Year 13 Science: The Doppler effect

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A 600 Hz source moves at 20.0 m s^{-1} towards a stationary listener. Using v = 340 m s^{-1}, find the frequency heard.

2. The same source moves away from the listener at 20.0 m s^{-1}. Find the frequency heard.

3. Find the wavelength of the sound in front of the source in question 1.

4. A galaxy's 486.1 nm hydrogen line is measured at 484.2 nm. Is it approaching or moving away, and how fast?

5. A car drives in a circle around you at constant speed, sounding a 400 Hz horn. What frequency do you hear?

Exam-style question: a jet boat on the river

A jet boat on the Waikato River sounds a 750 Hz horn while travelling at 22.0 m s^{-1} straight towards Mere, who is standing on a jetty in its path. Take the speed of sound in air as 343 m s^{-1}.

6. Calculate the frequency Mere hears.

7. Explain why Mere hears a different frequency from the one the horn emits.

8. The boat swerves past the jetty and travels directly away at the same speed. Calculate the frequency she now hears.

9. An underwater microphone ahead of the boat picks up its 400 Hz engine note as 406.0 Hz while the boat approaches at 22.0 m s^{-1}. Calculate the speed of sound in the water.

Fix the mistake

10. Correct this statement: "The source is approaching, so I used v + vs on the bottom."

11. Correct this statement: "The siren itself gets higher as the ambulance speeds up."

12. Correct this statement: "The sound travels faster in front of the moving ambulance."

13. Correct this statement: "At the moment the car passes me I hear the lowest pitch."

Answer key (for parents and tutors)

1. A 600 Hz source moves at 20.0 m s^{-1} towards a stationary listener. Using v = 340 m s^{-1}, find the frequency heard.
   f' = 600 × 340 ÷ (340 − 20.0) = 204 000 ÷ 320 = 637.5 Hz, about 638 Hz.

2. The same source moves away from the listener at 20.0 m s^{-1}. Find the frequency heard.
   f' = 600 × 340 ÷ 360 = 566.7 Hz, about 567 Hz.

3. Find the wavelength of the sound in front of the source in question 1.
   λ' = (v − vs) ÷ f = 320 ÷ 600 = 0.533 m.

4. A galaxy's 486.1 nm hydrogen line is measured at 484.2 nm. Is it approaching or moving away, and how fast?
   Δλ = 484.2 − 486.1 = −1.9 nm, shorter, so blue shifted and approaching; v = 3.00 × 10^8 × 1.9 ÷ 486.1 = 1.2 × 10^6 m s^{-1} towards us.

5. A car drives in a circle around you at constant speed, sounding a 400 Hz horn. What frequency do you hear?
   The car's velocity is always across your line of sight, never towards or away, so there is no shift: you hear 400 Hz.

6. Calculate the frequency Mere hears.
   f' = 750 × 343 ÷ (343 − 22.0) = 257 250 ÷ 321 = 801.4 Hz, about 801 Hz (Achieved).

7. Explain why Mere hears a different frequency from the one the horn emits.
   The boat moves forward between emitting one wavefront and the next, so the wavefronts ahead are closer together and the wavelength reaching Mere is shorter; the speed of sound is set by the air and is unchanged, so by v = fλ she receives more waves each second and hears a higher frequency (Merit for two linked ideas, Excellence for wavelength, constant speed and v = fλ together).

8. The boat swerves past the jetty and travels directly away at the same speed. Calculate the frequency she now hears.
   f' = 750 × 343 ÷ (343 + 22.0) = 257 250 ÷ 365 = 704.8 Hz, about 705 Hz (Achieved).

9. An underwater microphone ahead of the boat picks up its 400 Hz engine note as 406.0 Hz while the boat approaches at 22.0 m s^{-1}. Calculate the speed of sound in the water.
   406.0 = 400 × v ÷ (v − 22.0), so 406.0v − 8932 = 400v, 6.0v = 8932, v = 1489 m s^{-1}, about 1490 m s^{-1} (Merit for the correct substitution, Excellence for the correct rearrangement and answer).

10. Correct this statement: "The source is approaching, so I used v + vs on the bottom."
    Approaching must raise the frequency, so the bottom is v − vs, which is smaller than v.

11. Correct this statement: "The siren itself gets higher as the ambulance speeds up."
    The source frequency is unchanged; only the wavelength reaching the observer, and so the frequency heard, changes.

12. Correct this statement: "The sound travels faster in front of the moving ambulance."
    The wave speed is set by the air; the source's speed changes the wavelength, not the wave speed.

13. Correct this statement: "At the moment the car passes me I hear the lowest pitch."
    At the closest point the car moves neither towards nor away, so you hear the true frequency; the lowest comes as it moves off.