A system of alternating nodes and antipodes – a so-called standing wave – forms along the connection line between two synchronously oscillating, point-like wave generators. If the whole surface of the water is considered the nodes and antipodes each form a hyperbolic set with the locations of the two wave generators as focal points.

A system of alternating strips of rest and maximum wave amplitude can be observed perpendicular to the connection line between the two exciter centres.

Materials
from the accessory set of 11260-99

1 Wave generator, comb, 10 teeth
2 Dipper

Method

Experiment 1

Two point wave generators as far apart as possible are used to generate circular waves moving in opposite directions. The formation of the standing waves resulting from superimposition (interference) of these circular wave systems can be demonstrated in this way.

Experiment 2

The interference pattern of the circular waves emanating from two point wave generators is observed at different exciter frequencies and with different distances between the exciter centres. In this case, unlike experiment 1, the area of the waves moving in a perpendicular direction to the connection line between the exciter centres is observed instead of the area of standing waves between the generators.

Experiment 1:

Setup

Two dippers are fixed to a comb, one at each end. The mounting rod with comb is then fixed to the exciter arm and is moved to the middle of the wave tank (Fig. 1).

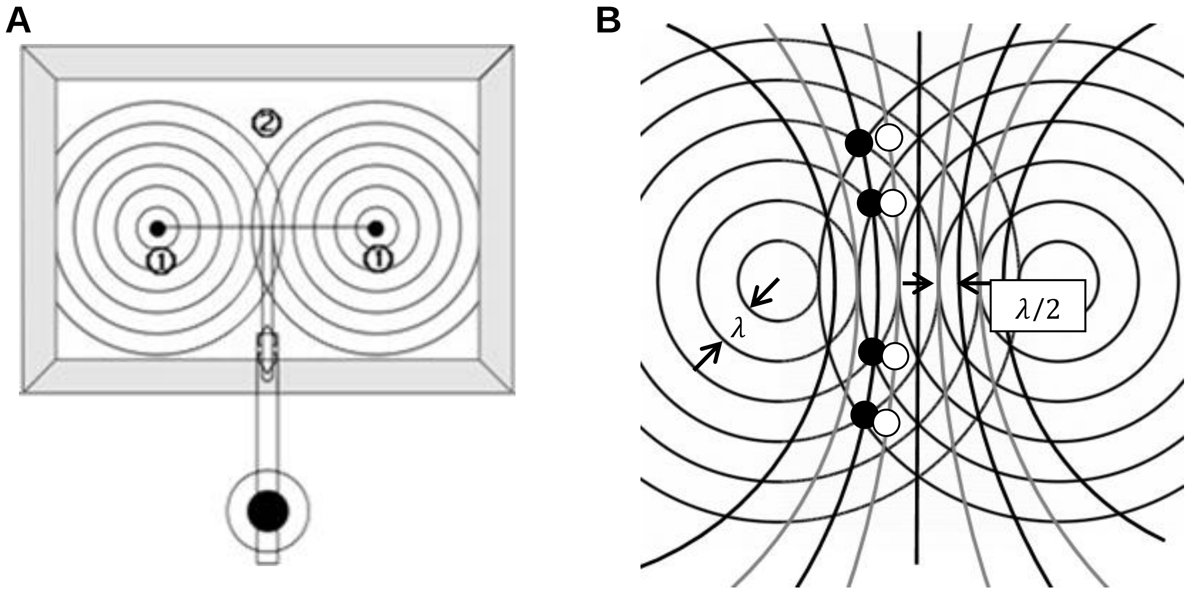

Figure 1: **A** – Experiment arrangement for interference of waves moving in opposite directions. The comb-shaped wave generator fitted with two dippers produces two circular waves ①, which interfere in the middle of the wave tank, i.e. along the connection line underneath the exciter arm ②.
B – Schematic illustration of the superimposition of the wave fields of two point generators with wavelength λ. Loci at which the wave trains constructively interfere (filled circles) lie on the black lines; those which destructively interfere (unfilled circles) lie on the grey lines. Together they form a standing wave pattern. The hyperbolae of constructive interference appear in the wave pattern as light-coloured stripes, the hyperbolae of destructive interference appear as dark stripes. Along the connection line between the generators the superimposition standing wave generated has a wavelength of $\lambda/2$.

