Generation of waves

Physics > Mechanics > Vibrations & waves

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/6002b99ceefa9f0003fe5ffc

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General information

Application

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Water waves due to rain

We encounter waves in many different ways: in rain puddles, on the beach or while surfing. The overlapping of different waves leads to the creation of huge water waves in storms on the high seas.

This experiment is about this phenomenon of superposition and its use in physics.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Other information (1/3)

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Prior knowledge

Ideally, Snell's law of refraction and the importance of surface tension should have been covered in class. However, they are not a prerequisite for understanding this experiment.

Scientific principle

The water waves are generated with the help of the integrated wave exciter. A rod with a swab mounted on its tip is clamped into the exciter unit. Any frequency (5-60 Hz) of the exciter can be set at which the swab is immersed in the water of the wave tank (11260-14). The immersion of the swab produces water waves.

Other information (2/3)

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Learning objective

Introduction of basic wave phenomena, such as generation, propagation, interference, refraction.

Tasks

1. Using two different wave exciters, it is shown that the water wave device can be used to generate both circular waves and waves with rectilinear wave fronts.
2. Demonstration of the generation of wave bundles by shading with the aid of apertures using the example of circular and parallel waves.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (3/3)

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A green LED light is installed at the bottom of the water wave device. This illuminates the wave tub from below and enables a high-contrast display of the water waves. Both continuous illumination and stroboscopic illumination are available as illumination modes. Stroboscopic illumination allows the speed of propagation of the water waves to be slowed to a complete standstill. Further information on the strobe lighting settings is given below.

The experiment table can be placed on the water wave device. If a white sheet of paper is placed on the experiment table, the wave pattern on the paper can be observed. Further, the paper can be used to document and explain the wave phenomena by tracing relevant wave structures on the paper. For better visibility of the water waves on the paper, it may be necessary to darken the room.

In the production of the wave images, focusing optical components are completely dispensed. The image formation is exclusively due to the refractive properties of the water surface.

Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Theory (1/4)

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In order to learn about the physical concept of "wave", demonstration experiments with waves that are directly visible as such are indispensable. The most important of the basic wave phenomena are conveniently illustrated with waves that are bound to a linear carrier (rope waves or torsion waves in a wave machine). With the aid of these linear waves, the propagation properties, the reflection at perpendicular incidence, the superposition of waves travelling in opposite directions to form a standing wave and dispersion can be demonstrated, as can the various forms of polarisation (linear, circular).

In reality, however, waves almost exclusively propagate in three dimensions, such as sound waves or electromagnetic waves. All phenomena characteristic of such waves (law of reflection, law of refraction, interference, diffraction) can be illustrated particularly clearly in two dimensions, and the knowledge thus gained can easily be transferred by the learner to the three dimensions of space. Water waves, which are familiar to everyone, can be used as directly visible waves of this kind for demonstration lessons.

Theory (2/4)

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The PHYWE water wave device is used to demonstrate the characteristic physical phenomena of surface waves. It is essential that with this device waves with circular wave fronts (analogous to the divergent light with spherical wave fronts emanating from a point light source) as well as waves with rectilinear wave fronts (analogous to parallel light with plane wave fronts) can be generated.

In the introductory experiments 1.1 and 1.2 it is shown that the fundamental observations of shadow casting and reflection are consistent with the laws of geometrical optics.

The speed of propagation c of the water waves is determined by the set excitation frequency f and by measuring the wavelength λ according to

$$c = \lambda \cdot f$$

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Theory (3/4)

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The fact that this speed is very small, only about 0.2 m/s (cf. 1.3), makes it possible to demonstrate in an impressive way the shortening or the enlargement of the wavelength in front of and behind a moving wave exciter (Doppler effect, 1.4).

If, for example, a light beam hits the boundary between an optically thinner and an optically denser medium at an angle, it is refracted towards the incident slot. Assuming different propagation speeds of the light waves in the two media, the observed refraction can also be made quantitatively understandable by applying Huygens-Fresnel's principle. The physical occurrence of refraction only becomes immediately clear in a parallel experiment with water waves, in which the optically denser medium is simulated by a shallow water zone. After the influence of a shallow water zone on the wave propagation velocity has been investigated quantitatively (2.1), experiments 2.2 and 2.3 illustrate the refraction in some important optical components such as a plane-parallel plate, a prism, a converging lens and a diverging lens.

