

Exercise walk-through

5.5

Simple harmonic motion, graphs and energy (143–147, 149–150, CP16)

Pearson Edexcel · International A-Level · Physics

Separate free, forced and damped oscillations

Term	Physical meaning
Free oscillation	After release, motion occurs at a natural frequency.
Forced oscillation	A periodic external force drives the motion.
Damping	Oscillation energy transfers to other stores.
Resonance	Large response near a natural frequency under comparable driving.

Use the evidence

One oscillator can be forced and damped at the same time.

Your turn: explain the bridge damper

Write a linked explanation

People walking apply periodic forces to a bridge. Under some conditions its motion grows dangerously large.

Explain the role of driving frequency, natural frequency and energy transfer.

Explain how a damper limits the response. Use cause-and-effect sentences, not a list of terms.

A linked explanation earns its conclusion

People supply a periodic driving force.



Drive near a natural frequency → efficient energy transfer → larger amplitude.



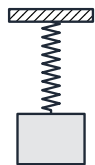
Damper opposes motion and does work
→ energy transfers to thermal stores.



For comparable driving, less oscillation energy means a smaller steady amplitude.

Exercise 2.1

2.1 An oscillator has amplitude 0.040 m and period 0.80 s. Find angular frequency, maximum speed and maximum acceleration. [4]

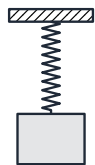


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$$T = 0.80 \text{ s}$$

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$$A = 0.040 \text{ m}$$

$$T = 0.80 \text{ s}$$

2.1 Use period to obtain angular frequency.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.80 \text{ s}} = 7.85 \text{ rad s}^{-1}$$

Angular frequency.

$$v_{max} = A\omega = (0.040 \text{ m})(7.854 \text{ s}^{-1}) = 0.314 \text{ m s}^{-1}$$

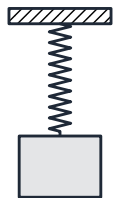
Speed.

$$|a|_{max} = A\omega^2 = (0.040 \text{ m})(7.854 \text{ s}^{-1})^2 = 2.47 \text{ m s}^{-2}$$

Acceleration.

Exercise 2.2

2.2 A 0.20 kg mass on a spring oscillates with period 0.60 s. With an extra mass on the same spring, period becomes 0.90 s. Find the extra mass. [3]

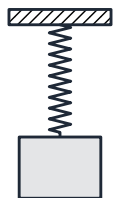


0.20 kg; 0.60 s

extra mass; 0.90 s

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0.20 kg; 0.60 s

extra mass; 0.90 s

2.2 Same spring gives squared period proportional to total mass.

$$m_2 = m_1(T_2/T_1)^2 = (0.20 \text{ kg})(0.90 \text{ s}/0.60 \text{ s})^2 = 0.45 \text{ kg}$$

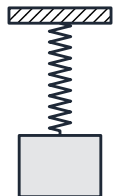
Total mass.

$$m_{\text{added}} = m_2 - m_1 = (0.45 - 0.20) \text{ kg} = 0.25 \text{ kg}$$

Added mass.

Exercise 2.3

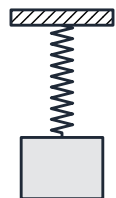
2.3 An undamped oscillator is released from $x = +A$ at $t = 0$. State x , velocity direction and acceleration direction at $T/4$, and x and velocity at $T/2$. Explain using the restoring condition. [4]



$x = +A$
released at $t = 0$

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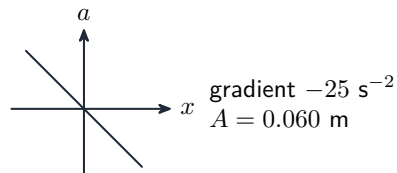


$x = +A$
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2.3 At $T/4$, $x=0$, velocity points in the negative x direction, acceleration is zero. At $T/2$, $x=-A$ and $v=0$. Acceleration is always $-\omega^2 x$, towards equilibrium; the initial restoring acceleration produces the negative velocity.

