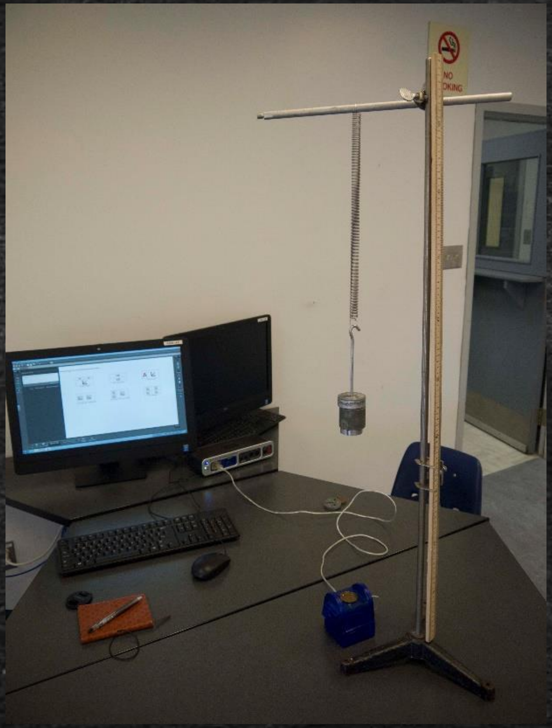

Simple Harmonic Motion

A physics laboratory exploring simple harmonic motion and some authentic scientific practices.

Overview and Objectives

- The main purpose of this experiment is to determine the spring constant *k* of a spring using two different methods.
- Another important objective is to confront your theoretical model to reality, and examine the possible ways the model can be improved.
- You will also study various aspects of simple harmonic motion (SHM), such as the effect of amplitude on the period of oscillation.
- Watch video 1 now!

The Model

- The mathematical model for the block-spring system is:
  - The system perfectly obeys Hooke's Law: $F_s = -kx$ where F_s is the spring's restoring force and *x* the displacement from equilibrium.
  - When the equilibrium is disrupted, the system oscillates in SHM and the period is: $T = 2\pi\sqrt{\frac{m}{k}}$ where m is the mass of the block.
- The following assumptions have been made:
  - Air resistance is negligible – no energy is dissipated from the system.
  - The mass of the spring is negligible.
  - The spring retains its elastic properties througout the experiment (no permanent damage is done due to over-stretching)

Part I – The Static Method.

- Watch video 2 now!
- Do not forget to include the mass of the hook.
- Do not forget to record x_0.
- If a low mass does not seem to cause any elongation, add 50 grams and try again.

Part II – The Dynamic Method.

- Watch video 3 now!
- Stretching the spring 2-3 cm is enough for oscillation. Do not over-stretch.
- You can use a timer to measure the period of oscillation, or connect your system to a motion sensor (your teacher will specify and give further instructions as needed)
- You may want to make (at least) 10 full oscillations for each mass. The longer the time interval measured, the smaller is the uncertainty on the period. (Why?)
- If a small mass does not provoke any elongation, or if the period is too short to be reliably measured, add 50 grams and try again.
- Do not forget to include the derivation of the relation between the force constant and the slope of the graph!

Part III – Effect of Amplitude on the Period

- Is there a relationship between the amplitude of oscillation and the period of oscillation?
- To answer the question, select a mass (400-600 gram range)
- Stretch the spring until the amplitude is 2 cm and release. Measure the period.
- Without changing the mass, repeat with an amplitude of 3 cm and repeat again with an amplitude of 4 cm.
- Record the period for your three different amplitudes. (Make a table) Did the period change?

Analysis – What's New?

- It is good practice, as a scientist, to present a realistic margin of error (we should say uncertainty – the word *error* is misleading) with any result. This involves error analysis. The challenge is to choose the right tools for the right experiment.
- In this experiment, finding the spring costant is best achieved with a linear fit of the data. Calculating the uncertainty of the slope is complicated. Annex Video D will show you how to do this automatically on Excel. Now watch all four videos – Skip only if you are already proficient with these concepts.
- Annex Video A: Margins of error. What to do with them?
- Annex Video B: Statistical errors and systematic errors.
- Annex Video C: Statistical analysis for beginners.
- Annex Video D: Making a trendline on Excel and finding the uncertainty of the slope.

Some Thoughts/Advice for the Discussion

- According to your model, what should the graphs be like? Compare with the graphs you obtained. Any difference?
- It is likely that one or both graphs reveal a limitation to your model. But which of the assumptions is at fault?
- How can you determine which assumption is at fault? Consider how each of the assumptions would affect each of the graphs. For example, would a non-negligible air resistance affect the period of oscillation? Would it affect the static equilibrium? Which graphs do you expect would be affected (and in what way) in each case, if an assumption was wrong?
- You can search the literature (online) to confirm or elaborate on your hypothesis. Remember to cite all your sources.

Discussion

- Compare the spring constants obtained with the two methods. How well do the intervals of uncertainty overlap? What can you conclude from your results?
- Can you improve (reduce) your uncertainties? How? If you were to perform the experiment again, what would you change? (i.e. what are your biggest sources of error and how can you reduce them?)
- Could you identify any systematic errors?

Questions

1. Why is it better to use the slope of the linear fit, rather than calculating *k* for each line in your data table and then taking the average?
2. Can you provide a physical explanation for the difference between the predicted graphs and the real graphs? In other words, do any of the assumptions (of the model) have a significant flaw? Clearly justify your work and your reasoning. Does the model need to be refined? How?
3. In part III, the oscillator quite clearly moves faster as the amplitude increases! So how can the period remain the same? Briefly explain.