Theory (4/4)

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Interference and diffraction-phenomena are the exclusive criteria, based on which the wave-character of light is provable. These optical experiments are convincing only if interference and diffraction have been demonstrated in a model-like manner in preceding experiments on illustrative waves. The corresponding interference and diffraction experiments are the subject of sections 3 and 4. Compared to optical experiments, experiments with water waves allow a much sharper delimitation of the terms diffraction and interference. In optical experiments, diffraction phenomena are always additionally accompanied by interference, since pure diffraction occurs only, for example, at slits whose width does not exceed the wavelength.

As the production of slits of a width of less than 1 µm causes great technical difficulties and, in addition, the energy reaching through such a small aperture would not be sufficient for visual observation, one must always use wider slits for optical experiments. With water-waves, on the other hand, the pure diffraction at a sufficiently narrow slit can be shown without problems.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Ripple Tank with LED light source, complete set	11260-88	1

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Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
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Set-up and Procedure

Set-up (1/13)

A green LED light is installed at the bottom of the water wave device. This illuminates the wave tub from below and enables a high-contrast display of the water waves. Both continuous illumination and stroboscopic illumination are available as illumination modes. Stroboscopic illumination allows the speed of propagation of the water waves to be slowed to a complete standstill. Further information on the strobe lighting settings is given below.

The experiment table can be placed on the water wave device. If a white sheet of paper is placed on the experiment table, the wave pattern on the paper can be viewed.

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Set-up (2/13)

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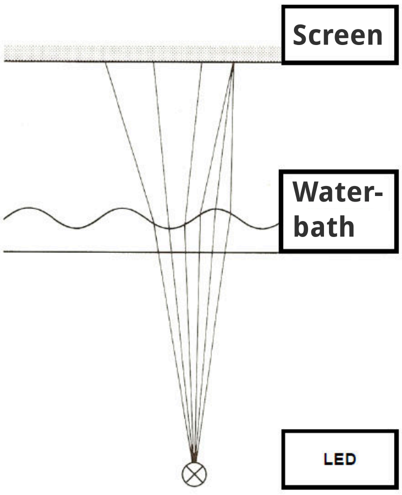

Projection course

Furthermore, the paper can be used to document and explain the wave phenomena by tracing relevant wave structures onto the paper. For better visibility of the water waves on the paper, it may be necessary to darken the room.

In the production of the wave images, focusing optical components are completely dispensed with. The image formation is exclusively due to the refractive properties of the water surface.

The light from the LED luminaire diverges through the wave troughs and converges through the wave crests. This causes the wave troughs to be visible as dark stripes and the wave crests as bright stripes on the viewing surface. This principle produces high-contrast and sharp wave images.

Set-up (3/13)

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It should be noted that a good image contrast is only achieved with small wave amplitudes. At larger amplitudes, the light beams emanating from the LED luminaire are already combined in front of the viewing surface and diverge again on their further path to the viewing surface, which leads to a disappearance of the wave image. For this reason, the wave exciter is equipped with amplitude control. This means that the excitation amplitudes, which differ for the individual experiments, can be set in each case.

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Robert-Bosch-Breite 10
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Set-up (4/13)

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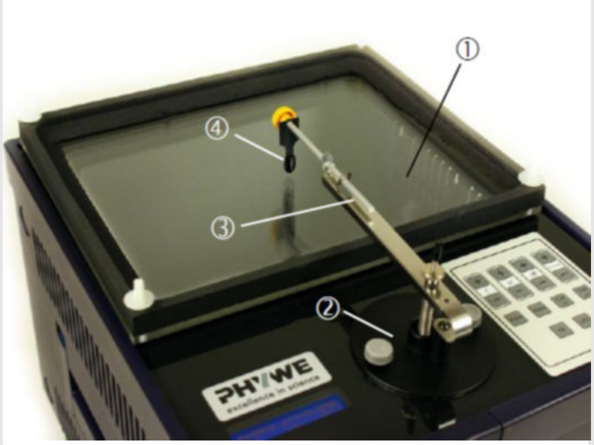

Wave trough

The inner edges of the wave trough are covered with foam. This allows an almost complete absorption of the water waves hitting the tub edges to prevent unwanted wave reflections. The supplied spray bottle is used to fill the wave tub. The tub should be filled to about three quarters with water.

