# Hacettepe University

Physics Engineering Department

## FIZ 117 General Physics Laboratory

# LABORATORY NOTEBOOK


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# ANALYSIS OF AN EXPERIMENT

**Experiment Name:** Investigation of the Dependence of Water Depletion Time on Water Height and Hole Diameter

**Objective**: To determine the relationship between physical quantities affecting an event by the analysis of the experimental data. For example, a cylindrical container with a diameter-changing hole at the bottom is filled with water at different heights and the depletion time of water in the cylinder is measured. Our aim is to determine of the effects of the water height (*h*) and the hole diameter (*d*) on the depletion time (*t*) of water, and also to obtain a formula between *t*, *h* and *d*, in such a system is the objective.

**Tools:** Three cylindrical containers with different diameter holes at the base, a ruler, a timer, and water.

**Experimental Procedure:** Each cylinder is filled with water at the heights of *h* = 10.0 cm, 7.5 cm, 5.0 cm and 2.5 cm, and the depletion times are measured. The data obtained during the experiment are given in Table 2.

**Table 2.** Hole diameter (*d*), water height (*h*) and water depletion time (*t*) values.

| | $h$ = 10.0 $cm$ | $h$ = 7.5 $cm$ | $h$ = 5.0 $cm$ | $h$ = 2.5 $cm$ |
|---|---|---|---|---|
| $d$ ($cm$) | $t$ ($s$) | $t$ ($s$) | $t$ ($s$) | $t$ ($s$) |
| 0.2 | 387.4 | 305.4 | 241.6 | 170.6 |
| 0.4 | 89.3 | 86.8 | 75.7 | 48.7 |
| 0.6 | 38.8 | 34.3 | 25.9 | 18.1 |

**Data Analysis:**

The formula between *t*, *d* and *h* is going to be searched using the graphs plotted according to the obtained data.

**SECTION I:** Investigation of the depletion time of the water as a function of the hole diameters at constant water heights

