COHERENCE

An important property of waves is their ability to interfere, to add constructively or destructively. But to do that waves must be coherent.

One way to talk about coherence is by analogy. Suppose we have a crowd of people moving down the street. Each moves at his own speed, each is a little out of step with the other. The crowd looks like a homogeneous blob. It is incoherent.

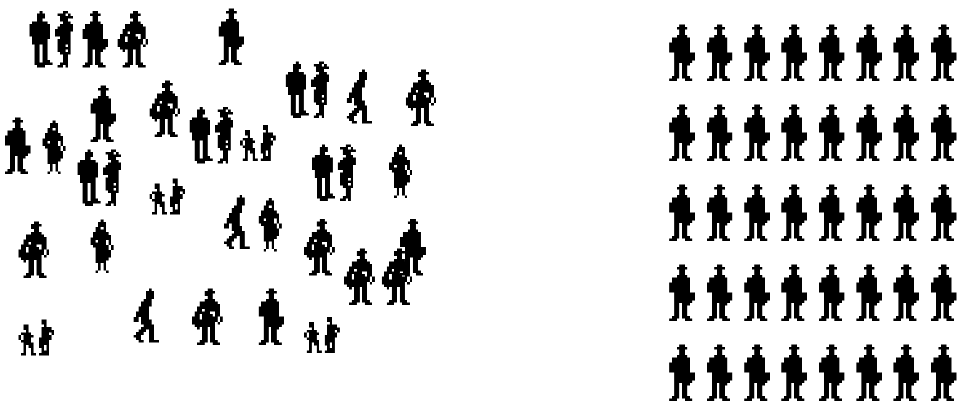
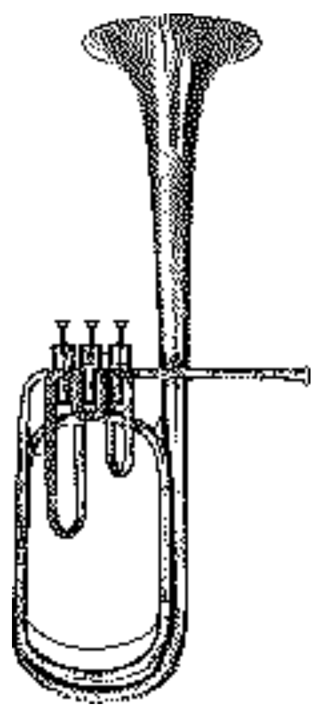


Figure 1. The randomly arranged strollers on the left can be said to be incoherent while the neatly arranged marchers on the right can be thought of as coherent.

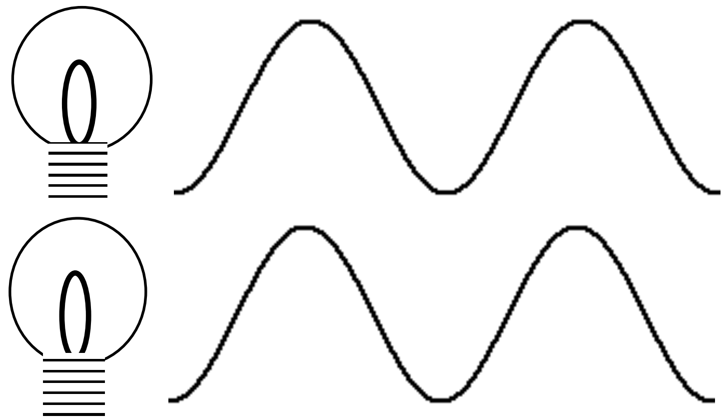
Suppose, on the other hand, the crowd is replaced by a marching band. Each band member marches in step, each member starts in a row of other band members, all start marching at the same time. The band does not look like a homogeneous blob, but like an organized lattice of human beings. It is coherent. The marching band has very different physical properties from the crowd. It can, for example, bring down a bridge by the resonance of its tread. (That's why soldiers break step marching across a bridge.)

