Exercise walk-through

Doppler effect for sound waves ▪ 7.3

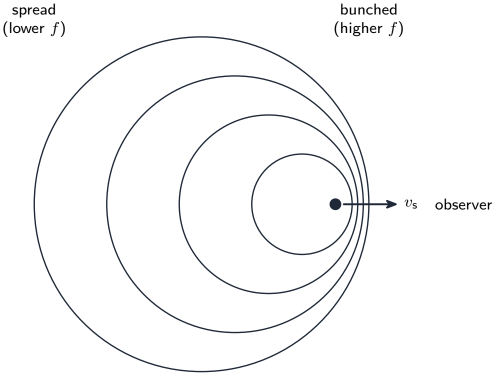
eXercise

You must be able to

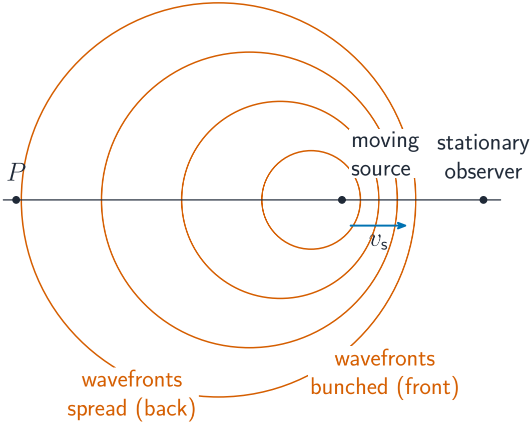
- explain why a moving source changes the observed frequency
- use $f_o = \dfrac{vf_s}{v \pm v_s}$ with the correct sign

Method — The Doppler effect

When the source moves, the wavefronts **bunch up ahead** (shorter λ, **higher** f) and **spread behind** (longer λ, **lower** f):



Method — The Doppler effect



The Doppler effect shifts observed frequency

Method — The formula

$$f_o = \frac{v f_s}{v \pm v_s}$$

- **minus** sign $\rightarrow$ source moving **towards** observer ($f_o > f_s$);
- **plus** sign $\rightarrow$ source moving **away** ($f_o < f_s$).

Worked example. Horn $f_s = 800$ Hz at 30 m s^{-1} **towards** a listener, $v = 340$ m s^{-1}:

$$f_o = \frac{340 \times 800}{340 - 30} = \frac{272\,000}{310} \approx 877 \text{ Hz}.$$

Practice 2.1 ▪ 1 mark

State what the **Doppler effect** is.

Solution 2.1

Method: The Doppler effect

Worked steps

The change in the **observed frequency** when the source of a wave **moves relative to** the observer **B1**.

Practice 2.2 ▪ 1 mark

State whether the observed frequency **increases** or **decreases** as a source moves **towards** the observer.

Solution 2.2

Method: The Doppler effect

Worked steps

It **increases** B1.

Practice 2.3 ▪ 1 mark

State which **sign** ($+$ or $-$) is used in the denominator when the source moves **towards** the observer.

Solution 2.3

Method: The formula

Worked steps

Minus $(-)$ **B1**.

Practice 2.4 ▪ 1 mark

Explain why the wavelength is **shorter** ahead of an approaching source.

Solution 2.4

Method: The Doppler effect

Worked steps

As the source moves forward, each new wavefront is emitted from slightly **closer** to the observer, so the wavefronts ahead are **closer together** (shorter λ) B1.

Exam-style 3.1 ▪ 3 marks

A horn of frequency 800 Hz moves at 30 m s^{-1} **towards** a stationary listener. Calculate the observed frequency.

Solution 3.1

Method: The formula

Worked steps

Source moving towards $\rightarrow$ minus sign **M1**; $f_o = \dfrac{340 \times 800}{340 - 30} = \dfrac{272\,000}{310}$ **M1** ≈ 877 Hz **A1**.

Exam-style 3.2 ▪ 2 marks

The same horn now moves **away** at 30 m s^{-1}. Calculate the observed frequency.

Solution 3.2

Worked steps

Source moving away $\rightarrow$ plus sign; $f_o = \dfrac{340 \times 800}{340 + 30} = \dfrac{272\,000}{370} \approx 735$ Hz M1 A1.

Exam-style 3.3 ▪ 1 mark

A source moving **away** from an observer gives an observed frequency that is:

- **A** higher than the source frequency
- **B** lower than the source frequency
- **C** the same as the source frequency
- **D** zero

Solution 3.3

Method: The Doppler effect

A higher than the source frequency

B lower than the source frequency ✓

C the same as the source frequency

D zero

Worked steps

B — lower than the source frequency.

Exam-style 3.4 ▪ 2 marks

Explain, in terms of **wavefronts**, why an approaching ambulance siren sounds **higher-pitched**.

Solution 3.4

Method: The Doppler effect

Worked steps

As the ambulance approaches, the wavefronts ahead are **bunched closer together** B1, giving a shorter wavelength and a **higher frequency** (higher pitch) B1.