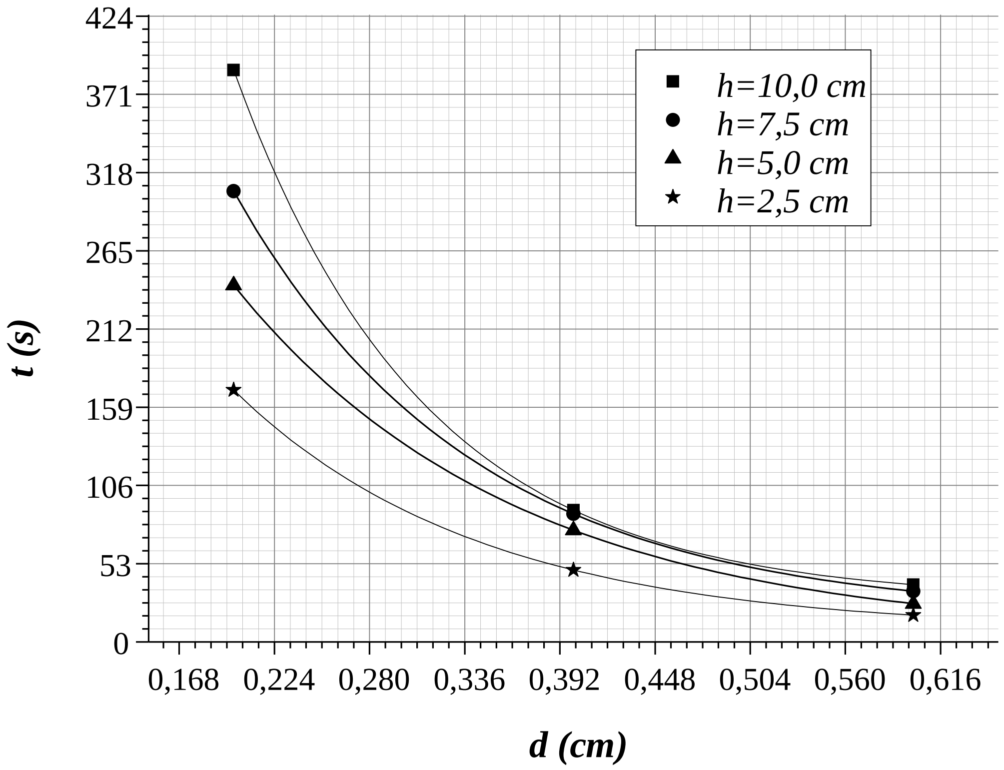



**Figure 3.** The variation of the depletion time (*t*) of the water as a function of the hole diameter (*d*) for each initial water height (*h*) value.

As can be seen in Figure 3, *t* is decrreases with when d increases, and this relation is not linear. So, there should be such a relationship between *t* and *d*

$$t \propto \frac{1}{d^n} \tag{1}$$

For finding the value of n in Eq. (1), the logarithm of each side of Eq. (1) should be taken into account as follows

$$\log(t) = \log\left(\frac{1}{d^n}\right) \tag{2}$$

$$\log(t) = -n\log(d) \tag{3}$$

$$n = -\frac{\log(t)}{\log(d)} \tag{4}$$

If the graph of the log(*t*) versus log(*d*) is plotted, a linear graph will be obtained, and the slope of the graph gives –*n*.

**Table 3.** *log(d)* and *log(t)* values for constant *h* values.

| | $h$ = 10.0 $cm$ | $h$ = 7.5 $cm$ | $h$ = 5.0 $cm$ | $h$ = 2.5 $cm$ |
|---|---|---|---|---|
| *log(d)* | *log(t)* | *log(t)* | *log(t)* | *log(t)* |
| -0.7 | 2.59 | 2.48 | 2.38 | 2.23 |
| -0.4 | 1.95 | 1.94 | 1.88 | 1.69 |
| -0.2 | 1.59 | 1.54 | 1.41 | 1.26 |

