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Faculty of sciences - common Basic of matter sciences

3rd PRACTICAL WORK: THE FREE FALL OF AN OBJECT UNDER THE INFLUENCE OF GRAVITY

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	First Name	Family name	Subgroup	Professor's name
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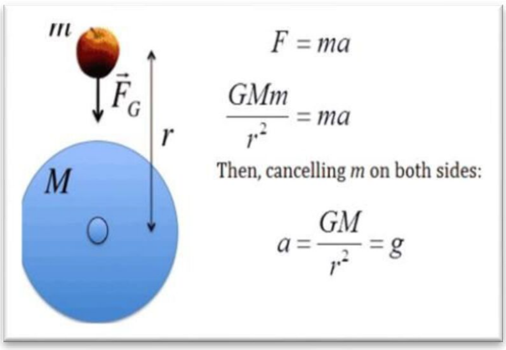
Purpose

The primary objective behind examining falling experiments is to enhance comprehension of the principles governing motion and their application to scenarios involving objects in free vertical descent or horizontal motion with an initial velocity. The study of falling experiments further confirms that, when the influence of air resistance is disregarded, all objects fall at a uniform rate of acceleration toward the ground. This exploration also facilitates the illustration that objects, when dropped from the same height, reach the ground at identical speeds and times, provided that the effects of air friction are discounted.

THEORETICAL REMINDER OF BASIC CONCEPTS



The phenomenon of objects falling is a fundamental aspect of physics that reveals the interaction between objects and the gravitational force generated by the Earth. This force pulls objects toward the Earth's center and induces acceleration in their descent when they are released or dropped. In essence, the descent of objects is a consequence of the interplay between gravity and the objects themselves. This interaction is precisely described by Newton's Universal Law of Gravitation, expressed in the following equation:

$$F = G\frac{M \times m}{r^2}$$ *Where:*

F *represents the gravitational force acting between the Earth and the object (measured in Newtons).*

G *is the universal gravitational constant which is a constant value approximately equal to (6.67430×10^{-11} $N.m^2/kg^2$).*

M *and* ***m*** *denote the masses of the Earth and the object, respectively.*

r *signifies the distance between the centers of the object and the Earth.*

This equation clarifies that the gravitational force between the Earth and the object intensifies with the increase in the object's mass ***M*** *and* ***m*** *and diminishes as the distance between them (**r**) grows. This force consistently operates toward the Earth's center, leading to the descent of objects and the acceleration of their motion toward the Earth's center.*

I) Free Fall Experiment

An experiment involves a cylindrical object with mass 'm' falling vertically without any initial velocity, conducted in an environment where air resistance is negligible. By applying fundamental principles of physics, we derive kinematic equations describing the cylinder's motion. This experiment isolates the effects of gravity and serves as a foundation for understanding universal free fall and environmental influences on descending objects.

Using the fundamental principle of dynamics, we can derive the kinematic equations for this cylinder.

Figure (01)

$$\sum \vec{F}_{ext} = m\,\vec{a}$$

where $\vec{a}$ represents the cylinder's acceleration.

$$\vec{P} = m\,\vec{a} \qquad \Rightarrow \; a = g$$

Taking into consideration the initial conditions (at t=0s, z(0) = 0, and v(0) = 0), we obtain the equation of motion for the cylinder in a gravitational field in the form:

$$z\,(t) = \frac{1}{2}\,g\,t^2$$

THEORETICAL PART

II) Free Fall Experiment

In experimental work, we measured the time it takes for a piece of iron to travel certain distances, and the results were as recorded in the following table:

$z(m)$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$t(s)$	**0.20203**	**0.24744**	**0.28571**	**0.31944**	**0.34993**	**0.37796**	**0.40406**	**0.42857**
$V_m(m/s) = \dfrac{z_f - z_i}{t_f - t_i}$								

Table (01)

1- *Based on the table values, calculate the mean velocity V_m of the cylinder between each two successive measurements.*

2- *As it is well-known, the mean (average) velocity (V_m) between two specific moments (t_i) and (t_f) is equal to the instantaneous velocity V_t at the midpoint of the time interval $[t_i\,, t_f]$ (i.e., at $t = \frac{t_i + t_f}{2}$), this relationship can be expressed as follows:*

$$V_m[t_i\,, t_f] = V\left(\frac{t_i + t_f}{2}\right) = \frac{z_f - z_i}{t_f - t_i}$$

Calculate the *instantaneous velocity V_t at each midpoint between two successive moments (t_i) and (t_f) from the previous table and record the results in the following table:*

Time range $[t_i\,, t_f]$							
$t(s) = \frac{t_i + t_f}{2}$							
$V_t(m/s)$							
$a_m(m/s^2) = \dfrac{V_f - V_i}{t_f - t_i}$							

Table (02)

3- *As it's known, the (mean) average acceleration between two time instants is equal to the result of dividing the difference between the two instantaneous velocities at those instants by the time interval between them. Also, the mean (average) acceleration (a_m) between two specific* *moments (t_i) and (t_f) is equal to the instantaneous acceleration a_t at the midpoint of the time interval $[t_i, t_f]$ (i.e., at $t = \frac{t_i + t_f}{2}$). This relationship can be expressed mathematically as follows:*

$$a_m[t_i, t_f] = a\left(\frac{t_i + t_f}{2}\right) = \frac{V_f - V_i}{t_f - t_i}$$

Calculate the average acceleration, record the results in Table 2, and then recalculate the times and corresponding instantaneous accelerations and record the results in Table 3

Time range $[t_i, t_f]$							
$t(s) = \frac{t_i + t_f}{2}$							
$a_t(m/s^2)$							

Table (03)

PRACTICAL PART

I.) Free Fall Experiment

*Perform the experimental setup shown in **Figure 1**, where the iron cylinder (with a height of 16 mm and a weight of 52 grams) is attached to an electromagnetic at a height of 70 cm from the optical barrier. Turn on the digital timer as the iron cylinder is automatically released downward to pass through the optical barrier. Record the time taken for the iron cylinder to pass through the optical barrier and the time interval (δt). Repeat the experiment to obtain precise readings.*

1- *Each time, adjust the distance between the iron cylinder attached to the electromagnet and the optical barrier according to the values in the table. Record the results and answer the following questions.*

$y(m)$	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Time $t(s)$							
$\bar{t}(s)$							
δt (s)							
$\overline{\delta t}$ (s)							

2- *For each measurement case, calculate the velocity (v) and then derive the expression for the value of gravitational acceleration (g) as a function of velocity and time. Calculate this value and record it in the following table.*

$\bar{t}(s)$							
$v(s)$							
$g(m/s^2)$							

3- *Calculate the mean value of g, the absolute Uncertainty Δg, and then write its value as $g \pm \Delta g$*

4- *Plot the curve v=f(t), then deduce the gravitational acceleration* $(\boldsymbol{g})$

5- *For each measurement case, calculate the kinetic energy* ($\boldsymbol{E_K}$)*, potential energy* ($\boldsymbol{E_P}$)*, and total energy* ($\boldsymbol{E_T}$)*, considering that gravitational potential energy at the optical barrier is equal to zero.*

$\boldsymbol{E_K}$							
$\boldsymbol{E_P}$							
$\boldsymbol{E_T}$							

6- *Record your observations about the obtained results*