Basic Principles of Ultrasonic Testing

Theory and Practice

AGFA

Krautkramer NDT

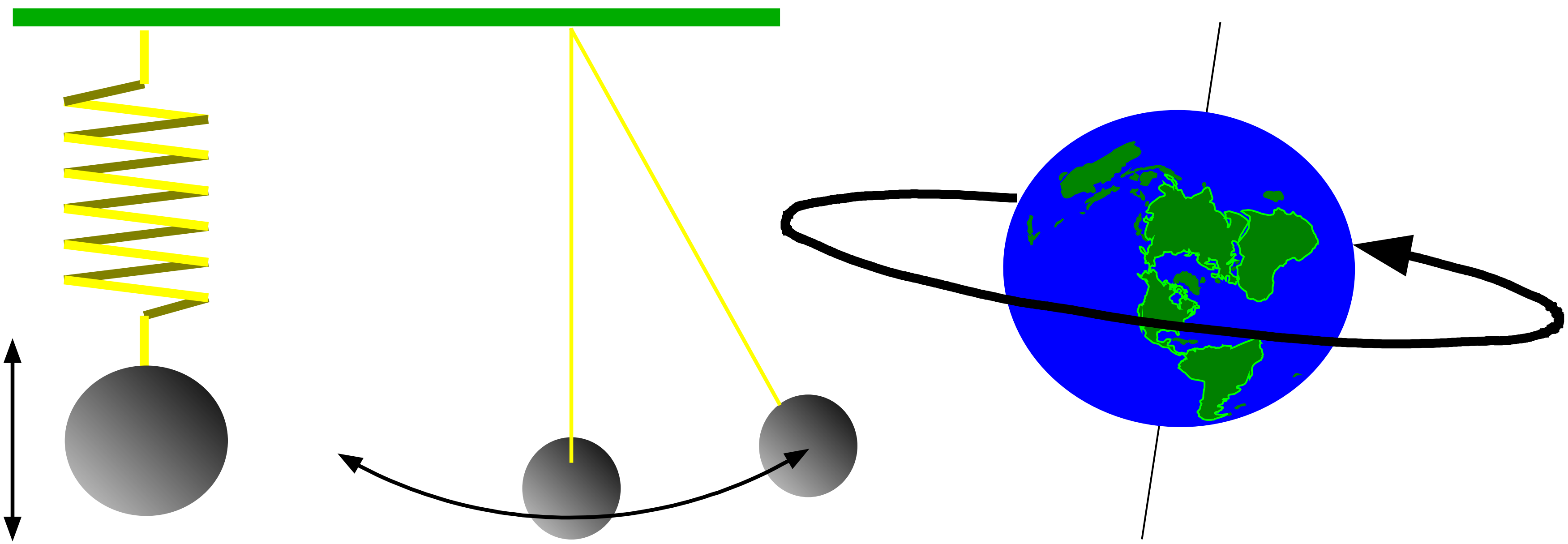
Basic Principles of Ultrasonic Testing

Examples of oscillation

ball on a spring

pendulum

rotating earth



a worldwide response

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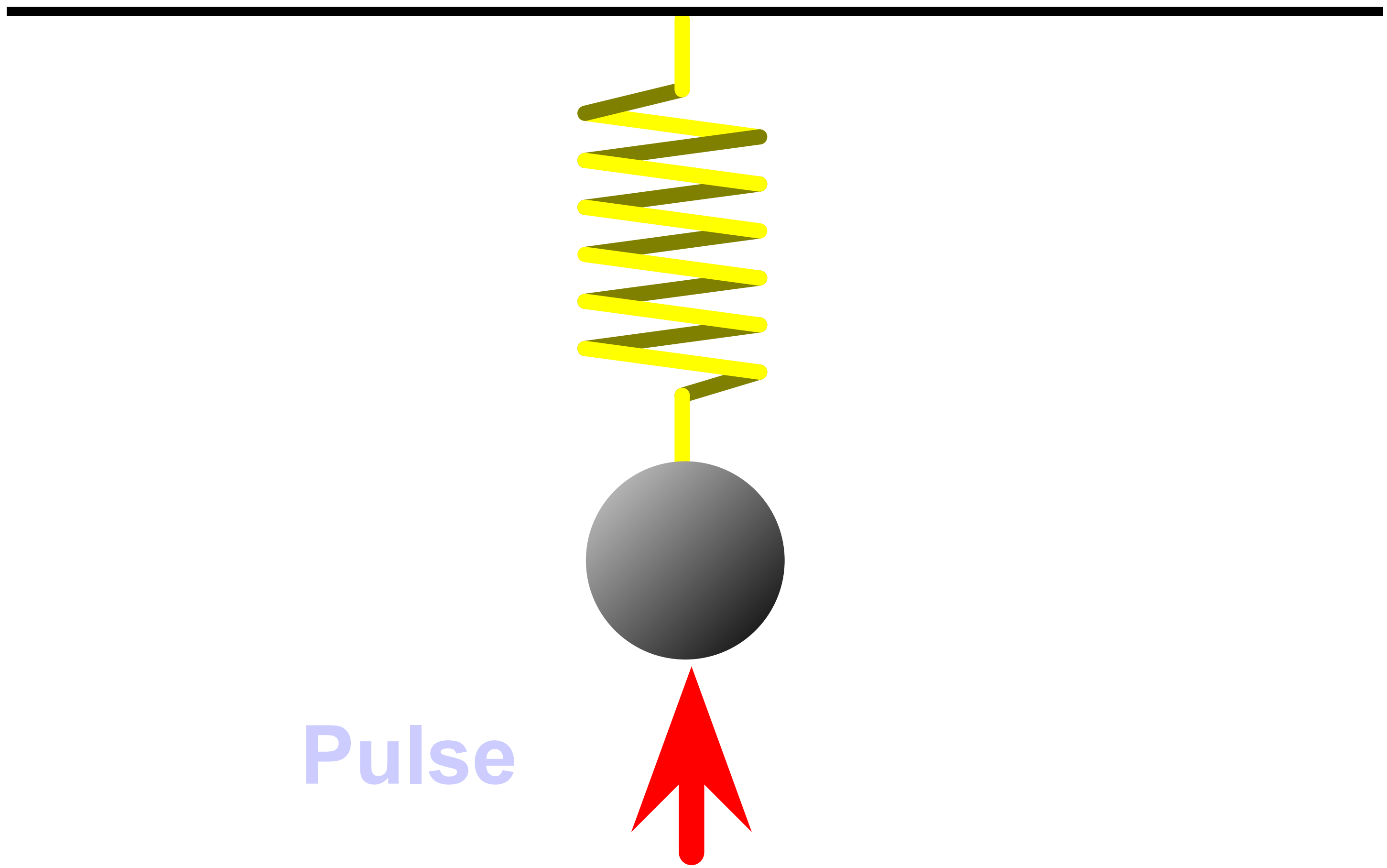

The ball starts to oscillate as soon as it is pushed

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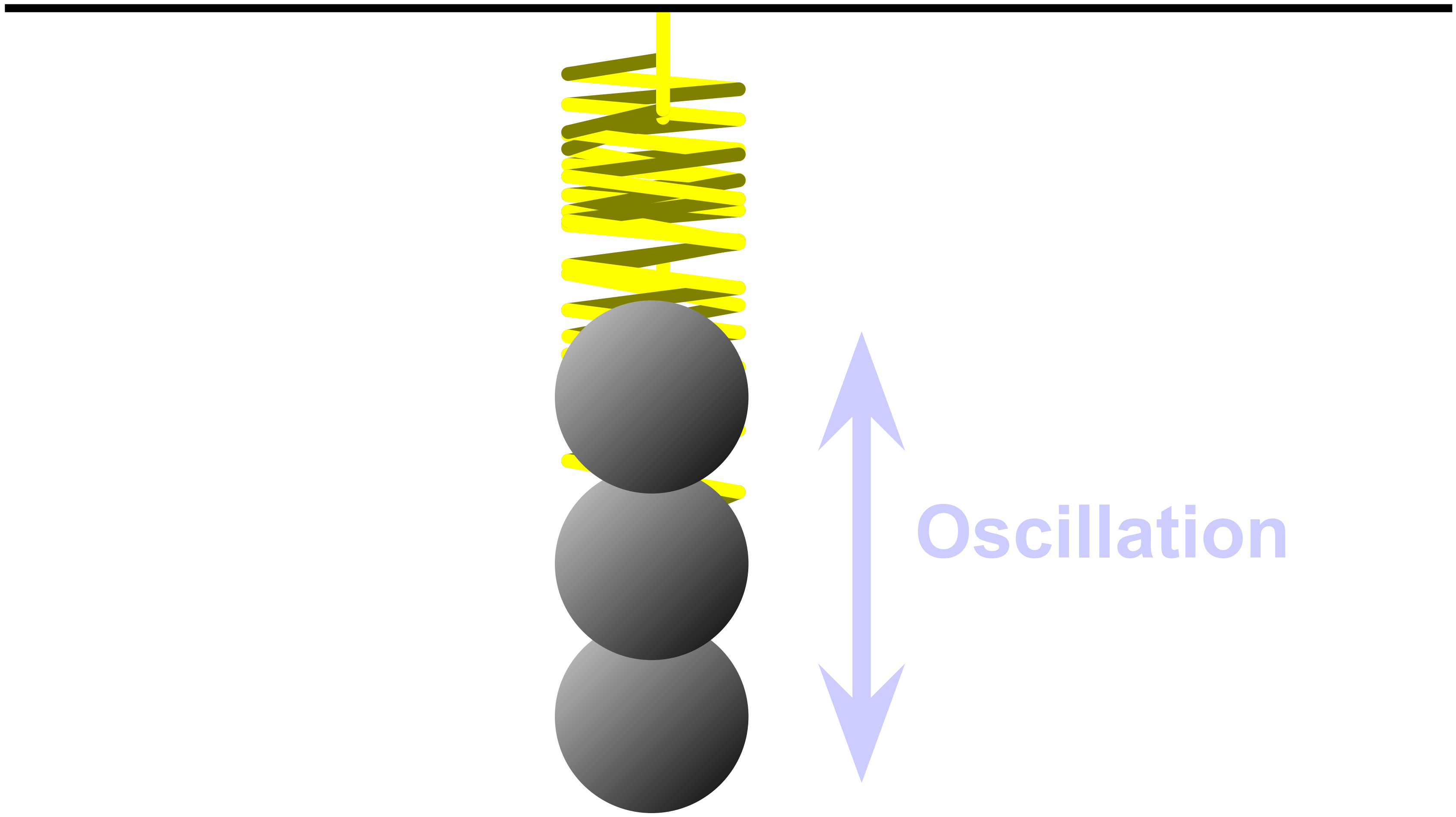

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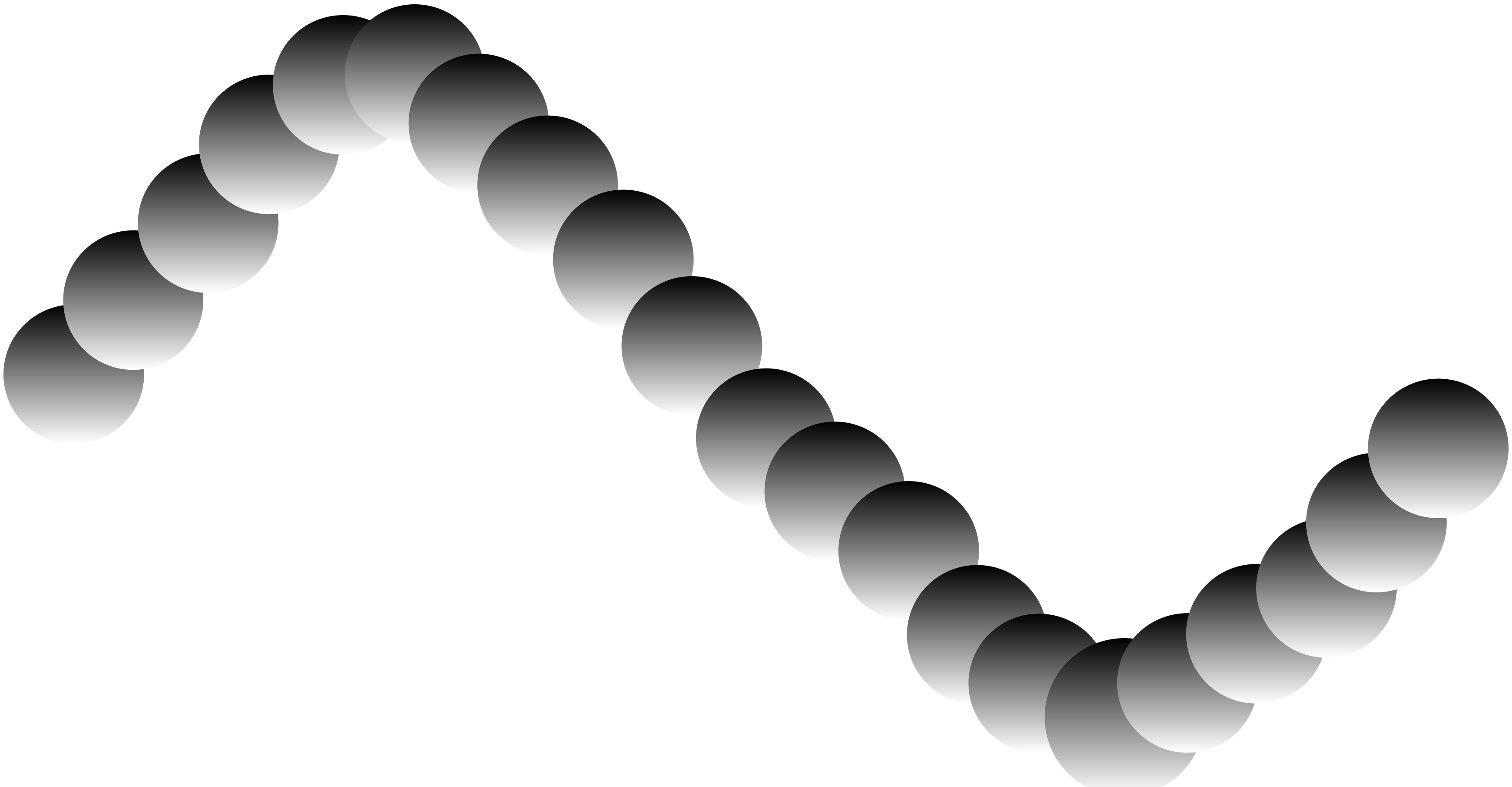
Movement of the ball over time



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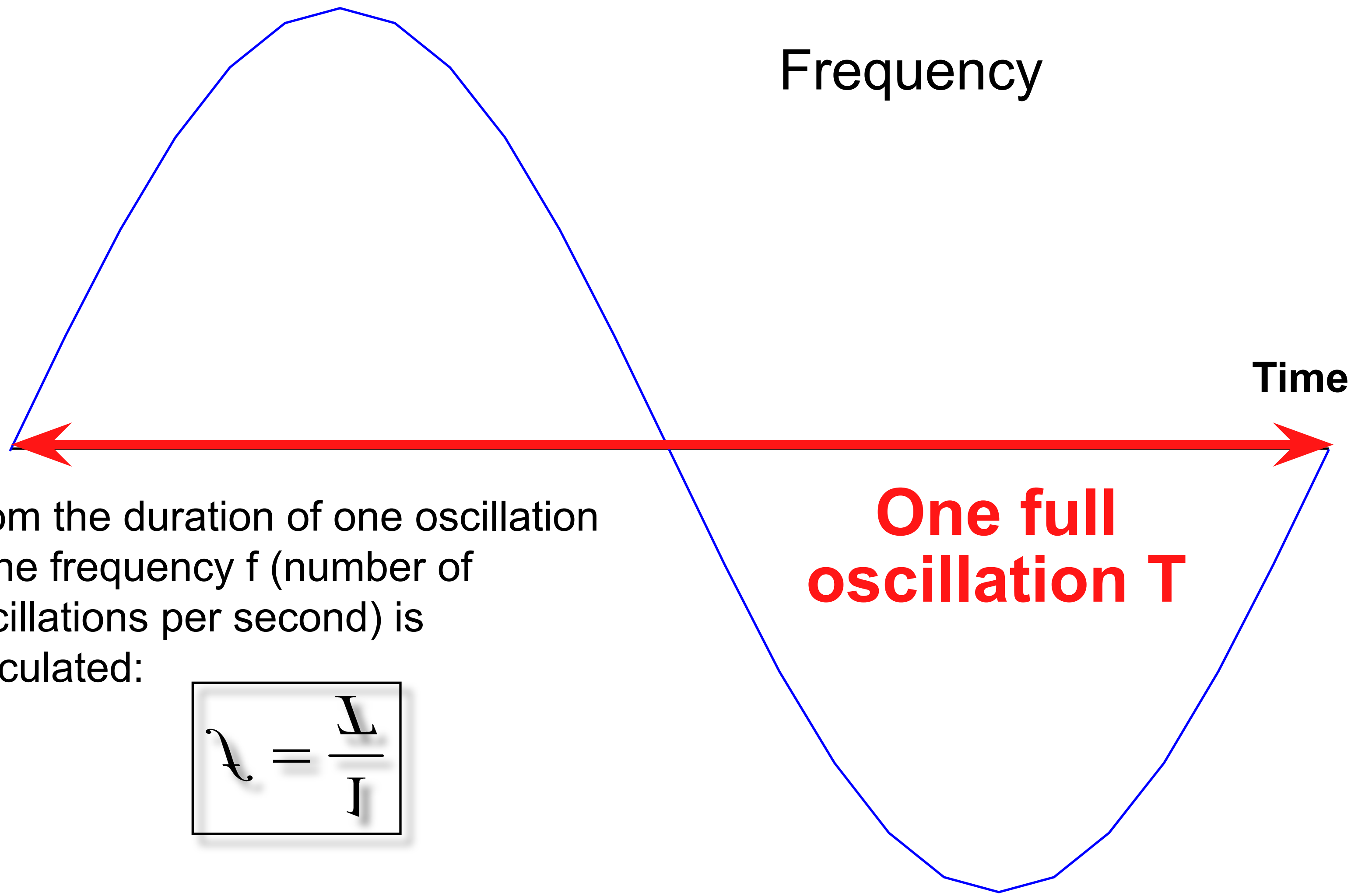

