## Reflection of planar ultrasonic waves at a plane surface

### Objects of the experiment

- Measuring the reflected intensity at a fixed angle of incidence as a function of the angular position of the receiver.
- Determining the angle of reflection.
- Confirming the relationship “angle of incidence = angle of reflection”.

### Principles

The aim of this experiment is to prove that the law of reflection “angle of incidence = angle of reflection” also applies for ultrasonic waves. The angle of reflection is defined as the angle between the perpendicular (with respect to the reflecting surface) and the maximum reflected intensity (see Fig. 1).

Two ultrasonic transducers – flexural resonators – serve as the transmitter and receiver, depending on their connection. A piezoelectric body converts electrical to mechanical energy.

When the AC voltage is applied to the piezoelectric body, the transducer configured as a transmitter supplies a sufficiently high sound amplitude at two different resonance frequencies (approx. 40 kHz and 48 kHz). Conversely, sound waves generate mechanical oscillations in the transducer when configured as a receiver. The amplitude of the resulting piezoelectric AC voltage is proportional to the sonic amplitude.

The first transducer, which can be considered as a point-type ultrasonic source, is placed in the focal point of a concave reflector so that a planar wave is formed. The signal of the second transducer, the receiver, is fed to an oscilloscope via an AC amplifier. The square of the amplitude of this signal serves as a measure of the reflected intensity.

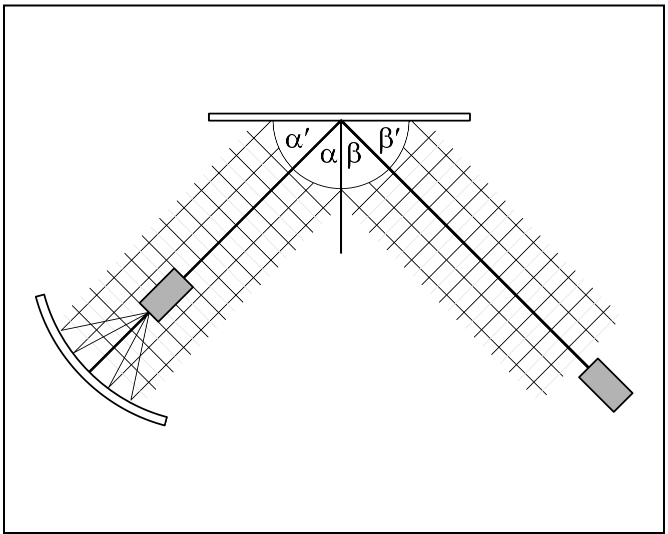


Fig. 1 Reflection of planar ultrasonic waves at a plane surface
$\alpha$ = angle of incidence
$\beta$ = angle of reflection

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## Apparatus

| | |
|---|---|
| 2 Ultrasonic transducers, 40 kHz | 416 000 |
| 1 Generator 40 kHz | 416 012 |
| 1 AC amplifier | 416 010 |
| 1 Concave mirror | 389 241 |
| 1 Sensor holder for concave mirror | 416 020 |
| 1 Two-channel oscilloscope 303 | 575 211 |
| 1 Screened cable BNC/4 mm | 575 24 |
| 2 Optical benches with short lateral bracket | 460 43 |
| 1 Swivel joint with angle scale | 460 40 |
| 1 Reflection plate | 578 66 |
| 1 Large stand base, V-shape | 300 01 |
| 2 Small stand bases, V-shape | 300 02 |
| 1 Stand rod, 50 cm, 10 mm dia. | 301 27 |
| 1 Stand rod, 25 cm, 12 mm dia. | 300 41 |
| 1 Stand rod, 10 cm, 12 mm dia. | 300 40 |
| 1 Universal bosshead | 666 615 |
| 2 Leybold multiclamps | 301 01 |
| 1 Bull's eye Spirit level, | 361 051 |
| 1 Steel tape measure, 2 m | 311 17 |

## Setup

Set up the experiment as shown in Fig. 2.

**First:**

- Mount the two optical benches **(a), (b)** on the small stand bases and connect them to the angle scale with the swivel joint **(c)**.
- Slide the stand rod (301 27) through the swivel joint **(c)** (do not fix it in place) and attach it to the large stand base.
- Carefully align the optical benches horizontally; check the alignment with the spirit level.
- Mount the reflection plate on the stand rod.
- Place the assembly consisting of the concave mirror, the sensor holder and the first ultrasonic transducer **(d)** on optical bench **(a)**.
- Attach the second ultrasonic transducer **(e)** to optical bench **(b)** and adjust it to the same height as the first ultrasonic transducer.
- Connect ultrasonic transducer **(d)** to the generator, and set the generator to continuous operation.
- Connect ultrasonic transducer **(e)** to the oscilloscope via the AC amplifier.

**Adjustment:**

- Set up the assembly so that $\alpha + \beta = 180°$ (see Fig. 1).
- Use the tape measure to align the reflection plate as nearly parallel as possible to the optical bench.
- Reduce the gain of the AC amplifier to minimum and observe the receiver signal on the oscilloscope.
- Adjust the frequency of the generator so that the receiver signal reaches the maximum amplitude.

