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МЕТОДИКА ПРЕПОДАВАНИЯ ФИЗИКИ
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Scientific bases of elementary physics courseon the example of the part «Conservation laws in mechanics»

The article is devoted to the conservation laws in mechanics. In this paper, an overview of the 3 fundamental physical laws, which are important in physics is quite huge. Conservation laws hold of all the laws of nature a special position. It should be noted, however, that they are the basis for the most important calculations in physics and its technical applications, in some cases, allow to predict the effects and phenomena in the study of a variety of physical and chemical systems and processes. The conservation laws allow a relatively simple way, without considering the forces acting on the body and without motion tracking system of bodies, to solve a number of practical problems.

Keywords: impulse, energy, angular momentum, homogeneous, isotropic, closed system, the increased complexity of the problem.

The conservation laws — the fundamental physical laws, according to which, under certain conditions, some measurable physical quantities characterizing a closed physical system does not change over time. The philosophical background to the discovery of these laws were laid more ancient philosophy, and Descartes and M.V. Lomonosov.

Some of the conservation laws are carried out always and under all conditions (for example, the laws of conservation of energy, momentum, angular momentum, mass, electric charge), or, at least, have never been observed processes, contrary to these laws.

The value of conservation laws in mechanics and physics huge. In addition, and most importantly, open to the mechanics of the laws of conservation of momentum and energy in physics play a huge role, far beyond the scope of most mechanics. Even in those cases, when the laws of Newtonian mechanics can not be used (for example, the motion of electrons in the atom), the laws of conservation of mechanical variables do not lose their value. They apply both to the bodies of normal size, and to the cosmic bodies and elementary particles.

It is the universality of the conservation laws and their applicability to all the phenomena of nature, and not only to the mechanical make these laws is very important.

Conservation laws hold among all the laws of nature, a special place. The generality and universality of the conservation laws determine their great scientific, methodological and philosophical significance [1].

The discovery and synthesis of conservation laws occurred with the development of the whole of physics.

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

– the law of conservation of momentum;

– thelaw of energy conservation;

– the law of conservation of angular momentum;

The laws of conservation of energy, momentum and angular momentum are, as it turned out, very deep origin, associated with the fundamental properties of space and time — homogeneous and isotropic. Namely, the law of conservation of energy is related to the homogeneity of time, and the laws of conservation of momentum and angular momentum — according to homogeneous and isotropic space. The foregoing should be understood in the sense that these conservation laws can be derived from Newton's second law, when he was joined by the corresponding symmetry properties of space and time.

Opening the possibility of a different approach to the various mechanical phenomena, laws of conservation have become very powerful and effective tool for the study, which routinely use physics. This essential role of conservation laws as a research tool due to a number of reasons.

1. The conservation laws do not depend on the particle trajectories, nor the nature of the active forces. Therefore, they provide a number of very common and important conclusions about the properties of various mechanical processes, without going into a detailed examination of their using the equations of motion. If, for example, it turns out that such a process is contrary to the laws of conservation, we can just assert that this process is impossible and pointless to try to implement it.

2. The fact that the conservation laws do not depend on the nature of the forces makes them even when the forces are unknown. In these cases, the conservation laws are unique and irreplaceable research tool. Thus, for example, is the case in elementary particle physics.

3. Even in those cases where the force is exactly known conservation laws can be of great help in solving many problems of the motion of particles. While all of these problems can be solved with the help of the equations of motion (in this respect, from the conservation laws we do not get any additional information), attracting conservation laws often provides a solution to the most simple and elegant way, saving us from the cumbersome and tedious calculations. Therefore, when new challenges are usually accepted to adhere to the following order: first of all, one by one, apply the relevant laws of conservation, and just making sure that this is not enough, then transferred to a solution with the help of the equations of motion.

Consider the law of conservation of momentum.

Momentum has an interesting and important property, which is only a few physical quantities. This preservation of the property.

What is it?

The property is maintained - this property is to remain unchanged. It is such a pulse property of bodies. It refers to the case where two or more bodies interact with each other, but they are not acted upon by external forces. Such a group of bodies, or, as they say, *body system, called closed: closed system of bodies — a collection of bodies interacting with each other, but do not interact with other bodies* [2].

We explain the concept of a closed system and the preservation of the property of the momentum simple experiments.

