

Simple harmonic motion

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL 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.

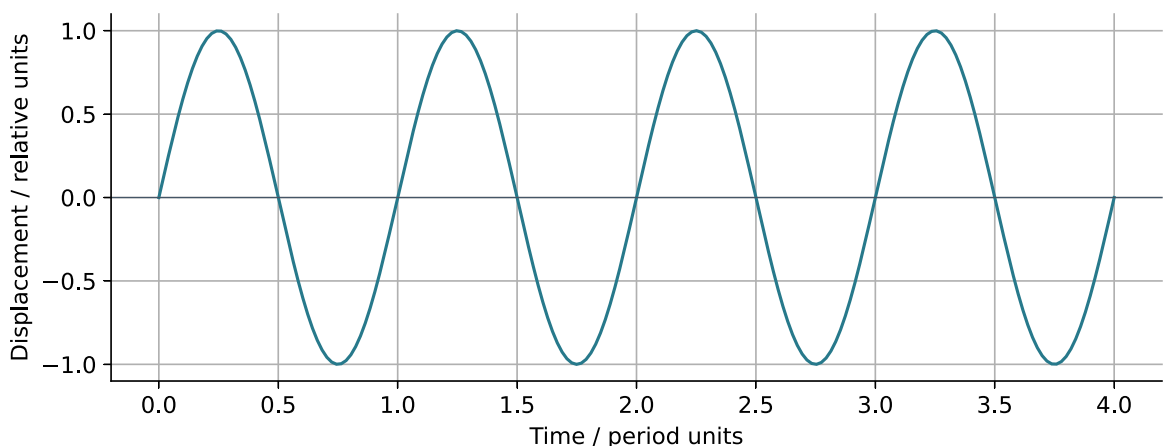
Oscillation, resonance and phase

■ 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.
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■ 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.
- $T = \text{total time} / \text{cycles} = 32 / 20 = 1.6 \text{ s}$.
- Frequency $= 1/T = 1/1.6 = 0.625 \text{ Hz}$.
- 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 0.40 s

- 40 cycles take 16 s.
- Find the period and the frequency. Not every periodic motion is simple harmonic.

■ **Write from a phase difference**

- Two points on a wave sit 0.50 wavelengths apart.
- Phase difference = $0.50 \times 360^\circ = 180^\circ$ – opposite phase: one rises as the other falls.

■ **Write from a resonance condition**

- A system's natural frequency is 2.0 Hz; a driver runs at 1.8 Hz, then 2.0 Hz, then 2.2 Hz.
- Amplitude peaks AT 2.0 Hz – driving at the natural frequency is resonance; the peak is the danger and the tool.