Set-up (5/13)

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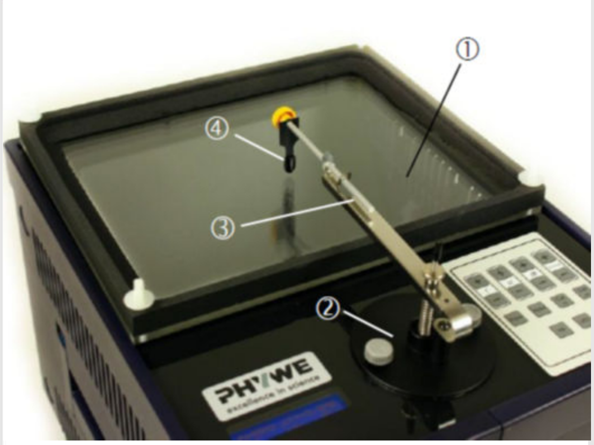

Wave trough

In order to suppress the reflection of the water waves at the edges, you should run your finger over the entire foam edge after filling, so that the foam can better absorb the water. The wave tub can be aligned horizontally with the help of the four adjustment screws. To do this, look flat over the surface of the water and take the height of the water level at the individual edges of the tub as a reference. By adjusting the four screws, the tub can now be aligned horizontally until the water level is approximately the same on all sides. However, exact adjustment is only necessary for tests with flat shafts.

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Robert-Bosch-Breite 10
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Tel.: 0551 604 - 0
Fax: 0551 604 - 107

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Set-up (6/13)

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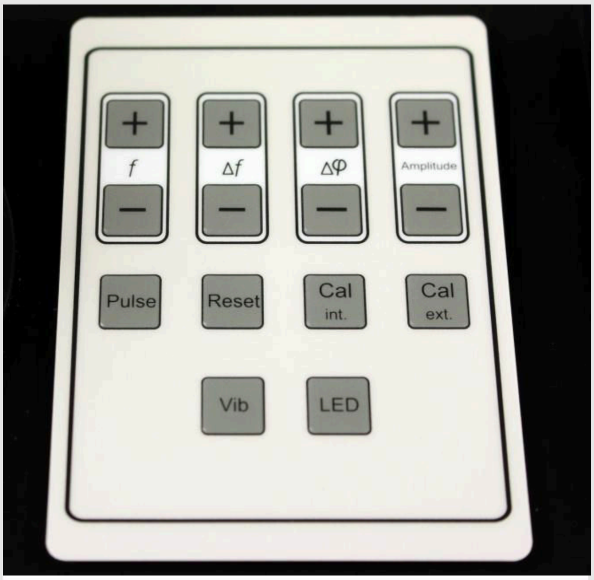

The water wave device has a control element and an LCD to display the settings used. The individual setting options are explained in the following slides:

Set-up (7/13)

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Key	Function
Vib	Switches the excitation unit (internal and external) on and off.
LED	This turns the LED on or off and toggles between continuous illumination and strobe illumination.
Pulse	Pressing the button triggers a single pulse in the exciter unit, causing the swab to dip into the water a single time. Releasing the button returns the swab to its original position.
Reset	Switches off the excitation unit and the LED. All other settings are retained in order to be able to quickly switch the device to the previous state.
Cal Int.	For calibration of the integrated exciter. The amplitude of the exciter can be varied in the range between 80 % and 120 %. If the amplitudes of the integrated and external exciter differ, the amplitude of the integrated exciter can be fine-tuned to that of the external exciter. First press the Cal int. key. Immediately afterwards, use the (+) and (-) keys of the amplitude control to carry out the fine tuning. The calibration is retained even after a reset or after disconnecting the mains plug.

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Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
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Set-up (8/13)

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Key	Function
Cal ext.	As Cal int. but for calibration of the external vibration generator.
f	Increases (+) or decreases (-) the frequency of the exciter between 5 Hz and 60 Hz.
Δf	Sets a frequency difference between the exciter and the strobe illumination. In the initial state, the two frequencies are equal (Δf = 0 Hz). A frequency difference between -2.5 Hz and +2.5 Hz can be set in steps of 0.5 Hz using the "+" and "-" buttons. If the frequency is the same, the generated wave appears as a standing wave; if there is a frequency difference, it can be displayed in "slow motion".
Δ/φ	Sets a phase difference between the integrated exciter and an additional second exciter which can be connected to the rear of the shaft unit via two connection lines. In the initial state, both exciters oscillate in phase. A phase difference between 0° and 360° can be set in 15° steps using the "+" and "-" buttons.
Amplitude	Increases (+) or decreases (-) the amplitude of the exciter. Amplitudes between levels 1 and 8 are possible.

