Wave properties of light

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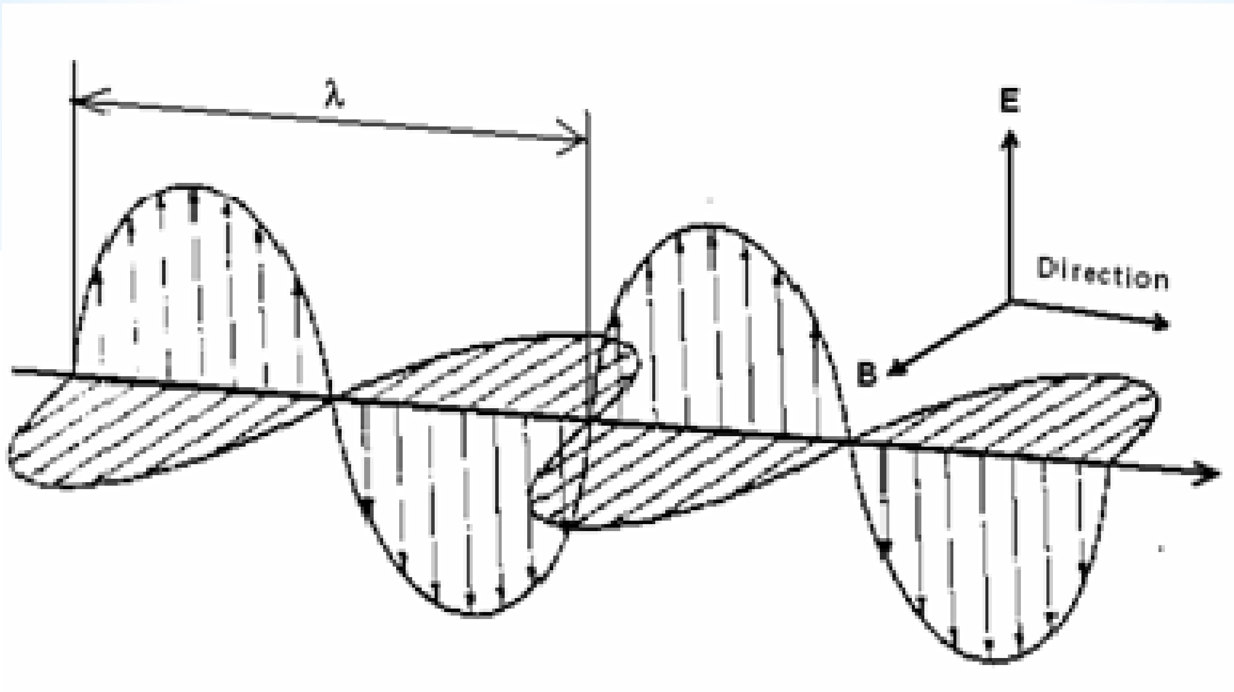


Electromagnetic character of light. *B* – magnetic flux density, *E* – intensity of electric field, l = wavelength.

Wave properties of light

Light can be described in terms of wave motion. The light waves are harmonic oscillations of an electromagnetic field – the vectors of magnetic flux density and intensity of electric field oscillate perpendicularly to the direction of light propagation.

Let us start from the **speed (velocity) of light**: $v = \frac{\lambda}{T} = \lambda f = \frac{c}{n}$

