OPTIKA® SCIENCE ITALY

Didactic guide Ver. 1.1.2

Cod. 3032
RIPPLE TANK

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INTRODUCTION

To observe mechanical-undulatory phenomena, it will be necessary:a perturbation generator and an elastic medium of propagation. The velocity propagation of elastic wave depends on physical characteristics of the propagation medium that could be solid, liquid or a gas. If its physical characteristics are the same in all its points, i.e. it is an isotropic medium, the velocity is constant in all directions, so in this case the motion is uniform. Keep in mind that whatever will be the medium, matter is not carried away by elastic waves; only quantity of motion and energy are transmitted by perturbation generator.
Every time a wave runs into a obstacle, or changes propagation medium, some phenomena will occur. Every phenomena are the same for every wave types. These phenomena can be visualized using waves that spread on water surface. You can use the ripple tank.
Ripple tank has the following advantages: simple to assemble, easy of carry out the experiments, reliable and repeatable results and an excellent visual resolution of the wave front.
The stroboscopic lamp is fitted with an extra-bright 3W LED, which is synchronised with the surface-wave generator.
The control unit is equipped with a digital display and allows to set or stop the synchronism of the vibrator with the lamp, to set also the modulation of wave amplitude and its frequency.
The vibrator is electro-dynamic type.
The tank is provided with two adjustable feet and with an ease-to-use drain pipe consisting of a piece of flexible plastic tube ending with a turncock.

PRACTICABLE EXPERIMENTS

1. Superficial waves on water
2. Wavefront
3. Wavelength
4. Propagation velocity
5. Reflection
6. Refraction
7. Interference
8. Standing waves
9. Diffraction
10. Huygens principle

Number of praticable experiments: 15

WARNING: prolonged use of the apparatus involves a heating of the wave generator. Turn the device off at the end of each experience.

This product complies with standard IEC 60335-1.

COMPONENTS TO MOUNT RIPPLE TANK

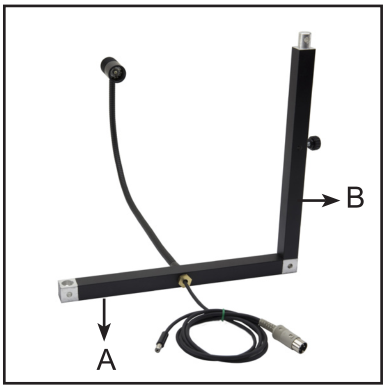
Fig. 1

Description

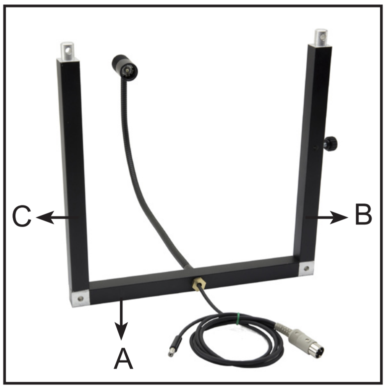
A metal crossbar with LED
B metal crossbar with handwheel
C lateral metal crossbar
D lock metal crossbar
E bar with adjustable feet
F fixing screw
G allen key
H screen
I tank
L drain pipe
M mirror
N vibrator
O wave generator
P power supply

HOW TO ASSEMBLE

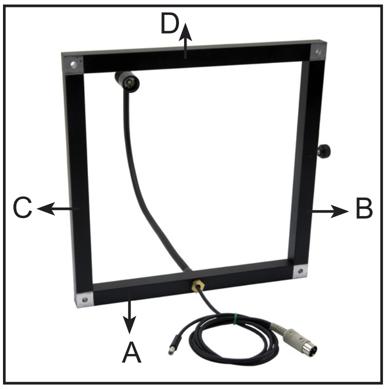
Below is described how to assemble the ripple tank, step by step (figure 2).



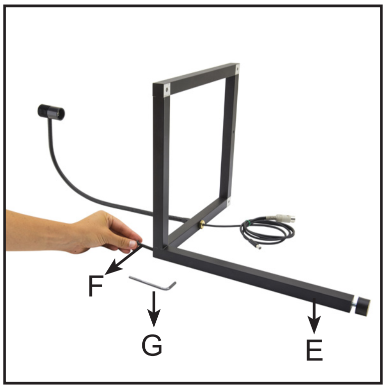
1° Insert crossbar B in A



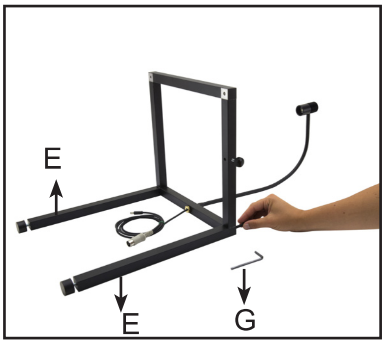
2° Insert crossbar C in A



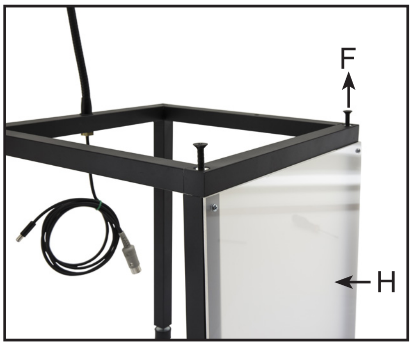
3° Insert crossbar D in B and C



4° Fasten with screw the first bar E



5° Fasten with screw the second bar E



6° Fasten with screw the screen H

7° Fasten with screw the tank I and the drain pipe L

8° Connect the vibrator N and the wave generator O

Fig. 2

COMPONENTS

The required components for the execution of the experience are described in figure 3.

