

# FYS2150

## Lab Report: Time and Frequency

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The goal for this lab was measuring time, and comparing three methods of doing so, of varying degrees of "sophistication"; an hourglass, a stopwatch and a photo-diode.

### I. INTRODUCTION

The lab spanned 6 hours and consisted of measuring the period of a pendulum using three different methods of measurement; an hourglass, a stopwatch and a photo-diode connected to a computer. The experiments were performed by myself, and my lab partner Lars K. Skaarseth. Before anything else, it is worth to note that the first experiment can largely be disregarded due to an error on our part, more on this in section III F 1.

### II. THEORY

The theory used in this lab report is almost entirely summed up by the following equations;

$$T = 2\pi\sqrt{\frac{L}{g}} \quad (1)$$

Where  $T$  denotes the period a swinging pendulum,  $L$  the length of the wire by which the pendulum is suspended and  $g$  the downward acceleration on the pendulum due to gravity.

$$\vec{R} = \frac{1}{M} \sum_i m_i \vec{r}_i \quad (2)$$

Where  $\vec{R}$  denotes the position of the center of mass of a body of mass  $M$  consisting of several smaller bodies of mass  $m_i$  with individual center of mass at  $r_i$ .

Further detail can be found in "Elementary Mechanics Using Python" [1], or most other books covering introductory mechanics.

### III. EXPERIMENTAL PROCEDURE

#### A. List of equipment used

- Hourglass, generic, unknown duration
- Pendulum, Aluminium cylinder, see Fig. 1
- Stopwatch, Cielo 100MT
- Photodiode
- Cables

- Meter-rule, Hultafors
- Powersupply
- Data aquisition tool, NI USB-6211
- PC with MATLAB installed
- Umbraco Key
- Screwdrivers
- Reflective tape

#### B. Preparation

We connected an aluminum cylinder to a block of aluminum secured to a desk with a (i believe nylon?) string as shown in Fig. 1. For the purposes of this experiment the string is assumed to be inextensible.

The string was turned on the Outer side of the screws on the top block, and the inner at the bottom so that the string would form a "V" shape, or positive angle. This was done in an attempt to limit the sideways motion of the block as much as possible, so that more of its kinetic energy would be restricted to the forward/backward motion (from the perspective of Fig. 1), which is the motion being measured in these experiments.

The length of the string, and later, the dimensions of the pendulum (As shown in Fig. 1) were measured using a Hultafors meter-rule with an uncertainty of  $\pm 1mm$  as well as a small uncertainty due to thermal expansion. Since we did not record the temperature in the room, i will assume standard temperature and pressure, thus negating the need to account for thermal expansion.

#### C. Hourglass

In this this initial part of the experiment, we wanted to measure the number of swings made by the pendulum for the duration of an hourglass with an unknown duration. After having released the pendulum, we let it swing for one period before starting the hourglass, then both i and my lab partner then counted the number of swings separately in an attempt to minimize the chance human error when counting. Since we only counted complete swings, the measured value has an uncertainty of  $\pm 1T$ . The hourglass was also kept still on a table for its complete duration.

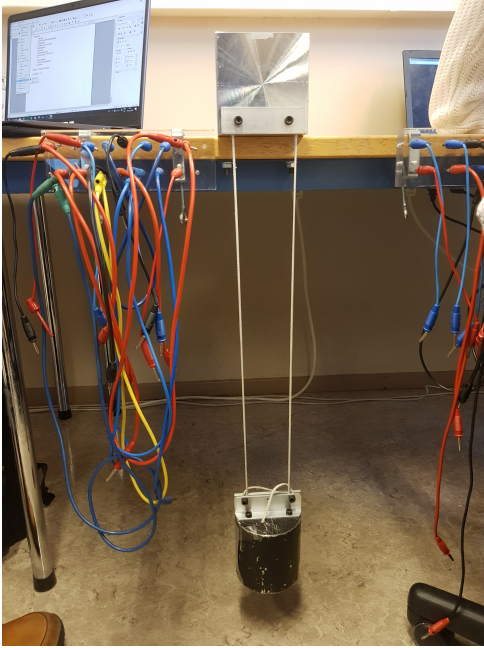


FIG. 1. A photograph showing how the pendulum was set up

#### D. Stopwatch

This part is mostly similar to the last one, the only difference being the method of measuring the period. This time we used a stopwatch (Cielo 100MT, uncertainty of  $\pm 0.01s$ ) to record the time. In order to minimize human error, we opted to only measure the time every 10th swing and again, both of us counted the swings individually ensuring we would not record the time at the wrong number of swings. We used the lap function of the stopwatch to save the time taken for every 10th swing as well as the total running time for the 100 swings that we recorded.

A rather significant source of error in this experiment comes from the reaction time, and to some extent the judgment of the person who is recording the time (he had to judge when the pendulum was at its apex).

