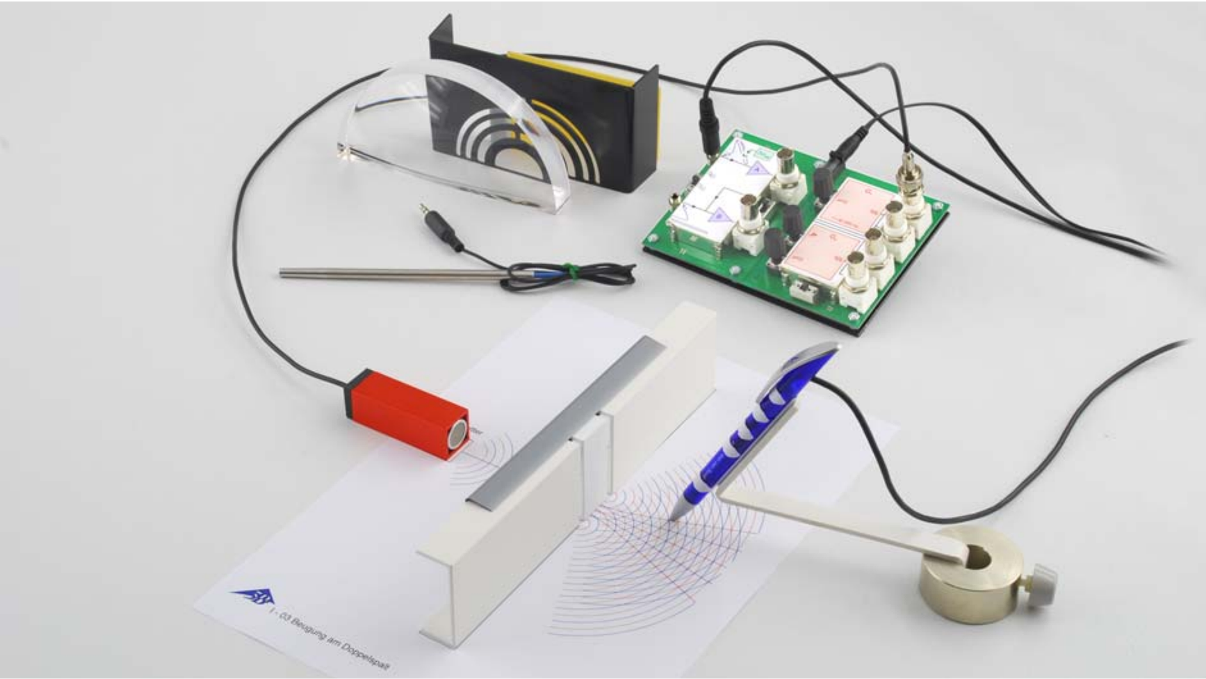
3B SCIENTIFIC® PHYSICS

...going one step further

SW Set - Ultrasonics (230 V, 50/60 Hz) 1012845
SW Set - Ultrasonics (115 V, 50/60 Hz) 1012846

Instruction manual

08/12 TL



1. Description

The SW set for ultrasonics is designed to demonstrate the fundamental properties of waves in the form of a space-saving table-top set-up, using 40-kHz ultrasonic waves as an example.