Description

1. Dipper for parallel waves
2. Single Dipper
3. Double Dipper
4. Long barrier
5. Curved barrier
6. Trapezoidal body
7. Convex body
8. Concavo body
9. Couple of barrier for diffraction
10. Central barrier for diffraction
11. Ruler
12. Opaque body
13. Silicone grease
14. Plastic wash bottle

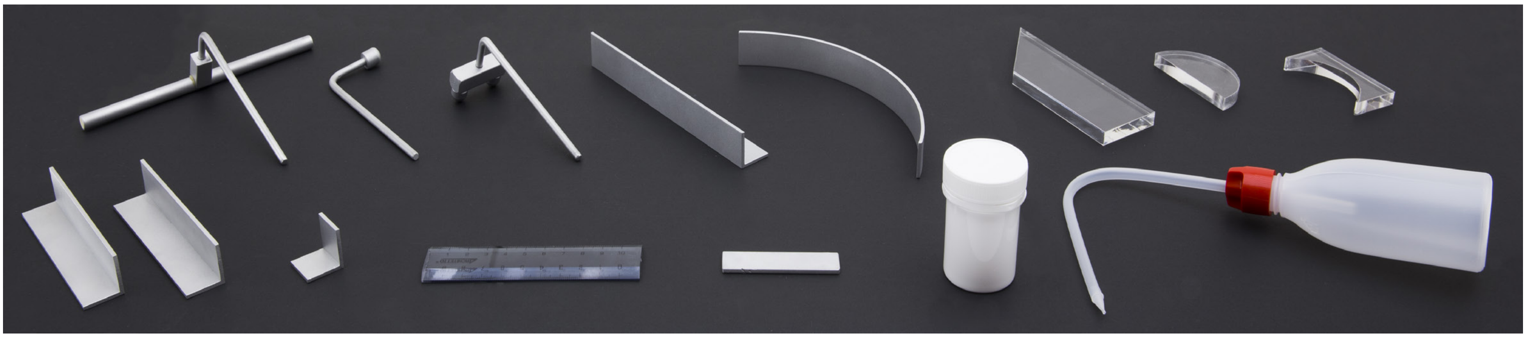


Fig. 3

Advices

1. Set the LED at the tank centre.
2. Put the drain pipe into the nozzle. Take care that the turncock is closed.
3. Fill the tank with 600 cm^3 of water, preferably distilled (about 1 cm height).
4. Before starting with any experiment, spread some silicone grease on dippers and bodies.
5. When you have finished, open the drain pipe and empty the tank.
6. Keep always clean tank bottom, taking care not to scratch it.
7. Do experiences in a dimly lit room
8. For cleaning tank, mirror and plexiglas bodies, use a wad of cotton, or a cloth extremely soft, alcohol moistened.

1° SUPERFICIAL WAVES ON WATER

Surface waves on water are two-dimensional type.
They don't behave like normal compression waves because molecules on water surface are affected by upward forces that are much weaker than those downward. Upward forces are caused by the air nature instead downward forces are caused by water nature. The water density is bigger than the air density.
Consequently superficial waves on water are a combination of transverse waves and longitudinal waves.
The variables that distinguish a periodic wave are:

Amplitude (A): is the maximum absolute value of the signal;
Period (T): is the duration of a complete oscillation and it is measured in seconds (s);
Source frequency (f): represents the number of cycles per second and is measured in Hertz (Hz);
Wavelength (λ): is the minimum distance between points that vibrate in phase and it is measured in meters (m);
Propagation velocity (v): depends on the properties of the propagation medium and it is measured in m / s;
Wave front: the set of points that, at a given instant, oscillate in phase.
Period and frequency are linked to each other thanks to the following relationship:

$$f = \frac{1}{T}$$

Frequency, wavelength and propagation velocity are linked to each other thanks to this relation:

$$\lambda = \frac{v}{f}$$

2° WAVEFRONT

EXPERIMENT NO. 1 : circular frontwave
Required material: 1 ripple tank, 1 single dipper (2).

Pour water into the tank until it reaches an height of about 1 cm. Put single dipper into the vibrator and fix it by tightening the hand wheel as shown in Figure 4.
Make sure that dipper tip just touches the surface of the water.
Regulate the vibration frequency between 30 Hz and 40 Hz and the vibration amplitude in order to obtain an image as possible sharp. You will observe that the water surface is the venue of circular waves which propagate from the center to the periphery. If you want to get a static wave configuration, set the synchronism between vibrator and light generator in ***"on"*** mode. If the picture is not completely stopped, act on frequency and amplitude command, as in Figure 5.

Fig. 4

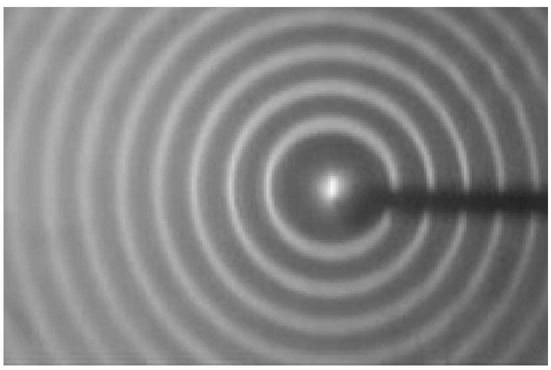


Fig. 5

Clean circles correspond to maximum amplitude; dark areas correspond to the minimum.

