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ITALY

Teaching guide Ver. 2.0.0

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

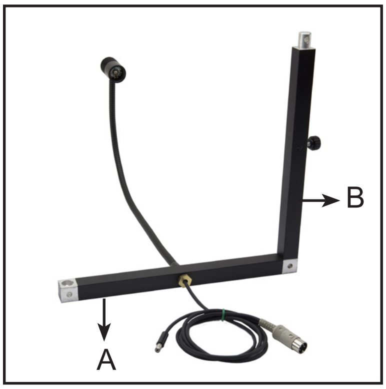
Fig. 1

Description

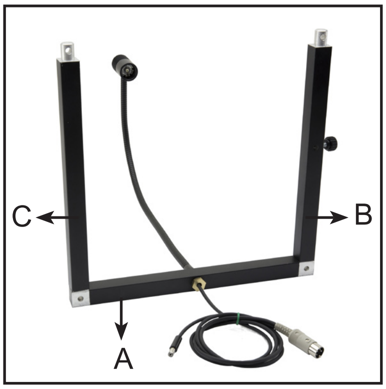
A metal crossbar with LED
B metal crossbar with handwheel
C lateral metal crossbar
D lock metal crossbar
E bar with adjustable feet
F fixing screw
G allen key
H screen
I tank
L drain pipe
M mirror
N vibrator
O wave generator
P power supply

HOW TO ASSEMBLE

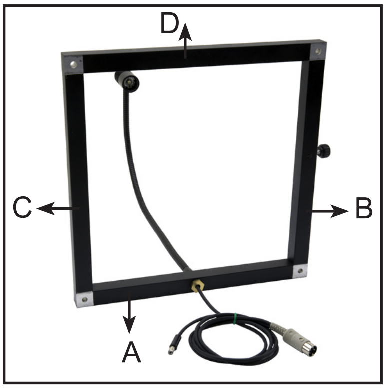
Below is described how to assemble the ripple tank, step by step (figure 2).