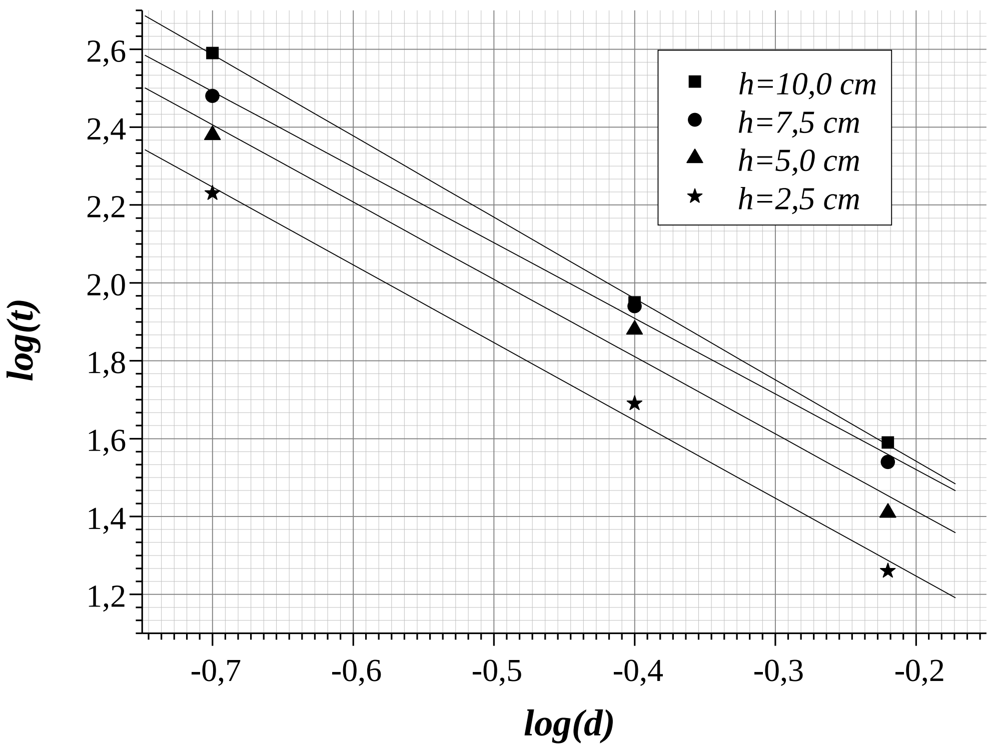



**Figure 4.** The variations of *log(t)* as a function of *log(d)* for constant h values.

The calculated slope is -2 for the lines in the graph (Figure 4), and the *n* value may be obtained by multiplying the calculated slope by -1 as *n* = 2. So, Eq. (1) can be written as $t \propto \frac{1}{d^2}$ . To test this relationship; a graph of *t* versus $1/d^2$ should be plotted to get a linear line with a positive slope.

**Table 4.** *t* and $1/d^2$ values for constant *h*.

| | $h$ = 10.0 $cm$ | $h$ = 7.5 $cm$ | $h$ = 5.0 $cm$ | $h$ = 2.5 $cm$ |
|---|---|---|---|---|
| $1/d^2$ ($cm^{-2}$) | $t$ (s) | $t$ (s) | $t$ (s) | $t$ (s) |
| 25 | 387.4 | 305.4 | 241.6 | 170.6 |
| 6 | 89.3 | 86.8 | 75.7 | 48.7 |
| 3 | 38.8 | 34.3 | 25.9 | 18.1 |

