Marine Science Lesson Enhancements
based on **Grade 11 & 12 curriculum** in
Physics, Chemistry & Biology

Waves & Currents

Ocean Explorer

Module 3

Bayworld Centre for Research & Education

BCRE

Overview

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1 - Waves, Sounds and Light

In the case of a stadium wave, the medium through which the stadium wave travels is the fans that are in the stadium. The fans are the particles which interact with each other !

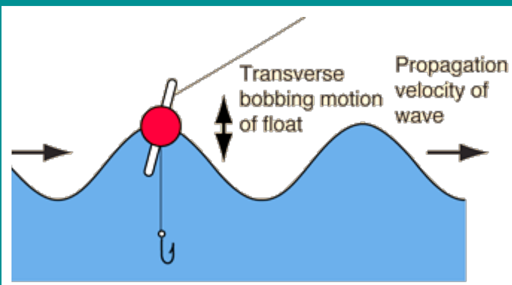
A wave is a repeating and periodic disturbance that travels through a medium from one location to another location. A pulse is a "once off" disturbance, it is not repeated.
A medium is a substance or material that carries the wave. It can be anything from water to metal. The medium is composed of parts that are capable of interacting with each other. The interactions of one particle of the medium with the next adjacent particle allow the disturbance to travel through the medium.

Waves transport energy

During a wave event, the individual particles of the medium are only temporarily displaced from their rest position. There is always a force acting upon the particles that restores them to their original position. In the water, it is the hydrogen bounds between molecules.
The difference between a waves phenomenon and any other type of force lies in the fact that molecules only transmit energy to their neighbour, which in return will transmit it to the next molecule, etc. A wave transports energy without transporting matter.

Info +

Light and sounds are waves. As such, they travel in the air just like sea waves in water. The same rules apply to the 3 types of waves.



Sea waves are seen to move through an ocean or lake ; yet the water always returns to its rest position. Energy is transported through the medium, but the water molecules are not transported. Proof of this is the fact that there is still water in the middle of the ocean. The water has not moved from the middle of the ocean to the shore !

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2 - Parts of a wave

There are 4 important parts used to describe a wave :

- **Crest :** The highest point of the wave.
- **Trough :** The lowest part of a wave found between two crests.
- **Wavelength :** The distance from one crest to the next crest.
- **Height or amplitude :** The height of a wave measured from the crest to the trough.

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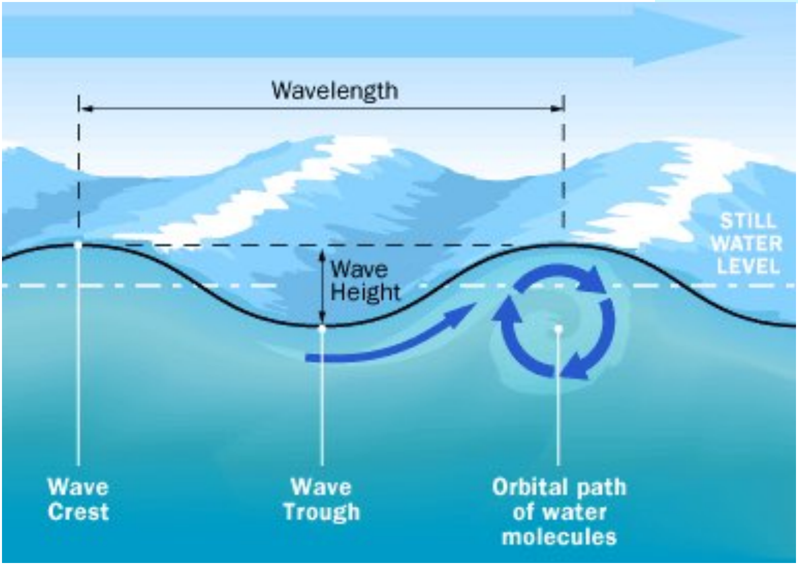
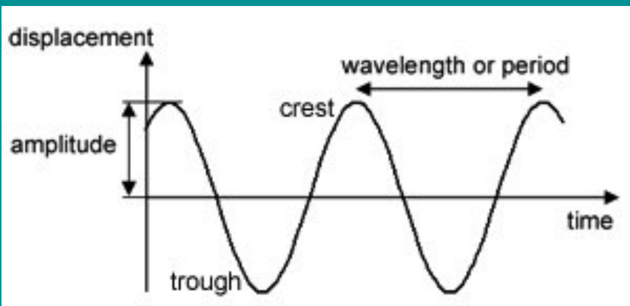
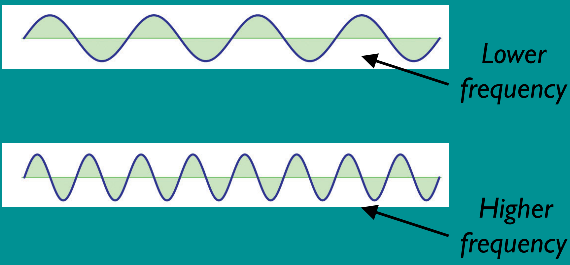
While normal waves have a wavelength around 100m, a Tsunami wave has a wavelength up to 200 kilometres long !





