

Basic Principles of Ultrasonic Testing

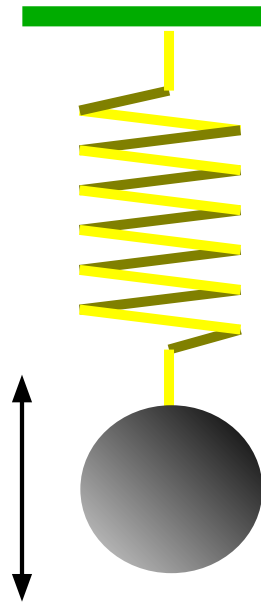
Basic Principles of Ultrasonic Testing

Theory and Practice

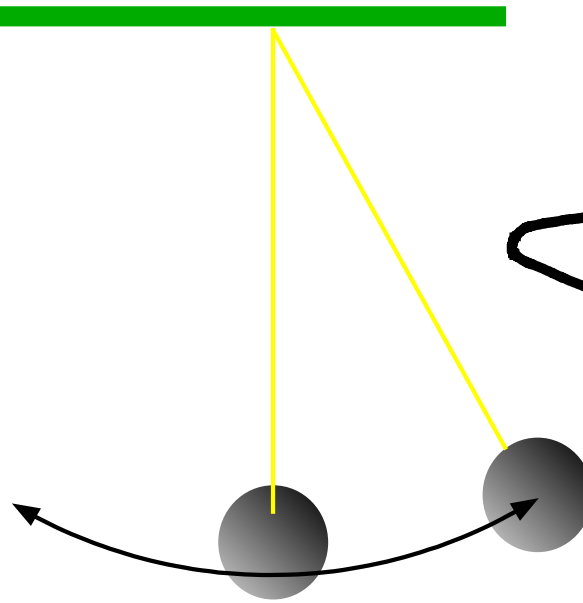
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Examples of oscillation

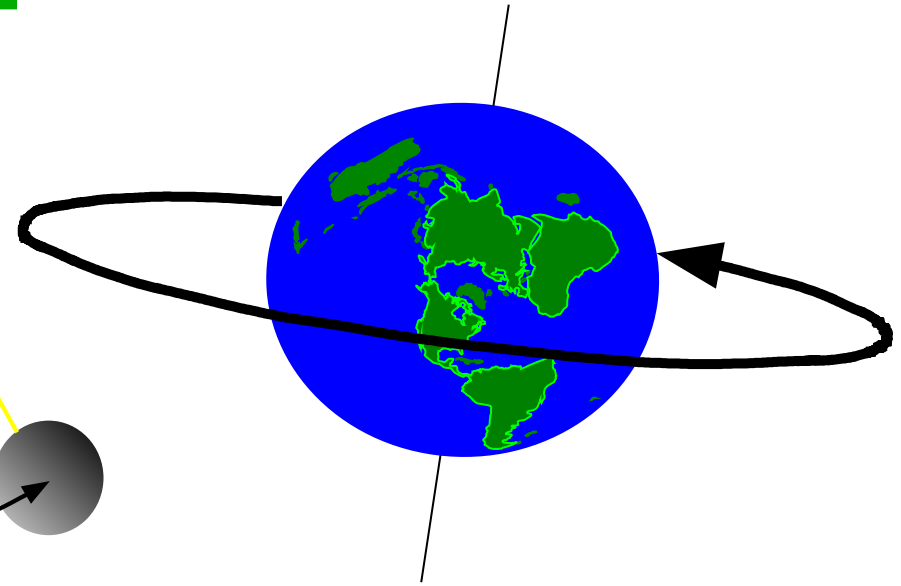
ball on a spring



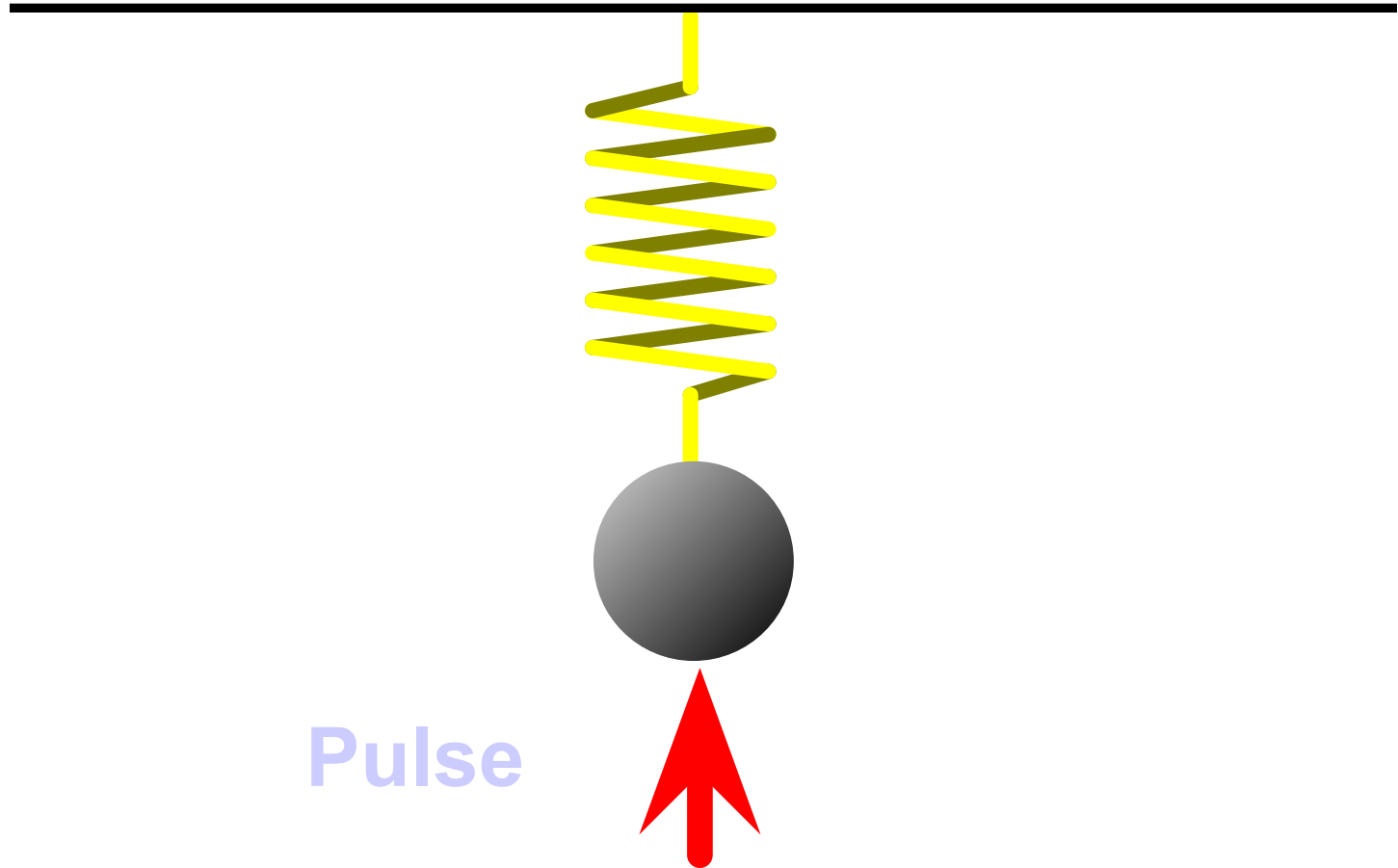
pendulum



rotating earth

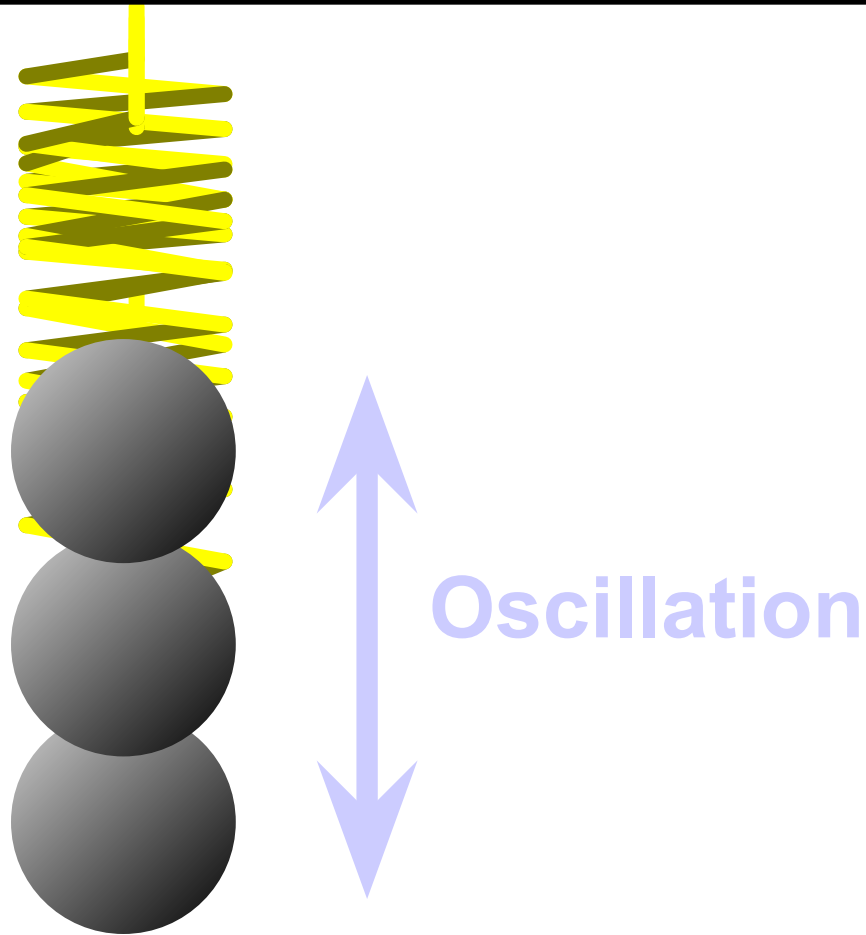


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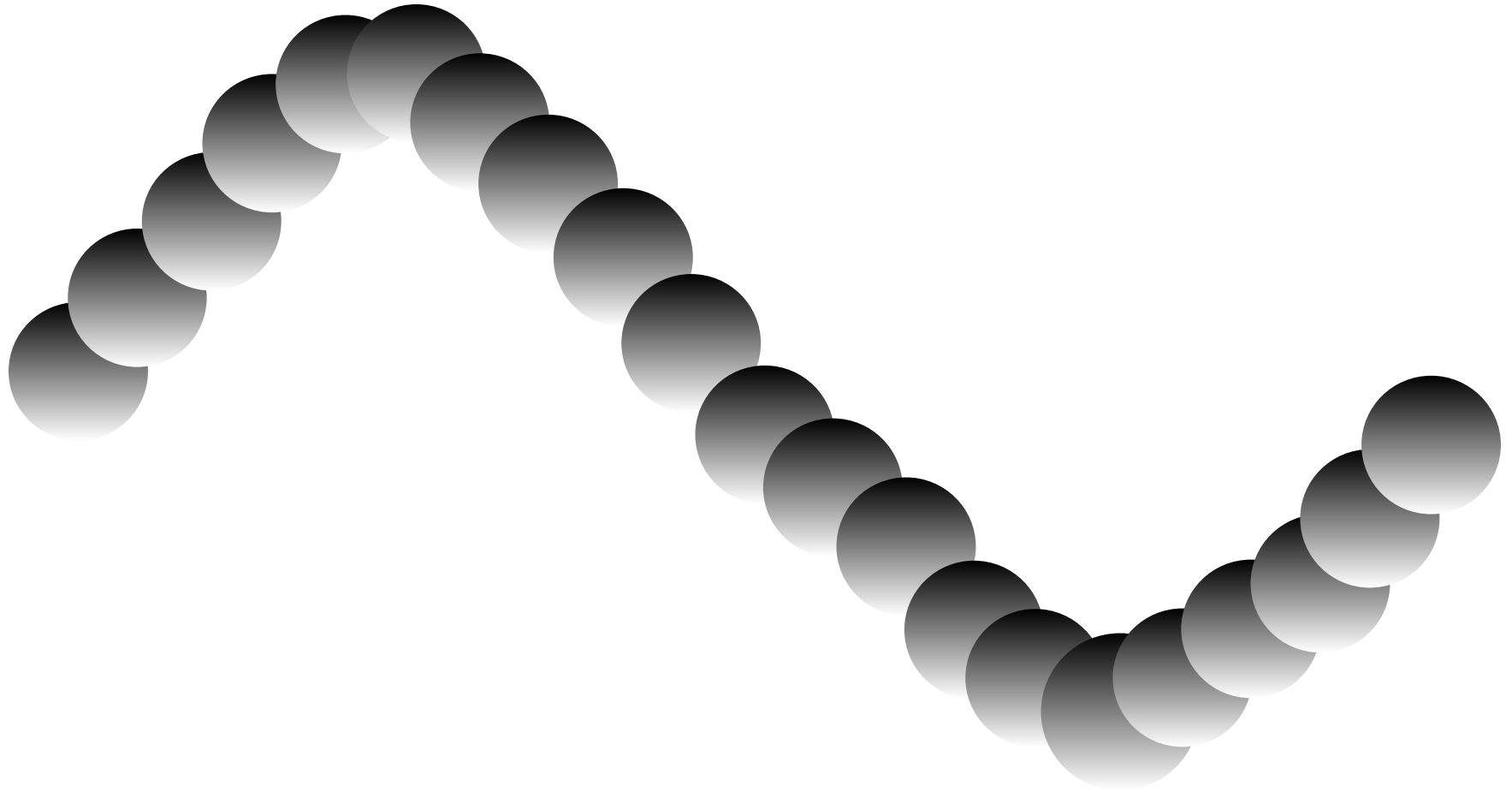
The ball starts to oscillate as soon as it is pushed

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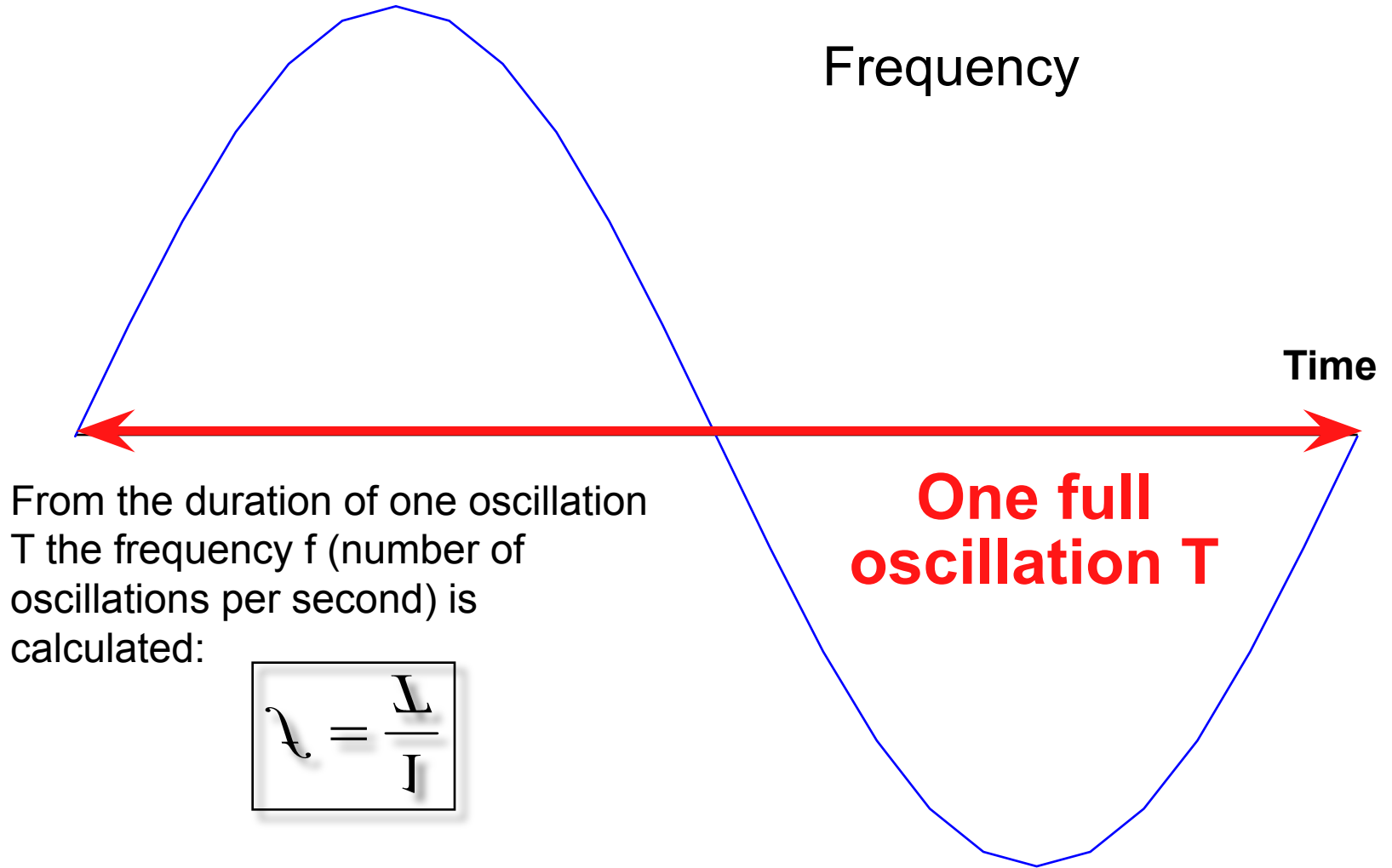


