T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY I
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Free Fall and Atwood's Machine

PREPARED BY

NAME AND SURNAME:

STUDENT NUMBER :

DEPARTMENT :

Signature:

Experimental Procedure:

Figure 1.3: Free fall and Atwood machine experiment set-up.

1. Experimental set-up is shown in Figure 1.3

2. Examine carefully the pulley, two sensors, mass holder and the bucket which are all fixed to the main vertical rod. The uppermost sensor and the holder are fixed to the same metal frame. The holder has an electromagnet inside which is always active when the main power of system is turned on. When one fixes a metal body to this holder the timer automatically resets itself. When the button is pushed the electricity feeding the electromagnet of the holder is cut and the body is released. Meanwhile the timer starts measuring the time at the moment of release and stops when the body passes through the second sensor which is further down on the main rod. The bucket with the sponge inside serves to stop the falling bodies gently without causing damage to the apparatus.

3. The metal frames which the sensors and holder are fixed. They can be moved up and down by loosening from the small black arms on their right. Make sure you are holding the frame with your other hand as you turn the arm to loosen the frame. The heights can be read from the ruler that is fixed behind the main rod. There is a white line on the frame to make the reading easier. Always record your measurements in millimeter accuracy.

4. The experiment consists of two parts, namely free fall and Atwood's machine.

5. Before performing the Atwood machine experiment align the holder height such that the masses on both sides should be able to swing freely without touching anywhere even one of the masses is at its topmost position. Don't forget to stop the swing motions of the masses by your hand before the measurement. To avoid unnecessary friction make sure that the rope touches nowhere other than the pulley during the experiment. Ask for help from the experiment responsible if necessary.

6. Before performing free fall experiment remove the rope from the pulley and remove the masses away from the falling path of the object. Take one of the metal balls and stick it to the holder. Make a trial release by pushing the button to make sure that the ball falls in the bucket. Record the holder height to the part on top of Table 1.1. To cope with the random errors you are asked to perform 5 measurements for 5 different heights. You can take an approximate value of 20 cm between your release heights. Always record the exact value that you read from the ruler.

7. Record your values to Table 1.1.

Holder height: ....

Table 1.1 Height vs. time table for free fall experiment

Sensor Height (cm)	**Time (s)**				
	t_1	t_2	t_3	t_4	t_5

8. Remove the metal ball and pass the rope over the pulley for Atwood machine experiment. (Read step 5 again) Ask the experiment responsible the values of masses to hang on both sides.

9. Take measurements in the same manner as the free fall experiment. (5 time measurements for 5 different heights.) Record your values to Table 1.2

Holder height: ....

m_1 = ... m_2 = ...

Table 1.2 Height vs. time table for Atwood machine experiment

Sensor Height (cm)	**Time (s)**				
	t_1	t_2	t_3	t_4	t_5

Analysis and Graphs

You are asked to plot height vs. time and velocity vs. time graphs for free fall and Atwood machine experiments.

