WAVES

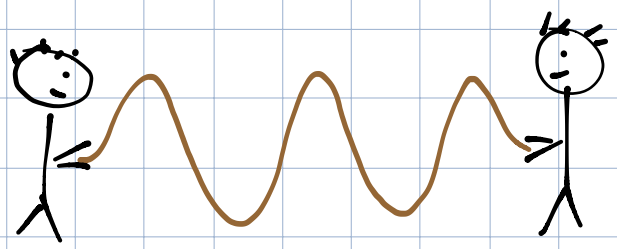
- A WAVE IS A DISTURBANCE OR MOVEMENT THAT TRANSFERS ENERGY THROUGH A MEDIUM WITHOUT ANY PERMANENT DISPLACEMENT.
- A PULSE IS A SINGLE DISTURBANCE (AS OPPOSED TO A CONTINUOUS DISTURBANCE).
- A MEDIUM IS A SUBSTANCE THROUGH WHICH WAVES TRAVEL.

TYPES OF WAVES

- TRANSVERSE WAVES: MATTER MOVES UP AND DOWN PERPENDICULAR TO THE DIRECTION OF PROPAGATION.

EXAMPLE

SHAKING A ROPE

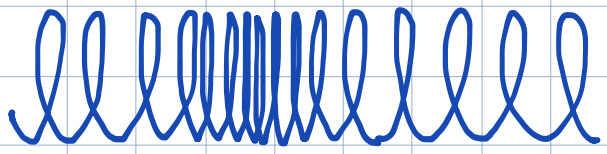


AKA COMPRESSION WAVES

- LONGITUDINAL WAVES: MATTER MOVES BACK AND FORTH IN THE SAME DIRECTION OF PROPAGATION.

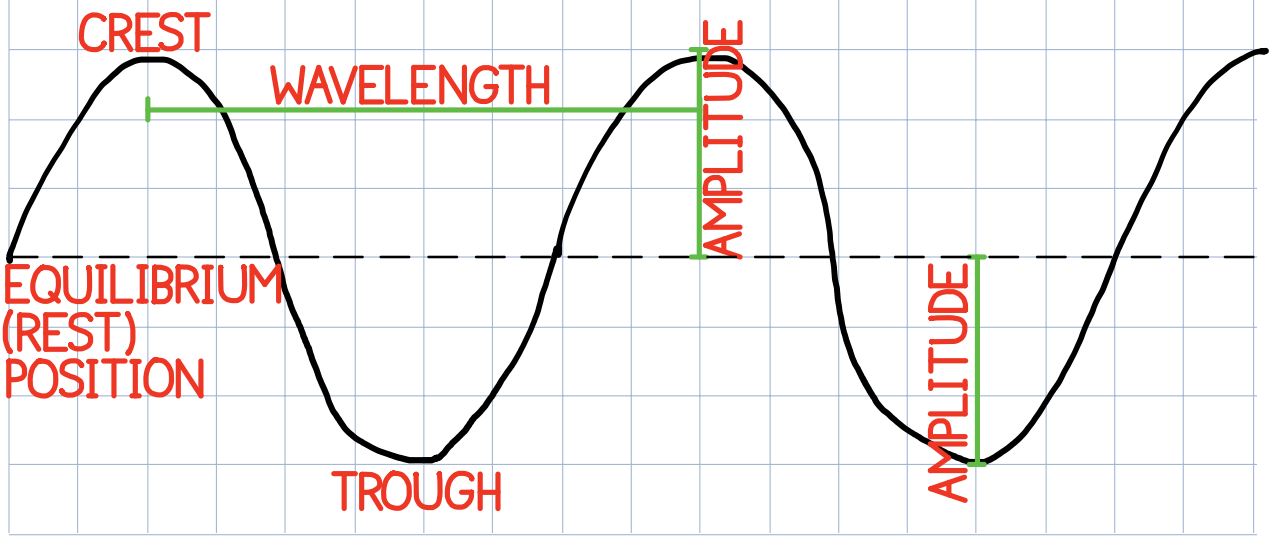
EXAMPLE

SOUND, SPRING



- MECHANICAL WAVES REQUIRE A MEDIUM IN ORDER TO TRANSPORT THEIR ENERGY.
- ELECTROMAGNETIC WAVES CAN TRAVEL THROUGH A VACUUM (I.E. THEY DO NOT REQUIRE A MEDIUM).

