Doppler effect in water waves

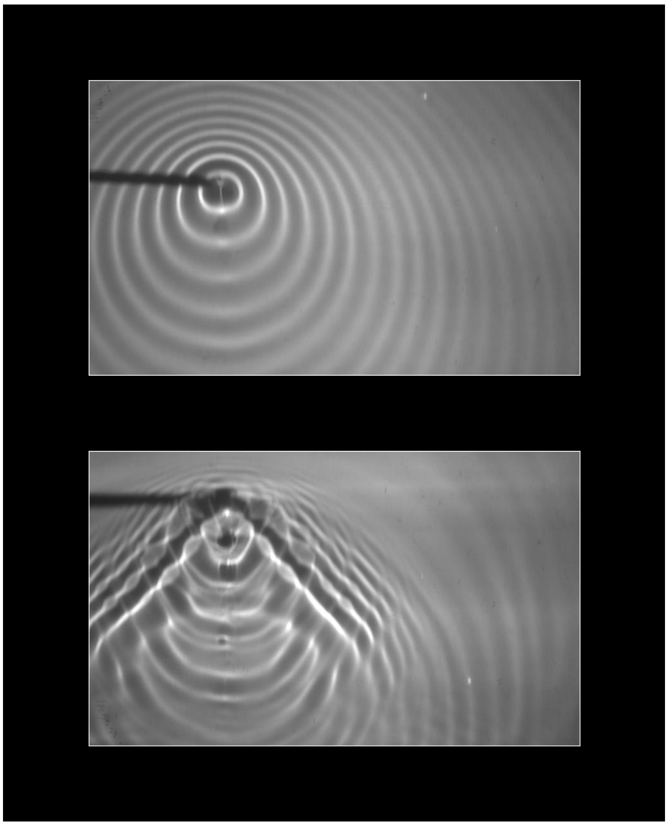
Object of the experiment

- Investigating the propagation of circular water waves for a moving exciter and a stationary observer.

Principles

For waves which propagate in a wave-carrying medium, the *Doppler* effect occurs when the exciter or the observer moves in relation to the medium. If the wave exciter moves, the wavelength in the medium changes. If the observer moves, the perceived wave velocity is changed.

By moving the holder for the point-type exciter for circular waves across the wave tank on a rail, we can observe the *Doppler* effect in water waves which occurs for a moving exciter and stationary observer.



A stationary observer B1, towards whom the wave exciter moves with a velocity u, measures a shortened wavelength λ_1. We can say

$$\lambda_1 = \lambda - \frac{u}{f} = \lambda \cdot \left(1 - \frac{u}{v}\right) \qquad \text{(I).}$$

(v: speed of propagation of wave).

A stationary observer B2, from whom the wave exciter moves away, measures an increased wavelength λ_2. We can say:

$$\lambda_2 = \lambda + \frac{u}{f} = \lambda \cdot \left(1 + \frac{u}{v}\right) \qquad \text{(II).}$$

If the velocity u of the exciter is equal to the propagation speed v of the waves, observer B1 observes all wave fronts arriving simultaneously with the exciter. If u exceeds the propagation velocity v, the exciter travels ahead of the wave fronts. The wave fronts have a common envelope, and the exciter is at its apex. In three-dimensional space, this envelope is known as a Mach cone. The angle of this cone decreases as the exciter velocity u increases.

Fig. 1 *Doppler* effect in circular water waves (photographs)
Top: exciter velocity $u < v$ wave velocity v
Bottom: exciter velocity $u > v$ wave velocity v

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Apparatus

1 Wave trough with motor stroboscope . . .	401 501
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.

– Mount a point-type exciter for circular waves at the end of rail **(i)** as shown in Fig. 3.

Carrying out the experiment

***Doppler* effect where $u < v$:**

– 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).

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

– Move the exciter back and forth along rail **(i)** at an even rate. Observe the edge of the observation screen.

– Observe the wavelengths in front of and behind the exciter as well as perpendicular to the direction of travel of the exciter.

– Repeat the experiment steps with a stroboscope. To do this, 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.