From the duration of one oscillation T the frequency f (number of oscillations per second) is calculated:

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

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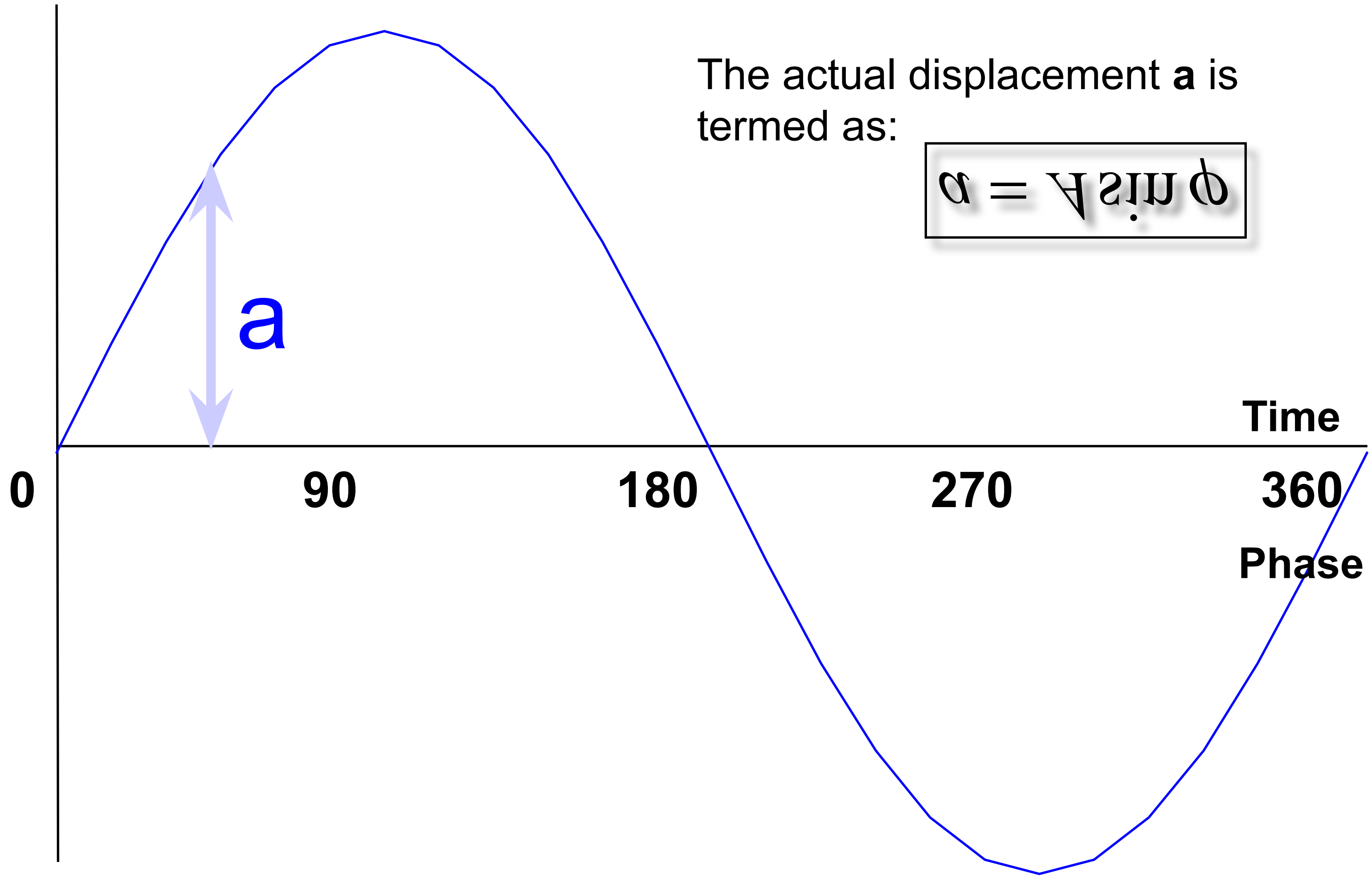

The actual displacement **a** is termed as:

$$a = A \sin \phi$$

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Spectrum of sound

Frequency range Hz	Description	Example
0 - 20	Infrasound	Earth quake
20 - 20.000	Audible sound	Speech, music
> 20.000	Ultrasound	Bat, Quartz crystal

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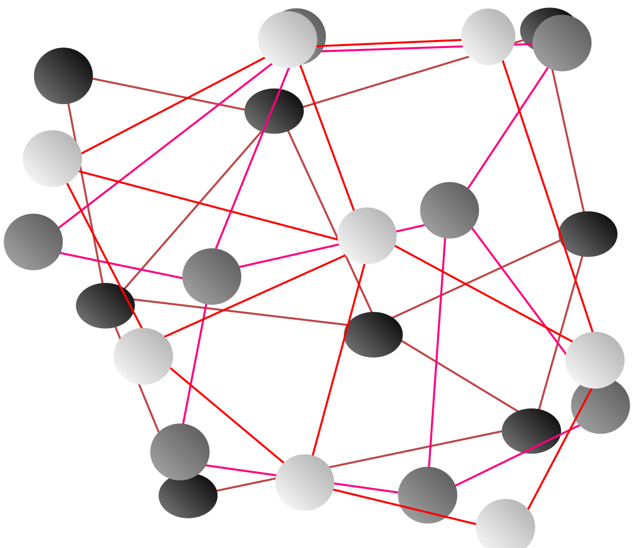
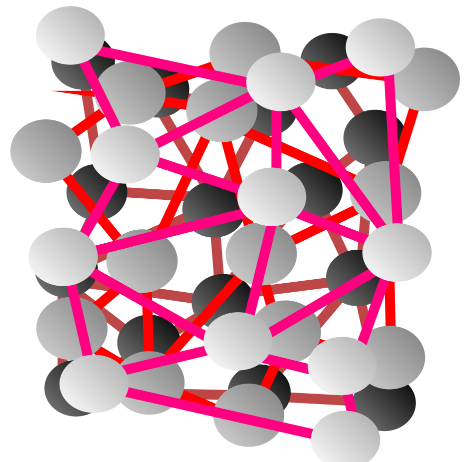
Atomic structures

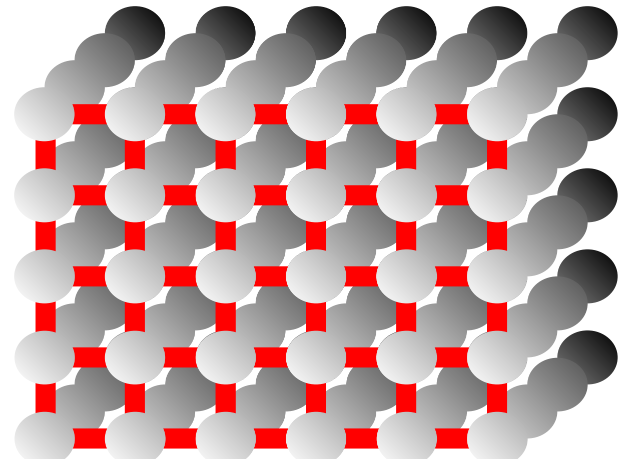
gas



liquid



solid



gas:
- low density
- weak bonding forces

liquid:
- medium density
- medium bonding forces

solid:
- high density
- strong bonding forces
- crystallographic structure

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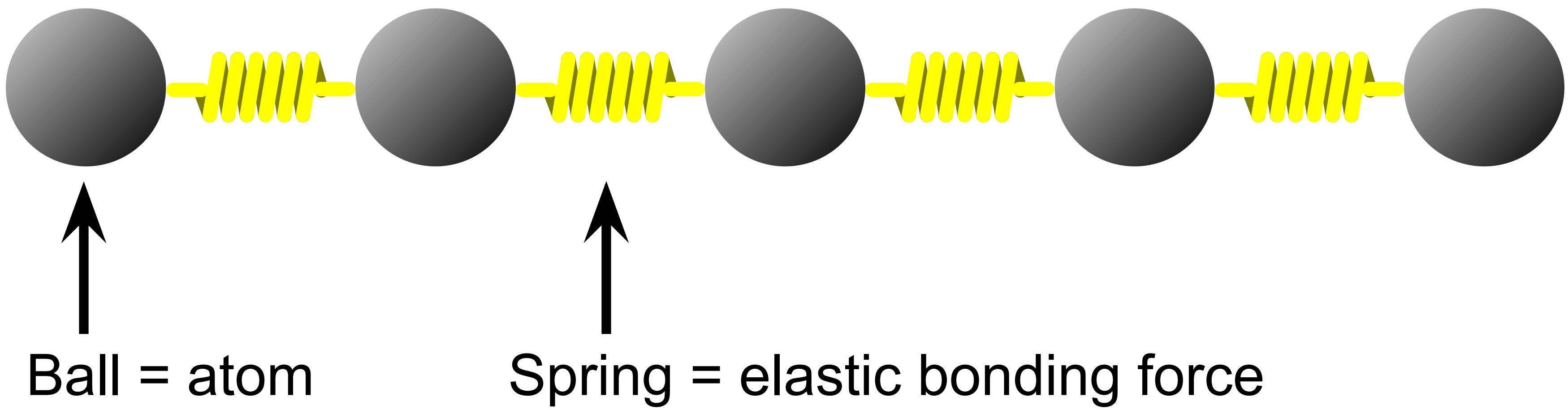
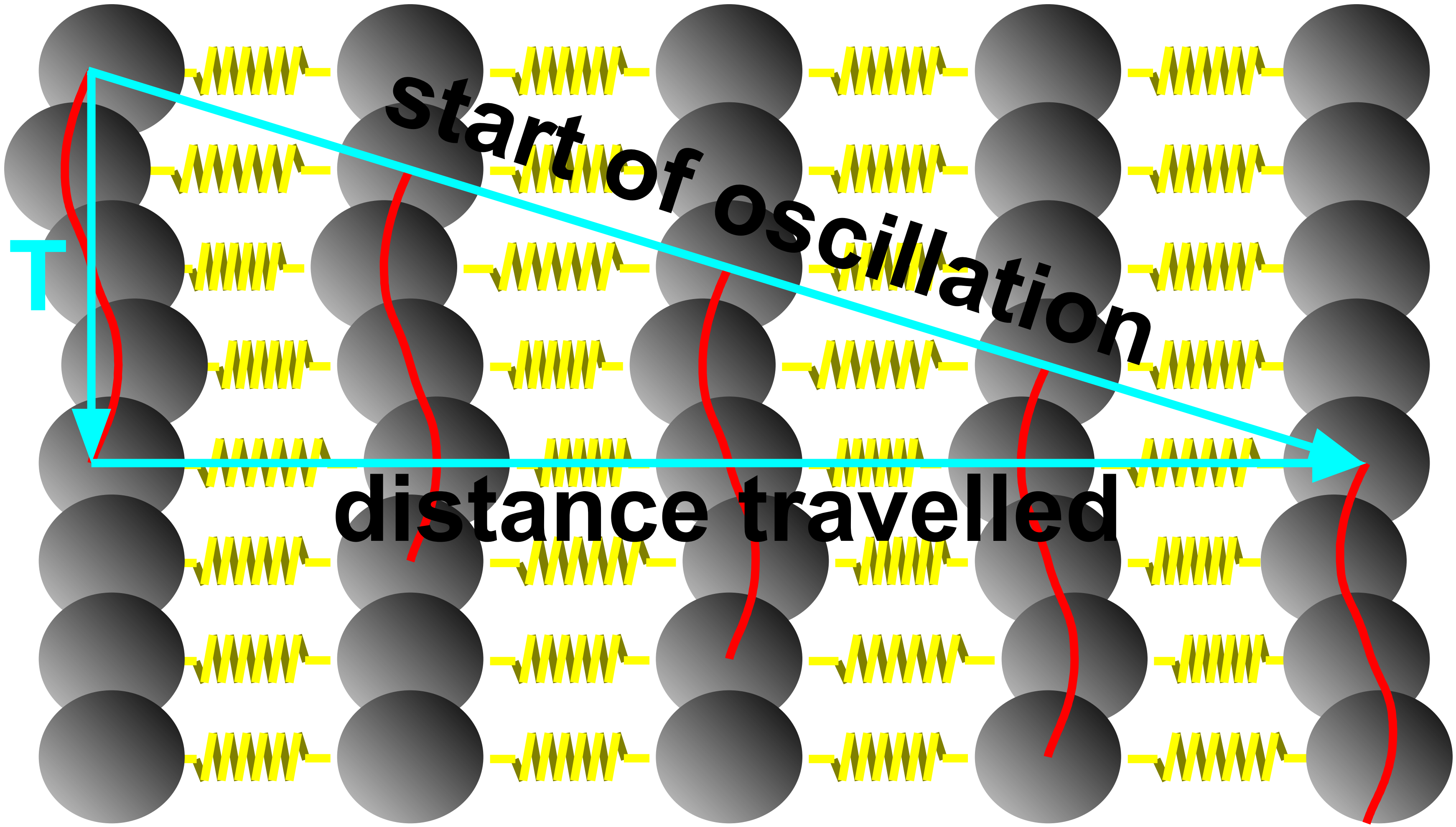
Understanding wave propagation:



Basic Principles of Ultrasonic Testing



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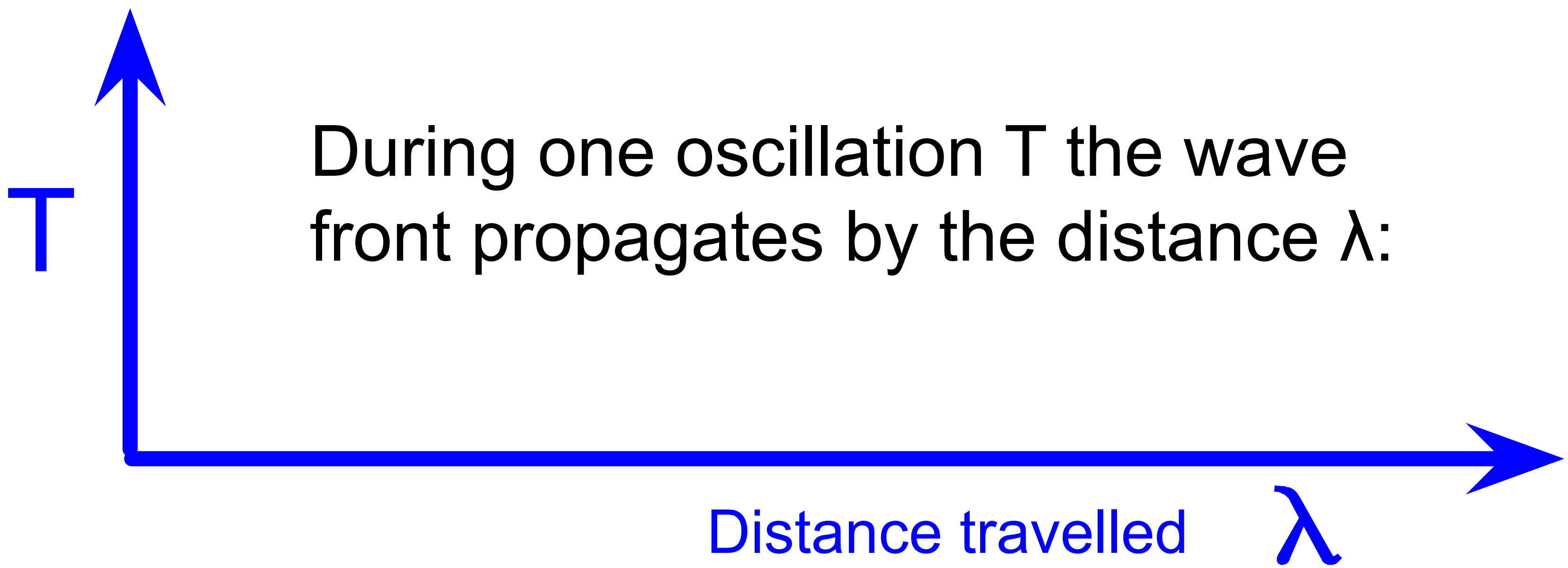

