Name:
Study group No.: 2
Date: April 17, 2017
Experiment No.: 4
Title of the experiment:

Pohl's pendulum

Obsah

1 Details of the laboratory execrcise

1.1 Purpose of the experiment

- To calculate coefficient of damping and period of free oscillations of the Pohl's pendulum of different dampings.
- To plot graphs of amplitude vs. time for free oscillations for different dampings.
- To investigate frequency characteristics of the forced oscillations of the Pohl's pendulum for different dampings and plot appropriate graph.
- Tank with a electrolyt

1.2 List of Apparatus

- Pohl's pendulum-size of error-$0.1[-]$
- Stopwatch-size of error-$0.01s$
- Power supply
- AC/DC converter
- Potentiometer

2 Data

2.1 Free oscillations

2.1.1 Time

Measured for free oscillation without damping.

	1	2	3	4	5
***Time*[s]**	17.87	17.64	17.76	17.83	17.58

Table 1: Total times of 10 periods.

2.1.2 Extreme positions

We use camere to measure these values from the right side of the pendulum.
Indicator position=1
U_b stands for potential going through an electromagnetic brake.

$U_b[V]$ \ $Ext.pos.[cm]$	1	2	3	4	5	6	7	8	9	10
0	19.4	18.6	18,2	17.4	16.8	16.2	15.6	15.2	14.6	14.2
4	18.8	17.6	16.4	15.4	14.6	13.4	12.6	12	11.2	10.2
6	16.8	14.4	12.6	11	9.6	8.2	7.6	6.4	5.6	4.8
8	15	11.6	9.4	7.2	5.6	5	3	2.6	2,2	2
12	10.8	6.4	3.6	2.2	1.6					

Table 2: Extreme positions for free oscilations

2.2 Forced oscillations

2.2.1 Time

Measured for 10 revolutions of the motor with electromagnetic brake disconnected.

$Motor[V]$	3	5	7	7.5	8	10	12
$Time[s]$	49.66	29.79	21.28	19.86	18.62	14.9	12.4

Table 3: Total times for 10 revolutions

2.2.2 Amplitudes

Indicator position=1

	Lower | Upper extreme point[cm]													
$U_B[V]$ \ $U_M[V]$	**3**		**5**		**7**		**7.5**		**8**		**10**		**12**	
4	0.4	1.4	0.2	1.6	-1.4	3.2	-11	12.6	-2.2	4.4	0.4	1.4	0.6	1.2
6	0.4	1.4	0.2	1.6	-1.3	3.0	-5.6	7.2	-2.4	4.4	0.4	1.4	0.6	1.2
8	0.4	1.4	0.2	1.5	-1.0	2.8	-2.8	4.4	-1.8	3.4	0.4	1.4	0.6	1.2
12	0.4	1.2	0.2	1.4	-1.0	2.8	-2.6	4.2	-1.8	3.4	0.4	1.4	0.6	1.2

Table 4: Displecemnts and frequencies of forced oscillations

U_B stands for voltage on the brake and U_M for voltage in the motort

3 Computations

3.1 Average period

Average of the measured values is calculated using this quation:
$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ where x_i are all measured values.

Average time for 10 periods is:$\bar{T_{10}} = \frac{1}{10}\sum_{i=1}^{10} T_i = 17.74s$

Average period:$\bar{T} = \frac{17.74}{10} = 1.77s$

3.2 Uncertainties

3.2.1 Standard A type

Standard A type uncertainty can be calculated with this equation:

$$u_A(\bar{x}) = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where n is the number of measurements, x_i are all measured values and $\bar{x}$ is an average of these values.

Period uncertainty:$u_A(\bar{T}) = \sqrt{\frac{1}{10(10-1)}\sum_{i=1}^{10}(T_i - \bar{T})^2} = \sqrt{0.00003} = 0.0055s$

3.2.2 Standard B type

Standard B type uncertainty can be calculated by:

$$u_B = \frac{\Delta}{\sqrt{12}}$$

where Δ is the least division on the scale of the measuring device.
Pendulum uncertainty:$u_B = \frac{0.1}{\sqrt{12}} = 0.029[-]$
Stopwatch uncertainty:$u_B = \frac{0.01}{\sqrt{12}} = 0.0029s$

3.2.3 Combined uncertainty

Combined uncertainty is calculated with this eqatuion:$\sqrt{u_A(x)^2 + u_B{}^2}$
$u_A(x)$ is standard type A uncertainty of sample and $u_B{}^2$ stands for standart type B uncertainty of used device.
Average period uncertainty:$\sqrt{0.00003 + 0.0000083} = 0.0062s$

Period $\boldsymbol{T = (1.7736 \pm 0.0062)s}$

3.3 Frequency

Frequency can be calculated using formula: $f = \frac{1}{T}$
where T is a period. $f = \frac{1}{1.7736 \pm 0.0062} Hz$

Frequency $\boldsymbol{f = (0.564 \pm 0.0002)s}$

3.4 Free oscillation

Average value of the logarithmic decrement of damping Λ and coefficient of dumping δ can be calculated using formula:

$$\Lambda = \delta \times T = ln\frac{\varphi(t)}{\varphi(t+T)}$$

3.4.1 Oscillation without damping

Initial position is 1 so we decrement each value by 1.