Height vs. time Plots

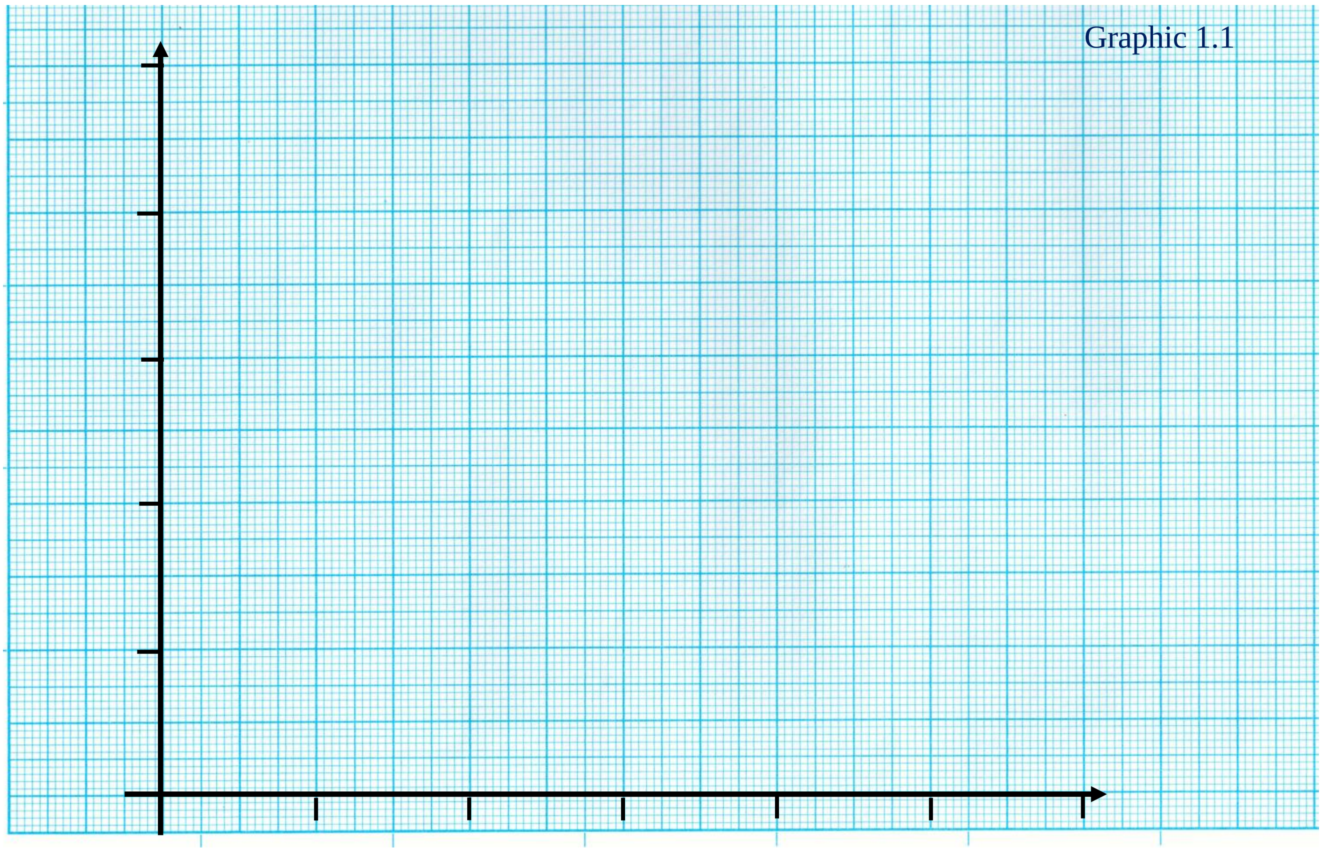
Fill in the right column of Table 1.3 by subtracting the heights in Table 1.1 from the holder height. Fill in the left column of Table 1.3 by the average values of the 5 time measurements of the corresponding heights.

Table 1.3 Fall time vs. fall height table for free fall experiment

Fall time (…..)	Fall height (…...)

Express the data in Table 1.3 as points on your plot. Regarding the theoretical background, what type of a curve is expected to pass through the points?

Draw this curve by fitting it to points as good as you can by your crude eye estimation.



Fill in the right column of Table 1.4 by subtracting the heights in Table 1.2 from the holder height. Fill in the left column of Table 1.4 by the average values of the 5 time measurements of the corresponding heights.

Table 1.4 Fall time vs. fall height table for Atwood machine experiment

Fall time (…..)	Fall height (…...)

Express the data in Table 1.4 as points on your plot. Regarding the theoretical background, what type of a curve is expected to pass through the points?

