OCR A Physics A-Level

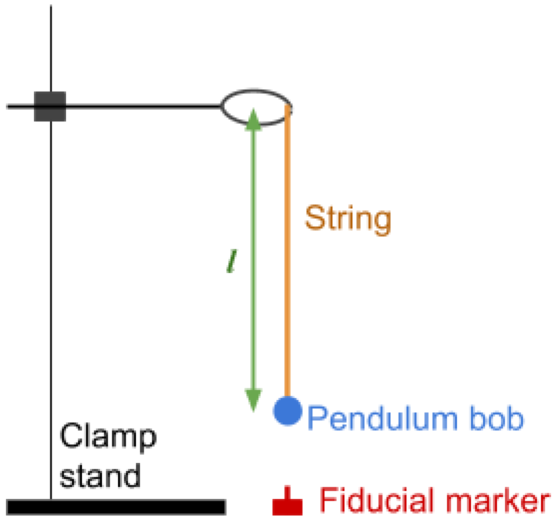
PAG 10.1

Investigate the factors affecting simple harmonic motion

Simple Pendulum

Equipment
- String
- Small, dense ball bearing (to act as the pendulum bob)
- Clamp stand
- Metre ruler
- Stopwatch
- Fiducial marker (e.g pin and blu-tack)

Method
1. Attach the ball bearing to the string and attach this to the clamp stand as shown in the diagram below.
2. Adjust the length l, which is from where the string is attached to the clamp stand to the center of the ball bearing, until it is 1.0 m using the metre ruler.
3. Wait until the pendulum bob stops moving completely, then place the fiducial marker directly underneath the bob. This represents the centre of oscillations and will make it easier to count how many oscillations the pendulum has undergone.



4. Pull the pendulum bob to the side slightly and let it go so that it is oscillating with a small amplitude and in a straight line.
5. As the pendulum passes the fiducial marker, start the stopwatch and count the time taken for it to complete 10 full oscillations.
6. Take two more readings of the time period for 10 oscillations and calculate a mean.
7. Reduce the length l by 10 cm and repeat the last 3 steps of the procedure.
8. Repeat the last step until the length l is 0.2 m.

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 l. Use your table to plot a graph of T^2 against l, and draw a line of best fit.

- Your line of best fit should be a straight line through the origin, showing that l is directly proportional to T^2.
- Your line of best fit follows the equation y = mx, where y is T^2 and x is l. You can use the equation for simple harmonic motion (in a pendulum) to find what your gradient represents:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$T^2 = \frac{4\pi^2}{g} \times l$$

$$y = m\,x$$

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

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.
- The angle by which you pull the pendulum bob to start it oscillating must be less than 10°, otherwise it will not undergo SHM.
- If you are unaware of the relationship between length and time period, you can plot a graph of $\log_{10}$ T against $\log_{10}$ l. The gradient of the graph will show the power relationship between the variables T and l as derived below:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$log\ T = log\ (2\pi \times \sqrt{\frac{l}{g}})$$

$$log\ T = log\ (2\pi) + log(\sqrt{\frac{l}{g}})$$ As log (AB) = log (A) + log (B)

$$log\ T = log\ (2\pi) + \frac{1}{2}log(\frac{l}{g})$$ As $\log (A^n) = n \log (A)$

$$log\ T = log\ (2\pi) + \frac{1}{2}log(l) - \frac{1}{2}log(g)$$ As log (A/B) = log (A) - log (B)

$$log\ T = \frac{1}{2}log(l) + log\ (2\pi) - \frac{1}{2}log(g)$$

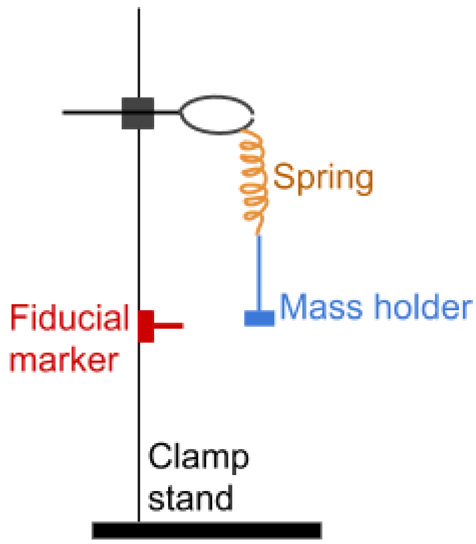
$$y = m\,x + c$$

As m = ½ , the power relationship is $T \propto l^{1/2}$.

Mass-spring system

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



a.

b.

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 of 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. Dropping them could 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. Alternatively, a G-clamp can be used to clamp the stand to the bench.
- 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.
- If you are unaware of the relationship between mass and time period, you can plot a graph of $\log_{10}$ T against $\log_{10}$ m. The gradient of the graph will show the power relationship between the variables T and m, as derived below:

$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$\log T = \log\left(2\pi \times \sqrt{\frac{m}{k}}\right)$$
$$\log T = \log(2\pi) + \log\left(\sqrt{\frac{m}{k}}\right)$$
As log (AB) = log (A) + log (B)
$$\log T = \log(2\pi) + \tfrac{1}{2}\log\left(\frac{m}{k}\right)$$
As $\log(A^n) = n \log(A)$
$$\log T = \log(2\pi) + \tfrac{1}{2}\log(m) - \tfrac{1}{2}\log(k)$$
As log (A/B) = log (A) - log (B)
$$\log T = \tfrac{1}{2}\log(m) + \log(2\pi) - \tfrac{1}{2}\log(k)$$
$$y \quad = \ m\ x + c$$

As m = ½ , the power relationship is $T \propto m^{1/2}$.