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ANALYSIS OF SPRING'S CONSTANTANT VALUE BY COMBINING THE CONCEPTS OF HOOKE'S LAW AND ARCHIMEDES' LAW

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Abstract. The purpose of this study was to determine the constantant value of a spring. This research was an experimental research consisting of several stages of preparation, determining independent and dependent variables, conducting experiments, analyzing and concluding. This research used a simple material that was solid beam with a length of 3.5 cm, width of 3.5 cm, height 4.5 cm and mass of 300 g, two types liquid of water and cooking oil, one spring to be calculated the value of spring constantant. The results showed that the volume of dyed objects was inversely proportional to the increase of the length of the spring and the density of the liquid type affected the magnitude of increase in the length of the spring. The constantant value of the spring in water was 21.43 N/m and the spring constantant value of cooking oil was 21,27 N/m. These results can be used as a proof of the truth of equations that combine the concepts of Hooke's law and Archimedes' Law. It can then be used as an alternative to investigating the value of spring constantant k in addition to Hooke's law experiments and simple harmonic motion.

Keywords**:** Spring's Constantant Value; Hooke's Law; Archimedes' Law

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I. INTRODUCTION

Spring is a simple and inexpensive device that can be used to show important concepts in physics. Almost all Physics laboratories include at least one or two experiments that utilize springs. Most of the experiments carried out were Hooke's law and simple harmonic motion.

Along with the development of science encourages researchers to conduct other simple spring-based experiments conducted in the Physics laboratory of Sebelas Maret University. The main idea is to use a spring to observe the buoyant force acting on the part of the submerged object.

According to Archimedes' law, an object which is partially or completely dipped in a liquid undergoes a buoyant force equal to the weight of the liquid transferred by the object [1]. Students often have difficulty imagining and understanding the principle. The difficulty in visualizing the buoyancy force can be reduced easily using the help of simple experimental designs shown in Figures 2 and 3. Consisting of a spring, a glass of liquid, a ruler and a solid beam. The first step, measure the initial length of the spring, then hang the load in the form of a solid beam to the vertical spring in the air, then observe and measure the length of the spring. The next step, fill the glass with water, then give 9 marks on the beam to dip into the water, then observe the length expantion of the spring for each situation. Experimental results data are presented in Tables 1 and 2.

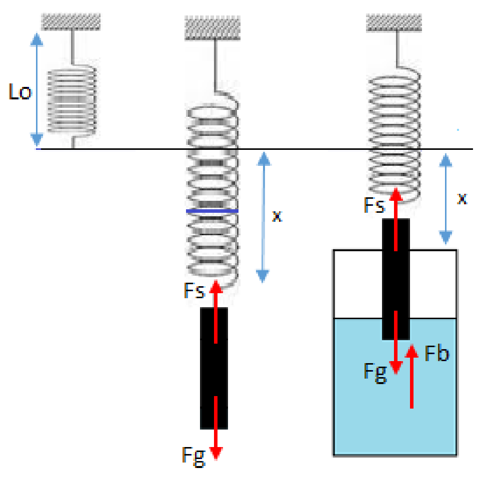

Fig 1. The combination of the concept of Hooke's law with the law of Archimedes

When the mass m is hung on a spring in the air (figure 1), the spring stretches until spring restoring force F_s is equal to the gravitational force F_g [2][3] :

$$kx = mg \tag{1}$$

where k is the spring constant, x is the increase in the length of the spring and g is the constant of gravity acceleration which is 9.8 m/s^2. The concept of Hooke's law and the law of Archimedes shown in figure 1.

When the mass m is partially or completely dipped in water, the buoyant force of F_b also acts [4]. In the equilibrium state the equation is obtained :

$$F_g = F_s + F_b \tag{2}$$

or

$$kx = mg - \rho g V_{sub} \tag{3}$$

where ρ is the density of the liquid and Vsub is the volume of the object immersed in the liquid [5].

When an object is partially submerged in water, the increase in the length of the spring x depends on the volume of the object immersed in Vsub [6].

