Diffraction & interference

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Diffraction

- Diffraction is the spreading of waves around objects or through gaps.
- Diffraction of sound is only significant for gaps smaller than the wavelength.
- (For light waves, diffraction can still be significant even when the gap is up to about 100 times larger than the wavelength.)

\[
\frac{\lambda}{d} \leq 1
\]
Diffraction

- The amount of diffraction is greater for longer wavelengths and smaller gaps.
- The amount of diffraction increases with wavelength, decreases with the gap.
- Diffraction of sound is only apparent when $\lambda/d \geq 1$.
- This explains speakers; high frequencies are only heard directly in front, low frequencies heard everywhere.
Diffraction through gaps
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Diffraction through gaps

Diffraction increases as the gap decreases.
Along this line, there will be points of local maximum intensity (antinodes) & minimum intensity (nodes).

The minima will be halfway between the maxima.

Anti-nodal line = local maximum intensity

Nodal line = local minimum intensity
Calculating interference patterns

- There is a series of nodal and anti-nodal lines (parabolic curves).
- Anti-nodal lines are caused by **constructive interference**, where the waves have travelled the same distance, or whole wavelengths different distances.
- The difference in distance from the point \( p \) to the sources \( s_1, s_2 \):
  \[
dPs_1 - dPs_2 = n\lambda \quad (n=0, 1, 2, 3...)
\]
- Nodal lines are caused by **destructive interference**, where the waves have travelled half wavelength different distances.
- If the point is a half wavelength (or 1.5, 2.5....) difference in distance between the two sources, **destructive interference** causes a nodal line.
  \[
dPs_1 - dPs_2 = (n - \frac{1}{2})\lambda \quad (n=1, 2, 3...)
\]
Calculating interference patterns - directly between sources.

Anti-nodal lines: \[ x - (d - x) = n\lambda \]

The central anti-nodal line is equidistant to the two sound sources.

eg. for a 2 m wave, with speakers 6 m apart

The central anti-nodal line (A_0) is at \( x = 3.0 \) m

The first anti-nodal line (A_1) is at:

\[ x - (6 - x) = 1 \times 2 \text{ m} \quad 2x = 8 \quad x = \frac{8}{2} = 4.0 \text{ m} \]  
(Also at 2.0 m)

The second anti-nodal line (A_2) is at:

\[ x - (6 - x) = 2 \times 2 \text{ m} \quad 2x = 10 \quad x = \frac{10}{2} = 5.0 \text{ m} \]  
(Also at 1.0 m)

Anti-nodal lines will be half a wavelength apart between the sources.
Calculating interference patterns - in front of one source

• Moving straight out from $S_1$, the two anti-nodal curves will be crossed.
• This occurs where the distances between the point and the two speakers are 1 & 2 wavelengths difference.
• The anti-nodal line ($A_1$) will be at a distance found by:

\[ x^2 + d^2 = (x + n\lambda)^2 \]

\[ x^2 + d^2 = x^2 + 2n\lambda x + (n\lambda)^2 \]

\[ x^2 + 6^2 = (x + 2)^2 \]
\[ x^2 + 6^2 = x^2 + 4x + 4 \]
\[ 32 = 4x \]
\[ x = 8 \text{ m} \]

(This is in fact the furthest line from $S_1$.)

• The anti-nodal line ($A_2$) will be at a distance found by:

\[ x^2 + d^2 = (x + 4)^2 \]
\[ x^2 + 6^2 = x^2 + 8x + 16 \]
\[ 20 = 8x \]
\[ x = 2.5 \text{ m} \]

Moving out from the speaker, the anti-nodal lines are spaced further apart.