Simple harmonic motion

International Baccalaureate · IB Diploma · Physics · SL

Scope and prerequisites

This handout covers selected SL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

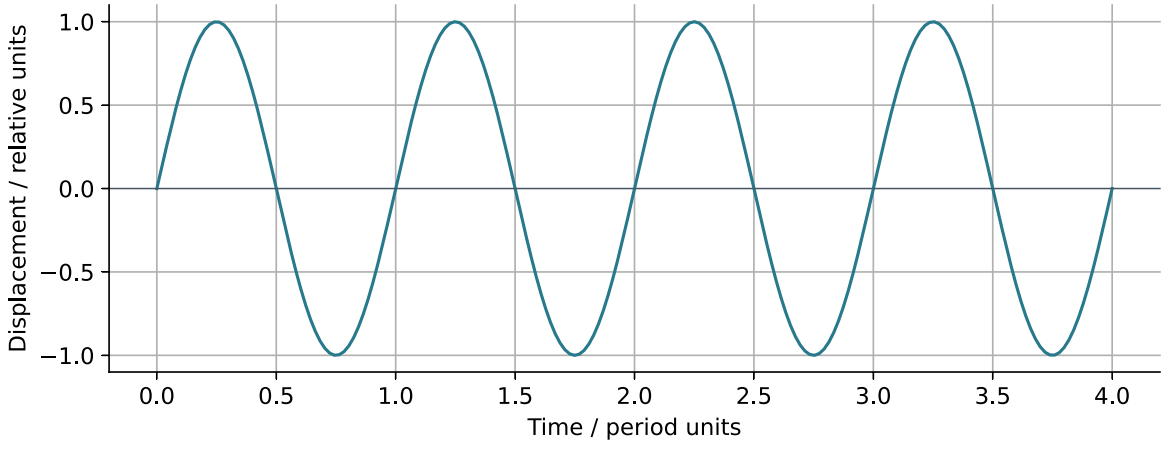
Oscillation, resonance and phase

What would explain this observation?

- A swing gains a large amplitude when pushes arrive with the right timing. The forcing frequency and **damping** help determine the response.

Build the model

- Simple harmonic motion has acceleration proportional to displacement and directed toward equilibrium.
- Period is time per cycle; frequency is its reciprocal.
- Damping transfers energy away from the oscillating system.
- **resonance**: A large response to periodic forcing near a natural frequency.
- damping: Energy transfer out of an oscillating system.



One complete oscillation takes one period T; $f = 1/T$

■ **Choose evidence that can test it**

- Velocity is greatest near equilibrium for ideal SHM, while acceleration magnitude is greatest at extreme displacement.
- Resonance can occur near the natural frequency under periodic driving, with amplitude limited by damping.

In the lab: Measure time for several complete oscillations and divide. Define a cycle consistently and use a small displacement when the model requires it. Keep pendulum paths clear and record damping effects rather than assuming perfect motion.

■ **Work from known quantities**

- Known: 20 cycles take 32 s.
- T=total time/cycles=32/20=1.6 s.
- Frequency=1/T=1/1.6=0.625 Hz.
- A shorter total timing interval would make reaction-time error a larger fraction of the measurement.

Your turn: 30 cycles take 45 s. Find period.

■ **Check the conclusion and its limits**

- Not every repeated motion is SHM.
- A force proportional to displacement but directed away from equilibrium does not produce SHM.

Not true: Every periodic motion satisfies the condition for simple harmonic motion. SHM needs a restoring force proportional to displacement and directed TOWARD equilibrium. Motion that merely repeats - a bouncing ball, a circular orbit - is periodic without satisfying that condition.

Key:

- Simple harmonic motion has acceleration proportional to displacement and directed toward equilibrium.
- Velocity is greatest near equilibrium for ideal SHM, while acceleration magnitude is greatest at extreme displacement.
- Watch for: not every repeated motion is SHM.

■ **Write from a period of 2.5 s**

- 20 cycles take 50 s.
- Find the period and the frequency. Not every periodic motion is simple harmonic.

■ **Write from a frequency of 2.5 hertz**

- A pendulum completes 10 cycles in 4.0 s.
- Period = 0.40 s, frequency = 1 ÷ 0.40 = 2.5 Hz – count cycles, divide time, invert.

■ **Write from a defining SHM check**

- A small-angle pendulum and a bouncing ball are both periodic.
- Only the pendulum is SHM: restoring force proportional to displacement, directed toward equilibrium – periodicity alone is not the criterion.

■ **Write from a frequency doubled**

- A simple pendulum's length is quartered.
- $T \propto \sqrt{L}$, so T halves and frequency doubles – the square root is the whole trick.