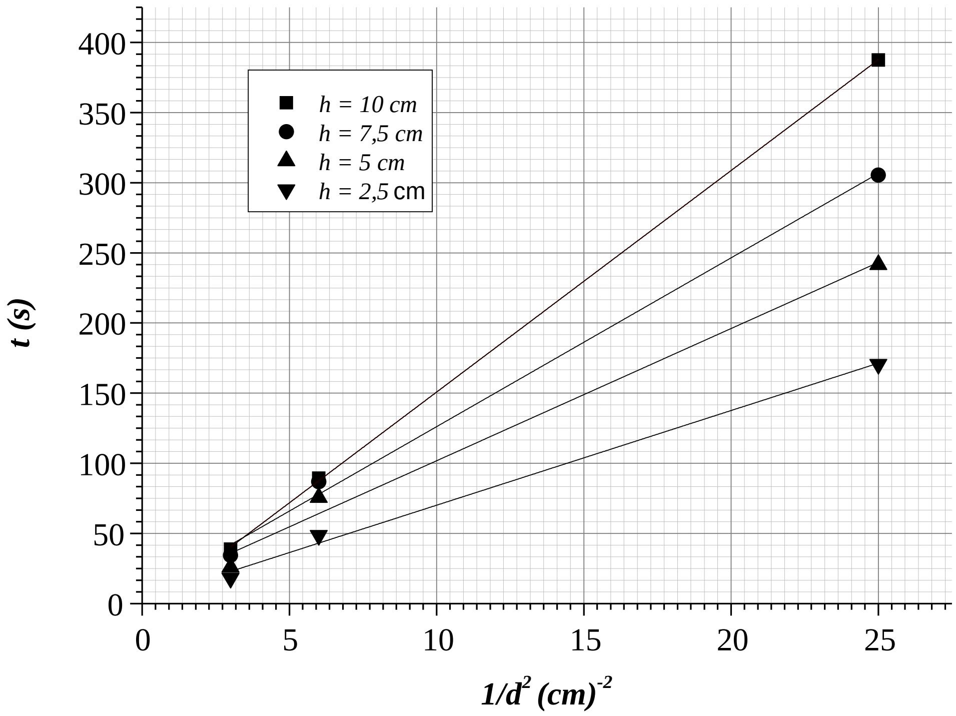


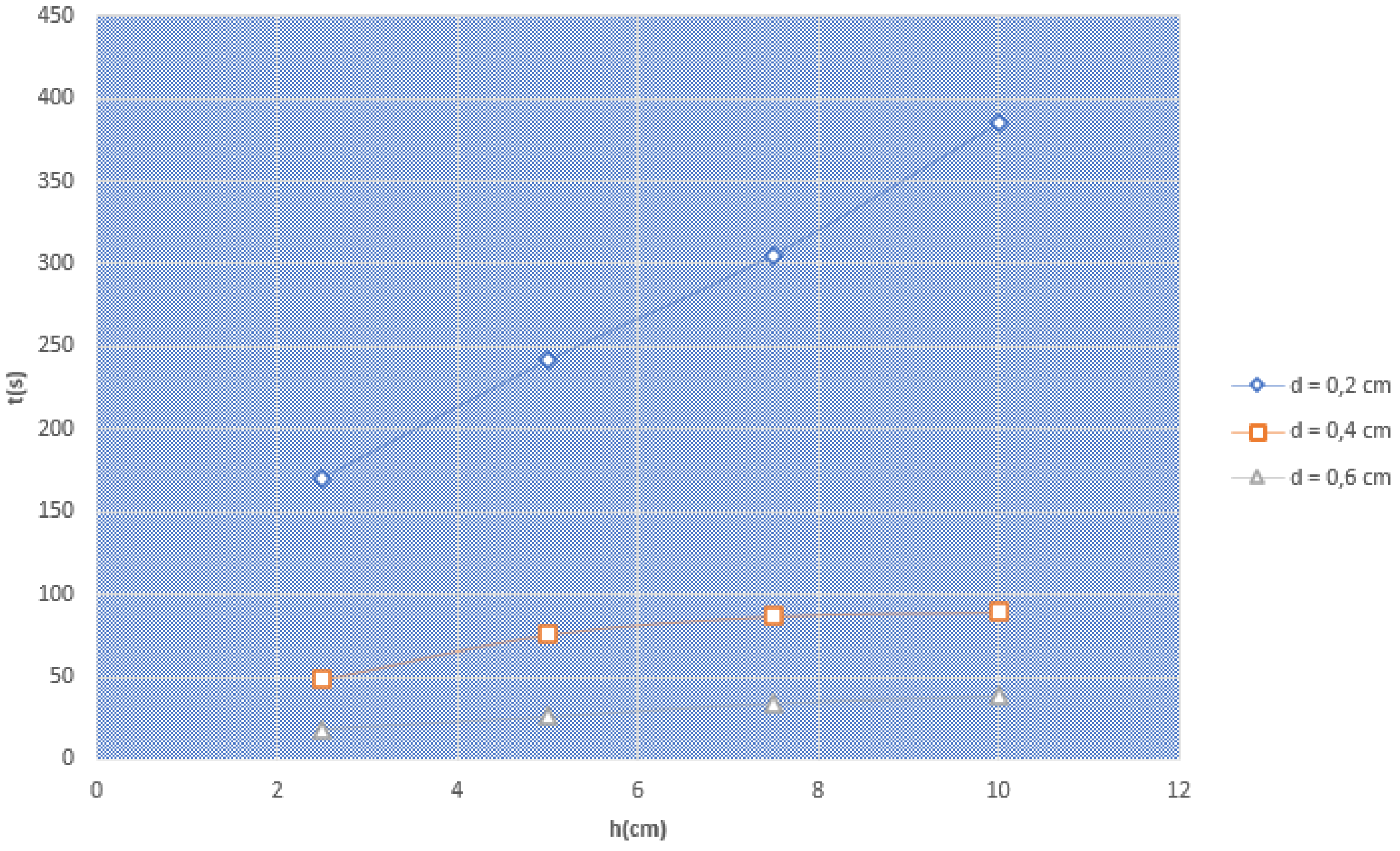

**Figure 5.** The variations of *t* with $1/d^2$ for constant *h* values.

So, it is determined that the depletion time of water is inversely proportional to the square of the hole diameter for constant water heights as in the following

$$t \propto \frac{1}{d^2} \tag{5}$$

**SECTION II:** Investigation of the depletion time of water as a function of the water heights at constant hole diameters

In this section, plot the graphs of the depletion times of water as a function of the water heights for each hole diameter using the experimental values given in Table 2.