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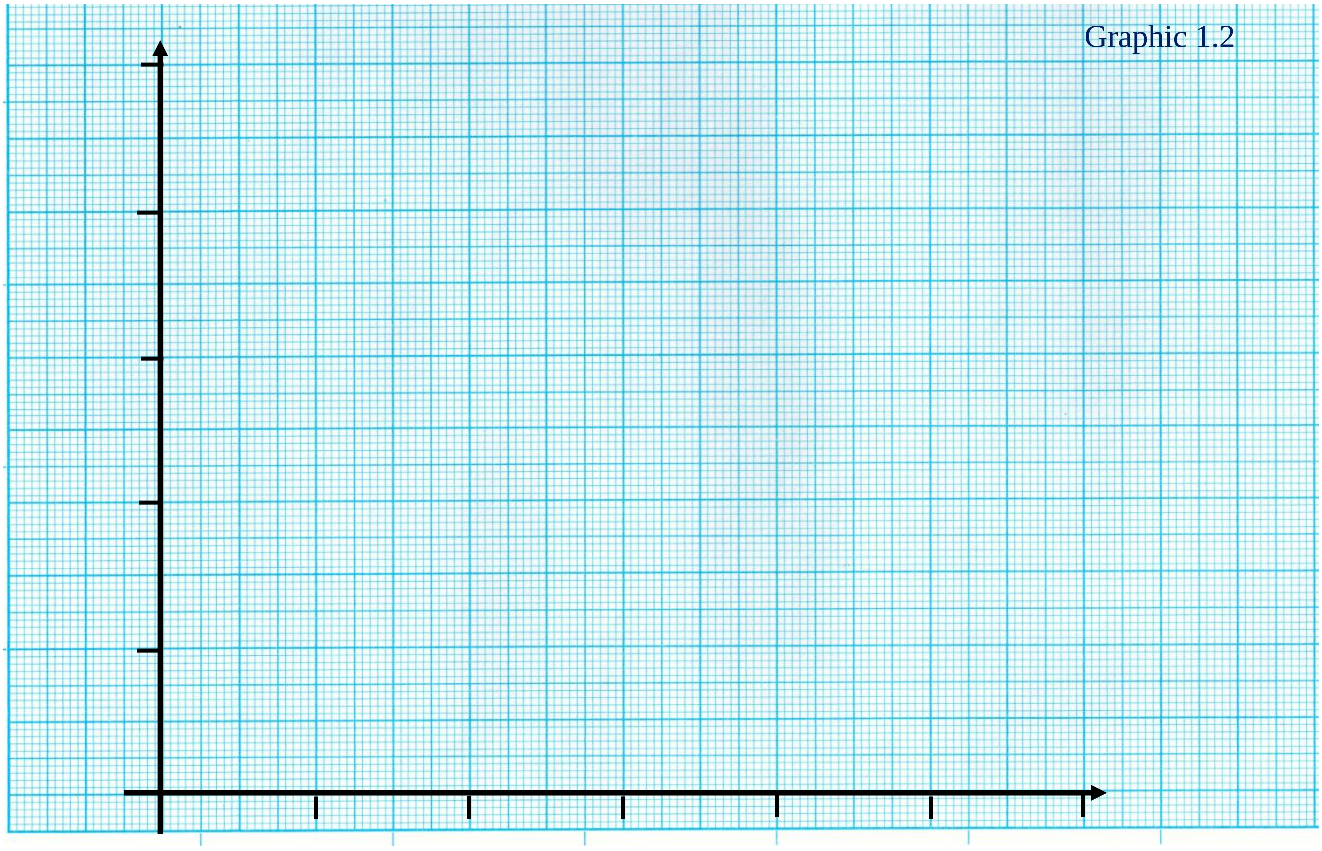
Draw this curve by fitting it to points as good as you can by your crude eye estimation.