FEATURES OF A WAVE



- THE LARGER THE AMPLITUDE, THE GREATER THE ENERGY TRANSPORTED BY THE WAVE.
  LARGER AMPLITUDE → GREATER DISPLACEMENT FROM EQUILIBRIUM POSITION → GREATER FORCE → GREATER WORK REQUIRED → GREATER ENERGY CARRIED BY WAVE

- THE PERIOD IS THE TIME FOR A FULL WAVELENGTH TO PASS A POSITION.

- FREQUENCY IS THE NUMBER OF WAVELENGTHS PASSING A POSITION IN ONE SECOND.
- SI UNIT: HERTZ (Hz) EQUIVALENT TO $\frac{1}{s}$

$$T = \frac{1}{f}$$

T: PERIOD (s)
f: FREQUENCY (Hz)

$$v = \lambda f$$

LAMBDA

v: WAVE SPEED ($\frac{m}{s}$)
λ: WAVELENGTH (m)
f: FREQUENCY (Hz)

WAVE SPEED IS NOT THE SAME AS SPEED OF THE PARTICLES IN THE MEDIUM. THE WAVE SPEED IS HOW QUICKLY THE DISTURBANCE TRAVELS THROUGH A MEDIUM. PARTICLE SPEED IS HOW QUICKLY A PARTICLE MOVES ABOUT ITS EQUILIBRIUM POSITION.

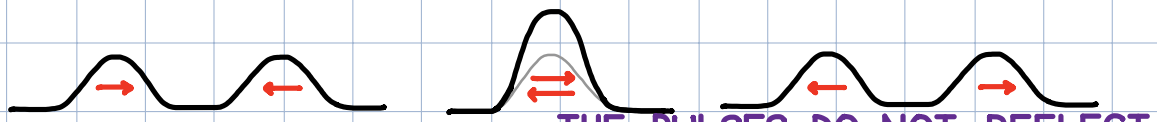
- THE SPEED OF A WAVE DEPENDS ON THE MEDIUM.
- THE FREQUENCY OF A WAVE DEPENDS ON THE SOURCE. ← WHAT CREATES THE WAVE

EXAMPLE

THE CREST AND ADJACENT TROUGH OF A TRANSVERSE WAVE ARE SEPARATED BY 2.0 m. IF THE WAVE IS TRAVELLING AT 20 $\frac{m}{s}$, HOW MANY WAVELENGTHS PASS A GIVEN POINT EACH SECOND?

SUPERPOSITION AND INTERFERENCE

- **PRINCIPLE OF SUPERPOSITION**: TWO SEPARATE WAVES IN A MEDIUM ADD UP.
- **CONSTRUCTIVE INTERFERENCE**: TWO CRESTS OVERLAP RESULTING IN AN INCREASED AMPLITUDE.

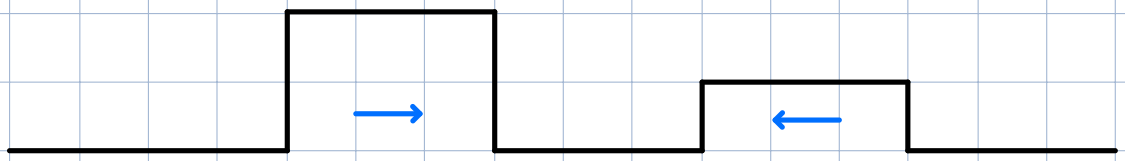


THE PULSES DO NOT REFLECT OFF EACH OTHER.

- **DESTRUCTIVE INTERFERENCE**: CREST AND TROUGH OVERLAP RESULTING IN A DECREASED AMPLITUDE.

EXAMPLE

TWO WAVE PULSES ARE PROPOGATING ALONG A STRAIGHT LINE TOWARD EACH OTHER, EACH WITH A SPEED OF ONE UNIT PER SECOND.