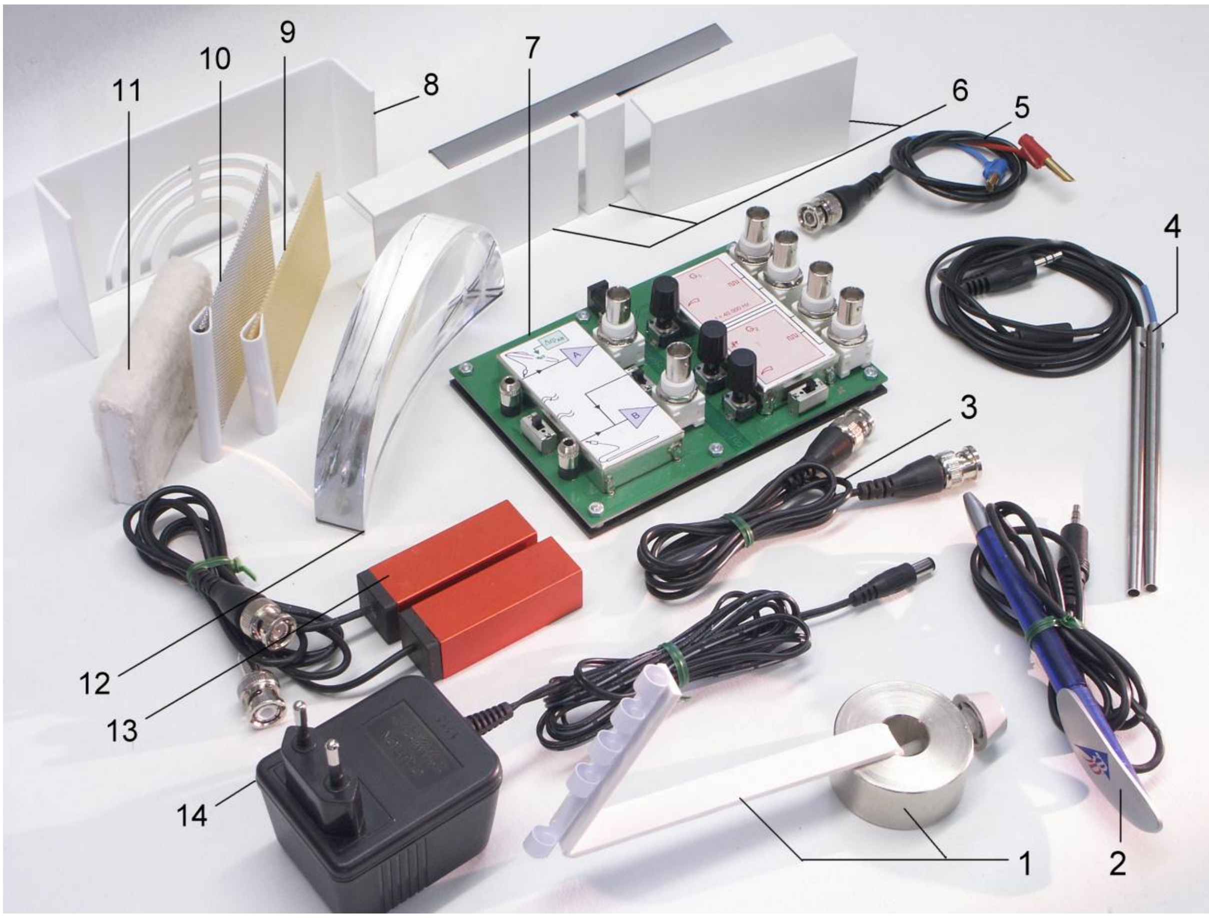
The sound is propagated along the surface of the table, to a good approximation. Diffraction objects, plane and convex mirrors etc. are therefore designed to be set up in the plane above the table top. This facilitates setting up easily understood experiments using work templates and overlays.

Suitable probes make it possible to record oscillations at any point of the wave and to measure the field of sound after reflection, wave diffraction and interference. One of these probes, the ultrasonic pen, also features a phase indicator in the form of an LED, the brightness of which is reduced to a minimum when the phase difference between the point where the measurement is being made and a selected reference point is a multiple of 360°. The ultrasonic pen can thus be used to record wave fronts as lines of similar phase, for example (isophases).

For some advanced experiments it is recommended that a multimeter with a suitable frequency response be used to measure the amplitude of ultrasonic waves. Connecting a dual-channel oscilloscope allows the ultrasonic oscillations at the location of the probe to be displayed.

The equipment set with the order no. 1012845 is designed for mains voltage of 230 V (±10%), while set no. 1012846 is for 115 V (±10%).

2. Equipment supplied



1 Holder for ultrasonic pen
2 Ultrasonic pen
3 BNC cable, 1 m (2x)
4 Microphone probes (2x)
5 BNC/4-mm cable
6 Set for double slit
including 2 mirrors/reflectors
7 Electronics board
8 Fresnel zone plate
9 Semi-transparent mirror, 50%
10 Semi-transparent mirror, 25%
11 Ultrasonic absorber
12 Convex mirror
13 Ultrasonic transmitter, 40 kHz (2x)
14 Plug-in power supply (230 V, 50/60 Hz)
or
Plug-in power supply (115 V, 50/60 Hz) not shown
Set of templates not shown

3. Electrical safety

The SW ultrasonics set conforms to safety regulations for electrical measurement, control and laboratory equipment as specified in DIN EN 61010 part 1. It is designed for operation in dry rooms suitable for electrical equipment.

Safe operation of the system is guaranteed if used as stipulated. Safety cannot, however, be assured if the equipment is treated incorrectly or carelessly.

