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Methodology For Developing Students' Competencies In The Field Of Symmetry And Conservation Laws Based On An Analog Approach

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Abstract: This article examines the issues related to developing students' competence in symmetry and conservation laws through an analogical approach. Such an analysis, based on comparing the studied phenomena and regularities, helps reveal their essence more deeply and comprehensively.

Generalizing information through analogy makes it possible to gain deeper insight into the nature of physical phenomena and to identify similarities in certain properties.

Keywords: Analogy, gravitational and electromagnetic interactions, potential, Coulomb's law, Newton's third law, charge, Cavendish experiment.

Introduction: One of the most perfect and orderly laws of nature is the law of symmetry. These regularities are reflected in all-natural phenomena and in the theoretical formulas that describe them. The deeper we study natural phenomena, the more perfect and complex the laws of symmetry appear. The application of symmetry laws in various physical processes has been studied and continues to be explored in many fundamental scientific investigations [4].

Realizing the above-mentioned possibilities of symmetry and conservation laws in physics, effective teaching based on the unity of historicism and logic, scientific and systematic in educational processes is an urgent pedagogical issue. This requires further improvement of the methodology, methods and means of teaching this subject using modern pedagogical technologies.

In methodological terms, the laws of symmetry and conservation play a special role, with the help of which all the laws of nature arise as ways of cognition. One of the features of conservation laws is that they manifest themselves under certain conditions and in the form of restrictions or even strict prohibitions on certain processes. It is with this opportunity that, in most cases, the process of their cognition begins. Whenever a person is faced with an impossibility in any processes, it is considered that he has made a discovery, which represents the amount of new conservation [2].

Research shows that sometimes, due to the complexity of symmetry laws, cases arise where similarities (analogies) in various processes are confused with symmetry. This is because the similarity of formulas describing phenomena or physical processes cannot reflect the differences in their underlying essence.

From this point of view, let us consider the following analogous relationships between the well-known gravitational and electromagnetic interactions.

"Generalizing information based on analogy makes it possible to delve deeply into the essence of physical phenomena and to reveal similarities in certain properties. Below is a depiction of the functional relationship between studying the kinematics and dynamics of rotational motion in physics and studying translational motion in an analogous manner".

Table 1

Translational motion	Rotational motion

displacement Δs	rotational angle $\Delta\varphi$
acceleration *a*	angular acceleration ε
velocity ϑ	angular velocity ω
$\vartheta = \vartheta_0 + at$	$\omega = \omega_0 + \varepsilon t$
$a = \vartheta - \vartheta_0/t$	$\varepsilon = \omega - \omega_0/t$
$S = \vartheta_0 t + at^2/2$	$\varphi = \omega_0 t + \varepsilon t^2/2$
$2as = \vartheta^2 - {\vartheta_0}^2$	$2\varepsilon\varphi = \omega^2 - {\omega_0}^2$
mass *m*	moment of inertia *I*
force *F*	moment of force *M*
momentum $p = m\vartheta$	angular momentum $L = I\omega$
the fundamental equation of dynamics $F = \Delta p/\Delta t$	the basic equation of dynamics $M = \Delta L/\Delta t$
mechanical work $A = F\Delta s$	work done $A = M\Delta\,\varphi$
kinetic energy $E = m\vartheta^2/2$	kinetic energy $E = I\omega^2/2$

The study of Coulomb's law can be presented in a manner similar to the universal law of gravitation. The torsion balance used in Coulomb's experimental setup is essentially the same as that in Cavendish's experiment. The phenomena themselves, as well as the laws and physical quantities that describe them, are also symmetric.

Table 2

Gravitational interaction	**Electromagnetic interaction**
obeys Newton's third law	obeys Newton's third law
$G = 6{,}67 \cdot 10^{-11}\, N \cdot m^2/kg^2$ determined by the Cavendish experiment	$k = 9 \cdot 10^9\, N \cdot m^2/C^2$ determined by the Coulomb experiment
$F_{1,2} = F_{2,1}$	$F_{1,2} = F_{2,1}$
central forces	central forces
$F = G\dfrac{m_1 \cdot m_2}{r^2}$	$F = k\dfrac{q_1 \cdot q_2}{r^2}$
the intensity of the Earth's gravitational field $E = \dfrac{F}{m}$ $E = G\dfrac{M}{r^2}$	the intensity of the electrostatic field of a charge $E = \dfrac{F}{q}$, $E = k\dfrac{q}{r^2}$

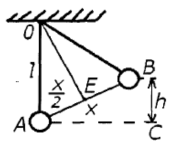
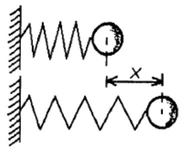
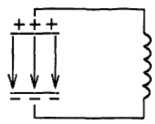
gravitational potential $\varphi = G\frac{M}{R}$	electrostatic potential of a charge $\varphi = k\frac{q}{R}$
potential energy of gravitational interaction $W = G\frac{m_1 \cdot m_2}{R}$	potential energy of electric interaction $W = k\frac{q_1 \cdot q_2}{R}$

Based on the symmetry of electrostatic and gravitational fields, these formulas for field intensity and potential can be provided in ready-made form through analogy, or they can be derived using the same principles when considering the electrostatic field. When considering the problem of electric field strength, we focus students' attention on the symmetry of the field lines for a point charge and a charged plane. Based on this symmetry, it is easier, for example, to explain why the field inside a conducting sphere is always zero.

