Core practical 16: Determine the value of an unknown mass using the resonant frequencies of known masses on a spring

Objectives

- To measure the resonant frequency of masses on a spring
- To use a graph of the results to determine an unknown mass by measuring its resonant frequency when on the spring

Safety

- The magnitudes of the masses and their energies are low and so there is little risk from displaced masses. You should, however, still watch out for falling masses hitting your feet.
- The spring should not be overloaded so that it passes its elastic limit or breaks when oscillating.
- The support stand should be weighted or clamped to prevent it falling over.

Specification links

- Practical techniques 1, 2, 3, 4, 11
- CPAC 1a, 2d, 4a

Procedure

Research

1. A spring obeys Hooke's law, $F = kx$ where F is the force applied and x is the consequent extension. When a mass m is hung on a spring it is related to the extension by $m = \frac{kx}{g}$. When subsequently pulled down and released, it oscillates with a resonant period T. You are to find an expression relating m and T.
2. Write a plan to measure the period of resonant oscillations of a range of masses and use your results to determine the magnitude of an unknown mass m.

Practical

1. Carry out your plan and record your results.
2. Determine your unknown mass m.

Notes on procedure

- It is intended that this practical be done as an experiment planned by the student. Neither the methodology nor the theory is particularly tricky, so students should be able to make a good attempt at an investigation and, if it is done late in the course, it should show the summation of their investigative approach. They should be told the approximate (to 1 significant figure) magnitude of their unknown mass so that they can plan a suitable range of readings.
- This exercise could be made more investigative by giving the candidates the apparatus at the start of a lesson and asking them to determine the unknown mass for themselves. They need not write a plan, and could still be assessed against CPAC 2d and CPAC 4a.

Answers to questions

1. Record multiple oscillations, 10 for example, repeat the reading and calculate a mean. Divide the mean by the number of oscillations.
2. Place a position sensor under the mass hanger and connect it to the datalogger. This can be used to measure the extension and the period.

   It might be that the resolution of the position sensor is 0.1 mm. This is better than a metre ruler. The method for measuring T described above is likely to have very small uncertainties (probably between 0.5% and 1%), so it is unlikely that the datalogger will improve measurements of T unless it is very small.
3. Free oscillations occur in this experiment. Once displaced and released, free oscillations take place. If energy is continually put into the system, for example, by moving the support up and down, then the oscillation is forced and the system gains energy and unless damped is likely to break.

Sample data

m/kg	*T*/s
0.100	0.397
0.200	0.477
0.300	0.551
0.400	0.619
0.500	0.676
0.600	0.729
0.700	0.776

A mass of 318 g (weighed) oscillated at T = 0.560 s.

The graph gives 310 g.

$$\%D = 100 \times \frac{(318 - 310)}{318} = 6\%$$

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All the maths you need

- Recognise and make use of appropriate units in calculations.
- Use ratios, fractions and percentages.
- Use calculators to find and use power, exponential and logarithmic functions.
- Use an appropriate number of significant figures.
- Find arithmetic means.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Change the subject of an equation, including non-linear equations.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.
- Understand that $y = mx + c$ represents a linear relationship.

Equipment

- spring
- slotted masses and hanger
- retort stand with bosses and clamps
- stop clock
- unknown mass
- mass balance

Procedure

Research

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Practical

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Analysis of results

1. You should use ICT to plot a graph of your results and then use the graph to determine m.
2. Compare your value with the weighed value of m. Comment on your accuracy compared with the uncertainty in your readings.

Questions

1. Explain the techniques you used to help ensure your results for T were accurate.
2. Explain how a datalogger might be used to improve these readings and the effect it would have.
3. Explain the difference between free and forced oscillations.

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Equipment per student/group	Notes on equipment
spring	25 mm expendable springs work well.
slotted masses and hanger	Five of 100 g and one of 50 g
stop clock	Hand operated
unknown mass	In the range 250–350 g. It must be possible to attach it to the spring.
retort stand with bosses and clamps	Two each of bosses and clamps
mass balance	

Notes