

Surfing the waves

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Project summary

Ocean waves are oscillations generated by the wind. We will show how waves are classified, using a mini-simulator and software programs. We will then present the dynamics of waves at high sea and along the shoreline, and the seasonal characteristics of waves in the world's oceans.

Project report

INTRODUCTION

Throughout history, humans have had to conquer waves. Waves have always preoccupied sailors, fearful of storms, and harbour managers, who are responsible for protecting ships and dikes from the destructive force of the sea. Oceanographers monitor underwater seismic activity, which can produce tsunamis—the most devastating waves in the history of humanity. Although waves are a cause of great concern, they are also very useful. They are considered a formidable source of energy. Sophisticated engineering projects are exploring the possibility of using waves to generate electricity on a large scale. Closer to shore, waves are a source of pure joy for surfers, providing extreme challenges for athletes. We will begin by studying waves as a physical and geographical phenomenon: the different types of ocean waves and the physical characteristics that distinguish them. We will also describe the dynamics of windwaves. We will then show how surfers use the energy and shape of waves as they break. We will end by discussing tsunamis—an exceptional type of wave.

WAVES

1.1 What is a wave?

A wave is a periodic disturbance of the water's surface. It is an oscillation made up of a series of crests and troughs. Contrary to popular belief, it is not the water that is displaced, but the wave generated by the local oscillation of the water particles. It is, in fact, energy that is transferred from one place to another. Waves are therefore a displacement of energy, not matter. When a wave passes, the water rises to form the wave, then falls. We are under the impression that the water is being displaced, when it is really just rising and falling, creating an illusion of displacement. A boat or an object floating on the surface of the water is not displaced when a wave passes; it only oscillates locally. Bottles wash ashore as a result of the ocean currents and winds that move them along.

1.2 Energy-transporting waves

Since waves transport wind and other source of energy, studies have been done to convert ocean swells into electricity. Since this is a costly proposition, however, no such projects have yet been carried out.

1.3 Five wave characteristics

1. Wavelength The distance between two wave crests. In general, a wavelength ranges from 10 cm to 1.5 km. Some waves—tsunamis or tidal waves, for example—can measure up to 200 km.
2. Height The distance between a wave crest and trough.
3. Period The time, in seconds, between two successive wave crests. Windwaves generally have a period of 1 to 25 seconds. In the case of tsunamis, however, the wave period is greater than 25 seconds.
4. Celerity The velocity of propagation of waves. It is calculated by dividing the wavelength by the period (length divided by time).
5. Camber The bend or curve of the wave. It is determined mostly by the wind direction and the force on one side that produces the wave camber. It is calculated by dividing the height by the wavelength.

1.4 Three types of waves

a) Tides

Tides are 12- to 24-hour waves. The six-hour tides that we see from shore actually last a quarter tidal period. Tides are produced by a combination of astronomical forces on the oceans, which make up 70 percent of the Earth's surface. For example, the Moon orbits the Earth, exerting a force of attraction on the mass of the oceans. This mass is distorted depending on the position of the Moon with respect to the Earth. The gravitational force of the Sun and the Earth also contribute to the phenomenon of the tides.

b) Windwaves

Windwaves are very different from tides and have a period of approximately 1 to 20 seconds. They are generated mainly by the wind, but also by other meteorological factors such as pressure (P) and temperature (T). Since the wind is not constant and can blow in several directions, it creates disturbances at the ocean's surface, which propagate and merge to form waves.

c) Exceptional waves: tsunamis

Tsunamis are gigantic sea waves that transport massive amounts of energy. They are produced by the telluric forces of earthquakes.

1.5 The formation and propagation of windwaves in the ocean

Windwaves are produced at high sea, far from the coast. They travel hundreds of kilometres and break on shore. They can measure less than one metre high. During storms, however, they can reach heights of 20 m. Wave progression can be described in three stages: (1) genesis, (2) propagation, (3) break.

(1) Genesis

When the wind blows, it creates a disturbance at the surface of the water. Very tiny waves (ripples) are produced as a result of the wind's discontinuous pressure. Although irregular at first, these waves cumulate at some point, forming a regular wave known as a swell.

(2) Propagation

A swell is a regular wave that generally forms from several other waves. A swell can travel hundreds of kilometres. It can, for example, start in the Indian Ocean, travel around the Earth

via Antarctica, continue northward across the Pacific ocean and end up in Alaska, having travelled 20 000 km since it was first formed.

Wave height is determined mainly by the force of the wind, the amount of time the wind blows and the length of the body of water that the wave travels across. A swell can vary in wavelength, period and celerity. Waves of greater wavelength will reach the coast first, since the celerity (velocity) of waves is proportional to wavelength. Typically, a swell propagates at a speed of 15 m/sec. (or 54 km/hr.).

The movement of water particles

We have already described the oscillation of water. It is interesting to note that oscillating water particles do not move vertically, like a point on a string. They rotate in the shape of an ellipse. We can describe several levels of rotating ellipses, starting at the surface of the water down to a maximum depth of half a wavelength. Wave motion cannot be detected beyond this depth.

Characteristics of different types of waves			
Type of wave	Period	Wavelength	Propagation velocity
Ripple	0.5 sec.	0.4 m	0.8 m/sec.
Shoreline wave	3 sec.	15 m	20 m/sec.
Regular swell	10 sec.	150 m	15 m/sec.
Heavy swell	20 sec.	600 m	30 m/sec.

(3) Break

A swell nearing the coast has a depth that is less than half its wavelength. The ellipses are subject to considerable friction as they interact with the ocean floor, which slows down the water

particles. At the same time, the next wave arriving above the water particles speeds them up. Given this state of disequilibrium (slow on the bottom and fast on top), the wave breaks on the shore. This is the principle behind the majestic waves that surfers enjoy riding. The slowing of the swell as it approaches the coast produces higher waves (greater amplitude).

1.6 Waves throughout the world

With the exception of tides and tsunamis, waves are associated with meteorological phenomena. By looking at satellite images, we notice interesting correlations between the location of strong winds and the highest waves. Waves and storms are closely monitored by satellite, so that ship captains can be regularly notified. Since coastal populations are also vulnerable to damage caused by waves, they are notified of approaching storms by the coast guard.

CONCLUSION

Whether you love them or hate them, waves are physical phenomena that we have to deal with. Learning more about the dynamics of waves and how to better map them helps all users of the ocean: fishers, oil companies, commercial maritime transportation companies, tour boat operators, surfers, pleasure boaters, port administrators and the coast guard.