2017 - 18 EXPERIMENTAL PROJECT

(FOR STUDENTS WORKING IN PAIRS)

MOTION OF A SLINKY UNDER GRAVITY

A. Introduction

A plastic slinky, held at the top end and hanging down, is initially in equilibrium under its own weight. When released, the vertical positions of the top and bottom turns, s_T and s_B respectively, are recorded as a function of time, t, using a video camera; t is measured using the time interval between frames. The longest available slinky should be obtained to produce sufficient measurements. Therefore, it may be necessary, in order to produce a slinky with suitable length, to join two (or more) slinkies to produce a longer slinky. This can be done using Araldite adhesive (this should only be used under supervision).

B. Experimental Arrangement

The plastic slinky is initially supported, in equilibrium under gravity, using the top one or two turns, by hand or mechanically. Its initial stretched vertical length is L. Both s_T and s_B are to be recorded as a function of t, against a background of a vertical metre rule or tape measure. Once the slinky is released, the camera records the motion of the two ends of the slinky. The filming requires the highest number of frames per second (fps) available with the longest slinky available. The *displacement* of the top turn is to vary from 0 to $2L$.

It may be necessary to repeat the experiment in order to record the positions of the top and bottom turns throughout their motions. For example, if only part of the motion is captured in the first experiment, then the subsequent motion can be captured by repeating the experiment and continuing from the last recorded values of 's' obtained in the first experiment. Some interpolation may be required to match the two recordings. The number of possible measurements, and their accuracy, will be limited by the number of fps.

- Enhancing graticules - If the major markings on the vertical scale cannot be easily resolved by the camera, they should be highlighted.

C. Measurements & Graphs

Three pairs of graphs are required, each recording the motion of the top and bottom turns.

(i) Plot s_T and s_B as a function of t. Produce smooth curves consistent with the measurements.

(ii) Using the curves in (i), plot the velocities, v_T and v_B, as a function of t.

(iii) From (ii) plot the accelerations, a_T and a_B, as a function of t.

All measurements should be tabulated and indicate the accuracy and uncertainties involved.

No theoretical analysis of the motions is expected.

D. Apparatus

- One, or more, plastic slinkies. *These are available online under **magic spring** or **rainbow slinky spring**, and have lengths up to 15 cm (6 inch). (Note: the quoted size may actually refer to the diameter, making the item large and expensive.) ebay has 6.5 cm long, 7.5 cm diameter ones for £1.99 +PP.*
- A video camera suitable for capturing as many fps possible
- Metre rule(s) or tape measure
- Access to a computer.

E. Experimental Report

The report should describe the experimental work and include data, tables, graphs, diagrams, and photographs, plus a discussion of errors and accuracy.

This report should contain:

(i) A concise description of the experimental procedure, including diagrams and photographs with the labels for your setup.

(ii) A brief description of what you observe happening.

(iii) An outline of any experimental techniques used to improve accuracy or reduce uncertainty, and modifications to the procedure from any trial experiments.

(iv) Precautions taken to consider safety.

(v) A photograph of the experimental arrangement.

(vi) Tables of measurements with headings and units, and correctly justified (positioned) within the columns.

(vii) Graphs

(viii) Errors and accuracy estimates and brief comments about them.

(ix) Calculations.

(x) A concise concluding discussion of results, units and accuracy.

F. Report Guidelines

There is no single correct way to write up a report. It depends on how you conducted the investigation. One critical feature is that it must be short and concise. Overlong and it is too much to read through whilst trying to remember the detail; too short and the reader cannot grasp the essence of the investigation. **The page limit is 12 pages, excluding tables and graphs.** Samples of the data should be given rather than all of the data from a data logger, which may run to tens of pages. CDs of data should not be submitted, as with the number of projects submitted, it is not possible to look through these. They should be kept for your own reference as part of your project.

Some examples of what makes up some of the elements of a good write-up will be placed on the new BPhO website www.BPhO.org.uk by the end of June. There is no single style, but rather an ordered guide to the techniques, ideas and results, using information which leads the reader through the process of experimentation.

Keep a log book; an A4 notebook from which pages cannot be ripped out, so that you can write and paste in tables, graphs, comments and ideas, along with names and details of your computer files. Learn to be organised. It helps you keep track of your progress and keeps the information in one place. You can refer to it and it makes writing up so much easier. All Experimental Physicists (and theoreticians) keep such a notebook.