#### E. Photo-diode

In this part, we made our measurements electronically using a photo-diode connected to a computer with MATLAB via a data acquisition box (NI USB-6211). A photo-diode sends out IR light, when this light is not reflected back to an IR sensitive receiver, the photo-diode emits a constant 5V. When the IR light is reflected back to it, it instead emits 0V. For this reason, we had to attach a reflective material to the block of aluminum. We opted for some aluminum foil. Once everything was properly connected (see Fig. 2) we ran a MATLAB script **svingepe-riode.m** to record the data and started the pendulum as previously. We repeated this 4 times with different set-

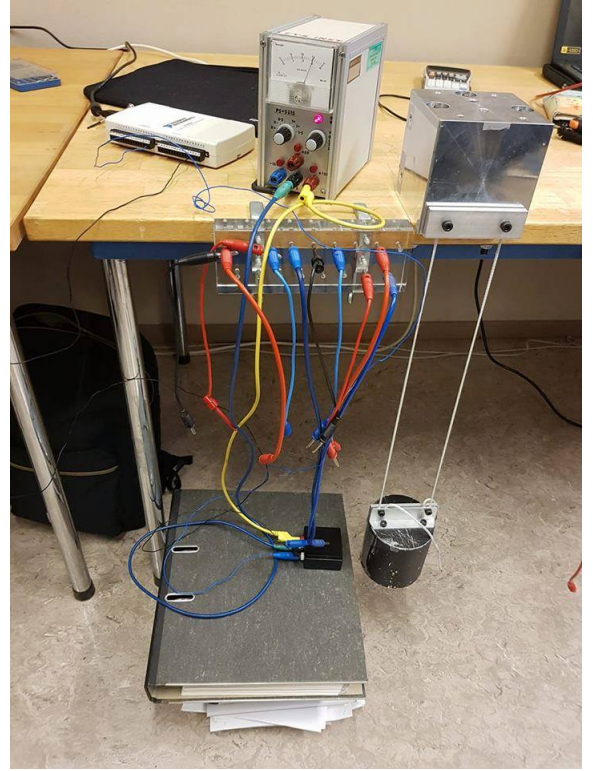


FIG. 2. A photograph showing how the photo-diode was set up and connected to the data acquisition box (NI USB-6211) for experiment no. 3 (Section III E)

tings and conditions. Experiment 1 & 2 were identical, measured at different frequencies. For experiment 3, we positioned the photo-diode such that it would aim at the top of the cylinder when it was at rest. In experiment 4, the pendulum was given a push rather than releasing it from rest.

#### F. Measuring lengths

##### 1. Length of string

When measuring the length of the string, we measured it between the middle of the two strings, from the bottom and top of the aluminum at the top and bottom parts of the string respectively. We took great care to ensure that the pendulum was at rest when making the measurement, and kept our heads level with the ruler, and one eye closed when taking the reading in an attempt to minimize any misreading due to parallax. We also rested the Hultafors meter-rule against a right-angle ruler in an additional attempt to minimize the error. We took 3 repeated readings, one of which was performed by a different person.

After we had completed our measurements with the hourglass, we noticed a rather large initial rotational and sideways instability in the pendulum, leading us to (mis-

takingly, see section V A) shorten the string by roughly 10cm. After having changed the length of the string, we repeated the exact same procedure of measuring the new length except we only did two measurements, again alternating who took the reading.

## 2. Dimensions of cylinder

The cylinder, and bracket on top where the string is connected was also measured using the Hultafors meter-rule. This time, we only made one measurement per length, all done by the same person. Other than that, similar considerations were made as when measuring the string.

## IV. RESULTS

TABLE I. Length of string

Measurement No.	1	2	3
Length, Hourglass experiment [cm]	53.4	52.9	52.9
( $\pm 0.1\text{cm}$ )			
Length, Stopwatch & Photo-diode experiment [cm] ( $\pm 0.1\text{cm}$ )	45.3	45.2	

### A. Pendulum & Hourglass

The number of oscillations during the draining of the hourglass is listed on table II

TABLE II. Measurements with Hourglass

Recording no.	Number of oscillations ( $\pm 1$ )
1	116
2	121
3	128
Mean	122
Std. Dev.	5

### B. Pendulum & Stopwatch

The period of the pendulum measured with the stopwatch is listed on table III

### C. Pendulum & Photo-diode

Fig.3, Fig.4, Fig.5 and Fig.6 shows the result from experiments 1-4 listed on table IV respectively.

TABLE III. Measurements with Stopwatch

Number of periods	Time per 10 oscillations [sec] ( $\pm 0.01$ )	Total time [min:sec] ( $\pm 0.01$ )
10	14.14	14.14
20	14.31	28.53
30	14.32	42.85
40	14.40	57.25
50	14.29	1:11.54
60	14.39	1:25.93
70	14.29	1:40.72
80	14.34	1:54.46
90	14.20	2:08.76
100	14.52	2:23.28
Mean period	14.33	N/A
Std. Dev	0.10	N/A

TABLE IV. Measurements with photo-diode

Experiment no.	Standard deviation of mean period	Mean period	Position of diode	Total measured time [s]	Measuring frequency [KHz]
1	5.6540e-4	1.4421	Bottom	120	25
2	8.8552e-4	1.4502	Bottom	120	200
3	0.0483	1.5816	top	120	25
4	0.0026	1.4922	Bottom	120	25