EXPERIMENT NO. 2 : plane frontwave
Required material: 1 ripple tank, 1 dipper for parallel waves (1).

Repeat the previous experience replacing the single dipper with the dipper for parallel waves, as is shown in Figure 6. You will observe that the water surface is the venue of waves whose front is plane. (Fig. 7).

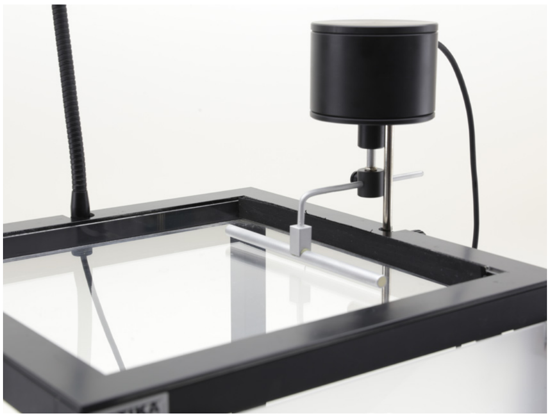


Fig. 6

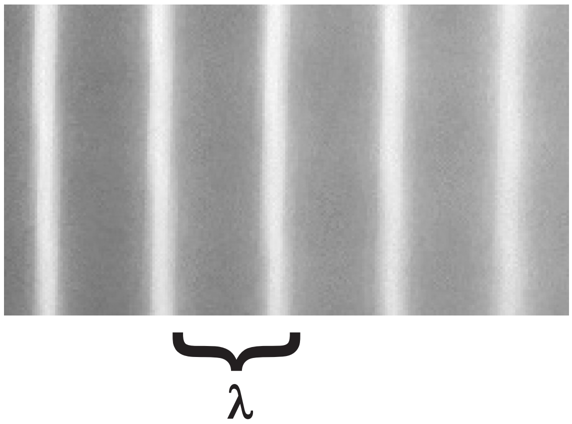


Fig. 7

3° WAVELENGTH

EXPERIMENT NO. 3 : how to measure wavelength
Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 opaque body (12).

Repeat the experience No 2: put the opaque body - 6 cm long - (12) on the bottom of the tank, so that the beginning of the opaque body coincides with the edge of a clear line.
Take note of the number ***"n"*** of wavelengths contained in the length of the opaque body. (Fig. 8).
You can determine the wavelength with the following relation

$$\lambda = \frac{d}{n}$$

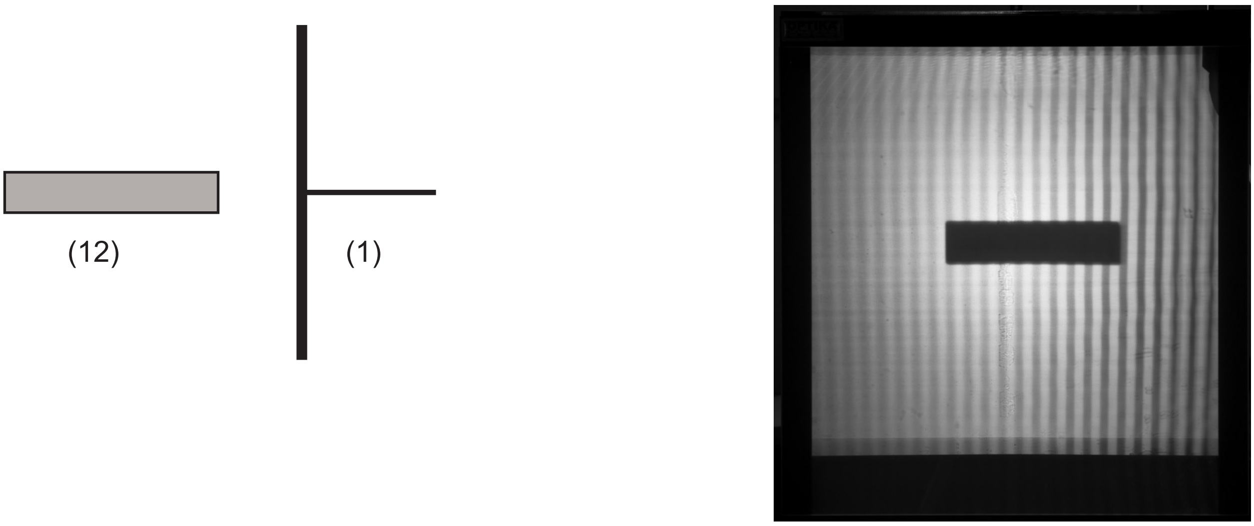


Fig. 8

4° PROPAGATION VELOCITY

Once determined the wavelength, thanks to experience no. 3, you can evaluate propagation velocity of surface waves on the water, using this formula

$$v = \lambda f$$

where f is the frequency of the wave generator. Theory shows that velocity propagation of waves on water surface is proportional to the square root of the water depth.

EXPERIMENT NO. 4 : waves velocity propagation on water surface depends on the water depth.
Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 trapezoidal body (6).

Check that the water is 1cm deep. Then repeat the experiment no. 2, putting on the tank bottom the trapezoidal body (6), as shown in Figure 9. Where the body is placed, water has shallowest depht so waves velocity is lower and the wavelength is shorter. (Fig. 10)
To make sure that this variation is evident, it should be better slowly release water by opening slightly the drain pipe until the water depth on the body is about 1 mm.

