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MATHEMATICAL INTERPRETATION OF THE LAWS OF PHYSICS

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Abstract

This article describes the mathematical interpretation of the laws of physics and the issues of teaching it. It is shown that the mathematical expression of these laws consists of relatively simpler linear, quadratic, exponential, and other functional relationships between physical quantities. The existence of limits to the implementation of these laws is shown by several examples, which show that in areas beyond the limits, legalities become complex. It is noted that such a mathematical approach can help students understand the essence of laws and remember them for a long time.

Keywords: physical law, functional coupling, thermodynamic forces, flow density, temperature gradient, exponential coupling, radiological chronology, convection, viscosity.

INTRODUCTION

It is known that the science of physics plays the main role in the study of nature among all fundamental sciences and serves as a fundamental basis for all specialized sciences in the field of technology.

Perfect mastery of physics requires students to have a deep understanding of the essence of physical processes, phenomena, and the laws that are subject to them. In this sense, a mathematical approach and interpretation of the laws of physics during training provides an opportunity to better understand the essence of these laws and to remember them for a long time. It is known that most of the laws of physics were discovered by research scientists, and students or undergraduate students remember these laws by the names of the authors and may not pay attention to the essence. Examples include Newton's laws, Ohm's law, Hooke's law, Bouguer's law, and others.

It can be overlooked that these and other similar laws are analytical expressions of some mathematical functional law. Below we present some examples of analytical interpretation of some physical laws based on mathematical approaches.

MAIN PART

Based on the analysis of the laws of physics, they can be defined as follows. The laws of physics explain the studied phenomena and processes in nature, expressed using a short verbal statement or mathematical formula, and determine the connections between various physical quantities.

It is known that all physical phenomena and processes are quantitatively characterized by physical quantities. These physical quantities are mathematically related to each other by some functional law, such as linear, quadratic, exponential, sine, cosine, or other more complex laws.

If the mathematical law of the state of a system or the occurrence of a physical process is clear, for example, linear, it will be possible to make a judgment about the state of this system or the course of the process at an arbitrary moment in time. If there is a deviation from this law, it means that another event may occur that causes it, it is explained to the students with examples.

For example, if the law or equation of kinematic motion of a material point and the initial conditions are known, it will be possible to determine its coordinate at an arbitrary moment. It is known that if no force acts on a material point or body, or if the equal effector of all applied forces is equal to zero, the body moves in a straight line and its coordinate is a linear function of time. If the acting force does not change, the body is in a straight-line planar accelerated motion, and we know that its coordinate changes with time according to the quadratic law. For example, if the impact force changes with time according to the law F = kt (k-proportionality coefficient is measured in N/s), the equation of motion has a more complicated form, and the body coordinate depends on the cube of time will depend.

The well-known English scientist Hook found that the magnitudes of mechanical stress and relative deformation applied to an elastically deformed body are linearly related. But in relatively larger deformations, that is, beyond the limit of elasticity, this law is not fulfilled. Because in large deformations, the coefficient of proportionality, that is, the mechanical-elastic property of the material of the body changes, and this leads to a deviation from the given law.

The resistance of metals is connected with the temperature by a linear law. At very low temperatures, there is a deviation from this law, that is, the resistance jumps to zero, and this is explained by the phenomenon of superconductivity and the occurrence of quantum effects.

In non-equilibrium thermodynamic systems, the flow densities of quantities such as charge, heat, mass, and momentum are considered to be the transfer phenomena of current flow, heat conduction, diffusion, and viscosity. These in turn are called Ohm's, Foure's, Fook's, and Newton's laws respectively.

The current strength (density) in the conductors is also linearly related to the applied voltage (field strength or potential gradient inside the conductor) and is called Ohm's law.

At relatively higher voltages, a deviation from the linear law is observed due to the change in the electrophysical property of the conductor material, the specific electrical conductivity. If the temperature is the same at all points of the gas or liquid considered as a thermodynamic system, the thermodynamic equilibrium is determined.

If a temperature gradient is formed in the system, heat flow occurs and an unbalanced state occurs in the system. At small values of the temperature gradient, the heat flow density is linearly related to it, and heat is transferred from one point of the system to another through the mechanism of heat transfer, i.e., the collision of molecules. At relatively large values of the temperature gradient, the system moves further away from the equilibrium state, the linear relationship between the heat flux density and the temperature gradient is broken, and a nonlinear situation appears in the system. At a greater value of the gradient, the liquid or gas does not have time to transfer a very large heat flow through the heat conduction mechanism, and convection occurs. An example of this is the Benar cell formed in liquids. In Benar's convective cell consisting of a six-sided regular prism, molecules with high energy begin to move upward along the center, and molecules with relatively lower energy begin to move downward along the surface of the prism. That is, between the movement of molecules there is a mutual compatibility and connection. In the sun, convective cells with a much larger height appear and form a convective zone.