Suppose the band gets a bit out of synch after a while, people losing step, the lines breaking up. Aside from the snappy uniforms and the instruments, it would begin to look like just another crowd. The distance over which this happens is the band's <u>coherence length</u>. If after about a mile the band looks like a milling mass of uniformed individuals, the band has a coherence length of one mile.

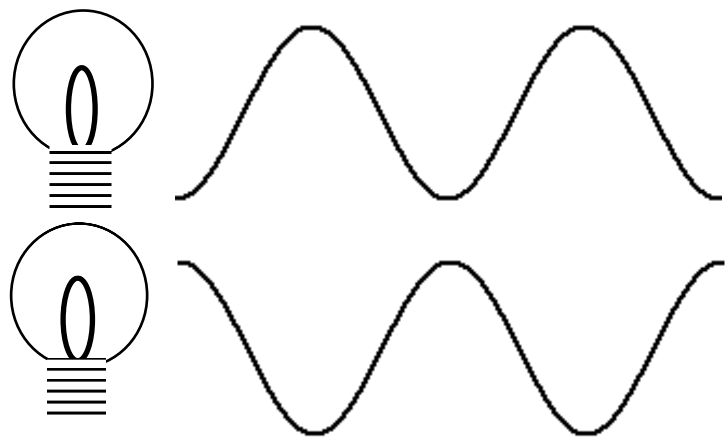
Light waves are like that. If the waves emanating from two sources are in step, they are coherent and can produce interference patterns. If the sources are **not** always in step with one another, the waves are incoherent, interfere randomly with one another and produce **no** visible interference patterns. In fact they do produce interference patterns, but the patterns vary so rapidly, about 10^{15} oscillations per second, that the eye, integrating them temporally, sees no pattern at all. The eye only sees the sustained interference effects due to coherent sources.



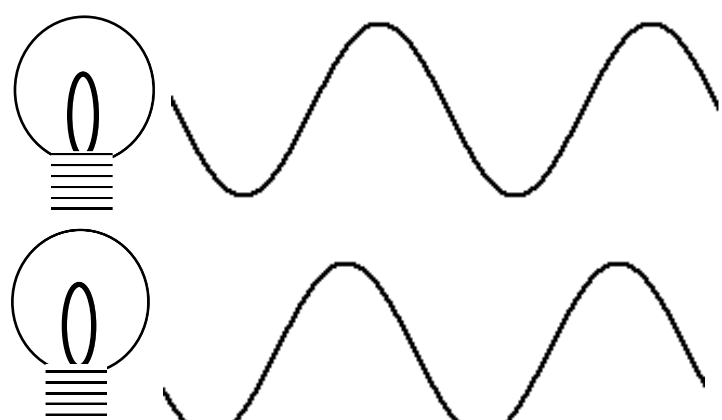
Two independent, *incoherent* sources will emit light waves that reinforce sometimes...



cancel sometimes...

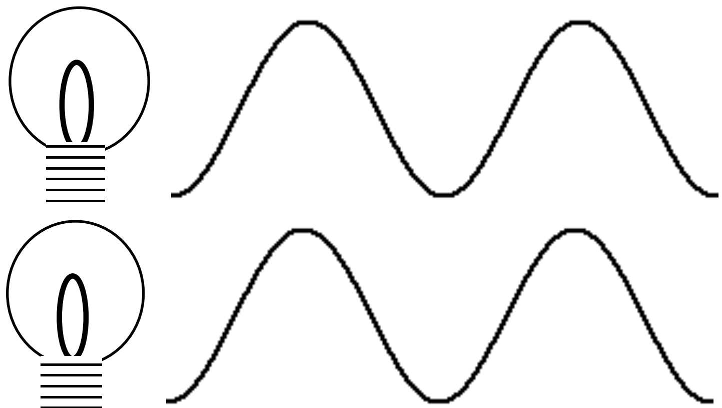


partially reinforce each other sometimes.

