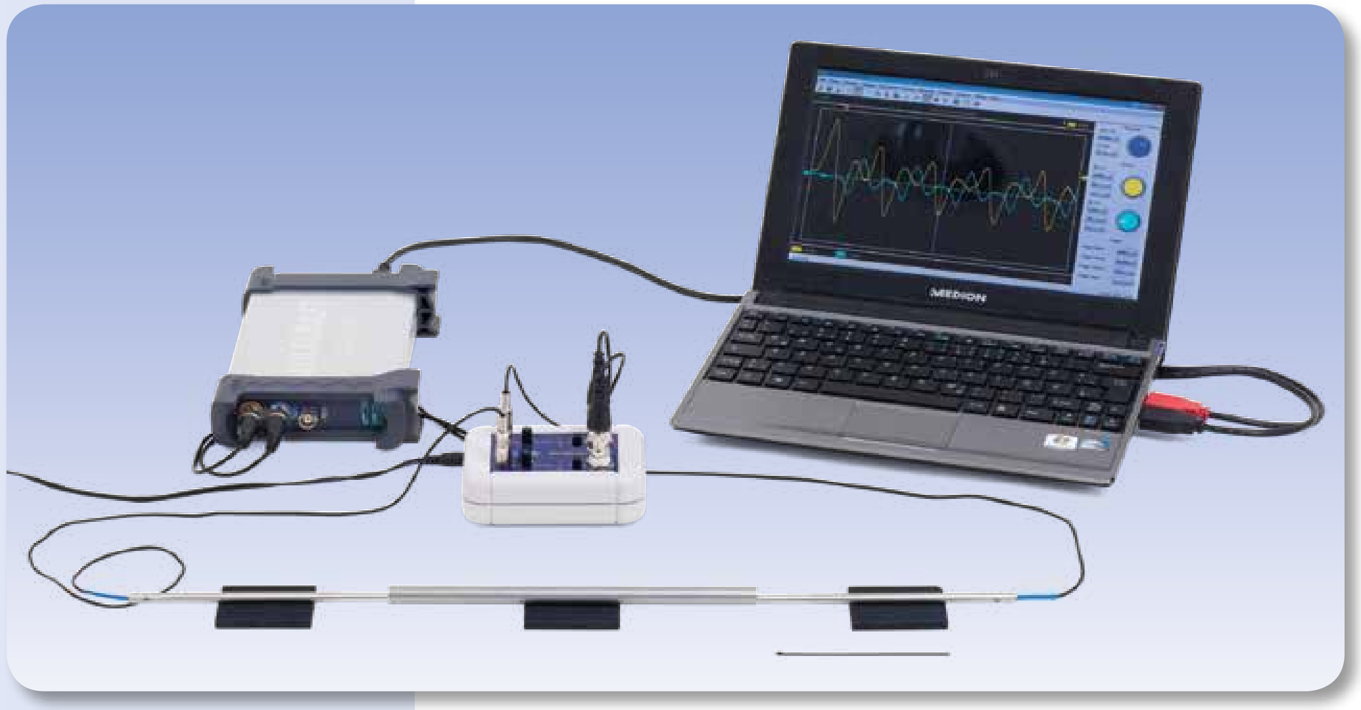
PROPAGATION OF SOUND IN RODS



EXPERIMENT PROCEDURE

- **Excite pulses of longitudinal sound waves in rods and use two microphone probes to detect them**
- **Analyse how the sound pulses are affected by the material and length of the rods by means of an oscilloscope**
- **Determine the speed of propagation of longitudinal sound waves in the materials from the time it takes the pulses to travel through them**
- **Determine the modulus of elasticity of the materials from the propagation velocity of longitudinal waves and their density**

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OBJECTIVE

Investigation of longitudinal sound waves in cylindrical rods and determination of propagation velocity for longitudinal sound waves

SUMMARY

Sound waves can propagate through solids in the form of longitudinal, transverse, dilatational or flexural waves. An elastic longitudinal wave propagates along a rod by means of a periodic sequence of expansion and contraction along the length of the rod. The speed of propagation depends only on the modulus of elasticity and the density of the material when the diameter of the rod is small in comparison to its length. In this experiment, it will be determined from the time it takes sound pulses to travel along the rod.

REQUIRED APPARATUS

Quantity	Description	Number
1	Sound Propagation in Rods Equipment Set (230 V, 50/60 Hz)	**1018469 or**
	Sound Propagation in Rods Equipment Set (115 V, 50/60 Hz)	**1018468**
1	USB Oscilloscope 2x50 MHz	**1017264**
2	Patch Cord BNC, 0.5 m	**5007670**

BASIC PRINCIPLES

Sound waves can not only propagate in gases or liquids, but also in solid bodies. Longitudinal, transverse, dilatational or flexural waves can all occur in solids.