4. CE compliance

The SW ultrasonics set (electronics board, ultrasonic pen and microphone probe) conform to European guidelines for electromagnetic compatibility (EC 108/2004) and are therefore CE compliant.

5.1 Electronics board

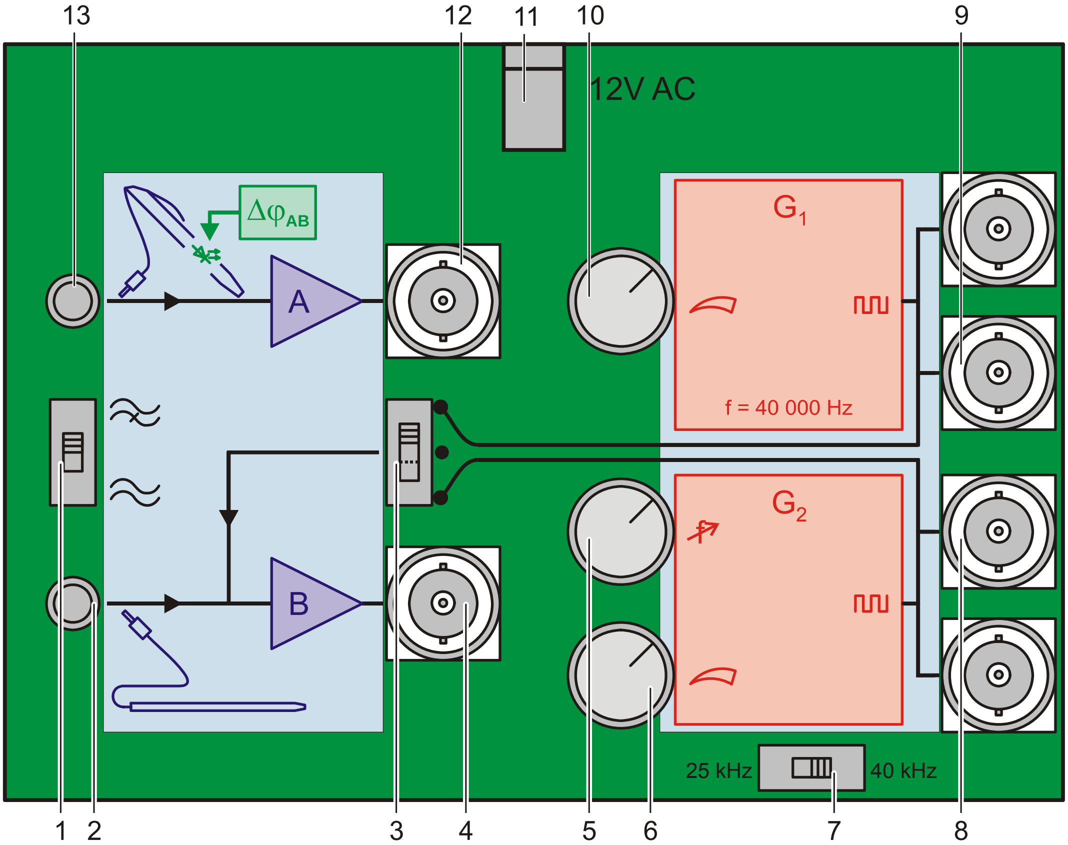


Fig. 1 Electronics board

1 Switch S1
2 Input for channel B
3 Switch S2
4 Output for channel B
5 Frequency trimmer for generator G2
6 Amplitude trimmer for generator G2
7 Switch S3
8 Outputs for generator G2
9 Outputs for generator G1
10 Amplitude trimmer for generator G1
11 Co-axial connector for plug-in power supply
12 Output for channel A
13 Input for channel A

The electronics board for operating the equipment provides the power feed for the ultrasonic transmitter and amplification for signals from the microphone probes or ultrasonic pen, as well as handling control of the phase indicator in the ultrasonic pen.

The electronics board consists of a generator block in two parts and a two-channel amplifier block, which also includes a functional unit for comparing phase between the two channels.

The AC voltages for the ultrasonic transmitter are produced in the generator block. Generator G1 is stabilised to 40.000 kHz by a quartz oscillator, while G2 can be switched between frequencies of 25 and 40 kHz, which can also be varied by about ±0.5%. Both generators are equipped with an amplitude trimmer and two output sockets connected in parallel.

In the amplifier block, the voltages from the ultrasonic probes are amplified and output to the BNC sockets. It is possible to connect a high-pass filter into the circuit for both channels, in order to filter out low-frequency components of the sound.

