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The Role of The Analysis and Synthesis Component in Developing Research Ability in Physics Education

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ABSTRAC

The article analyzes the problems of developing students' research potential. Based on the selected component of analysis and synthesis, corresponding problem solutions and analyses are presented.

Keywords: Research skills, analysis and synthesis, ability, perfection, real situation, aspiration.

INTRODUCTION

The rapid development of science and technology today has created a number of problems in physics education while simultaneously stimulating the formation of new technologies. In the process of teaching school students, it is becoming increasingly difficult to fully cover the achievements of modern science and technology. Due to the constant growth in the volume of scientific information, it is not always possible to continuously incorporate the many new developments in physics into classroom instruction. Moreover, special attention is being paid to the use of modern research methods in teaching physics at schools, in particular, the wide application of computer modeling based on digital technologies.

This issue is especially relevant in the teaching of gifted school students in physics. By giftedness, we mean students who show a keen interest in physics and achieve high results in this field. Consequently, in the process of physics education, their performance is evaluated in comparison with that of their peers. Later, such students may gain the opportunity to study at higher education institutions in the field of physics or engineering.

Gifted school students in the field of physics are usually interested in problems related to scientific and technological progress. Therefore, the lack of sufficient information about scientific and technological achievements may limit their ability to consciously choose their future professional career path.

In psychological and pedagogical literature, concepts such as "research abilities," "research preparedness," "research activity," and "giftedness" frequently appear. However, the meaning of these terms is specific and differs from one another. As many authors note, in particular, according to S.B. Rijikov, this distinction is often related to the research objectives defined by different groups of researchers as well as the differences in the experimental data obtained. This situation also applies to commonly used terms such as "intellect," "personality," and "talent." Therefore, it is necessary to begin this study by clarifying the meaning of these concepts and defining their boundaries: curiosity, exploratory activity, research process, discovery abilities, discovery activity, scientific research, children's potential, gifted children, and other similar notions [1,2].

In the process of teaching physics, the skill of analysis and synthesis plays a key role as one of the main components in developing students' research abilities.

The ability to analyze and synthesize [3] refers to the process of breaking down a whole into its constituent parts and identifying its distinctive features, properties, and essential aspects. This process represents the main function of analysis. Synthesis, on the other hand, is the stage of combining the elements identified during analysis into a single system. Real objects, natural phenomena, scientific concepts, laws, and other ideal objects can all be subjected to the process of analysis.

When real objects are analyzed, they can be directly observed, which makes it possible to gain a complete understanding of their features, advantages, shape, or content. In the analysis of real objects, human perception and imagination are engaged. For example, suppose we need to determine the volume of a jar of a certain size. Since we can see it directly, we are able to obtain sufficient information about it during analysis. In contrast, such direct observation is not possible when analyzing ideal objects, which is why memory and imagination are activated. An example of this is the task of calculating the size of the Moon — Earth's natural satellite.

Based on the ideas presented above, problems from the mechanics section can be identified that serve to develop the ability to analyze and synthesize. Sample solutions to these problems can then be examined, and their analysis carried out [4].

Problem 1: From one station, a car and a bus set off. Their average speeds are 100 km/h and 50 km/h, respectively. Assuming that upon reaching the second station they immediately turn back, determine how many times they meet within 0.8 hours. The distance between the two stations is 10 km (Figure 1).

Solution: When solving this problem, the student draws a graph of the relationship between coordinate and time, analyzes the speeds of the car and bus, and then determines the meeting times through synthesis. For convenience, a time interval of 0.2 hours is chosen. On the x-axis, the maximum value is set as $x_0 = 10$ km.

The graph is plotted using a continuous line for the car and a dashed line for the bus. The points where the two lines intersect represent the coordinates where the vehicles meet.

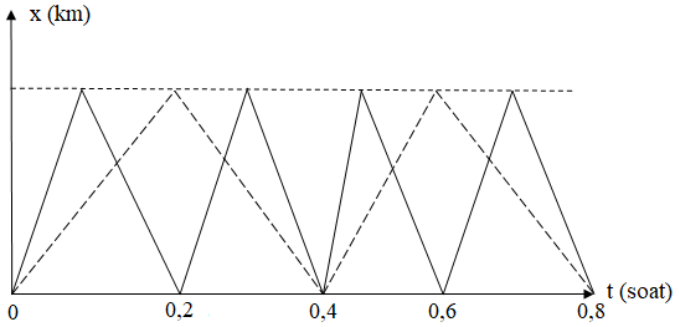

Figure 1

It can be seen that they meet **6 times**.
Answer: They meet 6 times.

Problem 2: From a homogeneous metal body in the shape of a hexagon, a circular part is cut out as shown in the figure (Figure 2). By how much has its center of gravity shifted from the original center of gravity?

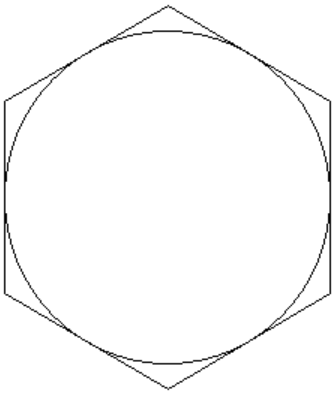

Figure 2

Solution: From the essence of the problem, it follows that the analysis of the object indicates the need to apply certain

physical laws. The student places the origin of coordinates at the center of mass of the hexagon before the cut is made (Figure 3).