This study uses beam-shaped objects, so:

$$V_{sub} = Ah \tag{4}$$

or

$$V_{sub} = plh \tag{5}$$

where h is the height of the part that is immersed. Taking this into account, Equation 3 can be written into

$$kx = mg - \rho gplh \tag{6}$$

$$x = \frac{mg}{k} - \frac{\rho gplh}{k} \tag{7}$$

From this equation it can be seen that the spring constant value k can be obtained by combining the concepts of Hooke's law and Archimedes' law. At present the experiment to investigate the value of the spring constant k is limited by the law of Hooke and simple harmonic motion, it is necessary to consider alternative sources of another experiment that more diverse experiments, one of which is to integrate the concept experiments Hooke's law and Archimedes' Law.

II. Methods

This research is an experimental research. The flow of this research includes preparation, determining independent variables and dependent variables, data collection, analyzing and concluding. In detail presented in the research flow diagram in Figure 2.

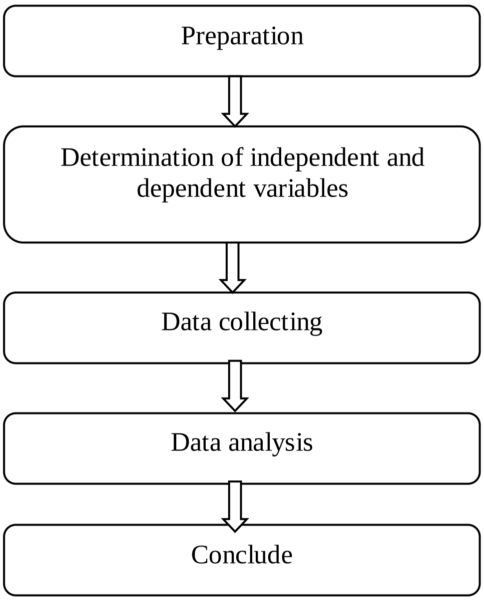

Fig 2. Research flow

The preparation phase includes the preparation of tools and materials, measuring the mass of the load and the density of the liquid which results in a load mass of 300 grams, the density of water is 1 gr / cm3, and the density of cooking oil is 0.8 gr/cm^3. Then give a line mark on the load to 9 marks. Tools and materials used in this study include springs, statives, loads in the form of solid beams, glass, liquid in the form of water and cooking oil, and ruler.

The second stage is the determination of independent and dependent variables. In this study the independent variable is the height of the object dipped in liquid. And the dependent variable is the increase in the length of the spring which is the difference between the length of the spring initially with the length of the spring when some of the objects are immersed in the liquid.

The third stage is data collecting, that is by measuring the spring length increase at each change in the height of the object immersed in liquid, in this study using 9 marks on the load, resulting in 9 data for each liquid. There are two types of liquid used, namely water and cooking oil.

The next stage is data analysis, from the experimental data then a graph h (the height of the object being immersed) against x (the length of the spring) is made, then an analysis is performed to obtain the spring's constantant value.

The final stage is to draw conclusions from data analysis. The experimental design in the study is presented in Figures 2 and 3.

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Fig 2. Experimental design for water

Fig 3. Experimental design for cooking oil

III. Result and Discussion

The purpose of this study is to determine the value of the k spring's constantant through experiments that combine the concepts of Hooke's law and Archimedes' law. Based on the data retrieval stage, the results of the spring length increase for each height of the object dipped in two liquids. The data is presented in table 1 for water and table 2 for cooking oil.

A. Analysis of k value in water

TABLE 1
DEPTH DATA FROM THE SUBMERGED OBJECTS (H) AND SPRING LENGTH INCREASE (X) FOR WATER

No	h (cm)	x (cm)
1	0,5	12,5
2	1,0	12,3
3	1,5	12,1
4	2,0	11,9
5	2,5	11,6
6	3,0	11,3
7	3,5	11,1
8	4,0	10,9
9	4,5	10,7

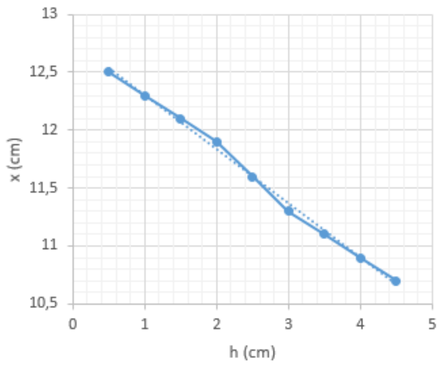

Fig 4. Graph of the correlation of the height of the immersed object (h) with the increase in the length of the spring (x) in the water