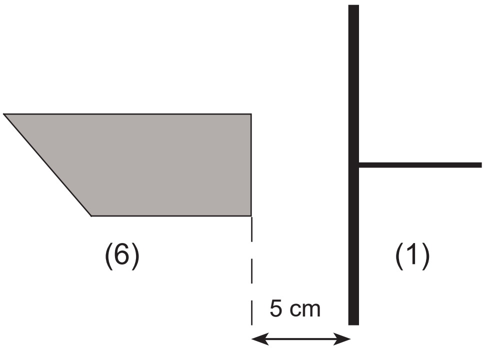


Fig. 9

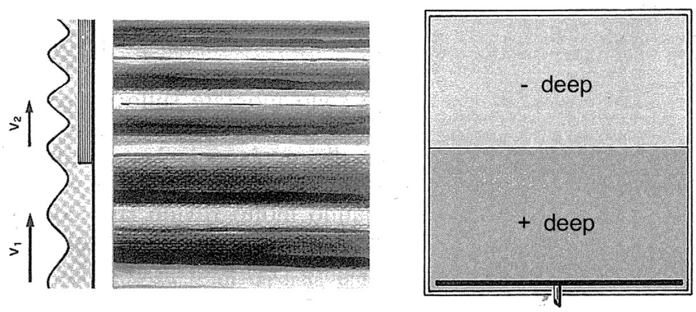


Fig. 10

5° REFLECTION

If along the wave path there is a rigid obstacle, you'll observe reflection phenomenon.
We must distinguish two cases, when the obstacle is flat and when the obstacle is curved.

EXPERIMENT NO. 5 : when we use long barrier
Required material: 1 tank, 1 dipper for parallel waves (1), 1 single dipper (2), 1 long barrier (4).

This phenomenon is shown schematically in Figure 11. To achieve this result, apply the dipper for parallel waves to the vibrator and put the long barrier (4) in the tank, in an inclined position.
On the screen, you will observe the intersection of incident and reflected waves. (Fig. 12).

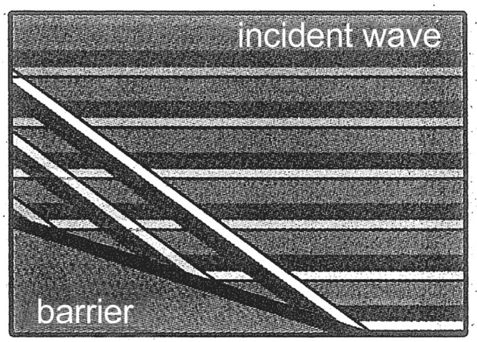


Fig. 11

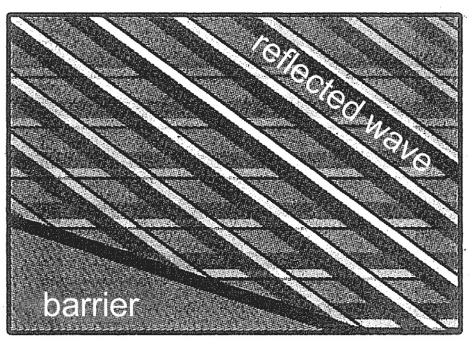


Fig. 12

Replace the dipper for parallel waves (1) with the single dipper (2).
Using this dipper you'll observe reflection of circular waves due to a plan obstacle.

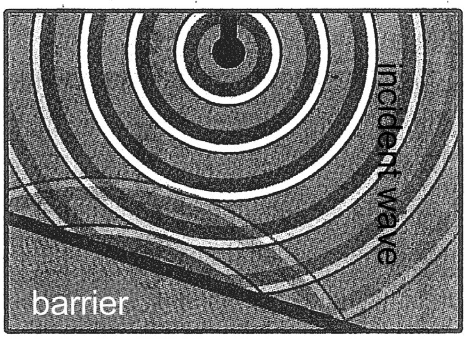


Fig. 13

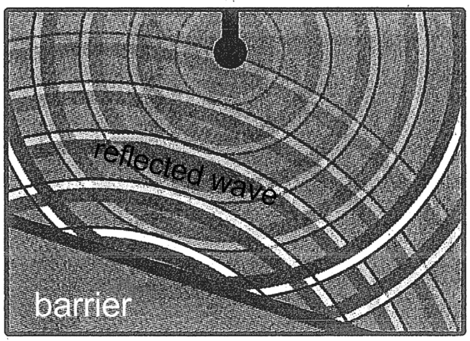


Fig. 14

Finally, a long barrier reflects the energy of the incident waves but it does not change the wavefront.

EXPERIMENT NO. 6 : when we use curved barrier
Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 single dipper (2), 1 curved barrier (5),

A curved barrier does not only reflect the energy of the incident wave, but it also changes the wavefront.
In the particular case in which the reflector is a curved barrier, a plane wave is transformed into a circular wave; parallel rays of the incident wave are concentrated in the focus of the barrier. (Fig 15).
You can observe this phenomenon using the dipper for parallel waves, placing the curved barrier (5) 10cm far from the dipper.

