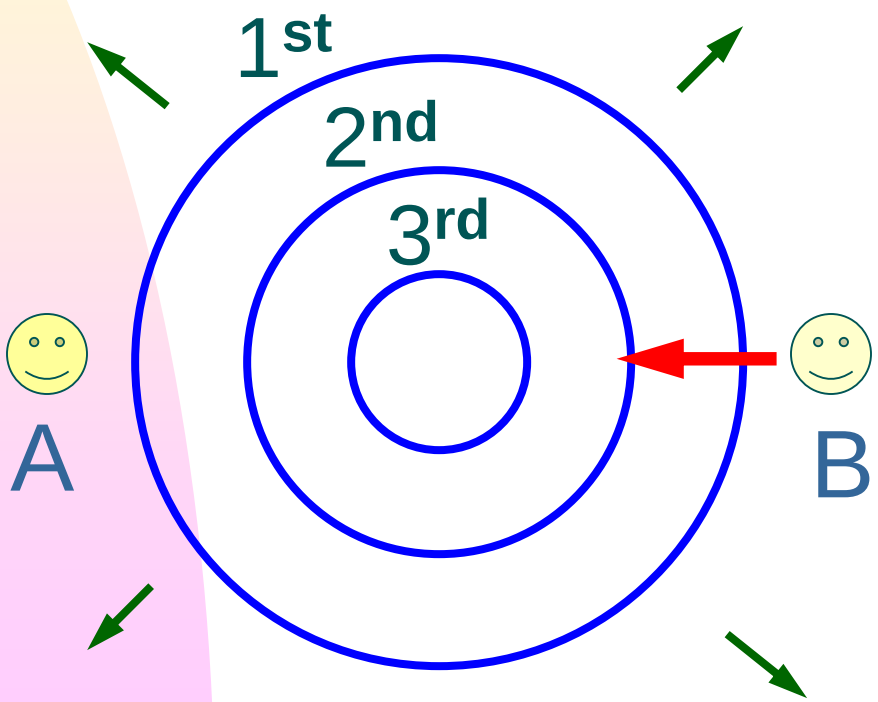
Physics 115 Lecture 15

The Doppler Effect II

February 27, 2018

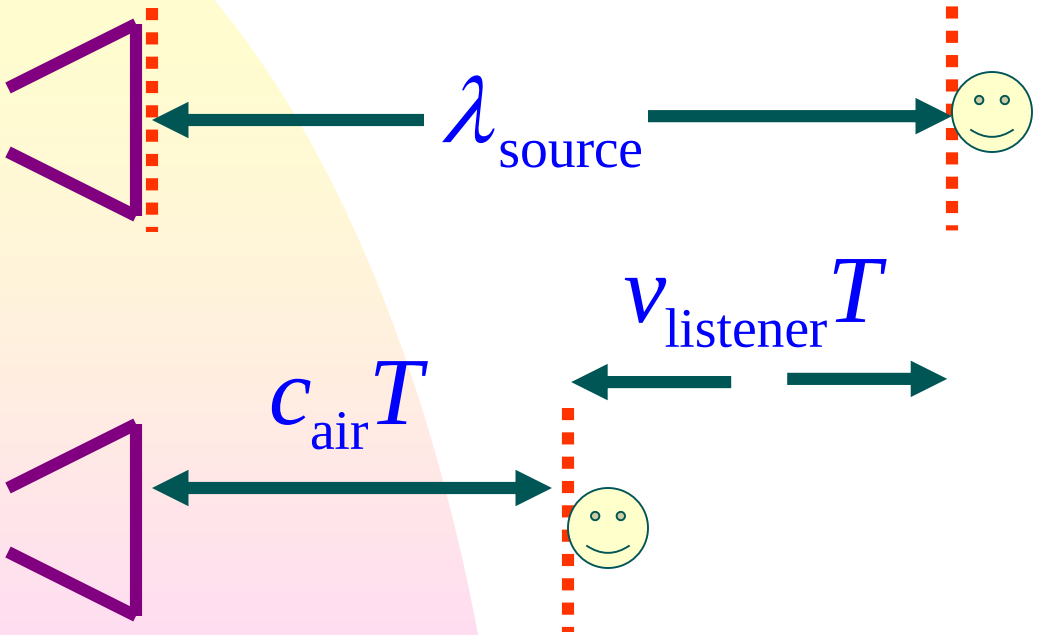
The Doppler Effect

- Suppose the source stays in one spot, but observer B approaches it:



Observer B measures a higher frequency than does observer A.