$$\Lambda = \frac{ln\frac{18.4}{17.6} + ln\frac{17.6}{17.2} + ln\frac{17.2}{16.4} + ln\frac{16.4}{15.8} + ln\frac{15.8}{15.2} + ln\frac{15.2}{14.6} + ln\frac{14.6}{14.2} + ln\frac{14.2}{13.6} + ln\frac{13.6}{13.2} +}{9} \doteq 0.037[-]$$

$$\delta = \frac{0.04}{1.77} \doteq 0.021/s$$

3.4.2 Results for all dampings

$$\boldsymbol{Period \quad T = (1.7736 \pm 0.0062)s}$$
$$\boldsymbol{Frequency \quad f = (0.564 \pm 0.0002)s}$$

Damping[V]	Λ	$\delta[s^{-1}]$
0	0.037	0.021
4	0.073	0.041
6	0.16	0.089
8	0.31	0.17
12	0.70	0.39

Table 5: Results for free oscillation

3.5 Forced oscillation

Due to the fact, that the stable position of a pendulum was not exactly zero, we calculated the amplitude as an average by formula: $A = \frac{(1-lowerextreme)+(upperextreme-1)}{2}$, where 1 is actual initial position.

3.5.1 Calculation for motor voltage 3V and brake voltage 0V

$$A = \frac{(1.0-0.4)+(1.4-1.0)}{2} = 0.5\ cm$$
$$T = \frac{T_{10}}{10} = \frac{49.65}{10} \doteq 4.97\ s$$
$$f = \frac{1}{4.97} \doteq 0.2\ Hz$$

3.5.2 Results for the voltages

$U_B[V]$ \ $U_M[V]$	Average displacement[cm] | Driving frequency[Hz]													
	3		5		7		7.5		8		10		12	
0	0.5	0.2	0.7	0.34	2.3	0.47	11.8	0.5	3.3	0.54	0.5	0.67	0.3	0.81
4	0.5	0.2	0.7	0.34	2.15	0.47	6.4	0.5	3.4	0.54	0.5	0.67	0.3	0.81
6	0.5	0.2	0.65	0.34	1.9	0.47	3.6	0.5	2.6	0.54	0.5	0.67	0.3	0.81
8	0.4	0.2	0.6	0.34	1.9	0.47	3.4	0.5	2.6	0.54	0.5	0.67	0.3	0.81
12	0.5	0.2	0.6	0.34	1.3	0.47	1.7	0.5	1.4	0.54	0.5	0.67	0.3	0.81

Table 6: Displecemnts and frequencies of forced oscillations

U_B stands for voltage on the brake and U_M for voltage in the motor

4 Results and conclusion

Free oscillations:

$$\boldsymbol{Period\ \ T = (1.7736 \pm 0.0062)s}$$
$$\boldsymbol{Frequency\ \ f = (0.564 \pm 0.0002)s}$$

Damping[V]	Λ	$\delta[s^{-1}]$
0	0.037	0.021
4	0.073	0.041
6	0.16	0.089
8	0.31	0.17
12	0.70	0.39

Table 7: Results for free oscillation

Forced oscillations:

	Average displacement[cm] | Driving frequency[Hz]													
$U_M[V]$ / $U_B[V]$	**3**		**5**		**7**		**7.5**		**8**		**10**		**12**	
4	0.5	0.2	0.7	0.34	2.3	0.47	11.8	0.5	3.3	0.54	0.5	0.67	0.3	0.81
6	0.5	0.2	0.7	0.34	2.15	0.47	6.4	0.5	3.4	0.54	0.5	0.67	0.3	0.81
8	0.5	0.2	0.65	0.34	1.9	0.47	3.6	0.5	2.6	0.54	0.5	0.67	0.3	0.81
12	0.4	0.2	0.6	0.34	1.9	0.47	3.4	0.5	2.6	0.54	0.5	0.67	0.3	0.81

Table 8: Displecemnts and frequencies of forced oscillations

U_B stands for voltage on the brake and U_M for voltage in the motor

We think that our results are not very accurate because we had little time to measure the values on pendulum and we also used swopwatch so human facotor played huge role in this laboratory exercise.

