Emptying time of a swimming pool with cylindrical output duct calculated with practice by a software

Tempo de esvaziamento de uma piscina com duto de saída cilíndrico calculado com a prática por um software

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ABSTRACT
The creation of new methodologies grows along with digital media as more and more solutions to problems encountered in engineering are required. This work has as main objective to develop an application to determine the necessary time of discharge of a fluid in a pool, since this can be established through the flow rate of the liquid in a permanent flow. Besides contributing to solve a problem found in the mechanics of fluids, the application ensures a more effective teaching-learning for the user who executes it. Some considerations have served to show that emptying of the industrial reservoir depends on some variables such as water column, reservoir base diameter, and fluid outlet duct. From the results obtained, it was observed that the larger the outlet duct diameter and, the lower the water column height, the shorter is the fluid emptying time in the pool.

Keywords: Emptying, Fluid, Time.

RESUMO
A criação de novas metodologias cresce junto com os meios digitais, à medida que mais e mais soluções para problemas encontrados na engenharia são necessárias. Este trabalho tem como objetivo principal desenvolver uma aplicação para determinar o tempo necessário de descarga de um líquido em um tanque, uma vez que isto pode ser

estabelecido através da vazão do líquido em um fluxo permanente. Além de contribuir para resolver um problema encontrado na mecânica dos fluidos, a aplicação garante um ensino-aprendizagem mais eficaz para o usuário que a executa. Algumas considerações têm servido para mostrar que o esvaziamento do reservatório industrial depende de algumas variáveis tais como coluna de água, diâmetro da base do reservatório e duto de saída do fluido. A partir dos resultados obtidos, foi observado que quanto maior o diâmetro do duto de saída e, quanto menor a altura da coluna de água, menor é o tempo de esvaziamento do fluido na piscina.

Palavras-chave: Esvaziamento, Fluido, Tempo.

1 INTRODUCTION

Conservation laws govern, in fluid flows, analyzes for both macroscopic systems and microscopic systems. The algebraic equations are expressed for stationary systems and the differential equations for the transient equations. Macroscopic balances have terms that consider in their analysis the relationships between the fluid and the solid surfaces [1].

Often it is necessary to know the time of emptying a fluid in a reservoir. Thereunto, the active methodologies can be used in conjunction with the new digital media to improve teaching and, consequently, solve problems encountered in everyday life. The Project-Based Learning (PBL) is a teaching method and, at the same time, an alternative that supports the preparation and qualification of professionals, based on the knowledge acquired with the environment and on problem-solving. In the context of engineering teaching, the use of the PBL contributes favorably to the laboratory experience of the problematic situations that occur in the daily life of this professional activity, allowing a better preparation for the labor market [2].

In this practice, the student coexists with real situations and has to deal with the decision-making according to the variables and general aspects of the situations encountered, in order to solve the problems in the best possible way [3]. Some Brazilian universities have been betting on programs that promote active learning in training and problem-solving in engineering courses. However, this application is subtle or does not represent great changes in the educational base, but is applied only in separate disciplines [4].

Working for projects is, in a way, collaborating with learning, since all participants need to help with the shared outcome. Instead of the students involved having only passive experiences, they begin to acquire learning elements through experiences with active reflection and conscious involvement of what they are working [5].

In practice, for flow measurement, the most widely used method for measuring a pipe is to estimate the amount of the fluid accumulation in a container over a constant period. The determination of the flow rate of a fluid flowing under the permanent condition is carried out in reservoirs with the measurement of volume or mass acquired in a known time interval. If this time interval is large enough to be measured with little uncertainty, the flow rates can be determined with a certain degree of precision [6].

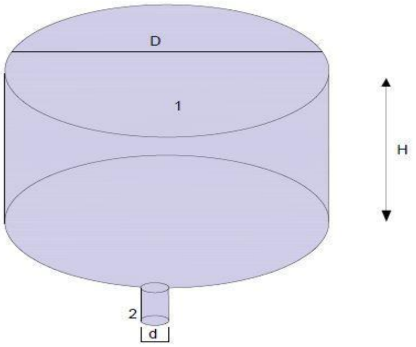
When there is an orifice for the flow of the fluid in the bottom of the reservoir, it is quite common to calculate the emptying time, and the choice of this time depends in the first instance of the designer. For example, the time can be chosen for a short duration of 8 hours or a long duration of 24 hours [7]. In addition, in some cases, pumping methods are used to perform the emptying.