In the graph you plotted, it should be seen that as *h* increases, *t* also increases and at the same time this increase is not linear. So, a relationship must be between *t* and *h* as in the following

$$t \propto h^m \tag{6}$$

For getting the *m* value, the logarithm of each side of Eq. (6) should be taken into account as in the following

$$\log(t) = \log(h^m) \tag{7}$$

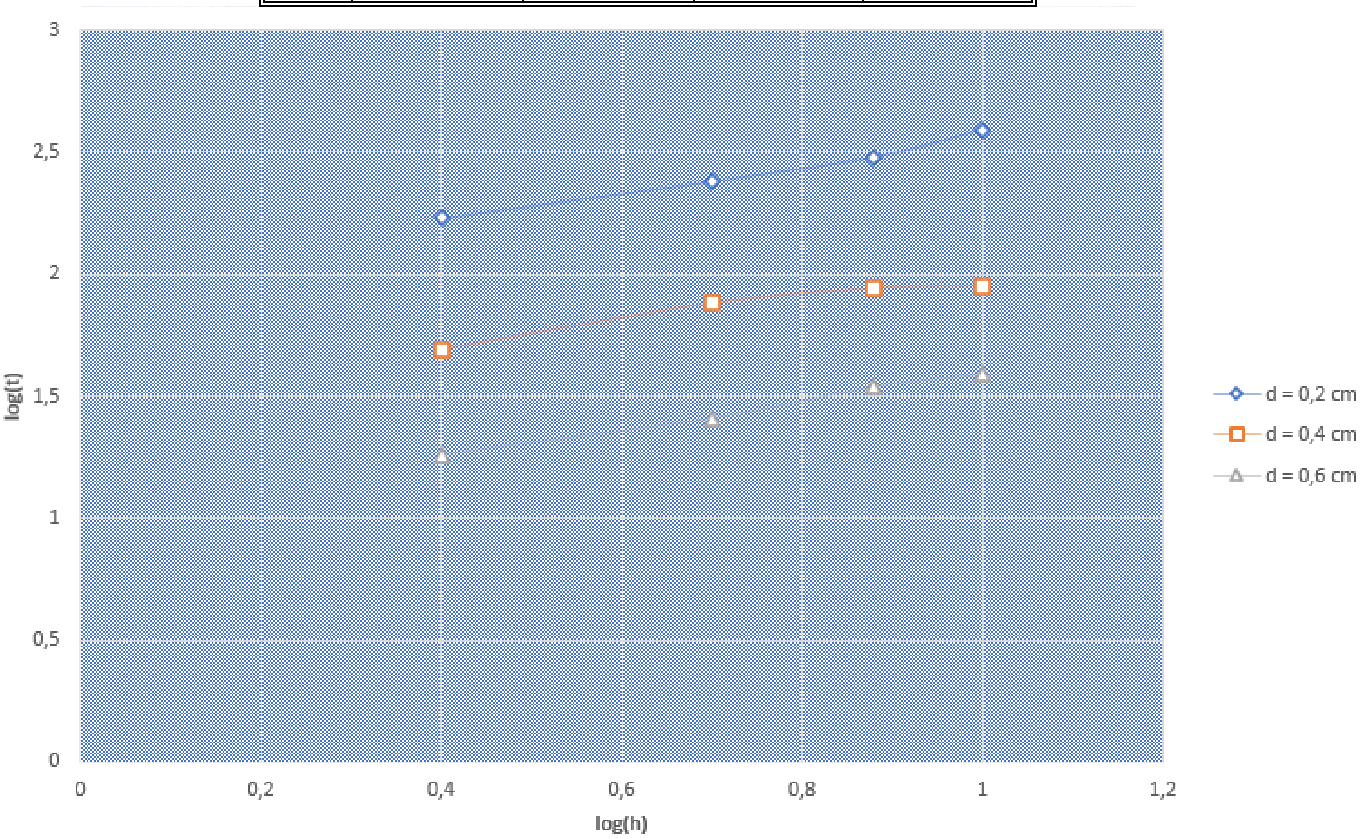
$$\log(t) = m\log(h) \tag{8}$$

$$m = \frac{\log(t)}{\log(h)} \tag{9}$$