During one oscillation T the wave front propagates by the distance λ:

From this we derive:

$$c = \frac{\lambda}{T}$$ or $$c = f\lambda$$

Wave equation

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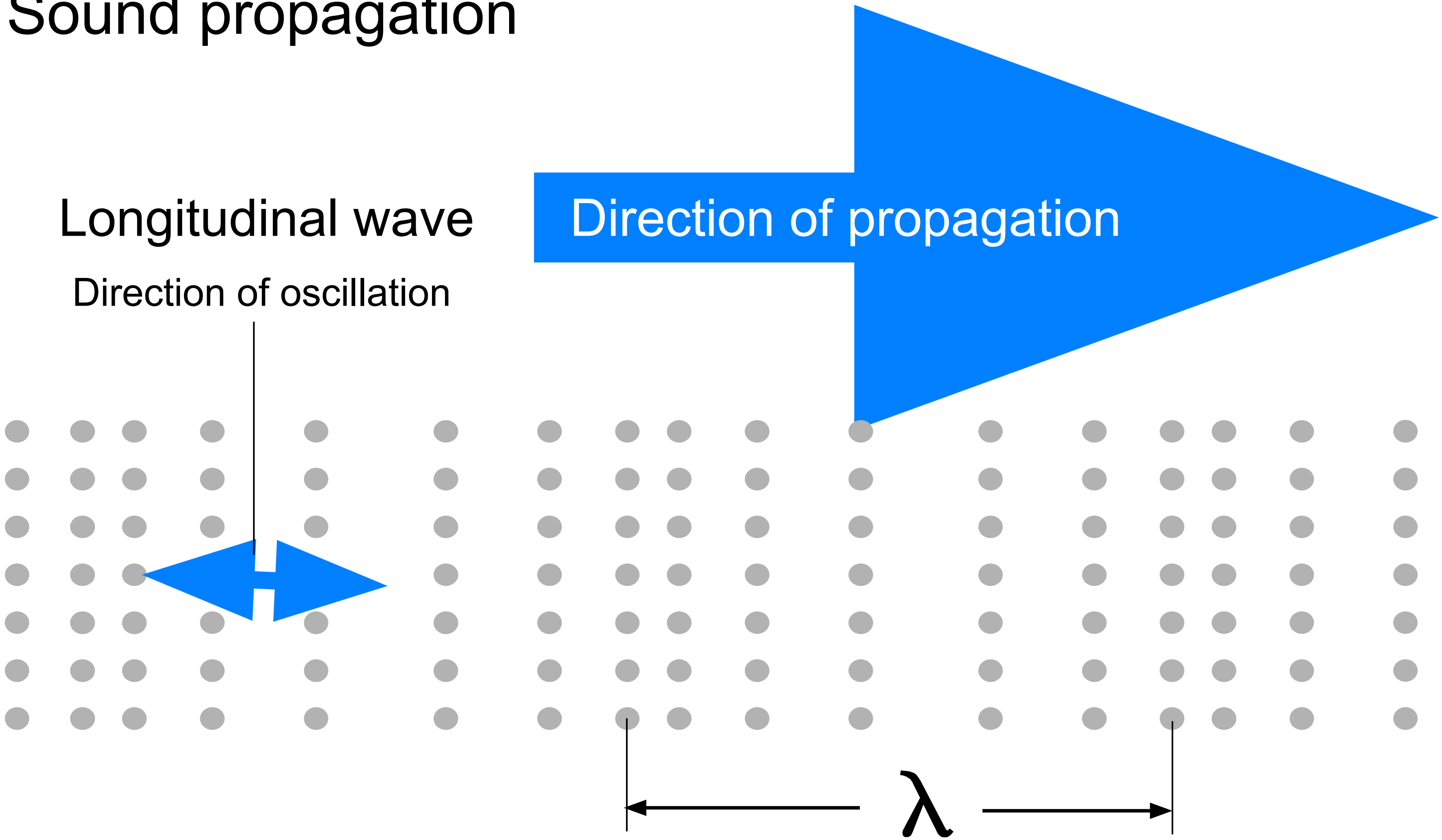
Sound propagation



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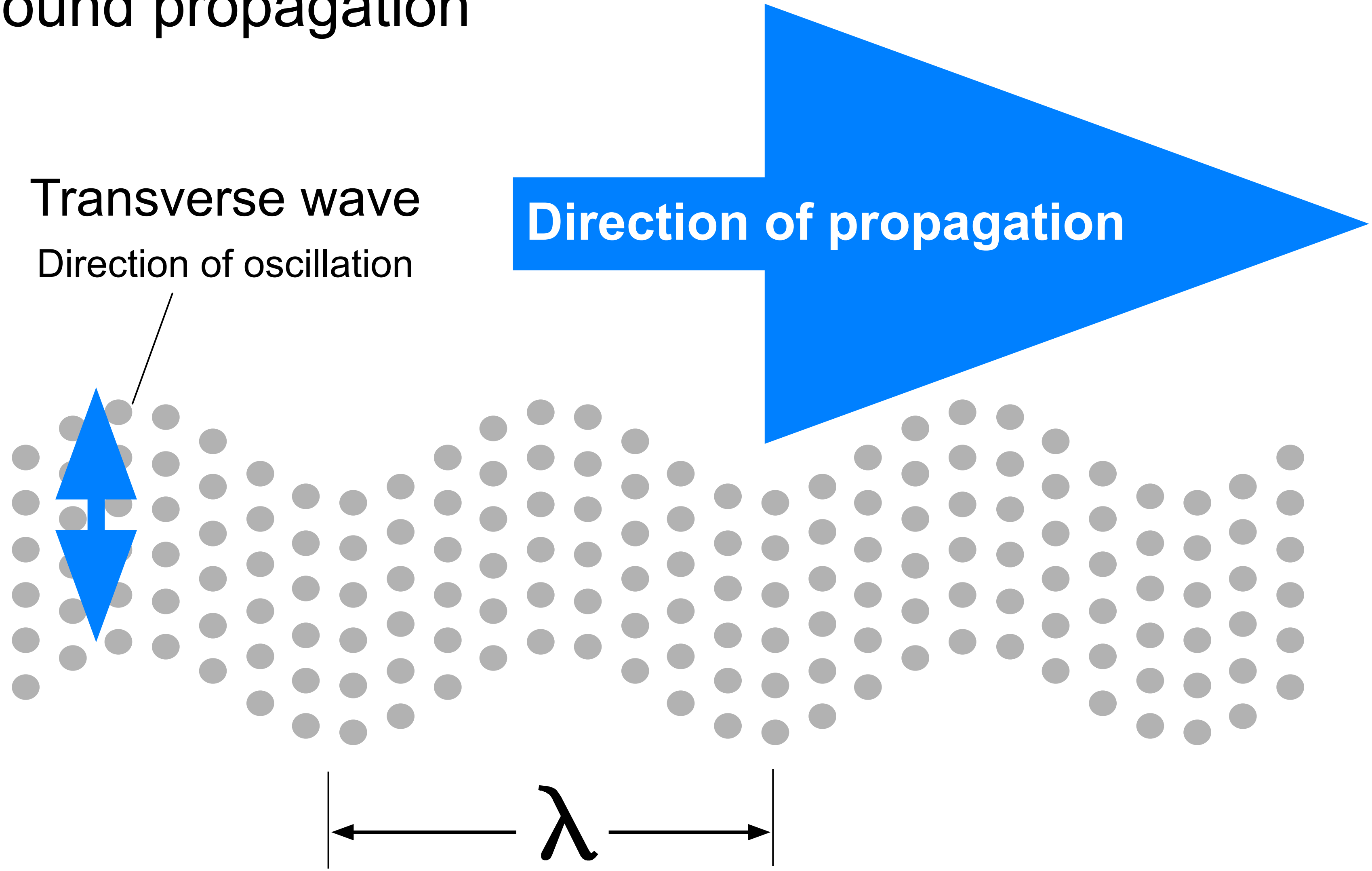
Sound propagation



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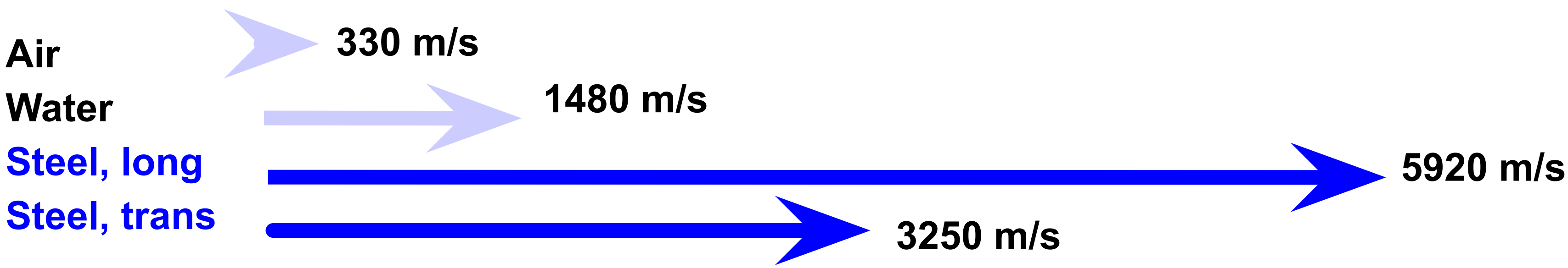
Wave propagation

Longitudinal waves propagate in all kind of materials.

Transverse waves only propagate in solid bodies.

Due to the different type of oscillation, transverse waves travel at lower speeds.

Sound velocity mainly depends on the density and E-modulus of the material.



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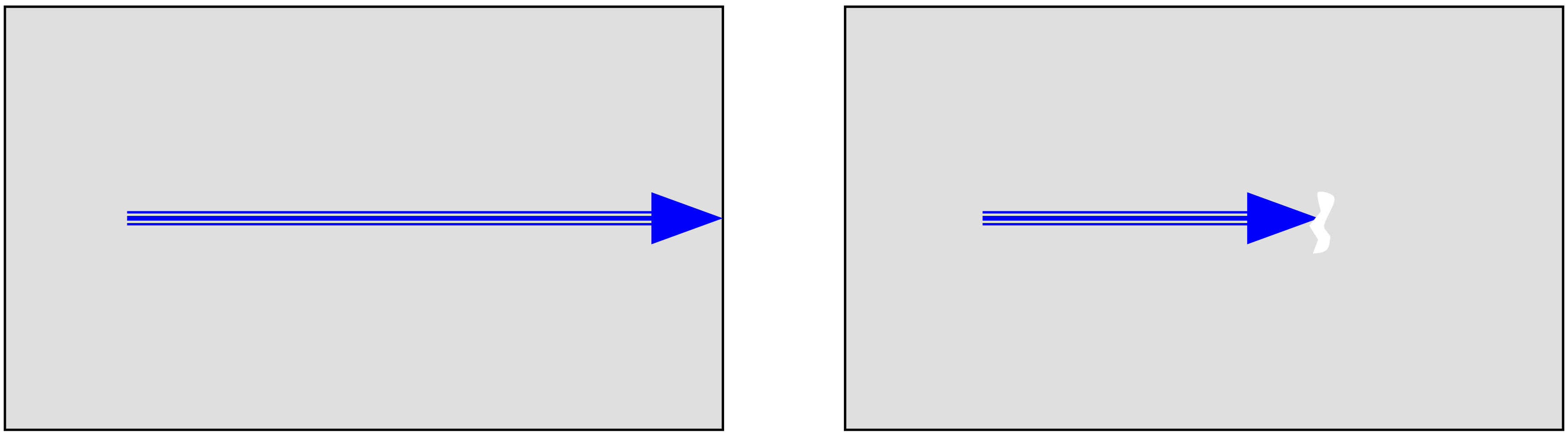
Reflection and Transmission

As soon as a sound wave comes to a change in material characteristics ,e.g. the surface of a workpiece, or an internal inclusion, wave propagation will change too:



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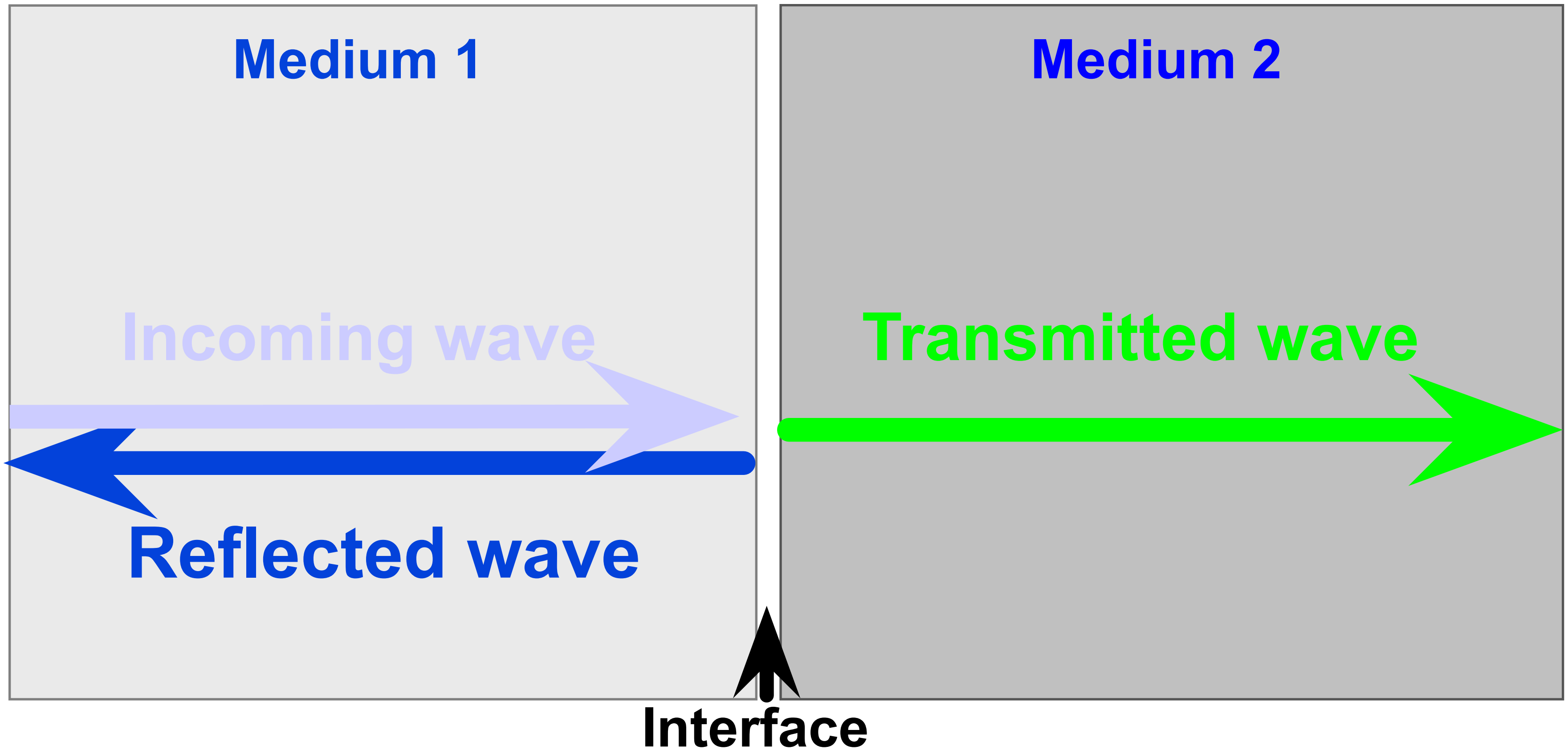
Behaviour at an interface