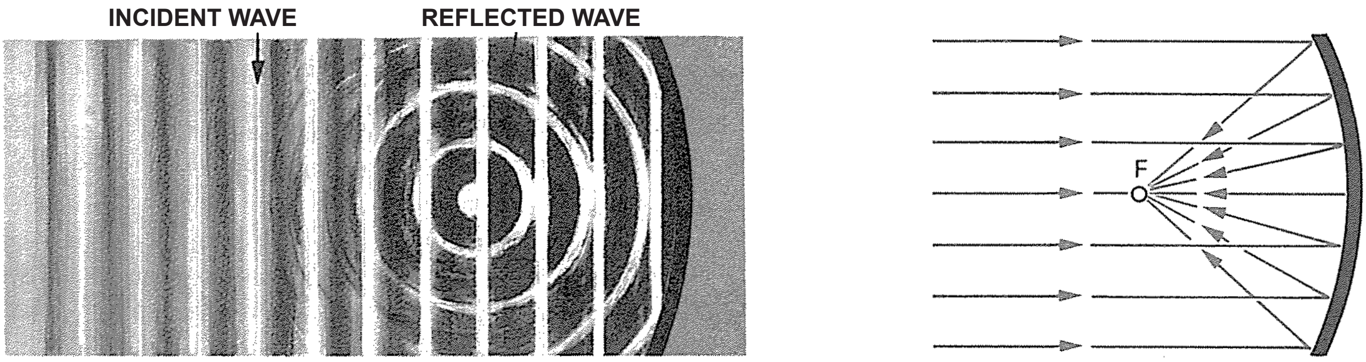


Fig. 15

6° REFRACTION

If the surface, between the areas at different speeds, is inclined with respect to the plane wave inclination, it occurs not only a variation of the wavelength but also a change in the direction of wave propagation.
You can observe this phenomenon with the following experience.

EXPERIMENT NO. 7 : when the separation surface is flat and inclined
Required material: ripple tank, dipper for parallel waves (1), trapezoidal body (6).

Arrange the trapezoidal body as shown in figure 16.

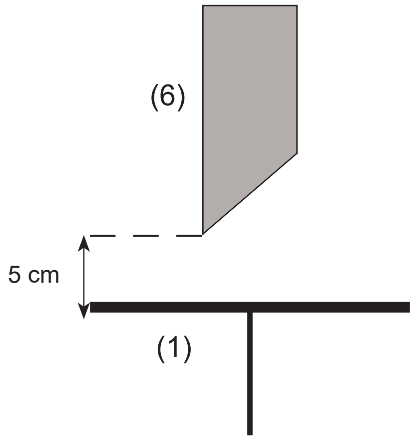


Fig. 16

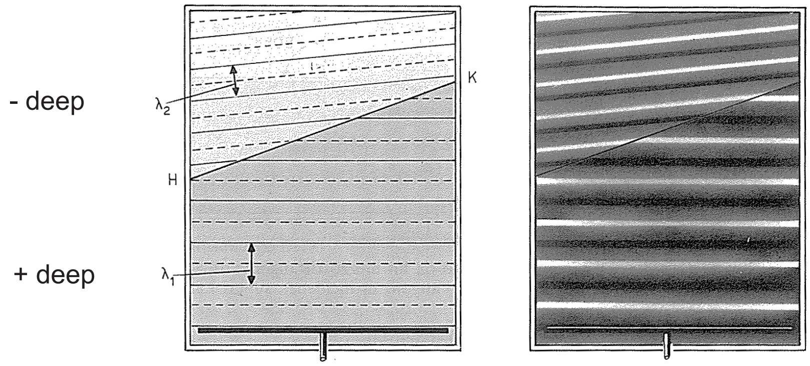


Fig. 17

In this case, the effects of the change in velocity are two: a decrease of the wavelength and a change in direction of refracted wave. This dual effect is shown in figure 17.
It can easily obtain by slowly lowering the water level, as in experience no. 4.

EXPERIMENT NO.8 : when the separation surface is convex
Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 convex body (7).

If the surface, which separates the two propagation media at different speeds, is curved, it is produced not only a variation of the wavelength but also a deformation of the wave front.
You can check it placing the convex body (7) as shown in Figure 18.
The resulting waves haven't a plane wave front but spherical one and they converge into the fire (Fig. 19).

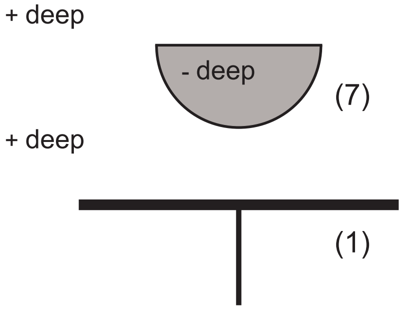


Fig. 18

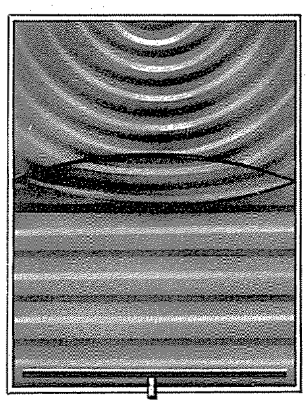


Fig. 19

EXPERIMENT NO.9 : when the separation surface is concave
Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 concave body (8).

Place the concave body (8) as shown in figure 20.
The resulting wave has spherical wave front and it is divergent. (Fig. 21).