Set-up (9/13)

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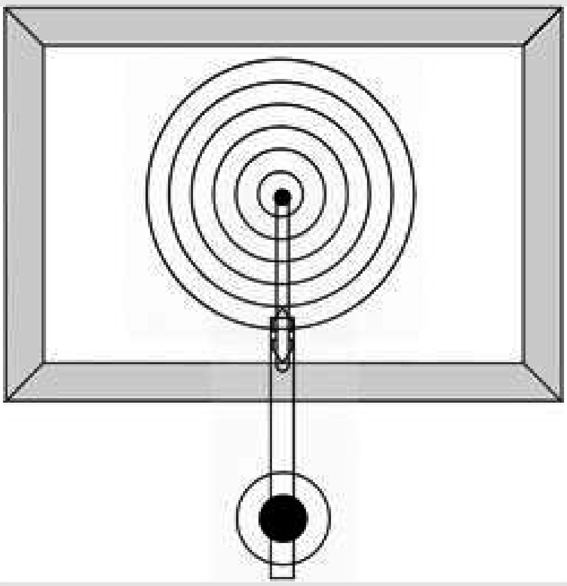

With the PHYWE water wave device, circular waves as well as plane waves can be generated.

To generate a circular wave, attach the single wave exciter to the exciter arm so that the exciter is approximately above the center of the wave tank. Turn the preload screw on the exciter arm to lower the wave exciter until it is immersed in the water of the wave tank. Then continuous light, an excitation frequency between 5 Hz and 25 Hz and a small amplitude are set. The experimental table with a white sheet of paper placed on it serves as the viewing surface. For a better visibility of the wave image it might be useful to darken the room.

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Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
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Set-up (10/13)

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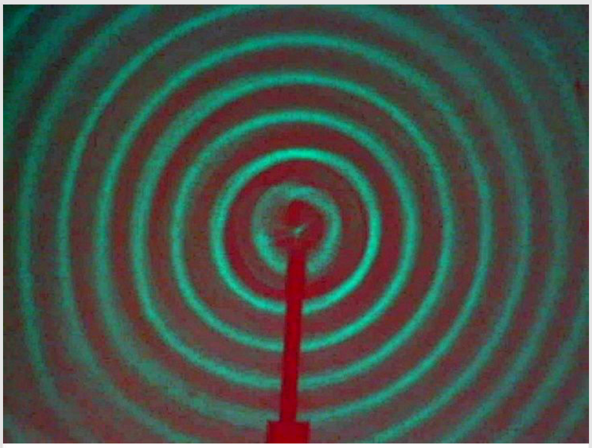

Snapshot of a circular wave field

If the wave image is distorted or unclear, vary the excitation frequency and/or amp-litude until a wave image similar to the displayed wave image is visible.

In addition, several circular waves can also be generated simultaneously. For this purpose, the double wave exciter or the comb with a maximum of 10 dabs is used.

Set-up (11/13)

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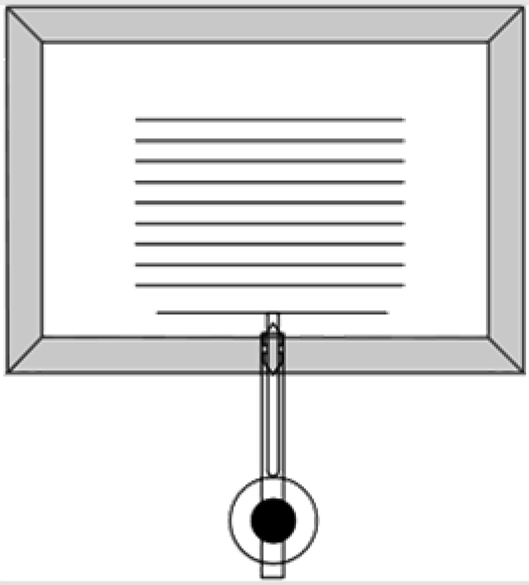

The generation of plane waves is somewhat more extensive, as it requires a more precise alignment of the wave pan and the plane wave exciter to be used. In addition, 1 to 2 drops of soap solution should be added to the water for better wetting. Care must be taken not to exceed the dosage, otherwise turbidity will occur and the image quality will deteriorate.

