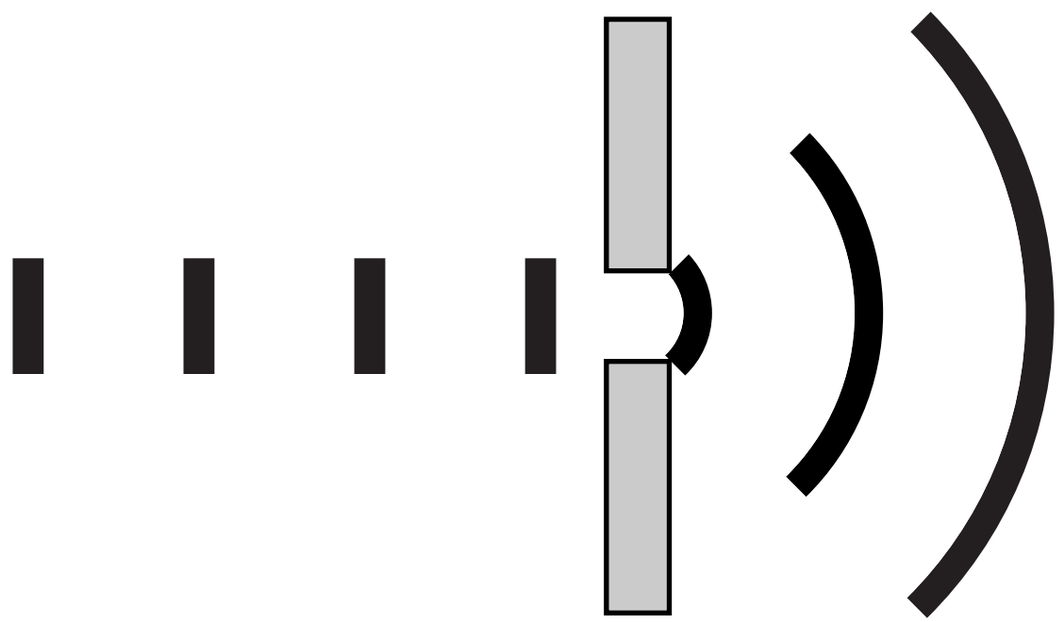
Diffraction & interference

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.)

