Archimedes Remote Lab for Secondary Schools

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Abstract— **This paper presents a remote lab designed for teaching the Archimedes' principle to secondary school students, as well as an online virtual lab on the general domain of buoyancy. The Archimedes remote lab is integrated into WebLab-Deusto. Both labs are promoted for usage in frame of the Go-Lab European project.**

Keywords: Remote labs, virtual labs, Archimedes' principle, buoyancy, secondary school education

I. INTRODUCTION

In this paper we describe how the Archimedes remote lab and the Splash virtual lab support teaching buoyancy in general, and the Archimedes' principle in particular. Remote labs allow students to conduct a real lab experiment using the internet instead of being in a laboratory [1]. In general, the remote labs are used in universities [2] [3], but they are also suitable and efficient for secondary schools. Recently, more and more effort is made to promote science in schools, using the remote lab as a tool for this purpose [4]. However, for a remote lab to be an effective learning tool, students need to have a basic theoretical understanding of the domain. This theoretical understanding can be supported by using a virtual lab or simulation in conjunction with a remote lab in the same domain [5].

Section II is devoted to the Archimedes' Principle in the classroom, Section III describes Splash and Archimedes, an online virtual la and a remote lab on buoyancy, and Section IV explains the didactical use of the Archimedes Lab in the classroom. Sections V and VI give some details of the implemented remote lab.

II. ARCHIMEDES' PRINCIPLE IN THE CLASSROOM

The Archimedes' Principle states that "an object fully or partially immersed in a fluid is buoyed up by a force equal to the weight of the fluid that the object displaces"[6]. The principle is taught at the secondary school level in Europe

Buoyancy and Archimedes' principle are illustrated in the classroom by showing different situations involving objects and liquids to students. An object is placed in the water and students observe whether the object sinks or floats, and how much fluid is displaced. Such experiments are repeated with different objects to determine when and why objects float or sink. The experiment is conducted by the teacher who asks the students questions that should initiate the inquiry process.

If the objects are well selected by the teacher, the students can discuss if the behavior of the object depends on its volume, weight, shape or density. Since there are many variables to consider, the students work in a typical scientific scenario.

There is also an additional concept. The density of the fluid affects the buoyancy of the object: the same object can float or sink in different fluids, for example, oil and water. Therefore a new variable – density of fluid – impacts experiments.

The student can observe whether the object floats or sinks, and can also measure different variables with scientific instruments. The weight of the object can be measured with a dynamometer. The weight of the object should be measured both in and out of the water to initiate a discussion around the concepts mass, weight and forces.

When an object is immersed into the water (or into the fluid), the water displacement can be measured with different instruments such as a test tube, a ruler, etc. Water displacement is one of the key concepts of Archimedes' principle.

The weight and its measuring, and the water displacement should be discussed carefully respecting whether the object floats or sinks. Therefore, again, there are more variables to study in the experiment.

Typically, the whole experiment is conducted in the classroom with a container filled with water and different objects. The students are around the container to see the behavior of the object when it is immersed into the water. The teacher can measure the weight of the object and the water displacement as well. Sometimes each student or groups of two conduct the experiment by themselves. The complexity of the experience should be fixed by the didactical objectives of Archimedes' principle in a specific subject by the teacher.

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III. ARCHIMEDES' PRINCIPLE WITH AN ONLINE LAB

Archimedes' principle, and buoyancy in general, can also be taught using a remote lab and/or a virtual lab [5], [7]. In this case the students are not in a physical lab doing hands-on experiments [8], but they are in front of a computer controlling a virtual lab or a remote lab. Studies have demonstrated that the learning outcomes of online labs are similar [9-10] or even better to those obtained with real experiments as described in the previous section [11-12]. The remote labs (e.g. VISIR) emerge as one of the main instructional technologies adopted and valued in engineering education, this corresponding to "one of the major shifts in engineering education in the last 100 years" [13].

Online labs can be virtual or real (remote labs). The advantages of using online labs are clear: availability, cost, low risk, recorded data, etc., but this is not the objective of the work. From our point of view, the real, the virtual and the remote labs are not opposite, but complementary educational tools. In a virtual lab, students can create objects without restrictions and they can measure everything. The biggest disadvantage is that maybe the immersion feeling is not enough for the experiment, and the students can feel that they are not doing science, but playing a game. Adding a remote lab to this situation will provide students with a complete science experience.