After the input amplifiers there is a functional block which compares the signals from channels

A and B and converts the results into a DC current proportional to the phase difference. This current is then fed via the input socket of channel A to the ultrasonic pen. If the phase difference is a multiple of 360°, the brightness of the LED on the pen will be reduced to a minimum.

Generator G1:

Frequency:	40.000 kHz, stabilised by quartz oscillator
Amplitude:	Adjustable
Output:	2 BNC sockets, connected in parallel

Generator G2:

Frequency range 1:	38 … 42 kHz approx.
Frequency range 2:	24 … 26 kHz approx.
Frequency ranges:	Switchable
Amplitude:	Adjustable
Output:	2 BNC sockets, connected in parallel

Amplifiers (channels A and B):

Input resistance:	10 kΩ
Bias:	8 V
Gain	100 approx.
Output resistance:	1 kΩ
Frequency range:	2 kHz … 43 kHz (± 3 dB) with high-pass filter 2 Hz … 43 kHz (± 3 dB) without high-pass filter
Inputs:	Jack sockets
Outputs:	BNC sockets

Phase comparison between A and B:

Control current for ultrasonic pen:	0 …15 mA (DC)
Coupling with B:	Generator signal G1, Generator signal G2 or off

General data:

Power supply:	12 V AC, 500 mA from plug-in transformer
Dimensions:	100x140x45 mm approx.
Weight:	530 g approx. including plug-in power supply

Plug-in power supply for 1012845:

Primary side:	230 V, 50/60 Hz
Secondary side:	12 V AC; 750 mA

Plug-in power supply for 1012846:

Primary side:	115 V, 50/60 Hz
Secondary side:	12 V AC; 500 mA

5.2 Ultrasonic transmitter, 40 kHz

Ultrasonic transmitter for setting up on a table top with an ultrasonic transducer located flush with the exit opening inside a square aluminium tube. Gently curved resonance characteristic for operation in frequency range 1 of Generator G2 or at a frequency of 40.000 kHz.

Note: Frequency range 2 on the ultrasonic electronics board can only be output using a separate ultrasonic transducer which is not included in the SW ultrasonics set.

Input voltage:	20 V AC RMS/ 70 Vpp max.
Impedance:	> 500 Ω
Acoustic pressure:	110 dB at 10 V
Band width:	> 7 kHz/-90 dB
Frequency:	40 kHz (±1 kHz)
Connectors:	BNC plugs
Dimensions:	20 x 20 x 60 mm approx.
Cable length:	1 m approx.

5.3 Microphone probe

Warning: The transducer in the microphone probe is sensitive to moisture and mechanical effects.

- Do not subject the transducer to any mechanical stresses and do not let it come into contact with liquids.

Microphone probe for setting up on a table top with transducer positioned flush with the entry opening in a thin metal tube.

Frequency range:	1 Hz to 43 kHz
Output:	Signal for channel A or B
Connectors:	3.5-mm jack plugs (tip)
Cable length:	1 m approx.
Dimensions:	6 mm x 150 mm approx.
Weight:	25 g approx.

5.4 Ultrasonic pen (including holder)

Warning: The transducer in the ultrasonic pen is sensitive to moisture and mechanical effects.

- Do not subject the transducer to any mechanical stresses and do not let it come into contact with liquids.

Ultrasonic probe with built-in transducer and additional phase indicator in the form of an LED, controlled by a current generated by the electronics board from the signal voltages of channels A and B. The brightness of the LED is reduced to a minimum when the phase difference between the point where the measurement is being made and a selected reference point is a multiple of 360°.

The equipment can be held and moved by hand or, in order to avoid interference from reflections, in the supplied holder.

Phase indicator input (from channel A only):	0 … 15 mA (DC)
Frequency range:	1 Hz to 43 kHz
Output:	Signal for channel A or B
Connectors:	3.5-mm jack plugs, input: ring output: tip
Cable length:	1 m approx.
Dimensions:	10 mm x 150 mm approx.
Weight:	32 g approx. without holder

5.5 Convex mirror

Transparent plastic convex mirror designed for the space above a table top.

Focal length:	100 mm
Radius of curvature:	200 mm
Dimensions:	140 x 20 x 70 mm approx.

5.6 Fresnel zone plate

Plastic Fresnel zone plate designed for the space above a table top.

Focal length:	35 mm
Dimensions:	140 x 20 x 50 mm approx.