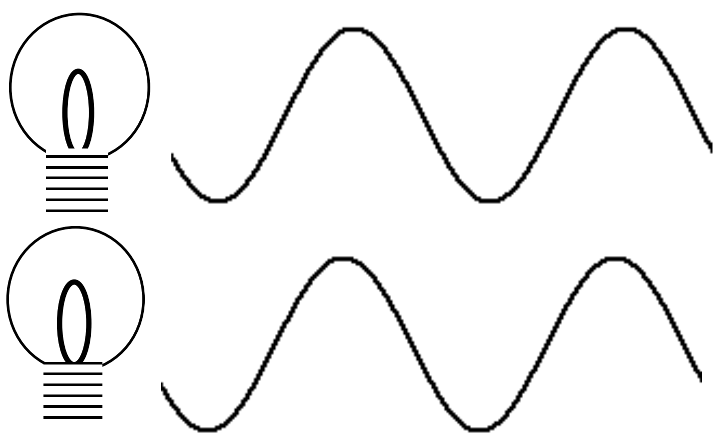


With incoherent sources there is no consistent phase relation so there can be no consistent interference. Reinforcement, cancellation, and partial reinforcement alternate so rapidly that the eye sees only some intermediate, averaged intensity. A screen lit by incoherent sources will be of uniform brightness. This is what happens with most ordinary light sources encountered in daily life.

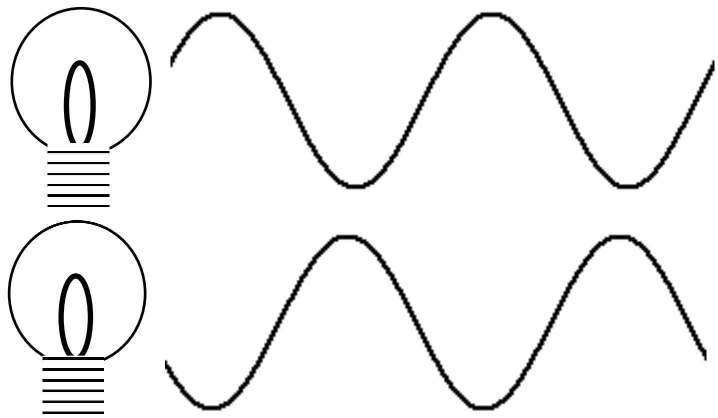
If two *coherent* sources emit light waves that reinforce each other...



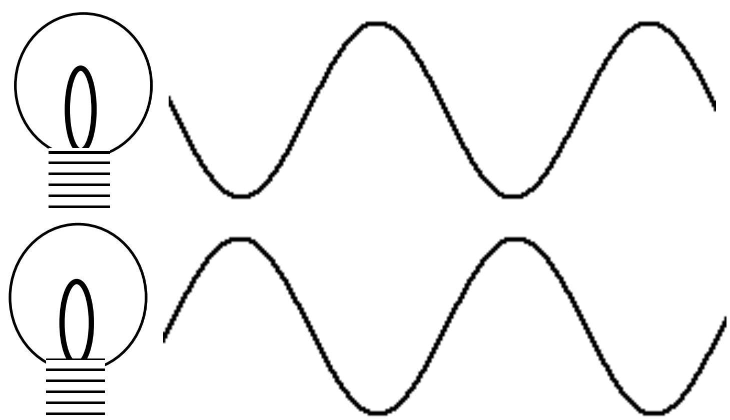
all other waves emitted by the two sources will be in phase with each other and reinforce.



If two coherent sources emit waves that are out of phase and cancel one another...



all other pairs of waves emitted by the two sources will be out of phase and cancel.



With coherent sources there is consistent phase relation so there can be consistent interference. Reinforcement, cancellation, or partial reinforcement persevere. A screen lit by coherent sources will, therefore, show interference patterns. There are two ways of producing coherent light sources:

> Make a wavefront interfere with itself, splitting it with half silvered mirrors, biprisms, or the like. This is how interferometers, anti-reflective coatings, and interference filters work.
>
> Cut off pieces of a wavefront with apertures so that each piece acts like a new, coherent source. This is the principle behind slit interference, diffraction by apertures, and zone plates like those in diffractive bifocal contact lenses.