Physics 115 Lecture 7

Sound propagation, interference, and beats

February 6, 2018
The speed of sound in air depends upon the temperature $T_c$ in °C:

$$c_{\text{air}} = 331.4 + 0.589T_c \text{ m/s}$$

- $c_{\text{air}} = 331.4$ m/s at 0°C (32°F)
- $c_{\text{air}} = 343.2$ m/s at 20°C (68°F)
The wavelength of sound emitted by a flute is determined by its shape, which remains constant. Therefore, as the air temperature decreases, the frequency of the flute’s sound

A. increases.
B. remains the same.
C. decreases.
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\[ c_{\text{air}} = f \lambda \]

The speed of sound decreases as temperature decreases, so if the wavelength remains constant, the frequency must also decrease. This is why musical instruments must be retuned when the temperature changes.
On a day when the temperature is 25°C, you hear a thunderclap 7.5 s after seeing a flash of lightning. How far away was the lightning strike?

A. 25.0 km
B. 7.50 km
C. 5.15 km
D. 2.60 km
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$c_{\text{air}} = 331.4 + 0.589(25^\circ \text{C}) = 346.1 \text{ m/s}$

$d = c_{\text{air}} t = (346.1 \text{ m/s})(7.50 \text{ s}) = 2600 \text{ m}$

$= 2.60 \text{ km} \times \frac{1 \text{ mi}}{1.609 \text{ km}} = 1.62 \text{ mi}$

A “rule of thumb” is that sound travels about 1 mile every five seconds.
Wave interference

- When waves meet, they pass through each other.
- When they do, their amplitudes add. (animation)
Wave interference

- In two dimensions, two in-phase sources produce a series of nodal and antinodal lines. (animation)
- The angle $\theta$ between these lines is proportional to the wavelength divided by the source separation.

$\theta \propto \frac{\lambda}{d}$

interference pattern formed by two sources of periodic waves in a water ripple tank
An interference pattern is formed by two sound sources that produce waves in phase with each other. As the two sources are brought closer together, the separation of the locations of maximum amplitude will ______.

A. increase
B. stay the same
C. decrease
An interference pattern is formed by two sound sources that produce waves in phase with each other. As the two sources are brought closer together, the separation of the locations of maximum amplitude will ______.

A. increase  
B. stay the same  
C. decrease

The angle $\theta$ and the separation $d$ are inversely proportional to each other

$$\theta \propto \frac{\lambda}{d}$$
Beats

- When two sources of waves have slightly different frequencies, an interference pattern in time is formed.
- The resulting wave exhibits a beat frequency.

\[ f_{\text{beat}} = |f_2 - f_1| \]
Beats

Amplitude: oscillates with beat frequency, $|f_1 - f_2|$

$y_{\text{total}}$: oscillates with average frequency, $\frac{f_1 + f_2}{2}$

Animated applet
Beats
You have three tuning forks with frequencies of 252 Hz, 256 Hz, and 259 Hz. What beat frequencies are possible with these tuning forks?

A. 2 Hz, 6 Hz, and 9 Hz
B. 3 Hz and 4 Hz
C. 3 Hz, 4 Hz, and 7 Hz
D. 8 Hz, 11 Hz, and 15 Hz
You have three tuning forks with frequencies of 252 Hz, 256 Hz, and 259 Hz. What beat frequencies are possible with these tuning forks?

A. 2 Hz, 6 Hz, and 9 Hz
B. 3 Hz and 4 Hz
C. 3 Hz, 4 Hz, and 7 Hz
D. 8 Hz, 11 Hz, and 15 Hz

\[ |f_2 - f_1| = |252 \text{ Hz} - 256 \text{ Hz}| = 4 \text{ Hz} \]
\[ = |252 \text{ Hz} - 259 \text{ Hz}| = 7 \text{ Hz} \]
\[ = |256 \text{ Hz} - 259 \text{ Hz}| = 3 \text{ Hz} \]