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#### SOLUTIONS OF THE PROBLEMS OF THE MECHANICAL DEPARTMENT OF PHYSICS BY MATHEMATICAL METHOD

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**Abstract.** Mathematics and physics are related sciences. Most of the problems of physics are solved by mathematical formula and calculation books. To develop the field of physics, increasing the mathematical potential of future physics teachers is considered an important issue of every era. This article is dedicated to the types of problems related to the Department of Mechanics expressed in a mathematical way and their solutions, using formulas of derivative, integral, and trigonometry subjects of mathematics. The article presents 6 physical problems and their mathematical solutions. Through the information provided in these problems, it will be possible to solve other problems related to the mechanics department of physics.

**Key words.** physics, mechanics, dynamics, statics, mathematical knowledge, pedagogy, teaching problems.

#### РЕШЕНИЕ ЗАДАЧ МЕХАНИЧЕСКОГО КАФЕДРА ФИЗИКИ МАТЕМАТИЧЕСКИМ МЕТОДОМ

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**Аннотация.** Математика и физика – смежные науки. Большинство задач физики решаются с помощью математических формул и книг по расчетам. Важным вопросом каждой эпохи считается развитие области физики, повышение математического потенциала будущих учителей физики. Данная статья посвящена типам задач кафедры механики, выраженным математическим способом, и их решению с использованием формул производных, интегралов и тригонометрии по предметам математики. В статье представлены 6 физических задач и их математические решения. Благодаря информации, представленной в этих задачах, можно будет решить и другие задачи, относящиеся к механическому факультету физики.

**Ключевые слова.** физика, механика, динамика, статика, математические знания, педагогика, проблемы преподавания.

#### INTRODUCTION

It is known that the physical law describing a physical phenomenon or process given in every subject of physics is expressed in mathematical form. Using these expressions in practical training, the content of the physical phenomena or processes described in the subject is strengthened and analyzed by solving issues, that is, the unknown being sought is identified, and on this basis the theoretical information is further strengthened.

For example, given the initial velocity, acceleration, and time of movement of an object, the distance traveled by it is easily found by next expression:

$$S = v_0 t + \frac{at^2}{2}$$

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In this way, it will be possible to solve the problems related to almost all branches of physics with the help of expressions describing the physical phenomena or processes presented in this section. However, there are cases when the presentation of the issue is expressed in a different interpretation. For example, the problem presented above can be expressed by the equation of motion of the body, that is, it can be in the following form:

$$x = At^2 + Bt + C$$

In this case, in order to determine the speed of the object, it is required to obtain the 1<sup>st</sup> order derivative from its equation of motion, that is, the speed of the object is determined as follows:

$$\dot{x} = 2At + B$$

The acceleration of the body is the 2<sup>nd</sup> order derivative from its equation of motion (or the 1<sup>st</sup> order derivative from its velocity expression) defined as

$$\ddot{x} = 2A.$$

Similarly, in some cases, physical problems can be expressed in a purely mathematical form. For this reason, the problems of improving the mathematical training of future physics teachers were analyzed in depth [1]. In it, the idea of identifying the complex of mathematical knowledge that serves to effectively master the General Physics course and creating educational and methodological support describing the application of this knowledge in solving physical problems was put forward. The task now is to determine the mathematical knowledge used in each department of physics and to demonstrate their application in solving problems expressed purely mathematically. In this sense, in this article, we will consider the types of mathematically expressed problems related to the Mechanics department of physics and their solutions.

It is no exaggeration to say that the laws of "motion and gravity" of bodies are studied in the Mechanics department of physics. Any transformation of matter is a complex movement. One of the simplest movements of matter is mechanical movement, and mechanical movement means a change in the position of bodies or parts of bodies relative to each other. Mechanics is mainly divided into two parts: kinematics and dynamics. Kinematics studies the movement without taking into account the causes that cause it, that is, it determines the position of the moving body and objects at any time. Dynamics studies the cause of the movement of bodies, that is, the laws of the body's response to external influences. Therefore, the dynamic branch of physics studies the reason why bodies are at rest or in motion as a result of external influences. [2].