The objective of this work is to improve students' teaching-learning with the implementation of a mobile application, as well as being a source of solution for determining the time needed to empty a common swimming pool.

2 COMPUTATIONAL PROCEDURE

The Bernoulli equation is theoretically used in cases of permanent flow, but if the surface of a given reservoir reduces with a sufficiently low velocity, the imprecision resulting from this fact is negligible. The Fig. 1 shows the design of a permanent regime with the application of the energy balance.

Figure 1: Schematic showing the emptying of a cylindrical pool.



Consider a current line between points 1 and 2 of the reservoir. Bernoulli's law can be applied to fluids that are in a steady state, are inverse and incompressible, but

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rather it is important to determine the speed with which the fluid exits the reservoir at both points.

At point, 1 it is considered that the fluid is under the influence of atmospheric pressure, since the top of the reservoir is open. The velocity at this point varies intrinsically very little as time passes, when taking into account the velocity of the output duct. The derivative of the height function h (t) expresses the instantaneous velocity at the point when Δt tends to zero. So,

$$v1 = \frac{dh}{dt} \quad (1)$$

In point, 2 it is interesting to use the Bernoulli equation to determine the velocity:

$$\frac{p1}{\rho 1} + \frac{v1^2}{2} + gh1 = \frac{p2}{\rho 2} + \frac{v2^2}{2} + gh2 \quad (2)$$

To do so, it is important to highlight some considerations before determining the velocity acting on point 2:

(1) Height h2 is zero because it is in the reference line of the system;

(2) The pressure is equal to atmospheric pressure ($p_1 = p_2 = p_0$);

(3) The surface flow velocity is approximately zero;

(4) The density is equal in both points, since it is the same liquid $\rho 1 = \rho 2 = \rho água$).

In view of these considerations, the Eq.2 reduces to:

$$v2 = \sqrt{2gh} \quad (3)$$

By the equation of continuity shown in Eq. 4, we can relate both speeds of the points studied:

$$v_1 A_1 = v_2 A_2 \quad (4)$$

In which,

A_1 is the area at point 1 (top of the reservoir);

A_2 is the area at point 2 (hole in the base of the reservoir).

Ergo,

$$\frac{dh}{dt}\left(\frac{\pi D^2}{4}\right) = \sqrt{2gh}\left(\frac{\pi d^2}{4}\right) \quad (5)$$

When separating the variables, we have that:

$$\frac{dh}{dt}D^2 = \left(\sqrt{2gh}\right)d^2 \qquad (6)$$

$$\frac{dh}{\sqrt{h}} = \left(\frac{d^2}{D^2}\sqrt{2g}\right)dt \qquad (7)$$

$$\int_0^H h^{0,5}dh = \left(\frac{d^2}{D^2}\sqrt{2g}\right)\int_0^t dt \qquad (8)$$

By integrating Eq. 8:

$$2\sqrt{H} = \left(\frac{d^2}{D^2}\sqrt{2g}\right)t \qquad (9)$$

Finally, the expression of the time of emptying of a reservoir is summarized in:

$$t = \frac{D^2\sqrt{2gH}}{gd^2} \qquad (10)$$

In which,

D = diameter of pool base;

d = diameter of the liquid outlet duct;

g = gravity (9.81 m / s²);

H = height of water column;

t = time of emptying the pool.

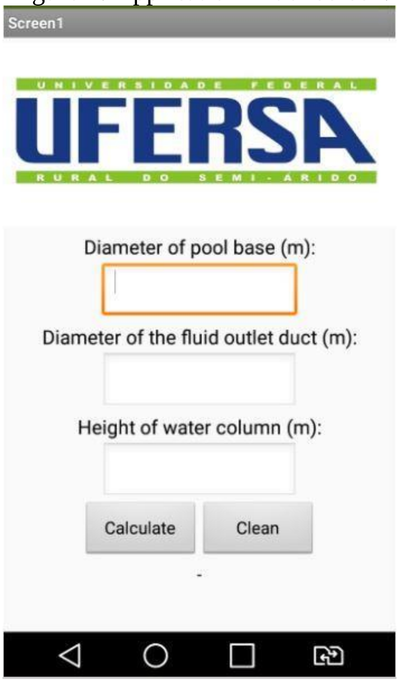
Fig. 2 shows the initial screen of the application. The software was developed in MIT App Inventor 2 platform, where it easily allows beginners in computer programming, to create software applications for devices with Android operating systems.