We use the same nomenclature for **light waves** and **sound waves.**

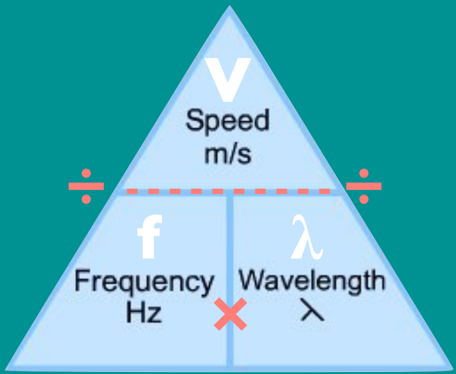
Frequency is the amount of wavelengths or periods per unit of time. It is calculated in **Hertz**.



$$Frequency = \frac{Velocity}{Wavelength}$$

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

$$Unit\ of\ Frequency: Hz$$



The formula triangle on the left helps you rearrange the formula. Simply cover the quantity that you are trying to work out, which leaves the other 2 components and their disposition !

What causes waves ?

The wind causes normal waves. When wind moves over the sea surface friction occurs between the moving air and the water. This causes a dragging action that creates waves.

The size of a wave is influenced by :

1. **The fetch** – the distance the wind blows over the water surface.
2. **The time wind blows** – the longer the wind has been blowing, the larger the wave will be.
3. **The strength of wind** – the stronger the wind, the larger the waves will be. Very strong winds can create storm surges in tropical cyclones.
4. **The direction of wind** – Wind that blows from the land to the sea blows in the opposite direction to the movement of the waves and makes the waves smaller.

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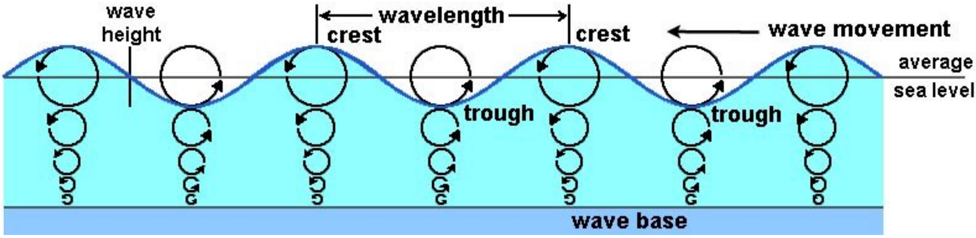
Oscillation waves

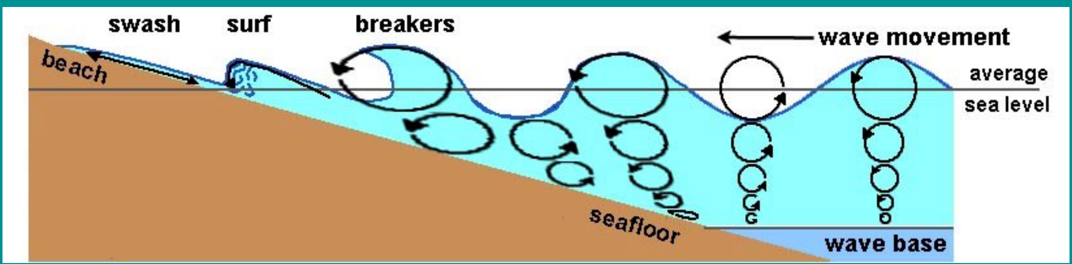
Oscillation waves are waves that do not "break". The wave moves up and down, but does not move forward. They are usually found far away from the shores.