The mounting rod with slider is attached to the exciter and brought to the lower end of the shaft trough.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

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Set-up (12/13)

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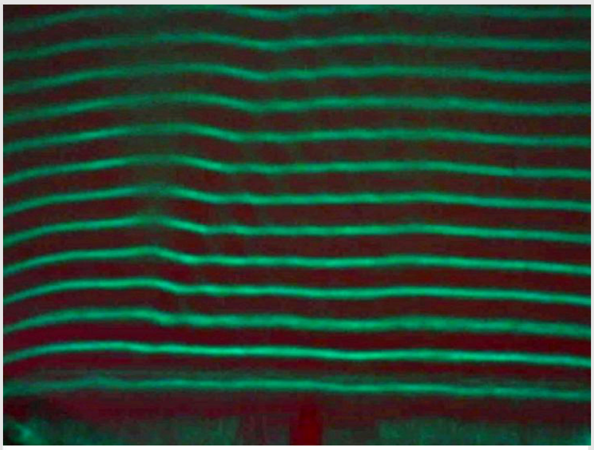

Plane water waves

Then the wave trough must be adjusted correctly, as the plane wave exciter must be immersed exactly evenly in the water. Otherwise, the wave image may be distorted or unclear. Instructions for the correct adjustment of the shaft trough can be found in the section "Shaft trough".

The plane shaft exciter must also be adjusted horizontally. To do this, attach it to the exciter unit in an approximately horizontal position and turn the pre-tensioning screw on the exciter unit until the plane shaft exciter is just above the water surface. Using the water surface as a reference surface, the plane wave exciter can now be aligned horizontally. When this is done, the preload screw on the exciter unit is turned further until the plane wave exciter is submerged in the water of the wave trough (about 1 mm to 2 mm). Then an excitation frequency between 15 Hz and 25 Hz, a small amplitude and continuous light are set. A wave image should become visible.

Set-up (13/13)

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Use of the strobe light

In the individual experiment descriptions, the use of the stroboscope light is only prescribed if it is necessary to achieve the respective experimental objective. All other experiments should initially be carried out without stroboscopic light, since the stroboscopic illumination changes the image impression considerably in some cases. Interference patterns can be seen much more impressively with continuous projection than with stroboscopic illumination.

In this context, it should be noted that the human eye is only able to detect the wave images in the lower frequency range (up to about 30 Hz) with continuous illumination. For this reason, it is recommended that only frequencies up to about 25 Hz be used when working with continuous illumination. For shorter wavelengths (higher frequencies), the stroboscopic light should then be used, thus slowing down the wave propagation and making it visible to the eye.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Procedure- Experiment 1 (1/2)

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1. circular waves:

The following settings are made on the water wave device:

Frequency exciter	5...20 Hz
Amplitude exciter	Level 1...2
Lighting	continuous

The wave exciter (swab) should be immersed approximately vertically in the water of the wave trough to avoid distortions of the circular shape of the wave crests and troughs.

Procedure- Experiment 1 (2/2)

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2nd level waves:

When generating plane waves, exact adjustment of the plane wave exciter and the wave trough is required.

Frequency exciter	15...20 Hz
Amplitude exciter	Level 1...2
Lighting	continuous

Any irregularities in the course of the wave crests and troughs may be due to incomplete wetting of the plane wave exciter (air bubbles). If necessary, the plane wave exciter should be freed from adhering air bubbles by hand. For better wetting, 1 to 2 drops of soap solution can be added to the water.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

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Procedure- Experiment 2 (1/2)

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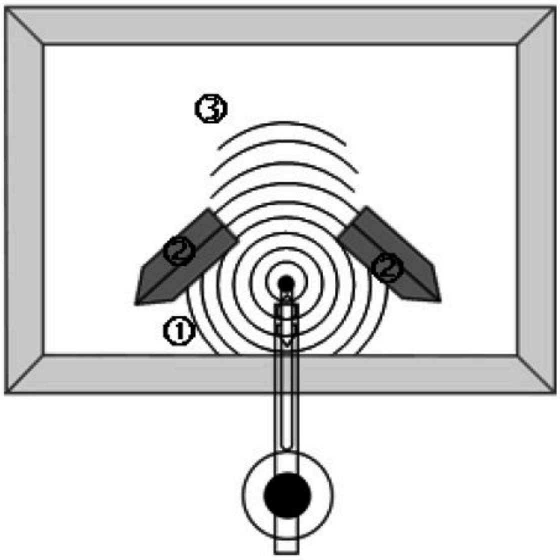

1. circular waves:

The mounting rod with the single swab as wave exciter is brought to the lower tub edge. The two barriers are placed in the wave tub.