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Movement of the ball over time

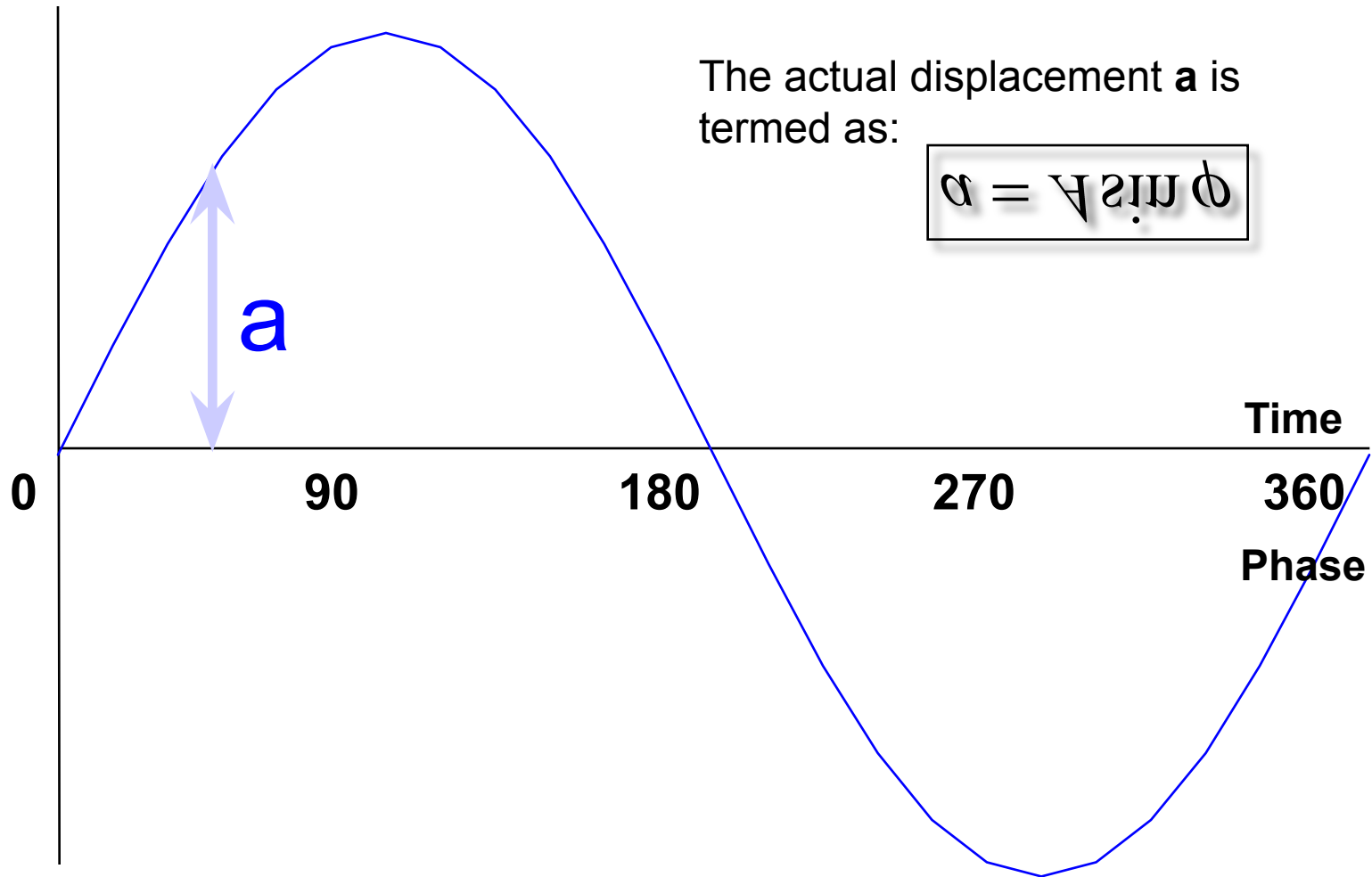


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$$f = \frac{1}{T}$$

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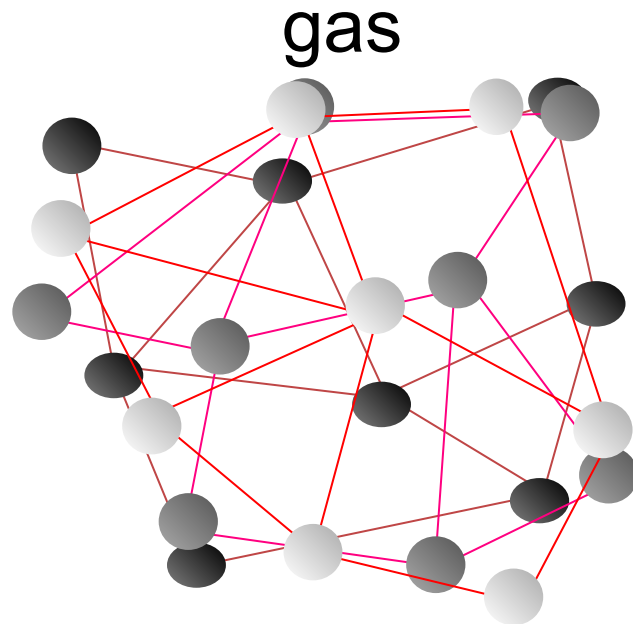
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Spectrum of sound

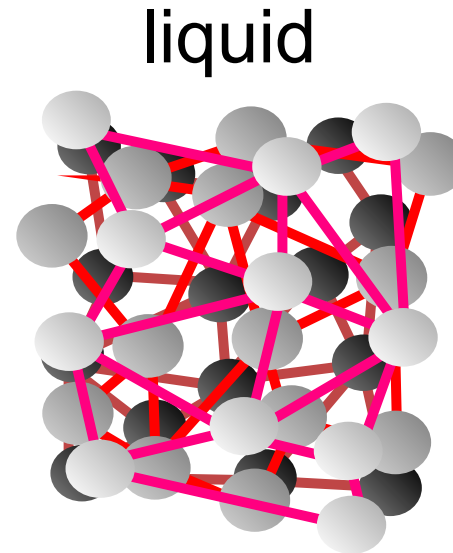
Frequency range Hz	Description	Example
0 - 20	Infrasound	Earth quake
20 - 20.000	Audible sound	Speech, music
> 20.000	Ultrasound	Bat, Quartz crystal

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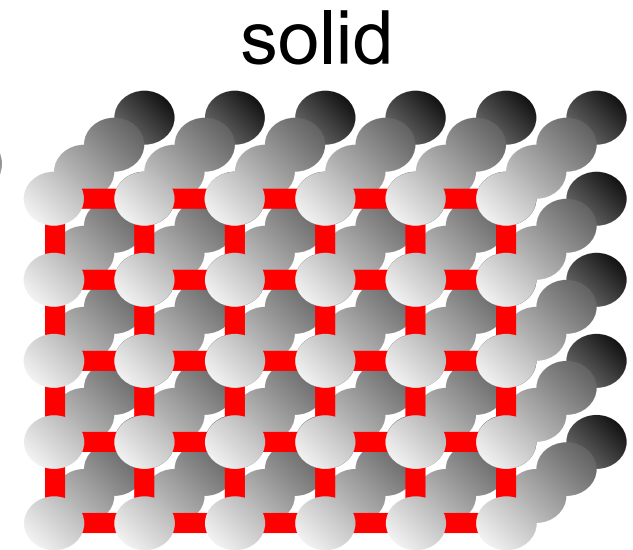
Atomic structures



- low density
- weak bonding forces



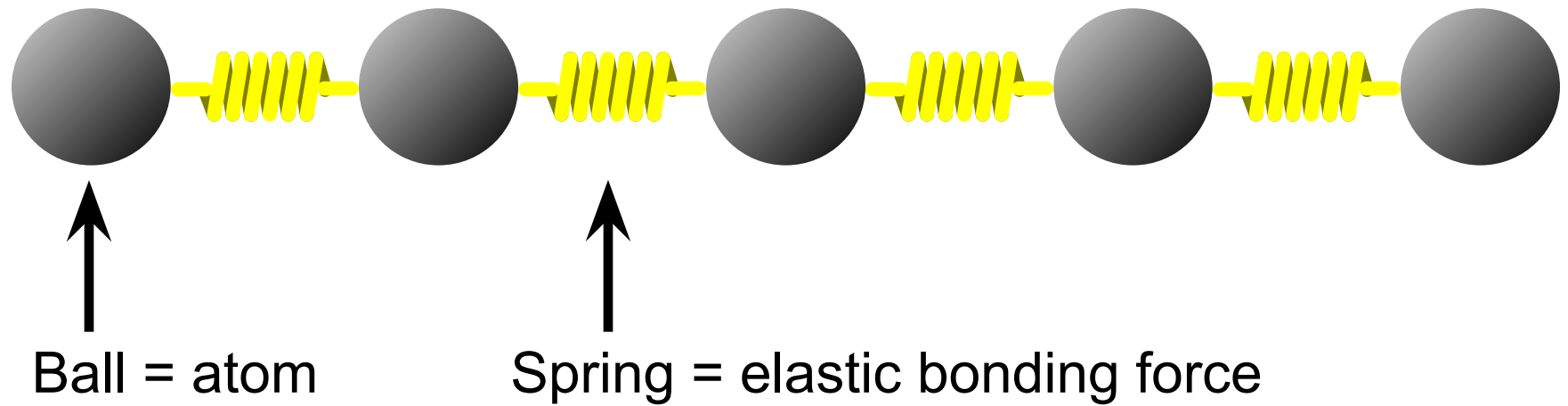
- medium density
- medium bonding forces



- high density
- strong bonding forces
- crystallographic structure

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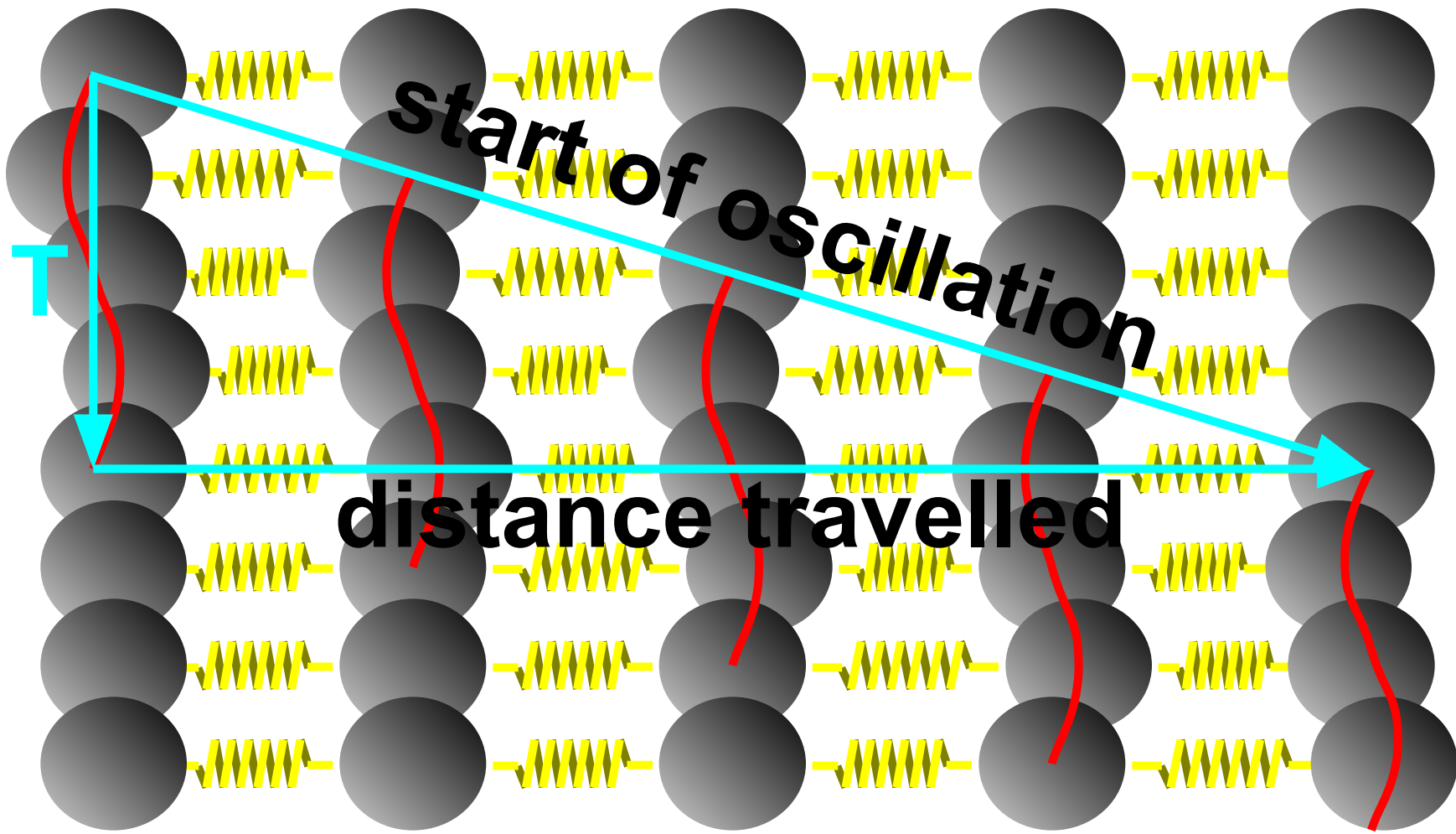
Understanding wave propagation:



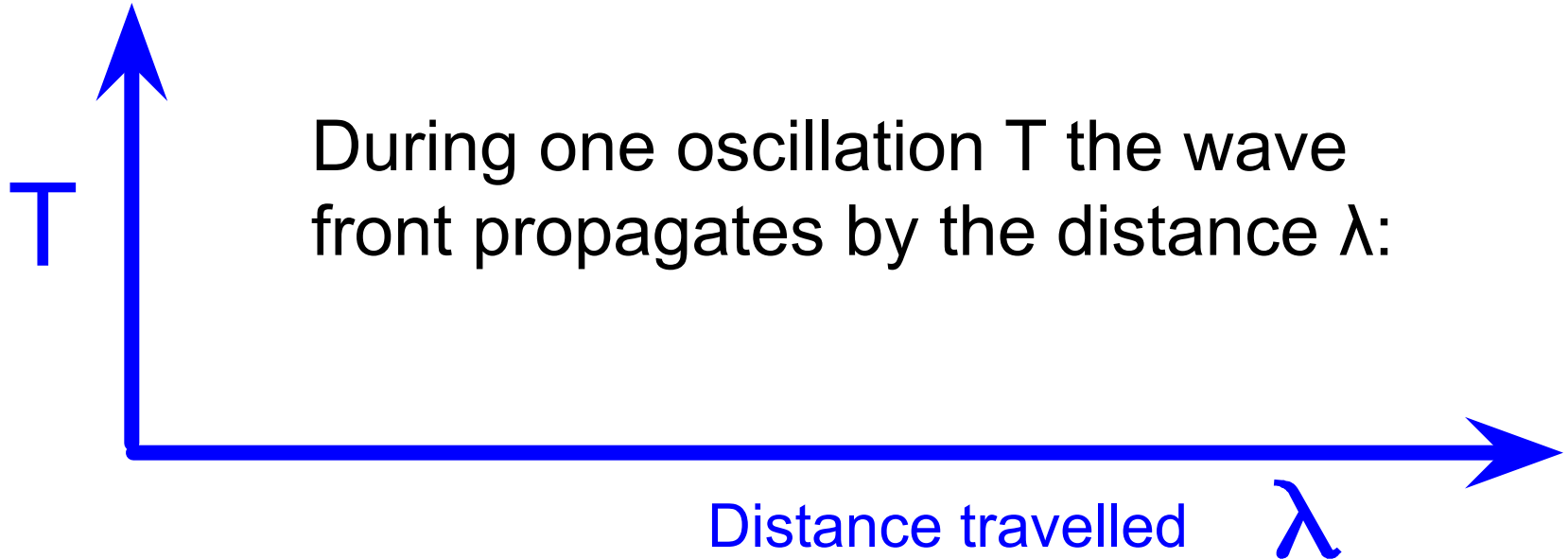
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ndt

a worldwide response



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From this we derive:

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

or

$$c = \lambda f$$

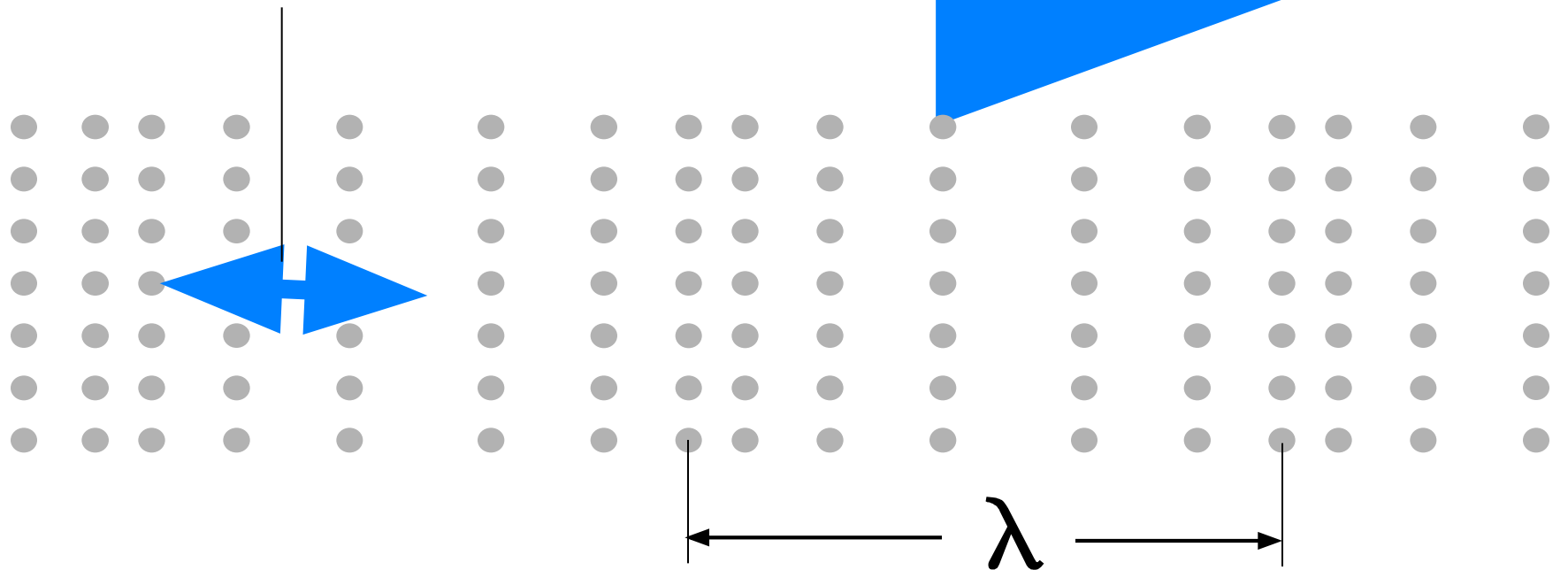
Wave equation

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Sound propagation

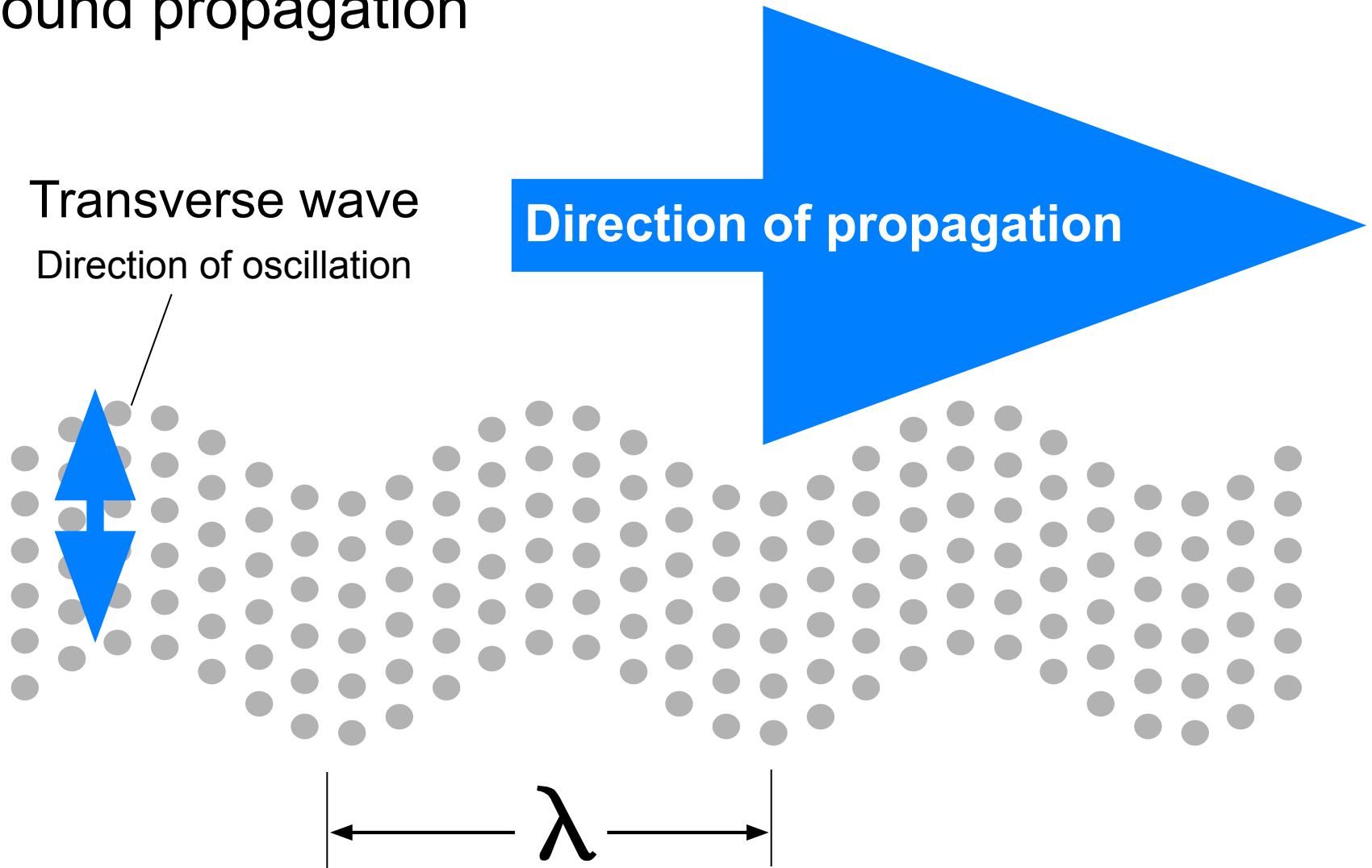
Longitudinal wave

Direction of oscillation



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Sound propagation



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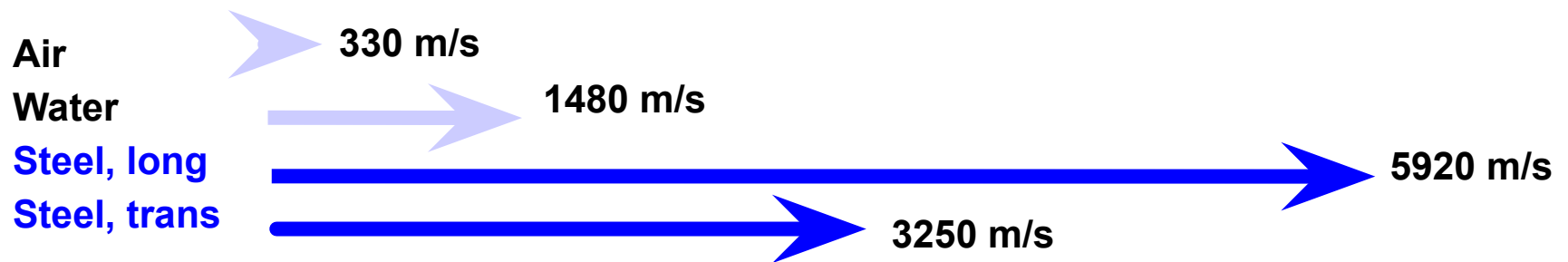
Wave propagation

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.

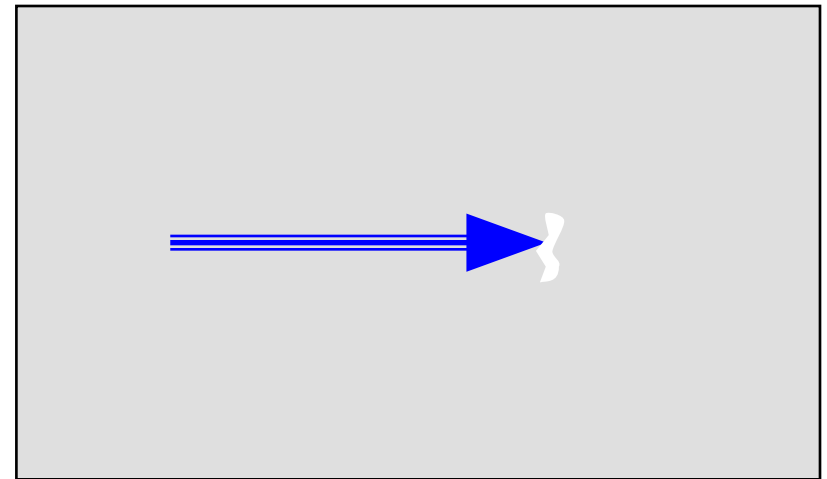
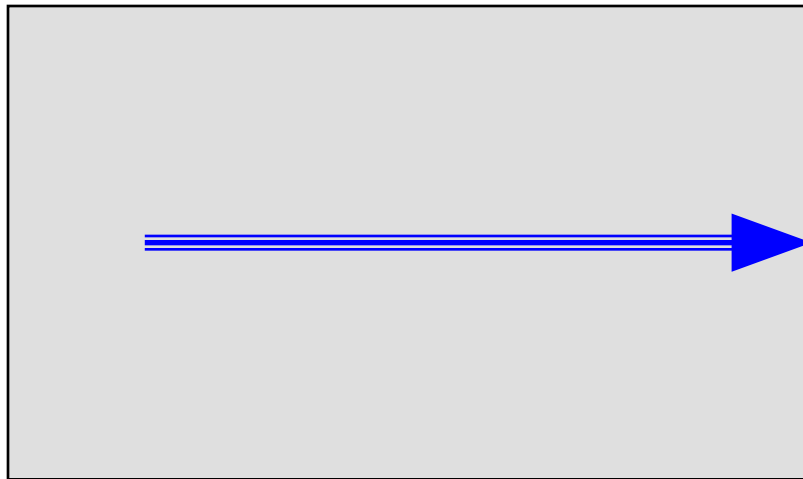
Sound velocity mainly depends on the density and E-modulus of the material.



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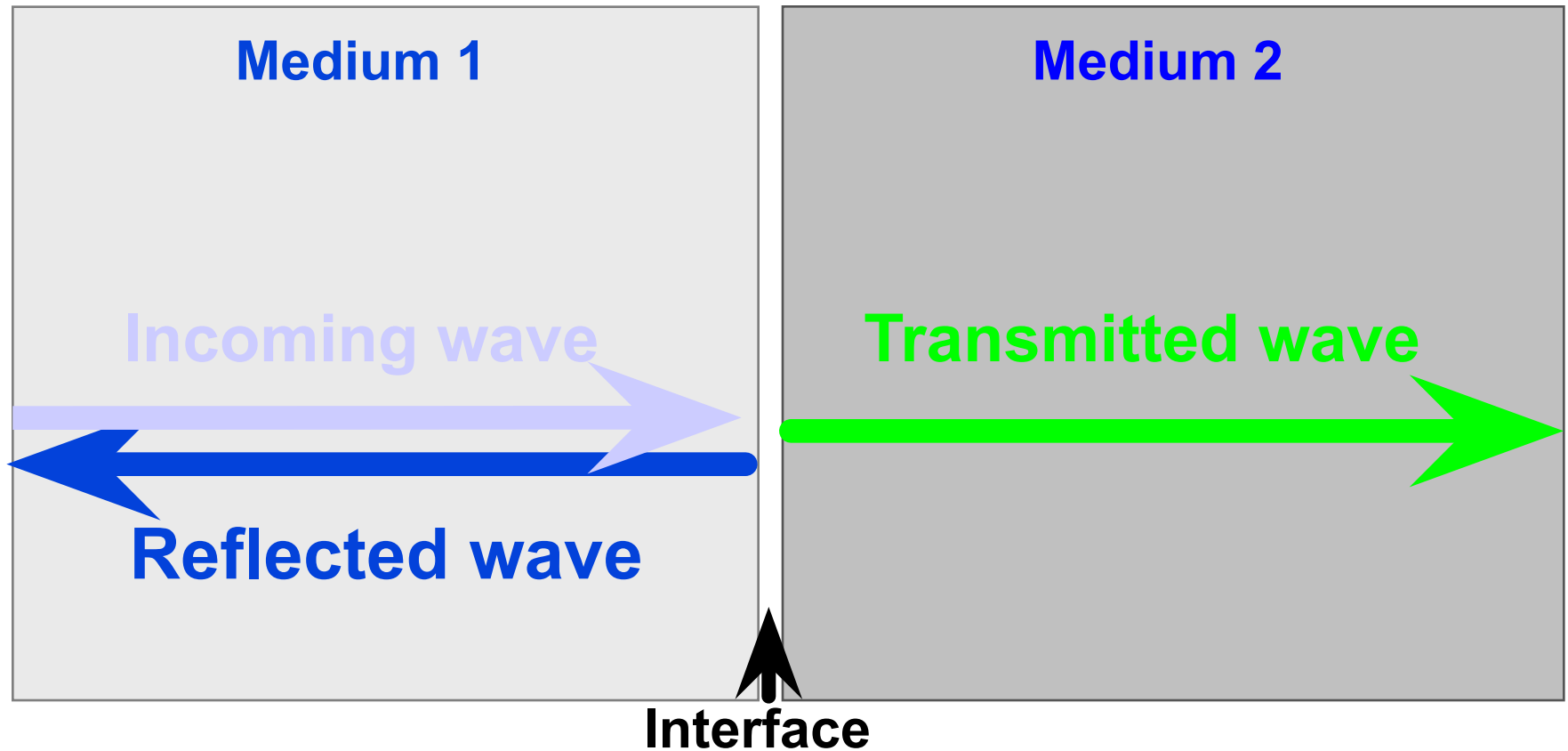
Reflection and Transmission