Wavelength is greater than the gap

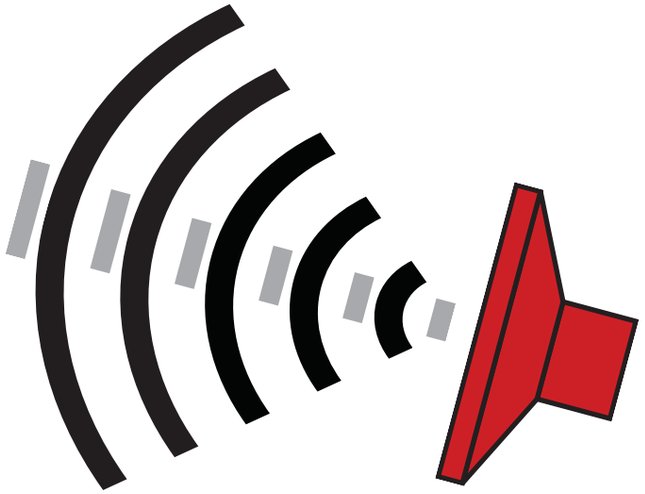
$$\frac{\lambda}{d} \leq 1$$



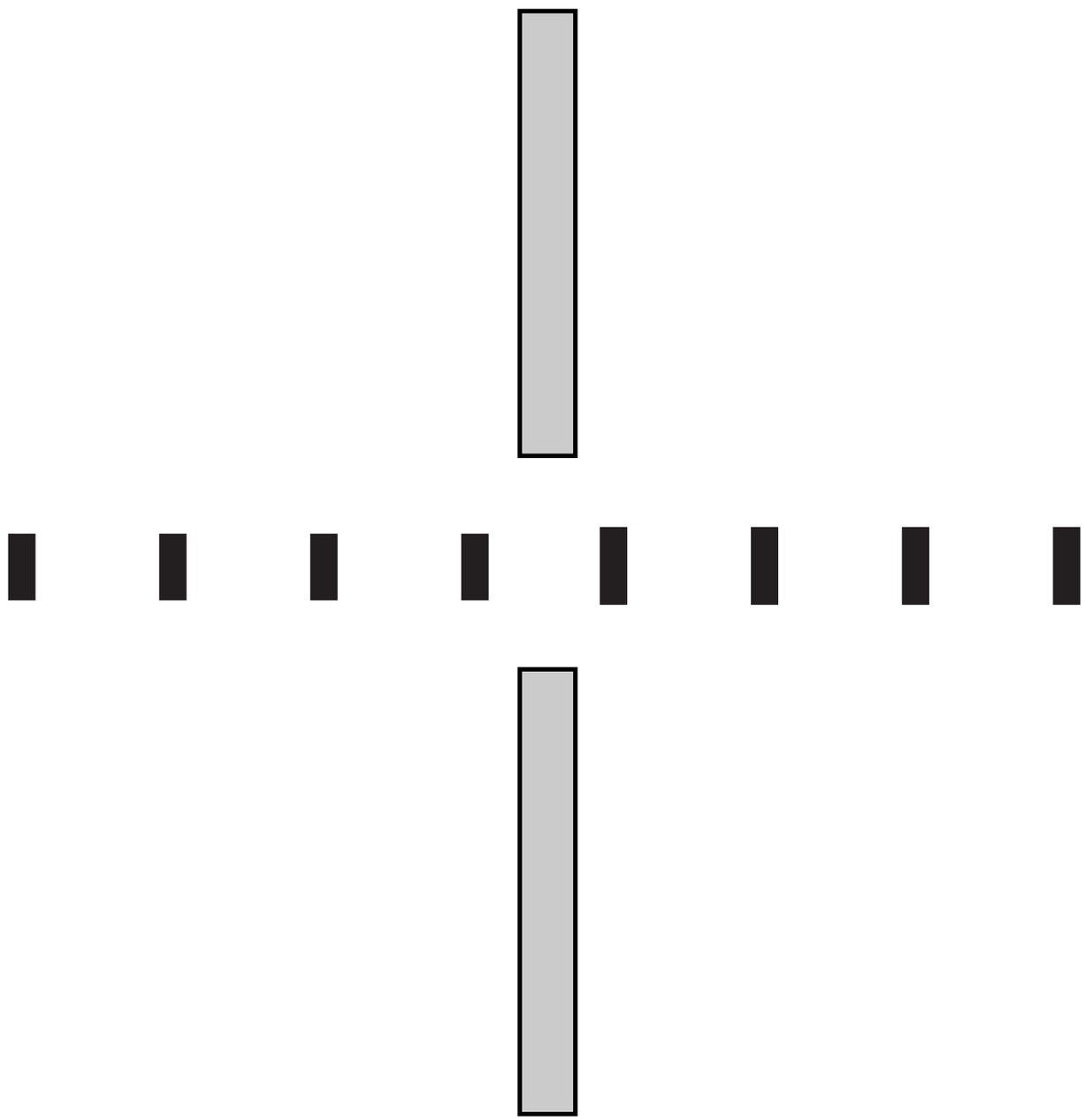
Wave Interference

Diffraction

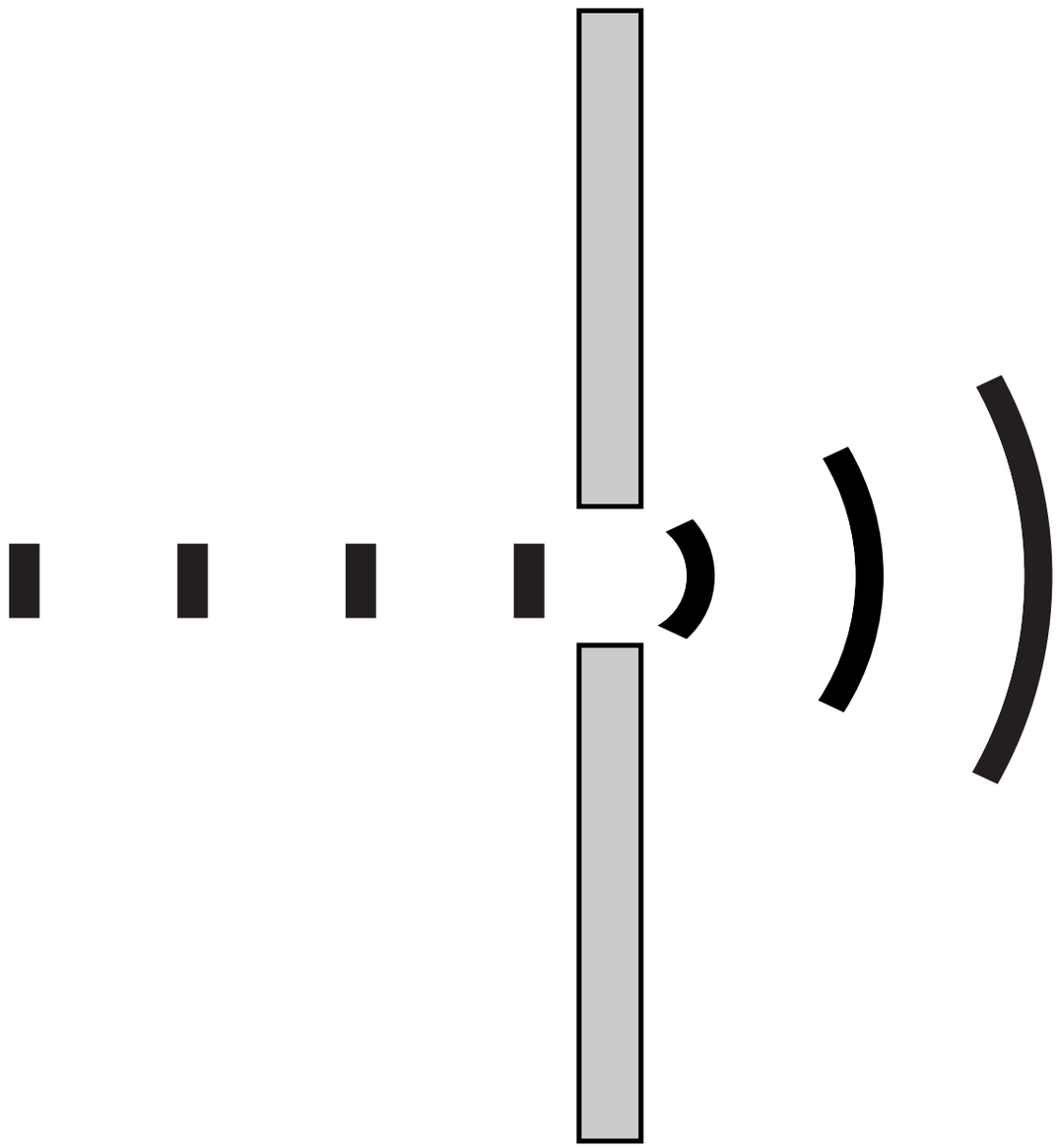
- The amount of diffraction is greater for longer wavelengths and smaller gaps.
- The amount of diffraction increases with wavelength, decreases with the gap.
- Diffraction of sound is only apparent when $\lambda/d \geq 1$.
- This explains speakers; high frequencies are only heard directly in front,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