Procedure

The resulting wave pattern is observed in permanent lighting and at different frequencies (between 15 Hz and 40 Hz). The exciter amplitude is adjusted to the respective set frequency so that a clear wave pattern results. The wavelength near the generator where the waves progress in a clearly visible way is compared with the stripe spacing in the area of the standing waves. It is advisable to do this by drawing several wave crests of the progressing wave area and several wave crests from the area of the standing waves on the sheet of paper on the bench to enable easier comparison of the wavelengths.

Then switch to stroboscopic lighting. The wave pattern in a stroboscopic frequency set slightly against the exciter frequency (Δf around −0.5 Hz to −1.0 Hz) is observed.

Experiment 2:

Setup

The mounting rod with double dipper is fixed to the exciter arm. (Optionally the comb-shaped generator can be used here, whereby a push-on base is pushed onto the second tooth on both sides seen from the middle of the comb. Here it is necessary to ensure that the push-on bases are attached at the same level.) The distance between the two push-on bases is 30 mm (the distance on the comb is around 40 mm). The mounting rod is then moved to the bottom edge of the tank as shown in Fig. 2.

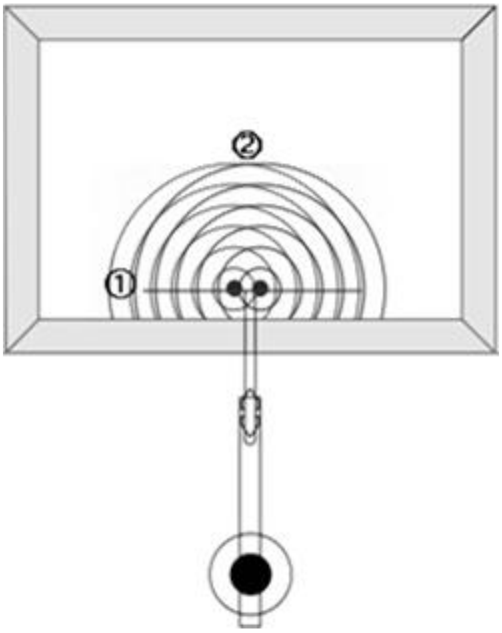

Figure 2: Arrangement for interference with two dippers. The two circular waves generated by the comb-shaped wave generator ① superimpose to form a characteristic interference pattern ②. (The wave pattern is the same as when the double wave generator is used.)

Procedure

An exciter frequency of between 20 Hz and 25 Hz is set at the ripple tank and the amplitude is chosen so that a clear wave pattern results.

The frequency is then varied and the effect of the frequency changes on the interference pattern is observed.

Finally the effect of changes in distance between the dippers on the interference pattern at a constant frequency (around 20 Hz to 30 Hz) is examined (the comb-shaped wave generator is now used here, whereby it must be ensured that the two dippers are always at the same distance from the middle of the comb).

Experiment 1:

Results

A standing wave pattern forms between the wave generators. The distance between the bright and dark stripes along the connection line between the wave generators (standing wave) is half the size of the wavelength of the progressing waves visible near the two exciter centres.

In the subsequent stroboscopic lighting, where a set frequency difference Δf enables the propagation velocity of the waves between the stroboscope and exciter frequency to be substantially slowed down, the same wavelength is observed between the wave generators as in the outer area. A periodic change between wave crests and troughs can be seen.

Fig. 3 shows a typical wave pattern at an exciter frequency of 25 Hz.

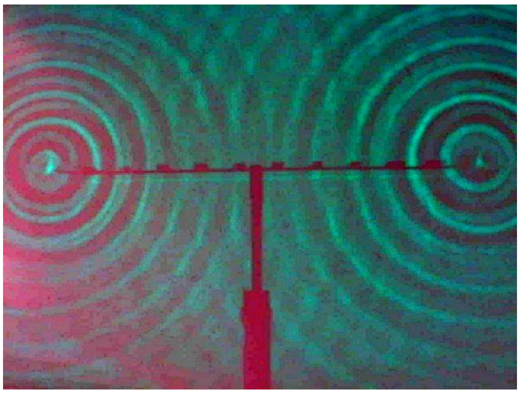

Figure 3: Snapshot as shown in Fig. 1. The interference pattern of the two circular waves can be clearly recognised. As this is a photo the resulting image is like that seen in stroboscopic lighting. The shortening of the wavelength in the area of the standing wave can therefore not be identified on the photo.

