Diffraction of water waves at a slit and at an obstacle

Objects of the experiment

- Investigating the diffraction of straight water waves at slits of various widths.
- Investigating the diffraction of straight water waves at obstacles of various widths.

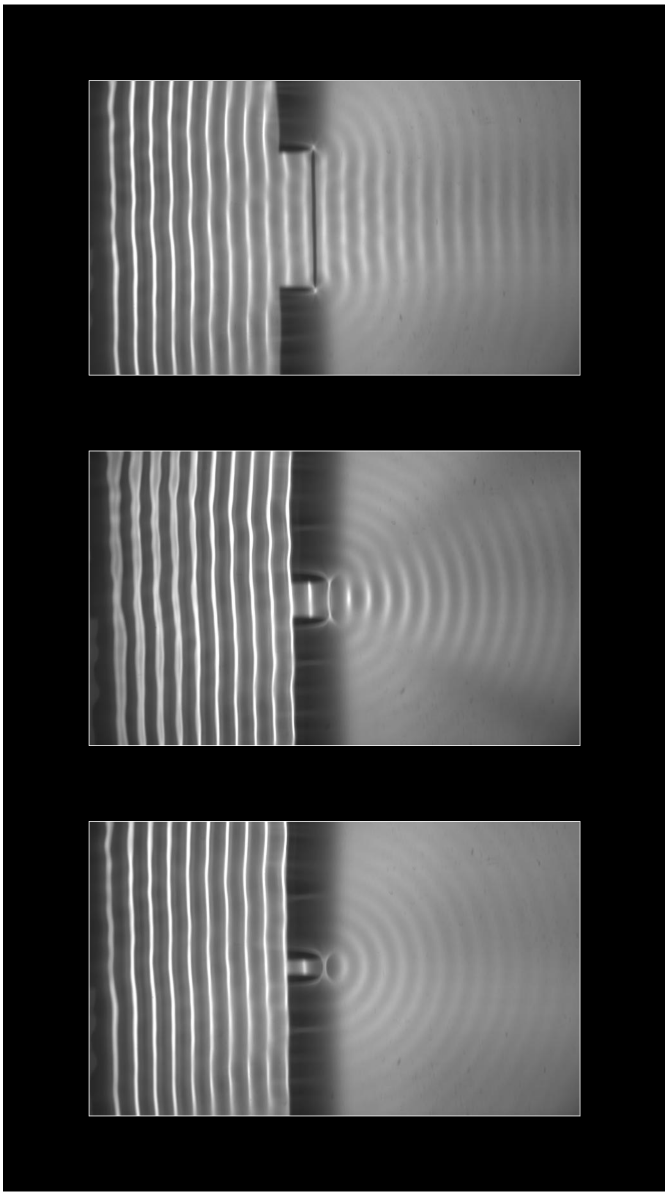

Fig. 1 Diffraction of water waves at slits of different widths (photographs)
Top: slit width much greater than wavelength
Middle: slit width somewhat greater than wavelength
Bottom: slit width smaller than wavelength

Principles

The waves behind an obstacle or slit do not only propagate in their original direction. We can also observe the diffraction phenomena which were discussed in the experiment "Huygens' principle for water waves" (P1.6.4.2). Each point in the plane of the slit, as well as the edges of the slit or obstacle act as point-type excitation centers of circular waves, Huygens' wavelets, which are superposed on each other. In the process, the amplitudes are reinforced at certain points (creation of maxima), and at others attenuated or even canceled out entirely (creation of minima). The interference phenomenon at any point is a function of the phase shift of the interfering waves at that point (see "Two-beam interference of water waves" (P1.6.5.1)).

In order to demonstrate diffraction and interference phenomena at a slit and behind obstacles, straight wave fronts are generated in the filled water trough, which strike slits and straight obstacles one after another.

Slits of different widths are realized using a diaphragm (obstacle with large slit) and two cover slides. Circular waves form behind a small slit (slit width smaller than wavelength). If the slit is somewhat wider than the wavelength, minima are formed from the sides in addition to the main maxima. When a slit with a width significantly greater than the wavelength is used, the straight waves pass unchanged between the edges of the slit. In this zone, the wavelets have no phase differences with respect to one another. Weaker, circular waves penetrate the shadow zone of the edges.

