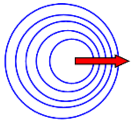
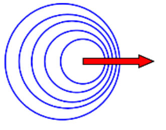
The Doppler Effect

Definitions

When a car sounding its horn speeds past, the note heard by an observer changes pitch. When approaching, the pitch is higher; when moving away, the pitch is lower. This is an example of the Doppler effect: when there is relative motion between a source of sound and an observer, the observed (apparent) frequency is different from the actual frequency.

In this case because the source is moving the waves are compressed ahead of the source and stretched out behind it. An observer ahead of the source hears a higher apparent frequency, f ' because the apparent wavelength has been reduced, and an observer behind the source hears a lower apparent frequency, f '. The greater the velocity of the source, the greater the Doppler effect.





Equations/Diagrams

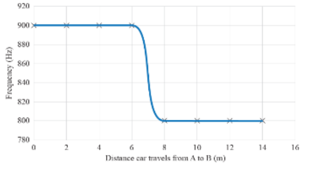
Equation	Quantity	Symbol	Unit
$f' = f\dfrac{v_w}{v_w \pm v_s}$	Apparent frequency	f'	Hz
	Actual frequency	f	Hz
	Velocity of wave	v_w	m s^{-1}
	Velocity of source	v_s	m s^{-1}
$v = f\lambda$	Velocity of wave	v	m s^{-1}
	frequency	f	Hz
	wavelength	λ	m

Questions

QUESTION THREE (2020;3)

The speed of sound in air is 3.40 x 10^2 m s^{-1}.
Lily and Dave are conducting an experiment to measure the frequency of the sound produced by a car horn as it travels past a stationary observer. Lily drives her car from point A to point B directly past (and very close to) Dave who is recording the frequency of the sound waves, as shown.

Using the data recorded, Dave was able to plot the frequency he observed on a graph.



(a) Using the graph, state the frequency Dave hears as the car travels towards him.

(b) By considering the motion of the sound waves from the car horn, give reasons why Dave's meter detects a change in frequency as the car approaches him, and then goes past him.

(c) Using the information above, calculate the constant speed of the car that Lily is driving.

(d) After Lily passes point B, she decides to accelerate away from Dave, who remains in the same position. Using your knowledge of the Doppler effect, explain how and why the frequency that Dave hears changes during this time.

Terms

Apparent frequency: Observed frequency of wave when source or observer is moving (f')

Doppler effect: An apparent shift in the frequency of a wave due to relative motion between the source of the wave and the observer

Tips

The (simplified) Doppler effect equation uses:

- (v_w - v_s) if the motion is **towards** the observer (so f ' > f)
- (v_w + v_s) if the movement is **away** from the observer. (so f ' < f)

- Because the equation has been simplified, it is not symmetrical.

Answers

(a) 900 Hz

(b) As the car approaches Dave, each successive wavefront is produced closer to the emitted wave than if the car was stationary causing the sound waves bunch up in front of the car. As v = f λ, and the wave speed is constant, Dave hears a higher frequency.

(c) →

When moving TOWARDS:

$$f' = f\frac{v_w}{v_w - v_s} \text{ (rearrange for } f)$$

$$f = f'\frac{v_w - v_s}{v_w}$$

When moving AWAY:

$$f = f''\frac{v_w + v_s}{v_w}$$

COMBINE to eliminate *f*:

$$f = f'\frac{v_w + v_s}{340} = f''\frac{v_w - v_s}{340}$$

$$900 \times \frac{340 - v_s}{340} = 800 \times \frac{340 + v_s}{340}$$

$$306000 - 900v_s = 272000 + 800v_s$$

$$34000 = 1700v_s$$

v_S = 20 m s^{-1}

(d) The frequency will be decreasing because if the car is accelerating away, then the v_s is increasing (with formula).