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:



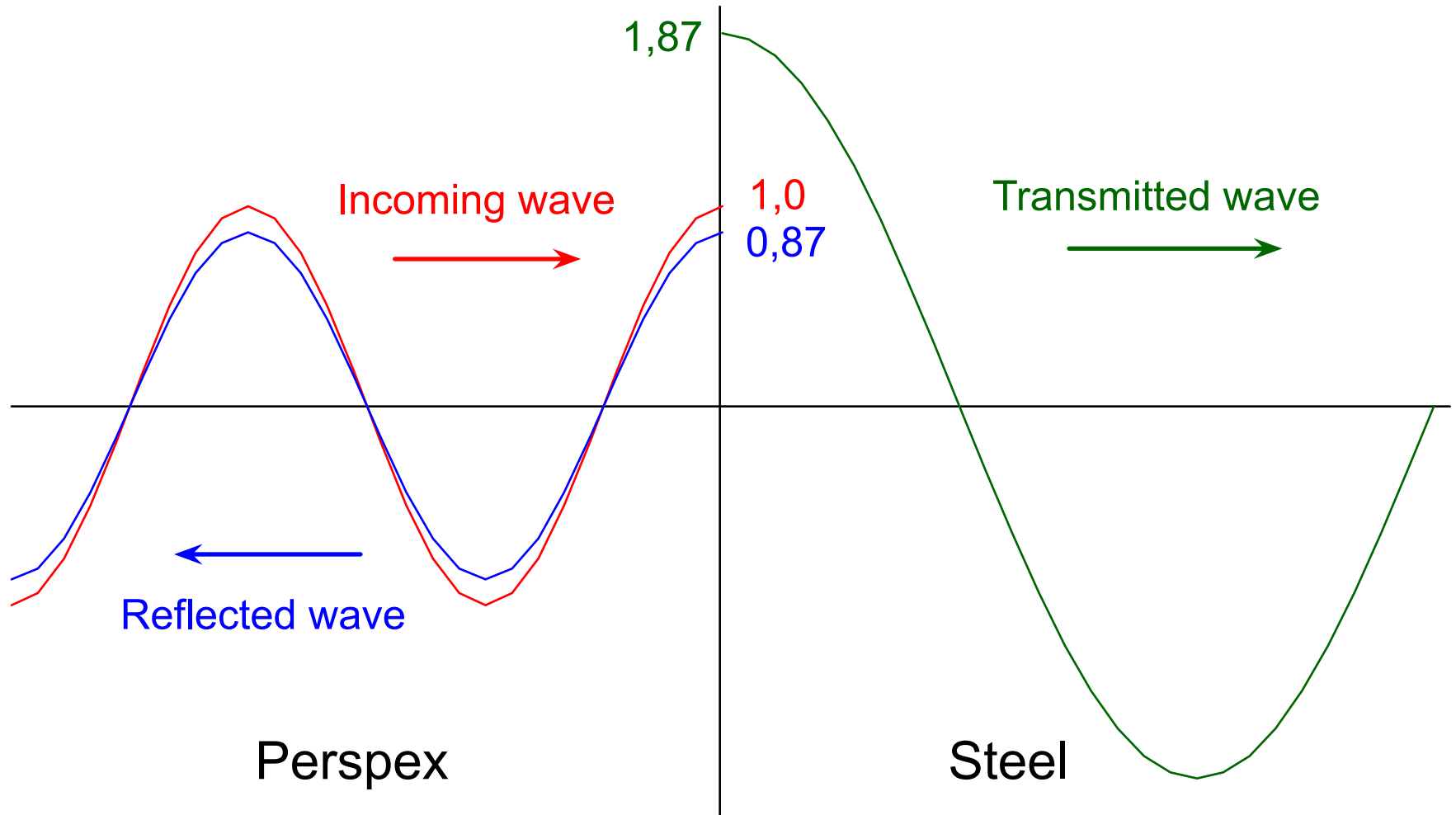
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Behaviour at an interface



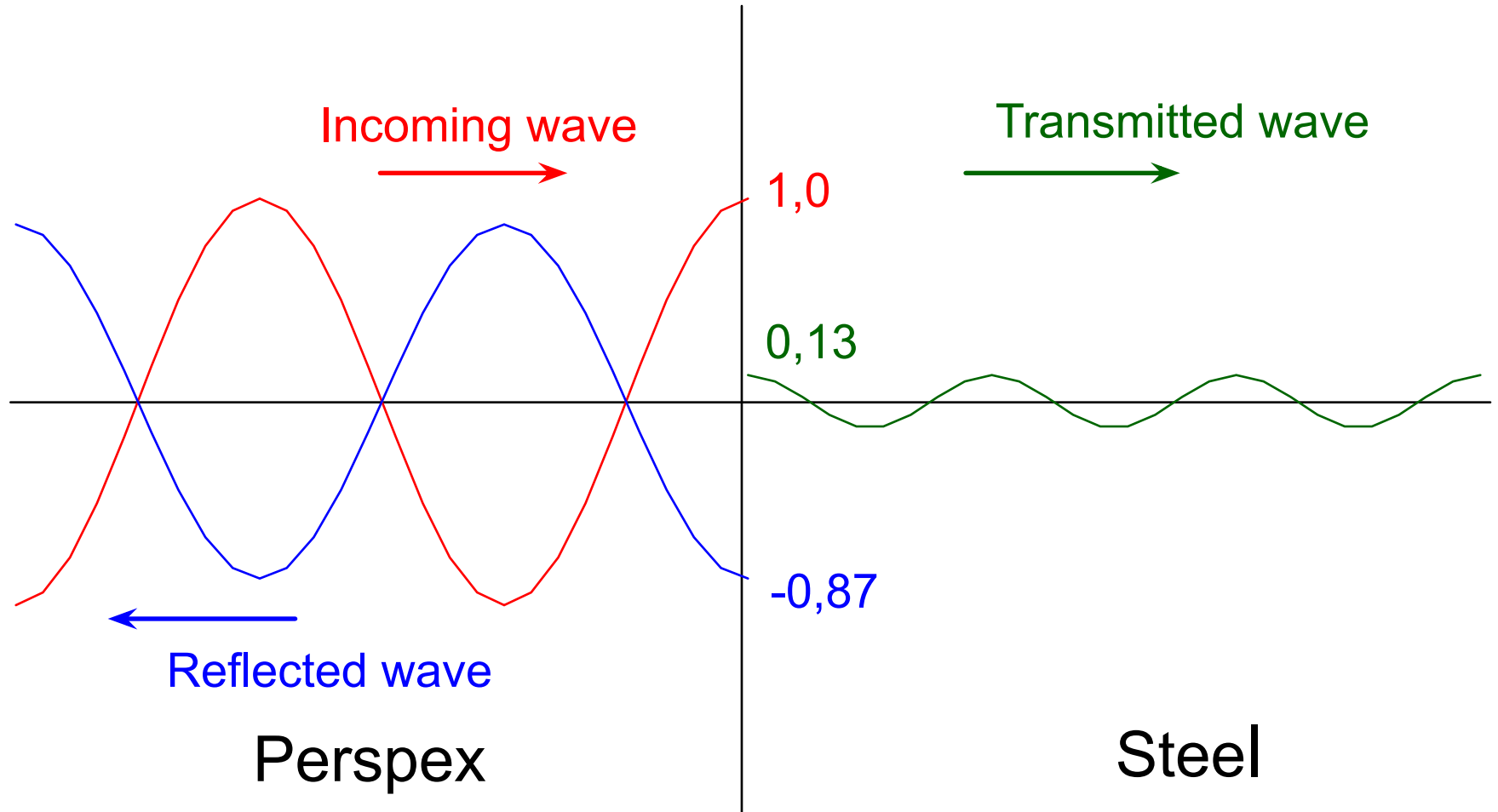
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Reflection + Transmission: Perspex - Steel



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Reflection + Transmission: Steel - Perspex



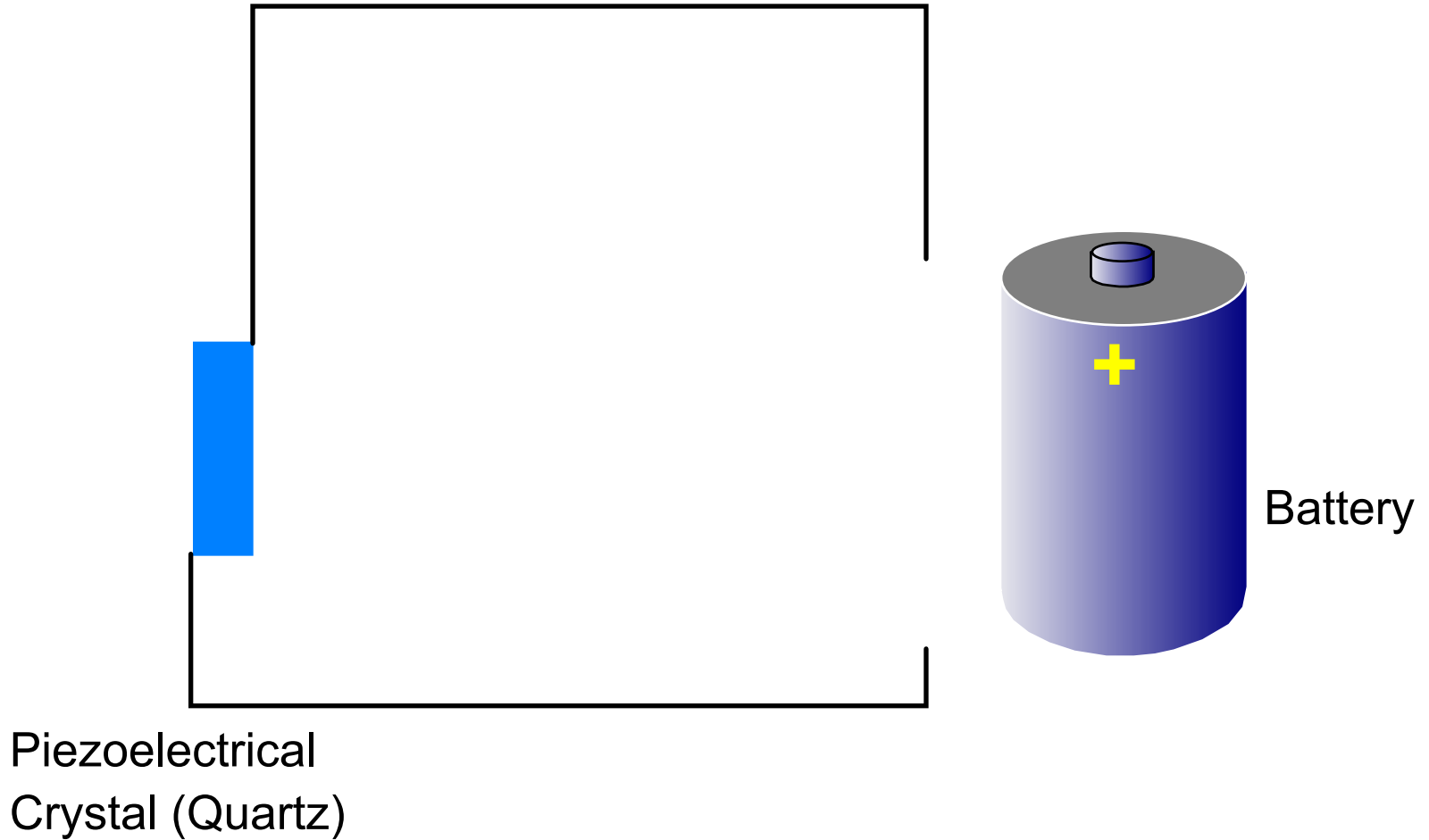
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Amplitude of sound transmissions:

Water - Steel	Copper - Steel	Steel - Air
<ul style="list-style-type: none">• Strong reflection• Double transmission	<ul style="list-style-type: none">• No reflection• Single transmission	<ul style="list-style-type: none">• Strong reflection with inverted phase• No transmission

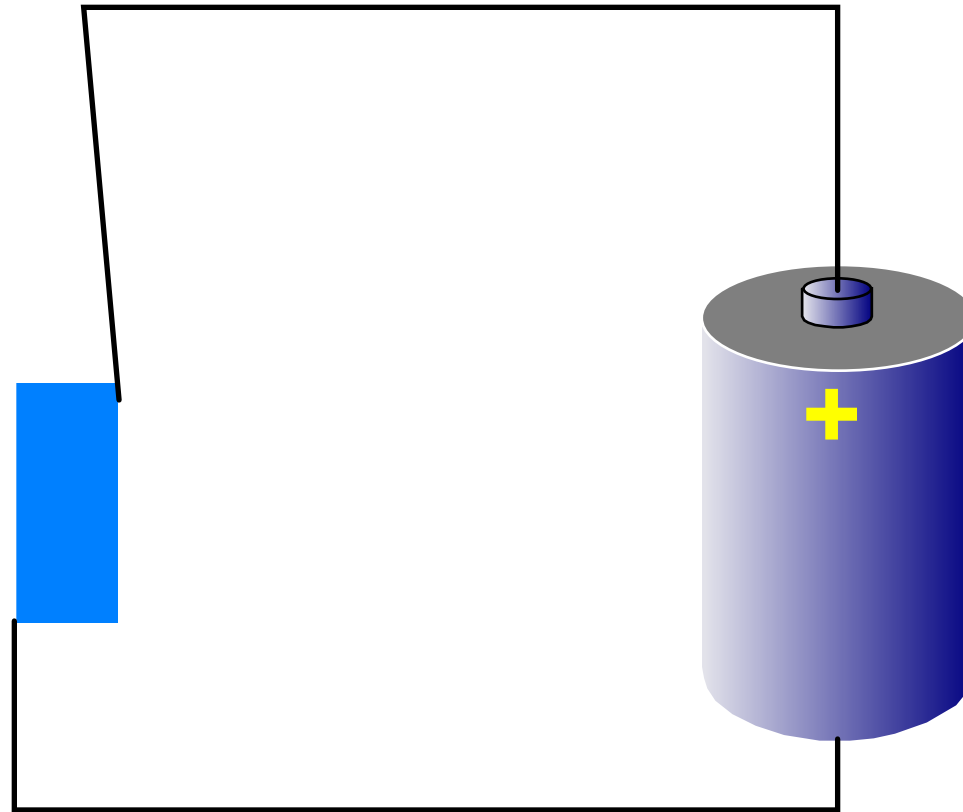
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Piezoelectric Effect