5.7 Ultrasonic absorber

Component for demonstrating sound insulation or for suppressing sound travelling directly from transmitter to microphone probe in some experiments.

Surface:	Fleece textile
Dimensions:	80 x 15 x 50 mm approx.

5.8 Set for double slit

Set of equipment for setting up a double or single slit or for use as individual reflectors or mirrors.

Surface:	Plastic coated
Dimensions:	100 x 20 x 50 mm approx. or 20 x 20 x 50 mm approx.

5.9 Semi-transparent mirror (50%) and Semi-transparent mirror (25%)

Partially transparent and partially reflecting mirrors made of perforated plastic (50%) or expanded aluminium (25%).

Dimensions:	100 x 20 x 60 mm approx.

5.10 BNC cable

For connecting amplifier outputs to an oscilloscope.

Cable length:	1 m approx.

5.11 BNC/4-mm cable

For connecting amplifier outputs to an analog voltmeter.

Cable length:	1 m approx.

5.12 Set of work templates

Work templates for experiments:

- Diffraction at an edge
- Propagation of waves beyond a slit
- Diffraction by a double slit
- Constructive und destructive interference arising from diffraction by a double slit
- Lloyd’s mirror
- Set-up for a simple interferometer
- Set-up for a Michelson interferometer

6. Operation

6.1 Ultrasonics experiments at 40.000 kHz

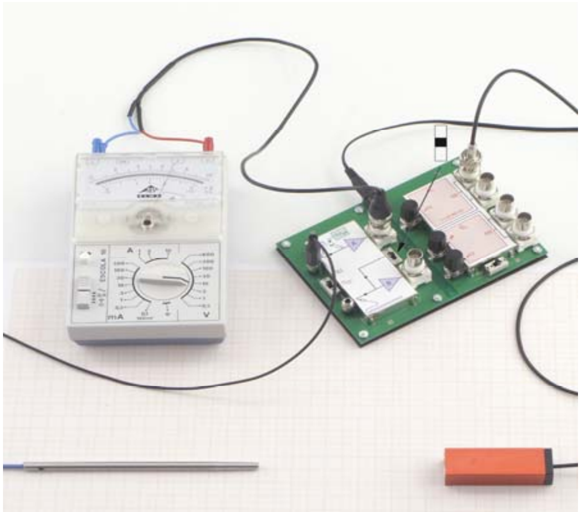


Fig. 2 Measurement of ultrasonic amplitude using a multimeter

Required:

1 Electronics board with plug-in power supply

1 Ultrasonic transmitter, 40 kHz

1 Microphone probe
or
1 Ultrasonic pen

1 BNC cable
or
1 BNC/4-mm cable

Additionally required:

1 USB oscilloscope, 2x40 MHz	1012845
or	
1 Analog oscilloscope, 2x20 MHz	1008695
or	
1 ESCOLA 10 multimeter	1006810

- Connect the supplied plug-in transformer to provide power to the equipment.
- Turn on the high-pass filter by means of switch S1 ( ) and set switch S2 to .
- Connect the 40-kHz ultrasonic transmitter to the output of Generator G1.
- Place the microphone probe opposite the transmitter and connect it to channel A or B on the electronics board.
  Note: The ultrasonic pen can be used instead of the microphone probe and connected to channel A or B. Its tip should point towards the sound source.
- Connect the output of the channel to an oscilloscope (measuring ranges 1 V/div, 2 µs/div) or a multimeter (measuring range: AC, 10 V).
- Observe the amplitudes of the oscillations with the oscilloscope or via the deflection of the multimeter and vary the amplitude of the ultrasound from the transmitter using the amplitude trimmer.

  Note: the deflection of the multimeter needle is initially proportional to the set amplitude. At higher amplitudes the amplifier becomes overdriven and the output voltage takes on a square-wave character, since the voltage level at Output A merely switches between the negative and positive operating voltages of the electronics board. The oscilloscope displays a trapezoidal or square curve.