In order to use the application, it is important that all measurement units be according to the International System of Units. Fig. 2 exposes the initial screen of the application developed with all the input parameters that the user must provide so that the program calculates what is desired. In this way, the blank fields represent, respectively:

1. Diameter of the base of the pool;
2. Diameter of the outlet duct of the fluid;
3. Height of the water column in the pool.

After these three fields are filled, the program will show the time required to completely drain the pool in minutes.

Figure 2: Application initial screen.



3 RESULTS AND DISCUSSIONS

Initially it was proposed to carry out the work in a common pool with the dimensions explained in Tab. 1:

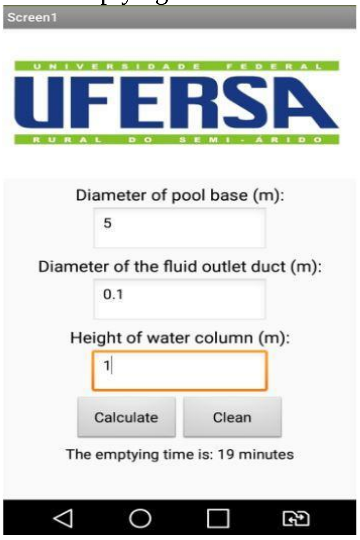
Table 1 - Initial Parameters for the Application

Column Height of water (m)	Base diameter of the pool (m)	Diameter of the duct fluid outlet (m)
1 m	5 m	0,1 m

When entering the height values of the water column, diameter of the pool base and the fluid outlet duct (shown in Table 1) on the initial application screen, it has been conquered the correct amount of time required to empty the pool, in which was 19 minutes. This can be seen in Fig. 3.

If the user wants to know the time of emptying of another pool with variable dimensions, of which it is cylindrical, the application calculates without exception, thus showing a good practicality in the real problems found.

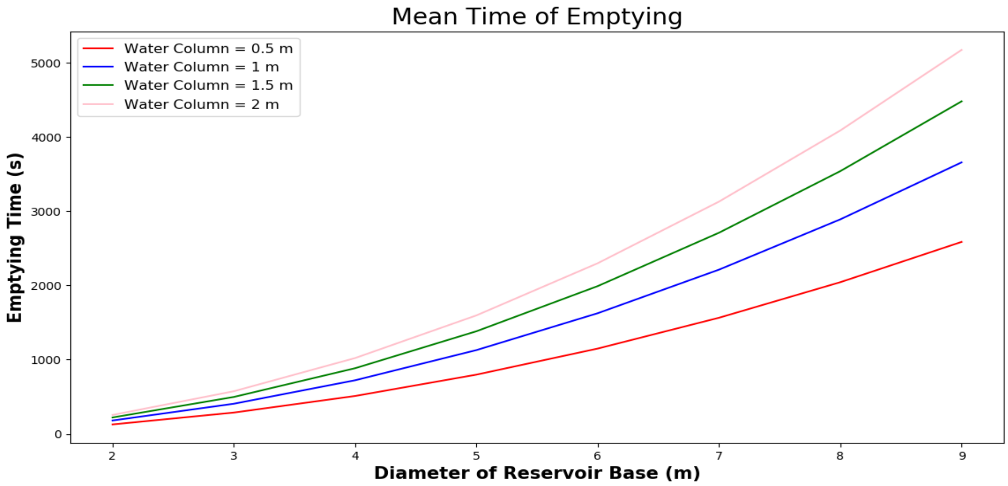
Figure 3: Value of the emptying time calculated in the application.



A graph was plotted to show the time of emptying of the pool according to the diameter of the base of this same deposit. In Fig. 4 it is observed that there are some increasing lines, starting from close points, for different values of water column heights.

This is explained by the small diameter values, since, with small diameters, the emptying time presents close values for lines that do not vary sharply the size of the water column. For this condition, the larger the pool diameter and the water column size, the longer the emptying time.