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Apparatus

1 Wave trough with motor stroboscope . . . 401 501

additionally required:

Dish soap

Obstacles of different widths are realized using the cover slides. When straight waves strike an obstacle, the edges of the obstacle act like the excitation centers of a double exciter. Behind the obstacle, the interference structure familiar from the double exciter appears (see "Two-beam interference of water waves" (P1.6.5.1)).

Setup

Set up the experiment as shown in Fig. 2.

– Set up the wave trough so that it is not subject to shocks and vibrations; observe all information given in the Instruction Sheet.

Carrying out the experiment

a) Propagation of straight waves behind slits of different widths:

– Place the obstacle with large slit in the center of the wave trough precisely under the lamp.

– Connect the exciter for straight waves as shown in Fig. 3 and set it up parallel to the obstacle at a distance of approx. 5 cm.

– If necessary, rotate the stroboscope disk out of the beam path using knurled screw **(f)** so that the glass pane in the bottom of the wave trough is completely illuminated.

– Using knob **(e)**, set a frequency of approx. 25 Hz, and carefully increase the excitation amplitude using knob **(d)** until wave fronts are clearly visible (see Instruction Sheet for wave trough).

– Vary the immersion depth as necessary with adjusting screw **(h)**.

– Observe the wave image behind the slit.

– Determine wavelength λ. Be sure to take the image scale into consideration to determine the actual wavelength (see Instruction Sheet for wave trough).

– Use the two wide cover slides to reduce the large slit so that the slit width is somewhat greater than the wavelength λ (see Fig. 4, center).

– Observe the wave image behind the slit.

– Repeat the experiment with frequencies of 10, 20 and 30 Hz.

– Use the two wide cover slides to reduce the large slit so that the slit width is less than the wavelength λ. (see Fig. 4, bottom)

– Set a frequency of 25 Hz, and adjust the amplitude as necessary.

– Observe the wave image behind the slit again.

b) Propagation of straight waves behind obstacles of different widths:

– Remove the obstacle with large slit from the wave trough. arrange the two wide cover slides as shown in Fig. 5 (top) and place them in the middle of the wave tank parallel to the wave exciter.

– Observe the wave image behind the obstacle.

– Set the frequencies 10, 15 and 20 Hz; adjust the amplitude if necessary and observe the wave patterns behind the obstacle.

– First slide the two wide cover slides together (see Fig. 5, middle) to make the obstacle smaller, and repeat the experiment steps.

– Then set up the narrow cover slides (see Fig. 5, bottom).

Measuring example

a) Propagation of straight waves behind slits of different widths:

Fig. 1 shows three photographs with measurement examples.

b) Propagation of straight waves behind obstacles of different widths:

Fig. 6 shows three photographs with measurement examples.

Results

a) Propagation of straight waves behind slits of different widths:

The diffraction phenomena described in the section "Principles" is confirmed by experiment:

When a slit with a width significantly greater than the wavelength is used, the straight waves pass unchanged between the edges of the slit. Weaker, circular waves penetrate the shadow zone of the edges. No minima or maxima are to be seen.

If the slit is somewhat wider than the wavelength, minima and secondary maxima are formed from the sides in addition to the wide main maximum. The interference patterns depend on the wavelength. The wave fronts of adjacent maxima are shifted by half a wavelength.

When the slit is smaller with respect to the wavelength, it acts as a point-type exciter for circular waves.

b) Propagation of straight waves behind obstacles of different widths:

The waves behind the obstacle do not only propagate in their original direction. They also arc around into the "shadow" of the obstacles and penetrate this area in the form of circular waves.

Interference phenomena are formed behind the obstacle, which resemble those of a double exciter. The two edges form the centers of excitation.

The interference patterns are determined by the width of the obstacle and by the wavelength. As the width increases and the wavelength decreases, the number of interference hyperbolas increases.

