OCR A Physics A-Level

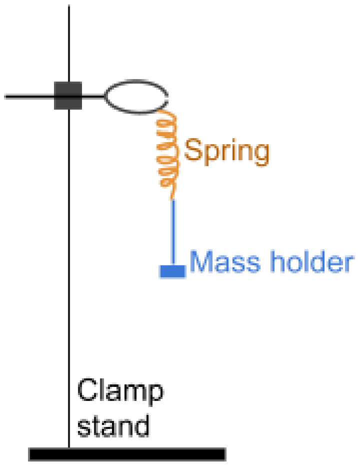
PAG 10.3

Comparison of static and dynamic methods of determining spring stiffness

<u>Static</u>

Equipment
- Clamp stand
- Spring
- 100 g masses with mass holder
- 30 cm ruler

Method
1. Measure the original length of the spring using the 30 cm ruler.
2. Set up equipment as in the diagram.



3. Measure the new length of the spring and record this value.
4. Add a 100 g mass to the mass holder and measure the new length of the spring.
5. Repeat the above step until the total mass reaches 800 g (including the 100 g mass holder).
6. Repeat the entire procedure to get a second value of length for each value of mass and calculate the mean length.

Calculations
- Calculate the force exerted by each of the recorded masses by calculating their weight:

$$Weight = m \times g$$

Where m is the mass and g is the gravitational field strength, 9.81 Nkg^{-1}.
- Draw a table of force exerted against the extension of the spring. You can calculate the extension by finding the difference between the new length and the original length.
- Use your table to plot a graph of force against extension, and draw a line of best fit.
- Your line of best fit should be a straight line through the origin showing that F and extension are directly proportional (Hooke's law).
- Your line of best fit will follow the equation y = mx where y is force (F) and x is the extension (ΔL), therefore the gradient must be the spring stiffness (k), following the Hooke's law equation:

$$F = k\,\Delta L$$

$$y = m\,x$$

- Therefore you can calculate spring stiffness by finding the change in force over the change in extension over a large interval.

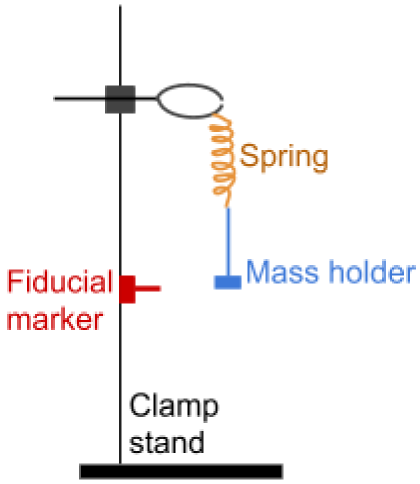
Safety
- Be careful when handling the masses. If dropped they may cause injury.
- If the clamp stand is unstable, a counterweight placed on the base of the clamp stand can be used to prevent it from falling over.
- Wear eye protection when using springs.

Notes
- You can reduce uncertainty in measurements of extension by using a spring with a small spring constant so that the extension is larger.
- Be careful not to exceed the elastic limit of the spring as it will no longer be following Hooke's law, and your results will not form a straight line graph.
- As you are measuring static objects you can take your time and so measurement errors are less likely.

Dynamic

Equipment
- Clamp stand
- Spring
- 100 g masses with mass holder
- Stopwatch
- Fiducial marker (e.g pin and blu-tack)
- Metre ruler

Method
1. Attach the spring to the clamp stand and attach the mass holder to the spring as shown in the diagram below.
2. Wait until the spring stops moving completely, then place the fiducial marker at the very bottom of the mass holder, using the metre ruler to align it perfectly. This represents the centre of oscillations and will make it easier to count how many oscillations the mass-spring system has undergone.



3. Pull the spring down slightly and let it go so that it is oscillating with a small amplitude and in a straight line.
4. As the bottom of the mass holder passes the fiducial marker, start the stopwatch and count the time taken for it to complete 10 full oscillations.
5. Take two more readings for the time period for 10 oscillations and calculate a mean.
6. Add a 100 g mass to the mass holder and repeat the last 3 steps of the procedure.
7. Repeat the last step until the total mass is 800 g (including the mass holder which is 100 g).

Calculations

- Divide the mean values of time period at each length by 10 to get the time period for a single oscillation (T).
- Draw a table of the values of T^2 against m. Use you table to plot a graph of T^2 against m, and draw a line of best fit.
- Your line of best fit should be a straight line through the origin, showing that m is directly proportional to T^2.
- Your line of best fit follows the equation y = mx, where y is T^2 and x is m. You can use the equation for simple harmonic motion (in a mass-spring system) to find what your gradient represents:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T^2 = \frac{4\pi^2}{k} \times m$$

$$y = m\,x$$

Therefore, the gradient of your graph is equal to $\frac{4\pi^2}{k}$, meaning if you multiply it by $\frac{1}{4\pi^2}$ and find its reciprocal you can calculate a value of k (the spring constant of the spring used).

Safety

- Be careful when handling the masses. If dropped they may cause injury.
- If the clamp stand is unstable, a counterweight placed on the base of the clamp stand can be used to prevent it from falling over.
- Wear eye protection when using springs.

Notes

- Using a fiducial marker and timing over several oscillations (as directed) will reduce the uncertainty in your measurements.
- Repeating measurements and finding a mean will reduce the effect of random errors.
- To reduce the uncertainty further you could use light gates attached to a data logger to record the period of 10 oscillations.
- Be careful not to exceed the elastic limit of the spring as it will no longer be following Hooke's law, and your results will not form a straight line graph.
- As you are measuring dynamic objects you cannot take your time and so measurement errors are more likely, however you can reduce the likelihood of this by using light gates attached to a data logger.

Overall Comparison

The static method is easier to carry out and more likely to give accurate results, however the dynamic method is also highly accurate when using light gates and a data logger.