Velocity vs. time plots and gravitational acceleration calculation

The velocities are not directly measured in the experiment hence you need to calculate them. If we consider the relation between height and the time $h = \frac{1}{2}gt^2$ and move one of the t's on the right hand side to the left we get the following equation:

$$\frac{h}{t} = g\frac{t}{2} \qquad 1.16$$

The left hand side of 1.16 has the dimension of velocity and equates to the *average velocity* of a freely falling body from a height of h. To be able to plot this value as an instantaneous velocity (by a point on graph) it should be plotted against the half of the flight time as can be seen from the equation. Give a physical explanation of this below:

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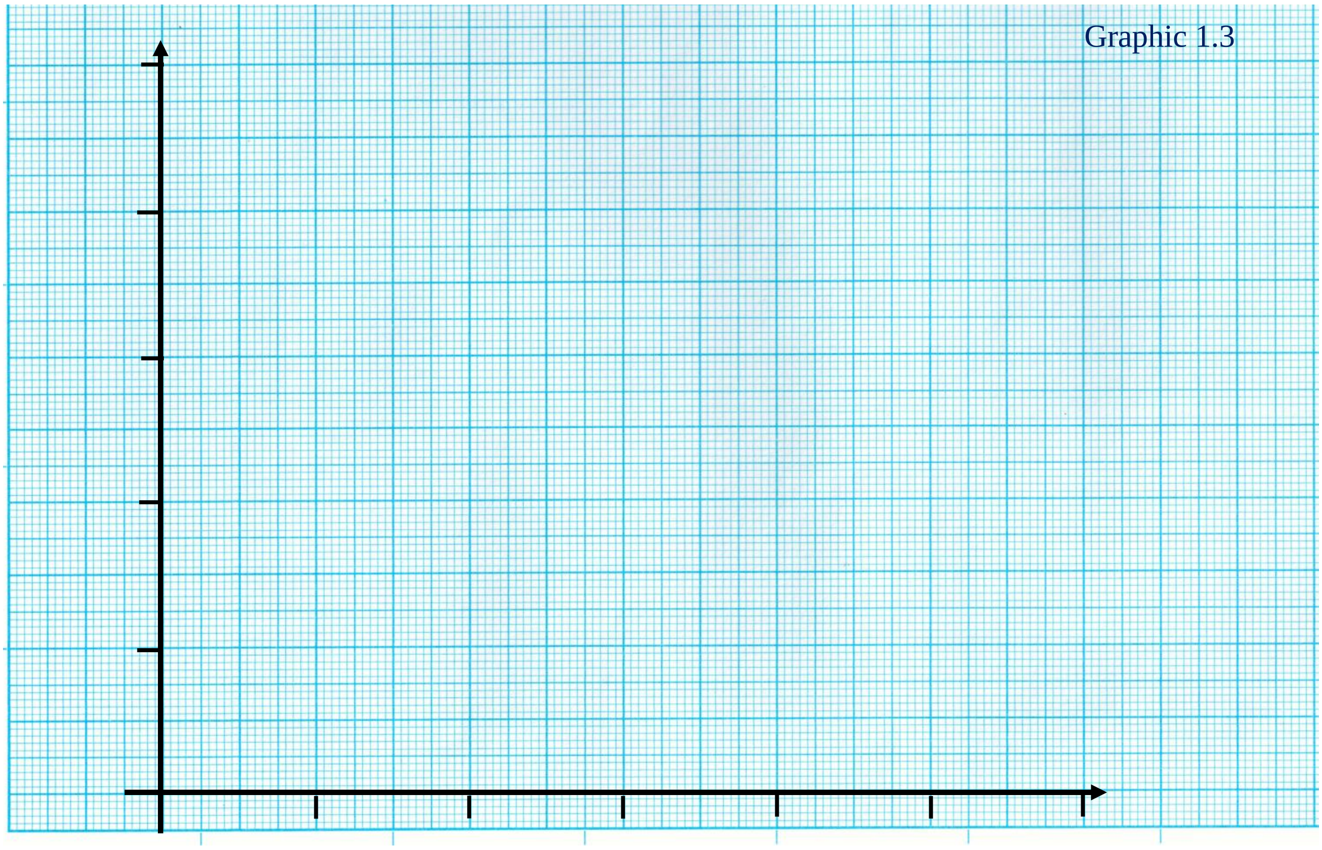
Fill in the left column of Table 1.5 using the half of the time values in the Table 1.3. Fill in the right column of Table 1.5 by dividing the height values to the time values in the Table 1.3.

