This experiment consists of two analogous experiments. The first part of the experiment illustrates the refraction of light waves on overrunning a plane-parallel plate. The law of refraction can be deduced from the observed wave pattern.
The refraction of water waves in a prism is examined in a second analogous experiment.

Materials

from the accessory set of 11260-99

1 Holder for plane wave generator
1 Plane wave generator
1 Refraction object, prism
1 Refraction object, plane-parallel plate

Method

Water waves are used to carry out analogous experiments to illustrate the refraction of light waves on passing through a plane-parallel plate and in a prism. The optically denser medium is simulated by a shallow water zone generated in the first part with the help of a rectangular plate placed obliquely in the wave tray and in the second part with the help of a triangular plate (prism).

Setup

Experiment 1:

The plane wave generator is fixed to the exciter arm and this is then positioned on the bottom edge of the ripple tank. (Optionally, both experiments can also be performed with the external vibration generator. The different plates must then be aligned accordingly.)
The plane-parallel plate from the refraction object set is placed in a tilted position in the wave tray opposite the wave fronts as shown in Fig. 1; the wave tray is then filled with water until the plate is completely covered with a thin layer of water. The wave tray and wave generator are then carefully adjusted (see Chapter 0.1).

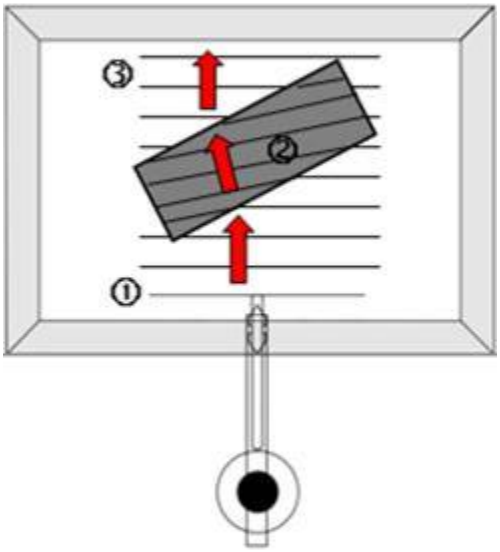

Figure 1: Arrangement for refraction of water waves at a plane-parallel plate. The wave front ① produced by the planar wave generator is refracted at the plane-parallel plate ② and is refracted back to its original direction on exiting the plate zone ③.

Experiment 2:

As experiment 1, however, instead of the rectangular plate, a triangular plate is placed in the wave tray as shown in Fig. 2.

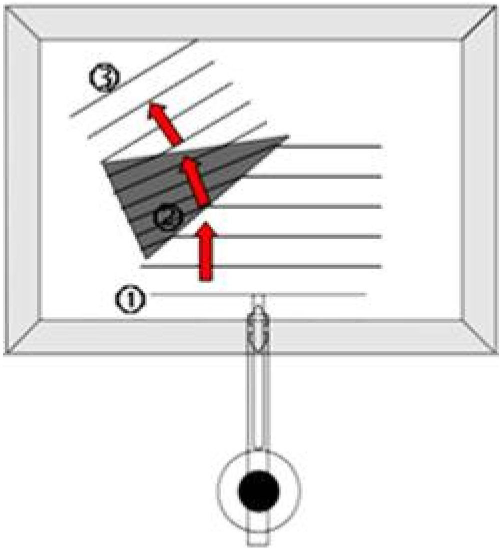

Figure 2: Arrangement for refraction of waves at a prism. The wave front ① produced by the planar wave generator is refracted ② on entering the shallow water zone of the triangular plate (prism) and is slightly diverted again in the same direction ③ on exiting the plate.

Procedure

Experiment 1 and 2:

The same settings apply to both experiments. Convincing results are obtainable with an exciter (wave generator) frequency of around 20 Hz to 25 Hz. The amplitude is selected so that a clear wave pattern results and then the stroboscopic lighting is switched on. The difference between strobe and the vibration generator frequency, respectively, should be selected so that a slow forward movement of the water waves can be recognised ($\Delta f > 0\ \mathrm{Hz}$).

The spray bottle is now used to suck water out of the wave tray until the refraction of the waves on entering the shallow water zone can be clearly seen. The wave propagation in front of, in and behind the shallow water zone is now observed. It can be useful to adjust the amplitude again to enable clear refraction to be recognised.

Note:

As the water level falls not only the refractive index increases but also the attenuation. The optimum water level for the experiment is reached when the wave pattern can only just be recognised behind the respective plate.

Results

Experiment 1

When the front of the plane waves enters the shallow water zone, bending of the wave front appears (Fig. 3). A change in the propagation direction of the waves towards the normal at the point of incidence can be clearly seen. On exiting the shallow water zone the wave is refracted by the same angle in the opposite direction: Behind the plate the wave front is once more bended to roughly parallel to the initial wave front.