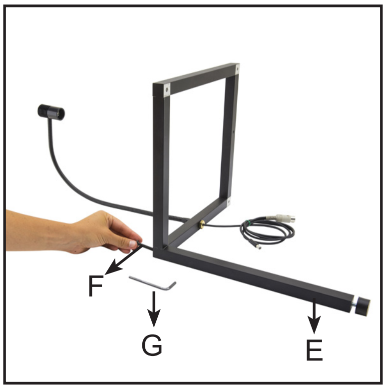
1° Insert crossbar B in A



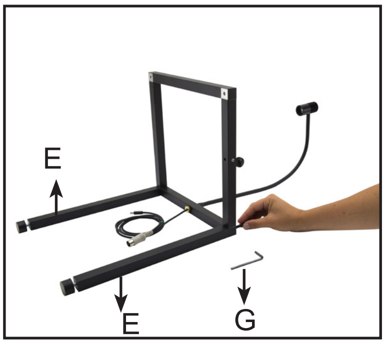
2° Insert crossbar C in A



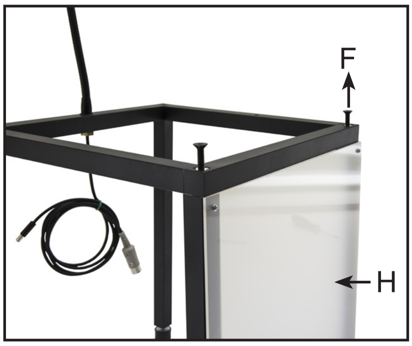
3° Insert crossbar D in B and C



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

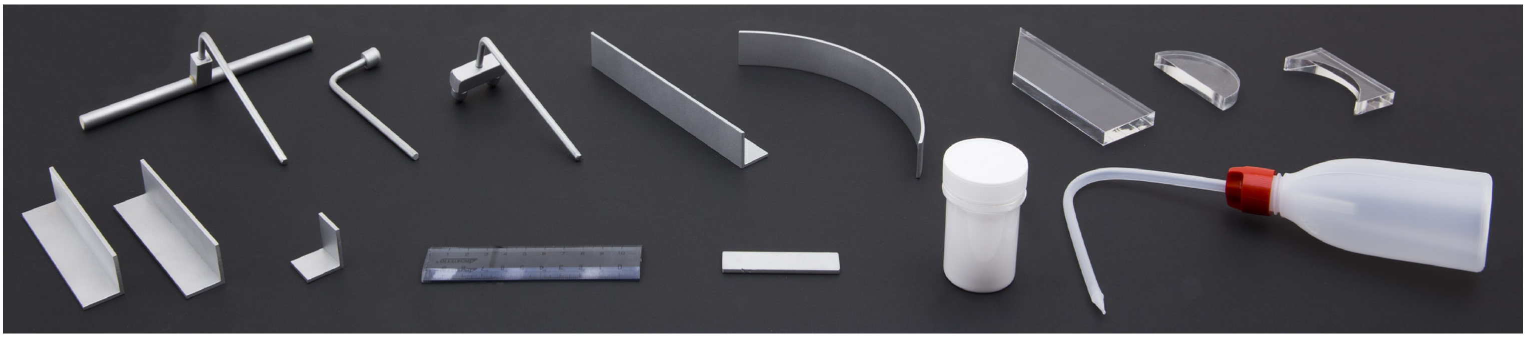
COMPONENTS

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. Concave body
9. Couple of barrier for diffraction
10. Central barrier for diffraction
11. Ruler
12. Opaque body
13. Silicone grease
14. Plastic wash bottle

1 2 3 4 5 6 7 8



9 10 11 12 13 14

Fig. 3

Advices

1. Place the ripple tank on a stable and flat surface; use the screws on the feet (E) so that the instrument is completely horizontal, to avoid unwanted reflections.
2. Place the projector at the centre of the tank.
3. Thread the water discharge tube into the nozzle in the tank and check that the tap is turned off.
4. Pour water (about 600 cm^3), preferably distilled, into the tank for a height of about 1 cm.
5. Before each experience, spread a very thin layer of silicone grease on the parts of the vibrator in contact with water.
6. Perform experiences in a dimly lit environment.
7. After you have completed your experiences, insert the drain tube into the glass and open the tap until complete emptying; then press on the rubber wall by dabbing it and help yourself with the spray to remove the last remaining water.
8. Always keep the bottom of the tray and the mirror clean, being careful not to scratch them.
9. To clean the tray, the mirror and the Plexiglas components, use a pad of cotton wool, or an extremely soft cloth soaked in alcohol.

   Important: After use, remove the vibrator from the vibrator and the vibrator from the holder.

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 wavefront

Required material: 1 ripple tank; 1 single dipper (2).

Pour water into the tray up to a 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 the tip of the dipper just touches the surface of the water.
Adjust the frequency and amplitude of the vibration to obtain the sharpest image.
You will see that on the surface of the water there are circular waves that propagate from the center to the periphery.
If you want to get a static wave configuration, set the synchronism between vibrator and light generator to ***on*** mode. If the image is not completely stationary, gently adjust the frequency and amplitude controls until you get a perfect stationary image, as in figure 5.
Contrary to what you might think, the light circles correspond to the minimum amplitude and the dark ones to the maximums. Can you tell why?

Fig. 4

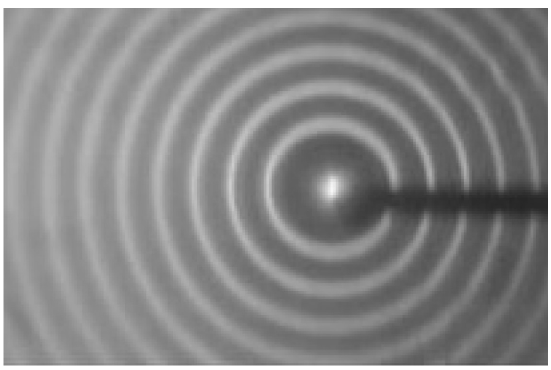


Fig. 5

EXPERIMENT NO. 2: Plane wavefront

Required material: 1 ripple tank, 1 dipper for parallel waves (1).

Repeat the previous experience by replacing the single dipper with the dipper for parallel waves, as shown in figure 6. You will see that the surface of the water is venue of waves whose front is flat (fig. 7).

Fig. 6

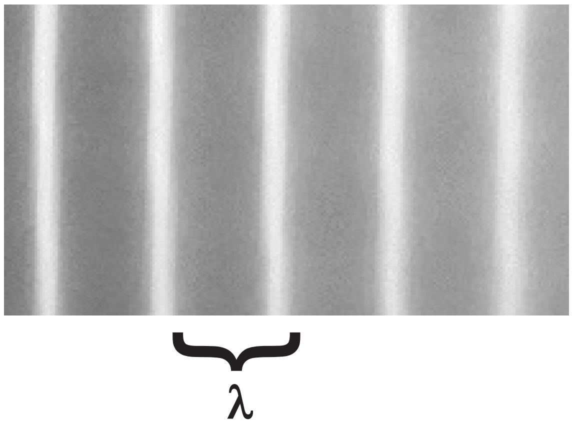


Fig. 7

3° WAVELENGTH

EXPERIMENT NO. 3: The measure of wavelength

Required material: 1 ripple tank, 1 dipper for parallel waves (1); 1 opaque body (12).

