Wave Concepts and the Scalar Wave Equation

The scalar wave equation:

\[ \nabla^2 \phi - \frac{n^2}{c_0^2} \frac{\partial^2 \phi}{\partial t^2} = 0 \]

where \( c_0 \) is the velocity of light in vacuum, 
\( n \) is the index of refraction \( = c_0/c(x) \),
\( t \) is time, \( \nabla \) is the gradient with respect to spatial coordinate \( x \), and \( \phi \) is a scalar measure of the wave field.
Plane Wave Solution and Wave Vector

$$\phi = \phi_0 \exp[i(k \cdot x - \omega t)]$$

is a plane wave solution of the wave equation, valid when the index of refraction $n(x)$ is constant in space. The angular frequency $\omega = 2\pi f$, where $f$ is the inverse of the period of oscillation (measured in Hz). The wave vector $k$ is a vector in the direction of propagation having magnitude (called the wavenumber)

$$k = \frac{n\omega}{c_0} = \frac{2\pi}{\lambda}$$

where $\lambda \equiv c_0/f$ is the wavelength.