If the graph of the *log(t)* versus *log(h)* is plotted, a linear graph will be obtained, and the slope of the graph gives *m*.

**Table 5.** *log (h)* and *log (t)* values for constant *d* values.

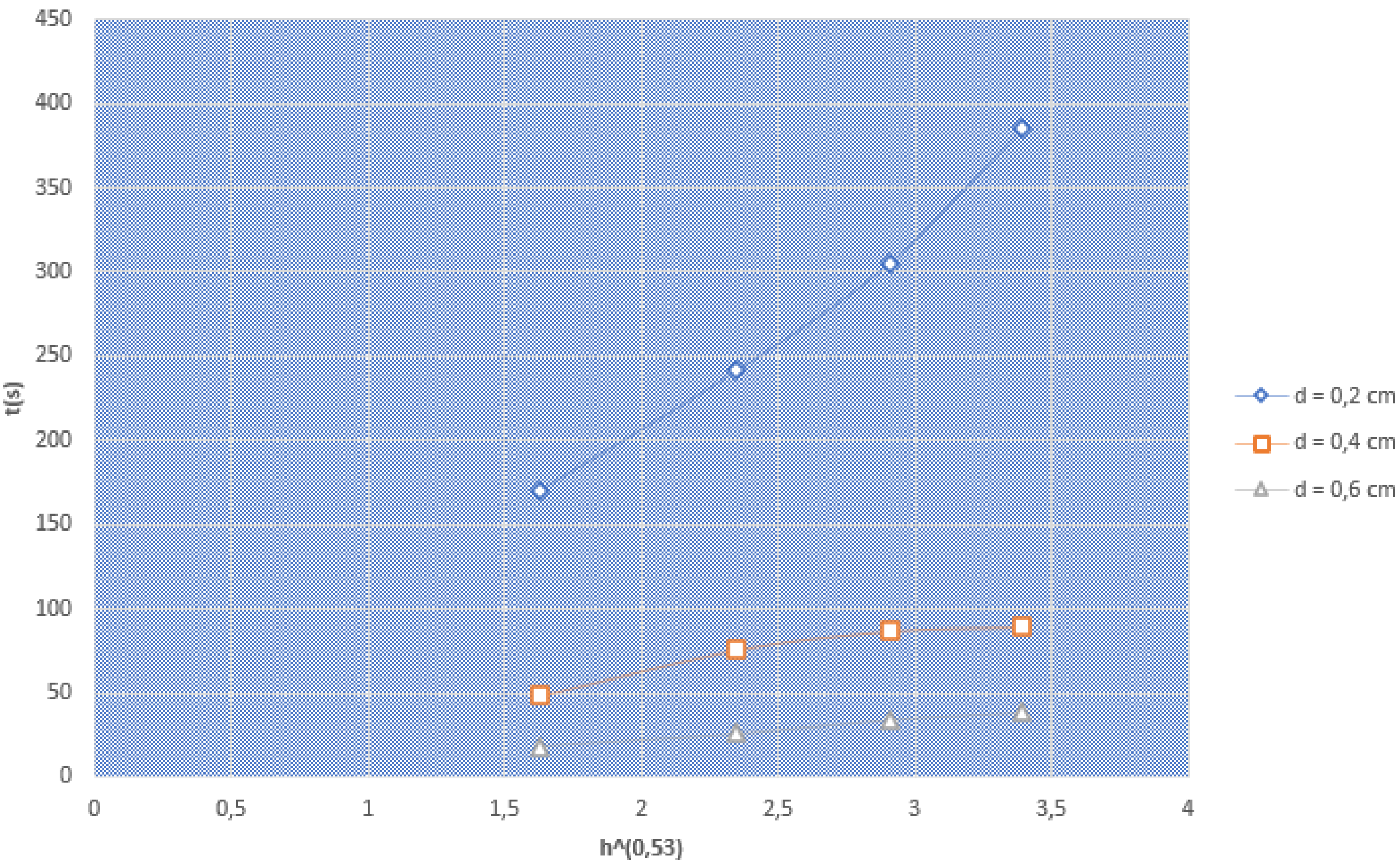
| | *log(h)=1.00* | *log(h)=0.88* | *log(h)=0.70* | *log(h)=0.40* |
|---|---|---|---|---|
| *d (cm)* | *log(t)* | *log(t)* | *log(t)* | *log(t)* |
| 0.2 | 2.59 | 2.48 | 2.38 | 2.23 |
| 0.4 | 1.95 | 1.94 | 1.88 | 1.69 |
| 0.6 | 1.59 | 1.54 | 1.41 | 1.26 |