Listener approaches stationary source



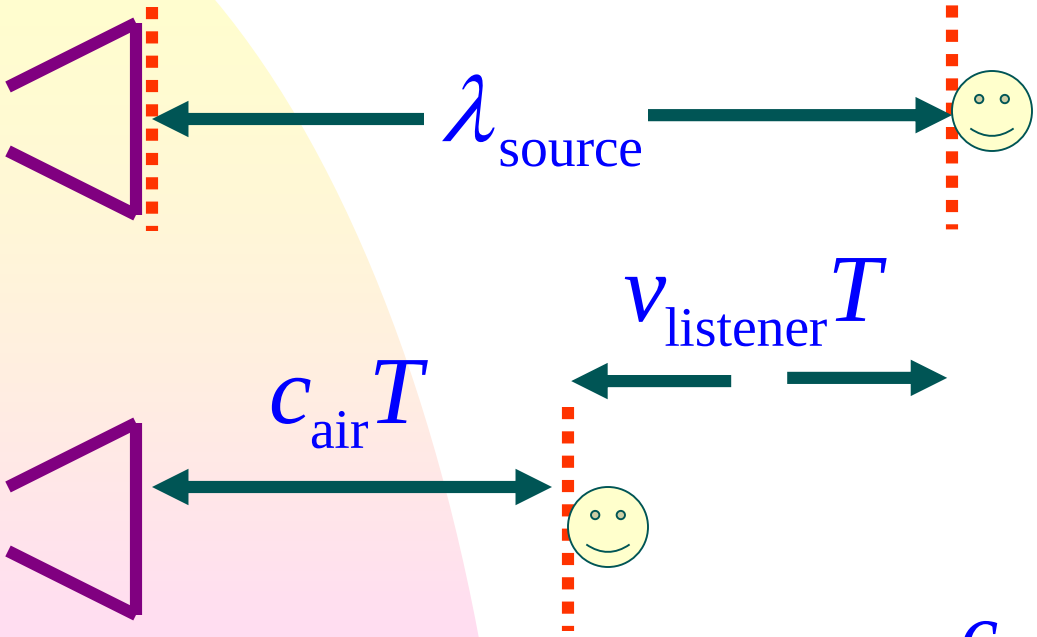
At $t = 0$, the listener detects a crest

At $t = T$, the listener detects the next crest.