Translation waves

Translation waves occur when the water depth decreases and friction against the seabed occurs. This causes the bottom of the wave to move slower than the crest, resulting in an increase in the wave height and the wave plunging forward as a breaker.

Translation waves not only transport energy but also matter, as the water molecules are sent with the wave onto the shore. It is the only type of wave that carries energy and matter !



The frictional interaction of waves with the seafloor causes particle orbital circles to stretch as wave energy is dissipated. After the waves breaks, the remains of the wave moves as a chaotic surf until it spreads onto the beach as swash.

Info +

Swash *:The white water that runs up the beach after the wave has broken.*

Backwash *:The water that returns back down the beach after the swash.*

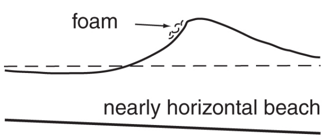
Constructive waves

Constructive waves (**spilling breakers**) build up a beach by depositing sediment because the swash is greater than the **backwash**. Their wave height is lower and they have a longer wavelength than destructive waves.

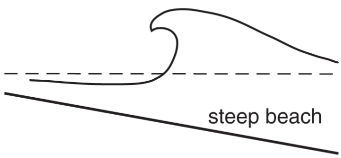
Destructive waves

Destructive waves (**plunging breakers** and **surging breakers**) erode a beach by removing sediment because the backwash is stronger than **swash**. Their wave height is greater and they have a shorter wavelength than constructive waves. They are steeper and more violent than constructive waves.

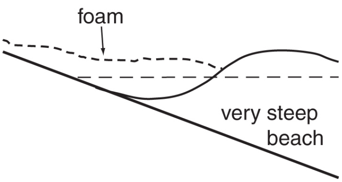
Spilling breaker



Plunging breaker



Surging breaker



Spilling breaker

Most common type of wave, associated with a moderate beach gradient (flat or gentle). Spilling breakers are waves that break slowly as they approach the shore. The wave energy is gradually released over time and the beach.

Plunging Breaker

Wave associated with beaches with steeper gradients; where wave energy is released suddenly as the crest curls and then descends violently. This is a typical surfer wave, it breaks very quickly and with substantial force

Surging breaker

Wave that does not break in the traditional sense. This wave starts as a plunging, then the wave catches up with the crest, and the breaker surges up the beach face as a wall of water (with the wave crest and base traveling at the same speed). This results in a quickly rising and falling water level on the beach face.

4 - Two-dimensional and three-dimensional wave fronts

Info +

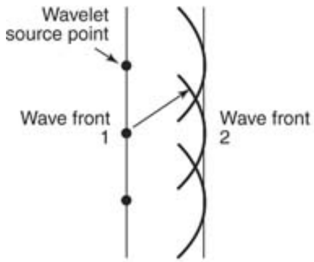
By dropping a pebble into still water, it causes an outward moving circle of ripples. These are the two-dimensional waves !

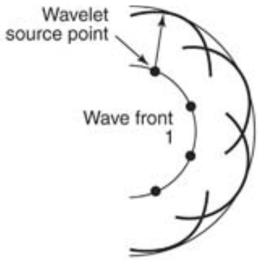
Many waves have the ability to travel in more than 1 dimension, such as water waves, sound waves and light waves. Two-dimensional waves can travel around corners for example.

Huygen's principle

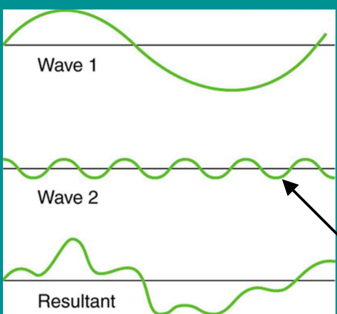
If a point source of light is switched on, the wavefront is an expanding sphere centered at the source. Huygens suggested that this could be understood if at any instant in time each point on the wavefront was regarded as a source of secondary wavelets, and the new wavefront a moment later was to be regarded as built up from the sum of these wavelets. For a light shining continuously, this process just keeps repeating.

Plane waves
wave fronts parallel to each other





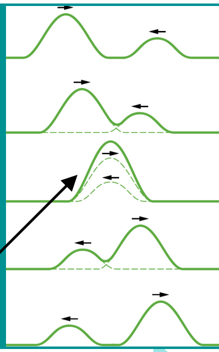
Spherical waves
spherical wave fronts centered on the source point



Principle of Superposition
When waves meet, they combine. In other words, if waves meet, you just add the contribution from each wave.