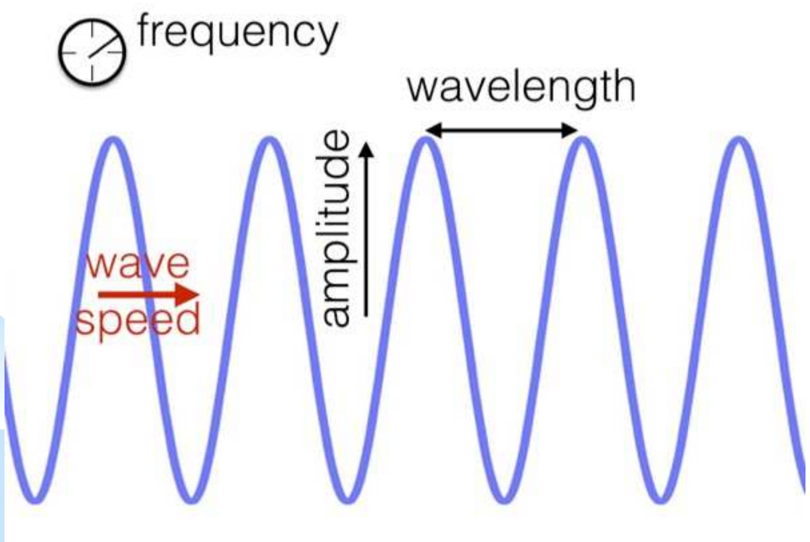
where *T* is the period of oscillations [s], *f* is their frequency [s-1], and *l* is their wavelength [m]; *n* is the index of refraction, and *c* is the speed of light in vacuum. Remember that the previously mentioned index of refraction depends strongly on the frequency or wavelength of light. The index of refraction increases with decreasing wavelength. Remember the relation mentioned in the paragraph about chromatic aberration:

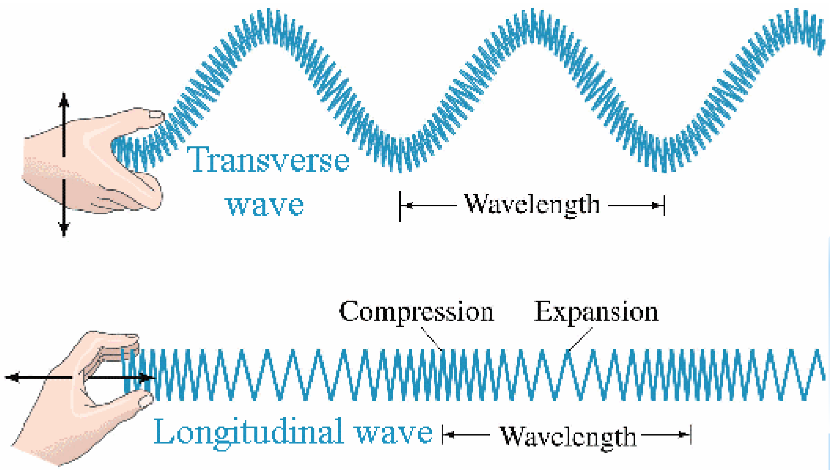
$$n_{red} < n_{yellow} < n_{violet}.$$

Wave properties of light

Therefore, the most refracted light is the violet light. According to the last equation we can write: $f = \frac{c}{\lambda_0} = \frac{v}{\lambda}$ then: $\frac{c}{v} = n = \frac{\lambda_0}{\lambda}$ hence: $\lambda = \frac{\lambda_0}{n}$

where f is the frequency of the light, c is the speed of light in a vacuum, v is the speed of light in given medium, λ is the wavelength of light in the given medium, and λ_0 is the wavelength of light in vacuum.