From the measurement of the length of the spring in several variations of the height of the dyed object, a graph can be made as shown in Figure 4. Based on the graph it can be seen that the height of the submerged object (h) is inversely proportional to the length of the spring (x). This means that the volume of the immersed object (Vsub) is inversely proportional to the length of the spring (x). In this study, the area of the base of the object is fixed, then the volume of the immersed object can be viewed from the height of the object being immersed. The graph is formed almost straight line, in accordance with equation 7. The spring constant k can be determined from the slope of the graph, based on the graph, the value of k in the liquid water is 21.43 N/m.

B. Analysis of k value in cooking oil

TABLE 2
DEPTH DATA FROM THE SUBMERGED OBJECTS (H) AND SPRING LENGTH INCREASE (X) FOR COOKING OIL

No	h (cm)	x (cm)
1	0,5	13,1
2	1,0	12,8
3	1,5	12,6
4	2,0	12,4
5	2,5	12,1
6	3,0	11,9
7	3,5	11,7
8	4,0	11,4
9	4,5	11,2

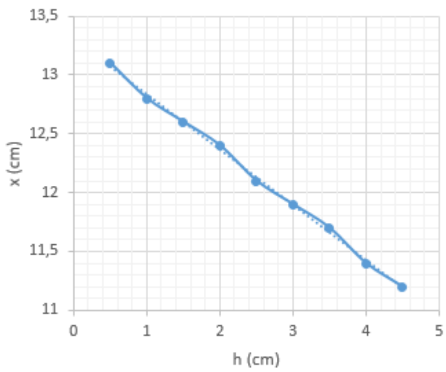

Fig 5. Graph of the correlation of the height of the immersed object (h) with the increase in the length of the spring (x) in the cooking oil

Based on the measurement of the length of the spring in several variations of the height of the object that is immersed can be graphed as shown in Figure 5. From the graph it can be seen that the height of the object dipped (h) is inversely proportional to the length of the spring (x). This means that the volume of the immersed object (Vsub) is inversely proportional to the length of the spring (x). In this study, the area of the base of the object is fixed, then the volume of the immersed object can be viewed from the height of the object being immersed. The graph is formed almost straight line, according to equation 7. The spring constant k can be determined from the slope of the graph, based on the graph, the value of k in the cooking oil liquid is 21.27 N/m.

From tables 1 and 2 it can be seen that the magnitude of the spring length increase in liquid water is smaller than the increase in spring length when the object is dipped in cooking oil. This is related to the density of the liquid, where the density of water is greater than cooking oil, the buoyant force on water is greater than the buoyant force of cooking oil. So that objects will be slightly raised when dipped in water, compared to when in cooking oil, the increase in the length of the spring will be smaller when the object is dipped in water, this is in accordance with equation 4.

The use of two types of liquid in this study was used to compare the increase in spring length with the density of the liquid, while the variation of the height of the immersed object was used to determine the relationship of the volume of the immersed object with the length of the spring according to equation 4.

The spring's constantant values produced from two types of liquids show slightly different results, this is likely to occur due to parallax errors when making measurements. But in general it can be concluded that the spring constant value used in this study is around 21 N/m. The k value is a constantant so it has a constant value.

There are many ways to investigate the value of spring's constantants, including the Hooke's law experiment and simple harmonic motion. Based on the results of this study it can be seen that through experiments by combining the concepts of Hooke's law and Archimedes' law can produce a spring's k constantant value, so this experiment can be used as an alternative to the investigation of the spring's constantant value.

IV. Conclusion

Based on the results of the study and discussion it can be concluded that the volume of the submerged object is inversely proportional to the increase in the length of the spring and the density of the liquid affects the magnitude of the increase in the length of the spring. The value of the spring's constantant in water is 21.43 N/m and the spring's constantant value in cooking oil is 21.27 N/m. These results can be used as proof of the truth of the equation that combines the concepts of Hooke's law with Archimedes's Law. Then it can be used as an alternative to probe the k value of spring's constantant in addition to Hooke's law experiment and simple harmonic motion.

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