Note: Frequency detected by listener = $1 / T$

⇨ $f_{listener} = 1 / T$ ⇨ $T = 1 / f_{listener}$

Listener approaches stationary source



$$\lambda_{source} = c_{air}T + v_{listener}T$$

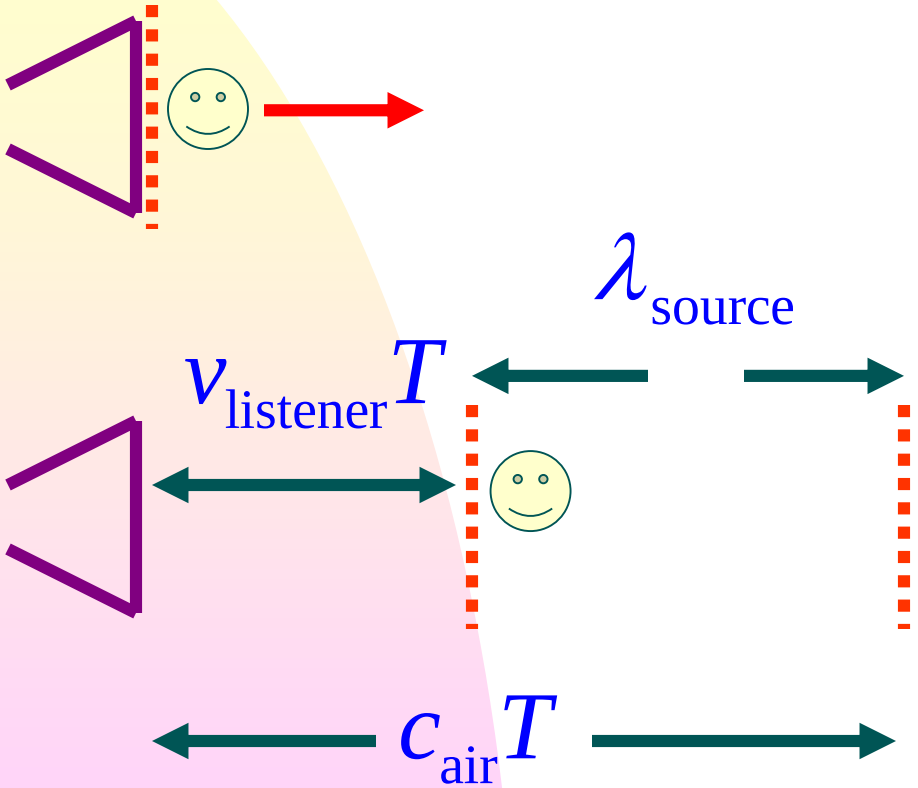
$$\lambda_{source} = T\left(c_{air} + v_{listener}\right)$$

$$\frac{c_{air}}{f_{source}} = T\left(c_{air} + v_{listener}\right)$$

$$\frac{c_{air}}{f_{source}} = \frac{1}{f_{listener}}\left(c_{air} + v_{listener}\right)$$

$$f_{listener} = f_{source}\left(\frac{c_{air} + v_{listener}}{c_{air}}\right)$$

Listener recedes from stationary source



$$\lambda_{source} = c_{air}T - v_{listener}T$$

$$\lambda_{source} = T\left(c_{air} - v_{listener}\right)$$

$$\frac{c_{air}}{f_{source}} = T\left(c_{air} - v_{listener}\right)$$

$$\frac{c_{air}}{f_{source}} = \frac{1}{f_{listener}}\left(c_{air} - v_{listener}\right)$$

$$f_{listener} = f_{source}\left(\frac{c_{air} - v_{listener}}{c_{air}}\right)$$

Grand Summary

$$f_{\text{listener}} = f_{\text{source}} \left(\frac{c_{\text{air}} \pm v_{\text{listener}}}{c_{\text{air}} \mp v_{\text{source}}} \right)$$

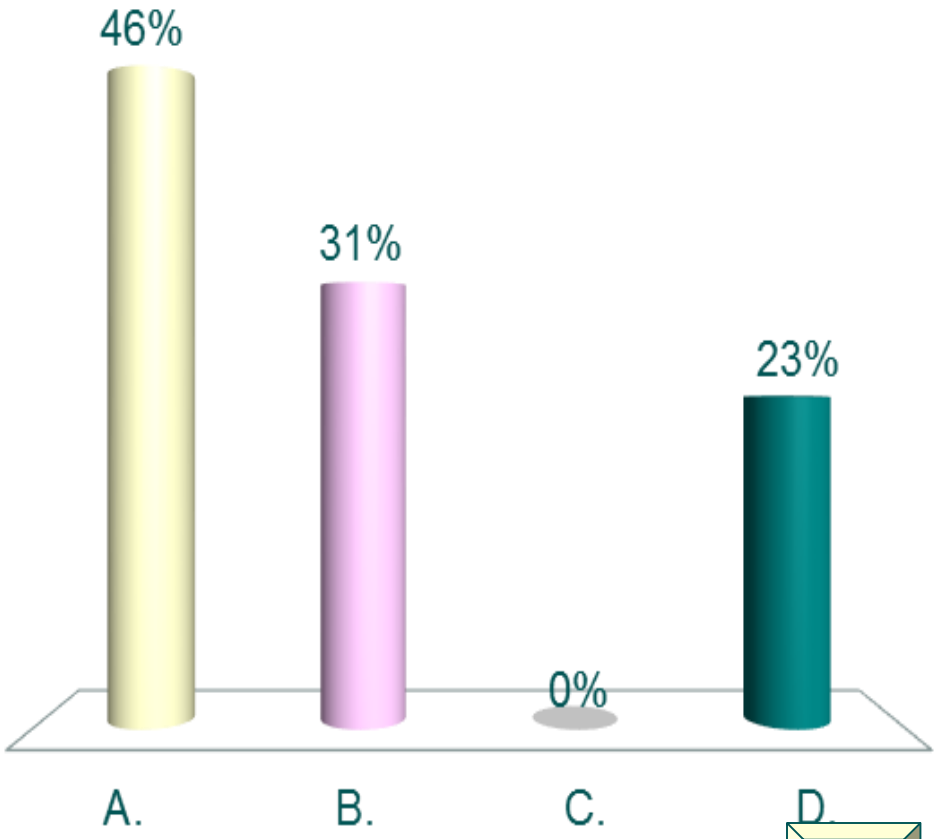
Use the upper sign when the source and the listener are approaching one another.