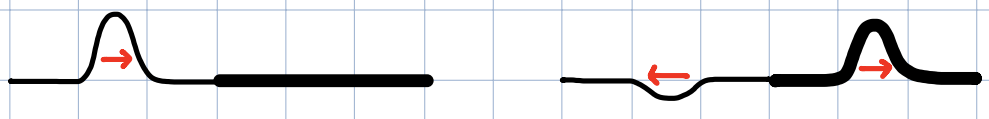


DRAW THE RESULTANT AFTER

a) 3s
b) 4s
c) 5s

BOUNDARY BEHAVIOUR

- BOUNDARY BEHAVIOUR DESCRIBES THE BEHAVIOUR OF A WAVE WHEN IT REACHES THE END OF A MEDIUM.
- UPON REACHING A BOUNDARY, SOME OF THE ENERGY CARRIED BY THE INCIDENT WAVE IS REFLECTED; THE REST IS TRANSMITTED.
  - BECAUSE THE ENERGY OF THE INCIDENT WAVE IS DIVIDED BETWEEN THE REFLECTED AND TRANSMITTED WAVES, THE AMPLITUDE OF THE INCIDENT WAVE IS ALWAYS GREATER THAN THE AMPLITUDES OF THE REFLECTED AND TRANSMITTED WAVES.
- WHEN A WAVE CHANGES MEDIA, THE SPEED CHANGES BUT FREQUENCY REMAINS THE SAME.
  - FREQUENCY DEPENDS ON THE SOURCE, NOT THE MEDIUM.
- TRANSMISSION FROM LESS DENSE TO MORE DENSE: WAVES TRAVEL SLOWER IN MORE DENSE MEDIA.
  - REFLECTED WAVE IS INVERTED (UPSIDE-DOWN).



- TRANSMISSION FROM MORE DENSE TO LESS DENSE:
  - REFLECTED WAVE IS NOT INVERTED.

- FIXED-END REFLECTION:
  - REFLECTED WAVE IS INVERTED.
  - ALMOST ALL OF THE ENERGY CARRIED BY THE WAVE IS REFLECTED. AMPLITUDE IS ALMOST IDENTICAL.

    EXAMPLE

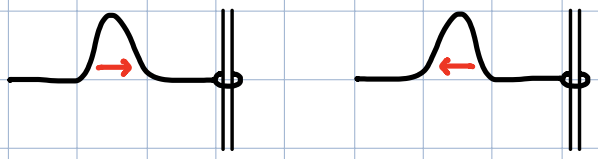
    TIED TO A POLE, CLOSED END OF A PIPE FOR SOUND WAVES

- FREE-END REFLECTION:
  - REFLECTED WAVE IS NOT INVERTED.
  - ALMOST ALL OF THE ENERGY CARRIED BY THE WAVE IS REFLECTED.