We put on two horizontal rails carts of equal mass m. To one end of which is fixed a ball of plasticine and each of them are fixed to the ends of the spring buffer (Fig. 1). Suppose first the trolley facing each other ends, devoid of springs.

We inform both carts same modulo speed toward one another.

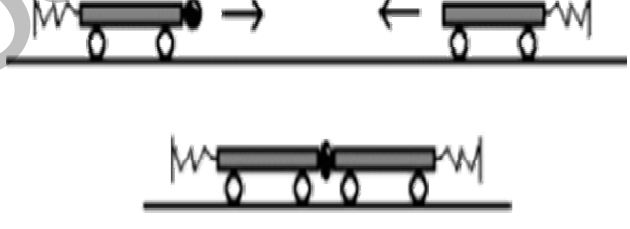


Figure 1. The collision carts without springs

Carts meet, plasticine hold them together, and they will stop. The test results are easy to understand. Two colliding carts — a system of two interacting bodies. It can be considered a closed system, because the action of the other bodies — the Earth and supports compensated. Before meeting the pulses of both carts on the module are equal to each other and in the direction opposite. Therefore, the sum of the pulses of both carts is equal to zero. During the collision carts interact, that is act on each other with some forces, equal in modulus and opposite in direction (Newton's third law) [3]. Therefore, the momentum of each of the carts changed. But the amount of pulses has remained the same, i.e., zero — because the carts stopped. We rotate the carts so that they face each other spring buffers (Fig. 2).

By repeating the experience, we see that after the collision carts disperse in opposite directions with equal in magnitude but opposite in direction velocity. It means, the interaction of the pulses changed again, but the sum of the pulse is still zero, as they say, it has been preserved.

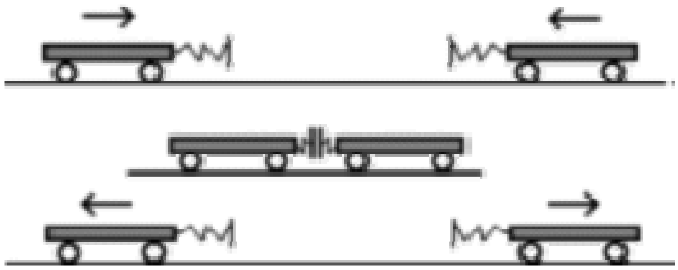


Figure 2. The collision carts with spring buffers

The masses and the velocities of the bodies may be different. We should not think that the total momentum of a system of bodies is saved only when it is zero.

Let the mass of carts are not the same: the mass of carts is left m_1, right — m_2. Let the velocity reported carts, are different — $\vec{\upsilon}_1$ at the left and $\vec{\upsilon}_2$ right carts. It means, the momentum before the collision left carts was $m_1\vec{\upsilon}_1$, right — $m_2\vec{\upsilon}_2$. In a collision the cart on the left acted some force $\vec{F}$, to the right — it is equal in magnitude but opposite in the direction of the force, that is $-\vec{F}$. Time t action of the force $\vec{F}$ is the same as the effect of force $-\vec{F}$. As a result of the forces of both velocities, carts changed. Let the speed of the left carts became equal $\vec{\upsilon}_1'$, right - $\vec{\upsilon}_2'$. Changed course and carts pulses.

Let us write the equation for each carts.

To the left carts:

$$\vec{F}t = m_1\vec{\upsilon}_1' - m_1\vec{\upsilon}_1;$$

to the right:

$$-\vec{F}t = m_2\vec{\upsilon}_2' - m_2\vec{\upsilon}_2.$$

Add up these equalities term by term

$$0 = m_1\vec{\upsilon}_1' - m_1\vec{\upsilon}_1 + m_2\vec{\upsilon}_2' - m_2\vec{\upsilon}_2, \text{ or } m_1\vec{\upsilon}_1 + m_2\vec{\upsilon}_2 = m_1\vec{\upsilon}_1' + m_2\vec{\upsilon}_2'.$$

In the left-hand side is the sum of the momentum of both carts before the collision, the right - the sum of the momentum of the same carts after the interaction. The momentum of each carts has changed, the sum remained unchanged.