Use the lower sign when the source and the listener are receding from one another.

Measure all speeds in the rest frame of the wave propagation medium.

Which of the following properties of a wave does NOT change due to the Doppler effect?

A. wavelength
B. speed
C. frequency
D. They all change.



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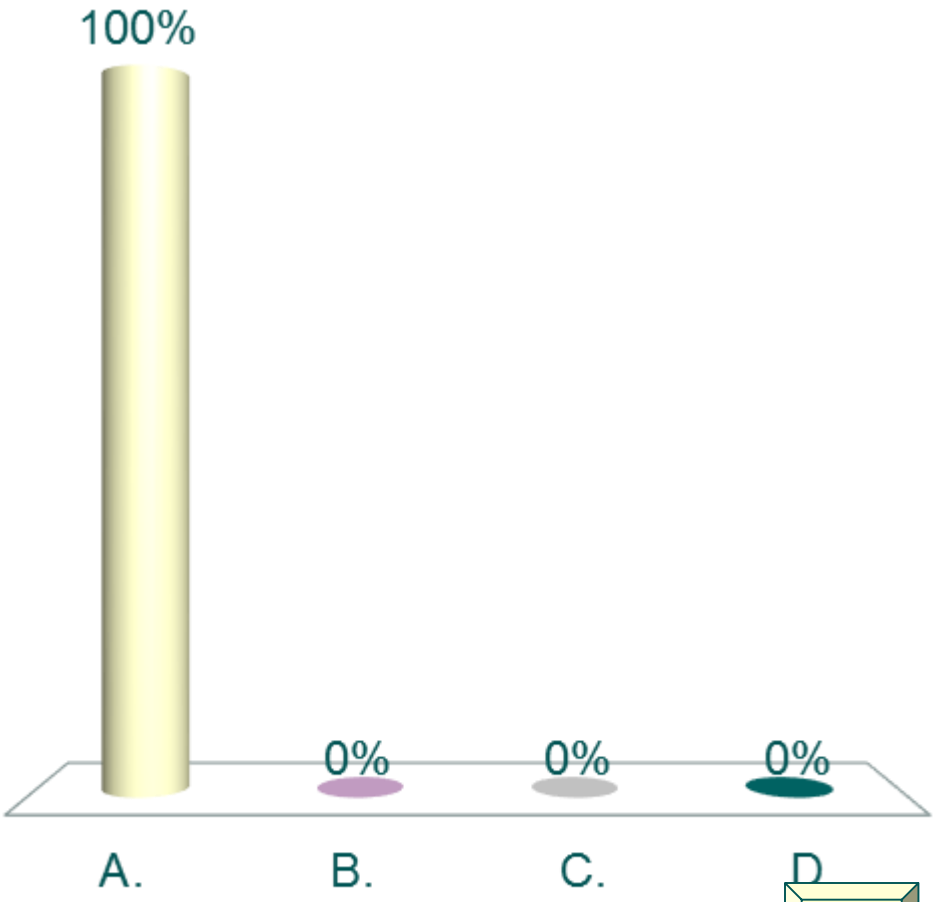
Which of the following properties of a wave does NOT change due to the Doppler effect?

