

## 3.2: Huygens' Picture of Wave Propagation

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, the process just keeps repeating.

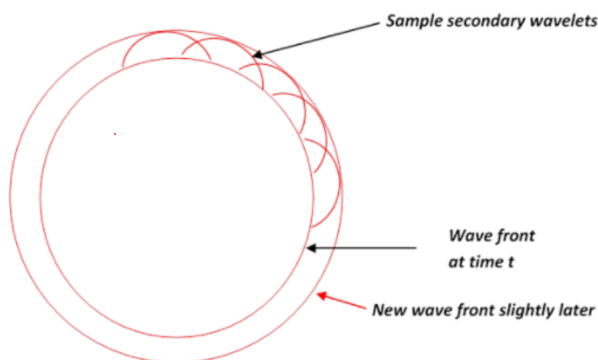


Figure 3.2.1: Huygens' picture of how a spherical wave propagates: each point of the wave front is a source of secondary wavelets that generate the new wave front

You might think that if a point on the wavefront is a new source, wouldn't the disturbance it generates be as likely to go backwards as forwards? Huygens did not address this point. In fact, it's not easy to give a short satisfactory answer. We'll discuss propagation of light (and of course other electromagnetic waves) fully in the second semester of E&M.

Huygens' principle *does* explain why the wavefront stays spherical, and more important, it explains *refraction* -- the change in direction of a wavefront on entering a different medium, such as a ray of light going from air into glass. Here's how: If the light moves more slowly in the glass, velocity  $v$  instead of  $c$ , with  $v < c$ , then Huygens' picture predicts Snell's Law, that the ratio of the sines of the angles to the normal of incident and transmitted beams is constant, and in fact is the ratio  $c/v$ . This is evident from the diagram below: in the time the wavelet centered at **A** has propagated to **C**, that from **B** has reached **D**, the ratio of lengths **AC/BD** being  $c/v$ .

But the angles in Snell's Law are in fact the angles **ABC**, **BCD**, and those right-angled triangles have a common hypotenuse **BC**, from which the Law follows.

Notice, though, the crucial fact: we get Snell's law on the assumption that the speed of light is slower in glass than in air. If light was a stream of particles, the picture would have to be that they encountered a potential change on going into the glass, like a ball rolling on a horizontal floor encountering a step, smoothed out a bit, to a different level. This would give a force perpendicular to the interface on going from one level to the other, and if the path is bent towards the normal, as is observed, the ball must speed up -- so this predicts light moves faster in glass. It wasn't until the nineteenth century, though, that measuring the speed of light in glass (actually I think water) was technologically possible.

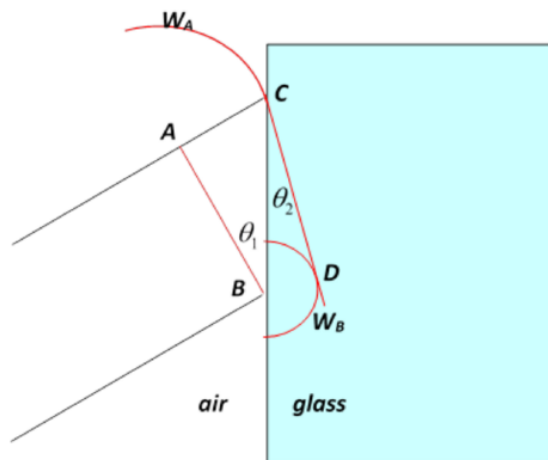


Figure 3.2.1: Huygen's explanation of refraction: showing two wavelets from the wavefront AB.  $W_B$  is slowed down compared with  $W_A$ , since it is propagating in glass. This turns the wavefront through an angle.

In fact, even in the early nineteenth century, the wave nature of light was widely doubted. Fresnel greatly improved Huygens' crude picture, fully taking into account the interference between secondary wavelets having different phases. One of the principal skeptics of the wave theory, the mathematician Poisson, pointed out that it was obvious nonsense because, using Fresnel's own arguments, it predicted that in the very center of the dark shadow of a sphere illuminated by a point source of light, there should be a bright spot: all the "light waves" grazing the edge of the sphere would generate secondary wavelets which would land at that spot in phase. A bright spot at the center of the dark disk seemed obvious nonsense, but an experimentalist colleague in Paris, Arago, decided to try the experiment anyway -- and the spot was there. It's now called the **Poisson spot**, and it gave a big boost to the wave theory in France (it was already fully accepted in England, where Thomas Young did the double slit interference pattern, and compared it to the wave pattern in a similarly configured ripple tank, presenting the results to the Royal Society in 1803).

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