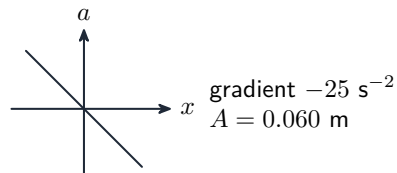
Exercise 3.1

3.1 A straight acceleration–displacement graph has gradient -25 s^{-2} . A mass 0.30 kg oscillates with amplitude 0.060 m . Find period, maximum kinetic energy and kinetic energy at $x = 0.020 \text{ m}$. [6]



Exercise 3.1

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3.1 The gradient is $-\omega^2$, so $\omega = 5.0 \text{ rad s}^{-1}$.

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{5.0 \text{ s}^{-1}} = 1.26 \text{ s}$$

Period.

$$E_{k,max} = \frac{1}{2}m\omega^2 A^2 = \frac{1}{2}(0.30 \text{ kg})(25 \text{ s}^{-2})(0.060 \text{ m})^2 = 0.0135 \text{ J}$$

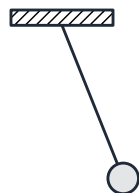
Energy method/value.

$$E_k = \frac{1}{2}m\omega^2(A^2 - x^2) = \frac{1}{2}(0.30 \text{ kg})(25 \text{ s}^{-2})(0.060^2 - 0.020^2) \text{ m}^2 = 0.0120 \text{ J}$$

Displaced energy.

Exercise 3.2

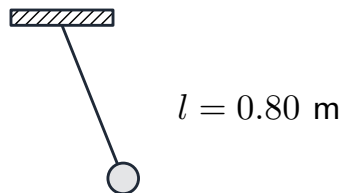
3.2 A pendulum length is 0.80 m from pivot to bob centre. Calculate its small-angle period using $g = 9.81 \text{ m s}^{-2}$. Explain the effect of doubling bob mass and identify two measurement choices improving a timing experiment. [5]



$l = 0.80 \text{ m}$

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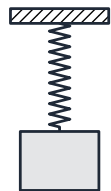
3.2 Use the small-angle pendulum model.

$$T = 2\pi\sqrt{l/g} = 2\pi\sqrt{\frac{0.80 \text{ m}}{9.81 \text{ m s}^{-2}}} = 1.79 \text{ s}$$

Period. Doubling mass does not change the ideal period. Time many complete oscillations and divide by their number; repeat at small amplitude, measuring pivot-to-centre length.

Exercise 3.3

3.3 Known added masses 0.10 and 0.30 kg give resonant frequencies 4.0 and 2.8 Hz on one spring assembly. Assume light damping and a straight calibration of $1/f^2$ against added mass, retaining its intercept. Infer an unknown added mass giving 3.2 Hz. Explain how the intercept can arise and two controls for this calibration. [7]



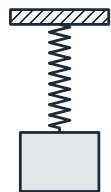
0.10 kg: 4.0 Hz

0.30 kg: 2.8 Hz

unknown: 3.2 Hz

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0.10 kg: 4.0 Hz

0.30 kg: 2.8 Hz

unknown: 3.2 Hz

3.3 Transform frequencies to reciprocal squares and interpolate that variable.

$$y_2 = f_2^{-2} = (2.8 \text{ Hz})^{-2} = 0.12755 \text{ s}^2$$

$$y_u = f_u^{-2} = (3.2 \text{ Hz})^{-2} = 0.097656 \text{ s}^2$$

Full solution 3.3

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Transformed values.

$$m_u = m_1 + (m_2 - m_1) \frac{y_u - y_1}{y_2 - y_1}$$

$$m_u = 0.10 \text{ kg} + (0.30 - 0.10) \text{ kg} \frac{(0.097656 - 0.06250) \text{ s}^2}{(0.127551 - 0.06250) \text{ s}^2} = 0.208 \text{ kg}$$

Interpolation/value. Hanger/effective spring mass contributes a nonzero intercept. Keep the same spring and support with small amplitudes below elastic limit; vary frequency slowly around each steady peak and repeat the reading. Two points are provided for this task; a real calibration needs more to test linearity.