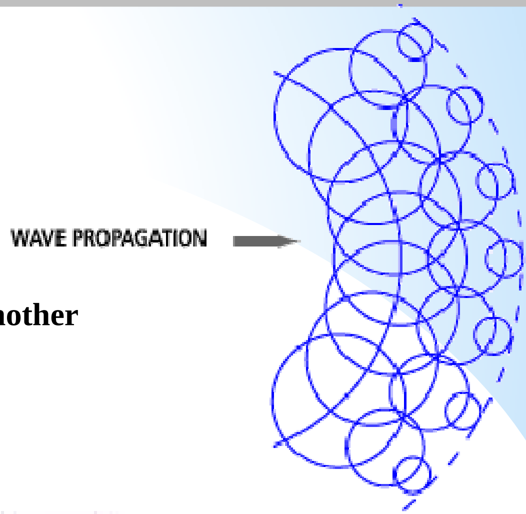


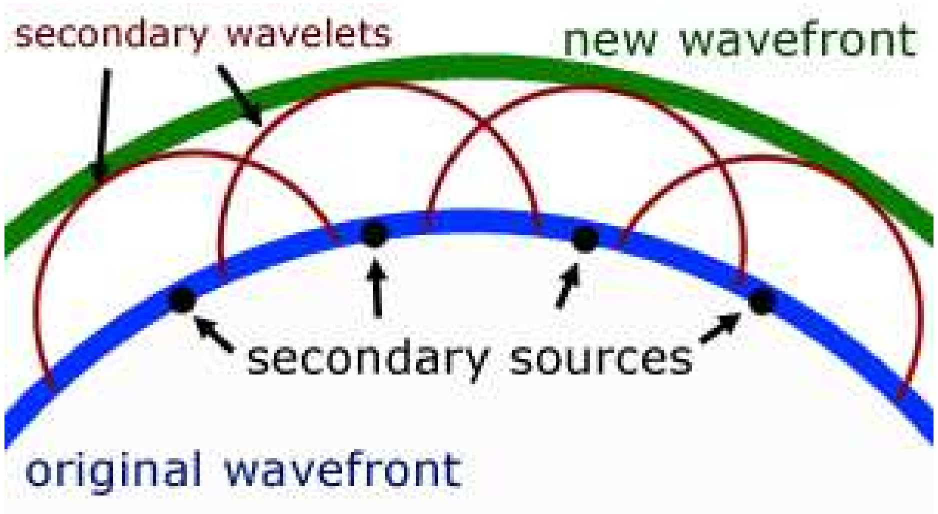
Wave properties of light

Huygens´ principle

All the point of a wavefront of light
thought of as new sources of smaller waves

These smaller waves expand in every direction and are in stepwith one another

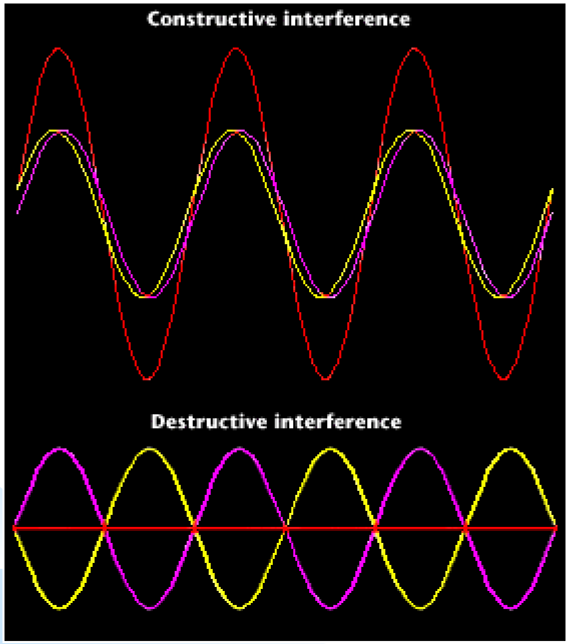


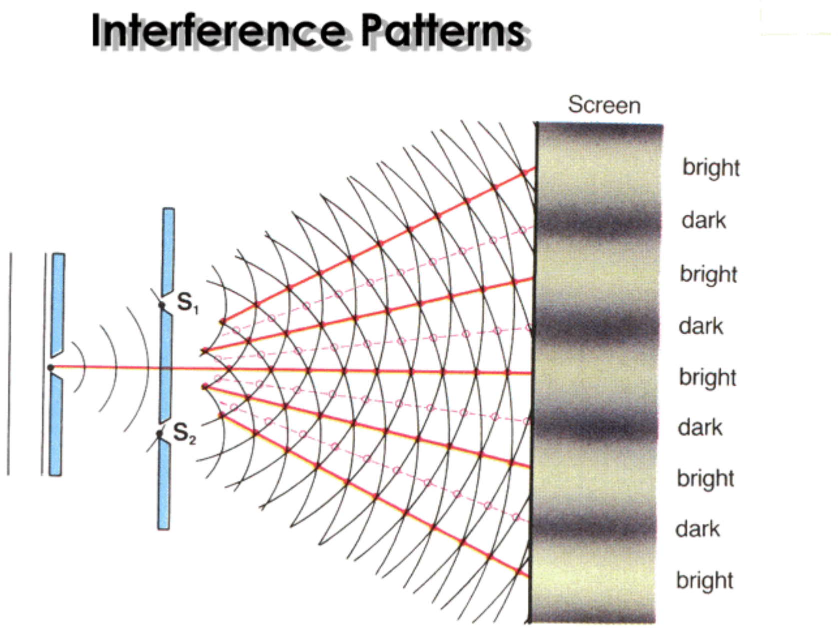


Wave properties of light

Interference of light:

Interference of light and related phenomena can be observed with beams of coherent light rays, i.e. rays of the same frequency and the same phase shift at a given distance from the source of light. Interference is a result of superposition (addition, summation) of oscillating vectors characterising the electromagnetic field.