Repeat experience No. 2 by placing the 6 cm long opaque body (12) on the bottom of the tank.
Make sure that the beginning of the opaque body coincides with the edge of a clear line. Make a note of the number n of wavelengths contained in the length d of the opaque body (fig. 8).
You can then determine the wavelength with the following relation:

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

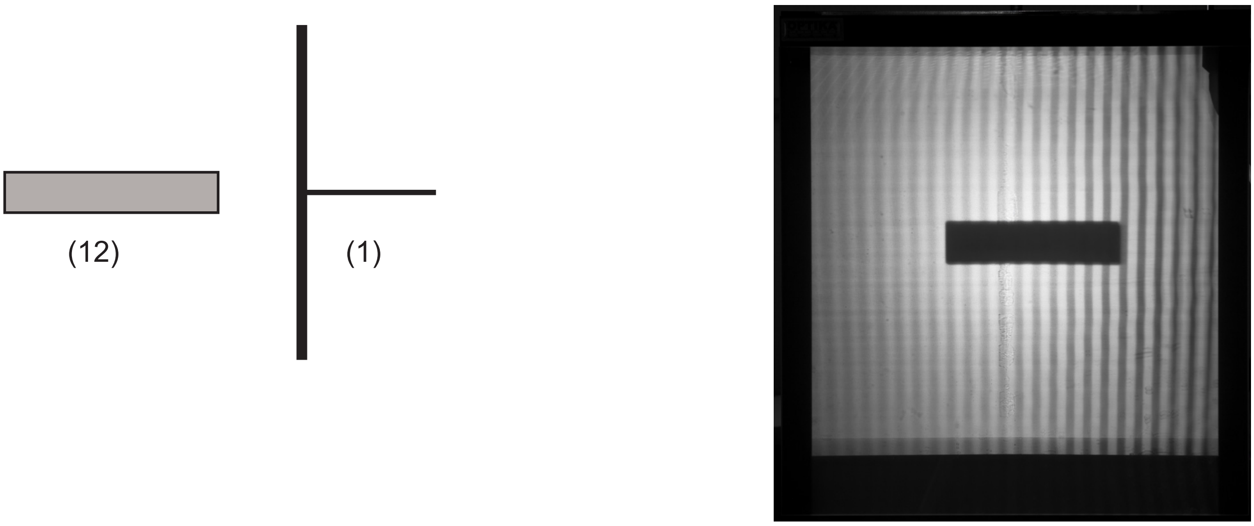


Fig. 8

4° PROPAGATION VELOCITY

Once you have determined the wavelength l by experience No. 3, you can evaluate the speed of propagation of surface waves in water by the following relation:

$$v = \lambda f \quad (1)$$

where f is the frequency of the wave generator. The theory shows that, if the water level is shallow (i.e. less than the wavelength), the speed at which surface waves propagate in the water is proportional to the square root of the depth and, in particular:

$$v = (g \cdot h)^{1/2} \quad (2)$$

To verify that you are in shallow water condition, measure the height of the water in the tank and compare the speed values obtained with (1) and (2) respectively. Within the experimental errors, you should get the same values.

EXPERIMENT NO. 4: The propagation velocity 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 depth is 1 cm. Then repeat experience No. 2, but place the trapezoidal body (6) on the bottom of the tank, in the position shown in figure 9. Where the body is placed, the water is shallower, so the speed of the waves is lower and, according to (1), 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.

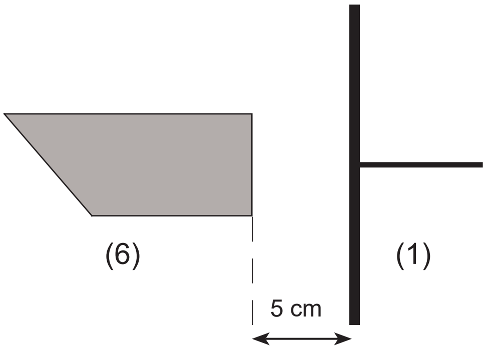


Fig. 9

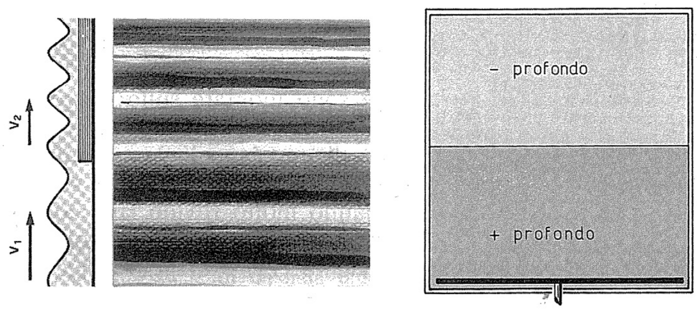


Fig. 10

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: Reflection with long barrier