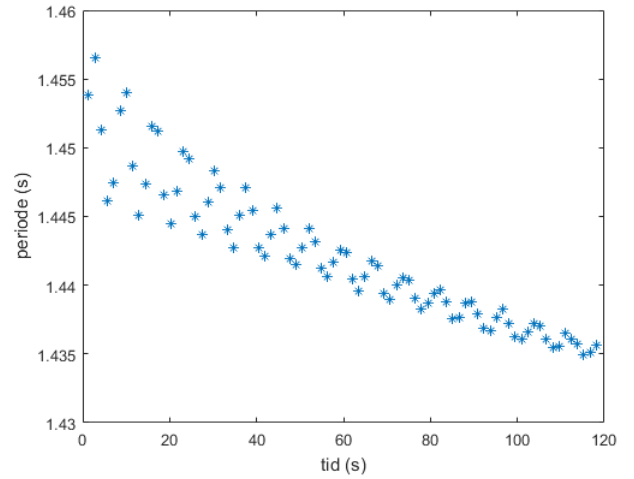


FIG. 3. Data from Experiment no. 1 using the photo-diode <sup>a</sup>

<sup>a</sup> Due to poor planning on my part, this figure, and the following all lack figure titles. I mistakenly did not keep all of the .mat files

## V. DISCUSSION

### A. Problems

As mentioned in the introduction, we did make one rather large experimental error, which does taint our

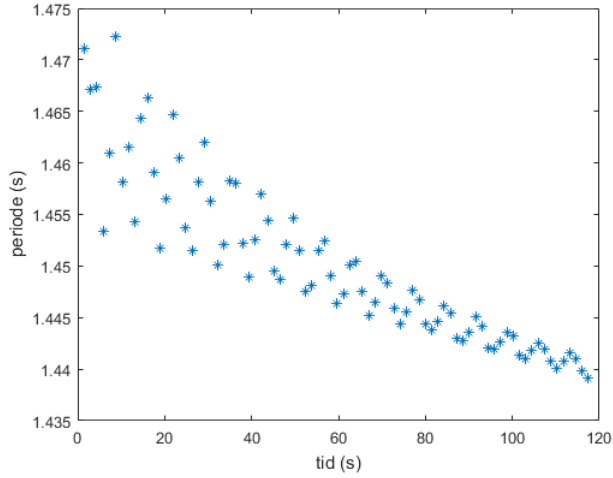


FIG. 4. Data from Experiment no. 2 using the photo-diode

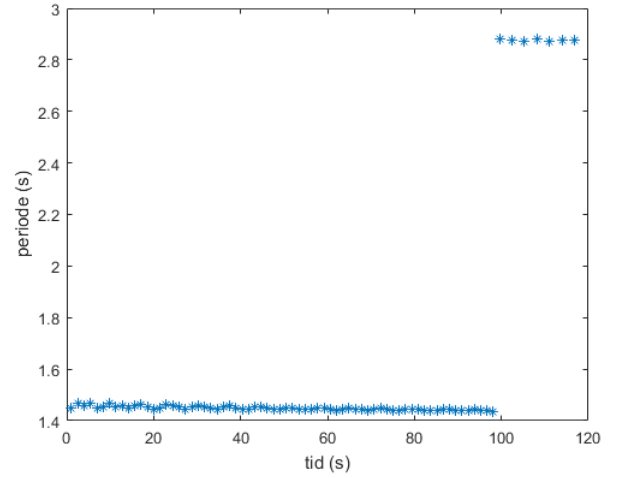


FIG. 5. Data from Experiment no. 3 using the photo-diode

data somewhat. After having completed our measurements with the Hourglass, we noticed a rather large initial sideways and rotational instability when attempting to start the pendulum for our measurements with the stopwatch. In order to minimize this instability, we decided to shorten the string, not considering the ramification this had on our data.

## VI. CONCLUSION

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- [1] Anders Malthe-Sorensen. *Elementary Mechanics Using Python*. Springer, 2015.

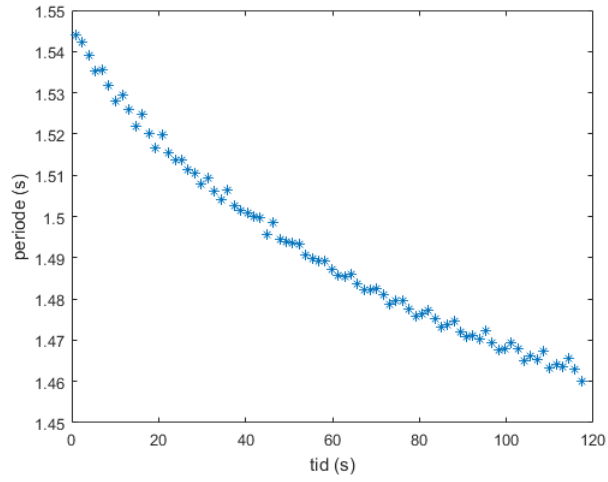


FIG. 6. Data from Experiment no. 4 using the photo-diode