In teaching physics, the theoretical information given to students during the lecture sessions is further strengthened in practical classes. For this reason, the importance of work aimed at the full coverage of theoretical knowledge in Physics in practical training and the improvement of the content of practical training is clearly visible [3-6].

### RESULTS AND DISCUSSIONS

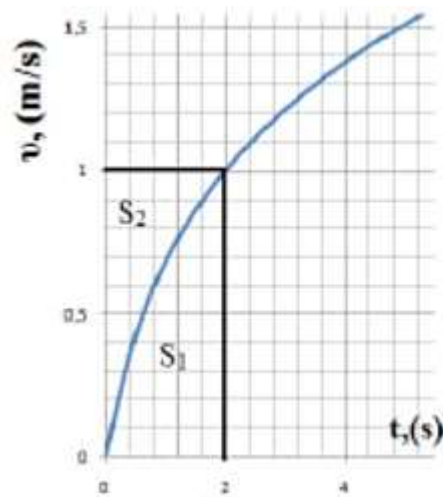
It is known that many branches of mathematics are used to solve problems related to mechanics of physics. In particular, the concepts and graphs of functions, algebraic equations and systems of equations, planimetry, trigonometry, differential and integral calculus are widely used. [7-9]. Below, we will focus on the solutions of some mathematically expressed problems using formulas from some sections of mathematics.

**Example 1.** The dependence of the speed of the body on time is given as follows:  $v^3 + v = t$ . If it is known that the body's coordinate is zero at the initial time, determine the body's coordinate (m) at the instant of time  $t=2$  s.

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**Solution.** It is known that the surface  $S$  of the time axis of the function graph is equal to the path. In our case (picture), this surface is given by  $S_1$ . In this case, it is much easier to integrate a function  $t = t(v)$  than to define a function  $v = v(t)$  and perform an integral operation on it. At  $t=2$ , the function becomes the following equation:  $v^3 + v = 2$ . It is known that the solution of this equation is  $v = 1$ . The function  $v = v(t)$  is shown in the figure below. It's not hard to look at the graph and see that the sum of the areas  $S_1$  and  $S_2$  is 2.



So,  $S_1 + S_2 = 2$ . Then, determining  $S_2$  is sufficient to determine  $S_1$ . That is,

$$S_2 = \int_0^1 t(v)dv = \int_0^1 (v^3 + v)dv = \frac{1}{4} + \frac{1}{2} = \frac{3}{4};$$

Finally, we have  $S_1 = 2 - \frac{3}{4} = 1\frac{1}{4} = 1,25(m)$ .

**Example 2.** A body with a mass of 0.5 kg moves in a straight line in such a way that the relation of the path  $s$  traveled by it to the time  $t$  is given by the equation  $s = A - Bt + Ct^2 - Dt^3$ , where  $C = 5m/s^2$  and  $D = 1m/s^3$ . Determine the magnitude of the force acting on the body at the end of the first second of movement.

**Solution.** The magnitude of the force acting on the body is determined by the formula  $F = ma$ . We determine the acceleration second derivate by first principles the equation of motion of the body:

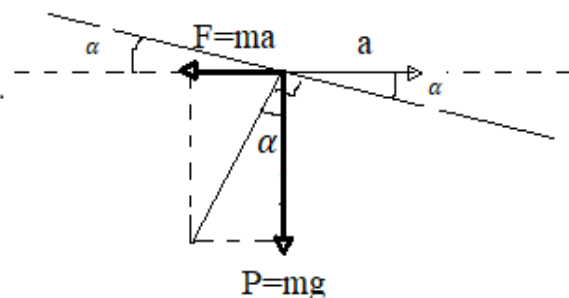
$$s'' = a = 2C - 6Dt = 2 \cdot 5 - 6 \cdot 1 \cdot 1 = 4 \frac{m}{s}$$

$$F = ma = 0,5 \cdot 4 = 2N.$$

So, the magnitude of the force acting on the body is 2 N.

**Example 3.** What is the angle  $\alpha$  with the horizon of the surface of the gasoline in the tank of a car moving with a constant acceleration of  $a = 2,44 m/s^2$ ?

**Solution.** It is known that a car moving with constant acceleration moves at an angle to the horizon. In this case, there is a right direction acceleration  $a$  and a downward acceleration  $g$ .



