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THE RELATION OF CONSERVATION LAWS TO THE SYMMETRY OF SPACE AND TIME

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Abstract:
This article analyzes the interaction of the symmetry of space and time with conservation laws. The existence of symmetry corresponding to each conservation law is justified by the example of the laws of physical conservation. As a result, it was established that the laws of symmetry and conservation are the methodological principles of physical knowledge of the Universe.

Keywords: symmetry, time and space, quantum physics, conservation law, law of conservation of momentum, law of conservation of energy, law of conservation of angular momentum.

Introduction

Fundamental physical laws are the most complete to date, but an approximate reflection of objective processes in nature. Various forms of motion of matter are described by various fundamental theories. Each of these theories describes well-defined phenomena: mechanical or thermal motion, electromagnetic phenomena. There are more general laws in the structure of fundamental physical theories covering all forms of motion of matter and all processes. These are the laws of symmetry, or invariance, and the related laws of conservation of physical quantities. The laws of conservation of physical quantities are statements according to which the numerical values of these quantities do not change over time in any processes or classes of processes. In fact, in many cases, conservation laws simply follow from the principles of symmetry.

The idea of conservation first appeared as a purely philosophical guess about the presence of the unchangeable, stable in an ever-changing world. Even the ancient materialistic philosophers came to the concept of matter as the indestructible and uncreated basis of all things. On the other hand, the observation of constant changes in nature led to the idea of the eternal motion of matter as an important property of it. With the advent of the materialistic formulation of mechanics, conservation laws appeared on this basis.

Conservation laws are closely related to the symmetry properties of physical systems. In this case, symmetry is understood as the invariance of physical laws with respect to a certain group of transformations of the quantities included in them. The presence of symmetry leads to the fact that there is a conserved physical quantity for this system. If the symmetry properties of a system are known, as a rule, it is possible to find a conservation law for it and vice versa.

The most important conservation laws valid for any isolated systems are:

the law of conservation of energy;
the law of conservation of momentum;
the law of conservation of angular momentum.

A certain hierarchy of conservation laws and principles of symmetry has been discovered in modern physics. Some of these principles are fulfilled in all interactions, while others are fulfilled only in strong ones. This hierarchy is clearly manifested in the internal principles of symmetry that operate in the microcosm.

I. Fundamental conservation laws

1) The law of conservation of energy in mechanical processes

Mechanical energy is divided into two types: potential and kinetic. Potential energy characterizes interacting bodies, and kinetic energy characterizes moving ones. Both potential and kinetic energies change only as a result of such interaction of bodies, in which the forces acting on the bodies perform work other than zero.

Let us now consider the question of the change in energy during the interaction of bodies forming a closed system. If several bodies interact with each other only by gravitational forces and elastic forces and no external forces act, then in any interactions the sum of the kinetic and potential energies of the bodies remains constant. This statement is called the law of conservation of energy in mechanical processes.

The sum of the kinetic and potential energies of the bodies is called the total mechanical energy. Therefore, the law of conservation of energy can be formulated as follows: the total mechanical energy of a closed system of bodies interacting with the forces of gravity and elasticity remains constant.

The main content of the law of conservation of energy is not only to establish the fact of conservation of total mechanical energy, but also to establish the possibility of mutual transformations of kinetic and potential energies in equal quantities during the interaction of bodies.

The law of conservation of total mechanical energy in processes involving elastic forces and gravitational forces is one of the basic laws of mechanics. Knowledge of this law simplifies the solution of many tasks of great practical importance in practical life.

For example, river energy is widely used to generate electricity. For this purpose, dams are being built and rivers are blocked. Under the influence of gravity, water from the reservoir behind the dam moves down the well at an accelerated rate and acquires some kinetic energy. When a rapidly moving stream of water collides with the blades of a hydraulic turbine, the kinetic energy of the translational motion of water is converted into the kinetic energy of the rotational motion of the turbine rotors, and then, with the help of an electric generator, into electrical energy.

Mechanical energy is not conserved if a friction force acts between the bodies. A car moving along a horizontal section of road, after turning off the engine, goes some way and stops under the action of friction forces. During the braking of the car, the brake pads, tires of the car, and asphalt were heated. As a result of the action of friction forces, the kinetic energy of the car did not disappear, but turned into the internal energy of the thermal motion of molecules.

Thus, in any physical interactions, energy does not arise, but only transforms from one form to another. This experimentally established fact is called the law of conservation and transformation of energy.

Energy sources on earth are large and diverse. Once upon a time, in ancient times, people knew only one source of energy - muscular strength and the strength of domestic animals. Energy was renewed through food. Now most of the work is done by machines, the energy source for them is various types of fossil fuels: coal, peat, oil, as well as water and wind energy.

If we trace the "lineage" of all these various types of energy, it turns out that they are all the energy of the sun's rays. The energy of the outer space around us is accumulated by the Sun in the form of energy from atomic nuclei, chemical elements, electromagnetic and gravitational fields. The sun, in turn, provides the Earth with energy, manifested in the form of wind and wave energy, tides, in the form of geomagnetism, various types of radiation, and the muscular energy of the animal world.