For this experiment, the same setting options apply to the water wave device as for experiment 1.

The position of the two barriers is corrected, if necessary, so that their longitudinal axes tangentially continue the circular wave passing through the gap. In this way, disturbing interferences, which can be caused by reflections at the leading and trailing edges of the slit, are avoided.

Procedure- Experiment 2 (2/2)

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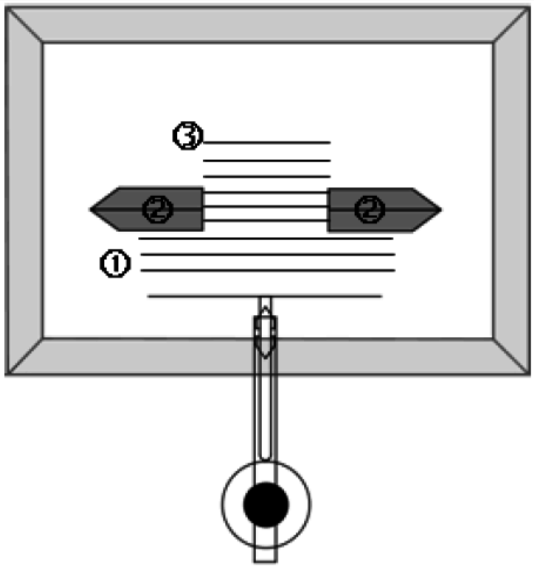


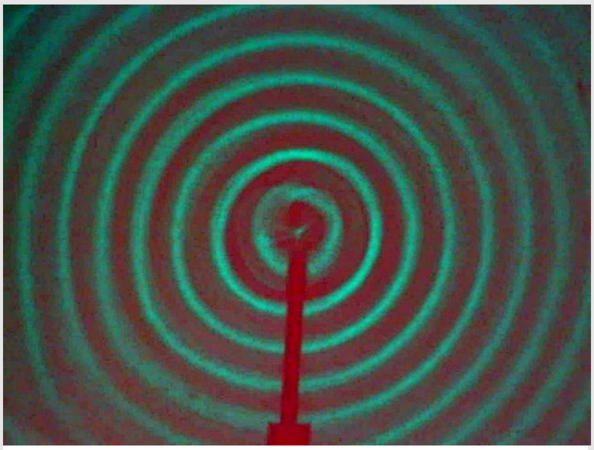
2nd level waves:

The single swab as exciter is now replaced by the plane wave exciter. The two barriers are arranged in the wave well in such a way that they form a slit diaphragm.

The plane wave exciter is carefully adjusted. The same adjustment possibilities apply to the water wave device as in experiment 1. A clear wave pattern should result.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Evaluation - Experiment 1 (1/3)



Snapshot of circular waves

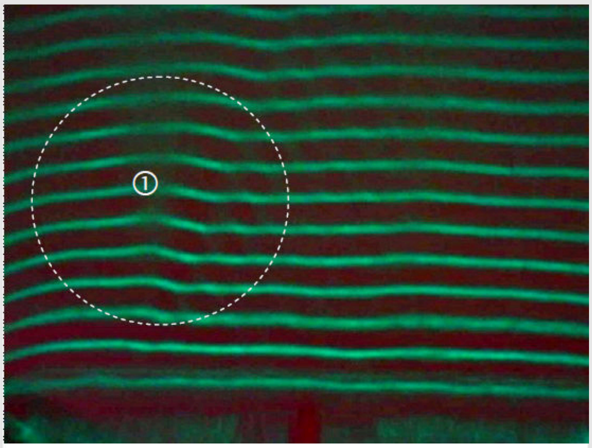
Complete.

From the single ________, ________ emanate whose peaks and valleys form concentric ________ with the ________ as the center.

swab | circles | wave exciter | waves

Check

Evaluation - Experiment 1 (2/3)



Snapshot of plane waves, the area (1) can be identified as an artifact.