We determine the tangent of the angle formed by the gasoline in the car tank with the horizon:

$$\operatorname{tg} \alpha = \frac{ma}{ma} = \frac{a}{g} = \frac{9,81 \text{ m/s}^2}{2,44 \text{ m/s}^2} \approx \frac{1}{4}$$

From this it can be determined that  $\alpha \approx 14^\circ$ .

**Example 4.** In the movement of a boat with a mass of 100 kg, the resistance force of water is proportional to the speed, and the coefficient of proportionality is equal to 9 kg/s. If the speed of the boat remains at 2.2 m/s after traveling a distance of 20 m, what was its initial speed (in m/s)?

**Solution.** If the boat has a certain speed at the beginning of its motion, its speed will slow down due to the drag force acting on it. There is no information about the boat's engine, so its thrust can be assumed to be zero.

$$\text{So: } F_{\text{tortish}} - F_{\text{qarshilik}} = m \cdot a$$

$$F_{\text{tortish}} = 0; F_{\text{qarshilik}} = k \cdot v$$

$$0 - kv = m \cdot a; \quad -kv = m \cdot \frac{dv}{dt}; \quad v dt = -\frac{mdv}{k}$$

$$\int_0^t v dt = -\int_{v_0}^v \frac{mdv}{k};$$

$$S = -\frac{m}{k}(v - v_0) = \frac{m}{k}(v_0 - v)$$

$$S = \frac{m}{k}(v_0 - v)$$

$$v_0 = \frac{k \cdot S}{m} + v = \frac{9 \cdot 20}{100} + 2,2 = 4 \text{ m/s}.$$

So, the initial speed of the boat was 4 m/s.

**Example 5.** The coordinates of a material point in space change depending on time according to the

equations  $x = -2 + 2t$  [m],  $y = \frac{2t}{3} + 4$  [m],  $z = t^2 - 24$  [m]. Find its displacement modulus (m)

during the first 3 seconds.

**Solution.** We determine the displacement between the initial position of the material point at  $t=0$ , i.e. at rest, and the position it occupies as a result of its movement until  $t=3$  seconds, using the formula of the distance between two points. First, we determine the state of the material point when  $t=0$ :

$$x = -2 + 2 \cdot 0 = -2 \text{ [m]}, \quad y = \frac{2 \cdot 0}{3} + 4 = 4 \text{ [m]}, \quad z = 0^2 - 24 = -24 \text{ [m]}.$$

Now, let's determine the position of the material point after 3 seconds:  $x = -2 + 2 \cdot 3 = 4$  [m],

$$y = \frac{2 \cdot 3}{3} + 4 = 6 \text{ [m]}, \quad z = 3^2 - 24 = -15. \text{ We calculate the displacement of a material point using}$$

the formula for determining the distance between two points:

$$S = \sqrt{(4 - (-2))^2 + (6 - 4)^2 + (-15 - (-24))^2} = \sqrt{36 + 4 + 81} = 11 \text{ [m]}$$

So, the s-displacement module of the body in 3 seconds is 11 m.

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**Example 6.** The coordinate of a harmonically oscillating body changes according to  $x = 0,5 \sin 3t$  [m] law. Write the equation [ $sm / s^2$ ] of acceleration of the object.

**Solution.** It is known that the time derivative of the coordinate of the body gives the speed, and the twice derivative gives the acceleration. So, as a result of taking the derivative of the given equation of motion twice, we create the equation of the body's acceleration:

$$(x = 0,5 \sin 3t)'' = (v = 1,5 \cos 3t)' = (a = -4,5 \sin 3t)$$

As a result, the equation of the body's acceleration will have the form  $a = -4,5 \sin 3t$ .

### CONCLUSION

Thus, we looked at some types of purely mathematical problems related to the Department of Mechanics and their solutions. Of course, such issues are diverse and broad in content. For this reason, the systematic study of such problems, the creation of educational and methodological support based on them, which includes the necessary topics of mathematics, examples of the application of mathematical knowledge to solving physics problems, will undoubtedly serve as a basis for the training of future advanced physicists and physics teachers.

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