6.2 Ultrasonic experiments with variable frequencies

Required:

1 Electronics board and plug-in power supply

1 Ultrasonic transmitter, 40 kHz

1 Microphone probe
or
1 Ultrasonic pen

1 BNC cable

Additionally required:

1 USB oscilloscope, 2x40 MHz	1012845
or	
1 Analog oscilloscope, 2x20 MHz	1008695

- Connect the supplied plug-in transformer to provide power to the equipment.
- Turn on the high-pass filter by means of switch S1 ( ) and set switch S2 to .
- Connect the 40-kHz ultrasonic transmitter to the output of Generator G2.
- Place the microphone probe opposite the transmitter and connect it to channel A or B on the electronics board.
  Note: The ultrasonic pen can be used instead of the microphone probe and connected to channel A or B. Its tip should point towards the sound source.
- Connect the output of the channel to an oscilloscope (measuring ranges 1 V/div, 2 µs/div).
- Observe the amplitudes of the oscillations with the oscilloscope and vary the amplitude of the ultrasound from the transmitter using the amplitude trimmer.
- Observe the period of oscillation with the oscilloscope and vary the frequency of the transmitter using the frequency trimmer.

6.3 Investigation of phase differences using the phase indicator on the ultrasonic pen

Required:

1 Electronics board and plug-in power supply

1 Ultrasonic transmitter, 40 kHz

1 Ultrasonic pen

2 BNC cables

Additionally required:

1 USB oscilloscope, 2x40 MHz	1012845
or	
1 Analog oscilloscope, 2x20 MHz	1008695

- Connect the supplied plug-in transformer to provide power to the equipment.
- Connect the ultrasonic transmitter to Generator G1 or alternatively to Generator G2.
- Connect the ultrasonic pen to channel A.
- Turn on the high-pass filter by means of switch S1 (≈) and either set switch S2 to in order to couple to Generator G1 or in order to couple to Generator G2.
- Connect the channel outputs to the oscilloscope..
- Move the ultrasonic pen to a position where the LED acting as a phase indicator is lit to its maximum intensity and compare the phase differences between the two signals.

  Note: the phase indicator shows the difference between the generator signal and the signal received from the ultrasonic pen.
  The phase relationship between two arbitrary points on the ultrasonic wave are analysed when a microphone probe is connected to channel A and switch S2 is set to .

6.4 Recording of isophases or determination of wavelength with the ultrasonic pen

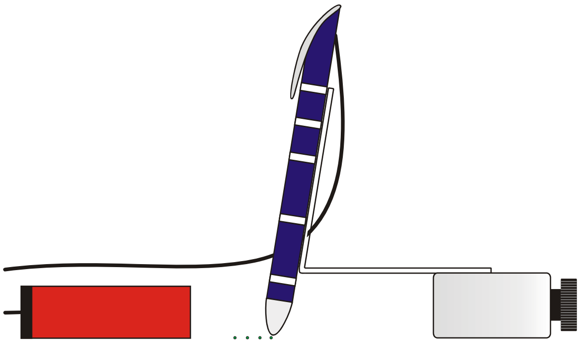


Fig. 3 Positioning of ultrasonic pen on work base and alignment towards sound source

Required:

1 Electronics board and plug-in power supply

1 Ultrasonic transmitter, 40 kHz

1 Ultrasonic pen

1 Holder for ultrasonic pen

- Use a plain sheet of paper as a base.
- Connect the supplied plug-in transformer to provide power to the equipment.
- Connect the ultrasonic transmitter to Generator G, for example.
- Connect the ultrasonic pen to channel A and set it up in its holder in such a way that the tip is only about 1 mm from the paper with the holder pointing towards the sound source.
- Turn on the high-pass filter by means of switch S1 (≈) and set switch S2 to in order to couple to Generator G1.
- Move the ultrasonic pen to a position where the LED is only lit to its minimum intensity.
- Use a fine pen to mark the position of the ultrasonic pen's tip on the paper.

To record isophases:

- Move the ultrasonic pen across the line of the beam until the phase indicator is once again at its minimum, making sure you keep the pen pointing towards the transmitter.
- Use a fine pen to mark the new position of the ultrasonic pen on the paper.

To determine wavelength:

- Move the ultrasonic pen in the direction of the beam until the phase indicator is once again at a minimum.
- Use a fine pen to mark the new position of the ultrasonic pen on the paper.

