Exercise walk-through

8.2
Simple harmonic motion (full C.1, SL)

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.

Exercises 2.1·2.3

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

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

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

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.

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.

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

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

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

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

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.

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

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

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

Exercise 3.3

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.