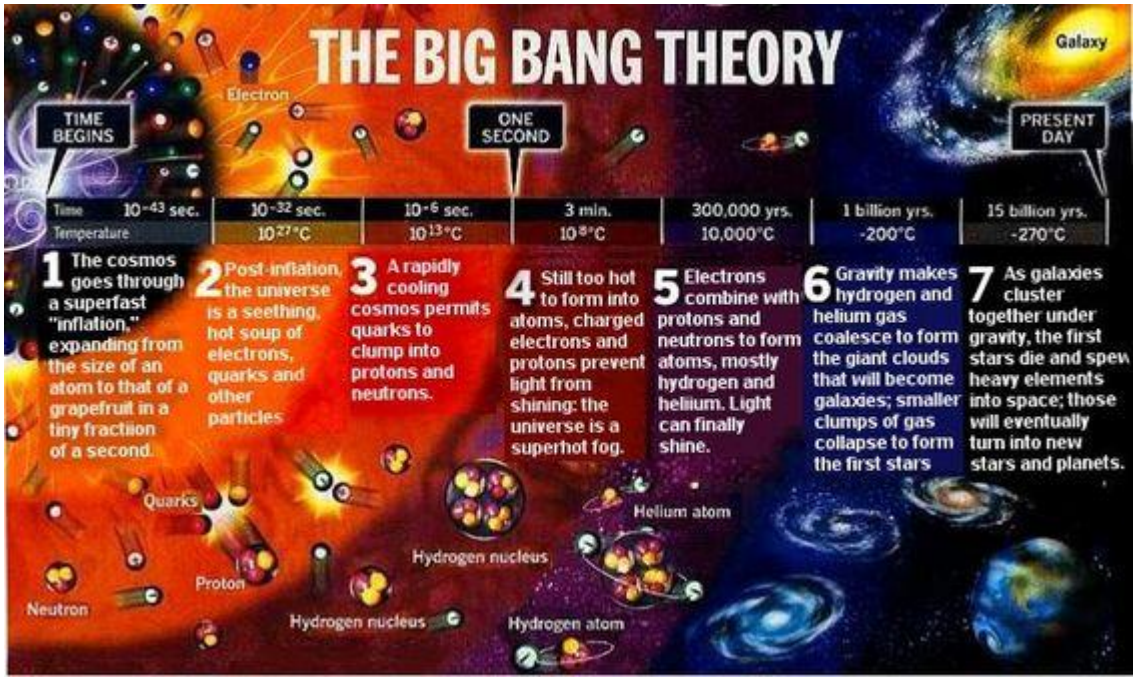

Fig. 6. The Big Bang (https://cz.pinterest.com/pin/194851121359996416/)

Further reading:

https://www.universetoday.com/54756/what-is-the-big-bang-theory/