

Exercise walk-through

7.3

Doppler effect for sound waves

A-Level Physics

Sheet 7.3 – what you need to know

You must be able to:

- explain why a moving source changes the **observed frequency**
- use $f_o = \frac{f_s v}{v \pm v_s}$ with the right sign
- find the source's speed from the frequencies heard

What the exam asks

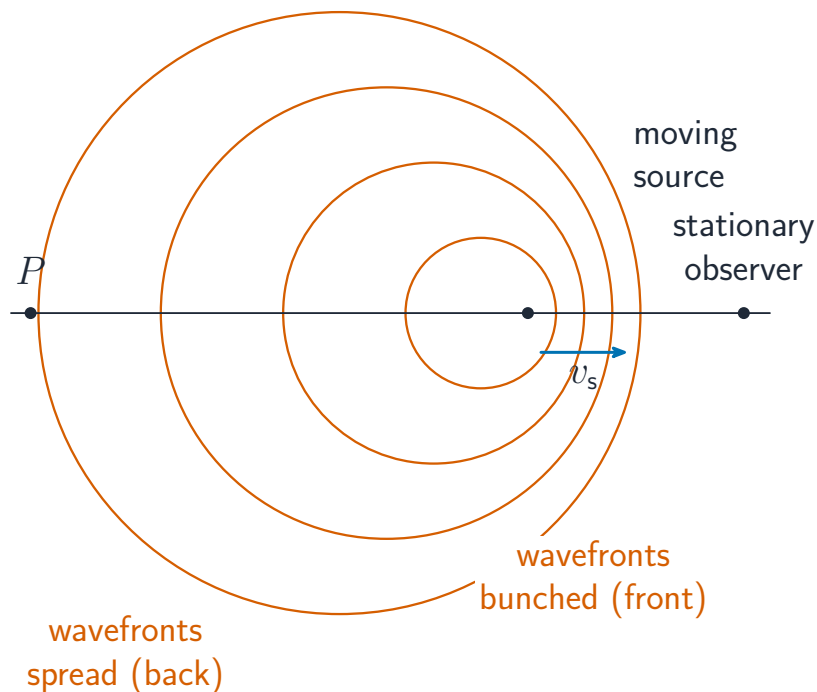
“Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.” [2]

“Determine the frequency, to three significant figures, of the sound heard by the child.” [2]

“Use Fig. 4.2 to determine the speed of the vehicle.” [3]

Practise on exercise sheet 7.3, then try the real exam questions on past-paper sheet 7.3.

Doppler effect



A moving **source** changes the frequency a **stationary observer** hears, because the **wavefronts** ahead are squashed:

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

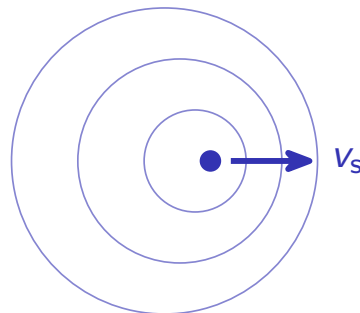
- towards → **minus**, wavefronts squashed, f_o higher
- away → **plus**, wavefronts spread out, f_o lower

Worked example – a car horn

$f_s = 800 \text{ Hz}$, $v_s = 30 \text{ m s}^{-1}$ **towards you**, $v = 340 \text{ m s}^{-1}$

$$f_o = \frac{f_s v}{v - v_s} = \frac{(800 \text{ Hz})(340 \text{ m s}^{-1})}{340 \text{ m s}^{-1} - 30 \text{ m s}^{-1}} \approx 877 \text{ Hz}$$

Higher than 800 Hz – as expected for approach.



bunched ahead

Exercises 2.1·2.2

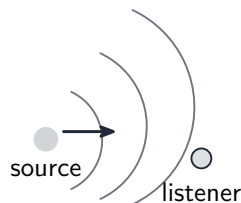
2.1 State what the **Doppler effect** is.

