

Exercise walk-through

# 5.6

## **Forced oscillations, resonance and damping (148, 151–153)**

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Pearson Edexcel · International A-Level · Physics

## CP15: attenuation is a thickness law

| Action                                                | Why it matters                                                                                |
|-------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Fix geometry and count time                           | Source contribution must be comparable across thicknesses.                                    |
| Measure and subtract background                       | Background does not follow the absorber transmission law.                                     |
| Repeat; plot log corrected rate versus lead thickness | Test exponential attenuation. Avoid near-background readings with large relative uncertainty. |

### Use the evidence

Three half-value thicknesses transmit  $1/8$ . Follow supervised source handling and shielding.

## 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.

## Use the documents in their learning order

Reference: learn the complete knowledge, methods and assumptions.



Skill sheet: supported practice → reduced support → exam-style demands.



Authentic set: transfer to original wording; correct with reasons.



Return to the reference for a diagnosed gap; reattempt before using reserved assessment questions.

## Exercise 2.1

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**2.1** A motor drives a platform at 2.0 Hz, while its undriven small-amplitude natural frequency is 1.6 Hz. State the steady forced frequency and distinguish forced from free oscillation. [3]

drive 2.0 Hz; natural 1.6 Hz



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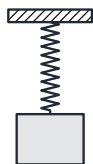


**2.1** The steady forced frequency is 2.0 Hz. Forced oscillation is maintained by continued periodic driving; free oscillation follows a disturbance without continued periodic forcing.

## Exercise 2.2

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**2.2** A damper removes 0.020 J of mechanical energy each cycle from an oscillator initially storing 0.10 J. Calculate the remaining energy after two cycles and the amplitude ratio, assuming spring constant unchanged. [4]



$$E_0 = 0.10 \text{ J}$$

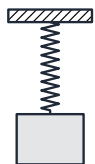
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**2.2** Subtract transferred energy from the initial store.

$$E_2 = E_0 - 2\Delta E = (0.10 - 2 \times 0.020) \text{ J} = 0.060 \text{ J}$$

Energy. Spring energy is proportional to amplitude squared.

$$\frac{A_2}{A_0} = \sqrt{\frac{E_2}{E_0}} = \sqrt{\frac{0.060 \text{ J}}{0.10 \text{ J}}} = 0.775$$

Ratio. Constant loss per cycle is stated for these two cycles, not a universal damping law.

## Exercise 2.3

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**2.3** Two otherwise identical small-angle pendulums have bob masses  $m$  and  $3m$ , equal length and equal angular amplitude. Compare periods and stored mechanical energies. Explain why these facts alone do not fix their damping times. [4]



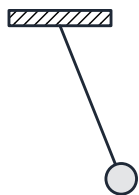
bobs  $m$  and  $3m$   
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**2.3** Ideal periods are equal because  $T = 2\pi\sqrt{l/g}$  does not depend on mass. Equal length and angle give equal vertical rise;  $E = mgh$  therefore gives energy ratio 1:3. Damping time also depends on the resistive mechanism and losses per cycle; those have not been specified.

## Exercise 3.1

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**3.1** A bridge has a natural lateral frequency near a crowd's stepping frequency. Explain the sequence from periodic forcing to potentially dangerous motion, then explain how a damper limits it. Distinguish driving frequency from amplitude. [6]

walking crowd



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walking crowd



**3.1** Walking provides a periodic driving force. Near a natural frequency, energy transfer into the relevant bridge mode is efficient; its amplitude grows. Large amplitude is the danger, not a claim that the bridge frequency grows indefinitely. Dampers do work against motion, transferring mechanical energy to thermal stores and limiting steady amplitude.

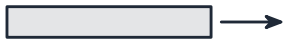
## Exercise 3.2

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**3.2** A protective strip is stretched beyond its elastic limit while a second strip is deformed only elastically. Explain which mechanism can absorb energy irreversibly and why elastic storage alone does not guarantee damping. Distinguish ductile from brittle failure. [5]



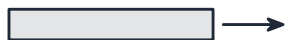
two strips



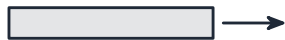
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two strips



**3.2** Plastic deformation persists after unloading and transfers mechanical energy irreversibly into internal energy. An ideal elastic strip returns its stored energy, so storage alone is not loss/damping. Ductile material can undergo substantial plastic deformation before fracture; brittle material fractures with little plastic deformation.

## Exercise 3.3

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**3.3** A team compares forced amplitude–frequency curves with and without an added damper. Describe a fair measurement method, predict two changes in the peak, and explain why the frequency of the greatest amplitude need not remain exactly the undamped natural frequency. [6]

optional damper



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**3.3** Keep driving-force amplitude and oscillator mass/spring/support unchanged. Sweep driving frequency and measure settled amplitude at each frequency, sampling densely near the peak and repeating. Added damping lowers the peak and broadens it. The amplitude maximum depends on damping as well as restoring/inertial properties, so stronger damping can shift it below the undamped natural frequency; only light damping makes them approximately equal.