When you calculate the slopes of the lines, the calculated value will give you the value of *m*. So, once you get the value of *m*, you will reach the exact relationship between *t* and *h*. To test its accuracy, plot the $h^m$ variation as a function of *t* at constant *d* values. The graph must be a straight line with a positive slope.

**Table 6.** t and $h^m$ values for constant *d* values.

| | $h^m =$ (3,39) | $h^m =$ (2,91) | $h^m =$ (2,35) | $h^m =$ (1,63) |
|---|---|---|---|---|
| *d(cm)* | *t (s)* | *t (s)* | *t (s)* | *t (s)* |
| 0.2 | 387.4 | 305.4 | 241.6 | 170.6 |
| 0.4 | 89.3 | 86.8 | 75.7 | 48.7 |
| 0.6 | 38.8 | 34.3 | 25.9 | 18.1 |




Now you should combine the results obtained in sections I and II. It has already been found in section I that the variation of the depletion time of water with the hole diameter was $t \propto \frac{1}{d^2}$ . In the graphs in Section II, you should find that the depletion time of the water varies with the height as $t \propto h^m$, and the constant *m* value is calculated from the slope of the *log (t) -log (h)* graph. So you can find the value of m, and then you can substitute it in $t \propto \frac{h^m}{d^2}$ expression. To write this expression as an expression, there must be a proportionality constant such as *k*.

$$t = k\frac{h^m}{d^2} \qquad (10)$$

To find the value of the propotionallity constant *k*, it is necessary to plot *t* as a function of $\frac{h^m}{d^2}$ using the previously calculated *m* value.