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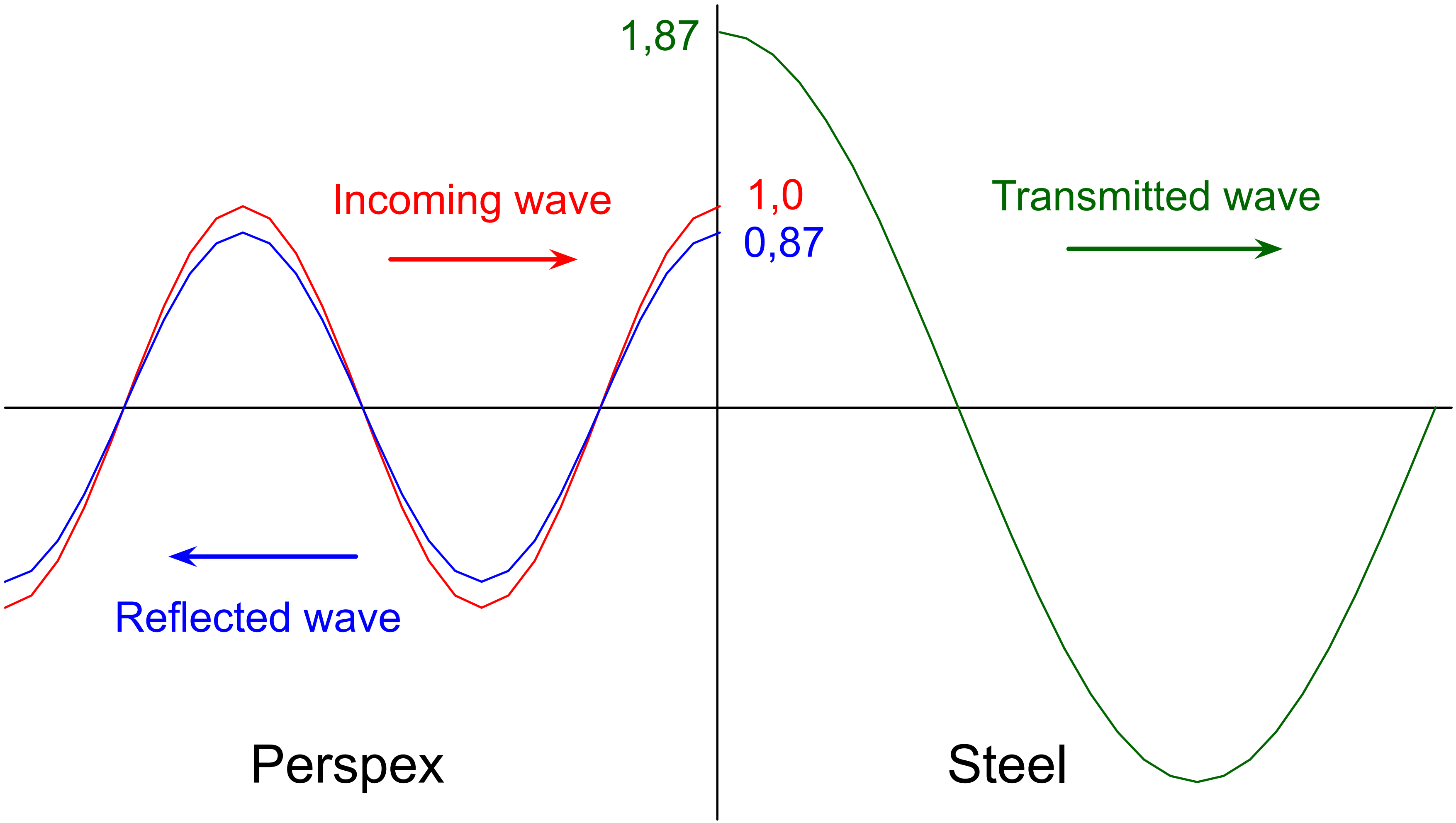
Reflection + Transmission: Perspex - Steel



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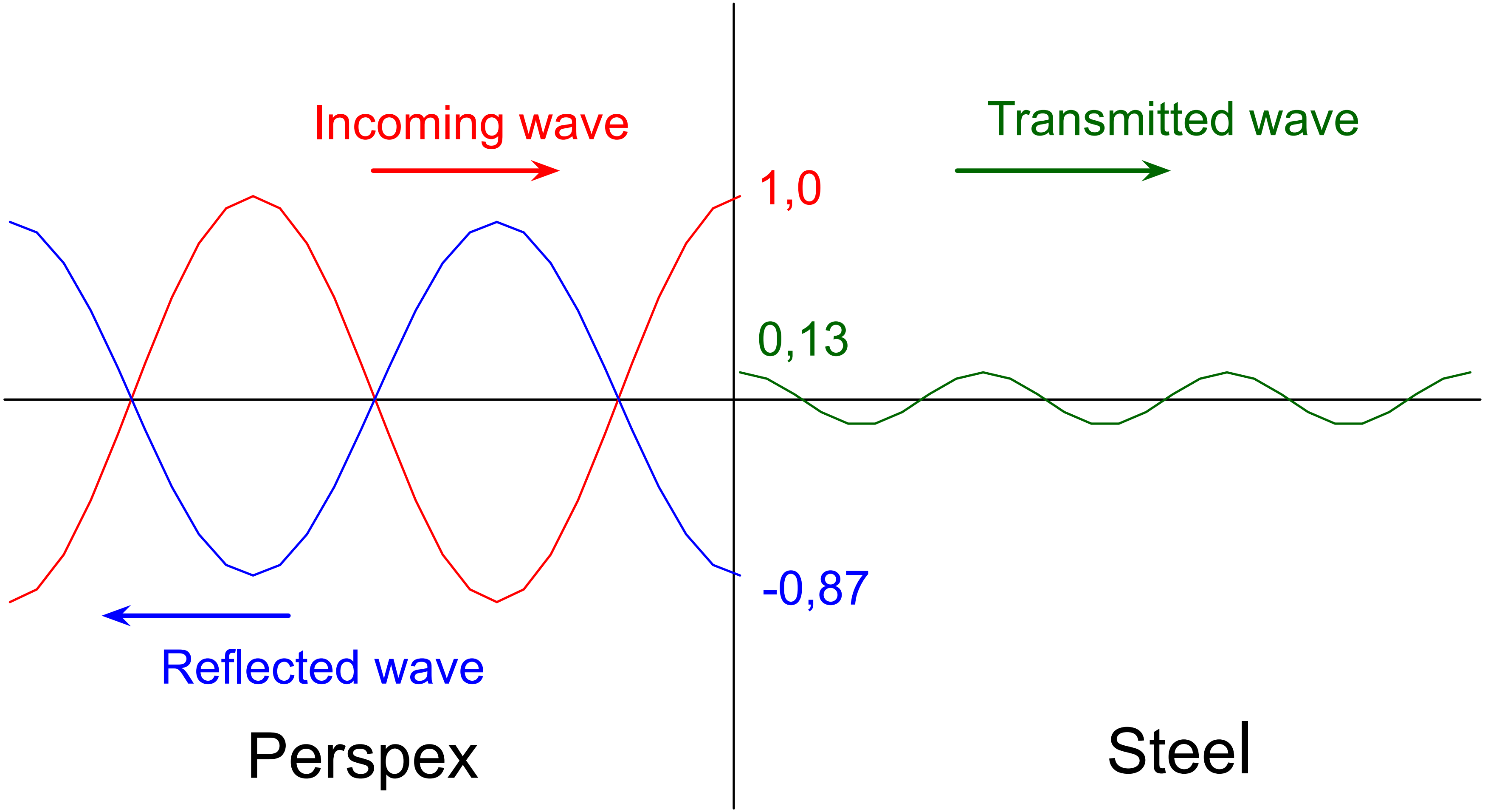
Reflection + Transmission: Steel - Perspex



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Amplitude of sound transmissions:

Water - Steel	Copper - Steel	Steel - Air
• Strong reflection • Double transmission	• No reflection • Single transmission	• Strong reflection with inverted phase • No transmission

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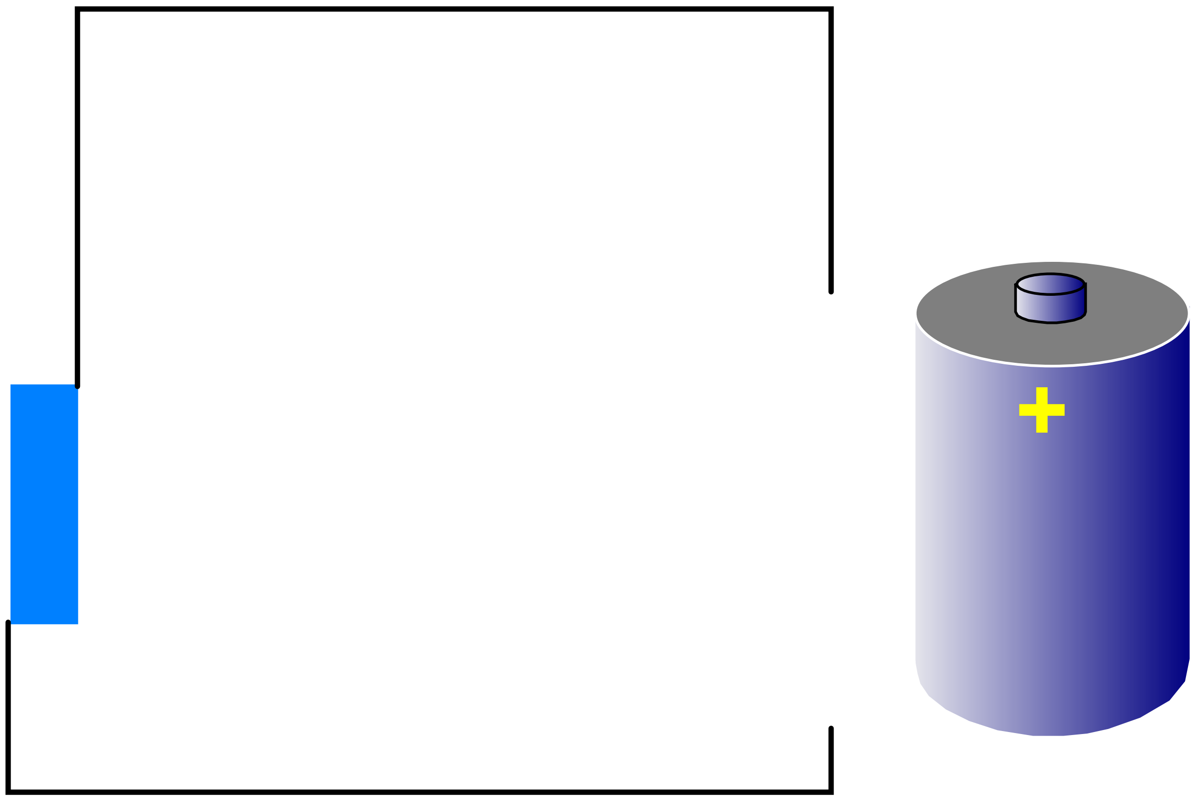
Piezoelectric Effect



Battery

Piezoelectrical
Crystal (Quartz)

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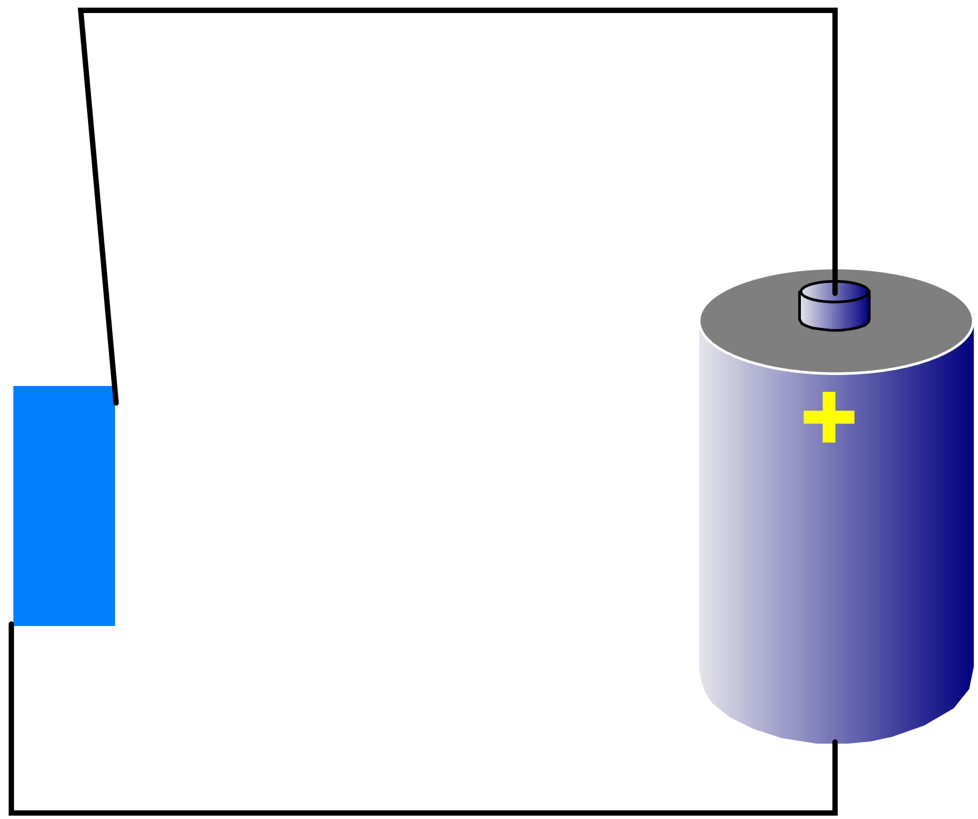
Piezoelectric Effect



The crystal gets thicker, due to a distortion of the crystal lattice

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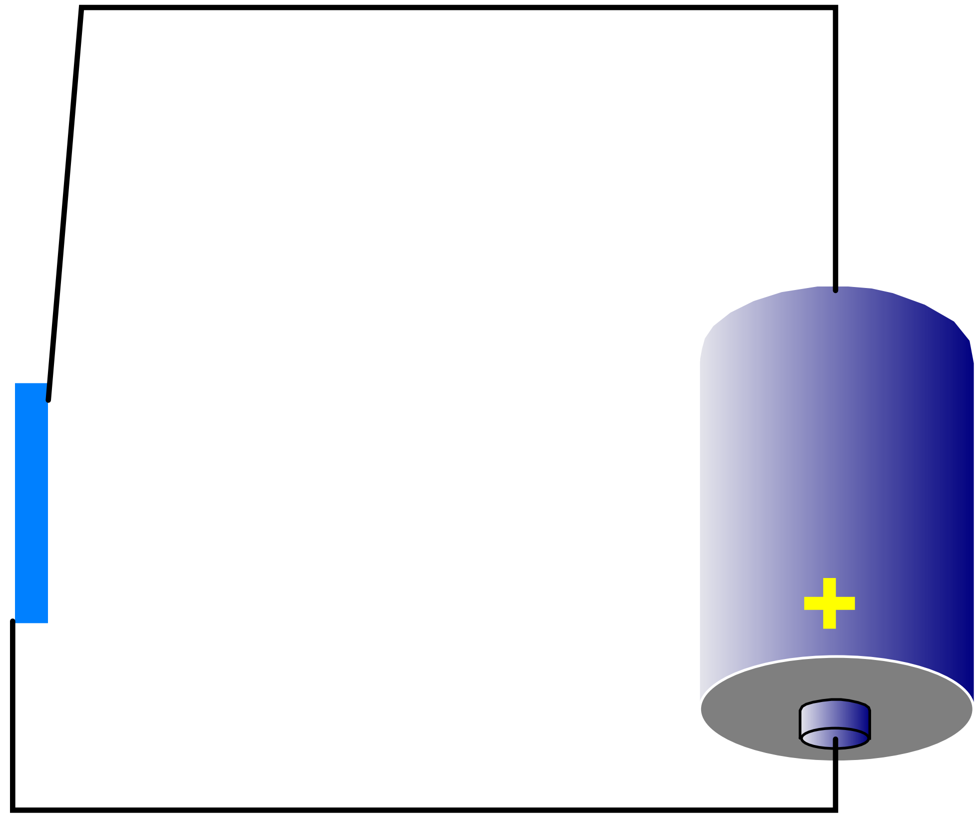
Piezoelectric Effect