If the signal is not sinusoidal, i.e. the gain is overdriven:

- Vary the frequency on the generator so that the operating frequency of the transmitter is slightly different from the resonance frequency.

**Fine adjustment:**

- Adjust the receiver so that it is exactly opposite the transmitter (maximum voltage amplitude of receiver signal).
- Set the transmitter arm to 45°, swivel the receiver arm and measure the voltage amplitude of the receiver signal as a function of the angle of the receiver arm.

If the voltage amplitude shows appreciable secondary maxima in addition to a maximum at approx. 45°:

- Check the adjustment of the ultrasonic transducer.

## Carrying out the experiment

**Part 1:**

- Set a fixed angle $\alpha = 45°$ (see Fig. 1).
- Vary angle $\beta'$ from 30° to 60° in steps of 1° and measure the voltage amplitude of the receiver signal.
- Write down each value $\beta = 90° - \beta'$ and the respective voltage amplitude in your experiment log.

**Part 2:**
**Confirming the law of reflection**

- Set an angle $\alpha' = 80°$.
- To determine the angle of reflection $\beta$, vary the angle $\beta'$ until you find the maximum voltage reading.
- Write down the angle of incidence $\alpha = 90° - \alpha'$ and the angle of reflection $\beta = 90° - \beta'$ in your experiment log.
- Set the next value for $\alpha'$ (Table 2).
- Determine the angle of reflection $\beta$.

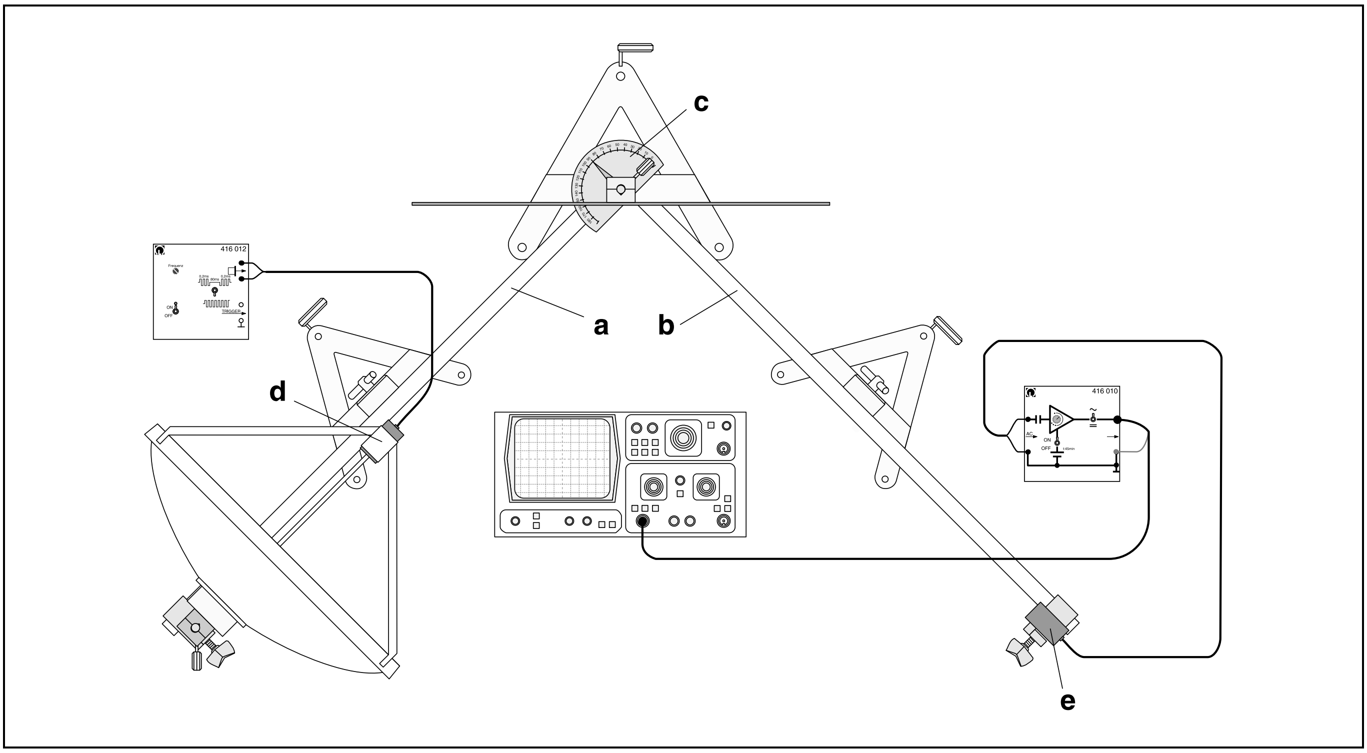


Fig. 2 Experiment setup for reflection of ultrasonic waves, top view

**Measuring example**

Table 1: Voltage amplitude $U$ of the receiver signal at $\alpha = 45°$ as a function of $\beta$.

