UM-SJTU Joint Institute

Physics Laboratory
(PHYS1410J)

Laboratory Report

Excercise 0

Measurement of the Acceleration Due to Gravity

Name: Jane Doe   ID:12345678   Group:0
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[rev4.1]

1 Introduction

The objective of the experiment was to find the value of the acceleration due to gravity, based on measurements of the period of a simple physical pendulum and the dependence of the period on the length of the pendulum.

A simple pendulum consists of a point mass m suspended on a mass less in extensible thread with length l, placed in a uniform gravitational field characterized by acceleration g. If a simple pendulum is displaced from the equilibrium position by a small angle α, it may be approximately treated as a harmonic oscillator, and the solution of its equation motion is a periodic function of time (cosine) with the period.

$$T = 2\pi \sqrt{\frac{l}{g}} \tag{1}$$

Hence, by measuring the period T and the length of l a pendulum it is possible to find the value of the acceleration due to gravity as

$$g = \frac{4\pi^2 l}{T^2} \tag{2}$$

2 Experimental setup

The pendulum used in the experiment is a metal ball attached to a fine light thread of adjustable length. The thread is suspended on a solid bar attached to the wall. The measurement system consists of an optoelectronic sensor OS connected to a digital timer MCR–21. The diagram of the experimental setup is presented in Figure 1.
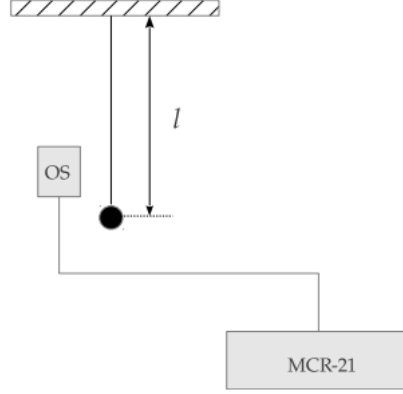
Figure 1: Experimental setup.

The optoelectronic sensor generates an impulse each time the thread passes through the gate of the sensor. The timer is a digital device allowing measurements with maximum uncertainty of $0.01s$. It starts the measurement after the first impulse from the sensor, skips the next impulse, and ends the measurement when the third impulse arrives, thus measuring the time of one period of oscillations.

The length of the pendulum was determined by using a measurement tape with maximum uncertainty $1mm$. However, the precision of this measurement was smaller. This is because the distance from the point the thread was attached to the ball and the ball's center could only be determined approximately. Therefore the maximum uncertainty of the thread length measurement has been estimated at $5mm$.

The length of the thread can be adjusted

3   Measurements

This part should describe the measurement procedure (it can be also mergedwith the previous section into a single section). This is also the section, where any comments/observations regarding the measurements should be made. These include, but are not limited to: abnormal functioning of measurement devices, instability of readings, etc.

3.1 Measurements of the period of oscillations

The position of the sensor was adjusted so that the pendulum placed out of the equilibrium was able to trigger a signal. After the digital timer was reset, the pendulum was displaced from the equilibrium position and released. The reading on the timer was recorded. The above measurement of the period of 3 oscillations was repeated ten times and the obtained data is presented in Table 1.

Then, the length of the thread was measured by measuring the distance between the suspension point and the center of the ball. Because of the fact that the position of the ball's center was determined only approximately, the uncertainty of this measurement is much larger than the maximum uncertainty of the measurement tape.

The period of oscillations was measured for different lengths of the pendulum (cf. Table Table 1).

$Measurement$	$l[m] \pm 0.005[m]$	$T[s] \pm 0.01[s]$	$T^2[s^2]$	$\mu_T^2[s^2]$
1	0.500	1.38	1.90	0.03
2	0.700	1.68	2.82	0.03

Table 1: Data for the dependence of the oscillation period on the length of the pendulum.

3.2 Relation between the period of oscillations and the pendulum length

The measurements of the period of oscillations were analogous to those in the previous section. For each length of the thread one measurement of the period was performed. The length of the thread was increased from 0.5 to 2.1 m in steps of 0.2 m. The results of the measurements are presented in Table 2 (columns 1 through 3).

4 Results

In this section the results of your measurements should be presented. Usually tables and graphs are the best ways to present the results. The values of all physical quantities (both: measured and calculated based on the measurements) must be expressed using the appropriate SI units. This section

should also include calculations with all intermediate steps (in case of re-peated calculations, one sample calculation is enough). If any values are calculated by data analysis software (e.g. Origin, QtiPlot, R), it should be clearly indicated.