Each physical law is fulfilled under certain conditions, i.e., only in the areas of certain values of the quantities that determine the conditions. For example, the plot of platinum linear size versus temperature will look like the one shown in the figure. Its transformation law can be expressed empirically in the form $\ell = \ell_0 (1 + \alpha t + \beta t^2 + \gamma t^3 + \cdots)$. In small temperature intervals, this relationship appears linear $\ell = \ell_0 (1 + \alpha t)$.

When studying harmonic vibrations, most students - students imagine vibrational processes in the sense of the vibration of an object. To understand the essence of harmonic vibrations, the following examples can be given. Suppose a ball is fired with a spring-loaded toy gun in space, in the absence of the gravitational field of other bodies and the absence of friction or environmental resistance. Its motion is a straight-line plane, its coordinate changes linearly with time, and the sphere moves infinitely away from the starting point. The coordinate of the second ball, one end of which is attached to a fixed belt spring and oscillating under the influence of elastic force, changes according to the law of sine or cosine over time under the same conditions, and the ball periodically returns to the position of the starting point and moves away.

If a solid body is moving in a viscous medium, for example, liquid or gas, the resistance force shown by the medium to the body depends on the body's speed. At relatively small speeds, the drag force is linearly related to the change in speed, as can be seen in the example of the Stokes force. At higher speeds, the drag force increases rapidly in proportion to the square of the speed. An example of this is the drag force on the wing of the aircraft. As a result of the rapid increase in the resistance force acting on the meteorite rock, which entered the Earth's thick atmospheric layer at a high speed, it can be explained with the help of the above connection.

Readers and students associate the absorption of electromagnetic radiation, including light, by matter with Bouguer's law, and may ignore the fact that this process occurs exponentially. The intensity or flux of light passing through a substance of any thickness is an exponential function of the thickness of the substance. By logarithmizing the expression of the exponent, it is possible to create a linear relationship between the quantities and thereby determine the absorption coefficient.

In the event of radioactivity, the number of decaying nuclei decreases with time according to the exponential law. It can be noted that the long-term preservation of high radiation activity in radioactively damaged areas occurs due to the exponential law. Based on this law, the age of ancient layers of the earth or other samples is determined by knowing the number of isotopes that have not decayed and decayed, as well as the half-life of the isotope. Radiological chronology uses uranium-lead, rubidium-strontium, potassium-argon, and other radiological methods. The isotope of uranium(238) turns into lead with a half-life of 4510 million years, and the isotope of rubidium(87) turns into strontium with a half-life of 50 billion years. The half-life of the potassium(40) isotope is 1280 million years. Therefore, the first two methods are used to determine the age of old rocks, and the potassium-argon method is used to determine the age of relatively younger samples. Today, radiological methods are one of the most reliable ways to determine the age of ancient specimens.

Experiments show the possibility that the change in temperature of a body that heats up or cools down under the influence of a constant heat flow also occurs with time according to an exponential or logarithmic law. It is possible to explain the fact that the surface of the earth does not suddenly get hot in the morning or cool down at night under the influence of the Sun's rays.

Many other natural phenomena have been observed to follow an exponential or logarithmic law. For example, it is known that the entropy of the system and the thermodynamic probability are related by a logarithmic relationship, or that a hot body cools in air with a logarithmic law.

The above-mentioned mathematical expressions or equations of the laws of physics can be considered solutions to some differential equations representing the dynamics of a certain system. There are infinitely many solutions of differential equations representing certain unbalanced, nonlinear systems, and it will not be possible to accurately predict the next state of the system. For example, as a result of small changes in the Earth's atmosphere, the equations representing the state of the atmosphere have many solutions, and therefore the possibilities of predicting climate changes in advance are limited.

CONCLUSION

Thus, many phenomena and processes in nature are expressed and explained using relatively simpler functional connections between the physical quantities characterizing them. As an example, many of the laws of physics studied in the sections of mechanics, molecular physics and thermodynamics, vibration and waves, electromagnetism, optics, and nuclear physics of the general physics course were mathematically interpreted. Physical laws expressed in terms of linear, quadratic, logarithmic, exponential, sine, or cosine functional relationships were analyzed. Such functional relationships are valid within the limits of certain physical conditions, and outside such limits, other more complex relationships and expressions are used. Paying attention to the nature of the laws of physics, their physical and mathematical interpretation, or mathematical interpretation during lectures and practical exercises will help readers and students to deeply understand the nature of these laws and to remember them.

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