| $\beta$ | $\frac{U}{V}$ |
|---|---|
| 30° | 0 |
| 31° | 0 |
| 32° | 0 |
| 33° | 0.05 |
| 34° | 0.12 |
| 35° | 0.12 |
| 36° | 0.1 |
| 37° | 0.1 |
| 38° | 0.3 |
| 39° | 0.4 |
| 40° | 0.5 |
| 41° | 0.9 |
| 42° | 1.25 |
| 43° | 1.95 |
| 44° | 2.15 |
| 45° | 2.3 |
| 46° | 2.1 |
| 47° | 1.75 |
| 48° | 1.25 |
| 49° | 0.8 |
| 50° | 0.45 |
| 51° | 0.4 |
| 52° | 0.5 |
| 53° | 0.5 |
| 54° | 0.5 |
| 55° | 0.5 |
| 56° | 0.25 |
| 57° | 0 |
| 58° | 0 |
| 59° | 0 |
| 60° | 0 |

Table 2: Angle of reflection $\beta$ as a function of the angle of incidence $\alpha$.

| $\alpha = 90° - \alpha'$ | $\beta = 90° - \beta'$ |
|---|---|
| 10° | 10° |
| 20° | 20° |
| 30° | 30.5° |
| 40° | 39.5° |
| 45° | 44.5° |
| 50° | 49° |
| 60° | 58° |
| 70° | 68.5° |
| 80° | 78.5° |

## Evaluation and results

Fig. 3 shows the graph of the reflected intensity as a function of angle $\beta$ for a fixed angle $\alpha = 45°$. The intensity is greatest at the angle of reflection $\beta = 45°$. At about 3° above and below the angle of reflection, the intensity diminishes by half, i. e. the half-value width of the intensity distribution is approx. 6°.

Fig. 4 confirms the law of reflection, “angle of incidence $\alpha$ = angle of reflection $\beta$”. Within the limits of measuring accuracy, the measured values for $\alpha$ and $\beta$ all lie on a straight line through the origin having a slope of one.

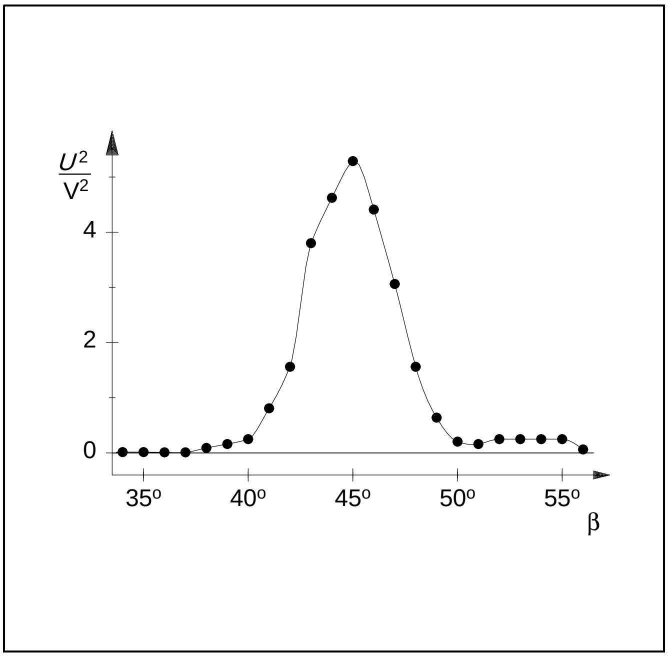


Fig. 3 Square of the voltage amplitude $U$ at the receiver as a function of angle β

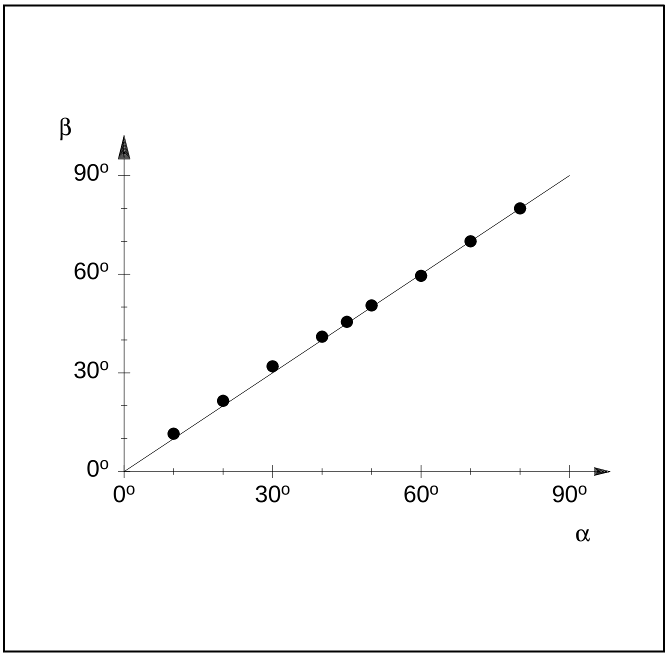


Fig. 4 Angle of reflection β as a function of the angle of incidence α