Interpretation

As the two wave generators oscillate in phase, the following relationship for the difference between their distance Δl from the two generators is expected at all locations

$$\Delta l = m \cdot \lambda \qquad (m = 0,\ \pm 1,\ \pm 2,\ \ldots)$$

At locations, whose path difference from the exciter centres is

$$\Delta l = \frac{2m+1}{2} \cdot \lambda \qquad (m = 0,\ \pm 1,\ \pm 2,\ \ldots)$$

the two waves must mutually cancel each other out. Loci with constant path differences to the two specified points are hyperbolae. The two specified points are the focal points of these hyperbolae.

In the case of standing water waves the nodes are visible to the eye as lines with constant average brightness. The loci of the antipodes on the other hand, as soon as a wave crest exists, are seen by the eye as intensive bright lines, while at the time of a wave trough the intensity is only negligently lower than in the area of the nodes. As the eye cannot differentiate between the phases of the oscillations due to its limited time resolution capacity, it only differentiates the lighter antipodes from the darker nodes in the time average. The distance between adjacent nodes or antipodes is as observed in the experiment $\lambda/2$.

In strobe lighting mode it is possible to see in the snapshot of the standing waves that their wavelength is identical to that of the progressing waves. If the stroboscope frequency ($\Delta f \neq 0$) is adjusted slightly the oscillations are slowed down for the eye to such an extent that the periodic change from wave crests to wave troughs can be recognised in the area of the antipodes of the standing waves.

Note

Standing waves can also be produced by reflection. A convincing demonstration can be achieved with the help of a point generator located in the centre of the circle of the concave reflector (see Experiment OW 1.2) from the accessories of the ripple tank. The standing waves near the reflector are the most marked.

Experiment 2:

Results

A waveband can be seen in the middle of the image moving perpendicular to and away from the connection line between the exciter centres (Fig. 4).

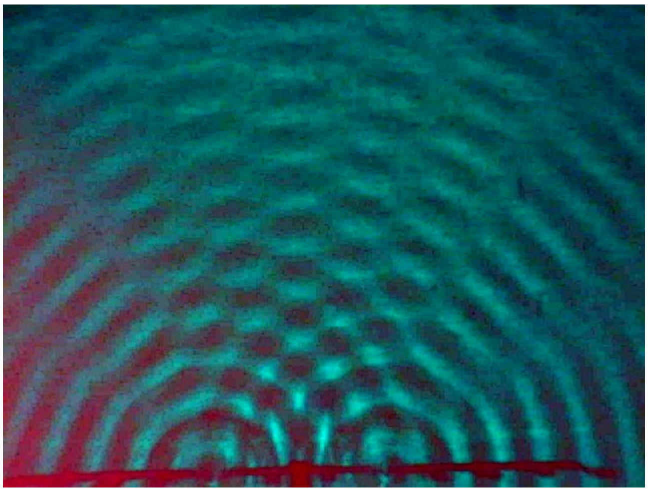

Figure 4: Snapshot as shown in Fig. 2. The interference pattern of the two circular waves in which wavebands with bands alternate with bands without wave generation can be clearly seen.

If the distance between the exciter centres is constant the distance between the wavebands reduces with increasing frequency. Thus, the number of different bands increases with the frequency. The same effect is achieved if the distance between the wave generators (dippers) is increased at constant frequency.

Interpretation

Along the mid-perpendiculars to the connection line between the two exciter centres there is no path difference (phase difference) between the superimposing circular waves, so that their amplitudes are added (zeroth interference order). Along the two geometric loci, for which the difference in distance Δl from the two exciter centres is defined by the relationship

$$|\Delta l| = \frac{\lambda}{2}$$

both waves are cancelled. Such loci are hyperbolae. Cancellation also occurs along the hyperbolae, for which

$$|\Delta l| = \frac{3}{2}\lambda,\ \ \frac{5}{2}\lambda,\ \ \frac{7}{2}\lambda,\ \ ...$$

is true.

Accordingly, at all hyperbolae with

$$|\Delta l| = \lambda \cdot m \qquad (m = 1,\ 2,\ 3,\ \ ...)$$

additive superimposition of the two wave systems occurs. The interference order is m.
It is easy to see that the distance between two adjacent interference orders becomes smaller the smaller the wavelength is: With reducing wavelength the corresponding difference in distance between two adjacent hyperbolae of constructive or destructive interference also reduces.

On the other hand, if the distance between the wave generators is increased the difference in distance to the generators in the observed wave area increases, which also causes the interference hyperbolae to move closer together.