You should give a full but concise description of the experimental procedure. Highlight any particular ideas you had to make the results more reliable, with results, tables, units, uncertainties, graphs, diagrams and images. This is elaborated below.
We do not want you to write a long report (12 pages maximum, excluding tables & graphs), but one which describes your progress and results in a way that would explain clearly to the reader what happens in the experiment, what you did, and what your results were, in such a clear way that they are persuaded that you knew pretty much what you were doing. You are trying to remove elements of doubt in the reader's mind that you might just be making random measurements. You should have an initial descriptive paragraph which describes how the slinky behaved as it fell. This helps you observe what is happening in detail, and provides the reader with a picture in his mind of what you are trying to measure.

- Put a title on the front, the date, your name and school, and ensure your name is on every page by putting it in the footer, along with page numbers. It then appears automatically on each page.
- Write-ups can be by hand, in Word, or in Latex if you have someone to help you get started. Hand written reports score well as the report is brief and to the point.
- You must include a plan of the experiment, such that a colleague could carry out the experiment from your instructions. You must also write about any additional points, the particular apparatus that you used, precautions you took and good ideas you had about reducing the uncertainties of your measurements and what were the difficult measurements to make and why. Do not write an essay but just a short comment about each good idea.
- Describe any trial measurements you made to see if the experiment was going to work, and what range of measurements you decided to take. Try out the apparatus

to investigate what goes on; discuss it with a partner to make sure that you see what there is to be seen.

- Say what changes or adjustments or range setting you made in the light of this experience.

- Take a **good range** of data, and **plot the graphs before you put the apparatus away**.

- Results tables should have the **original data** including any **repeated measurements**, with the **units** at the top of the column along with the **correct symbol** for the quantity. A column for the **average** can then be worked out. You might include a column with an **estimate of the uncertainty** on your average value. Have the columns justified (positioned) with the headings to be above the correct column. Making it look good makes your data more believable because it looks like you know what you are doing!

- If you feel that the results are not right, then don't scribble them out or delete them; keep them and just point out what might be wrong with them or why you have no confidence in them. The purpose is to show that **you have investigated the apparatus** and given it a good try out so that you can convince the reader that **you know and understand the Science behind the investigation**. Things can go wrong and you need to show how you can overcome setbacks. If you delete everything that does not seem right to you, the reader might see a nice final table of results, but they do not know how much investigative effort you have put in to get that set of results. The reader might indeed wonder whether they are that good. Do **not** write an essay, just a few bullet point comments.

- Graphs should have labelled axes, units on the axes, with the plotted data taking up a significant proportion of the graph paper area. Some gridlines, if done in Excel, so that the reader can get values off the graph, and a scatter graph with a line of best fit (trendline in Excel) – definitely do not "join the points". Display the equation for the trendline on the graph. You do not have to use Excel. You can draw graphs by hand, which are just as valid.

- **Comment on the graph** i.e. look at it and describe what you can see about the shape of the graph and maybe the scattering of the points. Does it go anywhere near the origin, is it a straight line or a curve (or is it hard to tell), is the data close enough to the line of best fit to agree with the uncertainties you wrote down in your table of results?

- The **conclusion** comes from the table of results and your graph. What **trends** are shown, or what **general comments** can you make to **summarise** your results. You should also make at least a **comment** about whether you yourself think that the results are reliable or not, and why. Do your results and observations reveal something new or unexpected, or confirm your original ideas or initial observations?

Good Luck with the experiment!

CHECKLIST

☑

1. Is your name and school on each page of the report ☐
2. Is the reported dated? ☐
3. Are the pages numbered? ☐
4. Short introduction to your report, including key findings. ☐
5. Apparatus list, with specific details. ☐
6. Diagram of experimental set-up, with measurable quantities indicated. ☐
7. Discussion of any relevant safety issues, with measures to reduce hazards. ☐
8. Outline of experimental procedure, including any problems and adjustments. ☐
9. Qualitative description of key observations from experiment. ☐
10. Tables of data, with correct column headings, units and significant figures. ☐
11. Graphs, full page, with clear title and axes labels (with units) throughout. ☐
12. Analysis section, including formulae used and clear logical structure. ☐
13. Uncertainties considered in some form, either discussed, calculated or both. ☐
14. Conclusion, summarising findings and uncertainties. ☐
15. Evaluation of project, considering validity of conclusions and improvements. ☐

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