Figure 4: graph of the emptying time x diameter of the base of the pool.

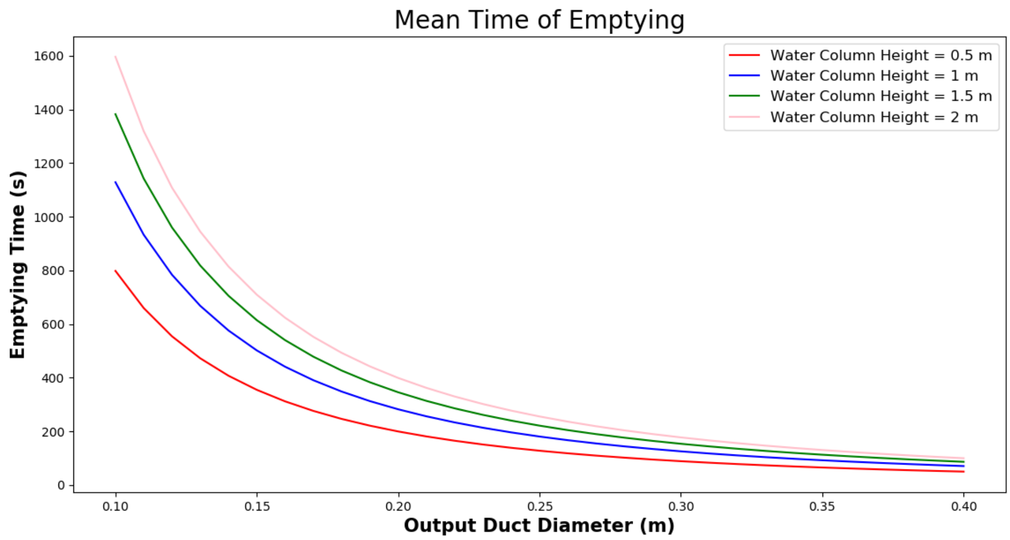


The second graph addresses the behavior of the emptying time curve varying with the diameter of the fluid outlet duct. In Fig. 5 it is possible to notice that different lines were plotted for different height values of the water column, to observe the behavior of the flow time.

From this, it is noted that the larger the water column and the smaller the outlet diameter of the fluid, the longer the pool drainage time, since the fluid passageway does not allow large amounts of water to exit the tank with speed. In the past, if the diameter of the outlet duct is larger, even if the water column size is maintained, the draining time decreases.

The same graph shows a time, practically the same, for different values of water column heights. This is due to the fact that the emptying time is inversely proportional to the square of the exit diameter.

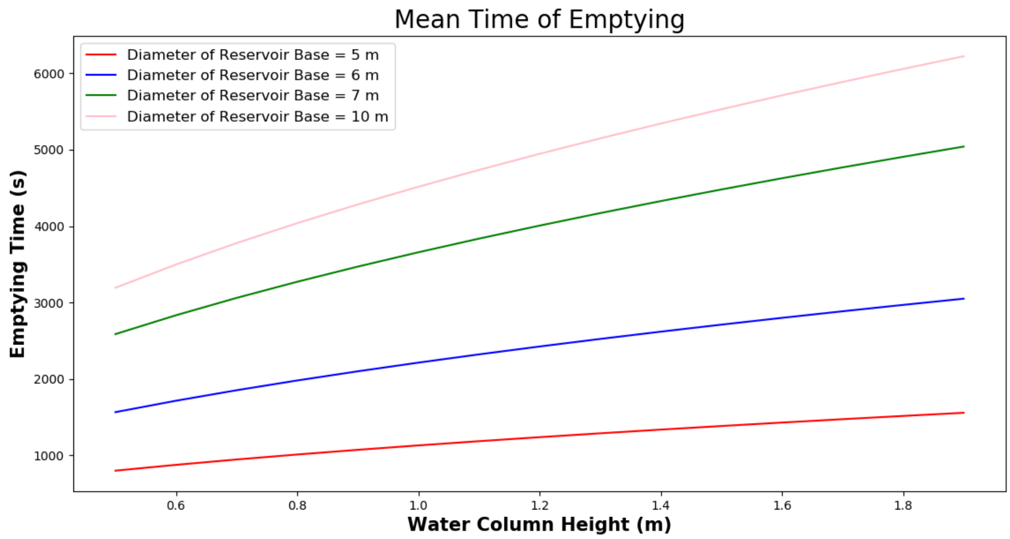
Figure 5: Graph of the drainage time x diameter of the fluid outlet duct (varying height of the water column).