Required material: 1 ripple 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).

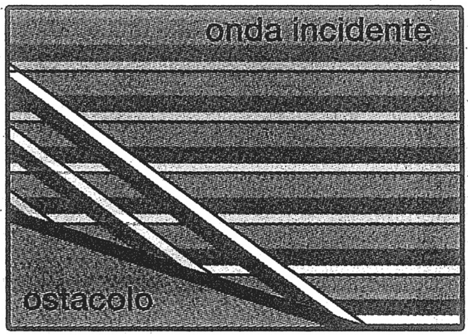


Fig. 11

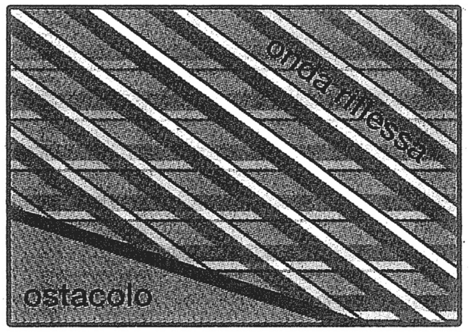


Fig. 12

Replace the flat dipper with the single dipper. This way, you can reflect circular waves on a plane obstacle. The scheme of this phenomenon is shown in figure 13, while figure 14 shows what appears on the screen.

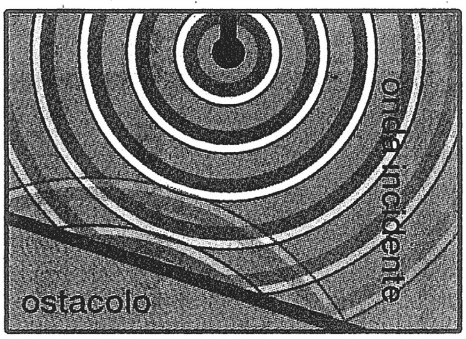


Fig. 13

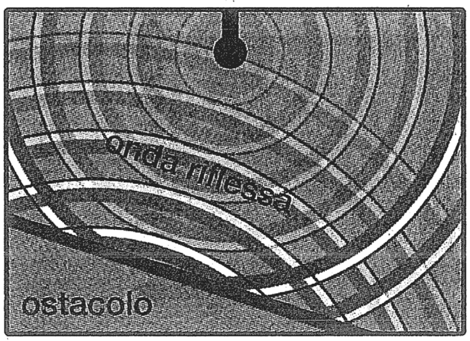


Fig. 14

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

EXPERIMENT NO. 6: Reflection with curved barrier

Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 single dipper (2), 1 curved barrier (5).

Unlike the flat reflector, the curved reflector does not only reflect the energy of the incident wave, but it also modifies the wavefront.
In the particular case where the reflector is a circular sector, a flat wave is transformed into a circular wave. The parallel rays of the incident wave are concentrated in the focus of the reflector (fig. 15).
You can observe this phenomenon by using the flat dipper and placing the curved barrier (5) at a distance of about 10 cm.

