15.2 Doppler effect: separate source motion from wave speed

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS Doppler shift • wavefront

Objective

Doppler effect: separate source motion from wave speed. Original classroom practice for IB HL; not an official IB paper.

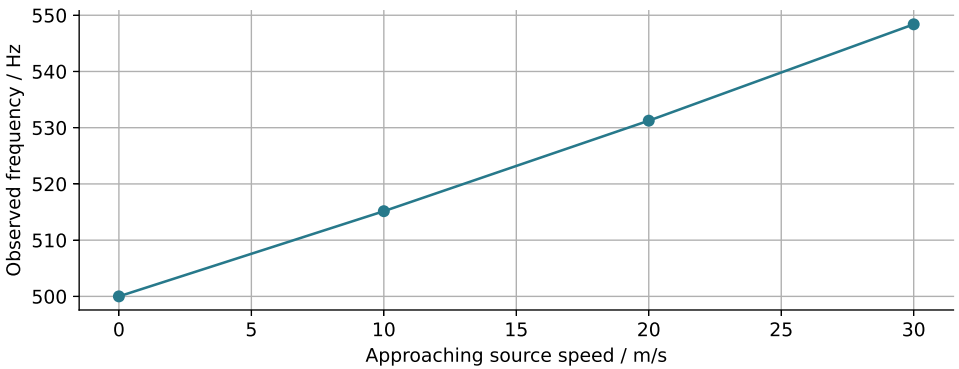
1 Key knowledge and worked examples

■ What would explain this observation?

- An approaching sound source is heard at a higher pitch even when the source produces a constant frequency.

■ Build the model

- **Doppler shift** arises from relative source-observer motion.
- A moving source compresses **wavefront** spacing ahead and increases it behind.
- For sound in a stationary medium, the wave speed relative to that medium need not change.
- Doppler shift: Change of observed frequency due to relative motion.
- wavefront: A surface joining points with the same wave phase.



■ Choose evidence that can test it

- For a source approaching a stationary observer along the line of sight, f observed = f source × v/(v−v source).
- Recession uses v+v source in the denominator.
- These are sound-wave models; light requires its appropriate relation.

In the lab: Use a simulation or recorded data with stated source and observer directions. Draw wavefronts before choosing signs. Avoid demonstrations near moving traffic or unsafe high-volume sources.

■ Work from known quantities

- Known: source frequency 500 Hz, sound speed 340 m/s, source approaches at 20 m/s.
- Observed frequency = 500 × 340/(340−20) = 531.25 Hz.
- The increase is 31.25 Hz; it is not the source frequency changing.

Your turn: A 600 Hz source approaches a stationary observer at 20 m/s. Use v = 340 m/s. Find observed frequency.

■ Check the conclusion and its limits

- A stationary source and moving observer require the observer-motion relation.
- Do not use the same denominator formula for every arrangement or import a sound formula into relativity.

Not true: The Doppler effect always means the wave speed in the medium changed. The wave speed in the medium is fixed by the medium. The Doppler shift comes from relative motion changing the spacing of wavefronts (moving source) or the rate they meet the observer (moving observer) - not from a change in wave speed.

Key:

- Doppler shift arises from relative source-observer motion.
- For a source approaching a stationary observer along the line of sight, f observed = f source × v/(v−v source).
- Watch for: A stationary source and moving observer require the observer-motion relation.

■ Write from an observed frequency of 510 Hz

- A 450 Hz source approaches a stationary observer at 40 m/s. The wave speed is 340 m/s.
- Find the observed frequency. The wave speed in the medium does not change.

2 Practice

2.1 Why is pitch higher in front of an approaching sound source? Choose one answer.

- **A** The listener creates extra source oscillations
- **B** Wavefront spacing is smaller
- **C** Sound speed must become infinite [1]

2.2 A 600 Hz source approaches a stationary observer at 20 m/s. Use v = 340 m/s. Find observed frequency. Show the relation, substitution and units. [2]

2.3 Decide whether this claim is true and justify: The Doppler effect always means the wave speed in the medium changed. [2]

2.4 Change of observed frequency due to relative motion: write the technical term. [1]

3 Exam-style questions

3.1 A 600 Hz sound source recedes at 20 m/s from a stationary observer; sound speed is 340 m/s. Find frequency and compare approach. Why is this not the light Doppler law? [4]

Solutions

2.1 B An approaching source emits each wavefront closer to the previous one in the direction of travel, so the spacing - the wavelength - shrinks in front, and at fixed wave speed a shorter wavelength means a higher pitch.

2.2 For approach, $f' = fv/(v-u) = 600 \times 340/(340-20) = 637.5$ Hz.

2.3 False. The wave speed in the medium is fixed by the medium. The Doppler shift comes from relative motion changing the spacing of wavefronts (moving source) or the rate they meet the observer (moving observer) - not from a change in wave speed.

2.4 Doppler shift. Doppler shift means Change of observed frequency due to relative motion.

3.1 Recession gives $600 \times 340/(340+20) = 566.7$ Hz; approach gives 637.5 Hz. Source direction is relative to a material medium; light requires its appropriate relativistic relation.