The effect inverses with polarity change

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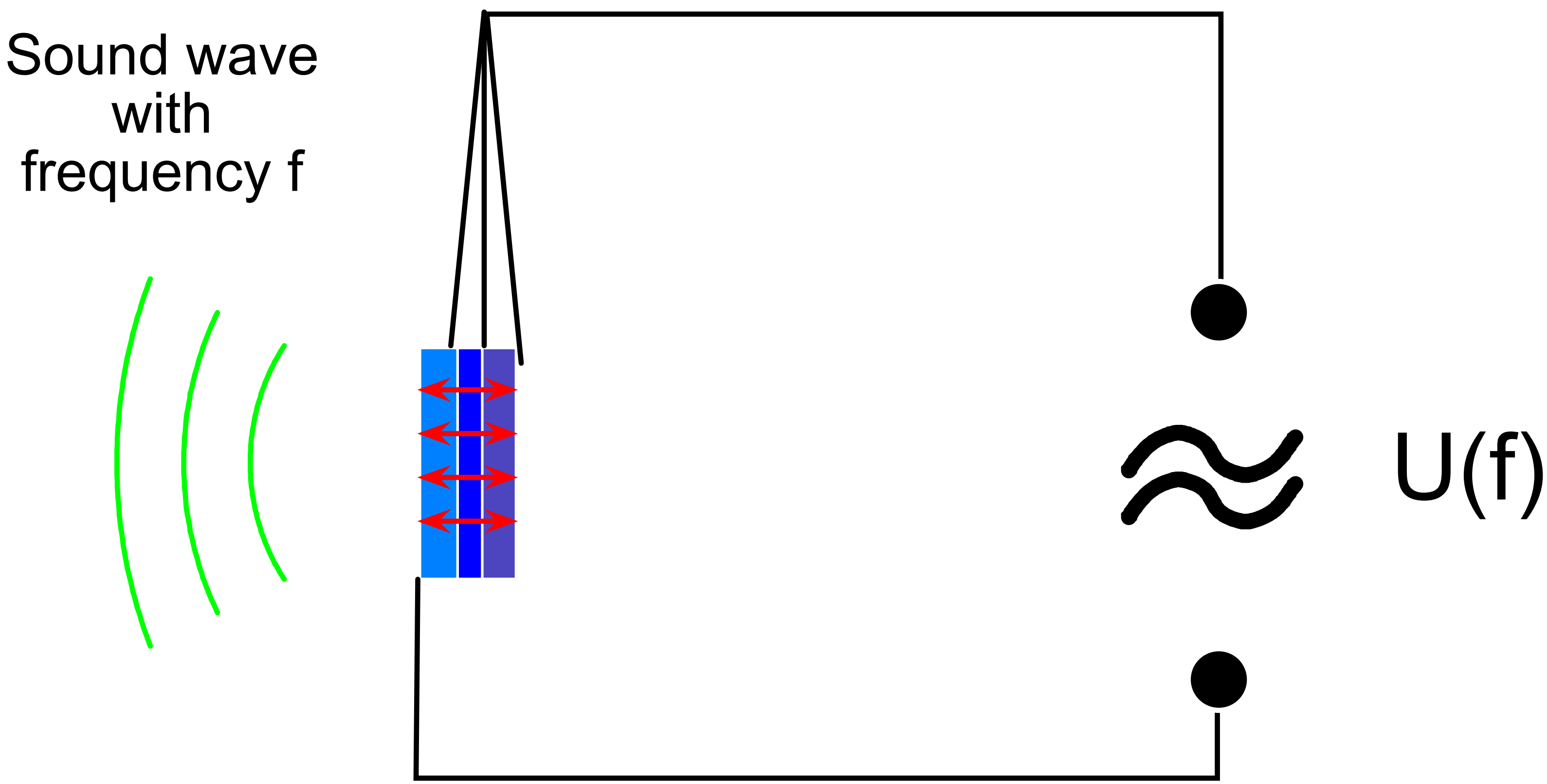
Piezoelectric Effect



An alternating voltage generates crystal oscillations at the frequency f

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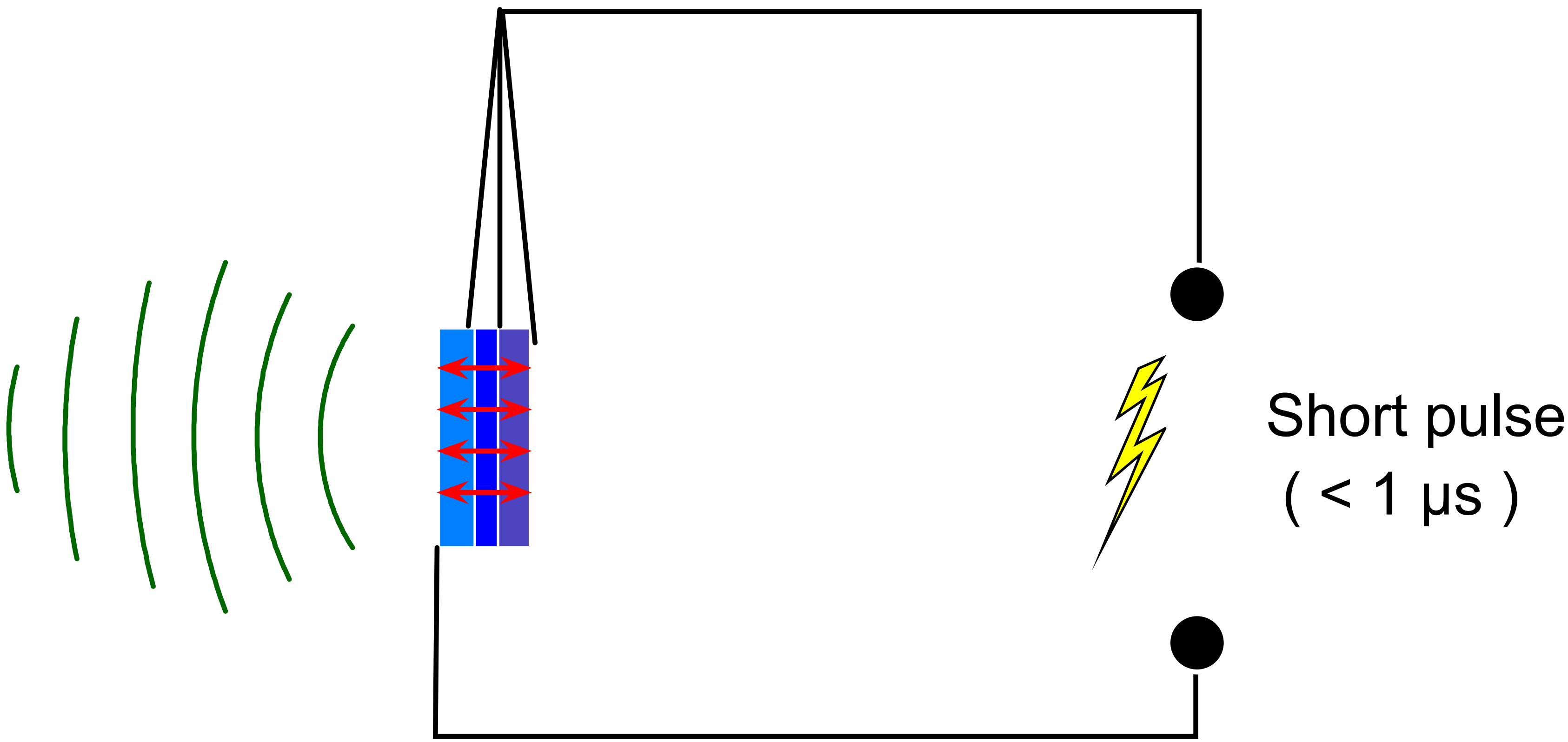
Piezoelectric Effect



A short voltage pulse generates an oscillation at the crystal's resonant frequency f_0

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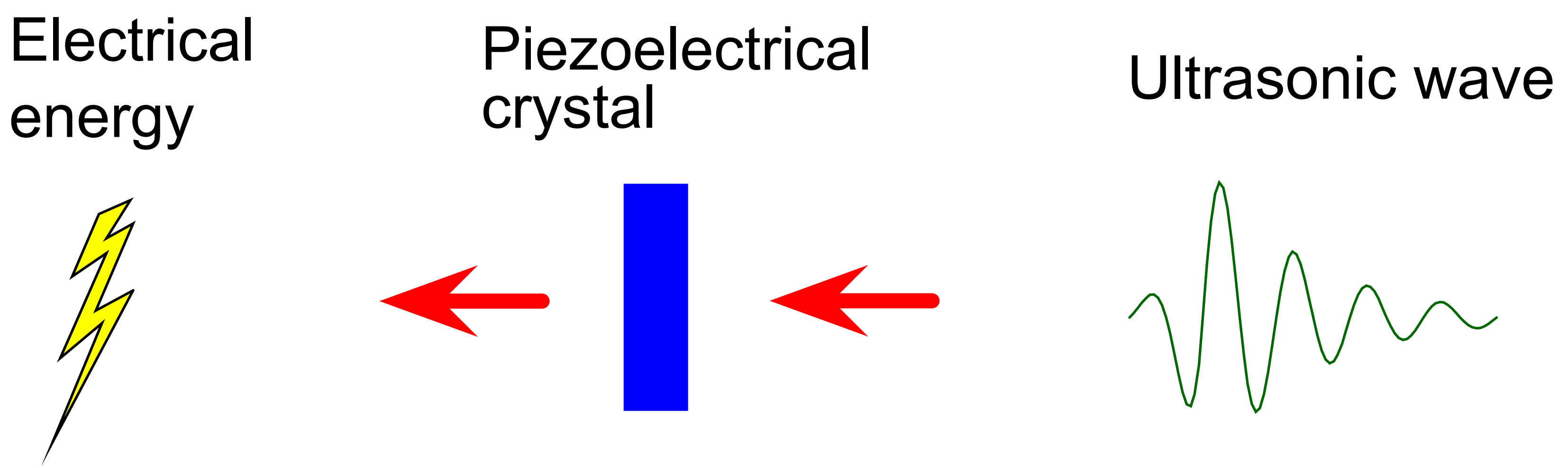
Reception of ultrasonic waves

A sound wave hitting a piezoelectric crystal, induces crystal vibration which then causes electrical voltages at the crystal surfaces.



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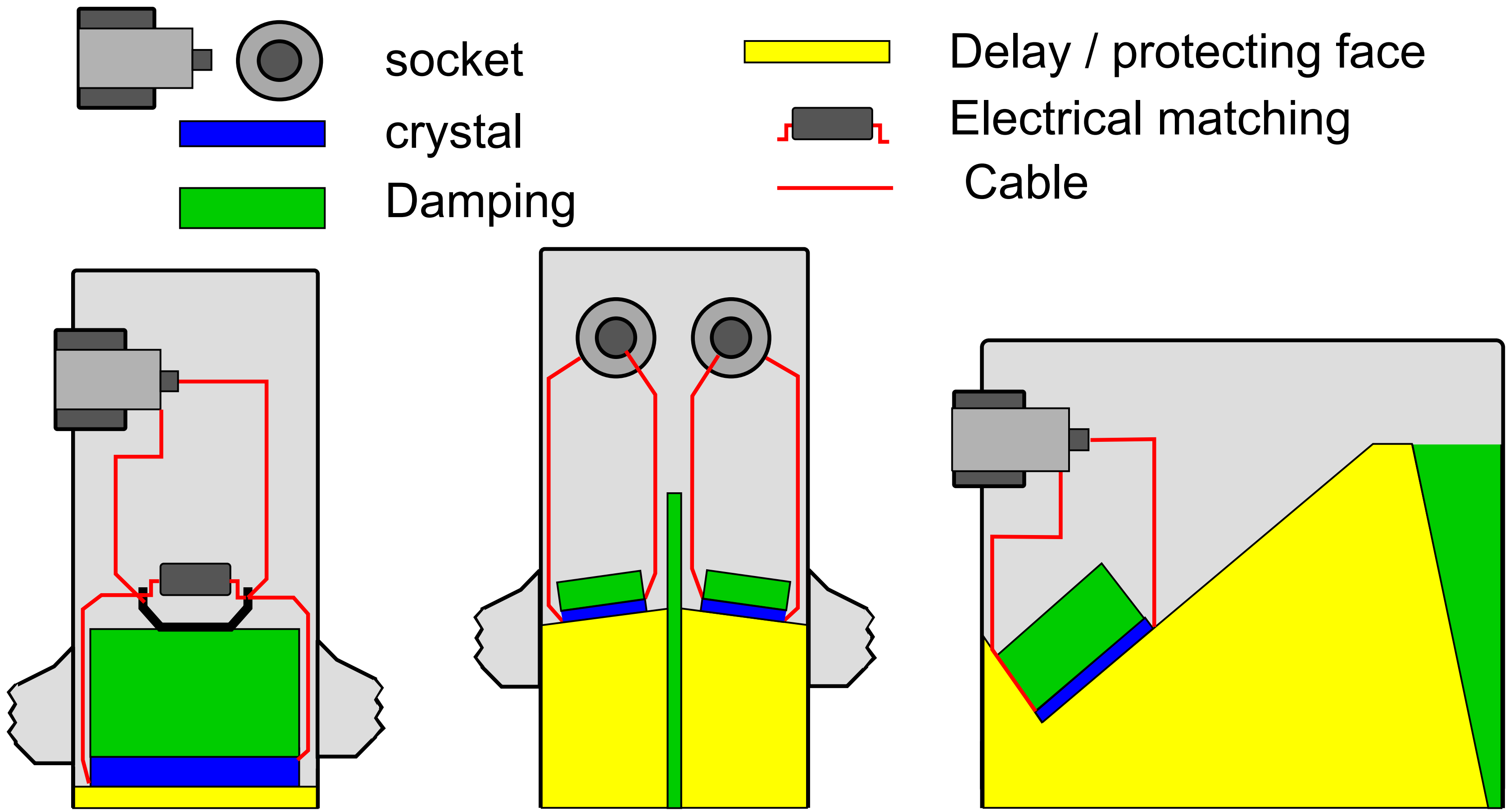
Ultrasonic Probes



Straight beam probe　　TR-probe　　Angle beam probe

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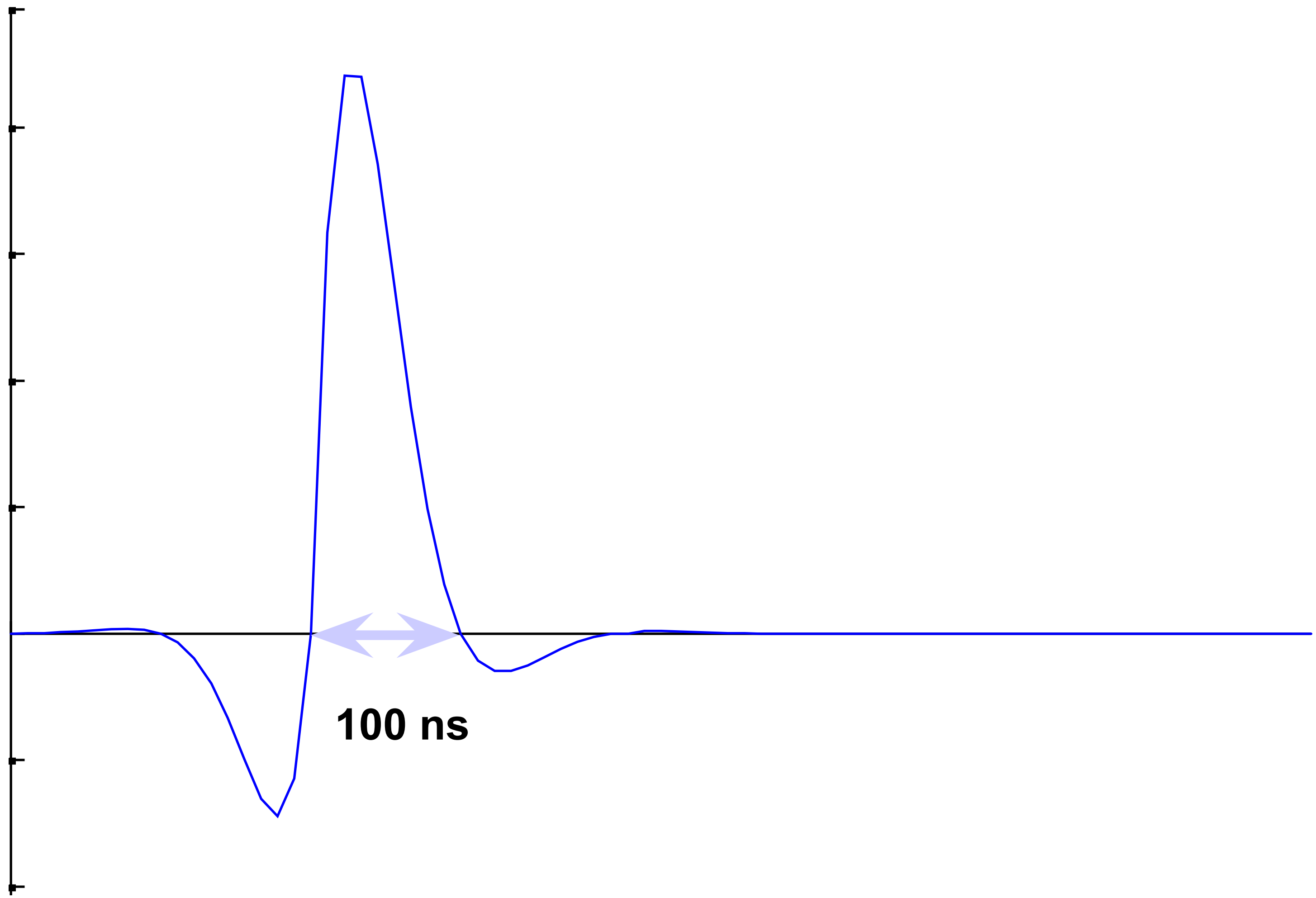
RF signal (short)