EXAMPLE

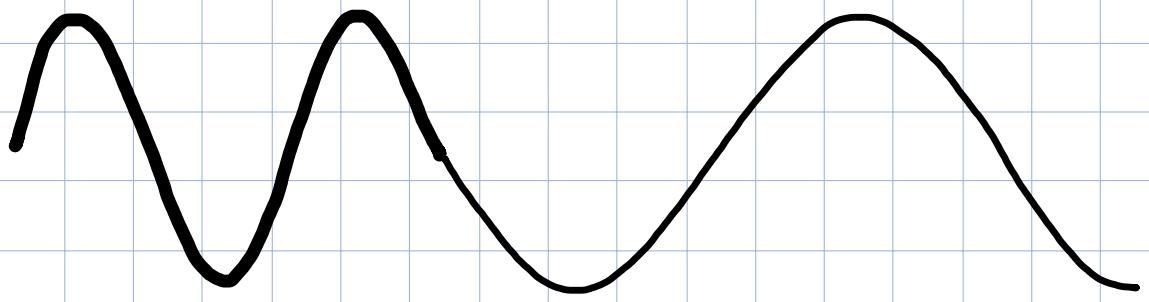
RING ON A POLE, OPEN END OF A PIPE

FOR SOUND WAVES



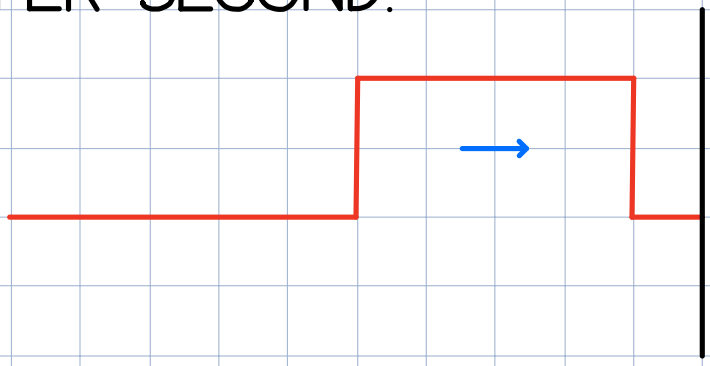
EXAMPLE

A WAVE TRAVELS DOWN A COIL AT A SPEED OF 1.5 $\frac{m}{s}$ AND A WAVELENGTH OF 2.0 m. THE WAVE EXTENDS INTO A SECOND COIL THROUGH WHICH THE WAVE TRAVELS AT 3.0 $\frac{m}{s}$. DETERMINE THE FREQUENCY AND WAVELENGTH IN THE SECOND COIL.



EXAMPLE

A WAVE PULSE IS PROPOGATING TOWARD A WALL AT A SPEED OF ONE UNIT PER SECOND.



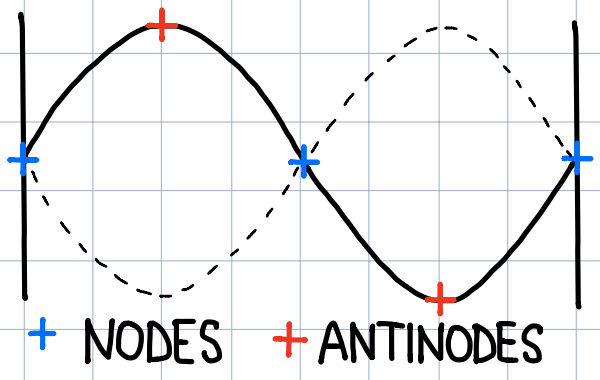
DRAW THE PULSE AFTER

a) 2s
b) 3s
c) 4s
d) 5s

STANDING WAVES

- STANDING WAVES ARE THOSE WHICH APPEAR TO BE VIBRATING VERTICALLY WITHOUT TRAVELLING HORIZONTALLY.
- STANDING WAVES RESULT FROM THE INTERFERENCE OF THE INCIDENT AND REFLECTED WAVES THAT ARE CONFINED TO A REGION.

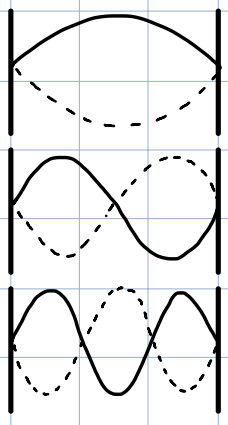
- NODES ARE POSITIONS WHERE THE WAVE DOES NOT VIBRATE.
- ANTINODES ARE POSITIONS WHERE THE WAVE VIBRATES WITH THE MAXIMUM AMPLITUDE.



- NATURAL FREQUENCIES OR HARMONICS ARE THE SPECIFIC STANDING WAVES THAT CAN OCCUR IN A REGION.

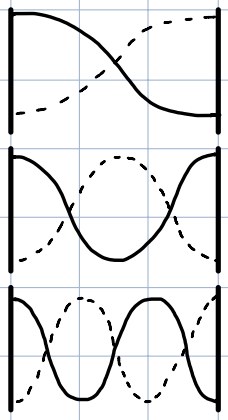
- THE WAVELENGTHS OF THE HARMONICS ARE DETERMINED BY THE BOUNDARY CONDITIONS.
  - FIXED-END: NODE AT BOUNDARY
  - FREE-END: ANTINODE AT BOUNDARY
- THE FIRST HARMONIC IS ALSO KNOWN AS THE FUNDAMENTAL FREQUENCY AND IS THE STANDING WAVE WITH THE LONGEST WAVELENGTH AND LOWEST FREQUENCY.