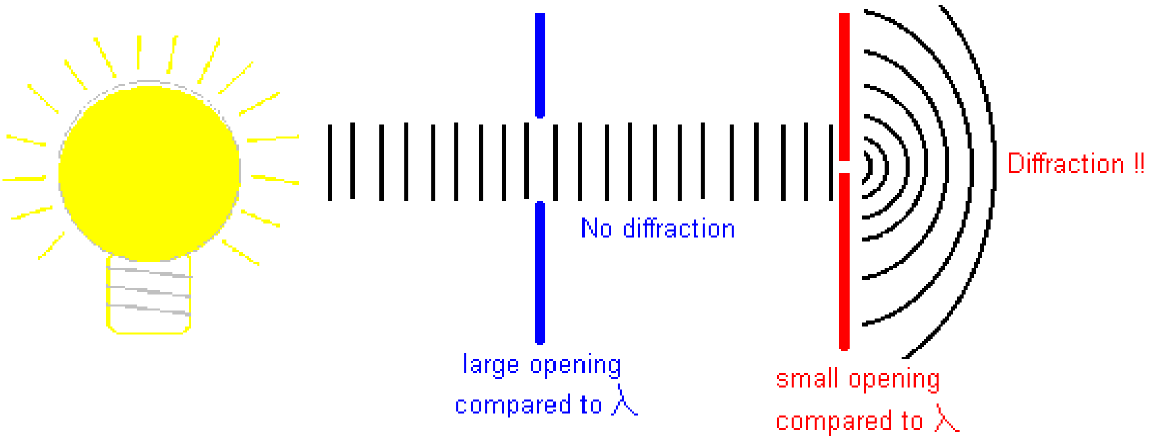


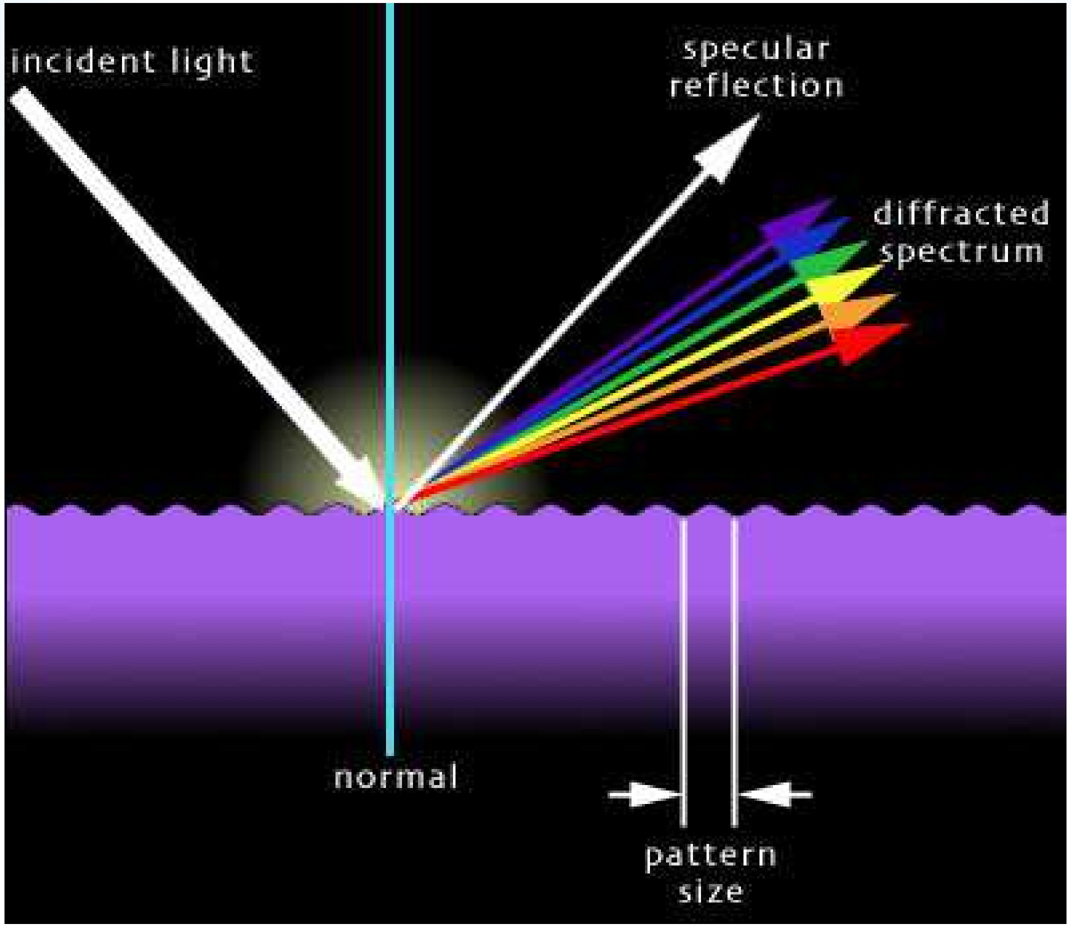


Wave properties of light

Diffraction of light:

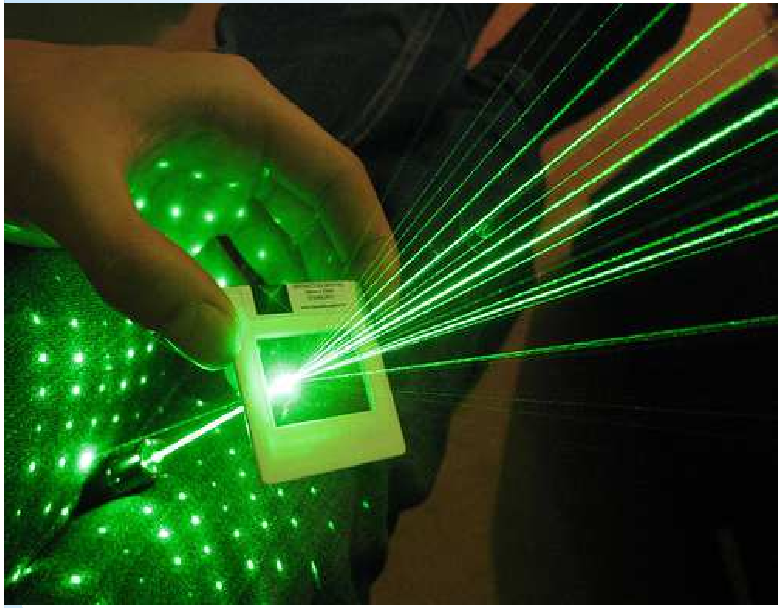
Light diffraction is a change of light propagation direction which occurs when light is incident on particles, holes, slits etc. the dimensions of which are comparable with the wavelength of light. It often demonstrates itself as the scattering of light. Light rays diffracted at openings, slits, double slits or diffraction gratings can interfere with each other. Therefore, we can observe also diffraction-conditioned interference phenomena.