[1]

Doppler effect

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

[1]



Exercises 2.1·2.2

2.1 State what the **Doppler effect** is.

[1]

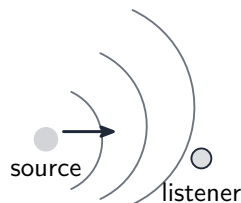
Doppler effect

2.1

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

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

[1]

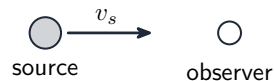


2.2

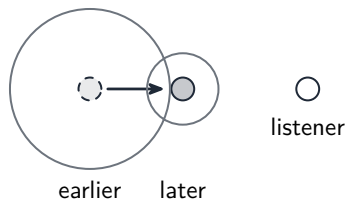
- it **increases**

Exercises 2.3·2.4

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

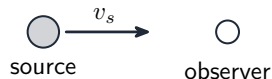


2.4 Explain why the wavelength is **shorter** ahead of an approaching source. [1]



Exercises 2.3·2.4

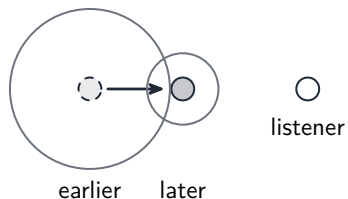
2.3 State which **sign** (+ or $-$) is used in the denominator when the source moves **towards** the observer. [1]



2.3

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

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

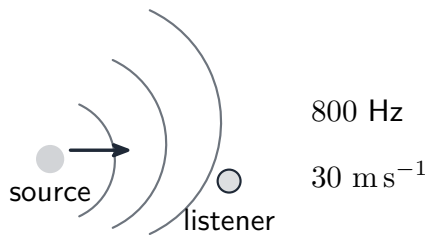


2.4

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

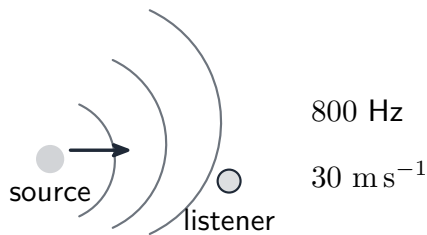
Exercise 3.1

3.1 A horn of frequency 800 Hz moves at $30 \frac{\text{m}}{\text{s}}$ **towards** a stationary listener. Calculate the observed frequency. [3]



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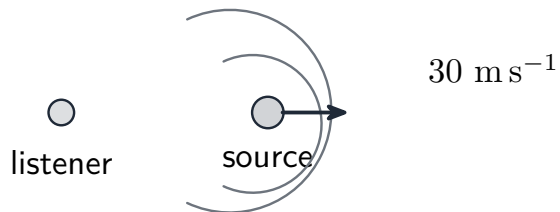
3.1

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

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

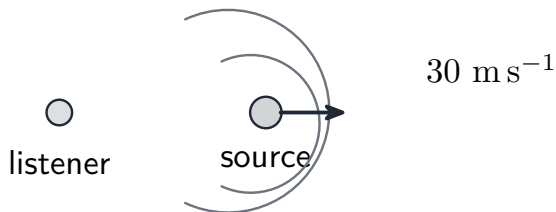
Exercise 3.2

3.2 The same horn now moves **away** at $30 \frac{\text{m}}{\text{s}}$. Calculate the observed frequency. [2]



Exercise 3.2

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3.2

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

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

Exercise 3.3

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

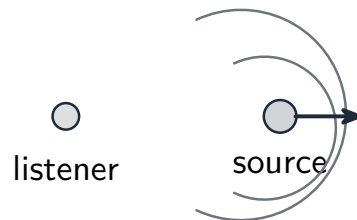
☐

A higher than the source frequency

B lower than the source frequency

C the same as the source frequency

D zero



Exercise 3.3

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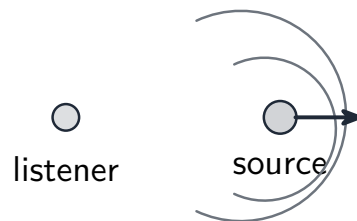
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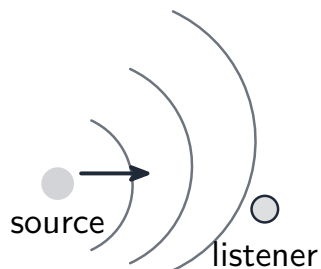


3.3 B

- 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)

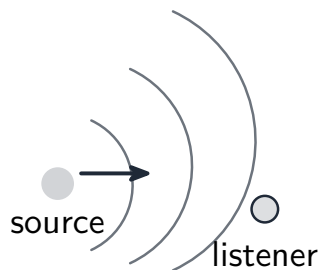
Exercise 3.4

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



Exercise 3.4

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3.4

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