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Vertical spring-mass system

Instructor version

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# Vertical spring-mass system – Instructor version

## Overview

* Topic: oscillation, graph interpretation, experimental process
* Target group: 1st year physics and non-physics students, high school students
* Timeframe: 1h30min for the experimental task with pre-lab preparation students do at home

In this exercise, students will study different forms of energies of a vertical spring-mass system that oscillates. Using *Tracker*, students will determine the different types of energies in the system as a function of time and analyze the obtained graphs.

## Required equipment

* Smartphone with acamera
* USB connectors
* Computer with a software for video analysis (e.g. *Tracker*)
* Springs with known spring constant
* Weights to put on a spring
* Stand for the spring
* Ruler

## *Tracker* - video analysis software

We chose *Tracker* for this experimental task. It is free software (<https://physlets.org/tracker/>), but feel free to use any other video analysis software.

Instructions on how to use tracker: <https://tracker.physlets.org/help/frameset.html>
Navigate to *Getting started* and *Installation* tab on the left-hand side.

During the lab, and while testing the software, we encountered some crashes and freezes. Because of that, it is recommended that students save their progress often in case of technical difficulties.

## Pre-lab preparation

It is recommended to give simple pre-lab exercise to students, e.g. plotting the kinetic energy of a free-falling ball using *Tracker*. That way students can learn how to use the software at home and conduct the experiment and data analysis faster and with more confidence.

## Orienting questions during the experiment

Recommended questions to ask students during the experimental task:

* In the formula for elastic force, there is a negative sign. What does it represent? Why is there no negative sign in the formula for elastic potential energy?
* Note to students it is helpful to draw sketches of the problem.
* How did you draw your predicted $E-t$ graphs?
* Where will you place the measuring stick (ruler) for calibration and why?
* Does the steadiness of video footage impact the experimental data?
* Why do we oscillate the system with small amplitudes?
* How did you choose which part of the object to track in *Tracker*?
* Why does the kinetic energy have its minimum and maximum twice as often as gravitational and elastic potential energy?
* Were your predictions in line with the result?
* How do you explain the graph of total mechanical energy? Why is it not constant? What are the potential causes of errors?

## Testing the equipment

Students should read the task instructions on how to perform the experiment carefully and try to conduct the experiment a few times before recording video footage which they will analyze. Instructors should check if video footage is good for data analysis otherwise students should conduct the experiment again.

## Data collection

Problems students had while recording the footage for data analysis:

* Recording the experiment with a smartphone in hand
* Oscillating the mass in all three dimensions
* The big amplitude of oscillation

Discuss with them how each of the above-mentioned points impacts the resulting energies of the system.

Some video files were too large to be sent to a computer via e-mail. Have a few USB cables at hand for students to transfer the video footage to the computer.

## Data analysis and representation

Students were provided with a guide on how to use *Tracker*. Steps students had to make in order to get graphs in *Tracker*: calibrating the scale, placing the coordinate system, tracking the object, entering parameters and entering formulas.  *Tracker* calculates velocity of the object based on the position of the point mass in each frame. The resulting energy – time graphs (Fig. 1.) are discussed with students.

Figure 1: Example energy-time graphs students made in Tracker

## Reporting

Students answer questions from the task instructions and sent the word/PDF file to the instructor. Note to students to attach all the graphs, tables, and explanations in the file they send.

It is recommended to ask students questions after they have finished the experimental task. Ask students how they conducted the experiment and what did they have to take into consideration.

## From our lab

Students were quite satisfied when they had to use their smartphones and computer software during the lab. Analyzing data was different than usual, and students reacted well to the experimental task. The use of digital technologies had a positive impact on students’ engagement in the experimental task.

Students did not want to give the wrong answer when asked to draw their prediction of $E-t$ graphs and they looked up the answers on the internet. Encourage students to make their own predictions. That way discussion when students plot graphs in the software will be more meaningful.

Students usually do not read the task instructions carefully. This results in video footage that will not give meaningful experimental data.

## Possible modifications

Each group formulates their hypotheses and test the hypotheses. E.g.: How does the period of oscillations depend on spring length? How does the amplitude depend on the mass of the object? How does the kinetic energy depend on the amplitude? … Each group can orally present their findings or write a report.

In the case of a distance learning scenario, instructors can record the experiment and send video footage to students. Instructors can record good and bad examples of the experiment (big amplitude, “wild” oscillations in three dimensions, shaky footage, …) and let students choose the footage they want to analyze and explain why they did not use other footage for the data analysis.