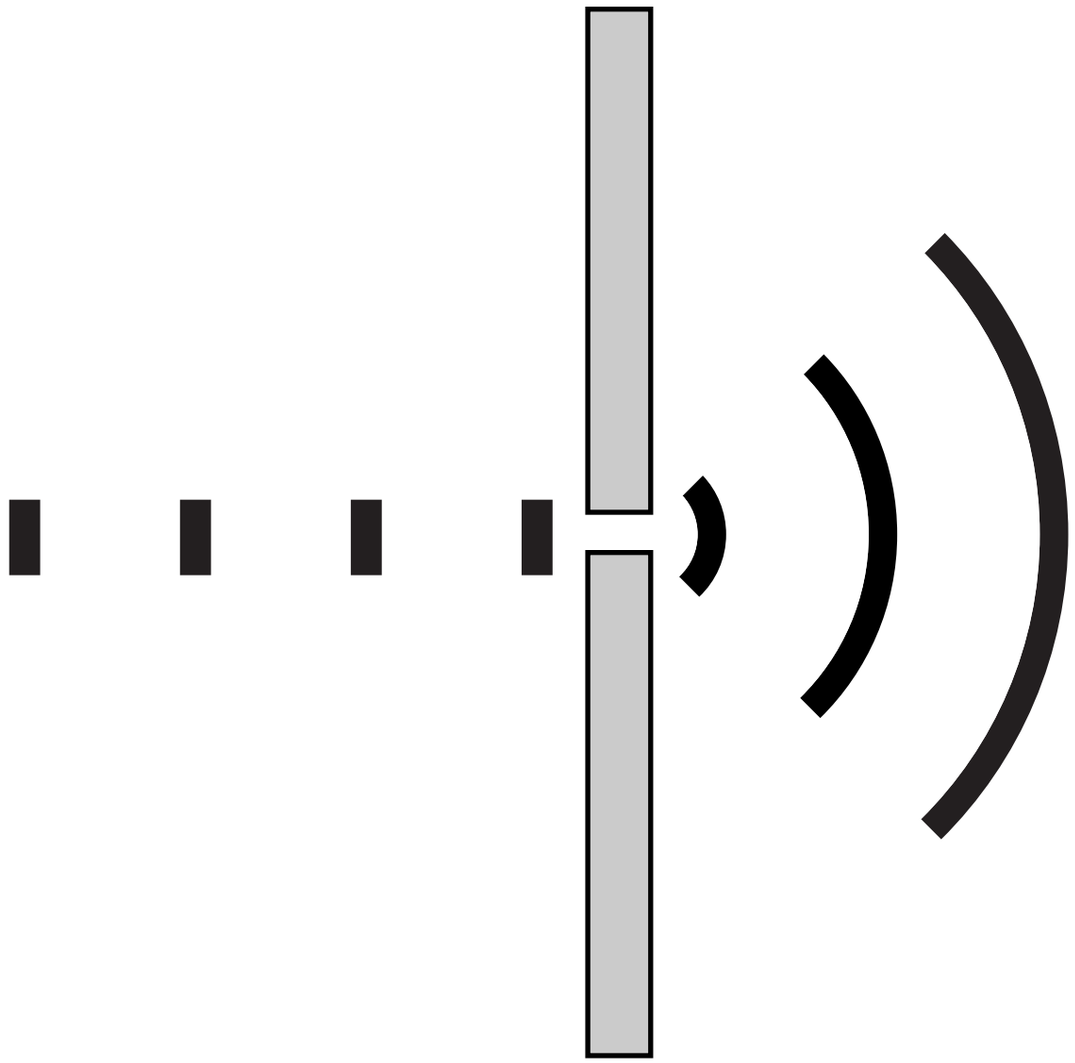
Diffraction through gaps



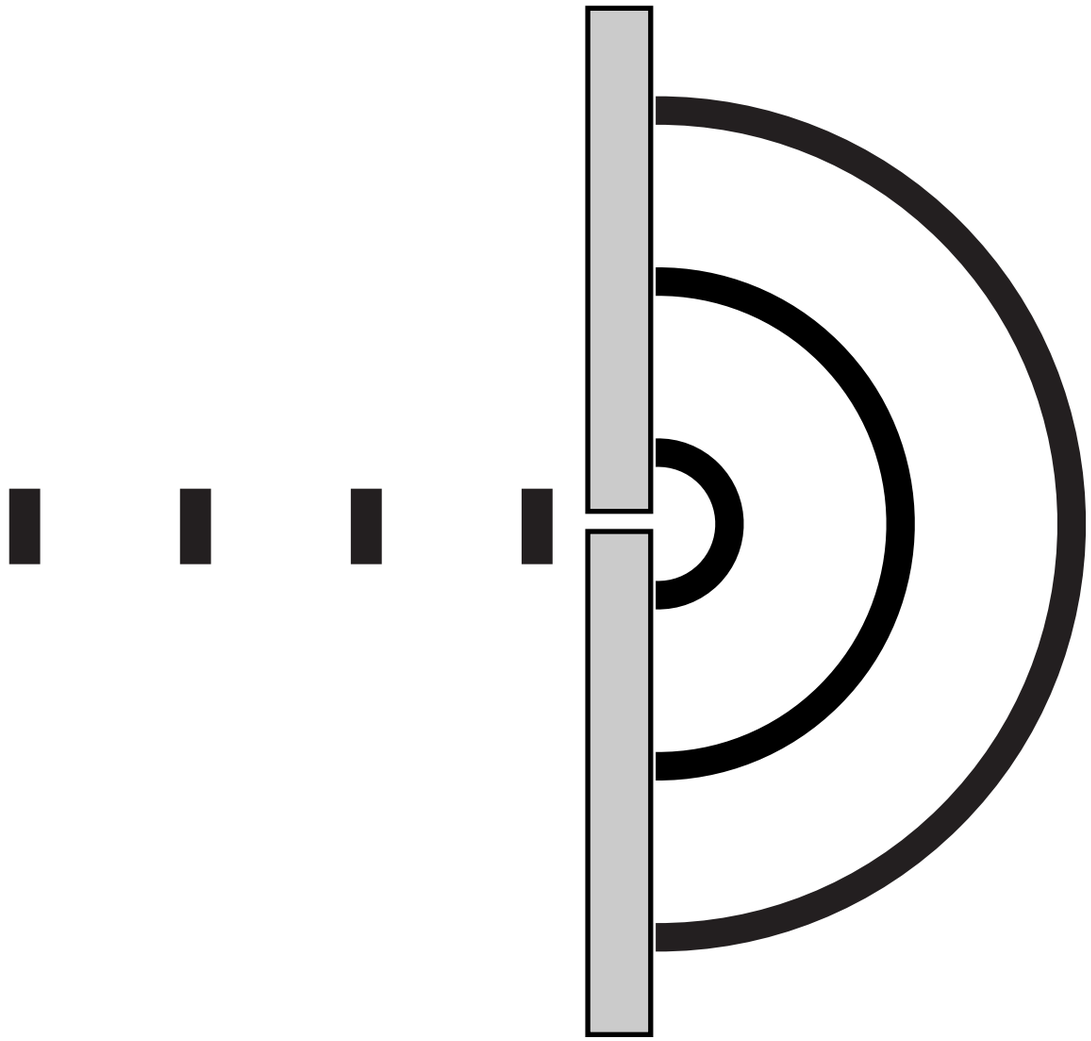
Diffraction through gaps



Diffraction through gaps

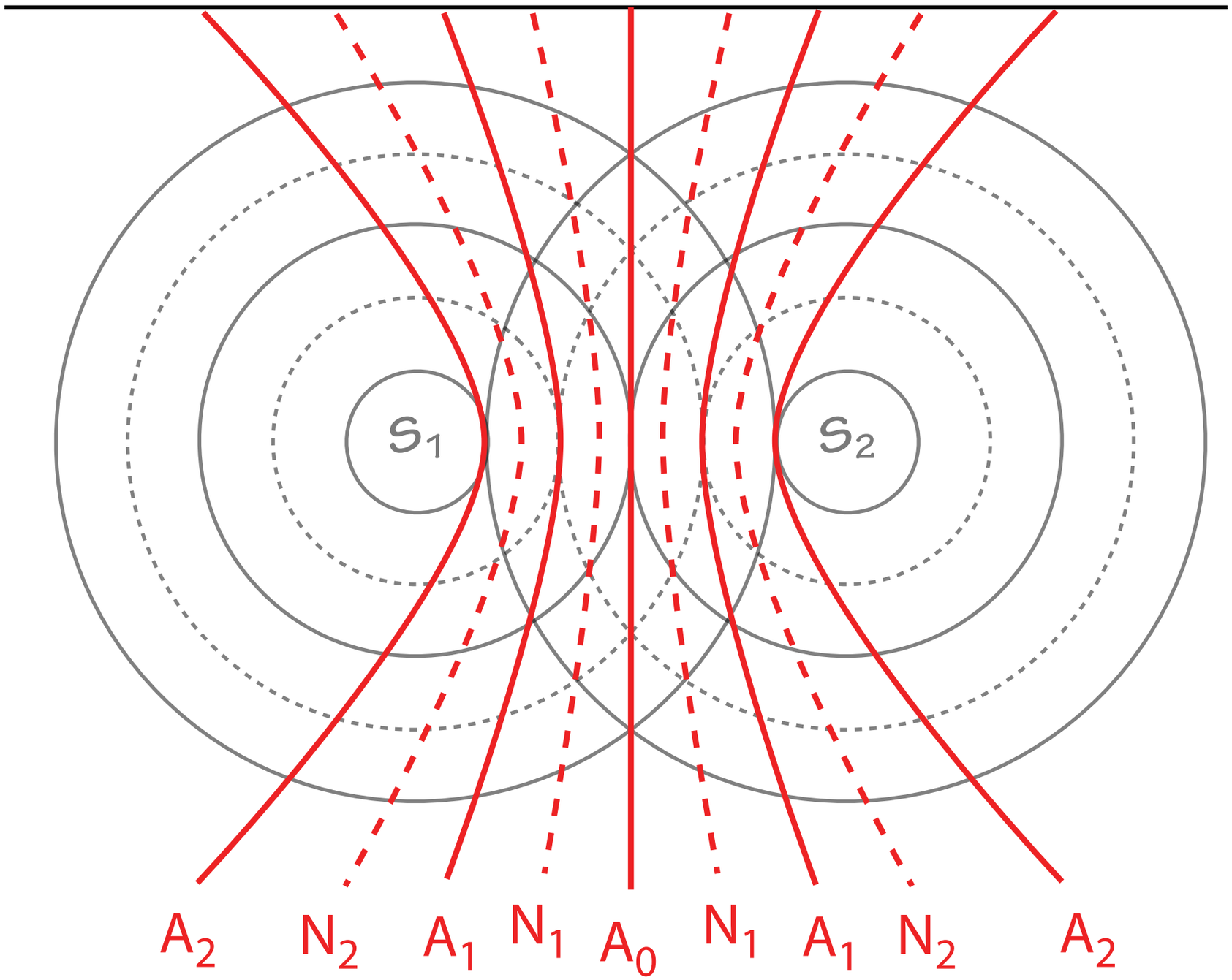


Diffraction through gaps