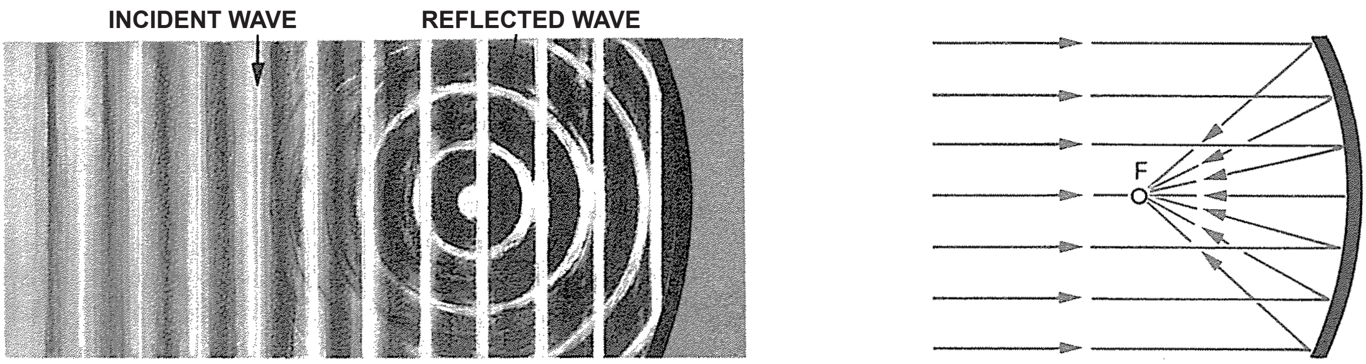


Fig. 15

6° REFRACTION

If the surface between the areas at different speeds is inclined with respect to the plane wave direction, 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: Refraction through a flat and inclined separation surface

Required material: ripple tank, dipper for parallel waves (1), trapezoidal body (6).

This is a repetition of experience No. 4; the only variant is that the trapezoidal body must be arranged as shown in figure 16. To reduce the effects of surface tension, we recommend adding a few drops of hand soap (not supplied) and dissolve it in the water being careful not to create foam.

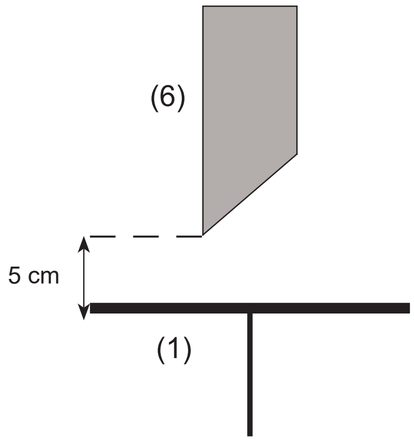


Fig. 16

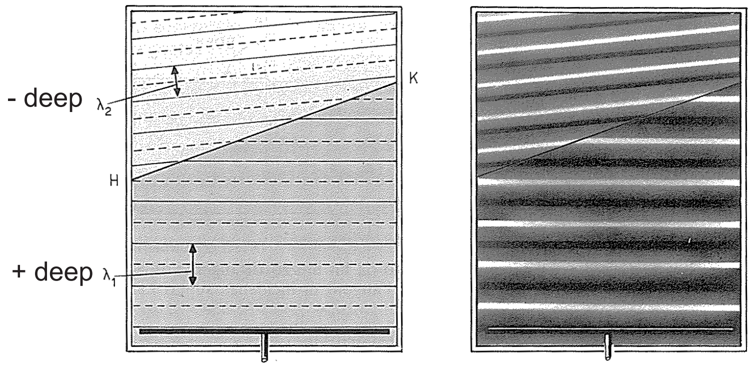


Fig. 17

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 : Refraction through a convex separation surface

Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 convex body (7).

When the surface separating the two media at different propagation speeds is curved, in addition to a change in wavelength, a deformation of the wavefront is also produced.
You can verify this by placing the convex plane body (7) as shown in figure 18. To reduce the effects of surface tension, we recommend adding a few drops of hand soap (not supplied) and dissolve it in the water; be careful not to create foam. The emerging wave is not flat but circular and converges in the focus of the lens (fig. 19). To observe the curvature of the wavefront it is necessary that the water level above the convex body is very low (less than 1 mm).

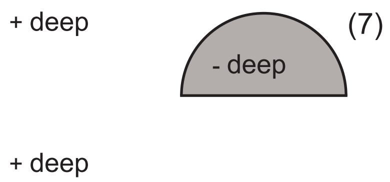


Fig. 18

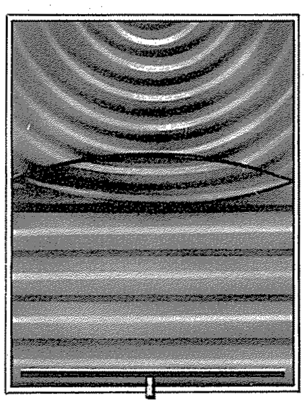


Fig. 19

For a better visualization of the phenomenon, insert the two barriers (9) between the source and the lens, such as shown in figure 18.1.

