

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. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

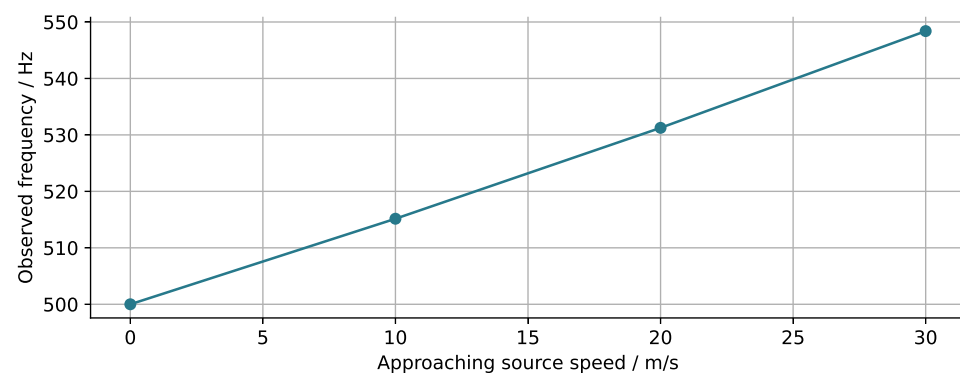
1 Key knowledge and worked examples

■ What would explain this observation?

- An approaching sound source is heard at a higher pitch even when the source produces a constant frequency.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ 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, $f_{\text{observed}} = f_{\text{source}} \times v / (v - v_{\text{source}})$. Recession uses $v + v_{\text{source}}$ in the denominator. These are sound-wave models; light requires its appropriate relation.
- 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

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: source frequency 500 Hz, sound speed 340 m/s, source approaches at 20 m/s. Observed frequency = $500 \times 340 / (340 - 20) = 531.25$ Hz. The increase is 31.25 Hz; it is not the source frequency changing.

Example:

A 600 Hz source approaches a stationary observer at 20 m/s. Use $v = 340$ m/s. Find observed frequency. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

The Doppler effect always means the wave speed in the medium changed. This claim is false: 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.

Key:

Doppler effect: separate source motion from wave speed: For a source approaching a stationary observer along the line of sight, $f_{\text{observed}} = f_{\text{source}} \times v / (v - v_{\text{source}})$. Recession uses $v + v_{\text{source}}$ in the denominator. These are sound-wave models; light requires its appropriate relation.

2 Practice

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

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

[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 A For a source approaching a stationary observer along the line of sight, f observed = f source $\times v/(v - v_{\text{source}})$. Recession uses $v + v_{\text{source}}$ in the denominator. These are sound-wave models; light requires its appropriate relation.

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

2.3 False. 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.

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.