Theoretical Introduction

Experiment "T U N I N G F O R K"

Simple and Damped Harmonic Oscillations

Harmonic oscillations are defined as the motion of a mass m, called an oscillator, along the coordinate x, which can be described by the equation:

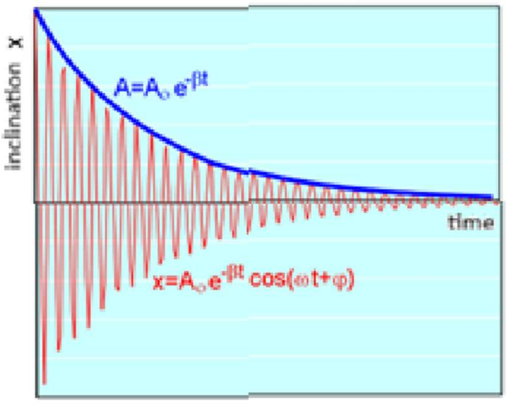
$x(t) = A\cos(\omega t + \varphi)$

where:

A - amplitude; ω – angular frequency of oscillations; φ - initial phase.

In the case of damped oscillations, this equation takes the form:

$x(t) = A_0 \cdot e^{-\beta \cdot t} \cdot \cos(\omega t + \varphi)$



Funkcja ta jest iloczynem dwóch funkcji: $A_0 e^{-\beta \cdot t}$and $\cos(\omega t + \varphi)$. Druga funkcja informuje iż są to drgania harmoniczne, natomiast pierwsza określa zanik amplitudy w czasie.

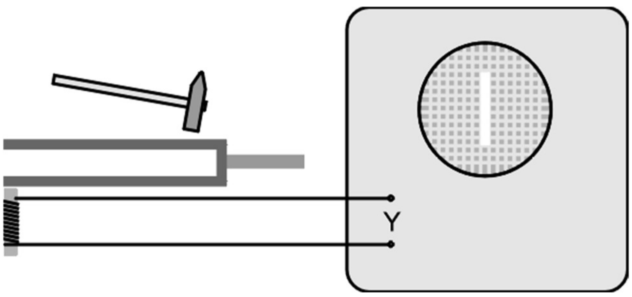
In the exponent of the exponential function, there is the damping coefficient β, expressed in units: [1/s].

Measure of the Amplitude of Tuning Fork Oscillations

A tuning fork is a mechanical instrument in the form of steel forks used to produce a sound wave of a fixed frequency. A standard tuning fork produces a sound with a frequency of: 440 Hz (which corresponds to the ton a^1).

In principle, considerations concerning the value of the amplitude of tuning fork oscillations are not justified, because the amplitudes are different at different points of the tuning fork. However, it is reasonable to discuss both changes in the amplitude of tuning fork oscillations and a measure of amplitude.

The measure of amplitude is reflected on the oscilloscope screen. Technically, this takes place in the way shown in the figure.



The rhythm of oscillations of the steel forks of the tuning fork is transferred to a disturbance of the magnetic field, the source of which is a magnetized core surrounded by an induction coil. Changes in the magnetic field induction induce an electromotive force in the coil windings, which are connected to the "Y" input of the oscilloscope. Changing the time base, the unit of the "X" axis of the oscilloscope, allows the oscillation waveform to be observed on the display..

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Preparation Questions:

1. What are harmonic oscillations?
2. Discuss damped and undamped harmonic oscillations.
3. What is the period of oscillation?
4. What is the frequency of oscillation?
5. Give and discuss the equation of harmonic oscillations.
6. What is the unit of the damping coefficient?
7. Give the dependence of the amplitude of damped oscillations on time.
8. What is a tuning fork?
9. What does the frequency of tuning fork oscillations depend on?
10. What is an oscilloscope?
11. In what frequency range does the human ear perceive sound?
12. What is the unit of sound intensity?
13. Which is greater: bel or decibel?
14. Wavelength — definition and unit.
15. Give and discuss the equation of damped harmonic oscillations.