Table 1.5 Velocity vs. time table for the free fall experiment

Time (…..)	Velocity (.....…...)

Express these data as points on your plot. Since it is expected to be a motion with constant acceleration we expect a line with the equation $v = gt$ to pass through these points. You are asked to calculate the gravitational acceleration g which corresponds to the slope of this line. Use the linear fitting formula to calculate g below:



$$\sum_{i=1}^{5} t_i =$$

$$\sum_{i=1}^{5} v_i =$$

$$\sum_{i=1}^{5} t_i v_i =$$

$$\sum_{i=1}^{5} t_i^2 =$$

$$g = \frac{5.\sum_{i=1}^{5} t_i v_i - \sum_{i=1}^{5} t_i \sum_{i=1}^{5} v_i}{5.\sum_{i=1}^{5} t_i^2 - \left(\sum_{i=1}^{5} t_i\right)^2} =$$

$g_{experimental} =$ ....

Use this value to plot the line on your graph and observe how it fits with your experimental points. Use Eq. 1.5 to calculate the gravitational acceleration at the lab that you performed the experiment. (Gebze Technical University latitude: North 40,81^o, Altitude: 13 meter)

$g_{expected} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

Compare the two values and calculate the percentage difference. Discuss the possible reasons for the differences.

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Now we are going to repeat the same procedure for Atwood machine experiment. But this time we expect the acceleration to be given by Eq. 1.13. Using the same logic use the values in Table 1.4 and the equation $\frac{h}{t} = a\frac{t}{2}$ to fill in Table 1.6.

Table 1.6 Time vs. velocity table for the Atwood machine

Time (…..)	Velocity (....…...)

Express these data as points on your plot. We expect a line with the equation $v = at$ to pass through these points. You are asked to calculate the acceleration a of the Atwood machine which corresponds to the slope of this line. Use the linear fitting formula using the values of Table 1.6 to calculate the acceleration below:

