

Exercise walk-through

# 8.2

## Simple harmonic motion (full C.1, SL)

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International Baccalaureate · IB Diploma · Physics · SL

# Oscillations · 2.1

## Reasoning

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.

# Oscillations · 3.1

## Reasoning

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. 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.

## The restoring condition matters

- 1 Set the model** An ideal mass–spring system has  $m = 0.50 \text{ kg}$  and  $k = 20 \text{ N/m}$ .
- 2 Calculate**  $T = 2\pi\sqrt{m/k} = 0.99 \text{ s}$ ;  $\omega = \sqrt{k/m} = 6.32 \text{ rad/s}$ . At  $x = 0.050 \text{ m}$ ,  
 $a = -\omega^2 x = -2.0 \text{ m/s}^2$ .

### Decision

Acceleration points toward equilibrium. A simple pendulum approximates SHM only at small angles.

## Exercises 2.1·2.3

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**2.1** State the defining equation of simple harmonic motion and explain the significance of its minus sign. [2]

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**2.2** An oscillator has frequency 2.5 Hz. Calculate its period and angular frequency. [2]

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**2.3** A 0.20 kg mass on a spring of stiffness 5.0 N/m oscillates. Calculate the period. [2]

## Exercises 2.1·2.3

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**2.1** State the defining equation of simple harmonic motion and explain the significance of its minus sign. [2]

**2.1**  $a = -\omega^2 x$ ; the minus sign shows acceleration is always directed opposite to displacement – toward equilibrium, the restoring condition.

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**2.2** An oscillator has frequency 2.5 Hz. Calculate its period and angular frequency. [2]

**2.2**  $T = 1/f = 1/2.5 = 0.40$  s;  $\omega = 2\pi f = 2\pi \times 2.5 = 16$  rad/s.

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**2.3** A 0.20 kg mass on a spring of stiffness 5.0 N/m oscillates. Calculate the period. [2]

**2.3**  $T = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.20/5.0} = 2\pi(0.200) = 1.3$  s.

## Exercises 2.4·3.2

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**2.4** Describe the energy changes over one complete cycle of a simple pendulum, from release at maximum displacement. [3]

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**3.1** A simple pendulum has length 2.5 m ( $g = 9.8 \text{ m/s}^2$ ). Calculate its period, and calculate the length that would double this period. [4]

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**3.2** A 0.30 kg mass on a spring oscillates with amplitude 0.040 m and period 0.25 s. Calculate the angular frequency and the maximum acceleration, and state where in the cycle the speed is greatest. [4]

## Exercises 2.4·3.2

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**2.4** Describe the energy changes over one complete cycle of a simple pendulum, from release at maximum displacement. [3]

**2.4** Starts all potential, zero kinetic; potential falls to zero as it passes equilibrium, where kinetic energy and speed are greatest; the exchange reverses on the far side and the cycle repeats, the total staying constant throughout.

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**3.1** A simple pendulum has length 2.5 m ( $g = 9.8 \text{ m/s}^2$ ). Calculate its period, and calculate the length that would double this period. [4]

**3.1**  $T = 2\pi\sqrt{2.5/9.8} = 2\pi(0.505) = 3.2 \text{ s}$ ; doubling  $T$  needs four times the length since  $T \propto \sqrt{l}$ :  $l = 4 \times 2.5 = 10 \text{ m}$ .

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**3.2** A 0.30 kg mass on a spring oscillates with amplitude 0.040 m and period 0.25 s. Calculate the angular frequency and the maximum acceleration, and state where in the cycle the speed is greatest. [4]

**3.2**  $\omega = 2\pi/T = 2\pi/0.25 = 25 \text{ rad/s}$ ;  $a_{\max} = \omega^2 x_0 = 632 \times 0.040 = 25 \text{ m/s}^2$ ; speed greatest as it passes equilibrium.

## Exercise 3.3

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**3.3** A student times 20 oscillations of a mass–spring system as 8.8 s, with mass 0.40 kg. Calculate the period and the spring stiffness, and state one assumption the calculation makes about the system. [5]

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**3.3**  $T = 8.8/20 = 0.44$  s;  $k = 4\pi^2 m/T^2 = 4\pi^2(0.40)/(0.44^2) = 82$  N/m; assumes ideal (massless) spring and no damping – amplitude constant.