A. wavelength
B. speed
C. frequency
D. They all change.

The speed of a wave is determined by the properties of the medium, not the speed of the source or the observer.

If a listener moves at 10 m/s toward a 2000-Hz sound source, while the source moves toward the listener at 20 m/s, what is the perceived frequency? c_{air} = 340 m/s

A. 2187.5 Hz
B. 1944.4 Hz
C. 2062.5 Hz
D. 1833.3 Hz



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If a listener moves at 10 m/s toward a 2000-Hz sound source, while the source moves toward the listener at 20 m/s, what is the perceived frequency? c_{air} = 340 m/s

A. **2187.5 Hz**
B. 1944.4 Hz
C. 2062.5 Hz
D. 1833.3 Hz

Choose the top sign because each is approaching:

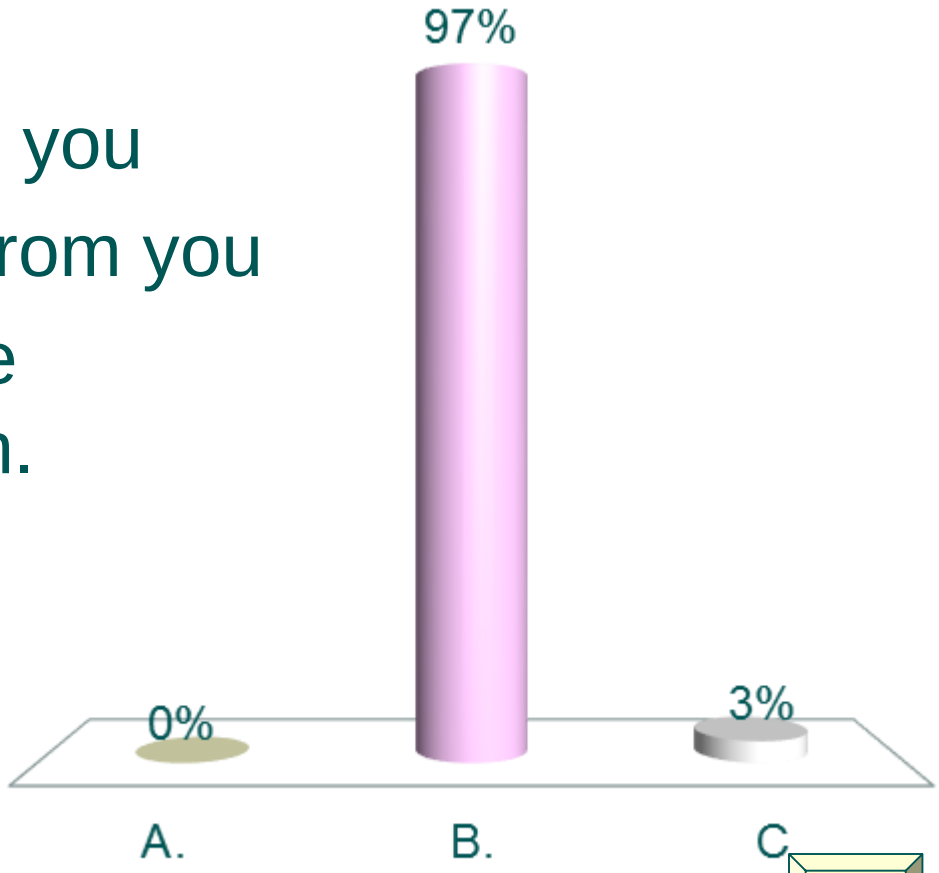
$$f_{\text{listener}} = f_{\text{source}}\left(\frac{c_{\text{air}} + v_{\text{listener}}}{c_{\text{air}} - v_{\text{source}}}\right)$$

$$= (2000\ \text{Hz})\left(\frac{340 + 10\ \text{m/s}}{340 - 20\ \text{m/s}}\right)$$

$$f_{\text{listener}} = \boxed{2187.5\ \text{Hz}}$$

Class Quiz: Which produces the higher detected frequency, a 110-Hz horn moving toward you at 12 m/s or a 220-Hz horn moving away from you with a speed of 24 m/s? c_{air} = 340 m/s