If the two do not interact, as in our examples, but many bodies, it is possible by applying to each of them a formula $\vec{F}t = m\vec{\upsilon} - m\vec{\upsilon}_0$, to prove that in these cases the sum of the momenta of the closed system of interacting bodies is unchanged (conserved). This is the law of conservation of momentum.

Geometric sum bodies momenta constituting a closed system remains constant in all the movements and interactions of the system bodies.

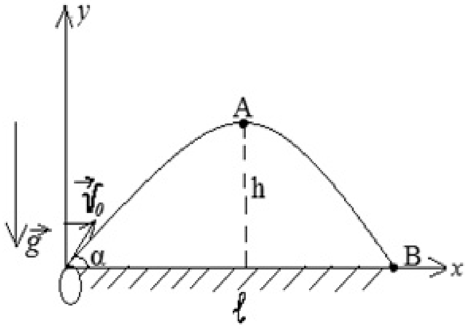
Consider the problem of high complexity, using the law of conservation of momentum.

Gunners shoot so that the kernel got into the enemy camp. At the time of departure the core from a cannon at him sits Baron Munchausen, and therefore the core falls short of the target. What part of the way Myunhauzen have to walk to get to the enemy camp? Accept that the Baron has a mass 5 times greater than the core. Planting Baron considered inelastic collision [4].

Given:
B.Myunhgauzen
$m_Б = 5m_Я$

η-?

Solution:



$$\upsilon_{0,x} = \upsilon_0 \cos\alpha \quad \upsilon_x = const = \upsilon_0 \cos\alpha$$

$$\upsilon_{0,y} = \upsilon_0 \sin\alpha$$

$$\upsilon_y(A) = 0 = \upsilon_0 \sin\alpha - gt_{OA}\,; \quad t_{OA} = \frac{\upsilon_0 \sin\alpha}{g}$$

$$t_{OAB} = \frac{2\upsilon_0 \sin\alpha}{g}\,;$$

$$l = \upsilon_0 \cos\alpha \cdot \frac{2\upsilon_0 \sin\alpha}{g} = \frac{\upsilon_0^2 \sin 2\alpha}{g}$$

$$m_я \vec{\upsilon}_0 = 6m_я \vec{\upsilon}_0'\,;$$

$$\vec{\upsilon}_0 \parallel \vec{\upsilon}_0'\,; \quad \alpha = \alpha'$$

modulo: $\upsilon_0' = \frac{\upsilon_0}{6}$;

$$l' = \frac{1}{36}\frac{\upsilon_0^2 \sin 2\alpha}{g}\,;$$

$$\Delta l = \frac{35}{36} l\,;$$

$$\eta = \frac{35}{36}$$

Let us turn to the law of conservation of energy.

If the body system can do the work, then we say that it has energy. Energy characterizes the ability of the body (or system of bodies) do work.

Making mechanical work, the body or system of bodies moving from one state to another, where their energy is minimal.

Energy in mechanics — the value determined by the state of the system — the position of body or body parts and their velocities [5].

The kinetic energy — the energy, which has a moving body.

The kinetic energy of a material point — a value equal to half the product of the mass of the square of its velocity:

$$E_k = \frac{m\upsilon^2}{2}.$$

Potential energy — the energy of interaction of bodies, due to their relative positioning of body parts.

An amount equal to half the product of *k* body elasticity coefficient of elongation or compression of *x* squared, called the potential energy of the elastic deformation of the body:

$$E_П = \frac{kx^2}{2}.$$

The law of conservation of mechanical energy:

In an isolated system, where there are conservative forces, the mechanical energy is conserved.

The law of conservation of mechanical energy linked to the homogeneity of time, i.e., invariance of physical laws on the selection of the starting time. For example, when the free fall of the body in the gravitational field of its speed and distance traveled depend only on the initial velocity and duration of the free fall of the body and does not depend on when the body began to fall.

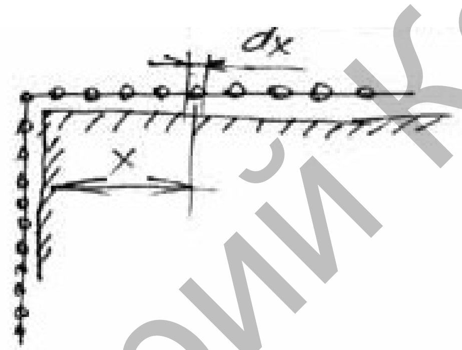
In order to introduce the concept of mechanical energy on the basis of Newton's law II, the concept of work. We proceed to solve highly complex challenges.