***Doppler* effect with $u > v$:**

– Move the holder of the point-type exciter back and forth along rail **(i)** and increase the velocity u of the exciter until you can observe a Mach cone.

Measuring example

Fig. 1 shows two photographs with measurement examples.

Results

***Doppler* effect with $u < v$:**

Due to the motion of the exciter, the stationary observer no longer observes the waves as propagating concentrically. The wave fronts in front of the exciter are compressed, while those behind it are spread out. An observer in front of the exciter perceives a shortened wavelength, while an observer behind the exciter notes an extended wavelength (see Fig. 4).

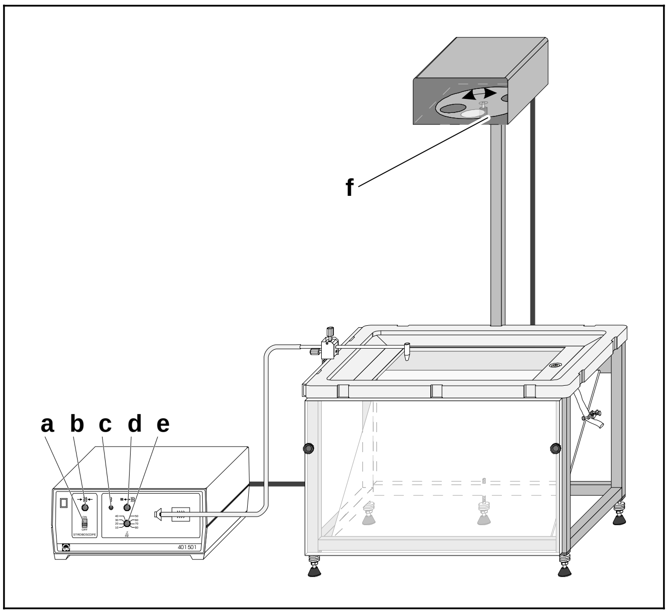
***Doppler* effect with $u > v$:**

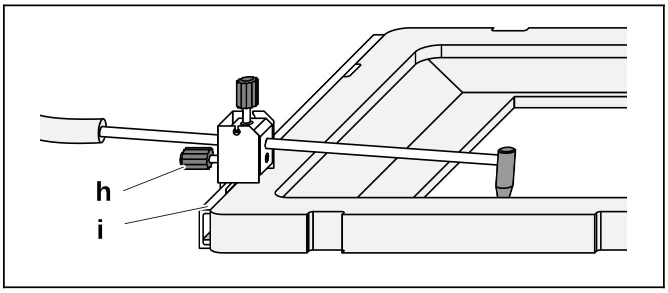
If the velocity of the exciter exceeds the propagation velocity v, the exciter moves ahead of the wave fronts. The wave fronts have a common envelope, and the exciter is at its peak (see Fig. 4). The angle of this cone decreases as the exciter velocity increases.

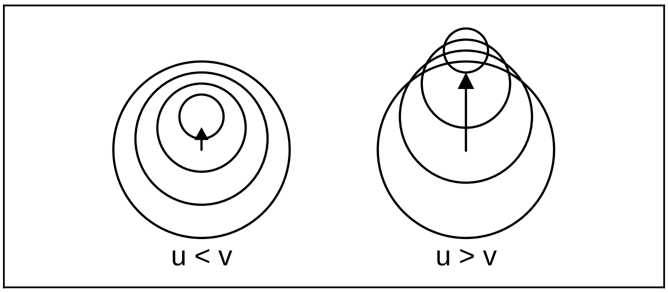
Fig. 2 Experiment setup for *Doppler* effect
a Stroboscope switch
b Knob (for fine adjustment of stroboscope frequency)
c Pushbutton (single-wave excitation)
d Knob (for adjusting amplitude of wave excitation)
e Knob (for adjusting frequency of wave excitation)
f Knurled screw (for manually turning stroboscope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

Fig. 3 Connecting the point-type exciter
h Adjusting screw (for setting immersion depth)
i Rail for mounting the point-type exciter

Fig. 4 Diagram of Doppler effect at various velocities u of the wave exciter







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