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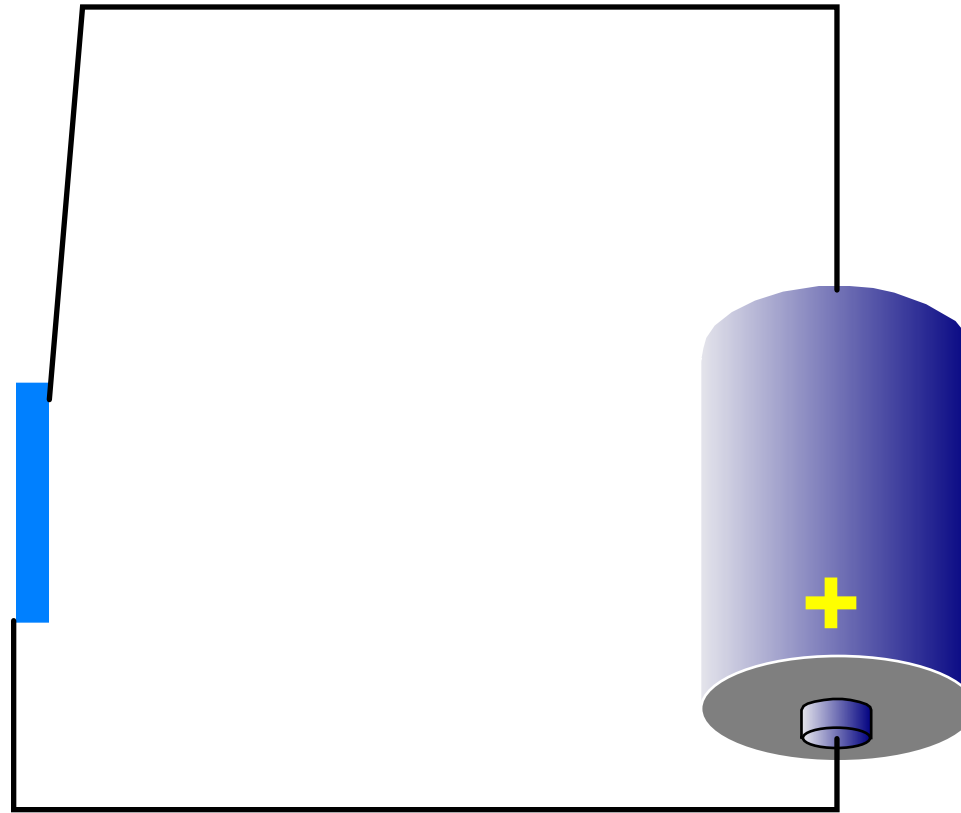
Piezoelectric Effect



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

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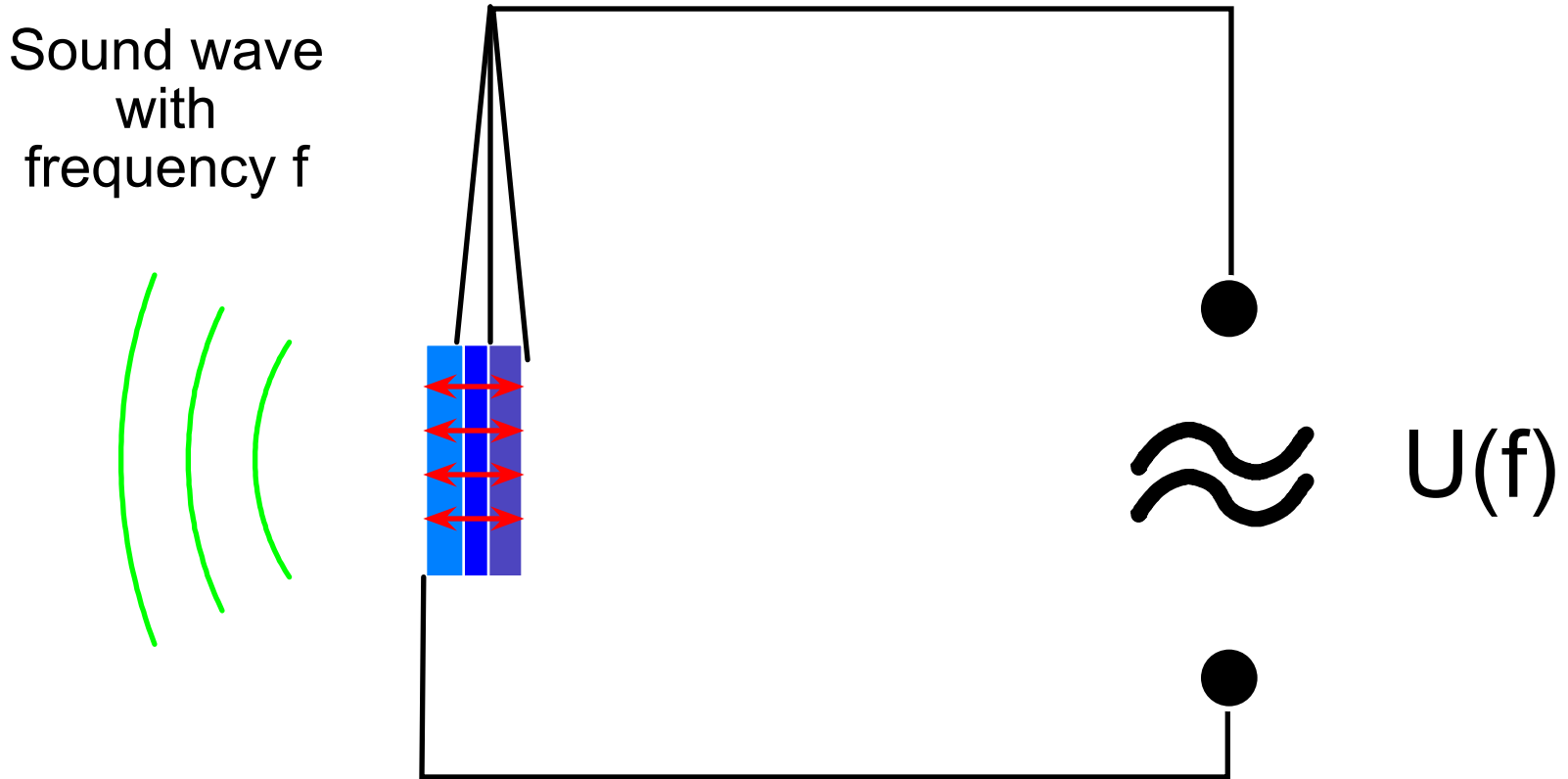
Piezoelectric Effect



The effect inverses with polarity change

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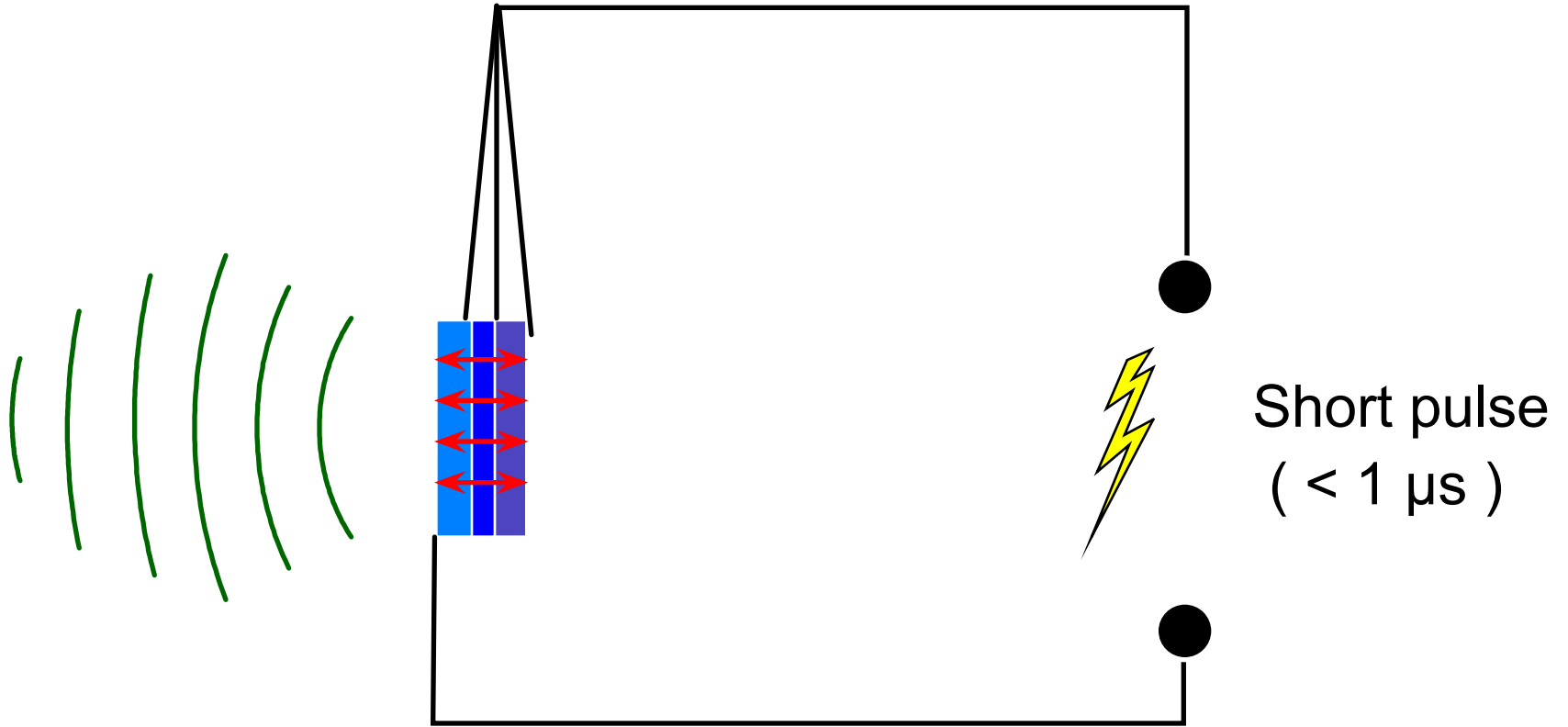
Piezoelectric Effect



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.

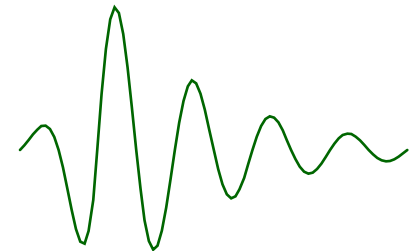
Electrical energy



Piezoelectrical crystal

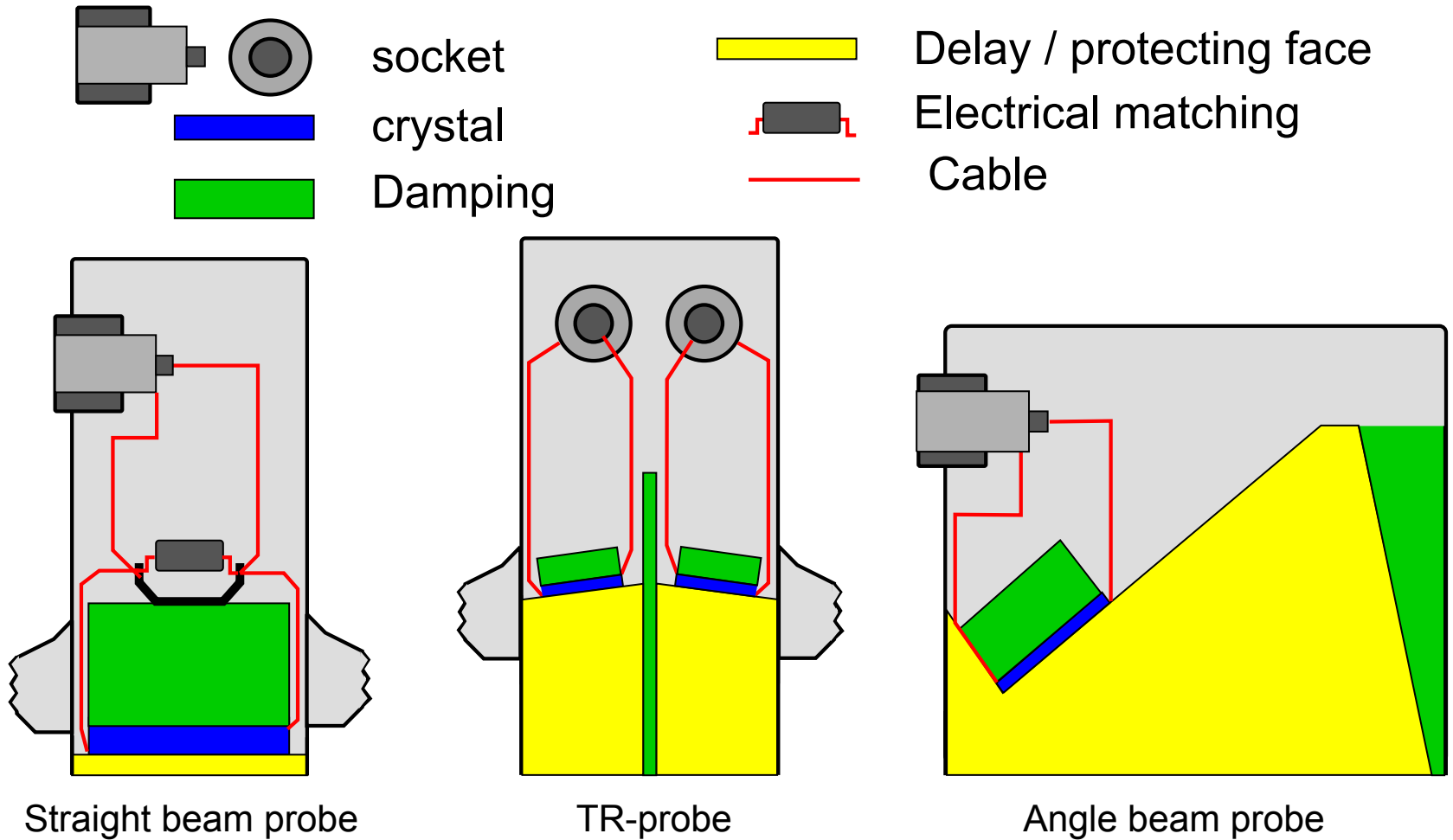


Ultrasonic wave



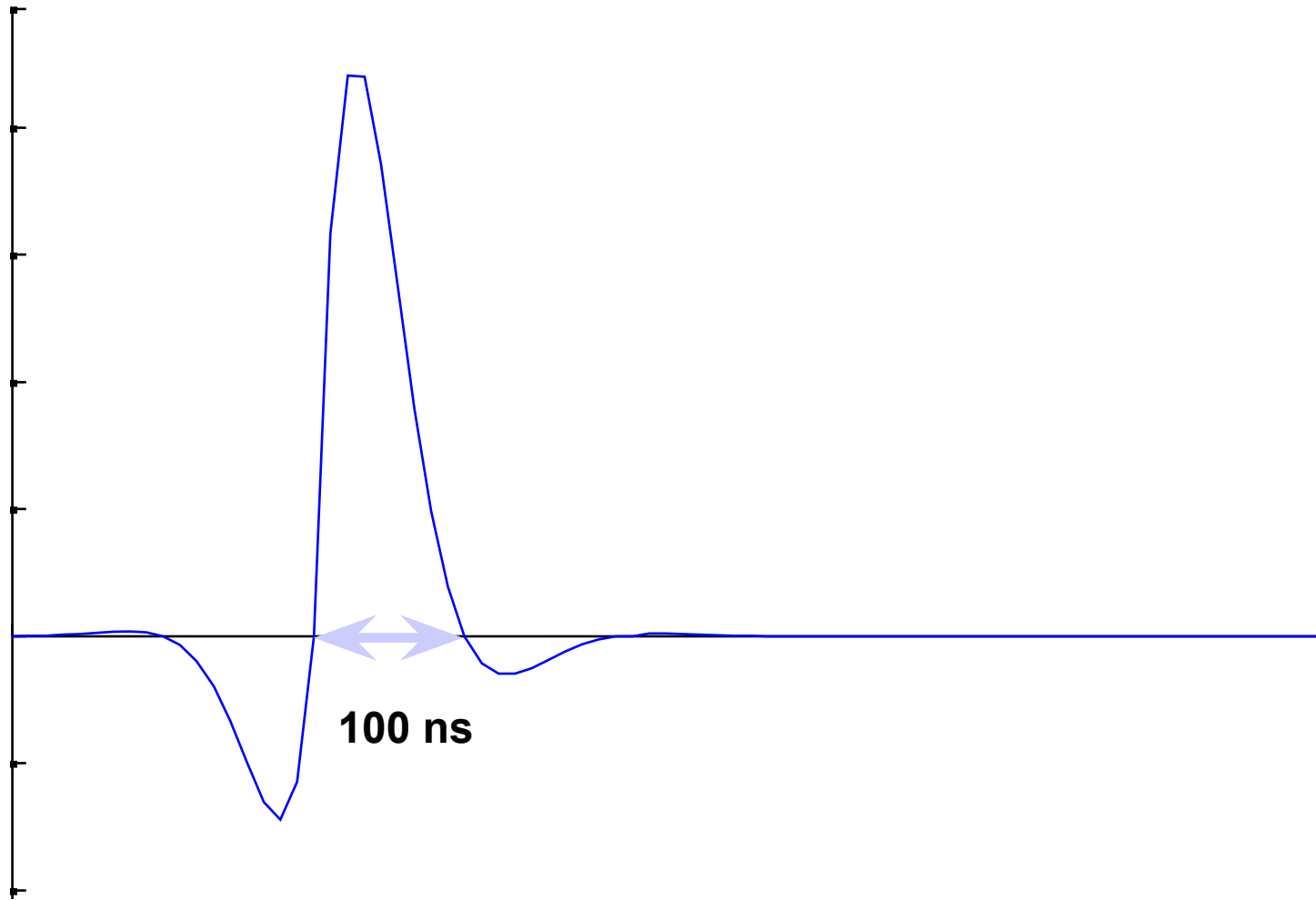
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Ultrasonic Probes