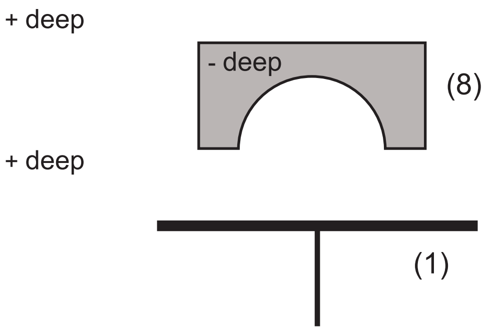


Fig. 20

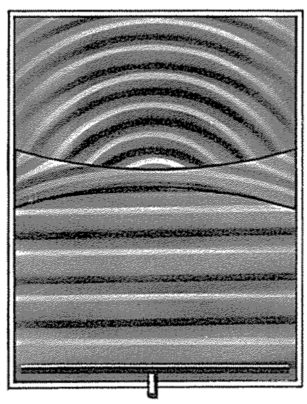


Fig. 21

7° INTERFERENCE

According to the ***superposition principle***, the elongation of the propagation medium in a point, where the two waves overlap, is equal to the sum vector of the elongations due to each wave.
If the elongations take place in the same plane, the resulting elongation is the algebraic sum of those components.
These elongations can have amplitude, wavelength and different phases, for this reason it is difficult to evaluate the characteristics of the wave resulting.
More simple is the case where the two sources have the same frequency, and no phase shift during all phenomenon duration; they are coherent sources.

EXPERIMENT NO.10 : when the sources are point-like and vibrate in phase
Required material: 1 ripple tank, 1 double dipper (3).

Check that the water depth in the tank is about 1cm. Then insert double dipper in the vibrator, as shown in Figure 22. Adjust the frequency to a value between 30 and 40 Hz. Observing the image that appears on the screen, you can clearly see that there are directions along which the resulting wave has maximum amplitude (***constructive interference***) and other along which its amplitude is minimum (***destructive interference***). (Fig. 23).

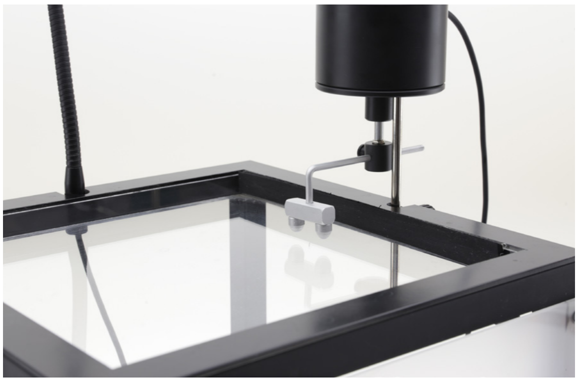


Fig. 22

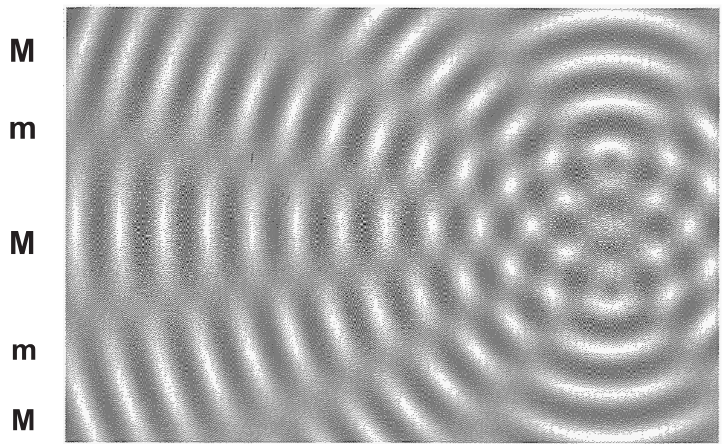


Fig. 23

We observe maximum amplitude in points where the difference Δx between the distance from the two sources is an even multiple of half of wavelength λ; we observe the minimum in points where such difference is an odd multiple of half wavelength. That is,

maximum amplitude (M) $\quad \Delta x = 2n \dfrac{\lambda}{2} \quad$ per n = 0; 1; 2; ......

minimum amplitude (m) $\quad \Delta x = (2n+1) \dfrac{\lambda}{2} \quad$ per n = 0; 1; 2; ......

8° STANDING WAVES

A particular case of wave interference is the phenomenon of standing waves. It occurs when, two coherent waves having the same amplitude, are propagating in the opposite direction (Fig. 24). The superposition of these two waves makes that the resulting wave doesn't move, as there are points of the medium where the vibration amplitude is always maximum (**antinodes of vibration**) and others in which the amplitude is always zero (***nodes of vibration***) as shown in Figure 25.
Consequently, the wave energy is not propagated to all points of the medium, but it stands in some of them, which are the antinodes.

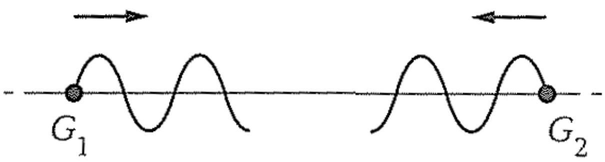


Fig. 24

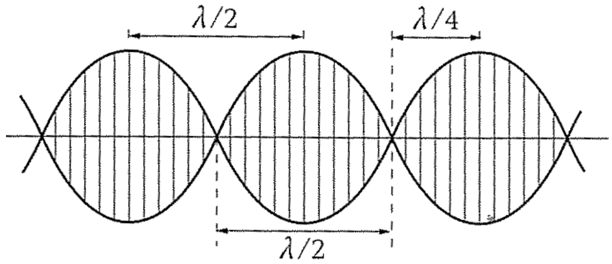


Fig. 25

The mathematical treatment of this phenomenon leads to the following important result: ***the distance between two antinodes or between two consecutive nodes is equal to a half wavelength, while the distance between an antinode and the next node is a quarter of a wavelength***.
An easy way to get standing waves is to catch a wave and its own wave reflected against an obstacle.
In this case the reflected wave undergoes a phase shift of 180 ° so that it is in phase opposition with respect to the wave incident.