The graph of Fig. 6 identifies the time of emptying of the pool with variation in the height of the water column. This time, lines with different values were plotted for the diameter of the reservoir base.

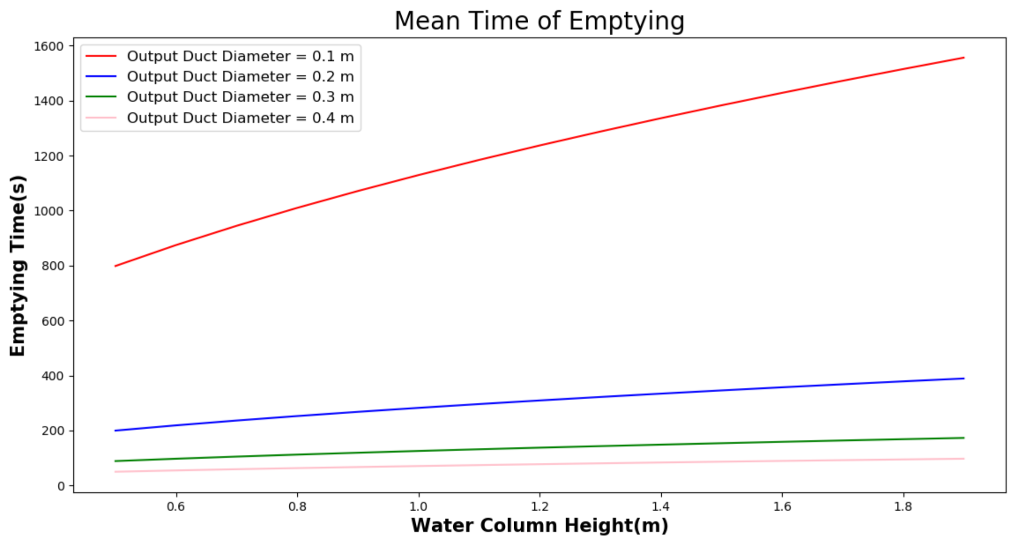
By the expression of the emptying time, it can be said that the time is directly proportional to the square of the pool diameter and the square root of the height of the water column. By increasing the values of the diameter of the pool base and the height of the water column, the time for emptying tends to be greater. This is noticeable in Fig. 6.

Figure 6: Graph of the drainage time x height of the water column (varying diameter of the pool base).



The Fig. 7 shows a graph with some similar conditions with the graph of Fig. 6. Likewise, it was interesting to plot some lines for different values of the outlet duct diameter of the fluid. Such that the emptying time is inversely proportional to the square of the outlet duct diameter of the fluid, and directly proportional to the square root of the water column. By increasing the outlet diameter of the fluid and the height of the water column, the emptying time of the reservoir is smaller, as shown in Fig. 7.

Figure 7: Graph of the drainage time x height of the water column (varying diameter of the fluid outlet duct).



4 CONCLUSION

To determine the time required to empty a pool with a cylindrical outlet duct, as shown in Fig. 1, the application developed in this work could be used. In addition to this function, the mobile application has a great importance for collaborating with the teaching-learning of those who use it, and contributes to the solution of major problems related to this bias in engineering.

With the data obtained in Fig. 4, it was possible to see that the emptying time will be longer, as the diameter of the pool base and water column size increases. Other graphs were generated for comparisons of the results of the emptying time, as some conditions had variations, and others remained constant. It was verified in Fig. 5 that the emptying time is smaller as the larger the outlet duct diameter is, and the lower the water column height of the reservoir type studied. Fig. 6 indicates that the emptying time will be longer, the higher the water column values and the reservoir base diameter. The Fig. 7 shows that the emptying time decreases as the fluid outlet diameter and height of the water column increase.

It is essential to highlight that the use of the application developed in this work, serves to help in the quick and practical solution of problems encountered in the everyday of fluid mechanics.

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