- TYPE A: TWO ENDS FIXED



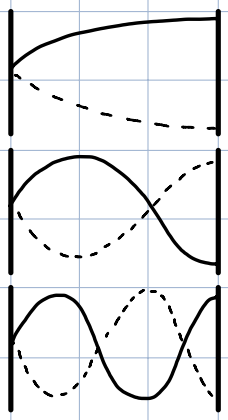
HARMONIC	λ	f
1	$2L$	$\frac{v}{2L}$
2	L	$\frac{v}{L}$
3	$\frac{2}{3}L$	$\frac{3v}{2L}$
N	$\lambda_N = \frac{2L}{N} = \frac{\lambda_1}{N}$	$f_N = N\frac{v}{2L} = N f_1$

· TYPE B : TWO ENDS FREE



HARMONIC	λ	f
1	$2L$	$\frac{v}{2L}$
2	L	$\frac{v}{L}$
3	$\frac{2}{3}L$	$\frac{3v}{2L}$
N	$\lambda_N = \frac{2L}{N} = \frac{\lambda_1}{N}$	$f_N = N\frac{v}{2L} = N f_1$

· TYPE C : ONE END FIXED, ONE END FREE



HARMONIC	λ	f
1	$4L$	$\frac{v}{4L}$
2	$\frac{4}{3}L$	$\frac{3v}{4L}$
3	$\frac{4}{5}L$	$\frac{5v}{4L}$
N	$\lambda_N = \frac{4L}{2N-1} = \frac{\lambda_1}{2N-1}$	$f_N = (2N-1)\frac{v}{4L} = (2N-1)f_1$

RESONANCE

- RESONANCE IS A PHENOMENON THAT OCCURS WHEN THE FREQUENCY OF AN APPLIED FORCE IS EQUAL OR NEARLY EQUAL TO ONE OF THE NATURAL FREQUENCIES OF THE SYSTEM ON WHICH IT ACTS.
- RESONANCE CAUSES THE SYSTEM TO OSCILLATE WITH INCREASED AMPLITUDE

EXAMPLE

PUSHING A CHILD ON A SWING

BREAKING A WINE GLASS WITH SOUND

JUMPING ON A BRIDGE

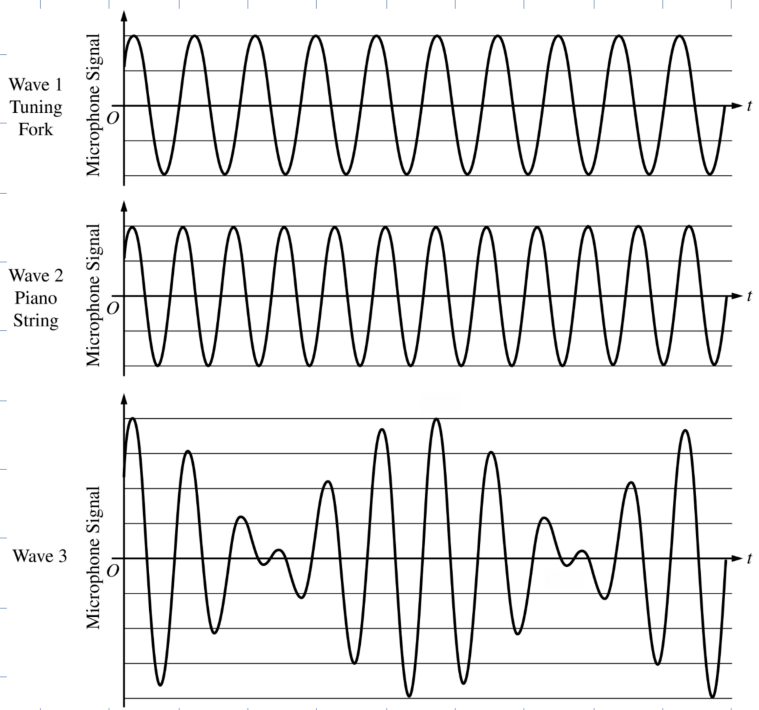
SOUND WAVES IN AN AIR COLUMN

BEATS

- WHEN TWO SOUND WAVES OF UNEQUAL BUT CLOSE FREQUENCIES ARE PLAYED, THERE WILL BE AN ALTERNATING CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE. THIS CAUSES THE SOUND TO ALTERNATE BETWEEN LOUD AND SOFT.

$$f_{beat} = |f_1 - f_2|$$

THE CLOSER f_1 IS TO f_2, THE SMALLER THE BEAT FREQUENCY (I.E. BEATING BECOMES SLOWER).