EXPERIMENT NO. 11 interference between an incident wave and its reflected wave
Required material: 1 ripple tank, 1 long barrier (4), 1 ruler (11), 1 dipper for parallel waves (11).

Add water in the tank (about 1 cm), mount on the vibrator the dipper for parallel waves (1) and adjust the frequency to a value around 40 Hz. Stop the image and measure the wavelength λ. At this point, put the long barrier parallel to the vibrator, at a distance of 5-6 cm. (Fig. 26). *When you turn off the synchronism between the vibrator and the light source, on the screen you will see that the space between the dipper and the long barrier is seat of stationary waves;* waves that do not propagate as is shown in figure 27. Measure, with a ruler, the distance *d* between two light lines, between two antinodes, so you can verify that

$$d = \frac{\lambda}{2}$$

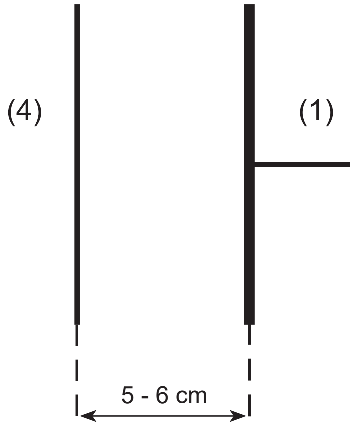


Fig. 26

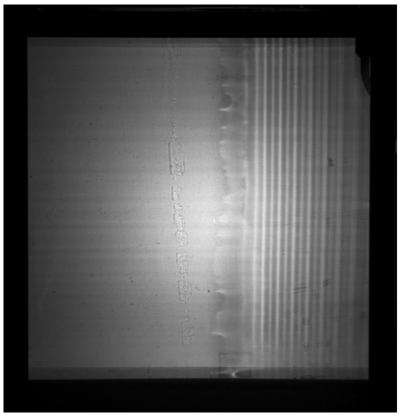


Fig. 27

9° DIFFRACTION

It is defined as "***diffraction***" the phenomenon that occurs each time a wavefront is intercepted by an obstacle that has a slit.
The wavefront that emerges from the slit, changes its shape depending on the relationship between the aperture size *L* and the wavelength λ.

EXPERIMENT NO. 12 when *L* > 4 λ
Required material: 1 ripple tank, 1 couple of barrier for diffraction (9), 1 ruler (11), 1 dipper for parallel waves (11).

Vibration frequency: 35 Hz, wavelength: about 0.7 cm.
Arrange the barriers 4 cm far from the dipper and make sure that they are 5 cm far from each other, as shown in Figure 28.
You will note that in correspondence of the central part of the slit, the wavefront is still plane, while at the borders there is a slight curvature; it occurs because the energy propagates also in directions that are not permitted by the barriers. (Fig. 29).

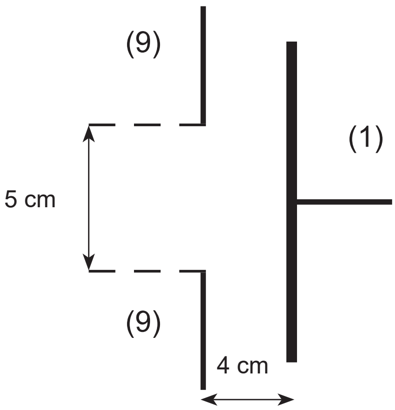


Fig. 28

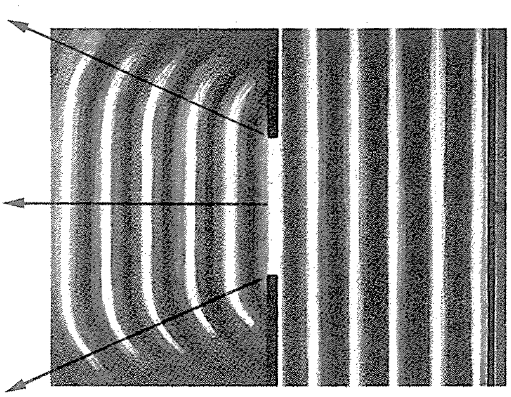


Fig. 29

EXPERIMENT NO. 13 when *L* ~ λ
Required material: 1 ripple tank, 1 couple of barrier for diffraction (9), 1 ruler (11), 1 dipper for parallel waves (11).

Repeat the previous experience, making sure that barriers are 1 cm far from each other. In this case we obtain an image like the one in Figure 30. This image clearly shows that, in correspondence of the opening, the plane wave is replaced by a spherical wave; the energy is propagated in all directions.
An explanation of diffraction phenomena is given by ***the principle of Huygens***, according to which any point of the propagation medium reached by the perturbation wave, whatever the form of the wave front becomes a source of spherical waves.
Consequently, any following surface wave can be considered as the envelope of the surfaces of the elementary waves generated by all the points of the preceding wave surface. (Fig. 31).

