EXERCISE 1

Measurement of the gravitational acceleration g on Earth

Objectives

In this laboratory exercise we are going to measure the gravitational acceleration, g, on Earth[1], at the place where the experiment takes place, using two different ways: (a) The free fall of objects, and (b) the simple harmonic oscillator. Both experiments offer an indirect way for the determination of the gravitational acceleration on Earth. The students will compare the results taken from the two methods and from literature.

Theoretical background

Free fall of objects

An object in free fall, falls under the influence of gravity only, the air resistance is negligible. To reproduce a free fall in the laboratory we use objects of high density with relatively small surface in order to minimize the air resistance effect. In figure 1, we release an object (black dot) from a height h above the floor. The path the object follows as it falls down is represented by the dashed line. The object will be in the air for a time interval $\Delta t = t_{fl}$ which is called time of flight. This is the time necessary for the object to cover the distance h.

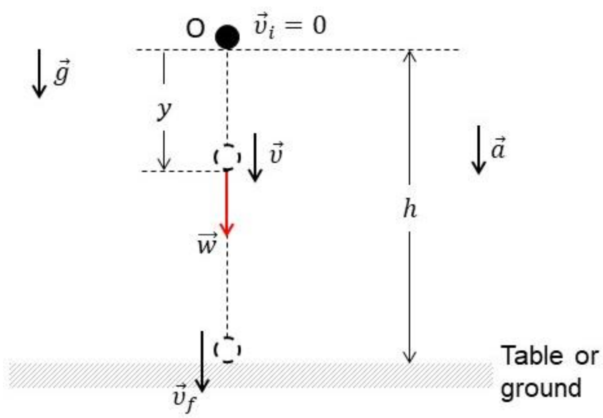

Figure 1: (Color online). *Free fall of an object from a height h above the ground.*

The object moves under the influence of its own weight $\vec{w}$. The magnitude of the weight is given by the formula $w = mg$, where m is the mass of the object and g is the gravitational acceleration on Earth. We'll find experimentally the value of g. We consider an arbitrary position of the object at a distance y from the initial point O the object released,

[1] The accepted value of the gravitational acceleration on Earth is $9.8\ m/s^2$.

see Figure 1. The object's velocity is v at that point and it accelerates as it falls down to the floor with acceleration equals to the gravitational acceleration g. Acceleration is the rate of change of the velocity, $\frac{\Delta v}{\Delta t}$. We have,

$$\frac{\Delta v}{\Delta t} = g \Rightarrow \frac{v - v_i}{t - t_i} = g \Rightarrow \frac{v}{t} = g \Rightarrow v = gt \tag{1}$$

To find the object's position equation, we draw the velocity – time diagram given by equation (1), see figure 2.

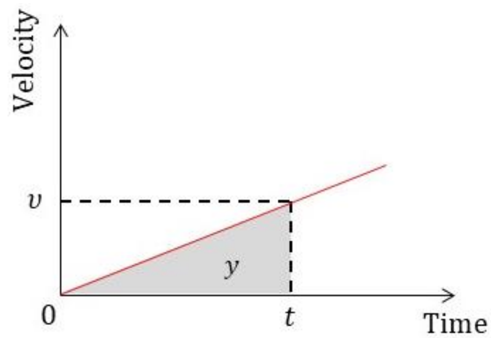

Figure 2: (Color online). Velocity – time diagram of an object in the free fall. The gray area equals to the distance y the object covers from the time instant $t = 0$ to the time instant t

The gray shaded area in figure 2 represents the distance the object covers in the free fall from the time instant $t = 0$ to the time instant t. Since the gray area is that of a right triangle, we have,

$$y = \frac{1}{2}vt \overset{(1)}{\Rightarrow} y = \frac{1}{2}(gt)t \Rightarrow y = \frac{1}{2}gt^2 \tag{2}$$

When the object hit the floor the time in equation (2) equals the time of flight of the object and the position y equals the height h from where the object was released. Therefore, the useful formula for the determination of the gravitational acceleration is

$$h = \frac{1}{2}gt^2 \tag{3}$$

Experimental procedures

The equipment needed for the free fall experiment includes the following materials:

One folding ruler of 2 meters length,
3 different solid spheres, and
one stopwatch.

Recognize the tools you are going to use and follow the next steps:

1. Release the steel ball from the heights above the floor given in table 1 of the student's worksheet.
2. Measure the time intervals needed for the sphere to hit the ground using a stopwatch.

3. Register the time intervals measured in step 2 on the second column of table 1 of the student's worksheet.
4. According to the theoretical background, think which quantity has to be calculated on the third column so that equation (2) to be linear. Justify your answer.
5. Repeat the steps 1 – 4 for the wooden and then for the brass balls.

Data analysis and results

To analyze the data of the free fall experiment, follow the steps:
1. Open up the school laptops, one laptop per team, and follow the path "Go → Documents → Labs_AUC → Lab_1". You will find there your electronic worksheet. Open the file named as "worksheet_Lab_1". On your screen you'll see the sheet named "Free fall". On the first table and on the column named "t (s)" type the values of the time intervals measured in the first experiment using the steel ball. The column named "t^2 (s^2)" calculates the values of the t^2. On the frame just below the table the data points of the diagram h vs t^2 appear. To draw a linear fit of the data, click anywhere in the diagram area. On the right panel of your screen click on "Series", then click on "Trendlines" and choose "Linear". The tabs "Show Equation" and "Show R^2" should be activated. Now you see the straight line through your data, along with the equation and the R^2 value.
2. Register the value of the slope on the student's worksheet.
3. Repeat the steps 1 and 2 for the brass and wooden balls.
4. Calculate and register on the student's worksheet the gravitational acceleration values for the three balls.
5. Calculate the average value of the gravitational acceleration, $\bar{g}$, and write the result on the student's worksheet.
6. Comment the values of the gravitational acceleration as determined using the three different balls.
7. Find the percentage error[2] of $\bar{g}$ (average value of gravitational acceleration) from the accepted value $g = 9.8\ m/s^2$ and comment your result.

Discussion and general comments

In the last section of your report, briefly describe the objectives of this laboratory session. Then summarize what you measured and how the experimental results are compared to the data. As an option, you may also write some thoughts for the improvement of the measurements.

[2] $\text{error}\% = (|\bar{g} - 9.8|/9.8) \cdot 100\ \%$

Measurements of the gravitational acceleration on Earth

Student's Worksheet – Lab 1

Student's name: ____ Grade: _________ Date: __________

Lab partner(s): ____

Method 1: Using the free fall of objects

Table 1

Steel ball			Brass ball			Wooden ball		
h (m)	t (s)		h (m)	t (s)		h (m)	t (s)	
0.8			0.8			0.8		
1.0			1.0			1.0		
1.2			1.2			1.2		
1.4			1.4			1.4		
1.6			1.6			1.6		
1.9			1.9			1.9		
Slope			Slope			Slope		
g			g			g		
Average gravitational acceleration on Earth $\bar{g} =$								