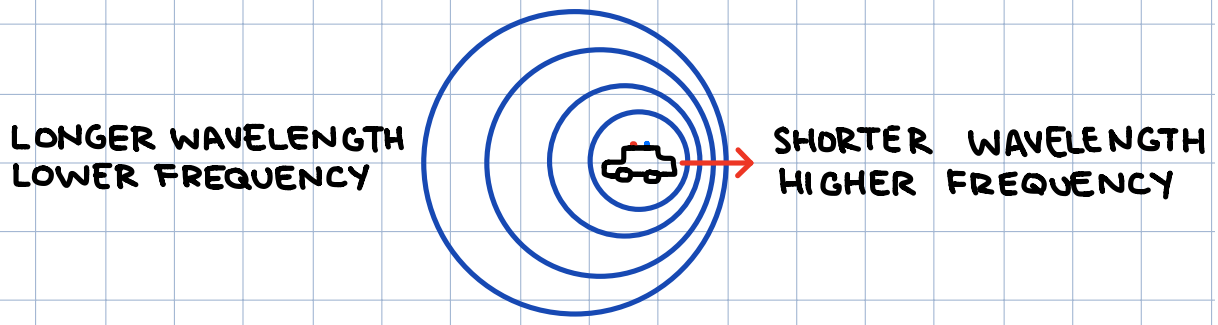
DOPPLER EFFECT

AKA DOPPLER SHIFT

- THE DOPPLER EFFECT IS THE CHANGE IN THE OBSERVED WAVELENGTH AND FREQUENCY OF A WAVE DUE TO RELATIVE MOTION BETWEEN THE WAVE SOURCE AND OBSERVER.

EXAMPLE

- SIREN ON A PASSING POLICE CAR
- REDSHIFT / BLUESHIFT OF RECEDING/APPROACHING STARS AND GALAXIES



WAVES IN TWO DIMENSIONS

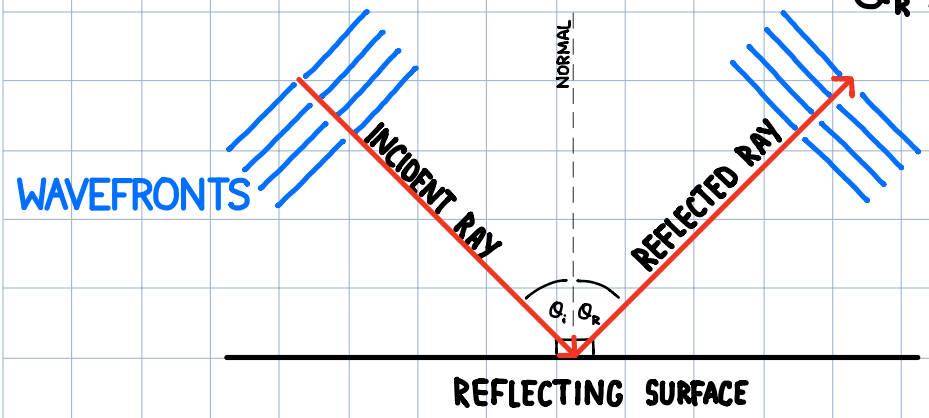
- A RAY IS A STRAIGHT LINE WITH AN ARROW POINTING IN THE DIRECTION THE WAVE IS TRAVELLING.
- WAVEFRONTS ARE LINES/CURVES REPRESENTING CORRESPONDING POINTS ON A WAVE THAT VIBRATE IN UNISON (I.E. IN PHASE).

- A WAVE REFLECTED BY A BARRIER FOLLOWS THE LAW OF REFLECTION: ANGLE OF INCIDENCE EQUALS ANGLE OF REFLECTION.

$$\theta_i = \theta_R$$

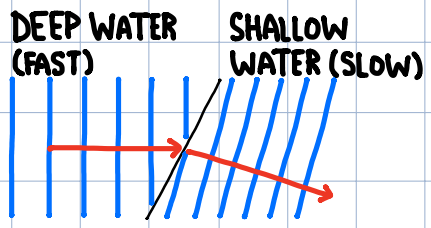
θ_i: ANGLE OF INCIDENCE

θ_R: ANGLE OF REFLECTION



- REFRACTION IS THE CHANGE IN DIRECTION OF A WAVE AT THE BOUNDARY BETWEEN TWO DIFFERENT MEDIA.

EXAMPLE



- DIFFRACTION IS THE SPREADING OF WAVES AROUND THE EDGE OF A BARRIER.

EXAMPLE

SOUND WAVES BENDING AROUND A CORNER