Addition can also be negative !

Two waves add when they meet



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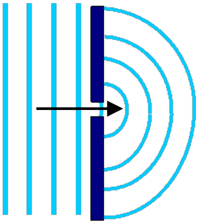
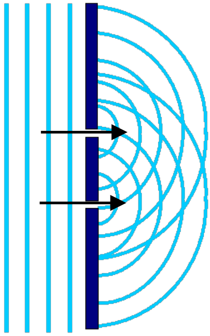
Slit interference

If you remember the Module 2, we talked about diffraction and waves passing through openings. Huygen's principle also provides a ready explanation of what happens when a plane wave front encounters a barrier with narrow openings (small compared to the wavelength of the wave).

Opening smaller than the wavelength

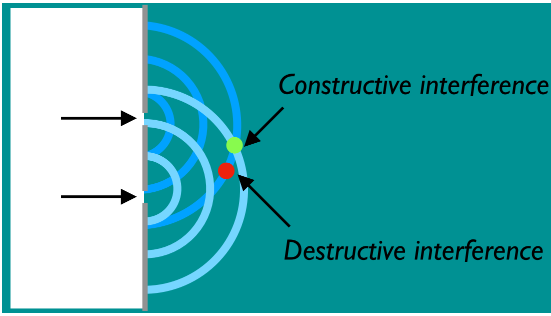


No interference



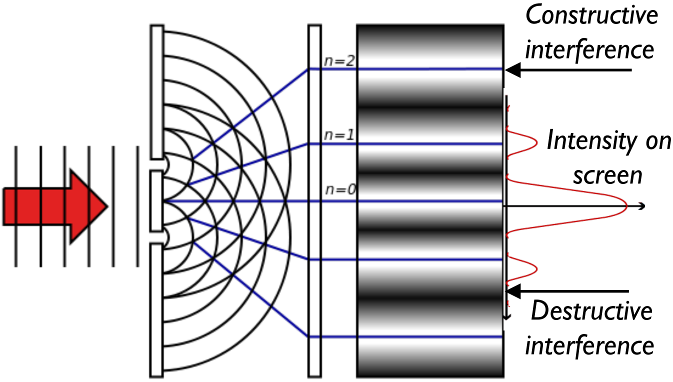
Two openings smaller than the wavelength

Interference happens between the two waves



Constructive interference : where wave crests meet (white on screen)

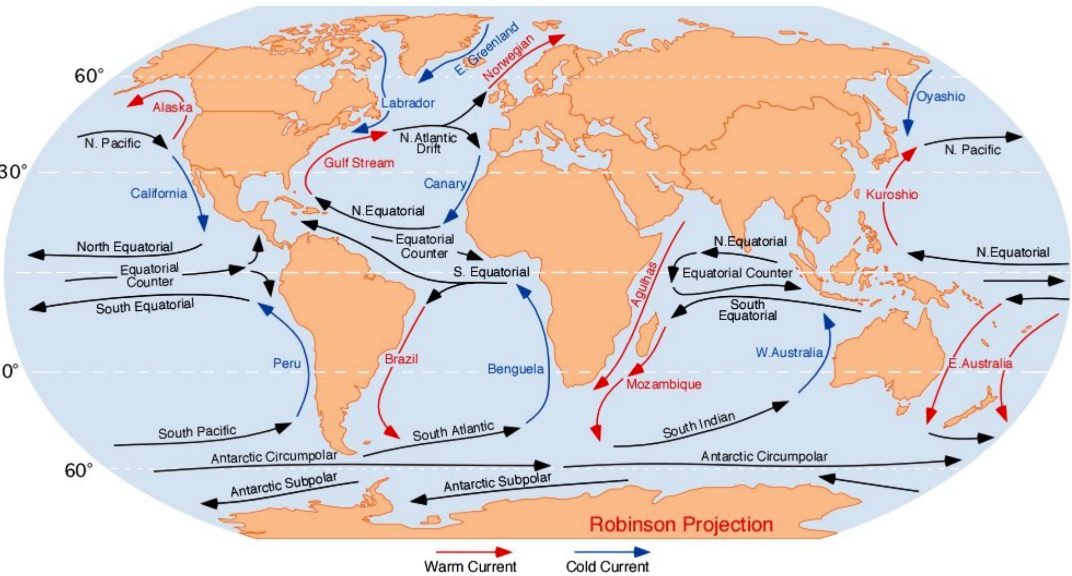
Destructive interference : where wave crest and trough meet (black on screen)



On the screen, interferences add up to form a diffraction pattern. This pattern shows where the wavelength combined additively or subtractively. The brightest spots are at the points where the waves from the two slits arrive exactly in phase.

