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An experimental outcome that affects buoyancy

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Abstract –This experiment was carried out to examine the relationship between the lifting force of a fluid and the shape of an object immersed in the fluid and the force of surface tension that acts on the surfaces that are in contact with the fluid. The experiment conducted established that lifting forces on an asymmetric object changed depending on the way the object had been immersed in the fluid and that such changes were caused by surface tension.

Key words: buoyancy, force of surface tension.

Introduction

An object's buoyancy in a fluid is dependent on its weight and the lifting force of the fluid in which it is immersed. If a solid object is immersed slowly in a fluid, a lifting force equal to the weight of the replaced liquid, is applied on the object. The magnitude of this lifting force increases as the more parts of the object is immersed. This process of immersion ceases before the solid object is totatly submerged as the lifting force equals to the weight of the object (**F=G**). Even If the the object is totatly immersed, the lifting force cannot beat the weight of the body, the object will submerge more into the fluid (**F<G**). Particulaly If the lifting force of fluid equals to the weight of the object (**F=G**), the object will stay where it is left. The upthrust affecting the object is expressed in the equation $\mathbf{F}=\rho_{liquid} V_{immerse}\, \mathbf{g}$. This equation is the mathematical expression of Archimedes' Principle which says that a "body immersed in a fluid is buoyed up by a force equal in magnitude to the weight of the displaced fluid." The small variations in the results obtained in a series of experiments that were carried out in the classroom on Archimedes' Principle and on the buoyancy of objects in a fluid led

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us to pursue this topic as a detailed classroom research project. In this context, the answer to the following question was explored: “Is Archimedes’ Principle the only way to explain the lifting force that affects an object that is immersed in a fluid?”.

The Experiment

The specific subject we questioned in this experiment was: “The relationship between the lifting force of a fluid and the shape of objects immersed in that fluid and the manner in which these objects come in contact with the fluid.” The same question became the research topic question for the project carried out in the classroom. To find an answer to the research question, the upthrust of fluids in which many solid objects were left was measured. In symmetrical objects, besides what we knew from Archimedes’ Principle, we were not able to observe any effect based on shape but we were able to observe that there was a change in the lifting force in asymmetrical objects depending on the way the object had been immersed in the fluid. The experiment in which we were best able to observe this effect is described below.

The materials used in the experiment were an asymmetrical glass hemisphere with a mass of 183.9 grams and a radius of ~3 cm, string to hang up the hemisphere, and a digital scale. A glass hemisphere is an object that completely sinks in water and thus is a suitable object with which to measure any effects of the fluid that are dependent upon shape.

The experiment was carried out in two phases. In the first phase, a beaker was half-filled with water and placed on the digital scale. Then the weight of the mass appearing on the scale was zeroed out by pressing the tare button. Later, the glass hemisphere was suspended on a string with the flat side looking up, as seen in Figures 1 and 2. It was immersed in the water until the reading on the scale no longer changed. The number on the digital scale was then noted. In the second phase, the same experiment was repeated, this time with the glass hemisphere immersed with its flat side looking down, as seen in Figures 3 and 4. While the reading on the digital scale in the first case had been 73.9 grams, in the second, the reading was 73.7 grams. It should be remembered that the value shown on the digital scale is the value of the response to the uplifting force. The difference between the lifting force affecting the object in the two cases is 0.2grams (here, the value measured on the scale is in grams, g is the acceleration due to gravity). How then are we to interpret the result of this experiment?

Phase 1

Figure 1 Suspended object (flat side up)

Figure 2 Scale measurement

Phase 2

Figure 3 Suspended object (flat side down)

Figure 4 Scale measurement

The outcome of this experiment can be explained as follows: The attraction between the molecules on the surface of the water in the container that come into contact with air causes a membrane to form. The force that creates this membrane is called “surface tension.” If a razor blade, 7-8 times more dense than water, was to be slowly placed (on the surface of) the water, the blade would cause the molecules on the surface of the fluid to draw away from each other, increasing the distance between them. When this distance increases, the force between the molecules will also increase (See Figure 7). The surface of the water then acts as an elastic membrane, preventing the blade from sinking. Surface tension is not only effective on the face between the air and material but also on the all faces between the liquid and material.