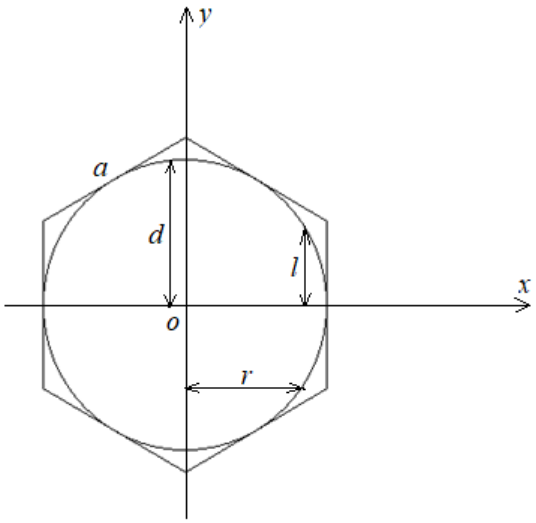

Figure 3

It can be seen that six mutually symmetric angular regions of equal mass remain. Therefore, the distance of their centers of mass from point O is determined using the formula for finding the center of mass.

$$y = \frac{m \cdot l + m \cdot d + m \cdot l + m \cdot (-l) + m \cdot (-d) + m + (-l)}{6m} = 0$$

$$x = \frac{m \cdot (-r) + m \cdot (-r) + m \cdot 0 + m \cdot 0 + m \cdot r + m \cdot r}{6m} = 0$$

Thus, it is determined that the plate's center of gravity does not shift along either the x-axis or the y-axis.

Answer: It does not shift.

Problem 3: A weightless rod of length 2.5 m is bent at its midpoint to form a 120° angle. Identical masses are attached to both ends, and the system is suspended from a thin nail driven into a wall at the bending point. Neglecting friction in the system, determine the small angular frequency of oscillations about the equilibrium position. $g = 10\,m/s^2$ (Figure 4).

Solution: In solving this problem, the student analyzes the system's deviation by a very small elementary angle and then, by depicting the initial state in a diagram, synthesizes the result to determine the required value.

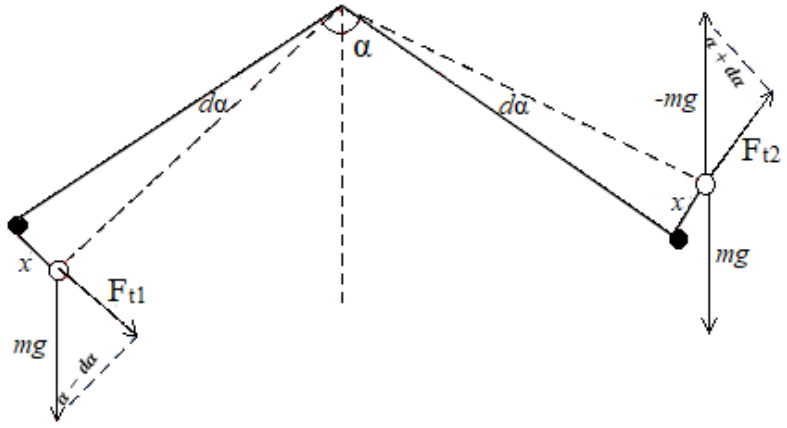

Figure 4

Thus, when the system oscillates, tangential forces arise: one mass is acted upon by a restoring force that tends to return it to the equilibrium position, while the other is acted upon by a force that tends to displace it from equilibrium (and vice versa, the process repeats).

According to the law of moments:

$$F_{t1} \cdot l + F_{t1} \cdot l = 0,$$

$$F_{t1} + F_{t1} = 0 \qquad (1)$$

From the diagram, it can be seen that:

$$\sin d\alpha = \frac{x}{l} \qquad (2)$$

By taking the projection of the weights of the bodies onto the direction of the tangential force, the equations of motion are written for both masses:

$$\begin{cases} F_{t1} + mg \sin(\alpha - da) = ma \\ F_{t2} - mg \sin(\alpha + da) = ma \end{cases}$$

The two equations are then combined to obtain the overall equation of motion for the system:

$$F_{t1} + F_{t2} + mg(\sin(\alpha - da) - \sin(\alpha + da)) = 2ma$$

They simplify the expression using trigonometric identities.

Here, so the problem does not become unclear, one should recall the difference-of-sines formula:

$$\sin\alpha - \sin\beta = 2\sin\frac{\alpha-\beta}{2}\cos\frac{\alpha+\beta}{2}$$

Based on this formula, the above expression is simplified as follows:

$$F_{t1} + F_{t2} + mg \cdot 2\sin\frac{\alpha - da - \alpha - da}{2}\cos\frac{\alpha - da + \alpha + da}{2} = 2ma \qquad (3)$$

Based on formula (1) was $F_{t_1} + F_{t2} = 0$, Relying on this, expression (3) is simplified as follows:

$$-2mg \cdot \sin da \cdot \cos a = 2ma \qquad (4)$$

By substituting expression (2) into (4), the following simplification is obtained: $-g\frac{x}{l}\cos\alpha = a$

$$a = -\frac{g\cos\alpha}{l}x$$

Then, recalling the differential equation of oscillations and, based on it $a = -\omega^2 x$, equating these expressions with each other, he derives the following formula:

$$\omega = \sqrt{\frac{g\cos\alpha}{l}} = \sqrt{\frac{10 \cdot 0{,}5}{1{,}25}} = 2\,rad/s$$

Answer: 2 rad/s.

When forming research skills in students, it is advisable to select such types of problems. In the process of choosing problems, aspects that develop research potential through analysis and synthesis were applied, and problems corresponding to this component were analyzed.

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