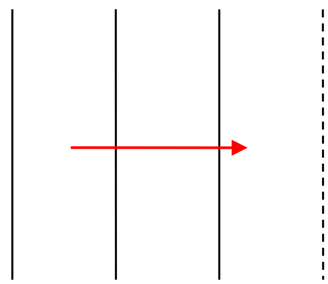
Teacher notes
Topic C

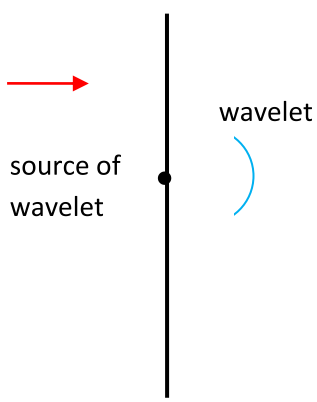
The Huygens principle

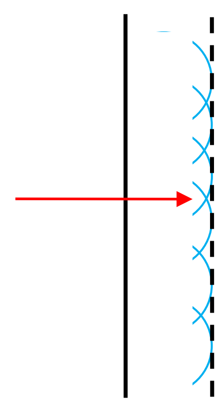
The diagram shows 3 planar wavefronts moving to the right. We know that in the absence of obstacles, apertures and changes in medium the next wavefront will be another planar wavefront, shown as the dotted line.



But how do we know that? Is there a way to **deduce** the shape of the next wavefront? In 1678 the great Dutch physicist Christiaan Huygens provided a partial answer.

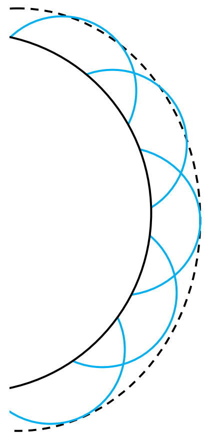
The diagram shows a single point on a wavefront. Huygens argued that this point acts as a source of a secondary, spherical wavefront, called a wavelet, of the same wavelength and speed as the original wavefront. The wavelet is assumed to be emitted only in the forward direction. The Huygens principle states that **every point** on the wavefront acts as a source of wavelets. The diagram shows the construction for 6 points.



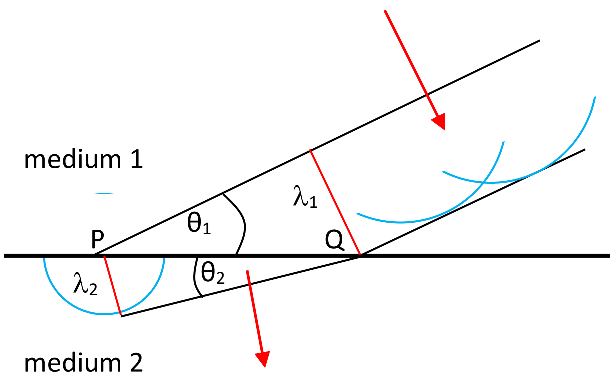


The new wavefront is assumed to the surface that is tangent to all the wavelets.

If the original wavefront is spherical, the Huygens construction shows that the next wavefront is also spherical.



Consider now the problem of refraction. Point P on the wavefront in medium 1 has reached the boundary of the two media and it will emit its wavelet in the second medium where the wave is slower. Hence the wavelength will be smaller than the wavelength in medium 1. This results in this construction:

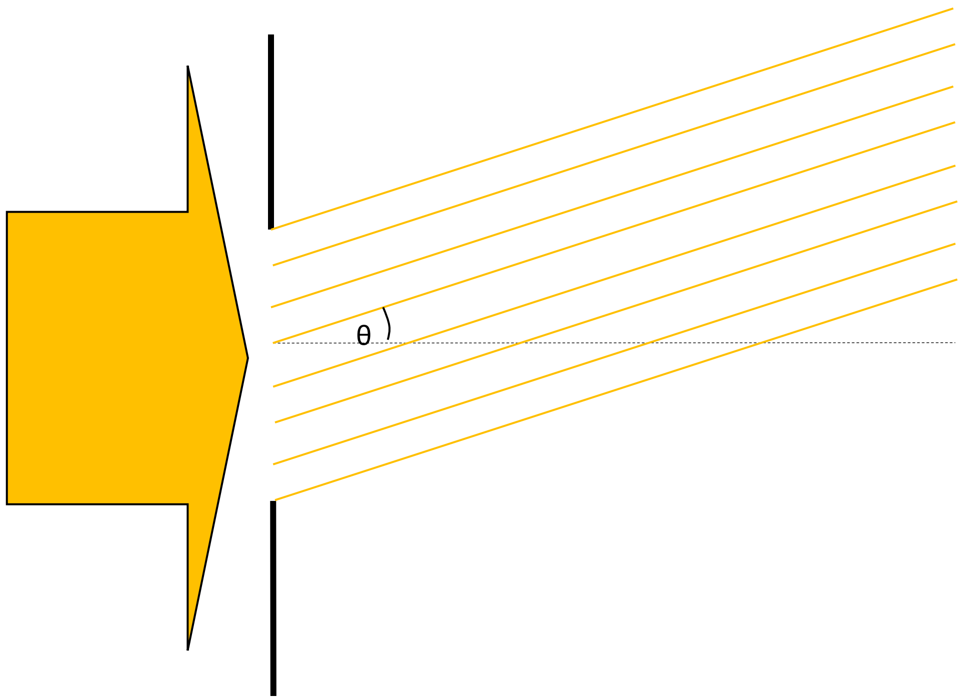


From the figure above, $\sin\theta_1 = \frac{\lambda_1}{PQ}$ and $\sin\theta_2 = \frac{\lambda_2}{PQ}$ which leads to $\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2}$ or $\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1 f}{\lambda_2 f} = \frac{c_1}{c_2}$ i.e. we get Snell's law of refraction:

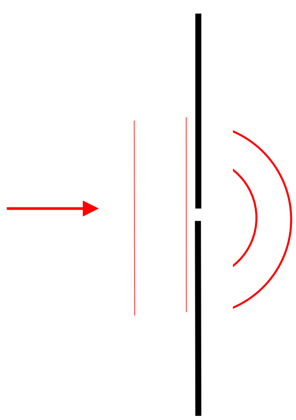
$$\frac{\sin\theta_1}{c_1} = \frac{\sin\theta_2}{c_2}$$

This construction also gives the right answer for reflected wavefronts so it also explains reflection.

We have implicitly used the Huygens construction when we talked about single slit diffraction. Each point on the wavefront going through the slit acts a source of secondary wavelets which interfere some distance away.

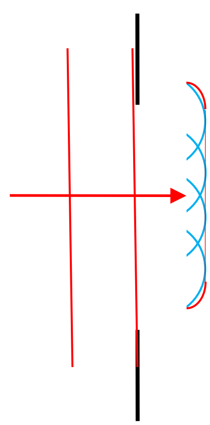


This shows, for example, that if the aperture is very small, i.e. almost like a mathematical point, then we have extreme diffraction: only one point on the incident wavefront emits wavelets and they are all spherical. And, similarly, when the aperture is very large, little diffraction takes place with wavefronts curving only at the edges.



$\lambda >> b$

lots of diffraction



$\lambda << b$

little diffraction

But the details of diffraction cannot be understood solely in terms of the Huygens construction. For example, Huygens assumes that along a wavelet the intensity of the wave is the same and this is problematic when discussing interference. An improved principle, the Huygens-Fresnel construction, gets most of the details right.