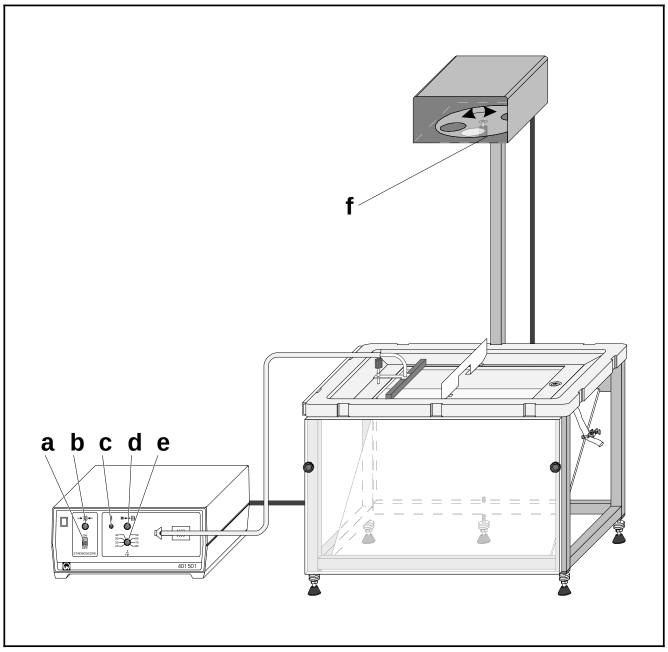


Fig. 2 Experiment setup (or interference of water waves
a Stroboscope switch
b Knob (for fine adjustment of stroboscope frequency)
c Pushbutton (single-wave excitation)
d Knob (for adjusting amplitude of wave excitation)
e Knob (for adjusting frequency of wave excitation)
f Knurled screw (for manually turning stroboscope disk)

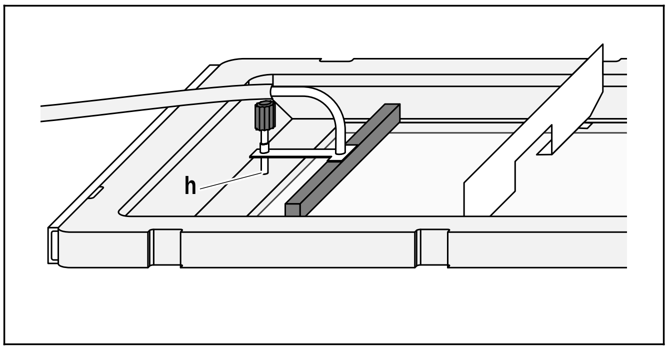
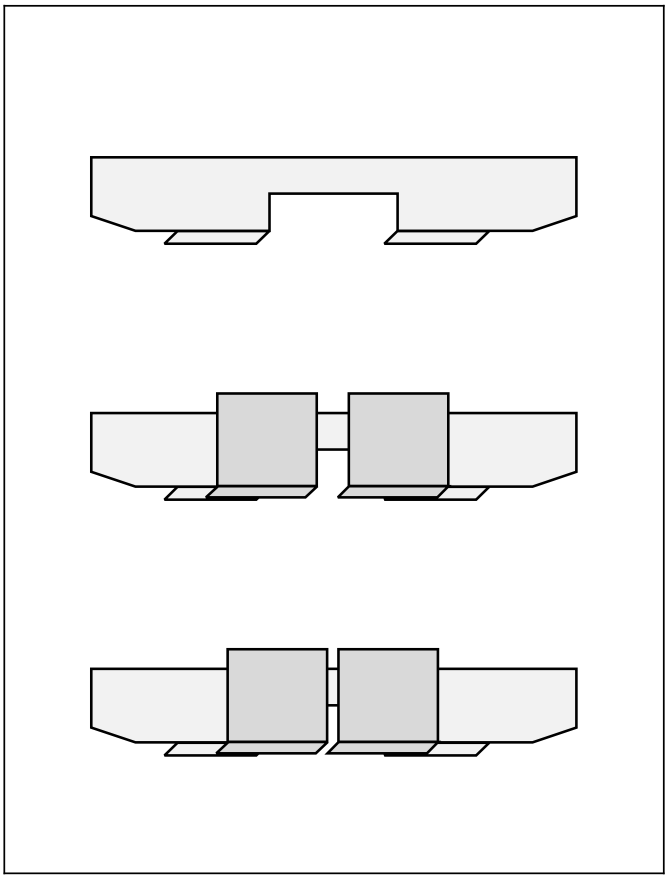
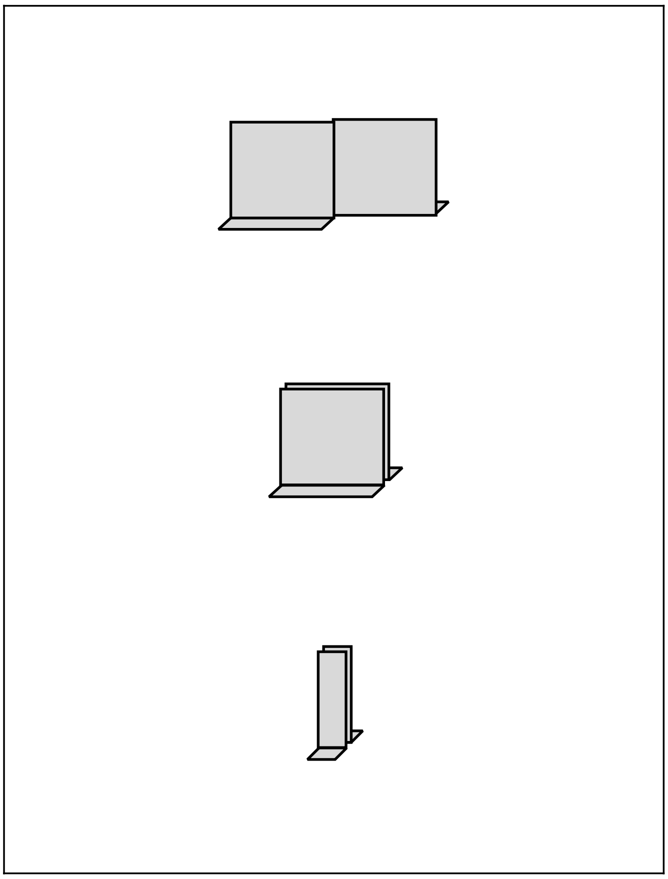


