Propagation of water waves in two different depths

Objects of the experiment

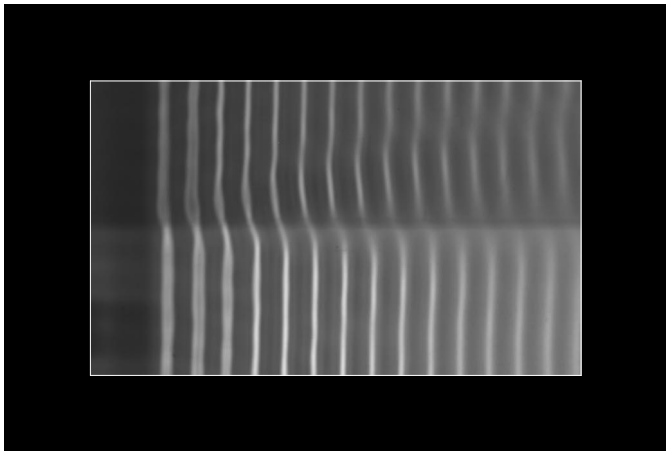
- Observing the propagation of water waves in two different depths.
- Comparing the wavelengths and wave velocities of water waves at two different depths as a function of frequency.

Principles

To observe the propagation of water waves at varying water depths, a plane-parallel plate is placed lengthwise in the wave trough filled with water. This creates zones with two different depths in which we can determine the wave velocity of straight water waves.

As long as the water depth is not greater than the wavelength, the wave velocity increases with the water depth. The shallower the water, the more intensive this effect is. Zones with different water depths are thus equivalent to experiments in optics on media with different refractive indexes. The shallower water zones are equivalent to the medium with the greater refractive index, while the deeper water zones are comparable to those with a lower refractive index.

Fig. 1 Propagation of water waves in two different depths (photograph)



Apparatus

1 Wave trough with motor stroboscope . . .	401 501
1 Ruler or tape measure . . . . . e.g.	311 77

additionally required:

Dish soap

Setup

Set up the experiment as shown in Fig. 2.

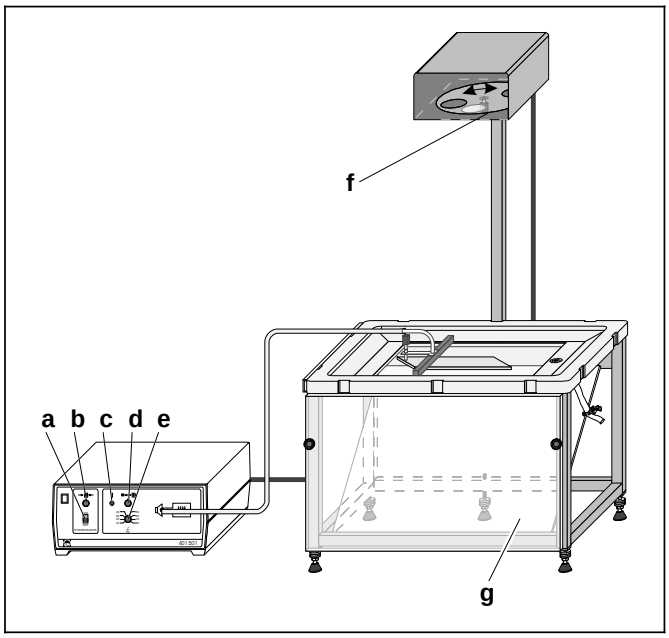
– Set up the wave trough so that it is not subject to shocks and vibrations; observe all information given in the Instruction Sheet. Use a spirit level and make sure that the glass plate is aligned precisely horizontally. Do not yet fill the wave trough with water.
– Place the plane-parallel plate of transparent acrylic glass lengthwise in the middle of the wave trough (see Fig. 3).
– Carefully pour water into the trough until the water level is 2-3 mm over the plate.
– Connect the exciter for straight waves and place it on the plane-parallel plate (see Fig. 3).
– 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. 20 Hz, and carefully increase the excitation amplitude using knob **(d)** until wave fronts are clearly visible (see Instruction Sheet for wave trough).

If no easily visible straight waves are generated on the plane-parallel plate:

– Vary the immersion depth of the exciter as necessary with adjusting screw **(h)**.
– Add some water to the wave trough.

If the wavelengths above and beside the plane-parallel plate do not differ greatly enough:

– Drain some water from the wave trough.



Carrying out the experiment

– To quantitatively compare the waves, switch on the stroboscope with switch **(a)**; after a short warm-up time, you may need to carry out a fine adjustment of the excitation and stroboscope frequencies using knob **(b)** until a stationary wave image appears.
– Measure the wavelength in both zones. To do this, measure the distance between 5-10 wave fronts on the observation screen **(g)**. Be sure to take the image scale into consideration to determine the actual wavelength.
– Compare the propagation velocities and wavelengths in both zones of the wave trough.
– Set different excitation frequencies between 10 Hz and 40 Hz and measure the wave images as described above.

Measuring example

Fig. 1 shows a photograph as a measuring example for the excitation frequency $f = 20$ Hz.

Table 1: Comparison of wavelength λ and wave velocity v in zone 1 (depth approx. 3 mm) and zone 2 (depth approx. 7 mm) for different excitation frequencies f

$\frac{f}{\text{Hz}}$	$\frac{\lambda_1}{\text{cm}}$	$\frac{v_1}{\text{cm}\cdot\text{s}^{-1}}$	$\frac{\lambda_2}{\text{cm}}$	$\frac{v_2}{\text{cm}\cdot\text{s}^{-1}}$
10	1.6	16	2.2	22
20	1.4	28	1.6	32
30	0.83	25	0.87	26
40	0.66	26	0.68	27

Results

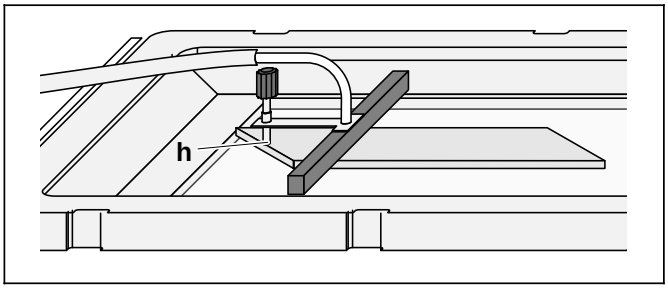
The edge of the plane-parallel plate represents the boundary between two zones of different depths, in which the propagation speed and the wavelength differ. The waves in shallow water travel more slowly than in deep water, and the wavelength decreases with water depth.

In terms of optics, the shallow water corresponds to the medium with the higher refractive index, e.g. a glass body. The deep water corresponds to the medium with the lower refractive index, e.g. air.

In water, the effect becomes less visible as the frequency increases, and is no longer observable above 40 Hz.

Fig. 2 Experiment setup for observing the propagation of water waves in two different depths
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)
g Observation screen

Fig. 3 Connecting the exciter for straight waves and arranging the plane-parallel acrylic-glass plate
h Adjusting screw (for setting immersion depth)



LEYBOLD DIDACTIC GMBH · Leyboldstrasse 1 · D-50354 Hürth · Phone (02233) 604-0 · Telefax (02233) 604-222 · e-mail: info@leybold-didactic.de