A-LEVEL PHYSICS • EXERCISE SHEET

7.3 Doppler effect for sound waves

Name: ____________ Class: ________ Date: __________ **Total: 12 marks**

KEY WORDS frequency 频率 • wave 波 • source 波源 • stationary 静止 • observer 观察者

Objective

Build the skills to answer exam questions on the **Doppler effect** 多普勒效应 for sound (moving source, stationary observer).

You must be able to:

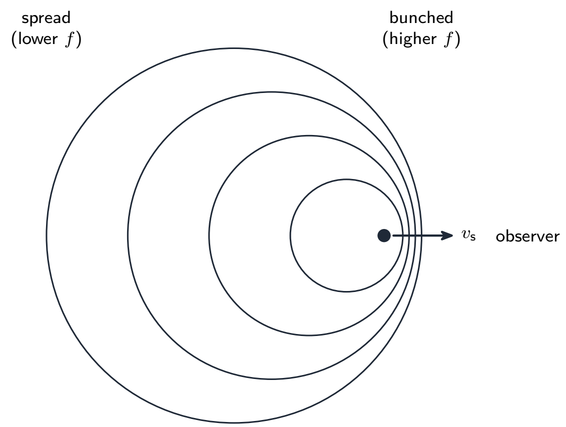
- explain why a moving source changes the observed frequency
- use $f_o = \dfrac{v f_s}{v \pm v_s}$ with the correct sign

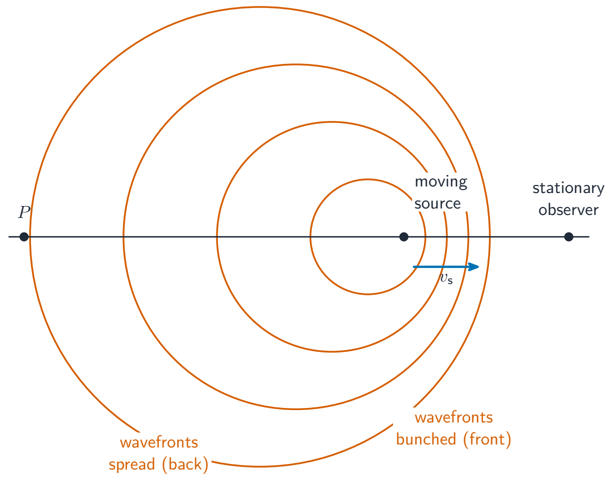
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ The Doppler effect

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





The Doppler effect shifts observed frequency

■ The formula

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

- **minus** sign → source moving **towards** observer ($f_o > f_s$);
- **plus** sign → 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}:

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

2 Practice

Now apply the methods above.

2.1 State what the **Doppler effect** is. [1]

2.2 State whether the observed frequency **increases** or **decreases** as a source moves **towards** the observer. [1]

2.3 State which **sign** ($+$ or $-$) is used in the denominator when the source moves **towards** the observer. [1]

2.4 Explain why the wavelength is **shorter** ahead of an approaching source. [1]

3 Exam-style questions

For these, take the speed of sound as $v = 340$ m s^{-1}.

3.1 A horn of frequency 800 Hz moves at 30 m s^{-1} **towards** a stationary listener. Calculate the observed frequency. [3]

3.2 The same horn now moves **away** at 30 m s^{-1}. Calculate the observed frequency. [2]

3.3 A source moving **away** from an observer gives an observed frequency that is: [1]

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

3.4 Explain, in terms of **wavefronts**, why an approaching ambulance siren sounds **higher-pitched**. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the change in the **observed frequency** when the source **moves relative to** the observer

2.2

- it **increases**

2.3

- **minus** ($-$) in the denominator when the source moves **towards** the observer

2.4

- each new wavefront is emitted from slightly **closer** to the observer, so the wavefronts ahead are **closer together** (shorter λ)

3.1

- source moving **towards** $\Rightarrow$ minus sign

$$f_o = \frac{(340\ \text{m s}^{-1})(800\ \text{Hz})}{340\ \text{m s}^{-1} - 30\ \text{m s}^{-1}} = \frac{2.72 \times 10^5\ \text{m s}^{-2}}{310\ \text{m s}^{-1}} = \mathbf{877}\ \text{Hz}$$

3.2

- source moving **away** $\Rightarrow$ plus sign

$$f_o = \frac{(340\ \text{m s}^{-1})(800\ \text{Hz})}{340\ \text{m s}^{-1} + 30\ \text{m s}^{-1}} = \frac{2.72 \times 10^5\ \text{m s}^{-2}}{370\ \text{m s}^{-1}} = \mathbf{735}\ \text{Hz}$$

3.3 B

- moving **away** stretches successive wavefronts, so λ rises; v is fixed by the medium, so f **falls**
- **A** is an *approaching* source (why a passing siren drops in pitch)

3.4

- as the ambulance approaches, the wavefronts ahead are **bunched closer together**
- shorter $\lambda \Rightarrow$ **higher frequency** (higher pitch)