

LAB: FREE FALL

Student's Name:

Objectives

1. Measure your reaction time.
2. Measure the acceleration of gravity

Introduction

Free fall is the motion only under the action of gravity. The acceleration in this case is $g = 9.8 \text{ m/s}^2$ and points downward. This is the acceleration of falling objects close to the surface of the Earth when the air friction is neglected. Objects for which the air friction can not be neglected will not follow a free fall motion, for example a feather, an extended sheet of paper or a parachute. The main difficulty in measuring the acceleration of gravity is the measurements of the time. Since every event takes a finite time, even the fast pressing of a button. We cannot use a stopwatch and manually press it to measure the falling time of objects from few meters above the ground. For example, the time that an object takes to fall from a height of 1.5 meter is 0.55 seconds. Most students have reaction times of between 0.3s and 0.2s, which changes from person to person. Therefore, the measurement of time with a manually controlled timer will generate a high error in the measurement of " g " (note that 0.25s is about 45% of 0.55s).

Important: If you **don't have access** to the materials in this lab, please used that data already collected by your instructor shown at the end of the handout(no points will be deducted). Although, I **encourage** you to try it and obtain your own data.

1 Measuring your reaction time (30 points)

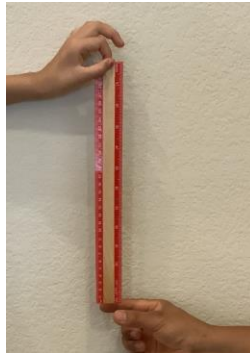
Materials

A ruler with a centimeter scale and another person to assist you (we will call this person B). For the following, you will be called person A.

Procedure

Follow the following procedure to measure your reaction time.

1. Person B will vertically hold a ruler from the one of the ends, the 30 cm mark.
2. Person A (for who will be measuring its reaction time) will place its hand (dominant one) with his thumb and index finger slightly open (see figure below), just below the lower end of the ruler.



3. Person B will drop the ruler and "A" will try to grab it by only closing its fingers.



4. Record in the table 1 the distance (d) in centimeters the ruler fell, that is, the number in cm at the tip of the fingers of person A.
5. Calculate the reaction time of A by using the following formula $t = \sqrt{\frac{2d}{980}}$
6. Perform the same procedure above two more times and fill the rest of table 1.

Trial	Distance d [cm]	Reaction time $t = \sqrt{\frac{2d}{980}}$ [s]
1		
2		
3		

Table 1

Show one calculation:

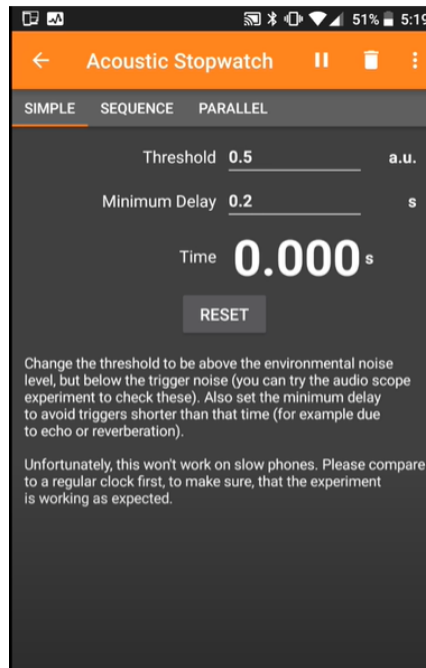
2 Measuring the acceleration of gravity (55 points)

Materials

- PHYPHOX app. Download and install the application “PHYPHOX” from the app store. **No need to paid anything** and during installation, just **skip** any payment option. Watch a short video of the use of this app for this experiment is given at:
https://www.youtube.com/watch?v=zRGh9_a1J7s
- A ruler, a pen, a measure tape, a small ball, a pen and a book or a metal plate (in this case I have used a book), or anything that makes a clear noise when the ball will hit the floor.

Procedure

- Open the app and choose the option of **acoustic stopwatch**. Set the setting for **threshold** and **minimum delay** with the values as shown below. Anytime you will start to measure time, you will have to press **reset** and the start button▶, otherwise the time will not be measure. Now the timer is ready to measure the time between two sounds.



- Place the ruler, the ball and the book as shown below. By using the measure tape, **measure** the **height (h) in meters** from the center of the ball to the book's cover. You will use different heights (for example, from the top of a chair, table, chest or refrigerator or any height available to you at home and can be less than two meters, **no need to climb**).



- Use the pen to hit the ruler near the ball (not the ball). The ruler will turn making an initial sound and the ball will fall. Then the ball will hit the book's cover making a second sound. The stopwatch of the app will **measure** the time between these two sounds. Record this time in Table 1.
- Calculate** the acceleration of gravity g , by using the formula $g = \frac{2h}{t^2}$ and record the value in table 2.
- Repeat the above procedure three more times and record your values in table 2.

Trial	Height h [m]	Time t [s]	Acceleration of Gravity $g = \frac{2h}{t^2}$ [m/s ²]
1			
2			
3			
4			

Table 2.

Now, calculate the average value of g by taking the average of acceleration of gravity g values in the last column of table 2 and write it below. Note that in order to find the average, you will have to add all values of the last column in table 2 and divide it by 4.

Average value for $g = g_{ave.} = \dots\dots\dots$ (with two decimals)

Let's compare this value with the accepted value of the acceleration of gravity which is 9.81m/s^2 . Use the average value of $g_{ave.}$ obtained above as the experimental value to find the error in the measurement of the acceleration of gravity:

$$Error = \left| \frac{g_{ave.} - 9.81}{9.81} \right| \times 100 = \dots\dots\dots \%$$

Note that the **error is always positive** because of the absolute value symbols in the definition (the two vertical bars). Errors below 5% are expected in experiments, but different factor can affect measurements and the error can be larger.

3 Questions (15points)

- (a) In this lab, you have measured two quantities, height and time. Which of these quantities do you think contributes more to the error and why? You can also look at the video to have some intuition.

(b) If you could use a marble (which is lighter), instead of a steel ball, would the new value of g change. In other words, does a heavier object fall faster than a lighter one?

(c) Do you think your reaction time for your dominant hand is very different from the one with your non-dominant hand? Could you try and give an estimate of the reaction time of your nondominant hand.

Table with data collected by your instructor

If you don't do the experiment you can use the following data to fill the tables in section 1 and 2 and complete the calculations in those sections.

Trial	Distance [cm] d	Reaction time $t = \sqrt{\frac{2d}{980}}$ [s]
1	10	
2	12	
3	7	

Trial	Height [m] h	Time t [s]	Acceleration of Gravity $g = \frac{2h}{t^2}$
1	0.43	0.300	
2	0.74	0.410	
3	0.94	0.470	
4	1.41	0.555	

4 References

[1] Jerry D. Wilson, Cecilia A. Hernandez-Hall. *Physics Laboratory Experiments*. Cengage, 8th edition, 2015.