A large movement of water in one direction is a current. Currents can be temporary or long-lasting; they can be near the surface or in the deep ocean. The largest ones shape the Earth's global climate patterns by moving heat around the world.

Many large currents are driven by differences in temperature and salinity. In the Arctic, cold salty water is left behind when ice freezes, and this denser water sinks towards the seafloor. This starts off a planetary current pattern called the **global conveyor belt** that slowly moves around the world, taking 1000 years to make a complete circuit.
Other large currents at the surface of the ocean are affected by global wind patterns and the Earth's rotation, such as the **Gulf Stream** off the eastern United States and the Kuroshio Current off the east coast of Japan.



Not all currents occur at such a large scale. Individual beaches may have rip currents that are dangerous to swimmers. **Rip currents** are narrow channels of water that form when waves of different intensities break on the shoreline and generate currents that try to keep the water level by pulling the large amount of water brought to shore by the waves back into the ocean.

Info +

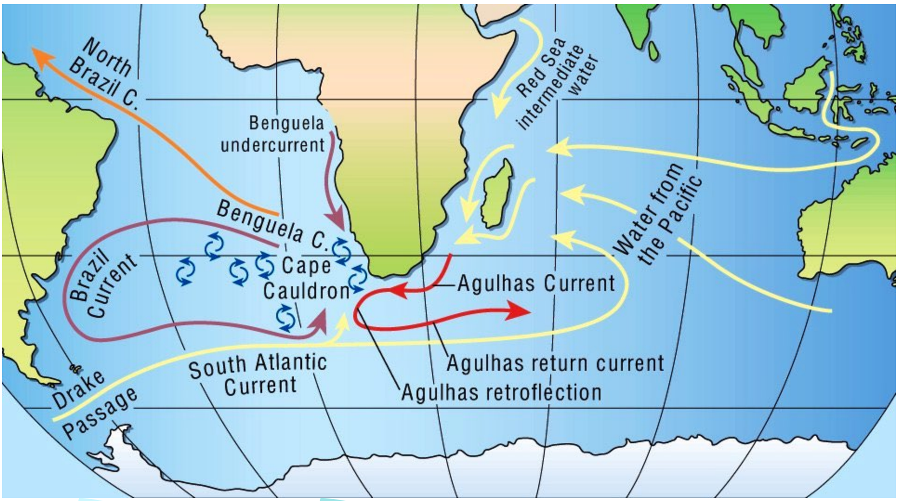
Rip currents can move faster than an Olympic swimmer, at speeds as fast as 2.4m/s. At these speeds, a rip current can easily overpower a swimmer trying to return to shore. Instead of attempting to swim against the current, experts suggest not to fight it and to swim parallel to shore.

6 - Currents around South Africa

What a complicated story ! Even after spending decades studying them, scientists still don't understand them fully. The major current around South Africa is called the Agulhas Current, and it is situated around the east coast.

Info +

More information about the South African currents can be found there : www.cfoo.co.za/seaatlas/index.php



Material needed

Twenty-five 3 x 5 index cards (approx. 75 x 125 mm) : smaller cards

Seventeen 5 x 7 index cards (approx. 125 x 175 mm) : larger cards

Masking tape that is 1 cm wide; the narrower the better

Transparent tape

Blue and red marker pens

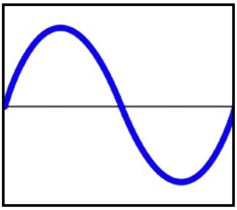
Scissors

Pencil

Preparation

For this activity, you'll need to first make a sine-wave template, and then use the template to create a set of cards with sine waves drawn across both sides.

