

# Oscillations, springs, pendulums and resonance

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Class: \_\_\_\_\_

How does the oscillation period of a hanging mass change as the mass increases? Use a simple spring, a stopwatch and a graph of  $T^2$  against  $m$  to test the relationship and to measure the stiffness of the spring.

**Level:** Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB C.1

## Aim

To find how the period of a mass on a spring depends on the mass, and to determine the spring stiffness  $k$  from a graph of  $T^2$  against  $m$ .

## Equipment

- Coil spring (stiffness about 20 N/m), clamp stand, boss and clamp
- Slotted masses (0.100 kg to 0.500 kg) and hanger
- Stopwatch (0.1 s resolution), metre ruler
- Small paper flag or marker as a fiducial mark

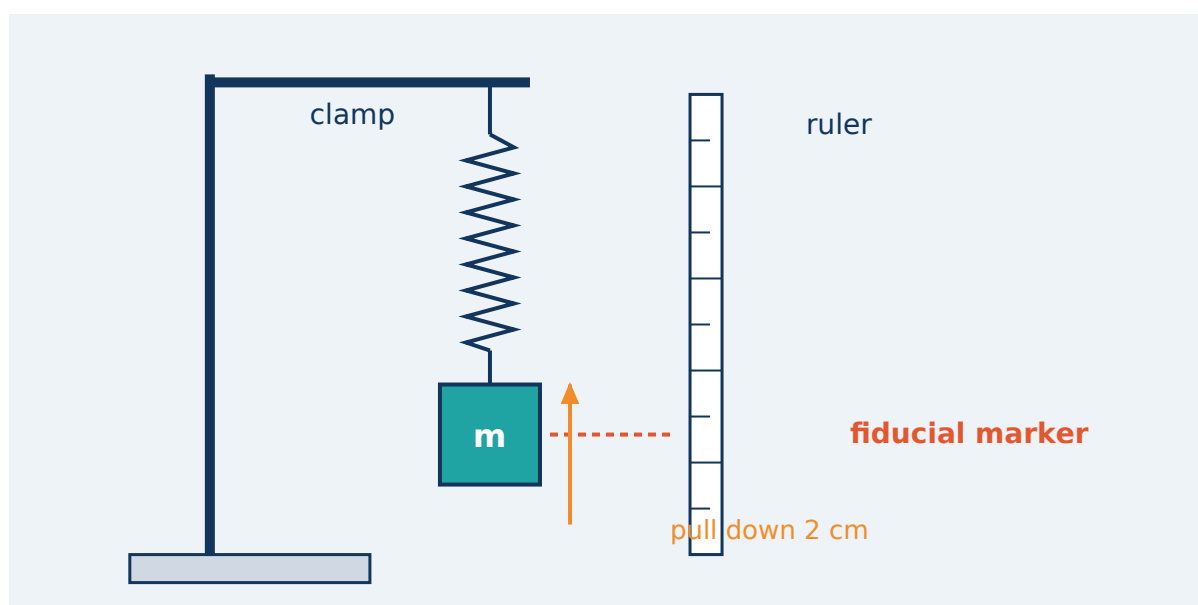
## Safety

### Safety

Clamp the stand to the bench or weigh down its base so it cannot tip. Keep feet clear of falling masses and wear eye protection in case the spring unhooks.

## Method

1. Hang the spring from the clamp and add the hanger plus a 0.100 kg mass.
2. Place the fiducial marker level with the bottom of the mass at rest.
3. Pull the mass down about 2 cm and release; check that it moves straight up and down.
4. Start the stopwatch as the mass passes the marker moving upwards and count 20 complete oscillations.
5. Record the time  $t$  for 20 oscillations, then repeat for masses up to 0.500 kg.
6. Calculate  $T = t \div 20$  and  $T^2$  for each mass.



Set-up: timing oscillations of a hanging mass.

## Results

Sample measurements (t is the time for 20 oscillations):

| m / kg | t for 20 oscillations / s | T / s | T <sup>2</sup> / s <sup>2</sup> |
|--------|---------------------------|-------|---------------------------------|
| 0.100  | 9.3                       | 0.465 | 0.216                           |
| 0.200  | 12.9                      | 0.645 | 0.416                           |
| 0.300  | 15.6                      | 0.780 | 0.608                           |
| 0.400  | 18.0                      | 0.900 | 0.810                           |
| 0.500  | 20.1                      | 1.005 | 1.010                           |

## Analysis questions

### Question 1 Calculate the period

Explain why the time for 20 oscillations is recorded, and check the entry for  $m = 0.300$  kg by calculating  $T$  and  $T^2$ .

### Question 2 Uncertainty in the timing

Take the timing error of the 20-oscillation measurement as  $\pm 0.2$  s. For  $m = 0.200$  kg, find the percentage uncertainty in  $T$  and then in  $T^2$ .

### Question 3 Plot and gradient

Plot  $T^2$  (y-axis) against  $m$  (x-axis), draw a best-fit line and calculate its gradient using the first and last points.

**Question 4 Spring stiffness**

From  $T^2 = (4\pi^2/k) m + c$ , find  $k$  from the gradient.

**Question 5 The intercept**

The line does not pass through the origin. Calculate the intercept and explain what it shows.

**Question 6 Testing proportionality**

A student claims that  $T$  is proportional to  $m$ . Use the data to show that this is wrong and state the true relationship.

**Question 7 Amplitude check**

Describe how to test that the period does not depend on amplitude, and state the expected result.

**Question 8 Improvements**

Suggest two improvements to reduce random and systematic errors.