4.1 Measurements of the period of oscillations

The period of oscillations was measured in the procedure described in section 3.1 and the average value was calculated based on the results presented in Table 1 as

$$T^- = \frac{1}{10} \sum_{i=1}^{10} T_i = 2.21 \pm 0.02s \tag{3}$$

Using the value of the slope from the linear in the relation (3), the acceleration due to gravity can be found as

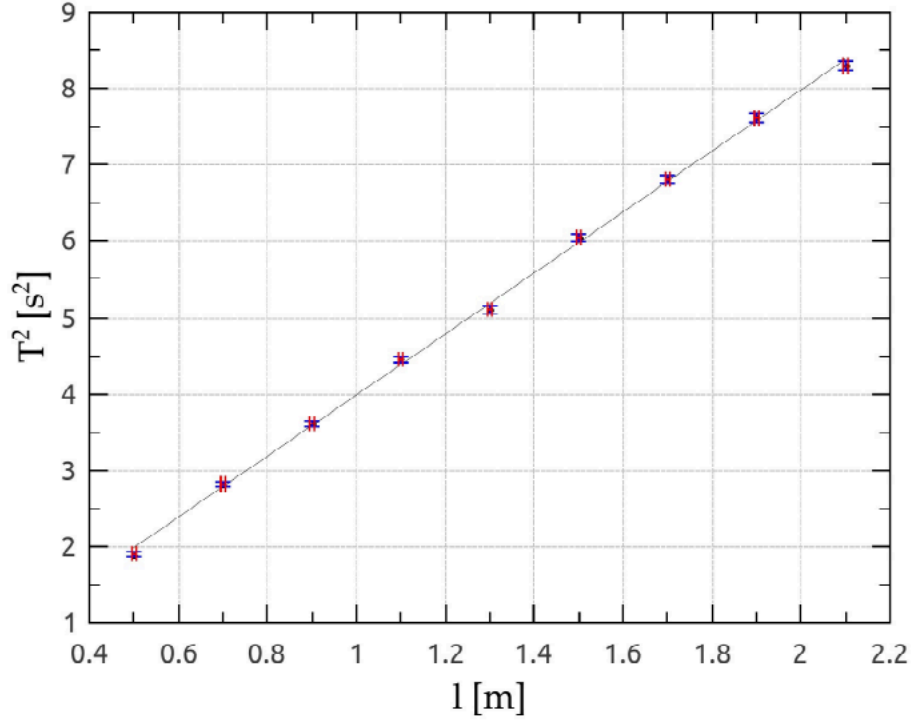$$g = \frac{4\pi^2}{\alpha} = \frac{4 \cdot 3.14159^2}{4.00} = 9.88 \pm 0.11 m/s^2 \tag{4}$$

Figure 2: Measurement data (dots) with error bars (red for l, blue for T^2) and a linear fit to the data (solid line) for the relation between the period of oscillations squared and the pendulum's length. The value of R^2 for the obtained fit is 0.999.

4.2 Relation between the period of oscillations and the pendulum length

5 Conclusions and discussion

In the experiment the acceleration due to gravity was found first by measuring the period of oscillations for a fixed length of the pendulum, and then by measuring the period for different lengths and finding the acceleration due to gravity from the slope of the T^2 vs. l line. The two methods yielded the values

$$g = 9.82 \pm 0.08 m/s \text{ and } g = 9.88 \pm 0.11 m/s, \tag{5}$$

respectively, with the former method yielding the result with slightly smaller uncertainty. Both values conform (within the uncertainty range) to the value $9.81 \pm 0.07 m/s2$ quoted for Happy Town in the paper A. Smith, Journal of Experimental Physics, 18 1234 (2001).

The fundamental source of inaccuracy of both methods is the fact that the formula for the period of oscillations (1) is valid only under the assumption that the motion is harmonic, what in the case of a simple pendulum is only approximately valid for small angles. In general, for a simple pendulum, the period depends on the amplitude, and for different angular displacements from the equilibrium position, the measured values of the period differ.

The other factors that have been neglected in the model yielding the formula (1) include: the fact that the thread is not perfectly in extensible; viscous air and other dissipative forces dampen the pendulum's motion; non-inertiality of the earth (the latter, however, being a small effect that can usually be safely neglected).

The precision of the measurements, can be further increased by re-designing the measurement of the pendulum's length. The uncertainty of this measurement, which is greater than the resolution of the measurement tape, is mainly due to the fact that the distance to the center of the ball cannot be measured accurately. Instead of measuring the total distance between the suspension point and the center of the ball by a measurement tape, the radius of the ball may be measured separately (e.g. in a calliper measurement).

A Datasheet

Please remember to attach the original data sheet signed by your instructor.