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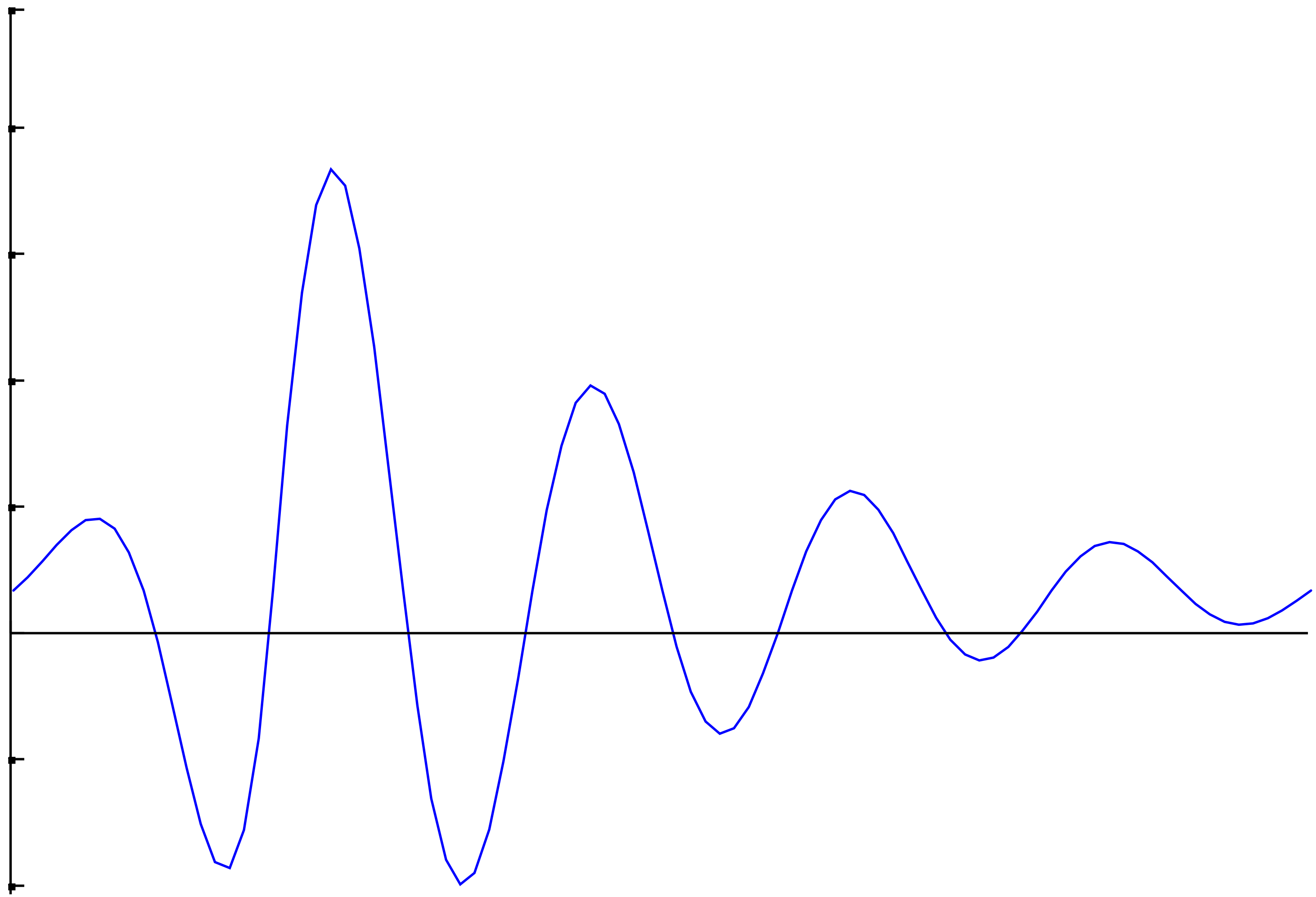
RF signal (medium)



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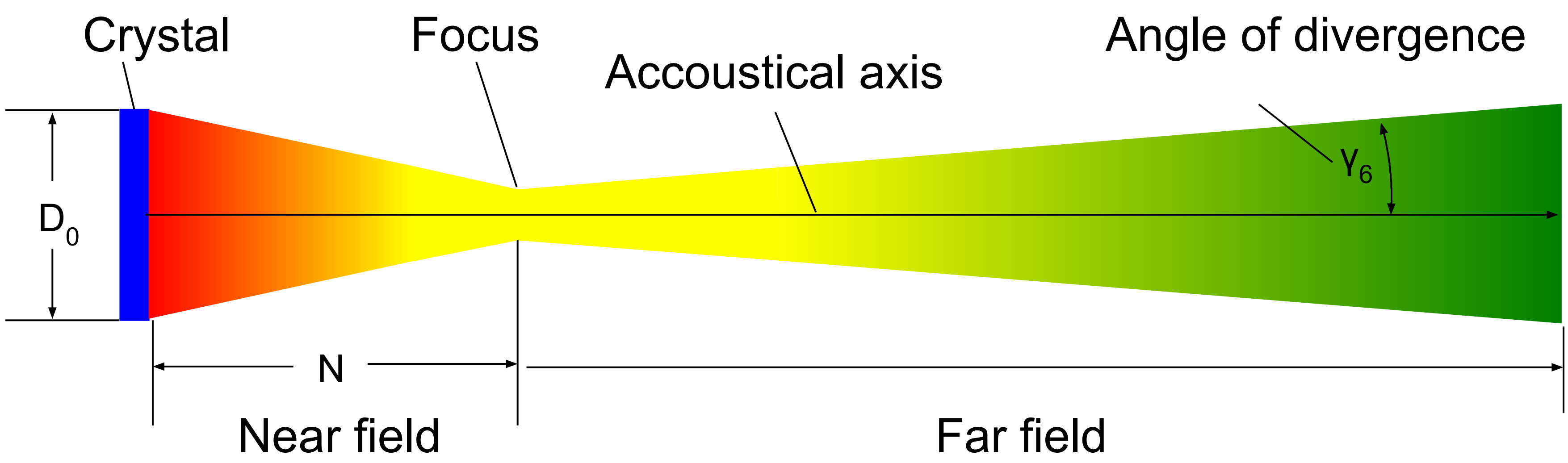
Sound field



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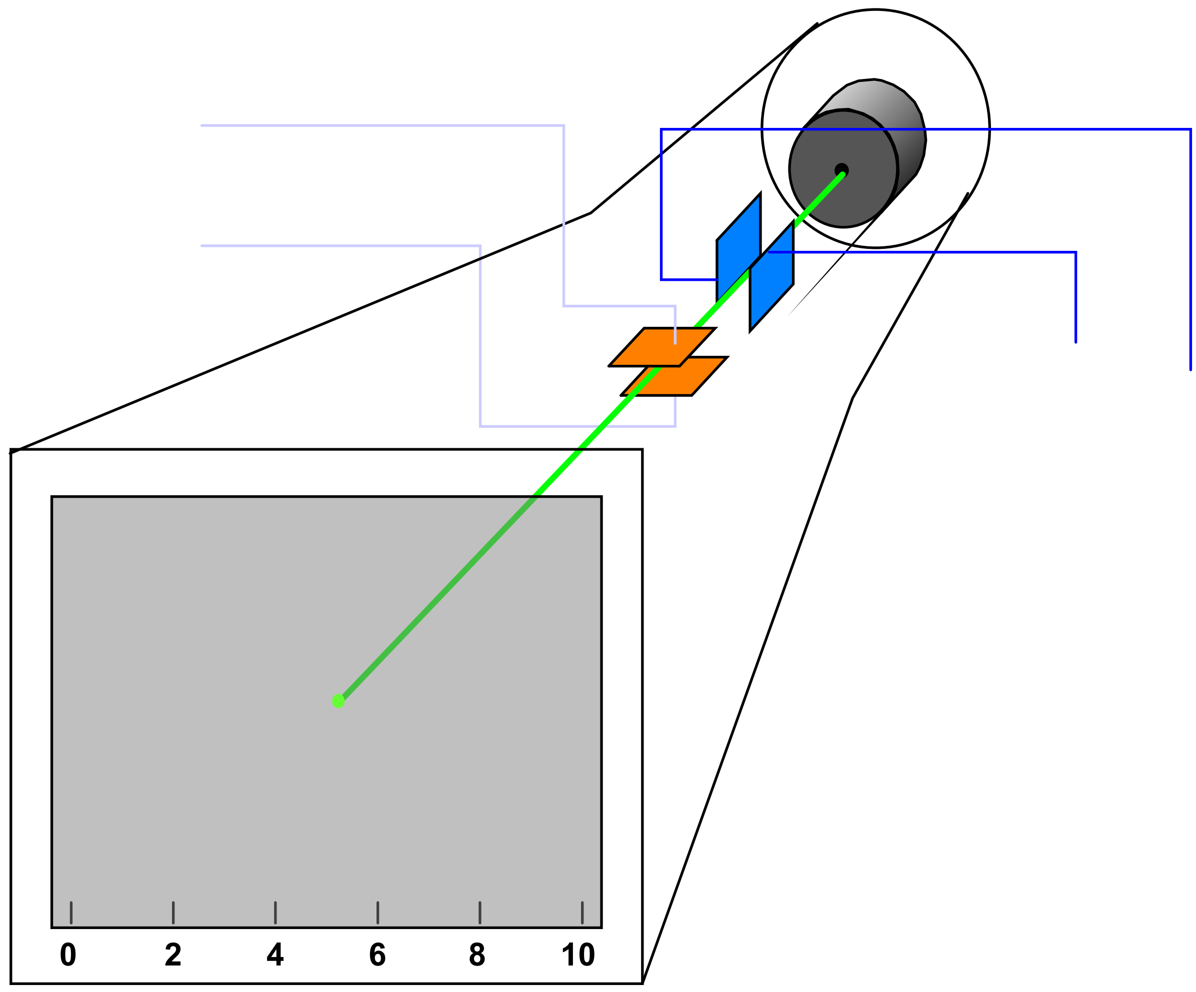
Ultrasonic Instrument



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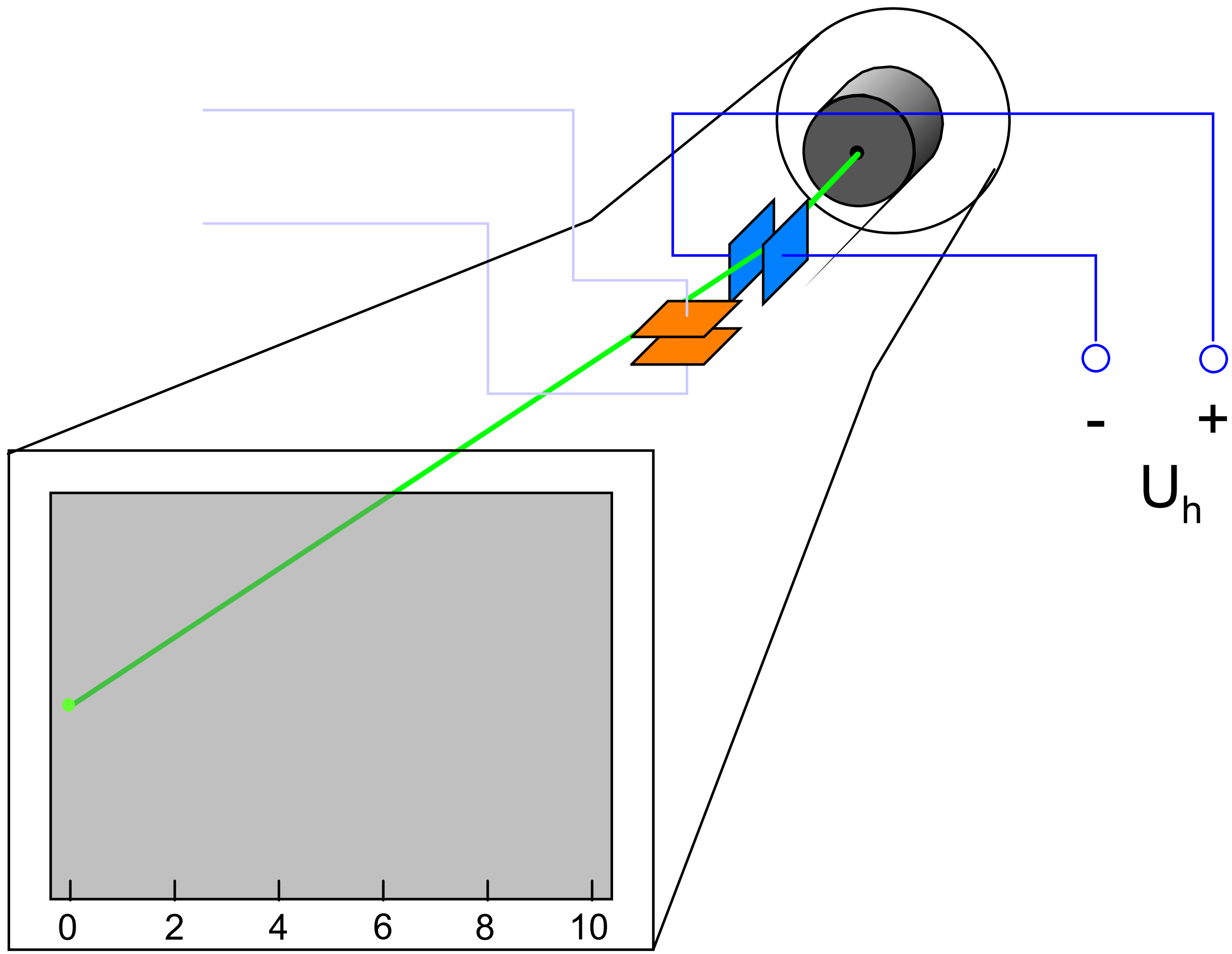
Ultrasonic Instrument