An elastic longitudinal wave propagates along a rod by means of a periodic sequence of expansion and contraction along the length of the rod. The expansion is caused by atoms being excited out of their rest positions. In a rod where the diameter is much smaller than the length, the contraction in the transverse direction is negligible, i.e. Poisson $\mu = 0$ to a good approximation. In this case, the relationship between the changes in time and space of the compressive tension σ and the extension ξ is given by the following equations:

$$\frac{\partial\sigma}{\partial x} = \rho \cdot \frac{\partial v}{\partial t} \quad \text{and} \quad \frac{\partial v}{\partial x} = \frac{1}{E} \cdot \frac{\partial\sigma}{\partial t} \quad \text{where } v = \frac{\partial\xi}{\partial t}, \tag{1}$$

ρ: density of material of rod,
E: modulus of elasticity for material of rod

This results in the following wave equations:

$$\frac{\partial^2\sigma}{\partial t^2} = \frac{E}{\rho} \cdot \frac{\partial^2\sigma}{\partial x^2} \quad \text{and} \quad \frac{\partial^2 v}{\partial t^2} = \frac{E}{\rho} \cdot \frac{\partial^2 v}{\partial x^2} \tag{2}$$

The speed of propagation of longitudinal waves is

$$c_\mathrm{L} = \sqrt{\frac{E}{\rho}}. \tag{3}$$

In this experiment, longitudinal sound waves are excited in rods of various materials and lengths in the form of pulses. The pulses are then detected at the end of the rod being excited and at the other end by means of microphone sensors and displayed on an oscilloscope. The ends of the rod act as reflective surfaces for sound, such that the sound pulses reflect back and forth along the rods. The time it takes for pulses to travel from one end of the rod to the other is determined from the oscilloscope traces.
In long rods the multiply reflected sound pulses are clearly separated in time. In short rods, they could easily be superimposed and form "standing waves".

EVALUATION

The velocity of the longitudinal sound waves is determined from the time they take to travel the length of the rod and back by means of the following equation:

$$c_\mathrm{L} = \frac{2 \cdot L}{T}, \ L\text{: Length of rod} \tag{4}$$

This is because the sound pulse travels the length of the rod twice (to the other end and back) in a time T.
The modulus of elasticity for each of the materials is determined using equation (3) from the speed of propagation measured and the density of the rods, as determined by weighing them.

Table 1: Speed of longitudinal sound waves c_L in various materials of density ρ and modulus of elasticity E.

Material	c_L (m / s)	ρ (g / cm³)	E (m / s)
Glass	5370	2.53	73
Aluminium	5110	2.79	73
Wood (beech)	5040	0.74	19
Stainless steel	4930	7.82	190
Copper	3610	8.84	115
Brass	3550	8.42	106
Transparent acrylic (perspex)	2170	1.23	6
PVC	1680	1.50	4

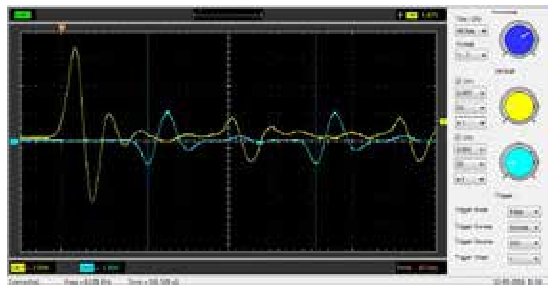

Fig. 1: Propagation of a sound pulse, signal at the excited end of the rod (yellow), (stainless steel rod, 400 mm)

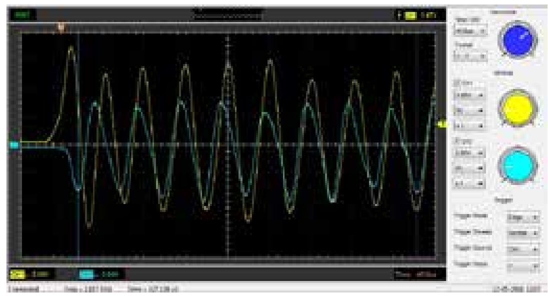

Fig. 2: Standing wave, signal at the excited end of the rod (yellow), (stainless steel rod, 100 mm)

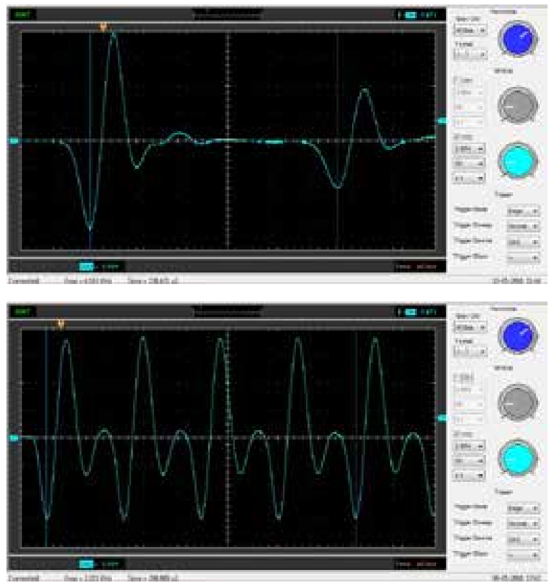

Fig. 3: Propagation of a sound pulse (top: PVC rod, 200 mm, bottom: glass rod, 200 mm), signal at the opposite end of the rod from the excitation (cyan)

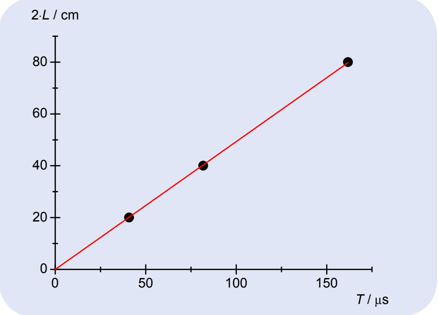

Fig. 4: Twice the length of the rods 2·L as a function of the time of travel T for stainless steel rods.