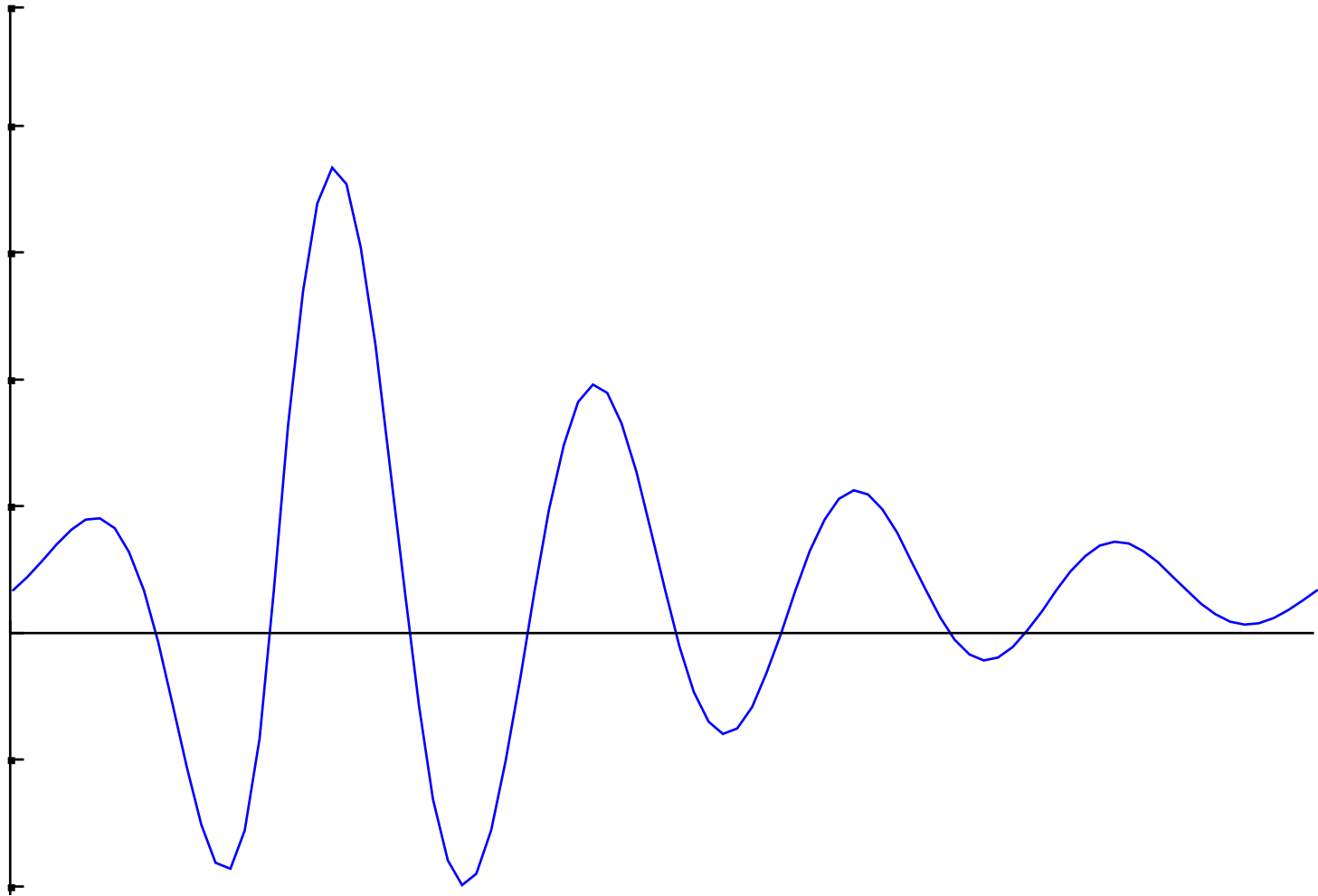
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RF signal (short)



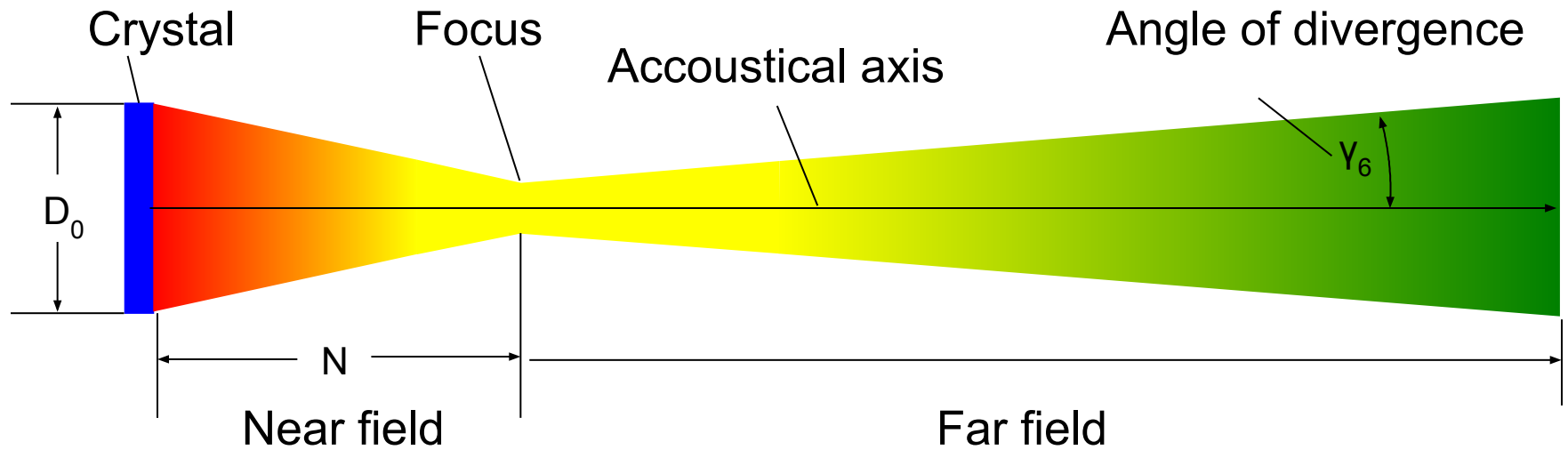
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RF signal (medium)



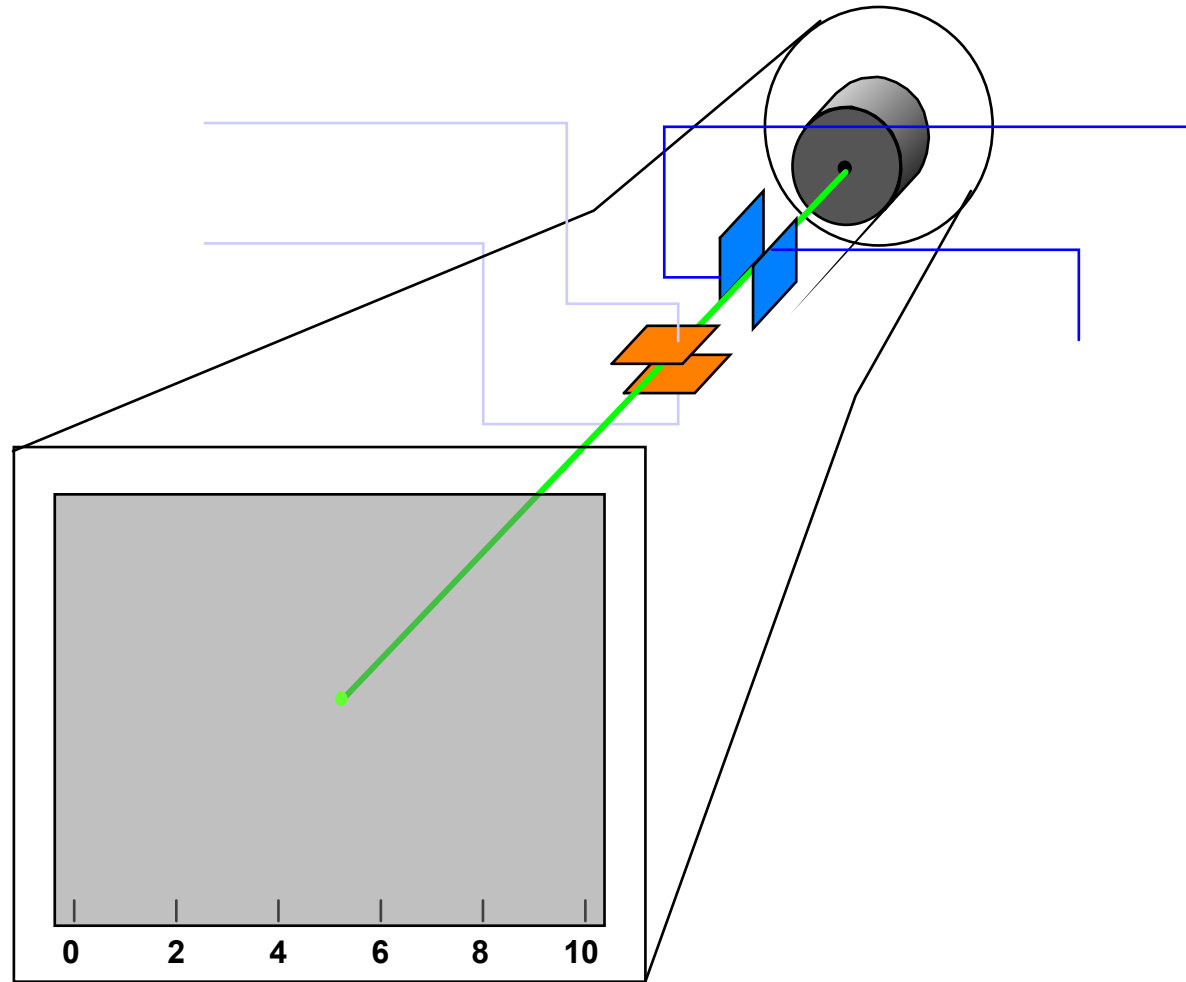
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Sound field



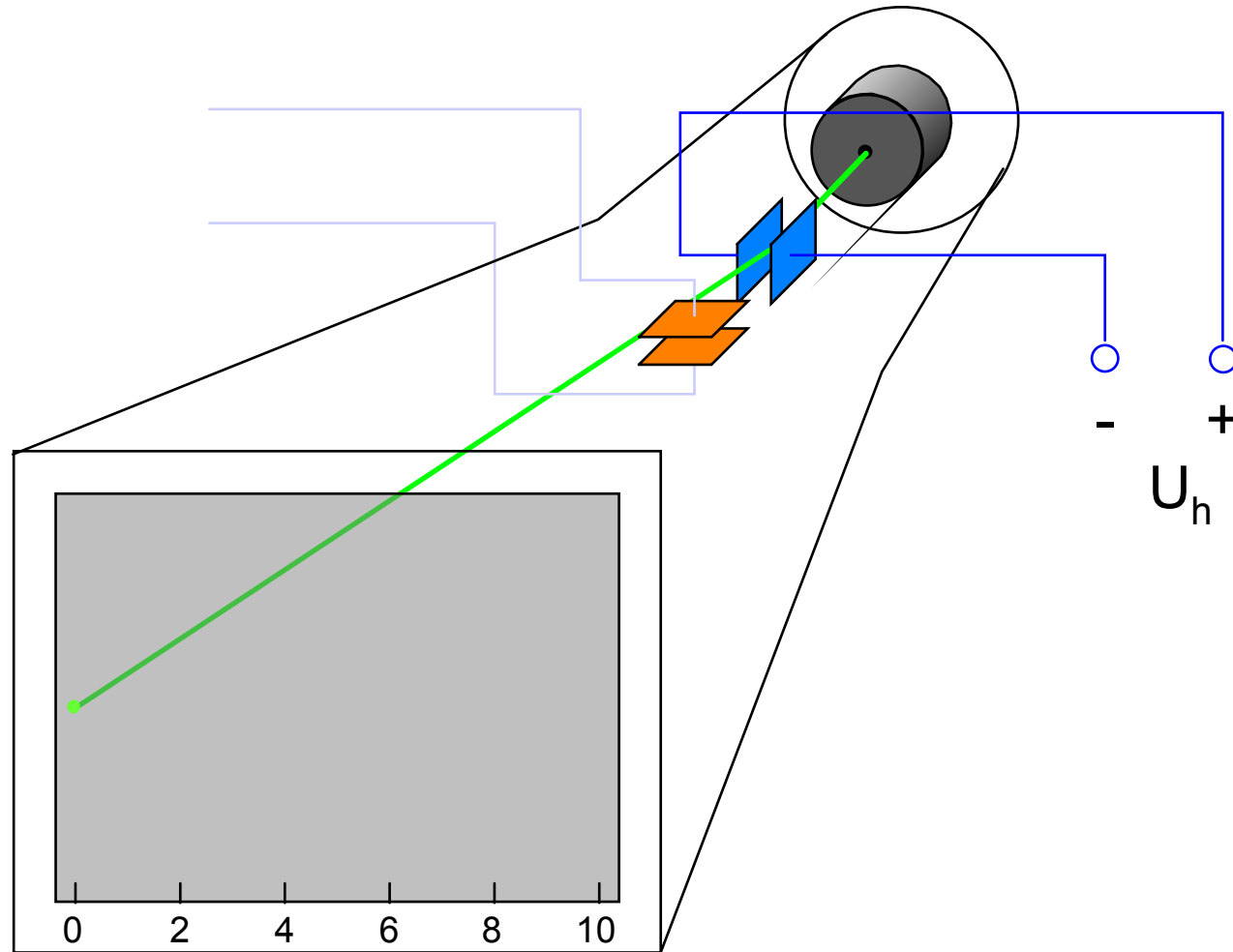
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Ultrasonic Instrument