A chain of mass m = 0.80 kg and length *l* = 1.5 m rests on a rough-surfaced table so that one of its ends hangs over the edge. The chain starts sliding off the table all by itself provided the overhanging part equals η = 1/3 of the chain length. What will be the total work performed by the friction forces acting on the chain by the moment it slides completely off the table? [6].

Given:
Chain
m=0,8 kg
l=1,5 м
$\eta = \frac{1}{3}$

$A_{TP} - ?$

Solution:



$$F_{mp} = k \cdot (1-\eta)mg = \eta mg$$

$k = \frac{\eta}{1-\eta}$ — friction coefficient

$$\delta A = \frac{\eta}{1-\eta}\frac{m}{\ell}xgdx$$

$$A = \frac{\eta}{1-\eta}\frac{mg}{\ell}\frac{x^2}{2}\bigg|_{(1-\eta)\ell}^{0} = -\frac{\eta}{(1-\eta)}\frac{mg}{2\ell}(1-\eta)^2 \cdot \ell^2$$

$$A = -(1-\eta)\eta\frac{mg\ell}{2}$$

If the body is rotating, it introduced its momentum.

The moment of momentum of the system can be changed only under the action of the total moment of the external forces. Hence it follows directly follows another important conclusion — the law of conservation of angular momentum:

The angular momentum of a closed system of particles remains constant, that is it does not change with time, and this is true for the angular momentum taken with respect to any point of the inertial reference system.

Thus, in the inertial reference system the angular momentum of a closed system of particles

$$\vec{L} = \sum \vec{L}_i(r) = const.$$

Demonstrate the law of conservation of angular momentum can be with the help of Zhukovsky bench. Let the man sitting on the bench, which is without friction rotates around a vertical axis, and holding in his outstretched hands dumbbells (Fig. 6) is shown in rotation with angular velocity of the ω_1. If the person will squeeze the dumbbells to her, the moment of inertia of the system is reduced. Since the moment of the external forces is zero, the moment of momentum of the system conserved, and the angular velocity ω_2 increases. Similarly, a gymnast during a jump is running out to the torso arms and legs to reduce its moment of inertia and thereby increase the angular velocity of rotation.

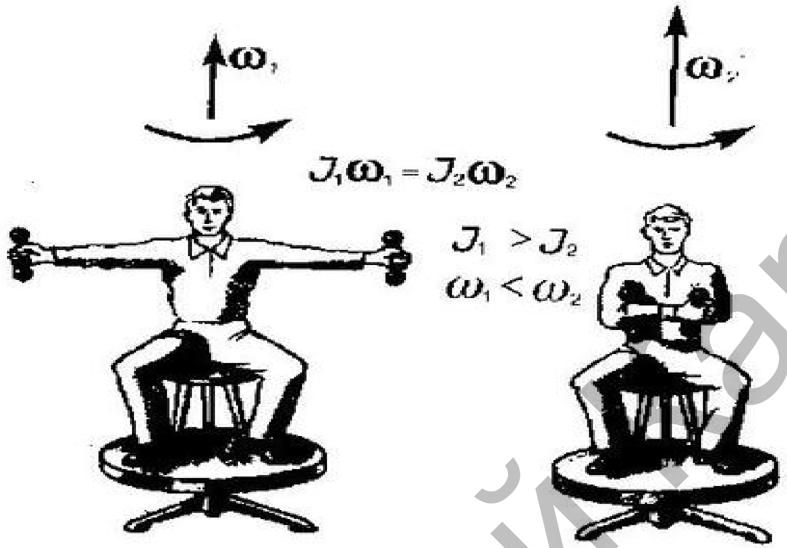


Figure 3. Demonstration of the law of conservation of angular momentum with the help of Zhukovsky bench

The law of conservation of angular momentum plays such an important role, as the laws of conservation of energy and momentum. Already in itself it does not allow in many cases a number of significant conclusions about the properties of various processes, it is not going into their detailed consideration.

Of particular interest are the cases where the angular momentum $\vec{L}$ conserved for open systems in which, as is known, the momentum $\vec{p}$ varies with time.

