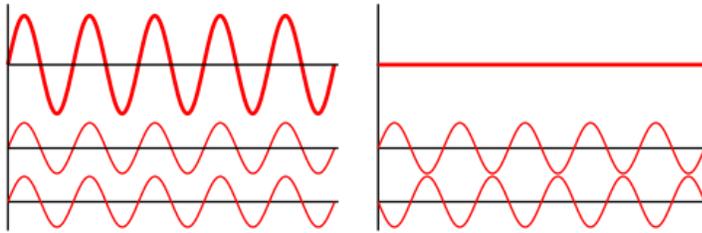


"[Interference pattern](#)" redirects here.



The interference of two waves. [In phase](#): the two lower waves combine (left panel), resulting in a wave of added amplitude (*constructive* interference). [Out of phase](#): (here by 180 degrees), the two lower waves combine (right panel), resulting in a wave of zero amplitude (*destructive* interference).



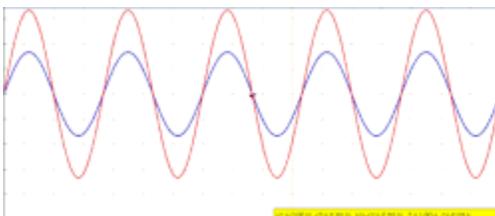
Interfering water waves on the surface of a lake

In [physics](#), interference is a phenomenon in which two [coherent waves](#) are combined by adding their intensities or displacements with due consideration for their [phase difference](#). The resultant wave may have greater amplitude (constructive interference) or lower amplitude (destructive interference) if the two waves are in phase or out of phase, respectively. Interference effects can be observed with all types of waves, for example, [light](#), [radio](#), [acoustic](#), [surface water waves](#), [gravity waves](#), or [matter waves](#) as well as in loudspeakers as electrical waves.

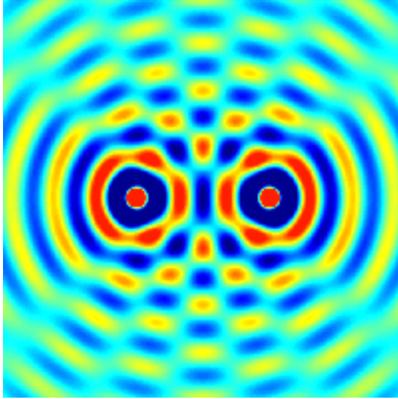
### Etymology

The word *interference* is derived from the [Latin](#) words *inter* which means "between" and *ferre* which means "hit or strike", and was used in the context of wave superposition by [Thomas Young](#) in 1801. <sup>[1][2][3]</sup>

### Mechanisms

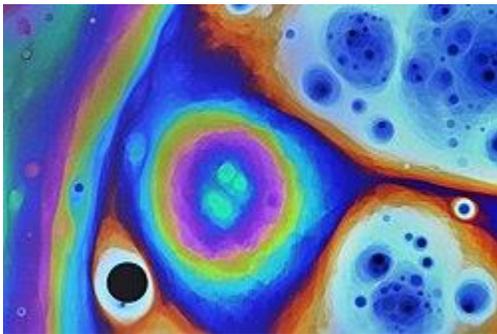


Interference of right traveling (green) and left traveling (blue)



waves in Two-dimensional space, resulting in final (red) waveInterference of waves from two point sourcesCropped tomography scan animation of laser light interference passing through two pinholes (side edges)

The [principle of superposition of waves](#) states that when two or more propagating waves of the same type are incident on the same point, the resultant [amplitude](#) at that point is equal to the [vector sum](#) of the amplitudes of the individual waves.<sup>[4]</sup> If a [crest](#) of a wave meets a crest of another wave of the same frequency at the same point, then the amplitude is the sum of the individual amplitudes—this is constructive interference. If a crest of one wave meets a trough of another wave, then the amplitude is equal to the difference in the individual amplitudes—this is known as destructive interference. In ideal mediums (water, air are almost ideal) energy is always conserved, at points of destructive interference, the wave amplitudes cancel each other out, and the energy is redistributed to other areas. For example, when two pebbles are dropped in a pond, a pattern is observable; but eventually waves continue, and only when they reach the shore is the energy absorbed away from the medium.



Photograph of 1.5cm x 1cm region of soap film under white light. Varying film thickness and viewing geometry determine which colours undergo constructive or destructive interference. Small bubbles significantly affect surrounding film thickness.

Constructive interference occurs when the [phase](#) difference between the waves is an even multiple of  $\pi$  ( $180^\circ$ ), whereas destructive interference occurs when the difference is an odd multiple of  $\pi$ . If the difference between the phases is intermediate between these two extremes, then the magnitude of the displacement of the summed waves lies between the minimum and maximum values.

Consider, for example, what happens when two identical stones are dropped into a still pool of water at different locations. Each stone generates a circular wave propagating outwards from the point where the stone was dropped. When the two waves overlap, the net displacement at a particular point is the sum of the displacements of the individual waves. At some points, these will be in phase, and will produce a maximum displacement. In other places, the waves will be in anti-phase, and there will be no net displacement at these points. Thus, parts of the surface will be stationary—these are seen in the figure above and to the right as stationary blue-green lines radiating from the centre.

Interference of light is a unique phenomenon in that we can never observe superposition of the EM field directly as we can, for example, in water. Superposition in the EM field is an assumed phenomenon and necessary to explain how two light beams pass through each other and continue on their respective paths. Prime examples of light interference are the famous [double-slit experiment](#), [laser speckle](#), [anti-reflective coatings](#) and [interferometers](#).

In addition to the classical wave model for understanding optical interference, quantum matter waves also demonstrate interference.

### Real-valued wave functions

The above can be demonstrated in one dimension by deriving the formula for the sum of two waves.

The equation for the amplitude of a [sinusoidal](#) wave traveling to the right along the x-axis is

where  $A$  is the peak amplitude,  $k$  is the [wavenumber](#) and  $\omega$  is the [angular frequency](#) of the wave. Suppose a second wave of the same frequency and amplitude but with a different phase is also

traveling to the right where  $\phi$  is the phase difference between the waves in [radians](#). The two

waves will [superpose](#) and add: the sum of the two waves is  $A \cos(kx - \omega t) + A \cos(kx - \omega t + \phi)$ . Using the [trigonometric identity](#) for

the sum of two cosines:  $\cos \alpha + \cos \beta = 2 \cos \left( \frac{\alpha + \beta}{2} \right) \cos \left( \frac{\alpha - \beta}{2} \right)$  this can be written  $2A \cos \left( \frac{\phi}{2} \right) \cos(kx - \omega t + \frac{\phi}{2})$ . This represents a wave at the original frequency,

traveling to the right like its components, whose amplitude is proportional to the cosine of  $\frac{\phi}{2}$ .

- **Constructive interference:** If the phase difference is an even multiple of  $\pi$ :  $\phi = 2n\pi$  then  $\cos \left( \frac{\phi}{2} \right) = 1$ , so the sum of the two waves is a wave with twice the amplitude
- **Destructive interference:** If the phase difference is an odd multiple of  $\pi$ :  $\phi = (2n+1)\pi$  then  $\cos \left( \frac{\phi}{2} \right) = 0$ , so the sum of the two waves is zero

### Between two plane waves