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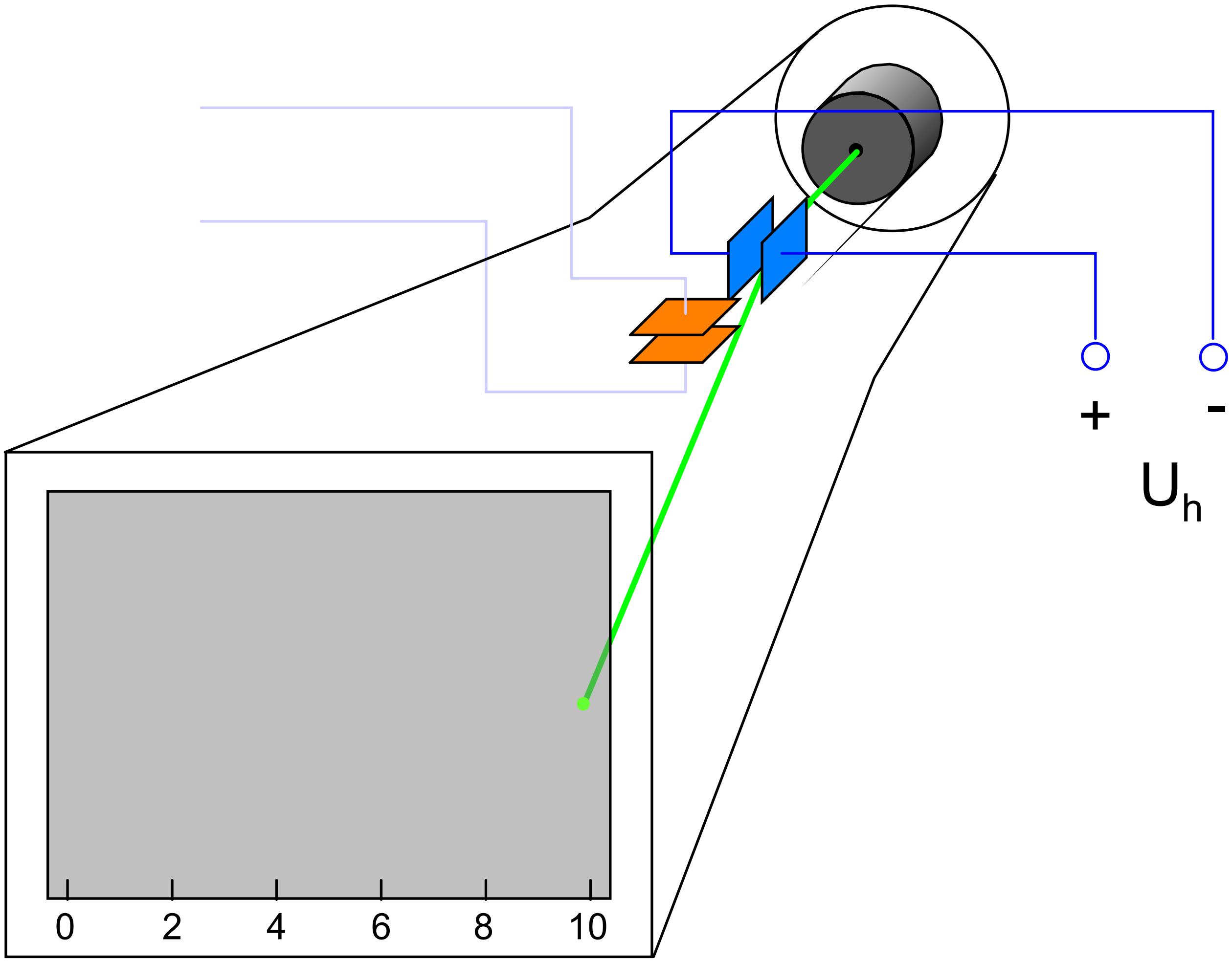
Ultrasonic Instrument



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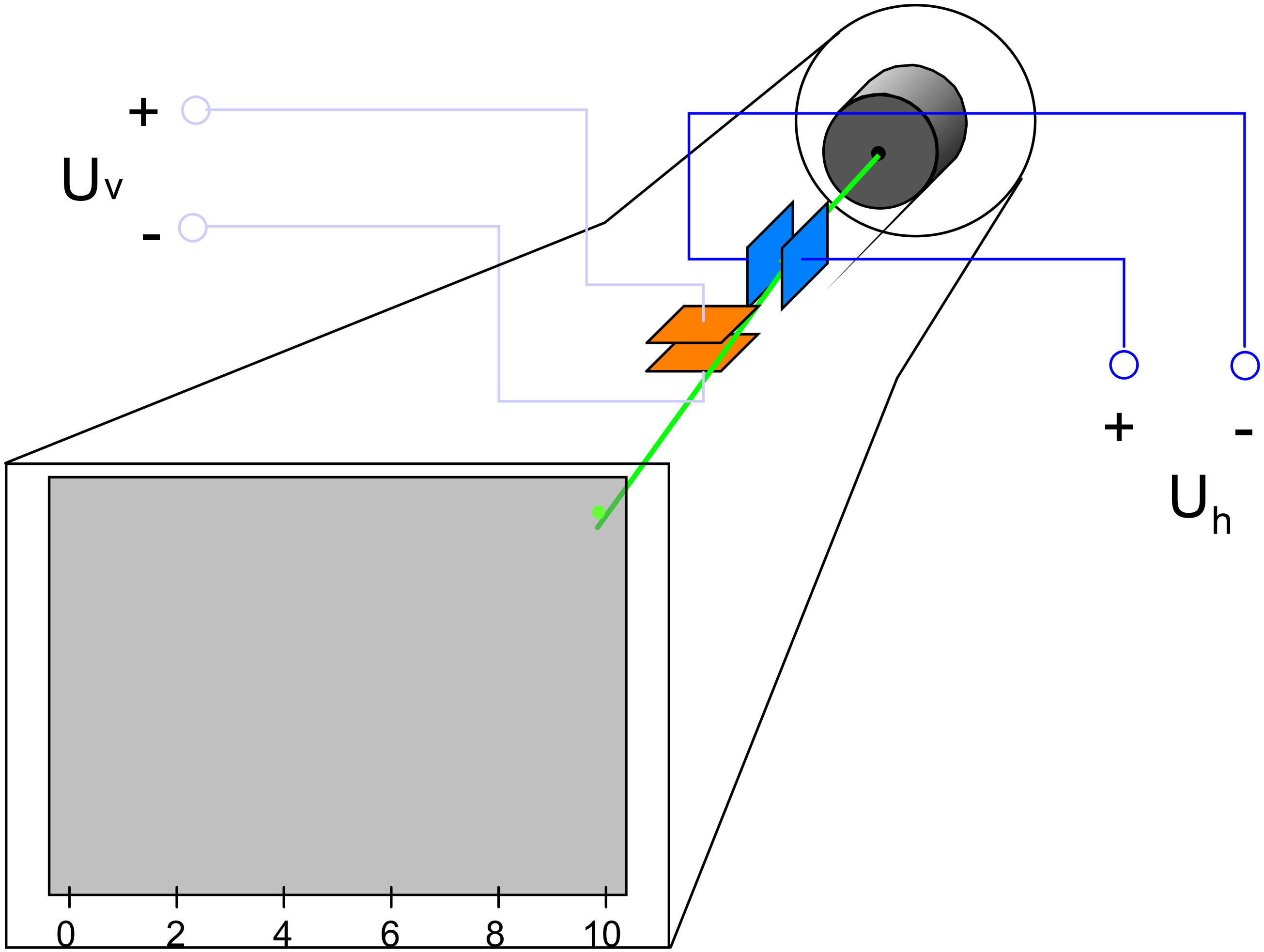
Ultrasonic Instrument



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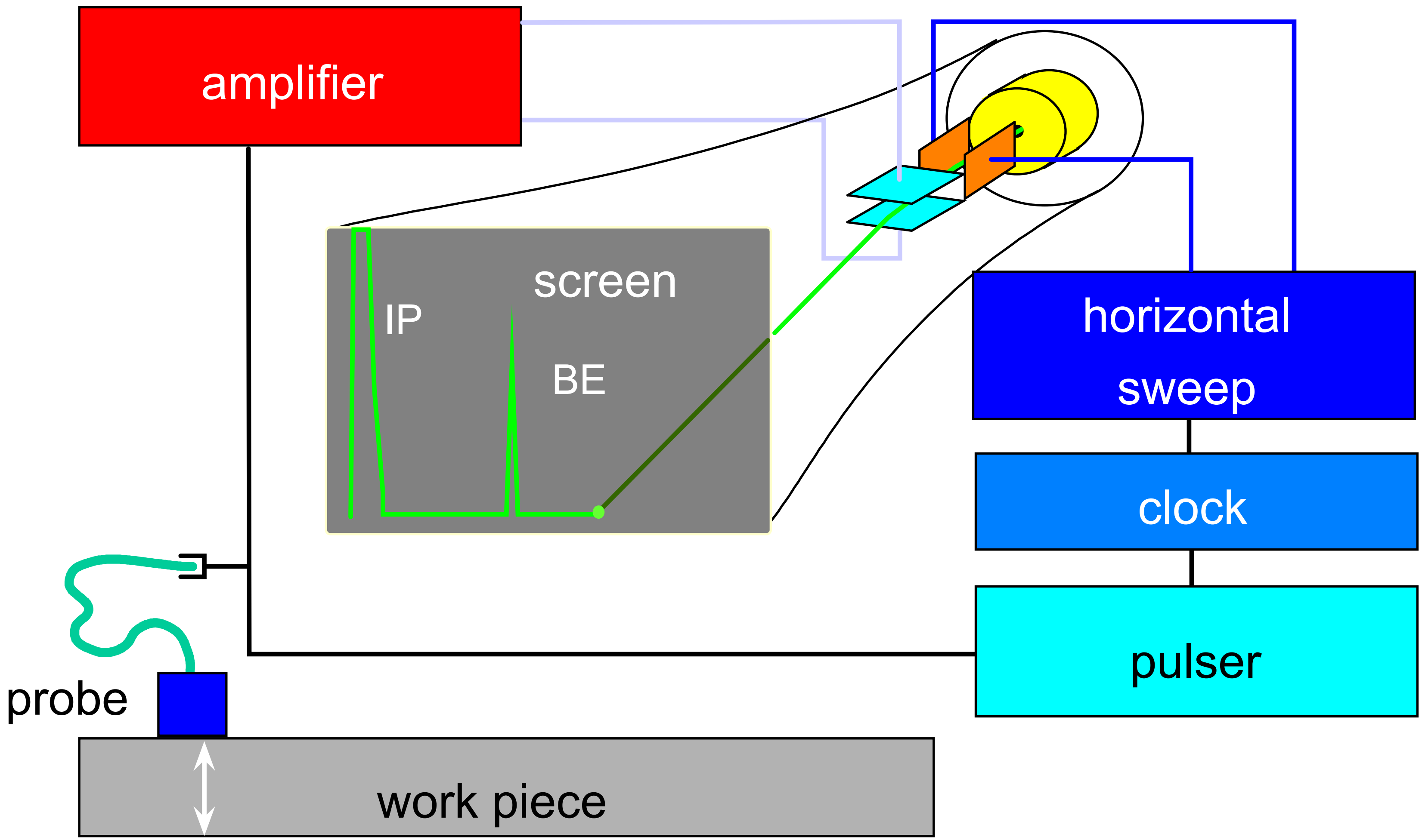
Block diagram: Ultrasonic Instrument



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Sound reflection at a flaw

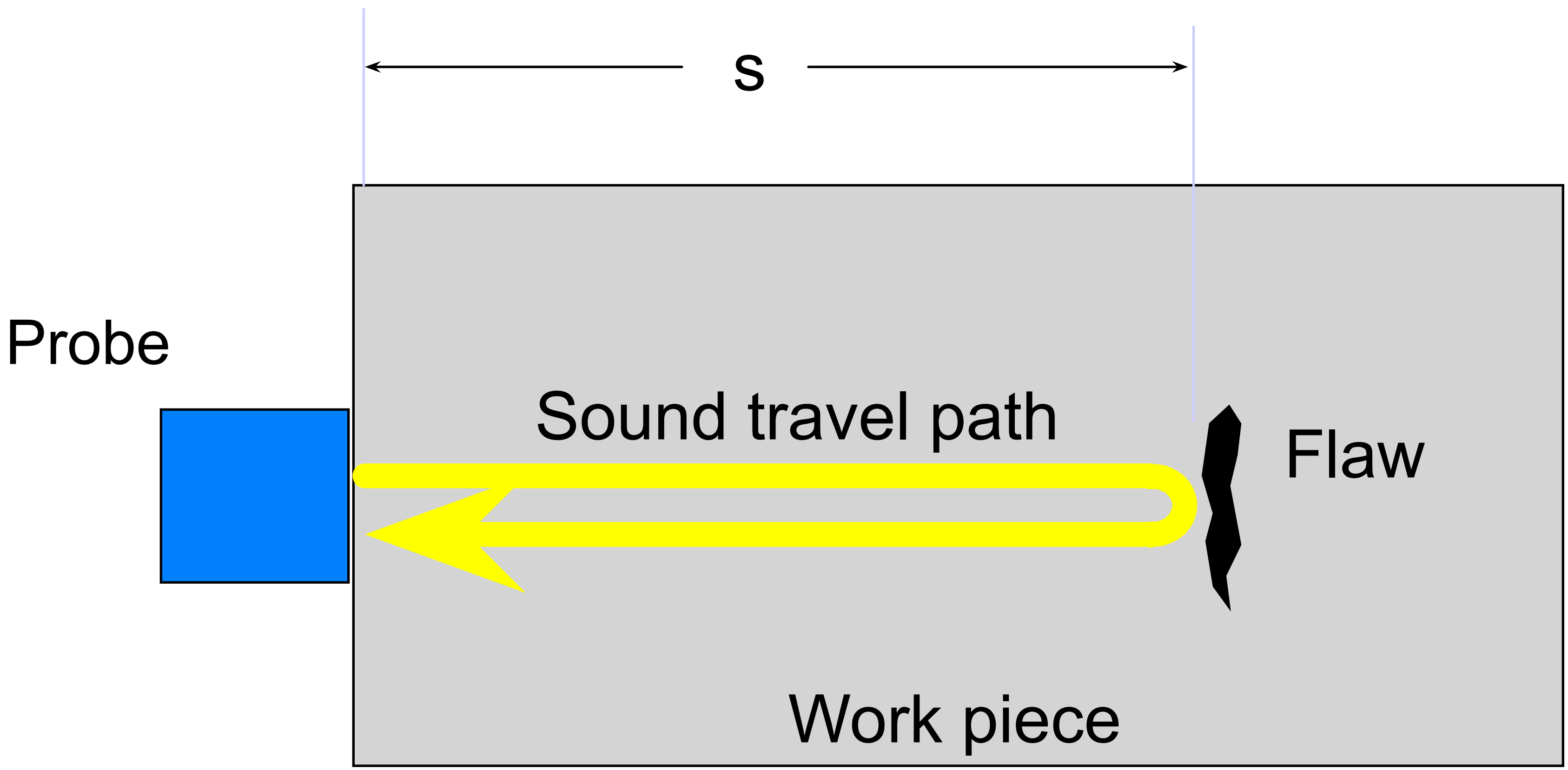

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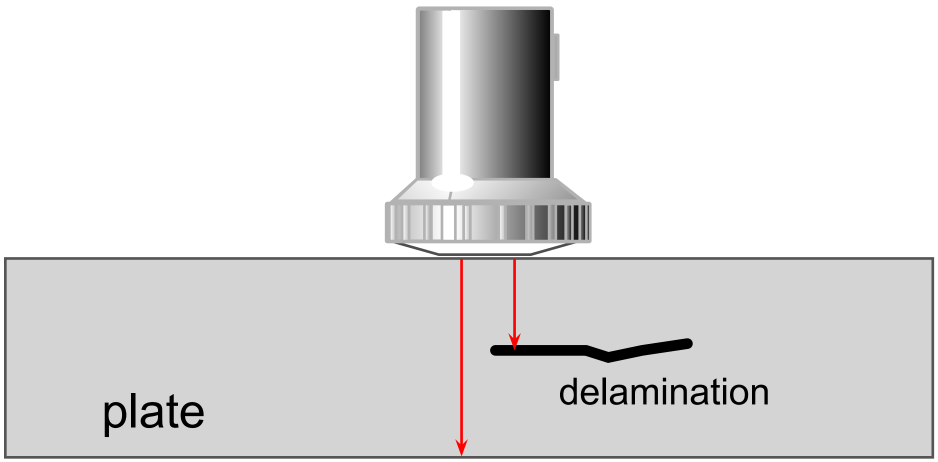
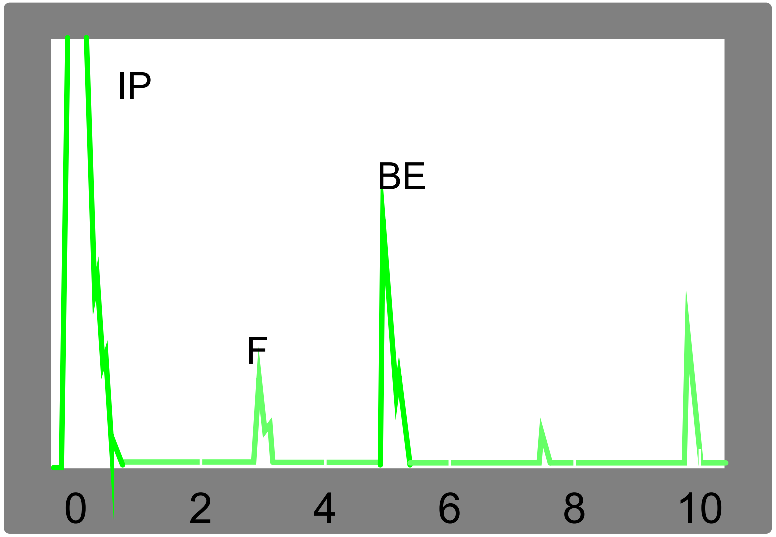
Plate testing