A. Horn moving toward you
B. Horn moving away from you
C. You detect the same frequency from each.



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Class Quiz: **Which produces the higher detected frequency, a 110-Hz horn moving toward you at 12 m/s or a 220-Hz horn moving away from you with a speed of 24 m/s? c_{air} = 340 m/s**

A. Horn moving toward you

B. Horn moving away from you

C. You detect the same frequency from each.

Horn moving toward you:

$$f_{\text{listener}} = f_{\text{source}}\left(\frac{c_{\text{air}} + v_{\text{listener}}}{c_{\text{air}} - v_{\text{source}}}\right)$$

$$= (110\ \text{Hz})\left(\frac{340 + 0\ \text{m/s}}{340 - 12\ \text{m/s}}\right)$$

$$f_{\text{listener}} = \boxed{114\ \text{Hz}}$$

Horn moving away from you:

$$f_{\text{listener}} = f_{\text{source}}\left(\frac{c_{\text{air}} - v_{\text{listener}}}{c_{\text{air}} + v_{\text{source}}}\right)$$

$$= (220\ \text{Hz})\left(\frac{340 - 0\ \text{m/s}}{340 + 24\ \text{m/s}}\right)$$

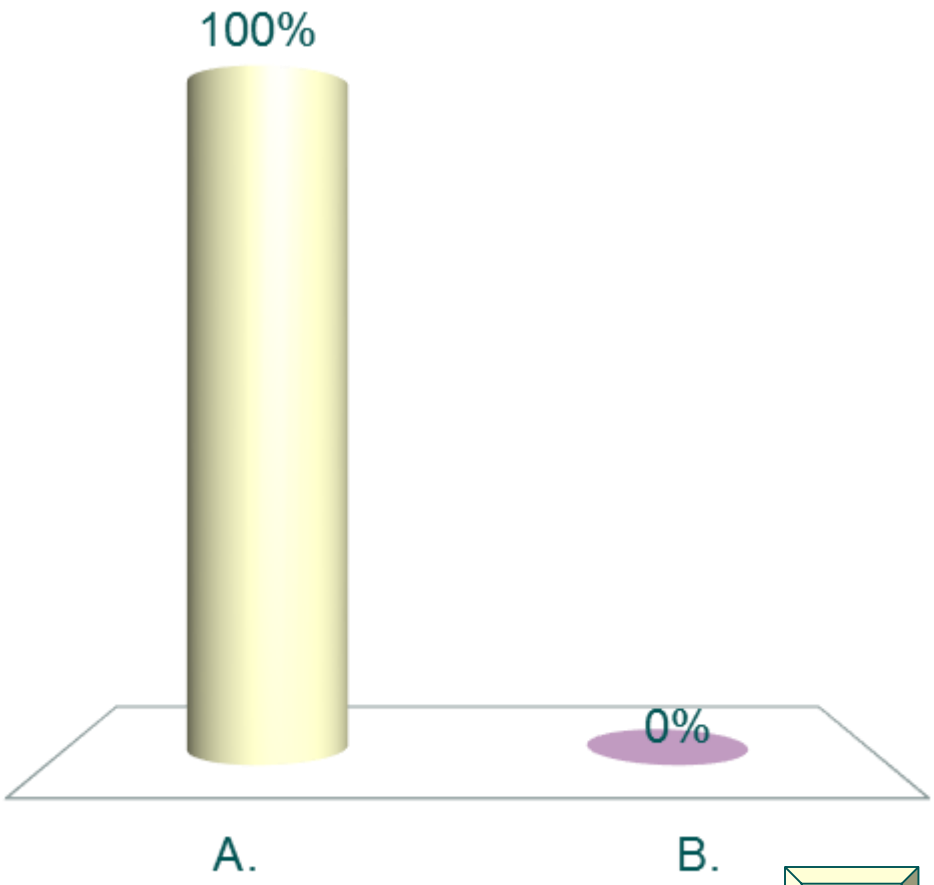
$$f_{\text{listener}} = \boxed{205\ \text{Hz}}$$

Doppler Effect

- In-class activity sheet

Did you complete the in-class activity?

A. Yes (20 pts)
B. No



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