5 Graphs

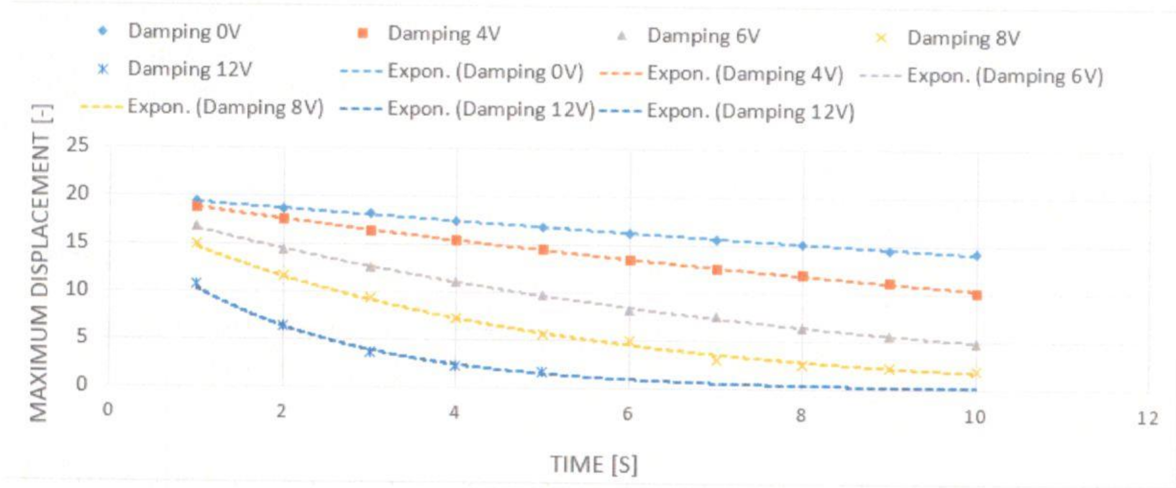

Figure 1: Dependence of the maximum displacement of the pendulum on time

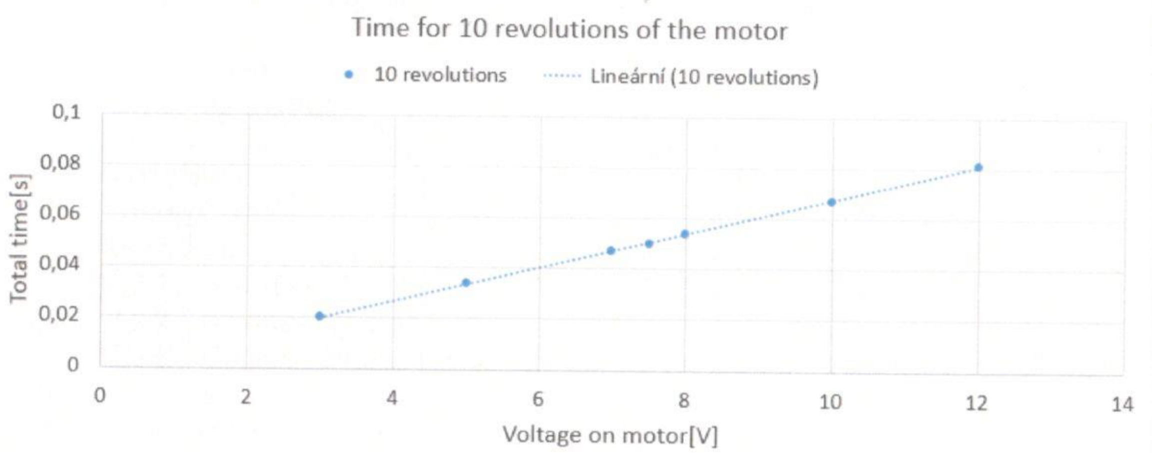

Figure 2: Relation between voltage on motor and periods

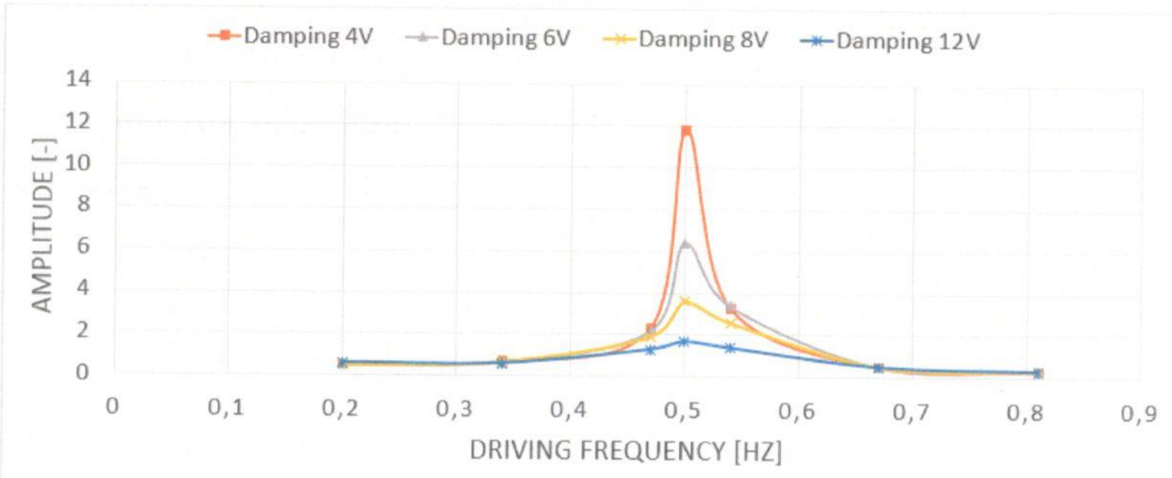

Figure 3: Dependence of amplitude on the driving frequency