Diffraction increases as the gap decreases.

Interference patterns - two sources



- Along this line, there will be points of local maximum intensity (antinodes) & minimum intensity (nodes).
- The minima will be half way between the maxima

Anti-nodal line = local maximum intensity

Nodal line = local minimum intensity

Interference

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):

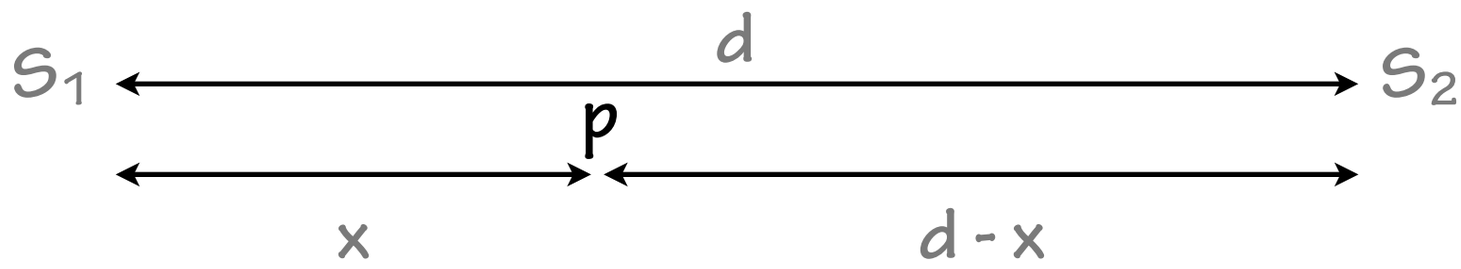
$$dPs_1 - dPS_2 = n\lambda \quad (n = 0, 1, 2, 3...)$$