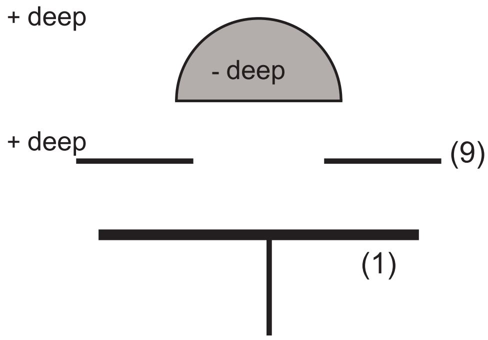


Fig. 18.1

EXPERIMENT NO.9: Refraction through a concave separation surface

Required material: 1 ripple tank, 1 dipper for parallel waves (1), 1 concave body (8).

Place the flat concave body (8) in the position shown in figure 20. To reduce the effects of surface tension, add a few drops of hand soap (not supplied) and dissolve it in water, being careful not to make foam.
The emerging wave is circular and divergent (fig. 21). To observe the curvature of the wavefront it is necessary that the water level above the convex body is very low (less than 1 mm).

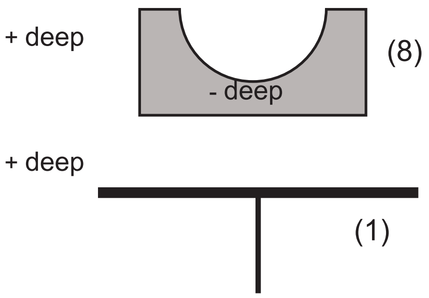


Fig. 20

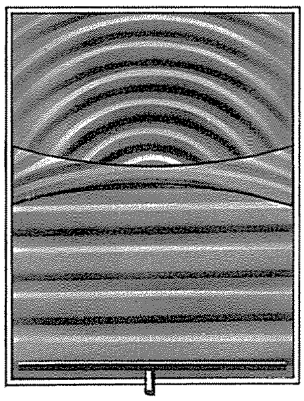


Fig. 21

Again, for a better visualization of the phenomenon, insert the two barriers (9) between the source and the lens, as shown in figure 20.1.

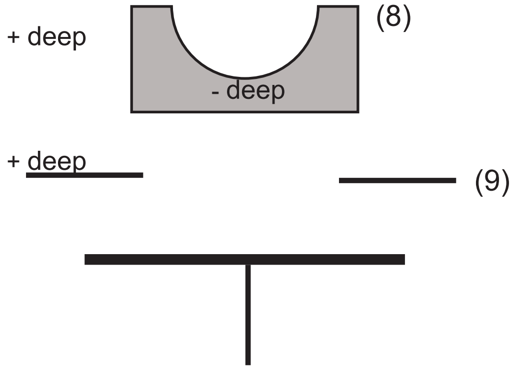


Fig. 20.1

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 vectorial sum of the elongations due to each wave.
If the elongations of the interfering waves occur in the same plane, the resulting elongation is the algebraic sum of the components.
These elongations can have different amplitudes, wavelengths and phases, for this reason it is difficult to evaluate the characteristics of the resulting wave.
Simpler is the case where the two sources have the same frequency, and no phase shift occurs; in this case we talk about coherent sources.

EXPERIMENT NO.10: Interference with two point sources in phase concordance

Required material: 1 ripple tank, 1 double dipper (3).

Check that the water depth in the tank is about 1 cm. Then insert the 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).

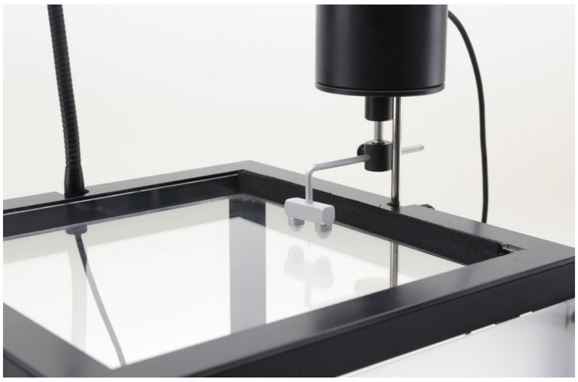


Fig. 22

M
m
M
m
M

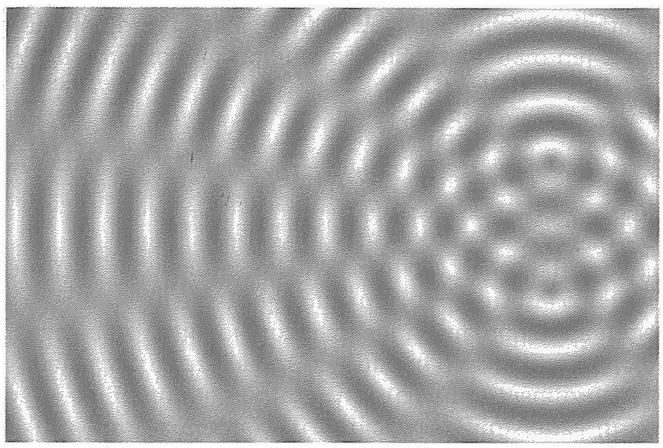


Fig. 23

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) $$\Delta x = 2n \frac{\lambda}{2} \quad \text{for } n = 0; 1; 2; \ldots$$

minimum amplitude (m) $$\Delta x = (2n + 1) \frac{\lambda}{2} \quad \text{for } n = 0; 1; 2; \ldots$$

