Wave Phenomena

No matter what the nature of a wave might be, there are a number of phenomena very characteristic of waves, clearly distinguishing them from particles.

Propagation of waves

In a homogeneous and isotropic medium waves propagate in all directions with the same constant speed v. Wavelength λ and frequency f are related

$$v = \lambda \cdot f$$

In some cases the wave speed depends on the wavelength (*dispersion*).

Examples: no dispersion for sound waves in air and light in vacuum, dispersion for light in media

Superposition of waves

Two waves of the same type often superpose, i.e. the displacement at a particular point equals the sum of the two independent displacements:

$$y(x,t) = y_1(x,t) + y_2(x,t)$$

Example: Surface waves travel at independent speeds depending on their wavelength.

Interference

If both waves in superposition have the same frequency, they *interfere*: There are places of constructive interference (high intensity) and places of destructive interference (low intensity). Interference maxima correspond to a *path difference* of $m \cdot \lambda$, interference minima to $(m + \frac{1}{2}) \cdot \lambda$.

Examples: Noise cancelling headphones, Young's double slit experiment

Waves and matter

When waves hit a massive object, the observed phenomenon depends on the ratio of the wavelength λ and the dimensions of the object (typical length d).

Wave rays ($\lambda << d$)

If the wavelength is much smaller than the object, the wave propagation can be described by *rays* (lines perpendicular to the wave fronts). In a homogeneous medium, light rays are straight lines.

Example: Ray optics (reflexion, refraction)

Diffraction ($\lambda \approx d$)

If the object's size is comparable to the wavelength, the wave is *diffracted*, i.e. it can also get to the regions behind the object which are not accessible according to the laws of ray optics.

Examples: Diffraction on a single slit, hearing „around the corner"

Scattering ($\lambda >> d$)

If a wave hits a particle with dimensions much smaller than the wavelength (e.g. an atom or molecule), a part of the wave's energy is absorbed by the particle and afterwards reemitted in all directions.

In the case of *Rayleigh scattering* the wavelength does not change. In this case the energy is scattered preferably perpendicular to the incoming wave and increases monotonously with the frequency.

Example: Rayleigh scattering of the sunlight on air molecules leads to a blue sky during the day and a red sky in the morning and evening.