Based on the law of conservation of energy, it is possible to derive formulas expressing the oscillation period of a spring pendulum, a mathematical pendulum, and an oscillatory circuit.

This material can also be presented in the form of Table 3.

Table 3

Mathematical pendulum	**Spring pendulum**	**Oscillatory circuit**
		
$W_p{}' = const$	W_p	W_p
$W_p{}' = const' = 0$	$W_p{}' = const' = 0$	$W_p{}' = const' = 0$
$(\frac{m\vartheta^2}{2} + \frac{mgx^2}{2l})'$=0	$(\frac{m\vartheta^2}{2} + \frac{kx^2}{2})^2$=0	$(\frac{LI^2}{2} + \frac{q^{2\prime}}{2C}) = 0$
$(\frac{2\vartheta\vartheta' m}{2} + \frac{2xx' mg}{2l})$=0	$(\frac{2\vartheta\vartheta' m}{2} + \frac{2xx' k}{2})$=0	$(\frac{2II' L}{2} + \frac{2qq'}{2C})$=0
$m\vartheta\vartheta' = -mg\frac{xx'}{l}$	$m\vartheta\vartheta'$ =- $k\,xx'$	$LII' = -\frac{qq'}{C}$
$x' = \vartheta$	$x' = \vartheta$	$q' = I$
$m\vartheta' = -mg\frac{x}{l}$	$m\vartheta'$ =- $k\,x$	$LI' = -\frac{q}{C}$
$\vartheta' = -g\frac{x}{l}$	$\vartheta' = -\frac{k\,x}{m}$	$q'' = -\frac{q}{LC}$

$x'' = \vartheta'$	$x'' = \vartheta'$	$q'' = I'$
$x'' = -g\frac{x}{l}$	$x'' = -\frac{k\,x}{m}$	$q'' = -\frac{q}{LC}$
$\omega^2 = \frac{g}{l}$	$\omega^2 = \frac{k}{m}$	$\omega^2 = \frac{1}{LC}$
$x'' = -\omega^2 x$	$x'' = -\omega^2 x$	$q'' = -\omega^2 q$
$T = 2\pi\sqrt{\frac{l}{g}}$	$T = 2\pi\sqrt{\frac{m}{k}}$	$T = 2\pi\sqrt{LC}$

Here, it is appropriate to focus students' attention on the fact that oscillations of different nature are expressed by equations of the same type, and the symmetry of the processes under analysis is manifested in this case [4].

The method of electroacoustic and electromechanical analogies is widely used in calculating electromechanical and electroacoustic transducers, because it allows students to understand the laws of electrical circuits and to mathematically model complex physical processes.

Such analogies are especially useful for determining the characteristics of complex mechanical systems with several degrees of freedom. Analyzing them by solving differential equations requires a great deal of effort.

Our pedagogical research shows that students' competencies regarding conservation laws, in particular the law of conservation of momentum, are insufficiently developed. They only have the understanding that the law of conservation of momentum is relevant for explaining certain mechanical realities of mechanics or the mechanical picture of the universe. An integrative approach, however, allows us to see that the law of conservation of momentum has a certain role not only in explaining the mechanical picture of the universe but also in understanding molecular and quantum phenomena [8].

Using the principles of symmetry, isn't it possible to create a unified theory according to which all particles originate from particles belonging to the same species, and all types of interactions originate from fundamental interactions between particles belonging to the same species? Since, in our opinion, it is extremely difficult to solve this problem, first of all, when theoretically solving most problems of physics, it will be necessary to imagine the concept of a material point that has no properties and dimensions, with the properties of the smallest particle (for example, a Planck particle) that actually exists in nature. Because, according to Planck, "the measuring quantities used in modern physics were developed to meet the needs of the earth's culture" [5]. Considering that such mutual equality of the values of fundamental forces, that is, symmetry, which exist in practice, are not accidental, the Planck particle claims that it is the smallest particle of the whole being.

CONCLUSION

In conclusion, these analogies play an important role in developing physical thinking, searching for new theoretical approaches, and in the scientific education process. However, one should not confuse similarity with symmetry, since the ontological nature and theoretical foundations of the two interactions are different. Therefore, a comparative study of gravitational and electromagnetic processes serves to gain a deeper understanding of physical phenomena and to illuminate their general laws.

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