General principles of modern physics. Interactions. Standard model.

Physics is the science studying two basic forms of the Nature – the **field** and the **substance** - by mathematical methods. Physics deals with the most general phenomena of the Nature named physical **objects**. An object is something that our action is focused/applied on.

The field is the active medium thorough which one charged body can affect the other one. It means that positioning of a body into the field results in generation of the **force** acting upon the body. The substance and the field can interconvert within the limits of energy stored in those. Different particles of substance cannot reside in the exactly same part of the space, but different fields can. The particles of substance have defined dimensions, whereas the particles of field does usually not.

Mechanical motion is a change of the location, position or shape of the body. One can talk about the motion only due to the fact that an observer has memory.

The forms of the motion are: the **translation** (change of the location), the **rotation** (change of the position), the **deformation** (change of the shape) and the **oscillation** (the periodic change of the position, location or shape of the body). We also know the oscillations as **vibrations** or **waves**.

Interaction is the cause that changes the mode of motion (velocity) of bodies. The physical quantity that describes the intensity of the interaction is **force**. The force is mutual – meaning that body number 1 exerts force upon the body number 2, then the body number 2 also exerts force on the body number 1. That is, the action is equal to the counteraction. During the interaction, the matter and the field are mutually transformed into each other. There are four main types of the interactions: **gravitational**, **weak**, **electromagnetic** and **strong**.

Charge is the physical quantity describing the property of the body to participate in some kind of interaction. For instance, only bodies or particles that have electric charge can participate in the electromagnetic interaction. Particles that participate in the weak but not strong interaction are called **leptons** and those possess **lepton charge**. Particles that participate in the strong interaction are called **quarks** and those possess strong interaction charge that is also called **colour charge**. All bodies or particles take part in the **gravitational** interaction, whereas the corresponding charge is called **heavy mass**. Every subatomic particle has a corresponding **antiparticle** with the same mass but an equal and opposite charge.

The general principles of physics are always at the end of the chain of questions considering physics that start with the word 'why'. We cannot answer why one or another principle is valid. All other claims about Nature except these principles themselves can be explained by the principles. In the given subject, we will use the atomic principle, the principle of absolute speed, the principle of energetic minimum, the Pauli exclusion principle, the principle of wave-particle duality and the Heisenberg uncertainty principle.

The atomic principle states that neither substance (matter) nor field can be limitlessly broken up into smaller parts. They both possess the smallest portions, which are called **fundamental particles** in case of matter, and **quanta** (single: *quantum*) in case of field. The word 'atom' (Greek *atomos*) in fact means the smallest particle at the given level of knowledge.

Work is a physical quantity that describes the process: it reflects both the change of the state as well as the necessary effort. In case of mechanical work, the position of the bodies relative to each other is altered.

Energy is a physical quantity that describes the state. Energy is the capability of a body or a force to perform work. In case if this capability originates from the movement of a body relative to other bodies, we can talk of **kinetic energy** E_k. In case if this capability originates from the positioning of a body relative to other bodies, we can talk of **potential energy** E_p. Because work is a process which leads to the change of state, it is always accompanied by the change of energy.

The resting energy of a body E_r originates from the sole existence of the body. The matter and the field are interconvertible within the limits of energy contained in those.

The principle of energetic minimum states that all spontaneous processes (that is, those not caused by an external force) proceed in the direction of reduction of energy. The system has a tendency to give away energy moving into the state with minimal energy.

The principle of absolute speed states that the motion of the purely field object (an object with zero rest mass) with respect to the substance is absolute (not depending on the reference frame). The motion of the every body with respect to the another body is relative. The absolute speed (c = 299 792 458 m/s) is mostly called the speed of light because the light is the most well-known purely field-type object.

The spin is an intrinsic form of motion of the particle. In case of a matter particle, a spin can be conditionally interpreted as a spinning or rotation of a particle around its intrinsic axis. This spinning cannot be stopped, but the direction of spinning axis in space (spin **direction**) can be changed. Two particles of matter that have oppositely directed spins can locate at exactly same point in space (inside each other). The spin of a field particle, on the other hand, can be attributed to its translational motion.

The Pauli exclusion principle (*Wolfgang Pauli*, Swiss physicist) states that within the place in space that is defined by the dimensions of one fundamental particle, a maximum of two substance particles can be located whereas these two must possess differently oriented spins. The other particles of substance (matter) are pushed out, excluded from this location. The particles of substance (matter), also called **fermions** are subordinate to the exclusion principle, whereas the field particles (also called **bosons**) are not. The strict distinction of fermions and bosons can be made on the basis of **spin**: fermions possess half-digit spin, whereas bosons possess full-digit (integer) spin. The spin of the fundamental fermions (leptons and quarks) is ½. It means that the angular momentum of the internal spinning is equal to $L_S = ½\ \hbar$, where $\hbar$ is the reduced Planck constant (the smallest possible portion of angular momentum).

The principle of wave-particle duality states that both substance and field possess both wave and particle characteristics. The wave characteristics become evident when particles move. In case of field particles (quanta) is occurs via propagation of the oscillations of the field. The wave associated with a matter particle is called matter wave or de Broglie wave (*Louis de Broglie*, French physicist); the quantity changing in this wave is the probability of existence of a particle in the given part of the space.

The Heisenberg uncertainty principle (*Werner Heisenberg*, German physicist) states that no event is either absolutely probable or absolutely improbable. All events occur with some kind of probability, but in case of an event termed impossible this probability is extremely small (close to zero). The present and the future of a physical object cannot be determined simultaneously: if we know where the object resides at the given point of time, we cannot absolutely surely forecast its behaviour in future. On the other hand, if the future behaviour of an object is absolutely certain, the we do not know anything about its current location.

According to the **standard model**, all particles of substance (matter) consist of 12 fundamental **fermions**. Those are 6 **leptons** (electron, muon, tauon and the three corresponding neutrinos) and 6 quarks (***d****own*, ***u****p*, ***s****trange*, ***c****harm*, ***b****ottom*, ***t****op*). The 12 corresponding **antiparticles** do also exist. Bosons (field particles) are responsible for the interactions. The electromagnetic interaction is transferred by **photons** (light particles), the strong interaction by **gluons** (yes, like a *glue*!), and the weak interaction by **W- or Z-bosons** (also called *weakons*). In 2013, the discovery of **Higgs bosons** constituting the Higgs field was announced. The Higgs field causes the inertia of bodies (the tendency to conserve their state of motion). The particles responsible for the gravitational interaction – **gravitons** – have so far not been experimentally discovered. They are only predicted theoretically.