Fig. 3 Connecting the exciter for straight waves
h Adjusting screw (for setting immersion depth)

Fig. 4 Slits of different widths, viewed from exciter
Top: slit width much greater than wavelength
Middle: slit width somewhat greater than wavelength
Bottom: slit width smaller than wavelength

Fig. 5 Obstacles of different width
Top: maximum width
Middle: medium width
Bottom: minimum width





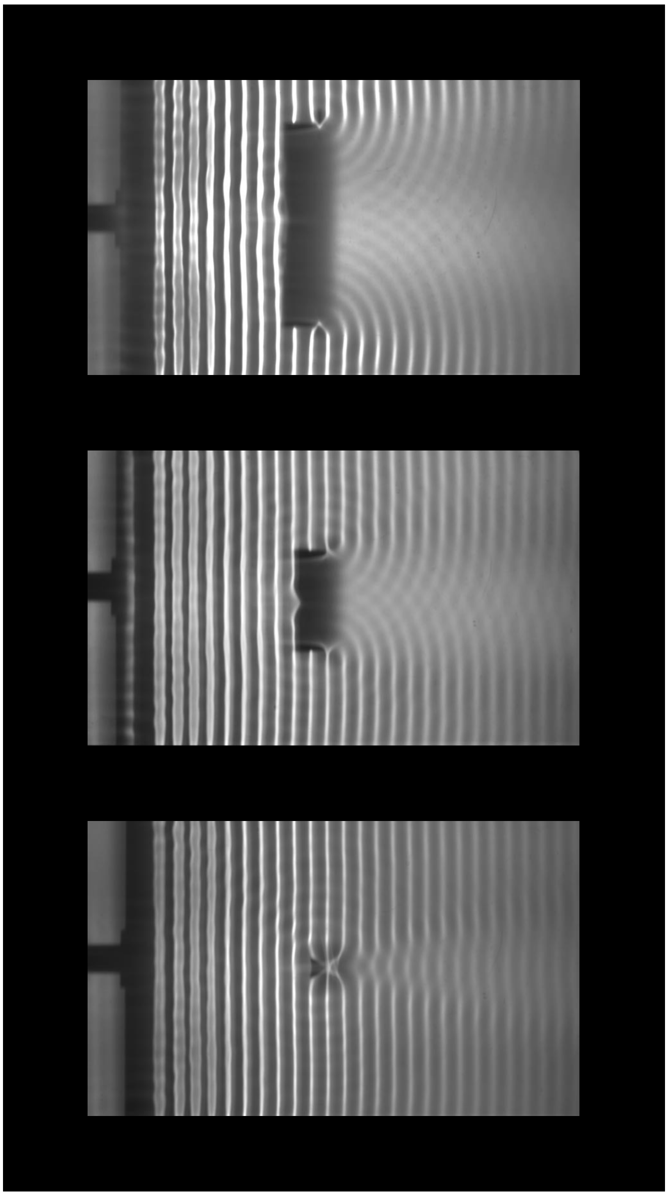


Fig. 6 Diffraction of water waves at obstacles of different widths (photographs)
Top: wide obstacle
middle: medium obstacle
Bottom: narrow obstacle