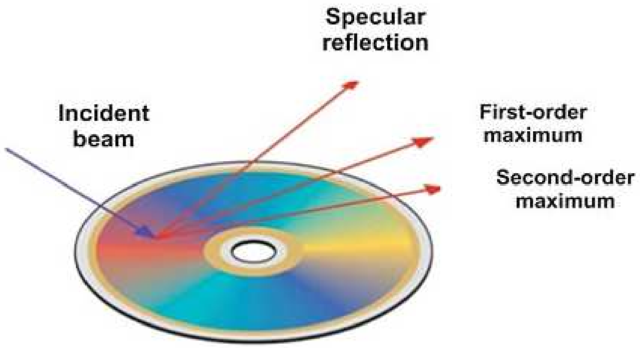

incident light
specular reflection
diffracted spectrum
normal
pattern size

Wave properties of light

Diffraction grating



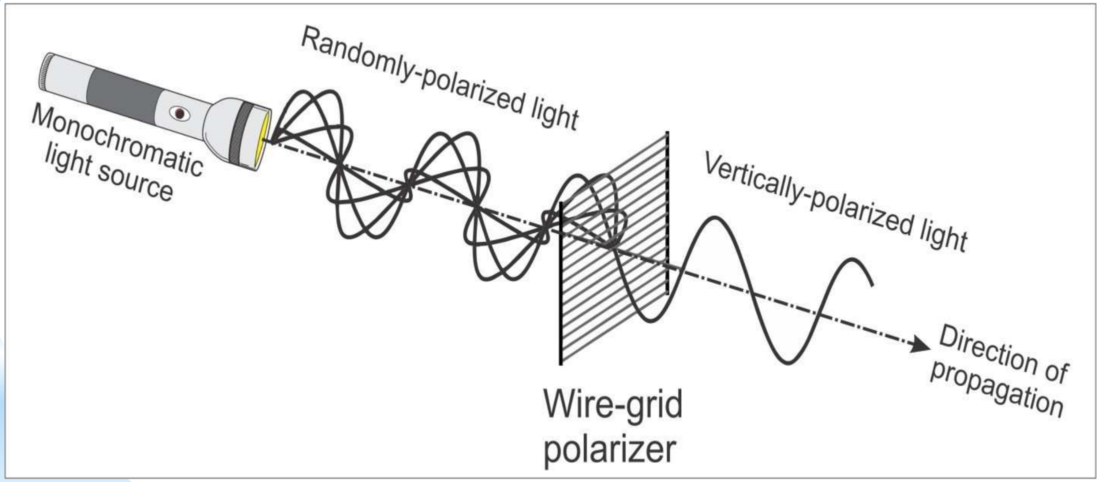
Reflection grating

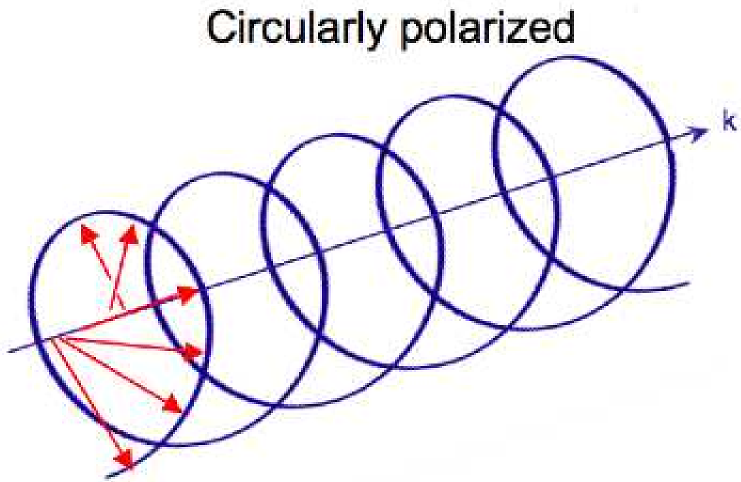


Wave properties of light

Polarised light

As already explained, visible light consists of electromagnetic waves which are characterised by vectors of ***E*** (electric field intensity) and ***B*** (magnetic flux density). These vectors oscillate perpendicularly to the direction of light propagation. If the light beam consists of more rays, their *B* and *E* vectors can either oscillate in many planes or only in a single plane (two perpendicular planes when considering both *B* and *E*). Such a plane is called the **polarisation plane**. In the first case we speak about non-polarised light, in the second case about **polarised light**.