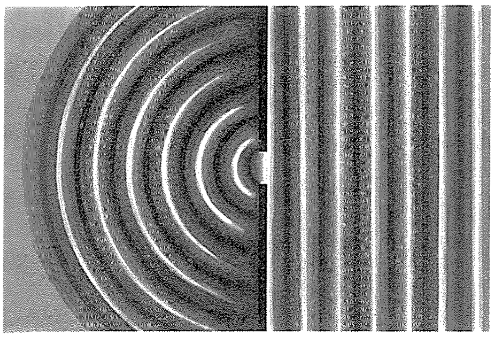


Fig. 30

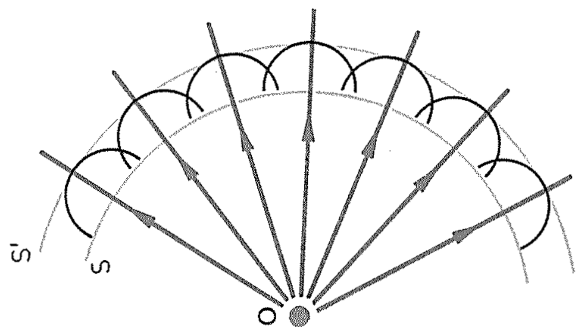


Fig. 31

10° HUYGENS PRINCIPLE

A verify of the Huygens principle is obtained by making two slits on a obstacle. If the width of the slits is comparable to the wavelength, each of them behaves like a point source of circular waves, giving rise to interference phenomena.

EXPERIMENT NO. 14

Required material: 1 ripple tank, 1 couple of barrier for diffraction (9), 1 dipper for parallel waves (1), 1 central barrier for diffraction (10).

After have put the dipper in the vibrator, arrange the three barriers as in figure 32, 4 cm far from the dipper. Vibration frequency: about 40 Hz.
Turned ***on*** the synchronism, gently change the amplitude and frequency to obtain a clear picture as the one in Figure 33.

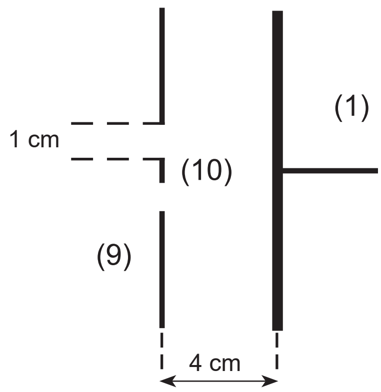


Fig. 32

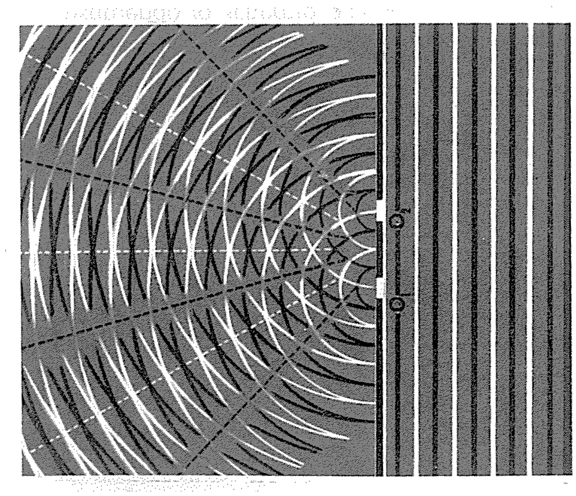


Fig. 33

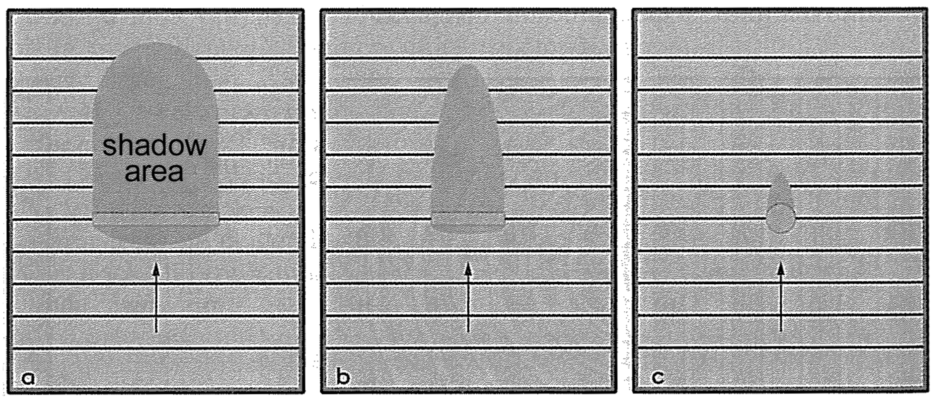
When the wavefront run across an obstacle without slits, the resulting shape of the wave depends on the ratio between the length of the obstacle and the wavelength λ .
If $l >> \lambda$ beyond the obstacle is formed a grey area fairly clear.
If $l > \lambda$ the grey area is rounded at the edges.
If $l \sim \lambda$ beyond the obstacle the grey area disappears almost immediately after the obstacle.
You can check these three situations with the following experience.

EXPERIMENT NO. 15

Required material: 1 ripple tank, 1 couple of barrier for diffraction (9), 1 dipper for parallel waves (1), 1 central barrier for diffraction (not included).

By using only one barrier of the pair, a central barrier for diffraction and a pencil you can view the previous three situations, as shown in Figure 34.

Fig. 34



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