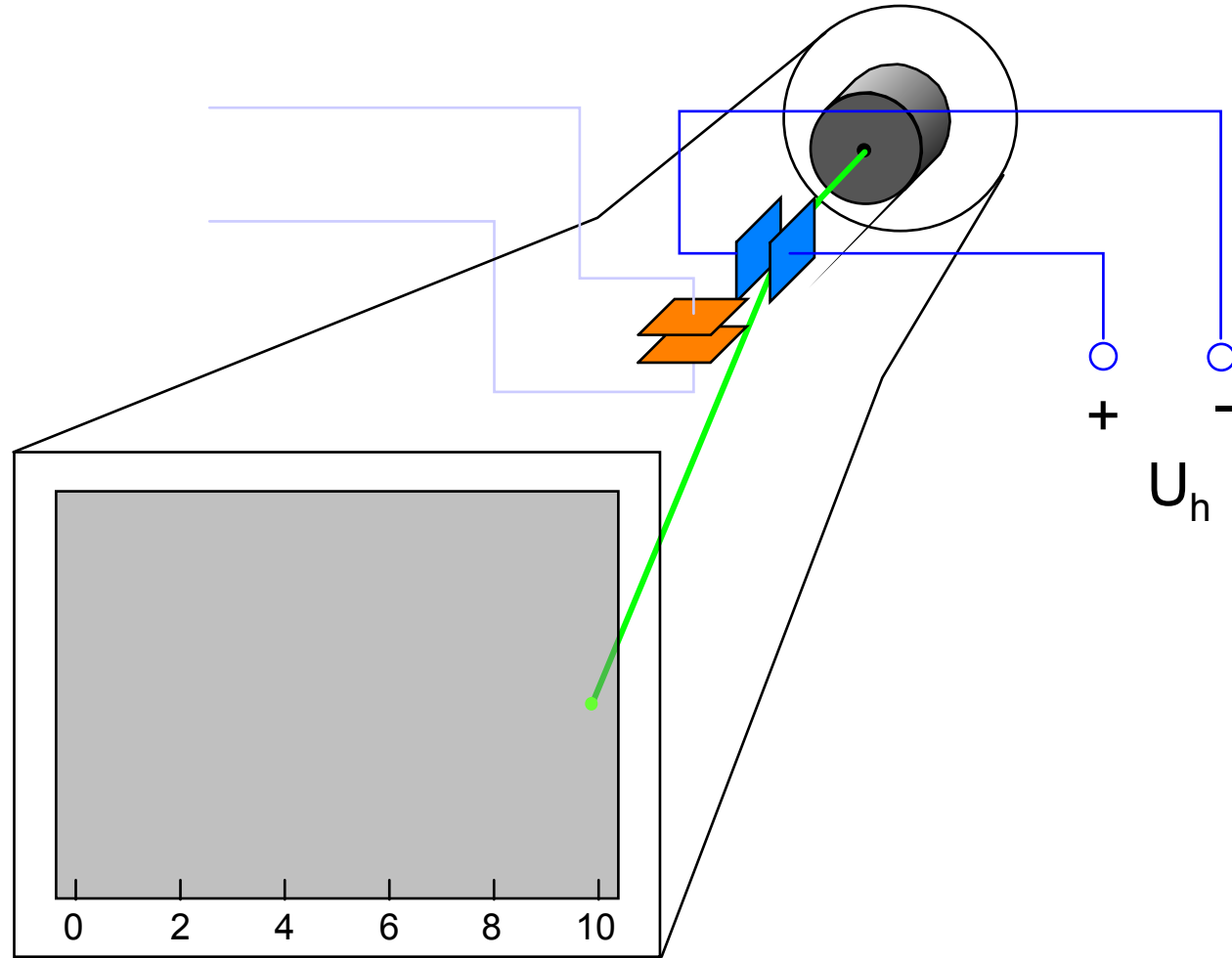
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Ultrasonic Instrument



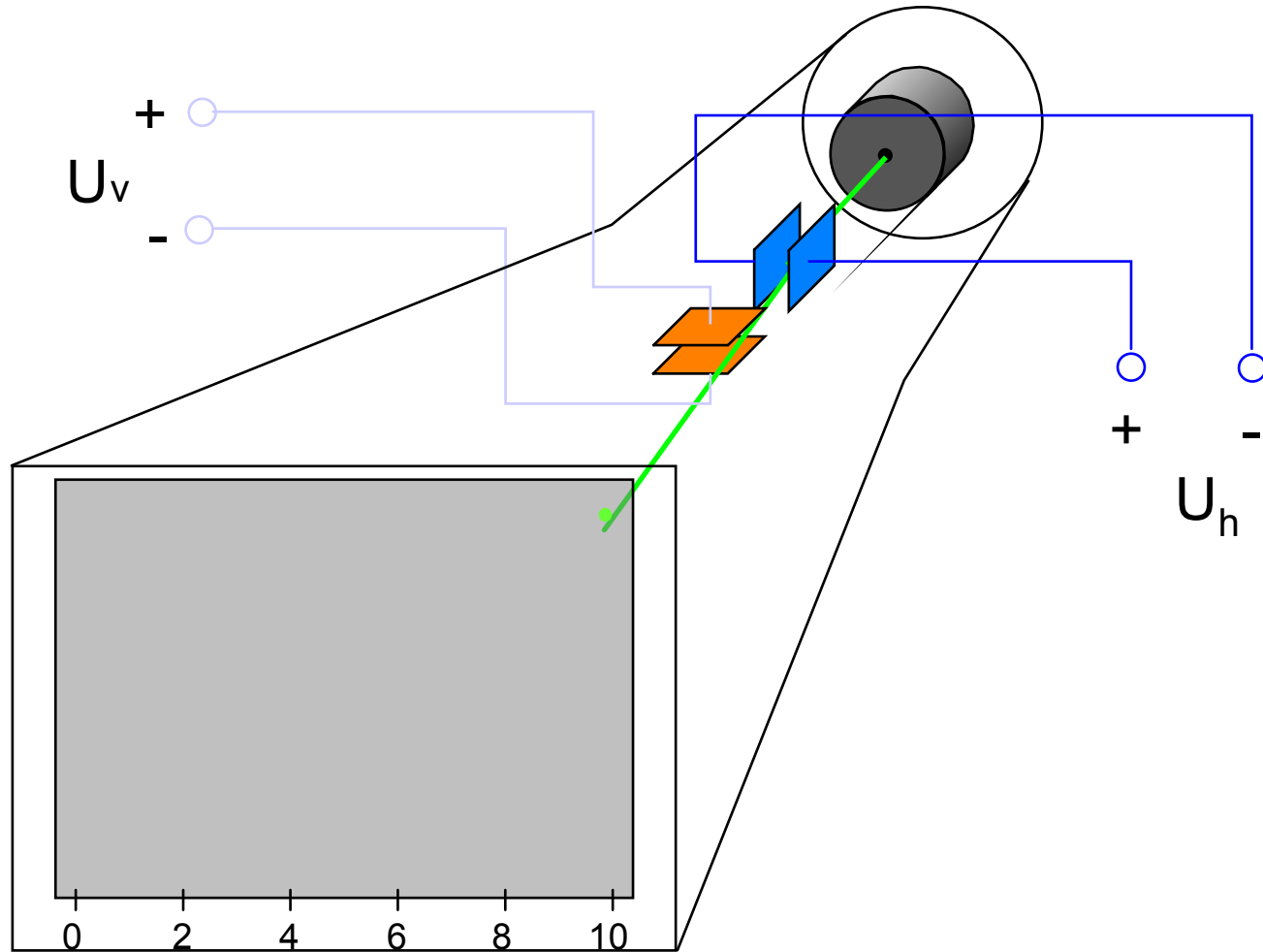
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Ultrasonic Instrument



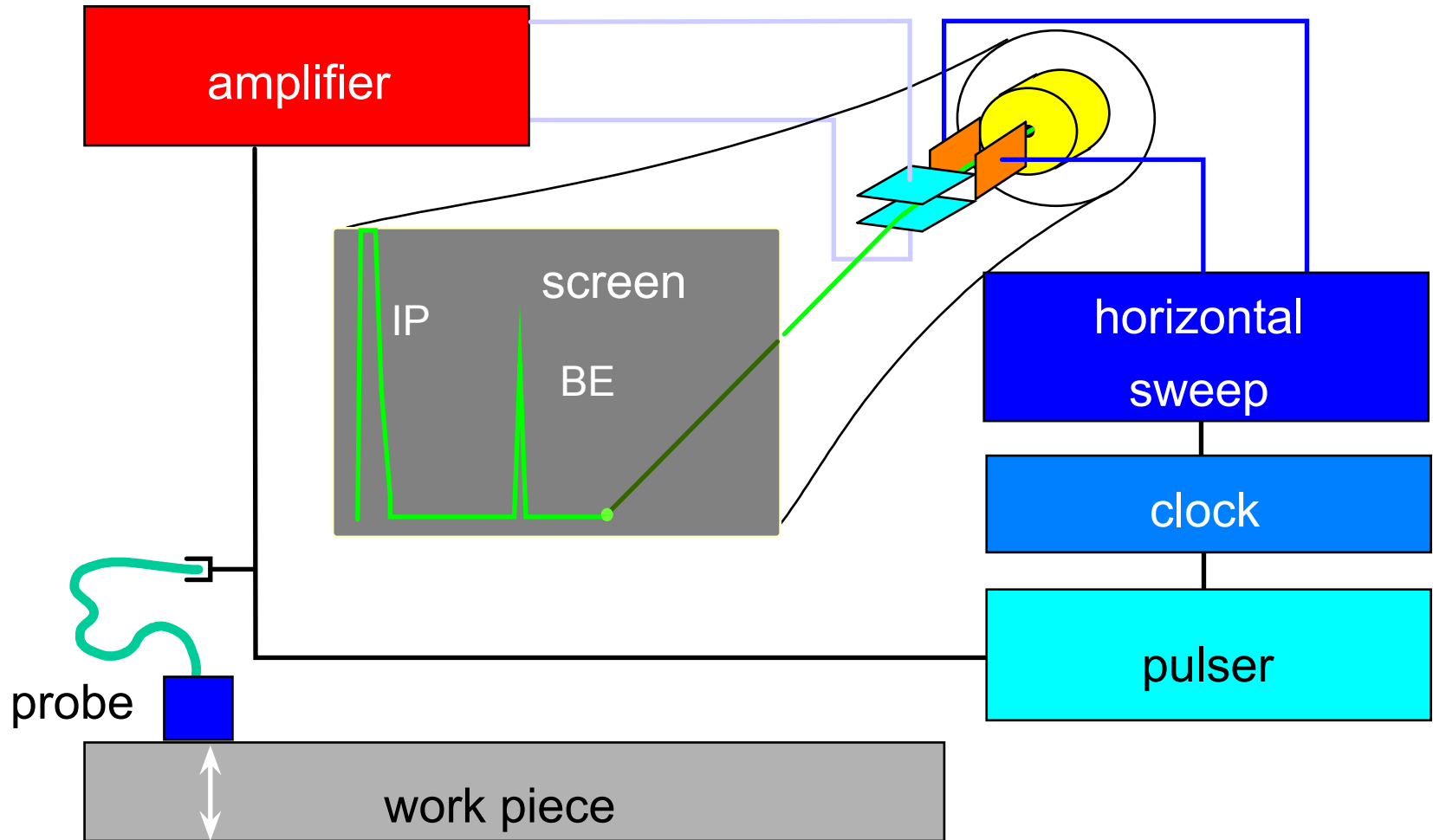
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Ultrasonic Instrument



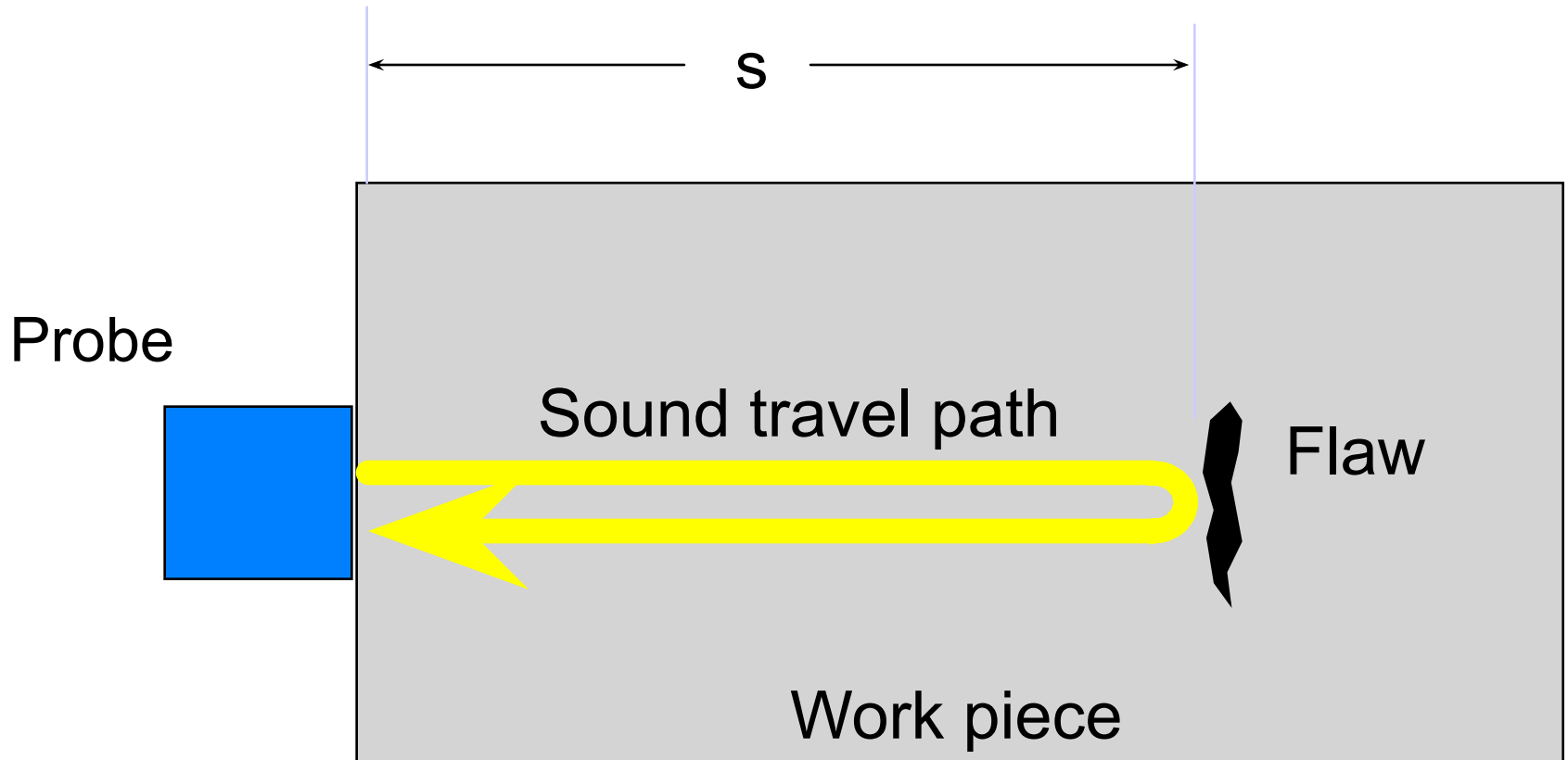
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Block diagram: Ultrasonic Instrument



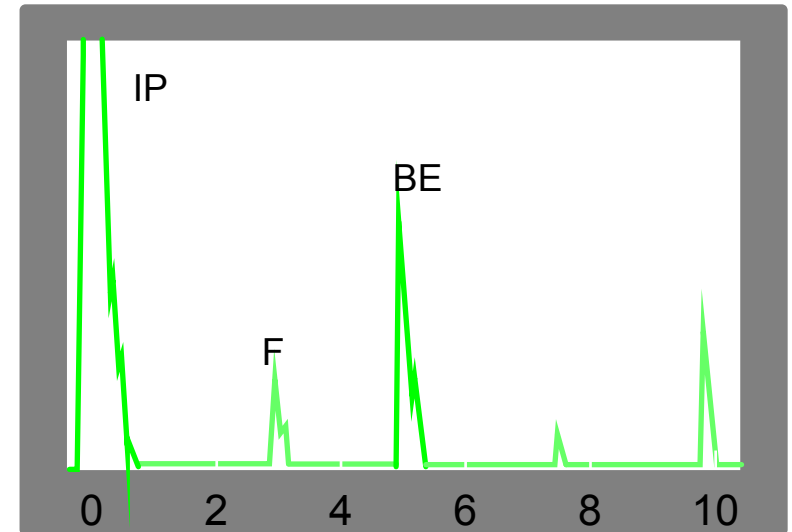
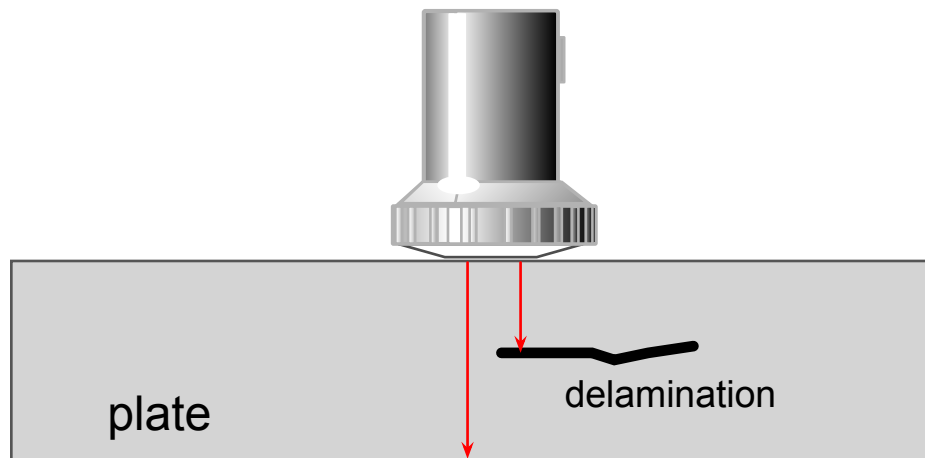
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Sound reflection at a flaw