7. Experiments

7.1 Lloyd's mirror

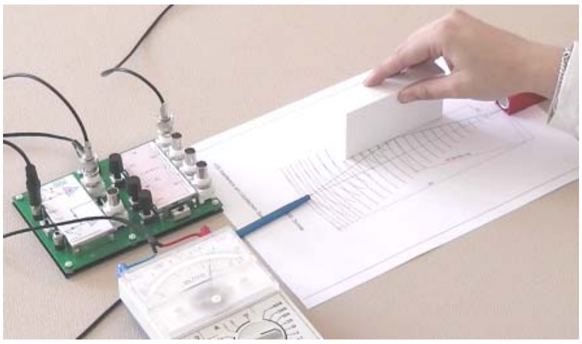


Fig. 4 Reflection from Lloyd's mirror

Required:

1 Electronics board and plug-in power supply
1 Ultrasonic transmitter, 40 kHz
1 Microphone probe
1 Reflector
1 BNC/4-mm cable

Additionally required:

1 ESCOLA 10 multimeter 1006810

- Connect the supplied plug-in transformer to provide power to the equipment.
- Connect the ultrasonic transmitter to Generator G1.
- Connect the microphone probe to channel A and set it up some distance in front of the transmitter.
- Connect the output of the channel to the multimeter (measuring range: AC, 10 V).
- Turn on the high-pass filter by means of switch S1 (≈) and set switch S2 to ▤.
- Set up the reflector parallel to the main beam.
- Change the distance of the reflector from the main beam and observe the maxima and minima in the measured sound amplitude.

Note: If the distance between the plane between the transmitter and receiver and reflecting surfaces such as the base plate is equal to certain specific values, then the direct beam and the one reflected from the surface may be superimposed in such a way that destructive interference ensues. With Lloyd's mirror it is possible to determine the minimum distance at which this effect occurs. The effect does not occur at all if the transmitter and receiver are set up so close together on the base plate that they are nearer to each other than this minimum distance.

7.2 Reflection from a convex mirror

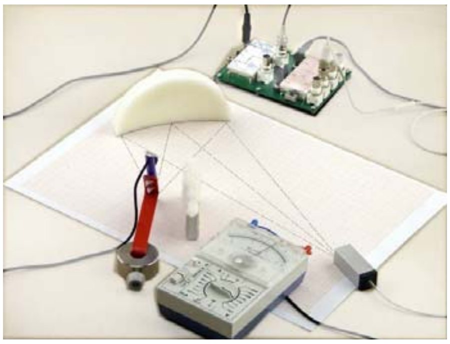


Fig. 5 Reflection of a diverging sound beam by a convex mirror

Required:

1 Electronics board and plug-in power supply
1 Ultrasonic transmitter, 40 kHz
1 Ultrasonic pen with holder
or
1 Microphone probe
1 Convex mirror
1 Absorber
1 BNC/4-mm cable

Additionally required:

1 ESCOLA 10 multimeter 1006810

- Connect the supplied plug-in transformer to provide power to the equipment.
- Connect the ultrasonic transmitter to Generator G1.
- Connect the ultrasonic pen, or alternatively a microphone probe, to channel A and set it up some distance in front of the transmitter.
- Connect the output of the channel to the multimeter (measuring range: AC, 10 V).
- Turn on the high-pass filter by means of switch S1 (≈) and set switch S2 to ▤.
- Set up the convex mirror and point the transmitter towards it.
- Set up the reflector parallel to the direct beam.
- Find the optimum position for the receiver by using a geometric construction and position the ultrasonic pen at that point.
- Move the ultrasonic pen until the received signal is at a maximum.

Note: The alignment of the receiver and transmitter with the convex mirror is comparable to a domestic satellite dish.

7.3 Diffraction by an edge

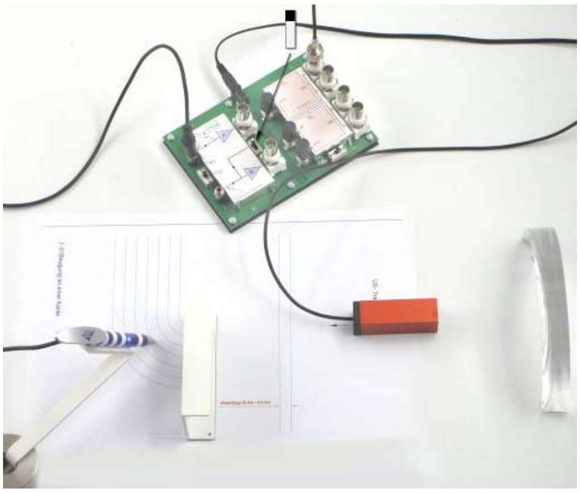


Fig. 6 Recording isophases when plane waves are diffracted by an edge

Required:

1 Electronics board and plug-in power supply

1 Ultrasonic transmitter, 40 kHz

1 Ultrasonic pen with holder

1 Convex mirror

1 Reflector

- Connect the supplied plug-in transformer to provide power to the equipment.
- Set up the convex mirror and mark the focal point (focal length 100 mm).
- Connect the ultrasonic transmitter to Generator G1 and set it up facing the convex mirror at the mirror's focal point.
- Turn on the high-pass filter by means of switch S1 (≈) and set switch S2 to in order to couple to Generator G1.
- Connect the ultrasonic pen to channel A and set it up in its holder in such a way that the tip is only about 1 mm from the template.
- Set up the ultrasonic pen in its holder behind the transmitter such that it is pointing towards the convex mirror.
- Move the ultrasonic pen until the phase indicator goes out and then mark the position of the ultrasonic pen on the template.
- To record the wave fronts after reflection from the convex mirror move the ultrasonic pen across the axis of the beam and mark the points where the brightness of the phase indicator is art a minimum.
- Move the ultrasonic pen in the direction of the beam and record the following isophase.
- Set up the reflector such that diffraction occurs at its edge and determine the altered isophases due to the diffraction.

Note: The isophases (points where the brightness is at a minimum) correspond to a "snapshot" of the wave fronts. The distance between two isophases is equal to one wavelength.

7.4 Diffraction by a double slit

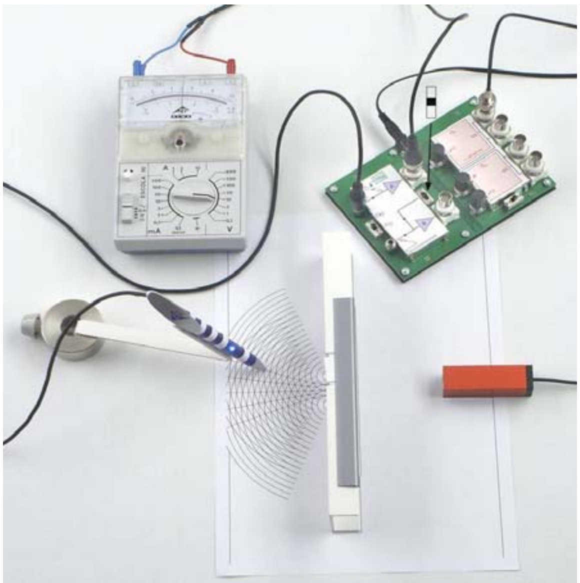


Fig. 7 Diffraction by a double slit

Note: New circular wave fronts emerge from both slits. The template already has such wave fronts drawn on it with a separation of half a wavelength. The points where these lines cross form lines (hyperbolae) indicating constructive and destructive interference.

Required:

1 Electronics board and plug-in power supply

1 Ultrasonic transmitter, 40 kHz

1 Ultrasonic pen with holder

1 Set for double slit

1 Absorber

1 BNC/4-mm cable

Additionally required:

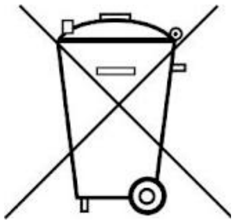
1 ESCOLA 10 multimeter 1006810

- Connect the supplied plug-in transformer to provide power to the equipment.
- Use the appropriate template.
- Set up the double slit, making sure the slits are the same width (about 5 mm).
- Connect the 40-kHz ultrasonic transmitter to Generator G1 and align it with the middle of the double slit.
- Turn on the high-pass filter by means of switch S1 (≈) and set switch S2 to in order to couple to Generator G1.

- Connect the ultrasonic pen to channel A and set it up in its holder in such a way that the tip is only about 1 mm from the template.
- Place the ultrasonic pen in its holder behind the double slit on one of the pre-drawn wave fronts.
- Move the ultrasonic transmitter in the direction of the beam till the phase indicator goes out.
- Confirm the locations of the wave fronts are as drawn on the template by moving the ultrasonic pen appropriately.
- Position the ultrasonic pen at a point on one of the blue hyperbolae, carefully align it towards the middle of the double slit and identify by the minimal needle deflection on the multimeter that this is a diffraction minimum.
- Move the ultrasonic pen parallel to the double slit and look for diffraction minima and maxima.

Note: If the ultrasonic pen is at the position of one of the first diffraction minima, covering one or other of the slits should cause the intensity at the measuring point to increase markedly. In addition, it is possible to demonstrate with the help of an oscilloscope that the measured curves from the two slits have the same amplitude but are phase-shifted by 180°.

8. Disposal



Should the equipment need to be scrapped, it must not be disposed of in normal household waste.

- Packaging and components should be disposed of at local recycling centres.