Complete.

Waves emanate from the ________ with ________ and valleys ________ and parallel to the ________.

exciter | mountains | straight | planar wave exciter

Check

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
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Evaluation - Experiment 1 (3/3)

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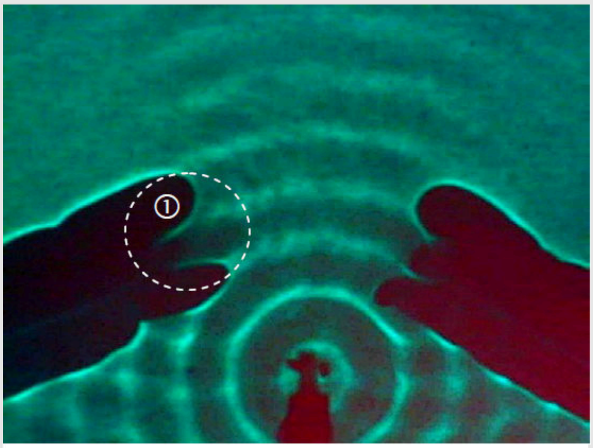
Interpretation

1. The single swab moving downwards in the water distorts the water level in its vicinity locally downwards due to the persistent wetting line at the swab. This disturbance of the water surface moves away from the swab in all directions with the same speed as a circular wave trough. During the subsequent upward movement, the water level in the vicinity of the swab is also raised. A ring-shaped wave crest is created, which follows the wave trough in the form of a concentric circle. The periodic upward and downward movement of the swab creates the continuous wave pattern shown.

2. The plane wave exciter behaves approximately like a multiplicity of closely adjacent, linearly arranged point-like wave exciters. According to Huygens' principle, the reproduced plane waves can be interpreted as superpositions of the circular waves emanating from these point-like exciters.

Evaluation - Experiment 2 (1/3)

PHYWE



Test result

Complete.

A wave bundle is blanked out of the complete circular wave domain by the ______. The boundaries of this bundle are ______ and have their ______ at the location of the ______. The wave bundle is no longer sharply defined.

origin | divergent | wave exciter | aperture

Check

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
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Evaluation - Experiment 2 (2/3)

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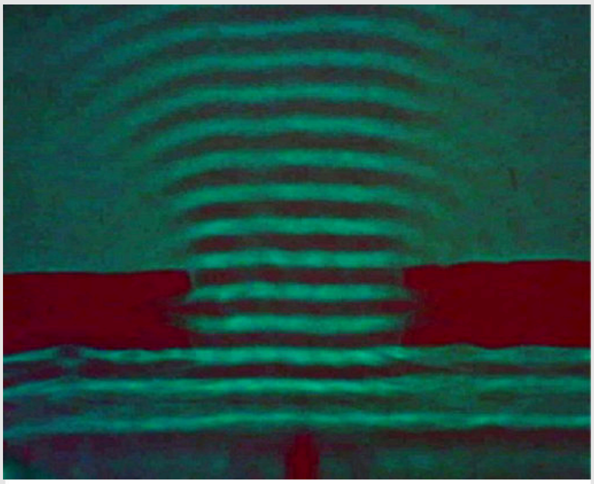

Test result

Complete.

A ________ is faded out from the ________. The boundaries of this bundle are ________. The wave bundle is no longer sharply defined, but the waves continue in the shadow area of the aperture in the form of a weak portion of non-planar waves.

parallel | wave region | wave bundle

Check

Evaluation - Experiment 2 (3/3)

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Interpretation

Geometric optics uses the terms "divergent" and "parallel" ray bundle. In the wave model, the divergent ray bundle corresponds to the circular wave bundle, the parallel ray bundle to the bundle of plane waves.

The experiment shows that these terms of geometrical optics represent an idealization which does not do justice to the wave nature of light: Due to the diffraction that always occurs when wave bundles are confined by apertures, sharp boundary lines do not result. Such diffraction phenomena are clearly visible in the illustrations.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

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Slide	Score / Total
Slide 30: Wave exciter	0/4
Slide 31: Plane shaft exciter	0/4
Slide 33: Circle Wave Area	0/4
Slide 34: Wave bundle	0/3

Total score 0 / 15

Show solutions

Repeat

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