- 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.

$$dPs_1 - dPS_2 = (n - \frac{1}{2})\lambda \quad (n = 1, 2, 3...)$$

Interference

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:

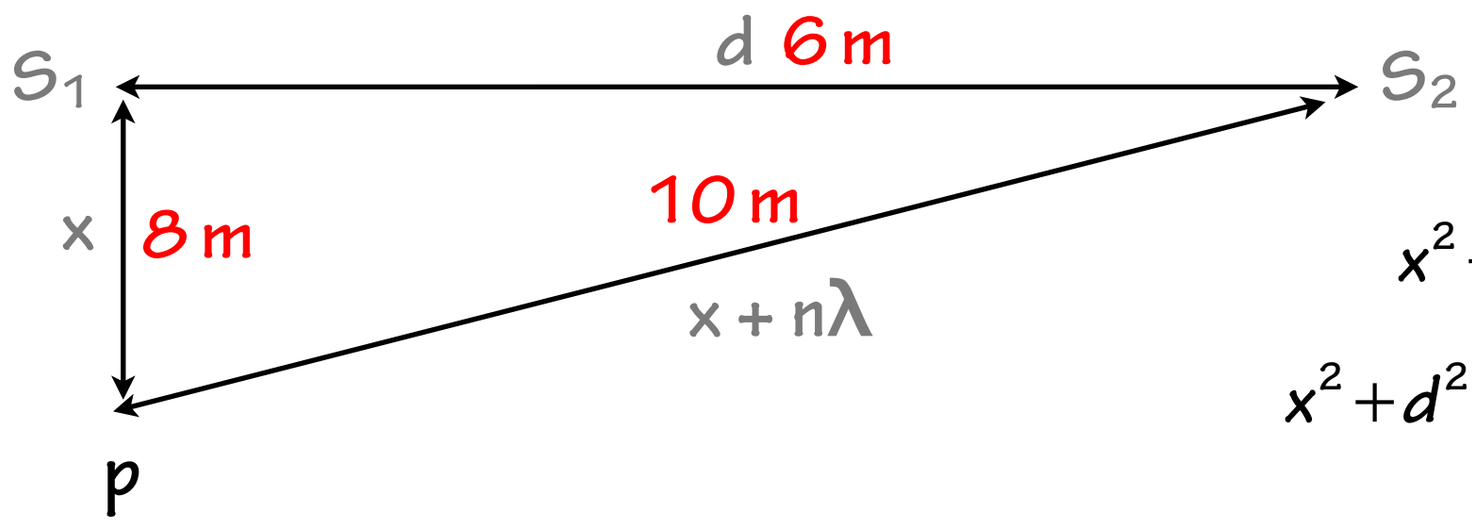
$x-(6-x)=1\times 2\text{ m}$ $\quad 2x=8 \quad x=\frac{8}{2} \quad x=4.0\text{ m}$ (Also at 2.0 m)

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

$x-(6-x)=2\times 2\text{ m}$ $\quad 2x=10 \quad x=\frac{10}{2} \quad x=5.0\text{ m}$ (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



$$x^2+d^2=(x+n\lambda)^2$$

$$x^2+d^2=x^2+2n\lambda x+(n\lambda)^2$$

- 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:

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

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

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

$x^2+6^2=(x+4)^2$ $\quad x^2+6^2=x^2+8x+16$ $\quad 20=8x$ $\quad x=2.5\text{ m}$

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