Draw 4 sets of accurate sine waves :



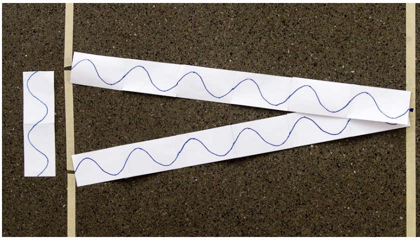
- You need to draw the pattern shown on each card, blue on the small cards and red on the large cards. Each wave needs to match the next.
- You'll need sine waves on the back of the cards too, so flip both your blue sine-wave template and the smaller cards over on a horizontal axis (from top to bottom) and draw a sine wave on the back that starts at the center of the left edge of the card and move downwards.
- Using transparent tape, tape the smaller cards together into two straight rows of twelve cards each, making sure that all the sine waves move upwards from the left side (following the original pattern of the template before you flipped the cards over). It's important that the sides of the cards touch but don't overlap. Do the same with the 2 sets of bigger cards.

Make a model of two slits :

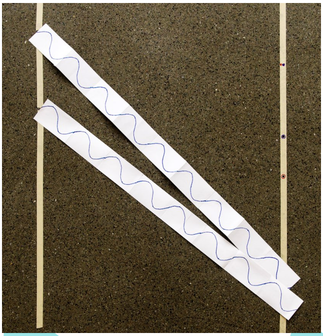
- Tear off several long strips of masking tape. Tape them in a line on the floor, leaving two small slits that are approximately two "blue" wavelengths (25 cm) apart.
- Tear off another long strip of masking tape, about two meters in length. Tape this down so it is parallel to and about five “blue” wavelengths (55 cm) away from the other tape. This strip represents your screen.

Method

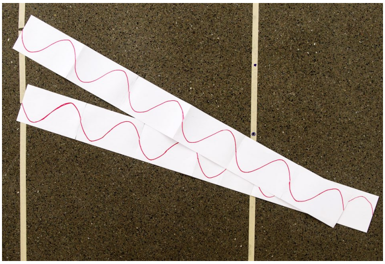
Compare the blue and red sine-wave cards. Notice the difference in length between the blue and red waves. The red light waves will be longer than the blue.
Look at any sine-wave card and notice three important points : the maximum (highest point), the zero crossings (where the wave crosses the middle line of the card, including at the leading and trailing edges), and the minimum (lowest point). Scientists describe these points using the term phase. When two waves add up “out of phase,” this means the highest point of one wave lines up with the lowest point of the other, canceling out the light. When waves add up “in phase,” this means the highest point of one wave lines up with the highest point of the other, strengthening the light.
Consider a light source like a laser shining into the two slits. The waves come into the slits in phase, oscillating together.



Take one strip of blue sine-wave cards and line it up with the center of one slit. Take the other strip of blue sine-wave cards and line it up with the center of the other slit. Make sure the two strips begin in phase at the slits. Unfurl both card strips towards the “screen” (second tape line), angling them so they cross the screen together at a point opposite the midway point between the two slits. Notice that both waves have the same phase at the screen. They add together in phase, producing a bright spot where they meet on the screen. Make a blue mark at this point on the tape.



Investigate other points on the screen, by stretching the strips from each slit to intersect at different places along the screen. Try to find a point where the two strips arrive out of phase. Here the light will be canceled, creating a dark spot. Make a black mark at the intersection point on the tape and draw a blue circle around it to note this is where blue light cancels out.



Repeat the experiment using the red sine-wave cards.

After you're done investigating both the blue and red sine-wave cards, change the distance between the slits, and repeat the experiment with fresh pieces of tape.

What's Going On ?

Both waves start out together with the same phase and travel the same distance to the center of the screen (the halfway point between the two slits), so they have the same phase when they add together. There is thus a bright spot in the middle of the screen. When one wave travels one–half of a wavelength further than the other, the lights cancel and create a dark region.

There are additional bright and dark regions that stretch out in both directions from the center. When the two light paths differ by an integer number of wavelengths, the waves arrive in phase and make a bright spot. When they travel an odd integer multiple of a half-wavelength, they add up out of phase and create a dark spot.

Info +

Since red and blue lights have different wavelengths, the distance between adjacent red maxima is different than the distance between adjacent blue maxima. The spacing between adjacent maxima is usually measured as an angle with its vertex halfway between the two slits. If the wavelength of the light is L, and the distance between the slits is d, then maxima occur when the angle, T, is an integer multiple of L/d.