Geophysical energy is released in the form of natural phenomena, metabolism in living organisms, useful work on moving bodies, changing their structure, quality, transmitting information, storing energy in various kinds of batteries, capacitors, in elastic deformation of springs, membranes.

All forms of energy, turning into each other through mechanical motion, chemical reactions and electromagnetic radiation, eventually turn into heat and dissipate into the surrounding space. This phenomenon manifests itself in the form of explosive processes, gorenje, rotting, melting, evaporation, deformation, radioactive decay. There is an energy cycle in nature, characterized by the fact that not only chaoticization is realized in outer space, but also the reverse process - the ordering of the structure, which can be clearly seen primarily in star formation, transformation and the emergence of new electromagnetic and gravitational fields, and they again carry their energy to new "solar systems". And everything goes back to normal.

The law of conservation of mechanical energy was formulated by the German scientist A. Leibniz. Then the German scientist J. R. Mayer, the English physicist J. Joule and the German scientist G. Helmholtz experimentally discovered the laws of conservation of energy in non-mechanical phenomena.

2) The law of conservation of momentum

Rest and movement of the body are relative, the speed of movement depends on the choice of the frame of reference. According to Newton's second law, regardless of whether the body was at rest, or moved uniformly and rectilinearly, a change in its speed of movement can occur only under the action of force, that is, as a result of interaction with other bodies.

There is a physical quantity that varies equally for all bodies under the action of the same forces, if the time of action of the force is the same, equal to the product of the mass of the body by its velocity and called the momentum of the body. Momentum is a vector quantity that coincides in direction with velocity. The change in momentum is equal to the momentum of the applied force. The momentum of a body is a quantitative characteristic of the translational motion of bodies.

Experimental studies of the interactions of various bodies - from planets and stars to atoms and electrons, elementary particles - have shown that in any system of interacting bodies, in the absence of forces from other bodies outside the system, or the sum of the acting forces is equal to zero, the geometric sum of the impulses of the bodies remains constant.

A system of bodies that do not interact with other bodies that are not part of this system is called closed. Thus, in a closed system, the geometric sum of the impulses of the bodies remains constant for any interactions of the bodies of this system with each other. This fundamental law of nature is called the law of conservation of momentum.

A necessary condition for the applicability of the law of conservation of momentum to a system of interacting bodies is the use of an inertial reference frame. Jet propulsion is based on the law of conservation of momentum, it is used in the calculation of directional explosions, for example, when tunneling in mountains. Space flights have become possible thanks to the use of multi-stage rockets.

3) The law of conservation of angular momentum

The angular momentum is a physical quantity that characterizes the amount of rotational motion. It obeys the law of conservation, which follows from the isotropy of space.

All rotating bodies have a moment of momentum. From the formula for calculating the angular momentum L =mvr, where m is mass, v is velocity, r is radius, it can be seen that the velocity should increase with decreasing radius. This law is used by ballerinas performing fouettes. This law is especially well manifested in figure skating. At the beginning of rotation, the arms and leg are separated to the maximum possible distance from the body. By pressing the body parts back, reducing the radius, the skater and the ballerina begin to rotate faster, causing, with luck, the delight of the audience.

The conservation of angular momentum occurs both in the processes of the microcosm and on the scale of rotating stars and galaxies - it has a universal character.

The principles of symmetry are closely related to the laws of conservation of physical quantities - statements according to which the numerical values of certain physical quantities do not change over time in any processes or in certain classes of processes. In fact, in many cases the conservation laws simply follow from the principles of symmetry.

The connection between the symmetry of space and the laws of conservation was established in 1918 by the German mathematician Emmy Noether (1882-1935). She formulated and proved the fundamental theorem of mathematical physics, named after her, from which it follows that if a certain system is invariant with respect to some global transformation, then there is a certain conserved quantity for it.

Noether's theorem, proved by her during her participation in the work of an entire group on the problems of general relativity, as if by accident, became the most important tool of theoretical physics, which established the special role of the principles of symmetry in the construction of physical theory. It can be said that the theoretical-invariant approach, the Erlangen principle, penetrated into physics and determined the expediency of formulating physical theories in the language of Lagrangians. Thus, the mentioned conservation laws are the consequences of symmetries existing in real space-time. The law of conservation of energy is a consequence of temporal translational symmetry - the uniformity of time. Due to the uniformity of time, the Lagrange function of a closed system clearly does not depend on time, but depends on the coordinates and impulses of all the elements that make up this system. By simple mathematical transformations, it can be shown that this leads to the fact that the total energy of the system remains unchanged during movement.

The law of conservation of momentum is a consequence of the translational Invariance of space (uniformity of space). If we require that the Lagrange function remains unchanged for any infinitesimal transfer of a closed system in space, then we obtain the law of conservation of momentum.

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