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Plate testing



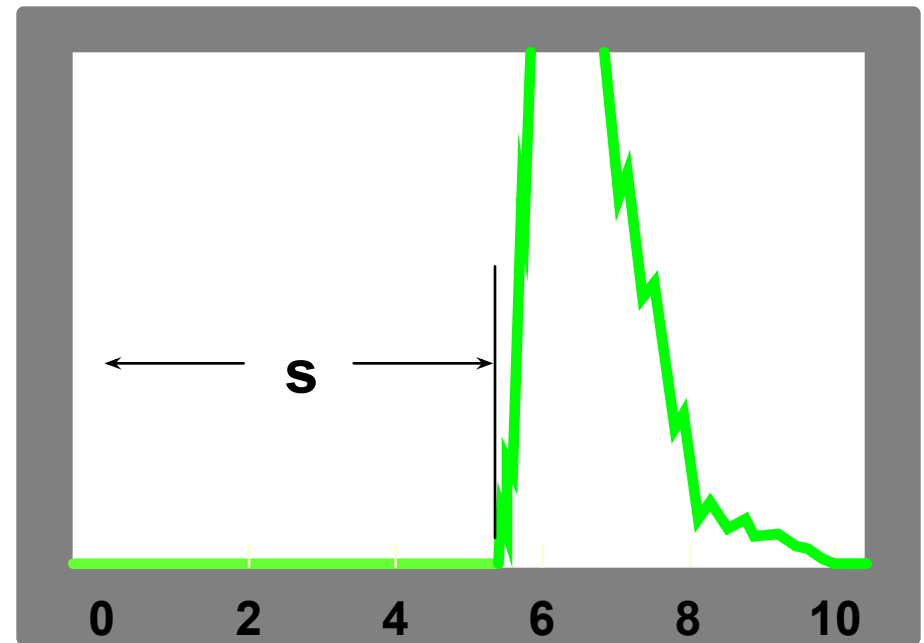
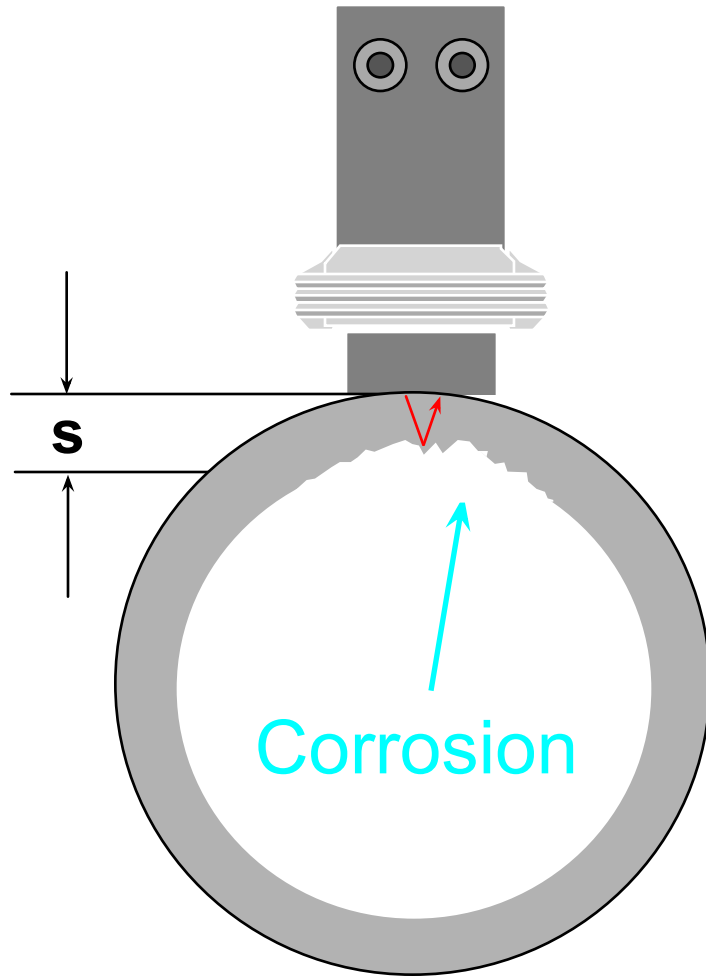
IP = Initial pulse

F = Flaw

BE = Backwall echo

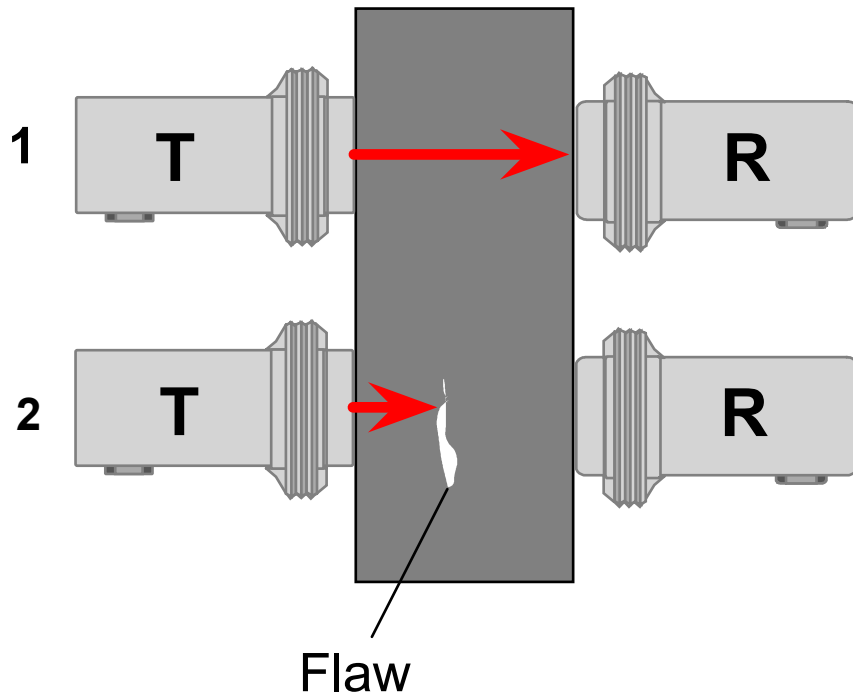
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Wall thickness measurement

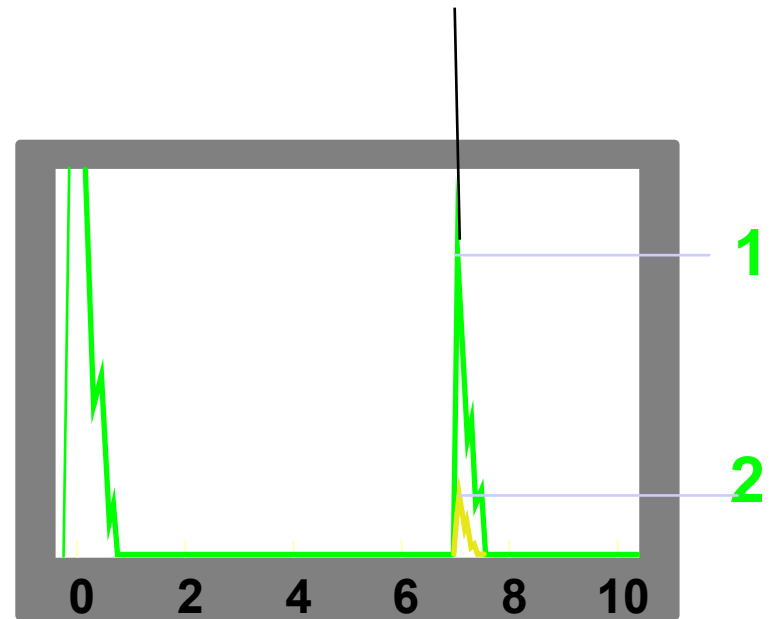


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Through transmission testing

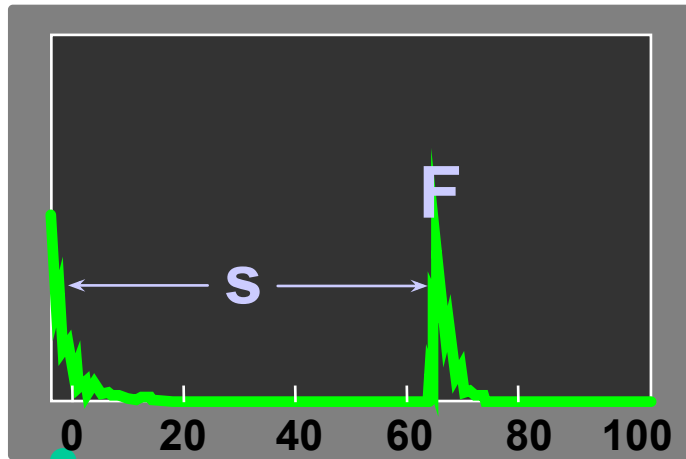


Through transmission signal



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Weld inspection



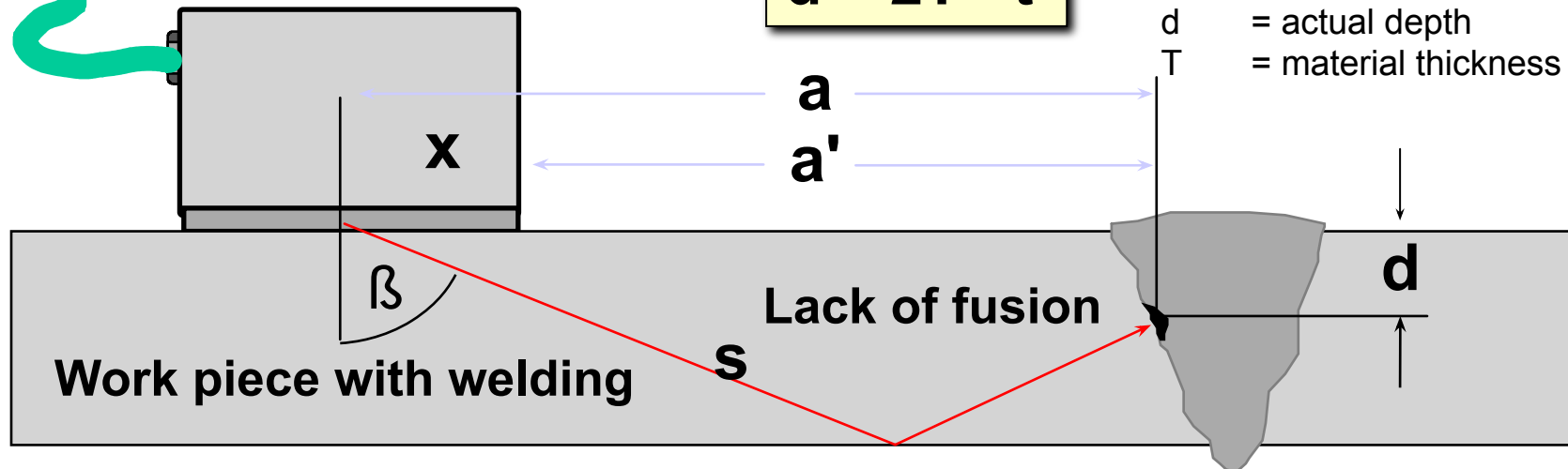
$$a = s \sin \beta$$

$$a' = a - x$$

$$d' = s \cos \beta$$

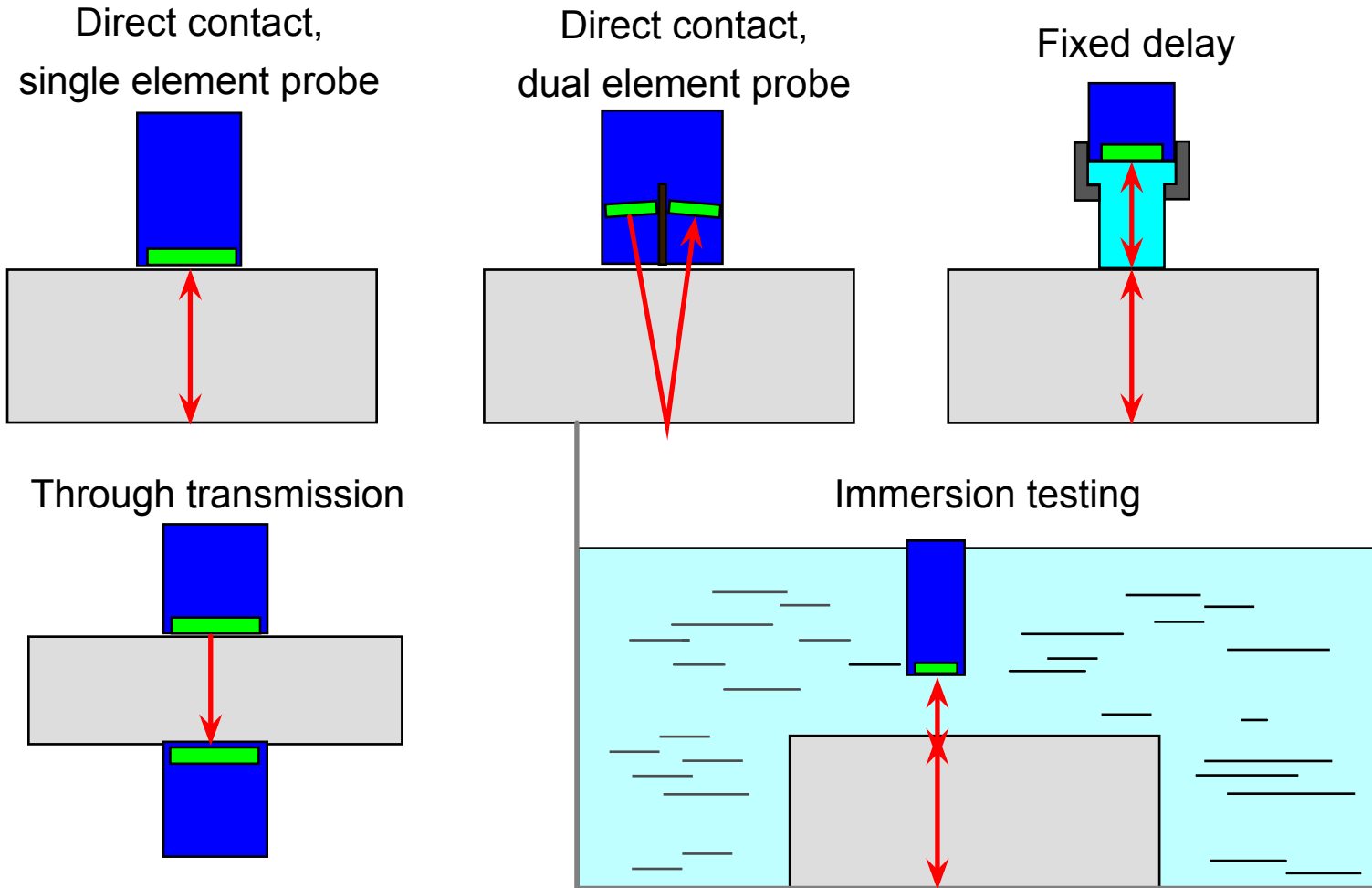
$$d = 2T - t'$$

- β = 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