Instructions for Performing the Measurements

1. Turn on the oscilloscope.
2. According to the instruction available at the workstation, set the oscilloscope measurement parameters:
   - measured voltage range: 200 mV per division,
   - measured time range: 2 seconds per division.
3. Using the rod available at the workstation, strike the tuning fork halfway up its height.
4. According to the instruction available at the workstation:
   - stop the reading of the graph waveform so that it occupies the largest possible part of the screen,
   - set the symmetry of the waveform,
   - set the beginning of the envelope on the first division,
   - set the voltage value reading using the cursor and place the reference cursor V_b on the axis of symmetry of the waveform.
5. Read the amplitude values every 2 seconds as voltage values at the intersection of the envelope with subsequent vertical time axes.
6. After completing the measurements, tidy up the workstation.
7. Perform the calculations according to the instruction and prepare a trial graph in a spreadsheet. In the calculations, remember to use the basic SI units for voltage and time.
8. Prepare a measurement protocol and measurement uncertainties.

NOTE:
Details concerning the operation of the oscilloscope are included in the instruction located at the laboratory workstation

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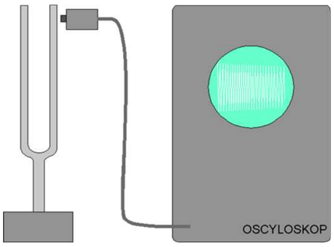
Methodological Template

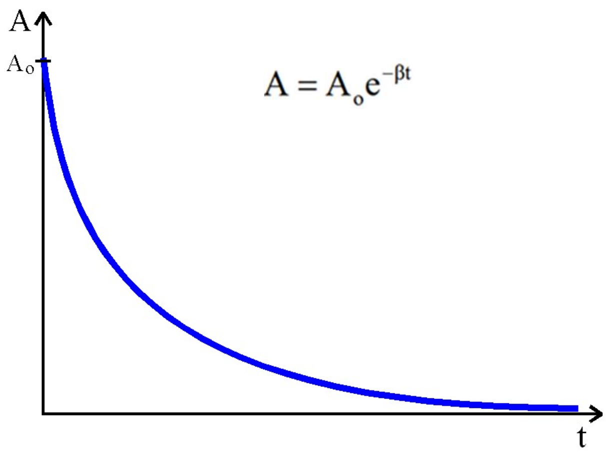
Student 1: Determination of the damping coefficient.
Student 2: Verification of the dependence of the amplitude of decaying oscillations on time.

Theoretical Basis

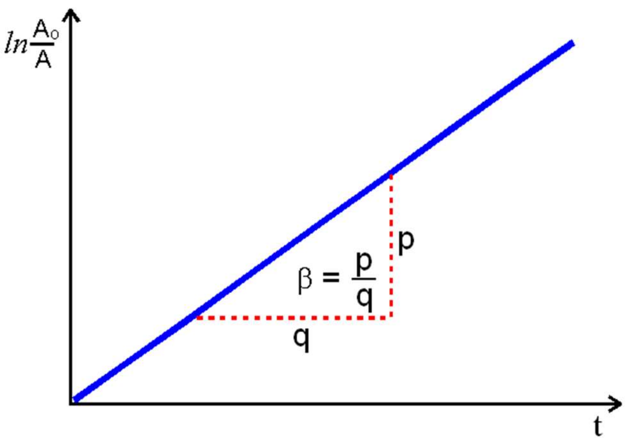


In order to both determine the damping coefficient and verify the theoretical time dependence of the damped oscillation amplitude, it suffices to measure a quantity proportional to the amplitude of oscillations.

The function A(t) models the time-dependent amplitude decay of damped oscillations.