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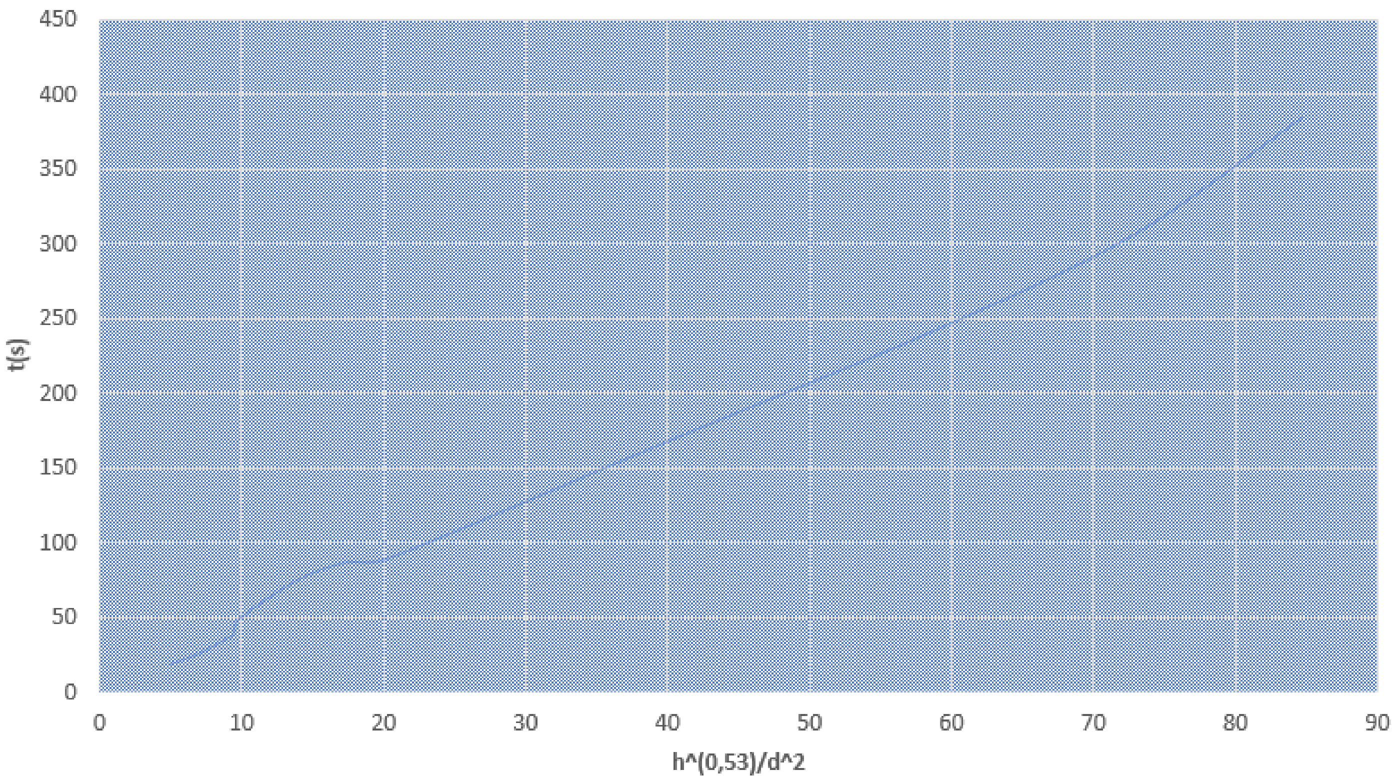
**Table 7.** $\frac{h^m}{d^2}$ and $t$ values.

| $\frac{h^m}{d^2}$ ( cm^-1,47 ) | $t$ (s) |
|---|---|
| 4,89 | 18.1 |
| 7,05 | 25.9 |
| 8,7 | 34.3 |
| 9,39 | 38.8 |
| 9,78 | 48.7 |
| 14,1 | 75.7 |
| 17,46 | 86.8 |
| 20,34 | 89.3 |
| 40,75 | 170.6 |
| 58,75 | 241.6 |
| 72,75 | 305.4 |
| 84,75 | 387.4 |



You are expected to draw a straight line in this graph which proves following relation

$$t = k\frac{h^m}{d^2}$$

The slope of the line is equal to the proportionality constant. Now you should interpret this result.

**CONCLUSION AND COMMENT**

In this experiment, we have created a formula and a constant k by keeping two variables dependent on it.

First, we determined the proportions of the two variables, respectively. Then we plotted the constant k using the experimental data and these variable coefficients. In the last graph drawn, we found the constant k as 4.32. As this experiment shows, we can create our own formulas and constants for many experiments.

However, there are many factors that do not contribute to this constant, such as temperature, surface tension, fluidity, and the raw material of the container used in the experiment.

As a result, the more we keep the number of variables, the closer we can get to the real formula and the constant k.

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