IP = Initial pulse

F = Flaw

BE = Backwall echo

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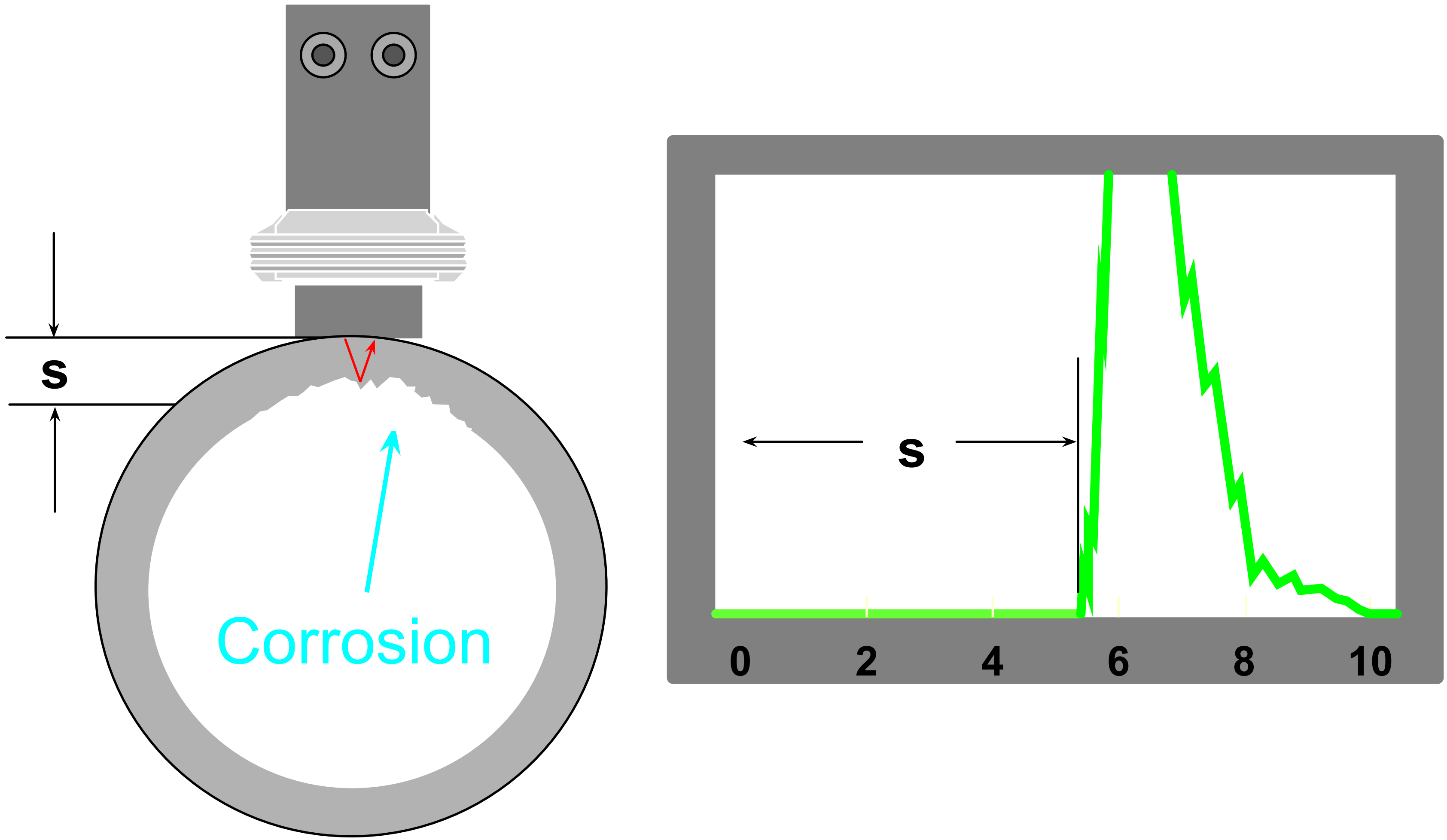
Wall thickness measurement



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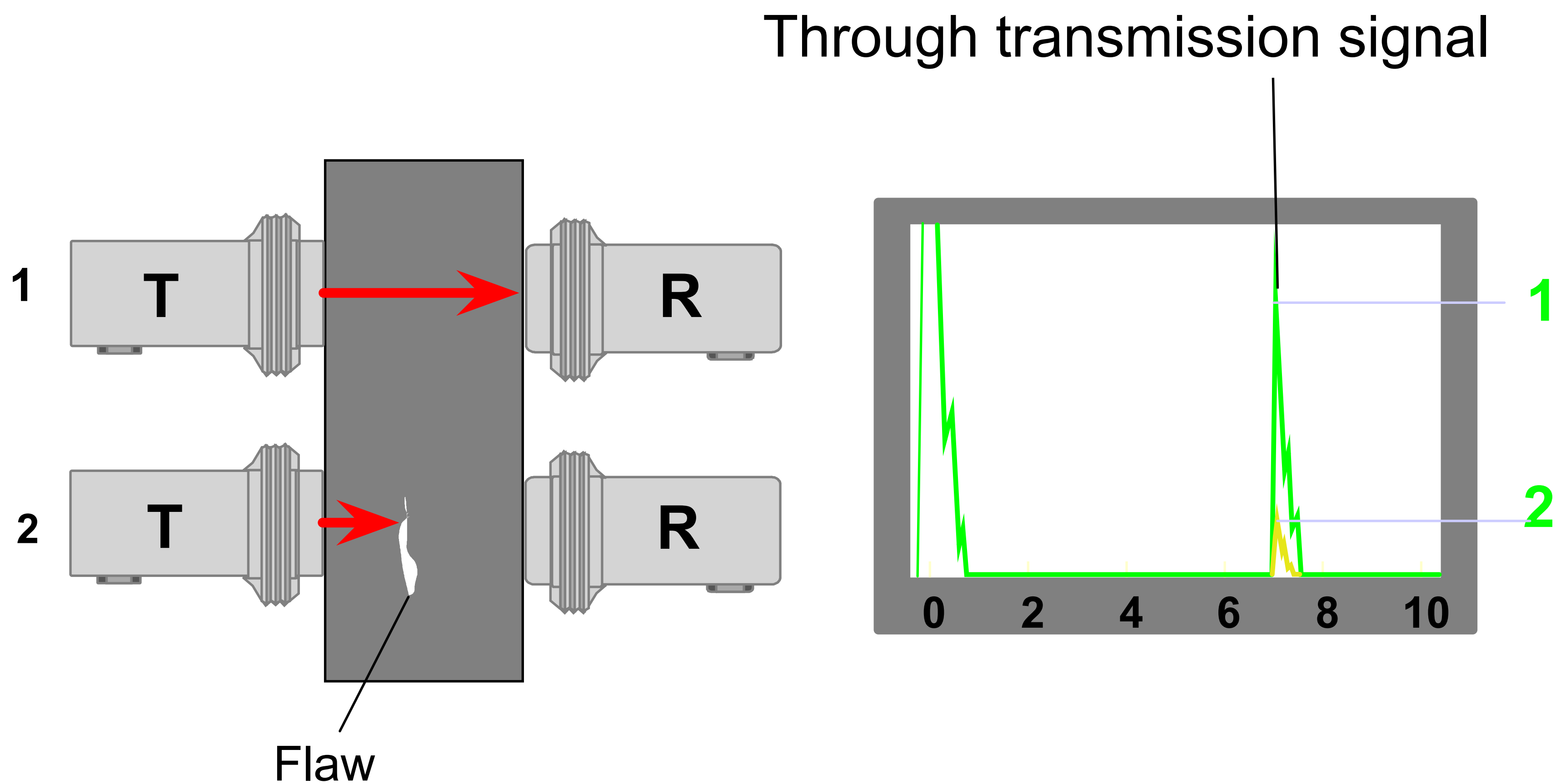
Through transmission testing



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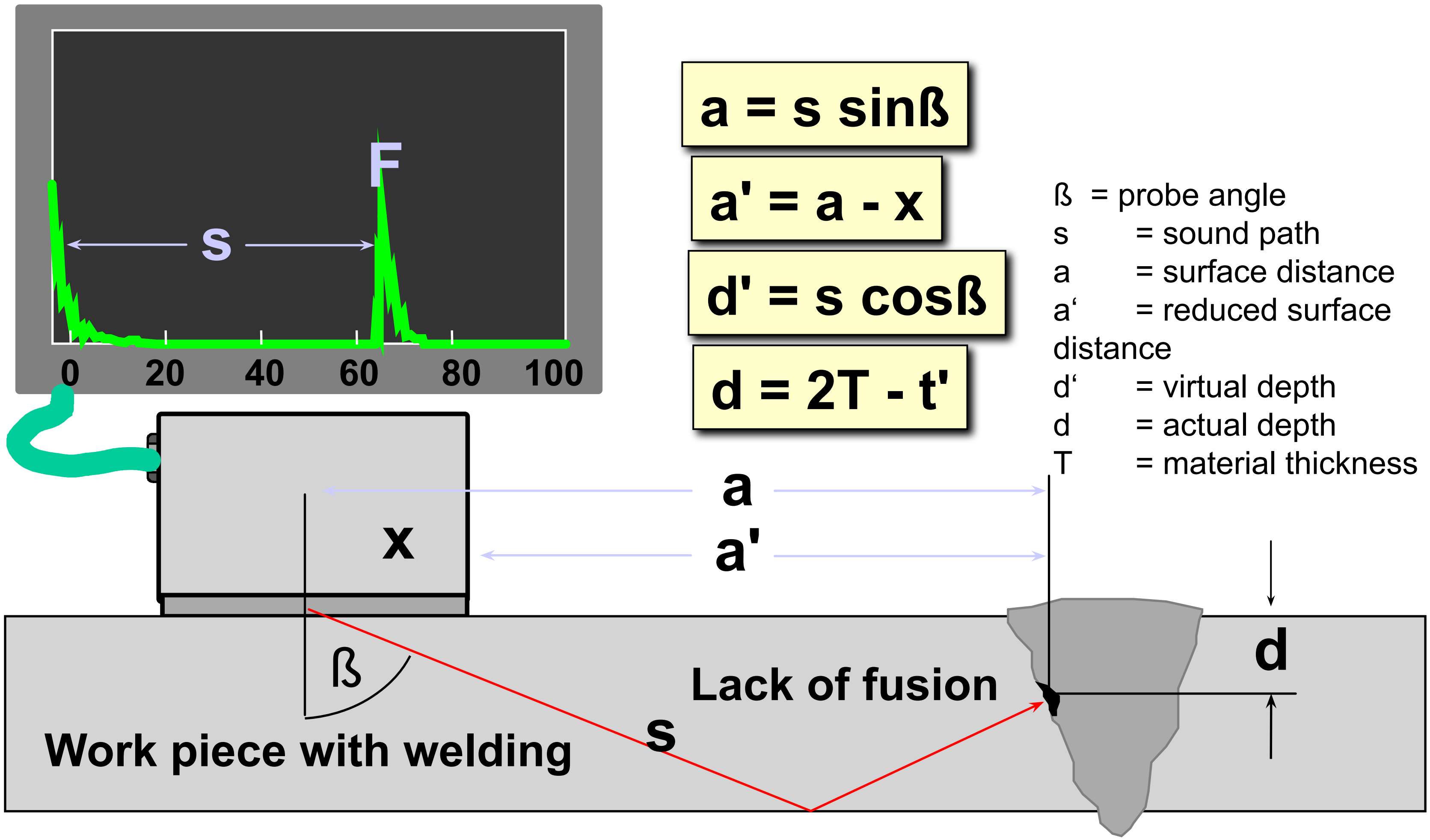
Weld inspection



$a = s \sin ß$

$a' = a - x$

$d' = s \cos ß$

$d = 2T - t'$

ß = probe angle
s = sound path
a = surface distance
a‘ = reduced surface distance
d‘ = virtual depth
d = actual depth
T = material thickness

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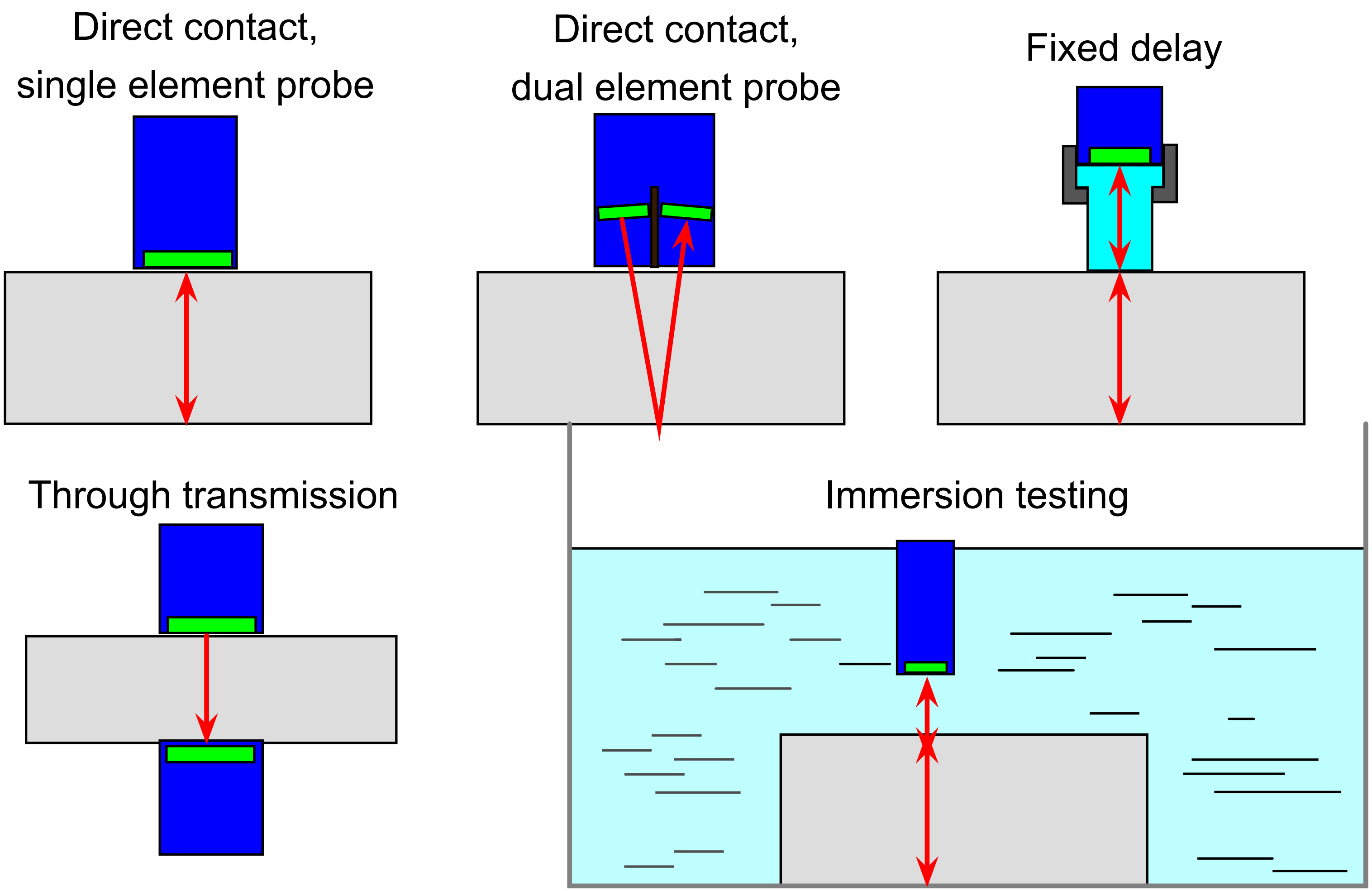
Straight beam inspection techniques:



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Immersion testing