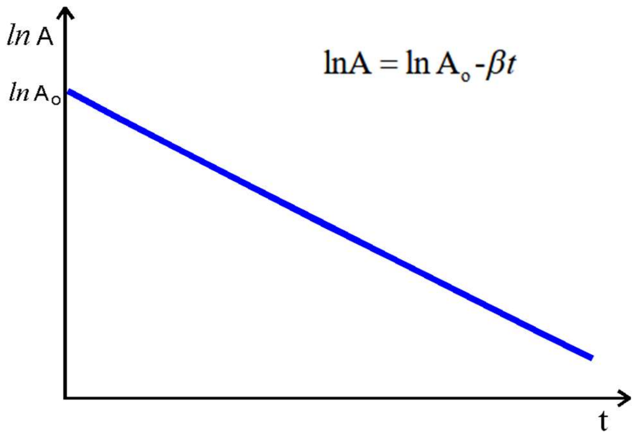


The observation of the oscillation amplitude decay over time can be carried out using a tuning fork, an electromagnetic transducer that converts the tuning fork's vibrations into an electrical signal (voltage), and an electrical voltage meter, such as an oscilloscope



Therefore, in order to determine the damping coefficient of the tuning fork, one should:

- perform measurements of the dependence of amplitude on time
  in practice, an electrical quantity proportional to the amplitude is measured,
- prepare a graph of the dependence:
  $\ln\frac{A_0}{A}$ as a function of: t
- read the value of the damping coefficient.



Therefore, in order to verify the dependence of the amplitude of tuning fork oscillations on time, one should:

- perform measurements of the dependence of amplitude on time
  in practice, an electrical quantity proportional to the amplitude is measured,
- prepare a graph of the dependence:
  $\ln A$ as a function of: t
- analyse its linearity.

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Wskazówki do sprawozdania – wyznaczanie

Student 1: Determination of the damping coefficient.

I. Methodology (conceptual plan of the exercise)
II. Course of the exercise
II.1. Course of activities
II.2. Sketch of the measurement setup
III. Results
III.1. Measurement results

		1	2	3	4	5	6	7	8	9	10
A	[...]										
t	[s]										

ΔA = ...
Δt = ...

III.2. Calculations (example calculations - referring, for example, to measurement no. 4)

$ln\frac{A_0}{A}=\ldots$

$\Delta\ln\frac{A_0}{A}=\frac{\Delta A}{A}+\frac{\Delta A}{A_0}=\ldots$

III.3. Calculation results

		1	2	3	4	5	6	7	8	9	10
t	[...]										
$\ln\frac{A_0}{A}$	[...]										
$\Delta\ln\frac{A_0}{A}$	[...]										

Δt = ...

III.4. Graph

- calculation of β, the slope of the "best-fit" straight line
- calculation of β', the slope of the deviated straight line
- calculation of:Δ β = | β - β'|

IV. Summary

The determined value of ... is ...
Accuracy of the method: ...
Additional conclusions, observations, causes of measurement uncertainties.

Report Guidelines – Verification

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Student 2: Verification of the dependence of the amplitude of decaying oscillations on time.

IV. Methodology (conceptual plan of the exercise)

V. Course of the exercise

II.1. Course of activities

II.2. Sketch of the measurement setup

VI. Results

III.1. Measurement results

		1	2	3	4	5	6	7	8	9	10
A	*[…]*										
t	*[s]*										

Δt = …

ΔA = …

III.2. Calculations (example calculations - referring, for example, to measurement no. 4)

ln A = …

Δln A = |ln A - ln (A + ΔA)| = …

III.3. Calculation results

		1	2	3	4	5	6	7	8	9	10
t	[s]										
ln A	[…]										
Δ ln A	[…]										

Δt = …

III.4. Graph

IV. Summary

Since on the graph … it is possible to draw a straight line passing through all measurement uncertainty rectangles, there are no grounds to conclude a deviation from …

Alternatively:

The deviation from linearity in the range … may result from …

Additional conclusions, observations, causes of measurement uncertainties.