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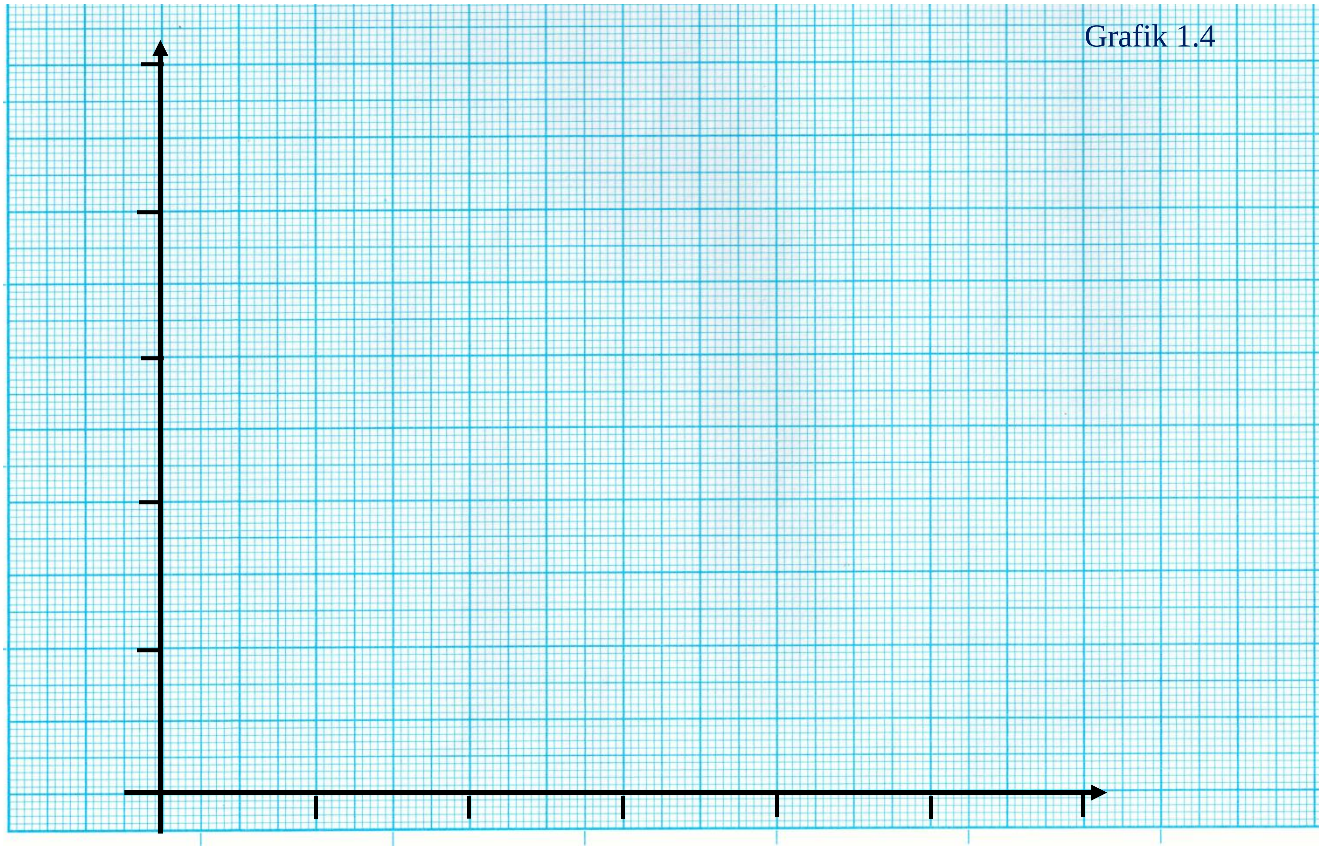

$$\sum_{i=1}^{5} t_i =$$

$$\sum_{i=1}^{5} v_i =$$

$$\sum_{i=1}^{5} t_i v_i =$$

$$\sum_{i=1}^{5} t_i^2 =$$

$$a = \frac{5 \cdot \sum_{i=1}^{5} t_i v_i - \sum_{i=1}^{5} t_i \sum_{i=1}^{5} v_i}{5 \cdot \sum_{i=1}^{5} t_i^2 - \left(\sum_{i=1}^{5} t_i\right)^2} =$$

$$a_{experimental} =$$

Draw the line on your graph using this acceleration and observe the fitness of the line to data points. Use Eq. 1.13 to calculate the expected value of the acceleration. The mass of the pulley is 8 grams. (M = 8 gr).

$a_{expected} =$

Compare the two values with each other. Calculate the percentage difference and discuss the possible reasons for this difference.

Calculate g using $a_{experimental}$. What is the percentage error? Which of the experiments (free fall or Atwood's machine) has less error? Discuss the reasons.

Conclusion, Comment and Discussion:

(Tips: Give detail explanation about what you've learned in the experiment and also explain the possible errors and their reasons.)

Questions:

1. Use Eq. 1.5 to calculate how much the gravitational acceleration differs on the poles and the equator of the Earth at sea level.

2. Compare the *distribution* of consecutive time values measured at same height in the free fall and Atwood machine experiment. Are the random errors same in these experiment. How can this be expressed mathematically. If the random errors are different what might be causing the difference?

3. Watch the video named: "Weak Equivalence Principle test on the moon" at the link: https://www.youtube.com/watch?v=MJyUDpm9Kvk.Calculate the falling times of the feather and the hammer which the astronaut drops. (Use Eq. 1.4 to calculate the gravitational acceleration on moon, investigate the other necessary constants on internet, assume he is dropping from a height of 1,5 meters) Does this time matches the one that you observe in the video?

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