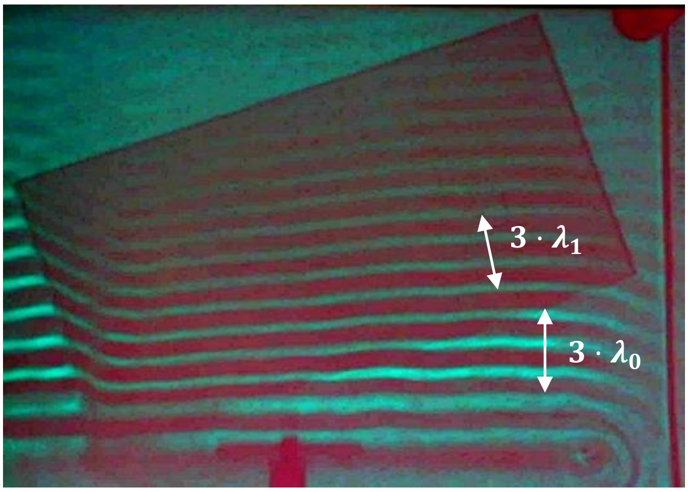

Figure 3: Snapshot as shown in Fig. 1. The bending of the plane wave front on entering the shallow water zone above the rectangular plate can be clearly seen. The wavelength is shorter in the shallow water zone than in the deeper water of the wave tray ($\lambda_1 < \lambda_0$).

Experiment 2

When the wave front enters the zone above the triangular plate clear bending of the wave crests and troughs can be seen. The wave front is refracted towards the base of the prism. On exiting the area of the shallow water zone the waves are bent again slightly in the same direction (Fig. 4).

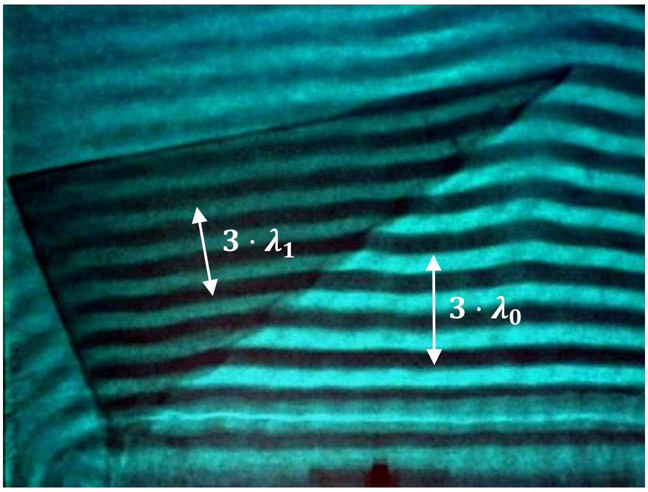

Figure 4: Snapshot as shown in Fig. 2. The bending of the plane wave front on entering the area above the triangular plate (prism), as well as the shortening of the wavelength that takes place there can be clearly recognised. The slight bending again on leaving the triangular plate is difficult to discern. This bending becomes clearer if the wave crests and troughs above and behind the triangular plate are drawn on the sheet of paper on the bench.

Interpretation

In Fig. 3 and Fig. 4 it can be clearly seen that the wavelength in the shallow water area is smaller than in the deep water. In addition, it can be seen that the wave crests (light stripes) run continuously along the boundary lines of the two areas. The observed pattern of the first experiment is schematically illustrated in Fig. 5, whereby unlike Fig. 3 a limited wave beam has been drawn.

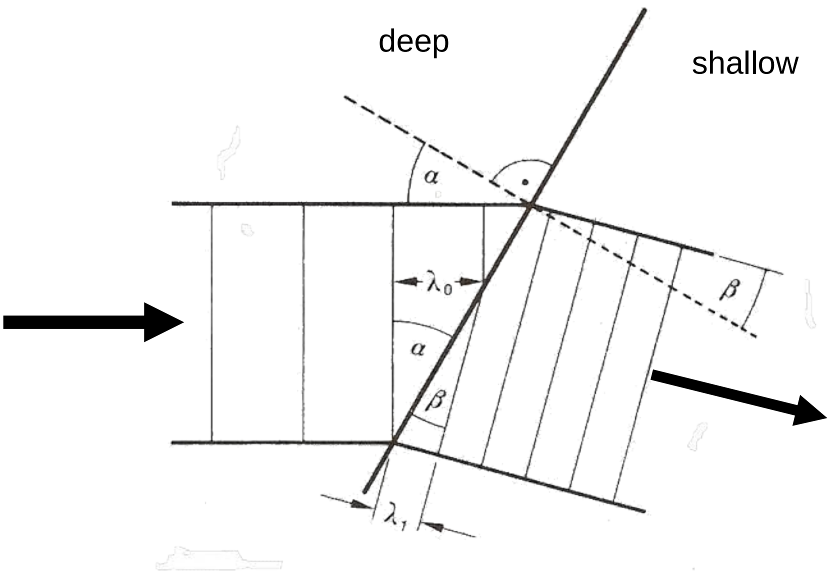

Figure 5: Geometrical description of the refraction of a plane wave at the interface of two different water depths.

For the relationship between the angle of incidence α and the reflection angle β, the following relationship is taken directly from Fig. 5

$$\frac{\sin\alpha}{\sin\beta} = \frac{\lambda_0}{\lambda_1}.$$

The quotient

$$n_{01} = \frac{\lambda_0}{\lambda_1} = \frac{c_0}{c_1}$$

(c_0 = Phase velocity in deep water, c_1 = phase velocity in shallow water) is called the refraction index for the crossover from deep to shallow water.

Summarising, the refraction law is obtained in the form familiar from optics

$$\frac{\sin\alpha}{\sin\beta} = \frac{c_0}{c_1} = n_{01}.$$

Both experiments directly illustrate the geometric construction, on which deduction of the refraction law from the Huygen-Fresnel principle is based.

The bending of the water waves on entering and exiting the shallow water zone corresponds to the refraction of light on passing through a plane-parallel plate and refraction in a prism.