8° STANDING WAVES

A particular case of wave interference is the phenomenon of standing waves. It occurs when two coherent waves of the same amplitude propagate in opposite directions (fig. 24). The superposition of these two waves makes the resulting wave stationary: 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 does not propagate to all points of the medium, but it stands in some of them, which are the antinodes.

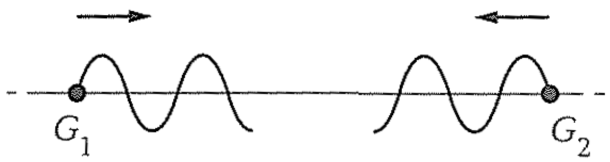


Fig. 24

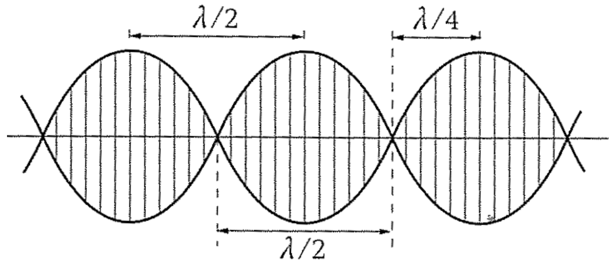


Fig. 25

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 make an interference between 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 incident wave.

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 dipper, 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 venue of stationary waves,* i.e. waves that do not propagate, as is shown in figure 27. Measure, with a ruler, the distance *d* between two light lines, cooresponding to two nodes; you can verify that:

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

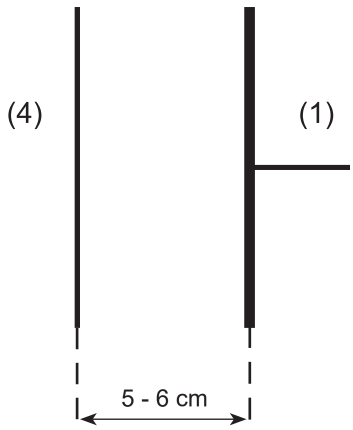


Fig. 26

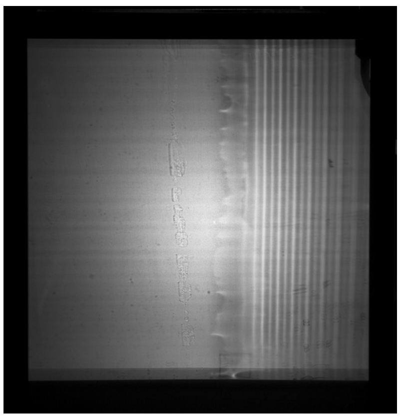


Fig. 27

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: The diffraction when $L > 4\lambda$

Required material: 1 ripple tank, 1 couple of barrier for diffraction (9), 1 ruler (11), 1 dipper for parallel waves (11).

Adjust the vibration frequency around 35 Hz; in this situation the wavelength is about 0.7 cm. Arrange the two barriers at a distance of 4 cm from the flat dipper and make sure that their distance is about 5 cm, as shown in figure 28.
You will notice that at the central part of the opening the wave front is still flat, while it has a slight curvature at the edges, demonstrating that the energy also propagates in directions not allowed by the barriers (fig. 29).