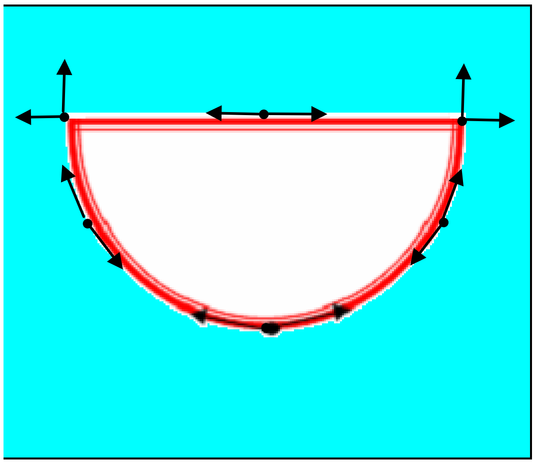

Figure 5 When the flat side of the object is facing up, the force of the surface tension is upward

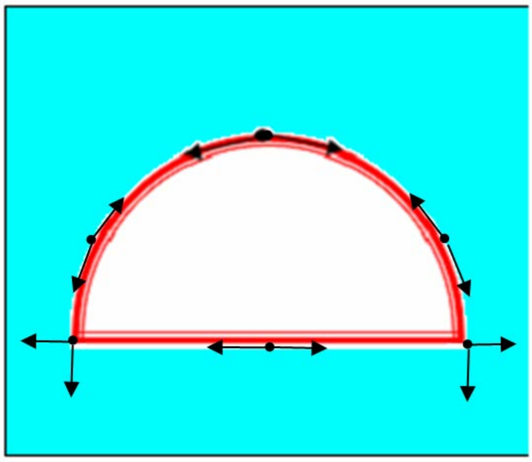

Figure 6 When the flat side of the object is facing down, the force of the surface tension is downward

A phenomenon similar to the one pictured above occurs on the surface of the water that is in contact with the air when, as in Figure 1, a non-symmetrical object is immersed. The molecules on the curved surface draw away from each other and stretch out over the surface. The forces exerted by molecules neighboring the ones on this surface increase (see Figure 7) and the total of these forces create a clear upward thrust (Figure 5) or a downward thrust (Figure 6). Thus, while the lifting force in Figure 5 increases, it decreases in Figure 6. In the experiment, the 0.1g of the 0.2g difference stems from the second situation.

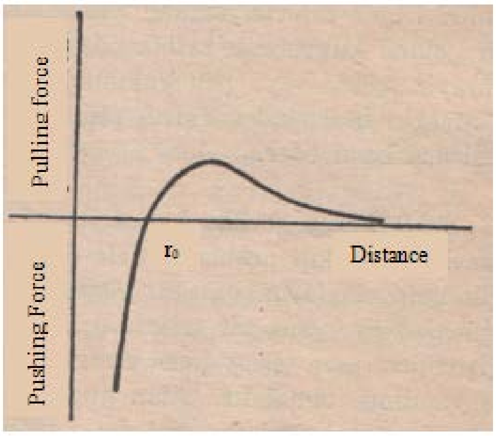

Figure 7 The force between molecules is a function of distance (Sears, 1965).

Conclusion

It was seen in this experiment that the lifting force on an asymmetrical object in a fluid changes according to the way the object has been immersed. This change, occurring under the effect of surface tension and depending on the shape of the object, is small but not of a negligible magnitude and therefore should be taken into consideration during an experimental procedure. This simple experiment has shown that the lifting force on an object immersed in a fluid (water) is dependent upon the shape of the object and that in asymmetrical objects, the way the object is immersed has an increasing or decreasing effect on the upward thrust

The experimental evidence described here has been interpreted and analyzed in the light of Archimedes' Principle and surface tension forces. Looking at a problem at hand from more than one angle has not only provided a solution to the problem but has formed a base for integrating knowledge gained in different fields.

References

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