A. Virtual Labs for the Archimedes' principle

The Go-Lab European project (www.go-lab-project.eu) offers a virtual lab for buoyancy, including the Archimedes' principle, called Splash. The lab can be accessed via the www.golabz.eu portal, and can immediately be used by many students at once since it does not involve physical materials [14]. Because Splash is web-based students only need a computer with an internet connection to perform experiments.

In Splash (Fig. 1) students can learn about several concepts related to buoyancy: density, floating and sinking, relative density, and Archimedes' principle. The laboratory is divided into five tabs that each covers one of the topics.

In the first tab students can discover about density. Three objects are filled with dots that represent the density of the objects. Students can adjust the mass, volume and density of these objects by means of a slider. The object visually changes when students move the sliders. For example, if they change the mass of the object, the object will not increase in size but it will be filled with more dots indicating more mass and thus a higher density.

The second tab elaborates on this. Students can adjust properties of the objects like in the first tab but can additionally see containers filled with water in which these objects are placed. Students can run experiments to find out how the density of an object influences if it sinks or floats in water.

The third tab adds to this the possibility to adjust the density of the fluid in the container, allowing students to discover about relative density.

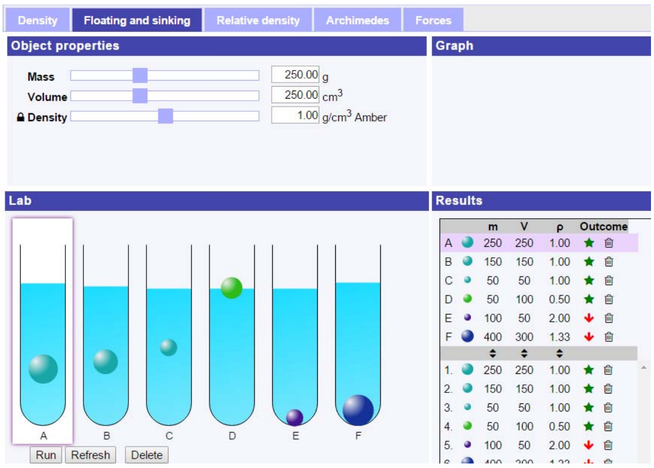


Figure 1. Splash lab of the Go-Lab project

The fourth tab introduces Archimedes' principle and adds a measuring cup that is placed on a scale. When an object is placed in the container, the container overflows (see Fig. 2). The fluid that is displaced from the container in which the object is placed flows into the measuring cup, allowing students to measure both the volume and the mass of the displaced fluid. Students can find out that a) if an object sinks, the displaced fluid has the same volume as the object's volume, and b) if an object floats, the mass of the displaced fluid is equal to the mass of the object.

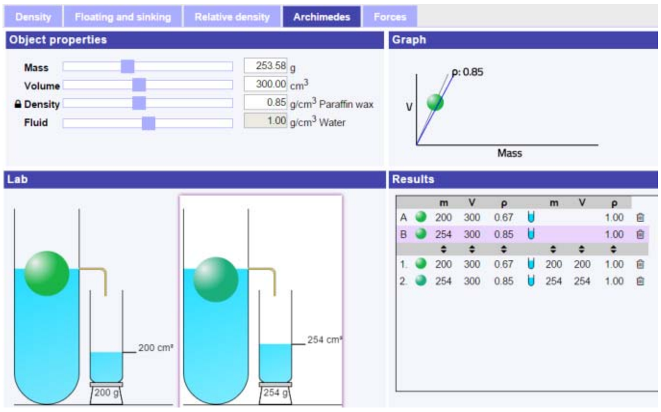


Figure 2. The tab regarding forces in the Splash lab.

In the fifth tab students hang the created object on a spring balance, so that they can observe the Normal weight of the object in the air (Wa) in Newton (N). The spring balance is then lowered in a container filled with fluid. Students can observe how the weight of the object decreases when the object submerges in the fluid. Meanwhile, they can see the container overflow and observe that the displaced fluid flows into a measuring cup that is placed on a scale. The measuring cup allows students to measure the volume of the displaced fluid, and the scale allows them to weigh the displaced fluid. At all times the forces upon the object and upon the displaced fluid (Fz, Fb) are represented as well, making it possible for students to see how these change and how these are related to each other.

Although there are many virtual labs on buoyancy, the Splash lab is relatively unique in that it offers all five buoyancy concepts in a single environment, allowing experimentation with: density, floating and sinking, relative density, Archimedes's principle and forces.