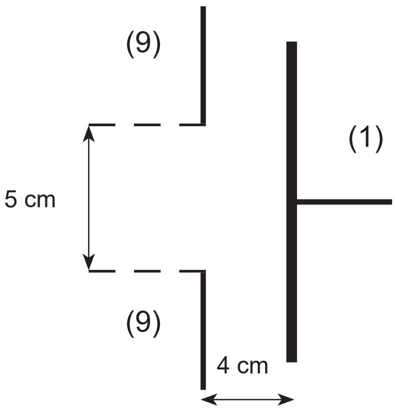


Fig. 28

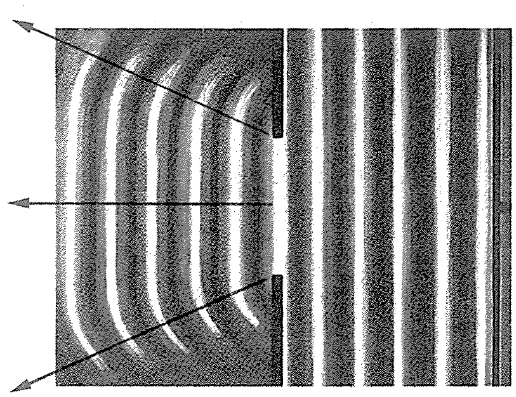


Fig. 29

EXPERIMENT NO. 13: The diffraction when $L \sim \lambda$

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 propagates in all directions.
An explanation of diffraction phenomena is given by ***the Huygens' principle***, according to which any point of the propagation medium is 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).

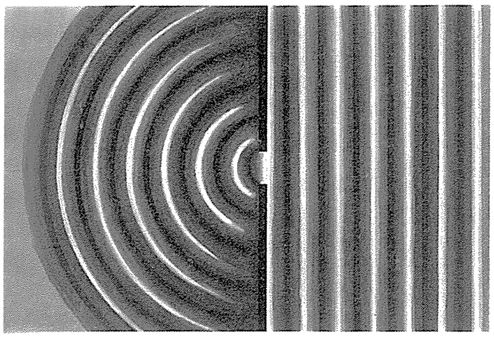


Fig. 30

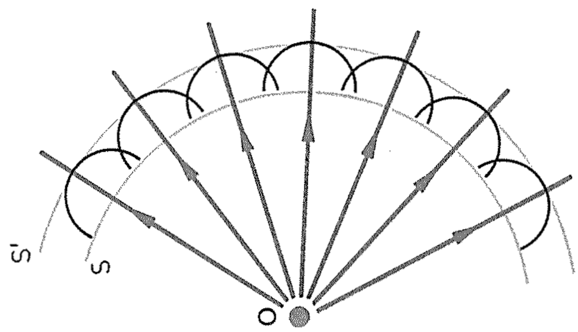


Fig. 31

10° HUYGENS' PRINCIPLE

A verify of the Huygens' principle is obtained by using an obstacle with two slits. 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: Huygens' Principle

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 having 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.

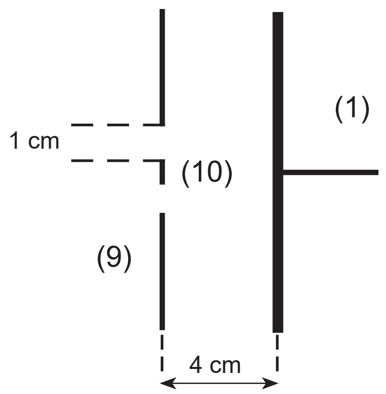


Fig. 32

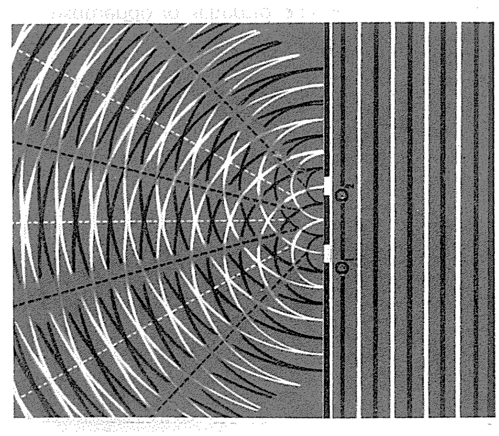


Fig. 33

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: The shadow zone

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

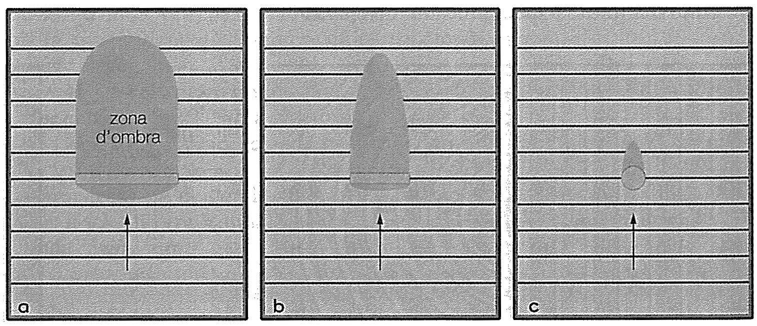


Fig. 34