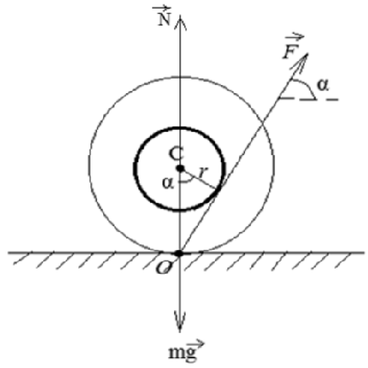
The reasoning that leads to the law of conservation of angular momentum is entirely based on the validity of Newton's laws. And as is the case in systems that do not obey these laws, such as electromagnetic radiation systems, atoms, nuclei, and others?

Given the huge role played by the law of conservation of angular momentum, in physics the concept of angular momentum to extend the non-mechanical systems (which are not subject to the laws of Newton) and postulated the law of conservation of angular momentum for all physical processes.

Such an expanded the law of conservation of angular momentum is no longer a consequence of Newton's laws, and is an independent general principle, which is a generalization of experimental facts. Along with the laws of conservation of energy and momentum conservation law of angular momentum it is one of the fundamental laws of nature. Consider the problem of increased complexity in the law of conservation of angular momentum.

The horizontal plane is the thread coil. Coil pull a thread. At what angle α between the force and the horizontal coil will accelerate in the direction of the thread taut? [7].

Given:	Solution:
Coil of threads R r	
α-?	



The condition of equilibrium (equation of moments): with respect to the point O; moment of force $F_{тяж} = 0$, force action line $\vec{F}$ should pass through this point;

$\cos\alpha = \frac{r}{R}$; $\cos\alpha > \frac{r}{R}$

$\alpha < \alpha_0$ — must be

Thus, the present article is devoted to the three integrals of motion, i.e., such physical characteristics that persist over time in closed or isolated system of bodies. The common property of integrals of motion is the addition. This means that the characteristic of a system of bodies is equal to the sum of the relevant characteristics of a system of bodies. This fundamental laws that are associated with the properties of space and time: the homogeneity of space, time, homogeneity, isotropy of space. Using the solution of problems of conservation laws facilitates this solution in comparison with the use of Newton's Law II. And in those cases where the closed system, the use of Newton's law II excluded. Moreover, there are areas of mechanics, for example, fluid mechanics and gas, in which «work» is the conservation laws, but in an unconventional way. So the equation of continuity — it is the law of conservation of mass; Bernoulli equation and the formula Torricelli — the law of conservation of energy.

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Т.С. Ковель, Л.Ф. Ильина

«Механикадағы сақталу заңдары» бөлімі мысалындағы элементарлы физика курсының ғылыми негіздері

Мақала механиканың сақталу заңына арналған. Авторлар физикада маңызы зор қосымшаларда үш фундаменталды заңдарды қарастырған. Яғни, олар физикадағы және техникалық маңызды негізгі есептеулер болып табылады және кей жағдайларда әр түрлі физика-химиялық жүйелер мен үрдістерді зерттеу кезінде әсер мен құбылыстарды алдын ала болжауға мүмкіндік туады. Сақталу заңдары салыстырмалы оңай түрде, денеге әсер ететін күштер мен жүйедегі дененің қадағалауын есепке алмай бірнеше практикалық маңызды есептерді шығаруға болады.

Кілт сөздер: импульс, энергия, импульс моменті, біртектілік, изотроптылық, жабық жүйе, жоғары деңгейлі есептер.

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Научные основы элементарного курса физики на примере раздела «Законы сохранения в механике»

Статья посвящена законам сохранения в механике. В работе приведен обзор трех фундаментальных физических законов, значение которых в физике является достаточно огромным. Законы сохранения занимают среди всех законов природы особое положение. Следует отметить и то, что они являются основой важнейших расчетов в физике и ее технических приложениях, позволяют в ряде случаев предсказывать эффекты и явления при исследовании разнообразных физико-химических систем и процессов. Законы сохранения позволяют сравнительно простым путём, без рассмотрения действующих на тела сил и без прослеживания движения тел системы, решать ряд практически важных задач.

Ключевые слова: импульс, энергия, момент импульса, однородность, изотропность, закрытая система, задачи повышенной сложности.

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