B. Remote Labs for the Archimedes' principle

A remote lab, just like a virtual online lab, can be used to teach Archimedes' principle. The Archimedes Lab is integrated into the WebLab-Deusto platform (weblab.deusto.es) as shown in Fig. 3.

Figure 3. Different remote labs in WebLab-Deusto

The Archimedes Lab has seven tubes with an object and a fluid (in our case water). Using the interface, the student can immerse an object into the water or lift it up out the water (see Fig. 4).

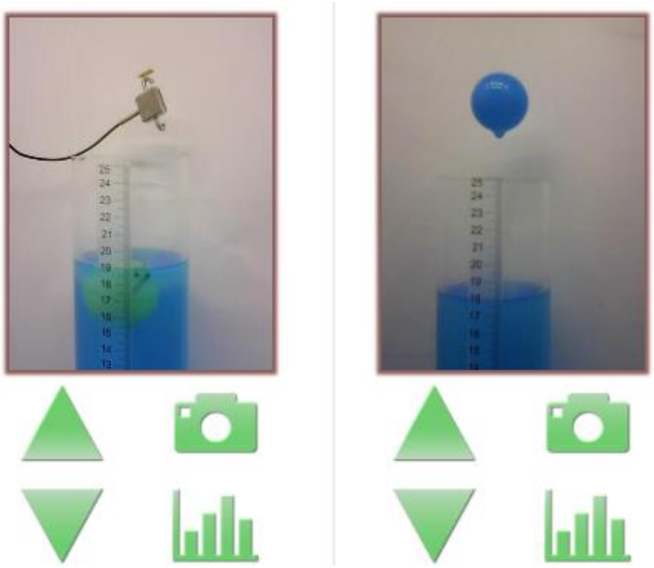
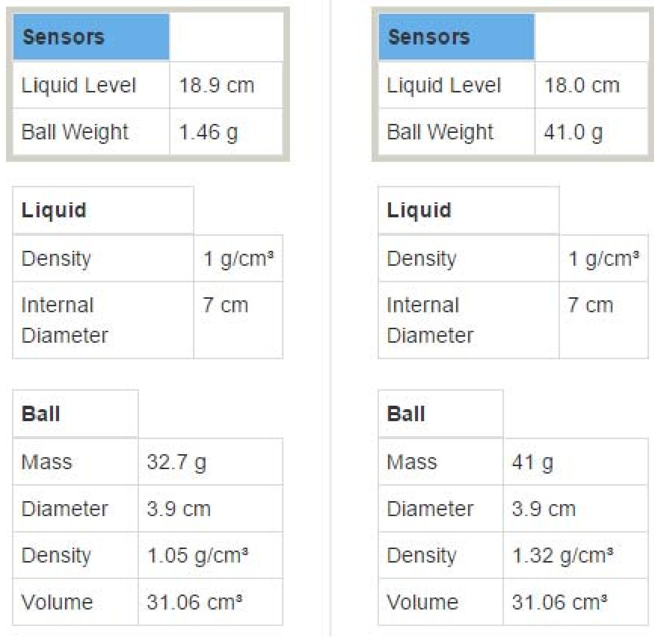


Figure 4. Interface of two tubes of the Archimedes Lab

Using a webcam, the student can see whether the object floats or sinks. Also with an HD camera, the student can take pictures of the tube (see Fig. 4), for example one with the object out of the water and another when the object is in the water.

The interface also offers the student some data obtained from the measuring instruments: the weight of the object and the water level. Additionally, the student can read some fixed data: volume of the object, mass of the object, density of the object and the dimensions of the tube (see Fig. 5).



Sensors	
Liquid Level	18.9 cm
Ball Weight	1.46 g

Liquid	
Density	1 g/cm³
Internal Diameter	7 cm

Ball	
Mass	32.7 g
Diameter	3.9 cm
Density	1.05 g/cm³
Volume	31.06 cm³

Sensors	
Liquid Level	18.0 cm
Ball Weight	41.0 g

Liquid	
Density	1 g/cm³
Internal Diameter	7 cm

Ball	
Mass	41 g
Diameter	3.9 cm
Density	1.32 g/cm³
Volume	31.06 cm³

Figure 5. Data of the experiments in the Archimedes Lab.

Fig. 6 shows the interface of the Archimedes remote lab.

Figure 6. Archimedes remote lab interface.

IV. DIDACTICAL USE OF THE ARCHIMEDES LAB

Using the interface, the teacher with the students can analyze the different elements of the Archimedes' principle: buoyancy, forces, density, relative density, mass, weight, fluid displacement, etc. The first four tubes have the same object (a table tennis ball with a diameter of 3.9 cm and 31.06 cm^3 of volume). Each ball is filled with different fluids: the first ball is filled with water, the second is filled with the solution of sugar in water, the third is empty and the fourth is filled with oil. Depending on the content, the density of each ball is different, and its behavior in the water will be different.

Using the Archimedes Lab the student can measure and can obtain the density of the object, or the volume, or etc.

Activity 1

The students drops the object, and if the object sinks (s)he can measure the water displacement, and this value will be equal to the volume of the object. After this experiment, (s)he can compare the result with the given data.

Activity 2

The student drops the object, and if the object floats (s)he can measure the water displacement, and this value will be equal to the mass of the object. After this experiment, (s)he can compare the result with the given data.

Activity 3

The students can measure the water displacement with the camera and with the ruler, using the formula of the cylinder. (S)he can also read the measurement provided by an electronic ruler. Finally (s)he can compare the two obtained values: by hand and with a computer based vision algorithm.

Activity 4

The student can analyze why sometimes the weight is negative. This reflection will help to understand the error concept. All the data obtained in an experiment must be analyzed before using them.

As the Archimedes Lab is a remote lab, the students can access it at home, and they can share the experience with their parents. By this way the parents can see at home an advanced tool for teaching science, which improves the confidence of the parents with the school.

V. Technical Description of the Archimedes Lab

For implementing a hardware-based remote lab, a server is used for getting online requests and interacting with hardware, e.g., sensors or actuators. For these purposes, BeagleBone Black - a Texas Instruments' embedded device, is used. This device can run different Linux based operating systems and contains some hardware based peripherals, e.g., an analog to digital converter, needed for performing sensor readings.

The Archimedes lab is equipped with some sensors for measuring parameters. For example, each lab contains a Futek LSB200 Load Cell capable of measuring the mass of the object. To get an output signal between 0-5V, a high precision instrumentation amplifier is needed, specifically the model INA125. This circuit's output signal is captured by the BeagleBone Black's 10bit analog-to-digital converter.

High definition camera: For measuring the liquid level, the BeagleBone Black captures an image with a camera and executes an artificial vision algorithm for detecting the liquid level. In order to facilitate image processing, the water is blue tinted for greater contrast between the liquid and the background.

The student can read two important parameters - ball weight and liquid level. In order to measure the ball weight a load cell with a high precision instrumentation amplifier is used. In order to record the liquid level a high definition camera is used. This camera is connected to the BeagleBone, which runs an algorithm that allows detecting the liquid level using "computer vision".

In order to change the position of the object, a direct current motor is used. It also is equipped with hall-effect sensor for measurement of the displacement of the objects. The students can also take images using the high definition camera attached to the BeagleBone Black.

Finally, the lab is equipped with a webcam used for video streaming. This allows to control the state of the remote lab at all times.

VI. Archimedes Lab in WebLab-Deusto

The Archimedes Lab is included in the WebLab-Deusto platform, and it is one of the more than ten available experiments. To access the experiment you can use the user/pass golab1/golab1 and run the experiment.

The WebLab-Deusto offers the teacher and the school two main advantages:

- User tracking to monitor the different experiences of the students: how many and how long they were connected, what they did during the experiment, etc.
- Connection to the web portal of the school: WebLab-Deusto allows the school to include the Archimedes lab in its LMS (Moodle, Sakai, etc.).

At this moment, the Archimedes Lab has been accessed by more than 100 students, and in total there are more than 1000 accesses (an average of 10 accesses per student) in two months. Still we are working on the collecting feedback from the user and cannot provide more detailed information of their experience.

VII. Conclusions

The Archimedes Lab is a hardware/software platform to implement a remote lab to allow the students and teachers to experiment with the Archimedes' principle in the classroom and at home (see Fig. 6).

The remote lab allows students and teachers to perform different experiments like a scientist would: test, measure and analyze the obtained results. The Archimedes Lab can be used in conjunction with the Splash virtual lab in which case the latter would be used to introduce the buoyancy domain and the main concepts.

Figure 7. A student using the Archimedes Lab in the classroom.

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