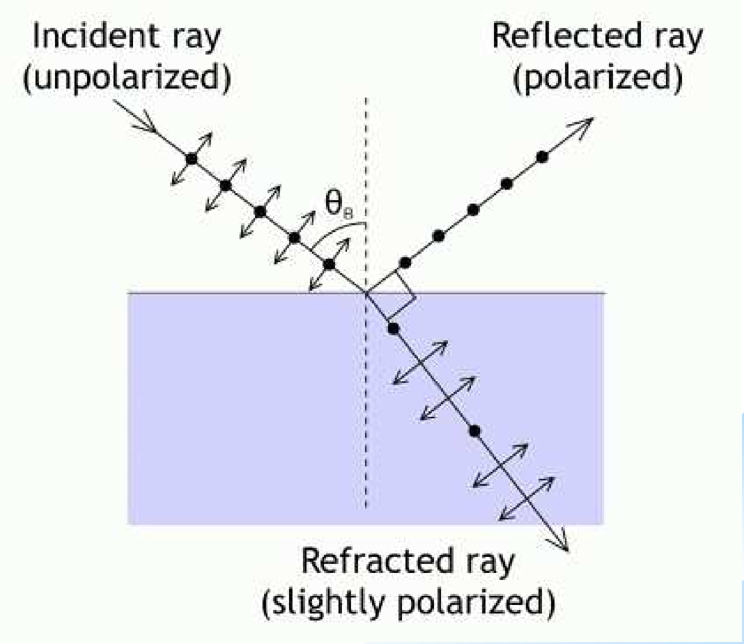




Wave properties of light

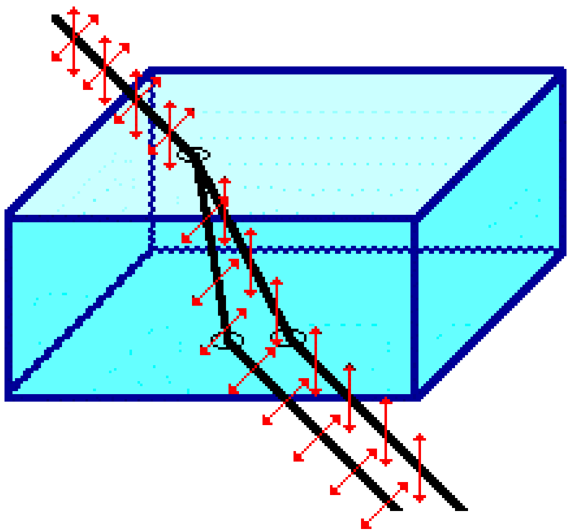
Light waves can be polarised by several different means:

- by **polarisation filters** (**polaroids**, e.g. in sun glasses). Such a filter can be passed through only by light the polarisation plane of which has an orientation allowing the passage.
- by **reflection** (the light reflected from glass, mirrors, polished surfaces etc. is partly polarised – this causes reflected light is reduced in intensity by polarised sun glasses.

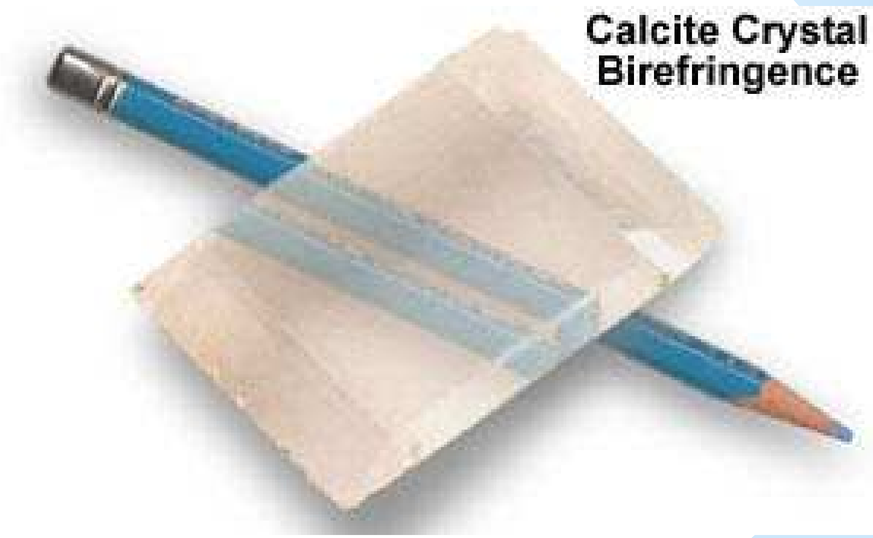


Wave properties of light

- Polarisation by **double refraction** (**birefringence**, encountered in anisotropic crystals, e.g. the Nicol prism). In this phenomenon, the original ray is split into two parallel rays polarised perpendicularly.

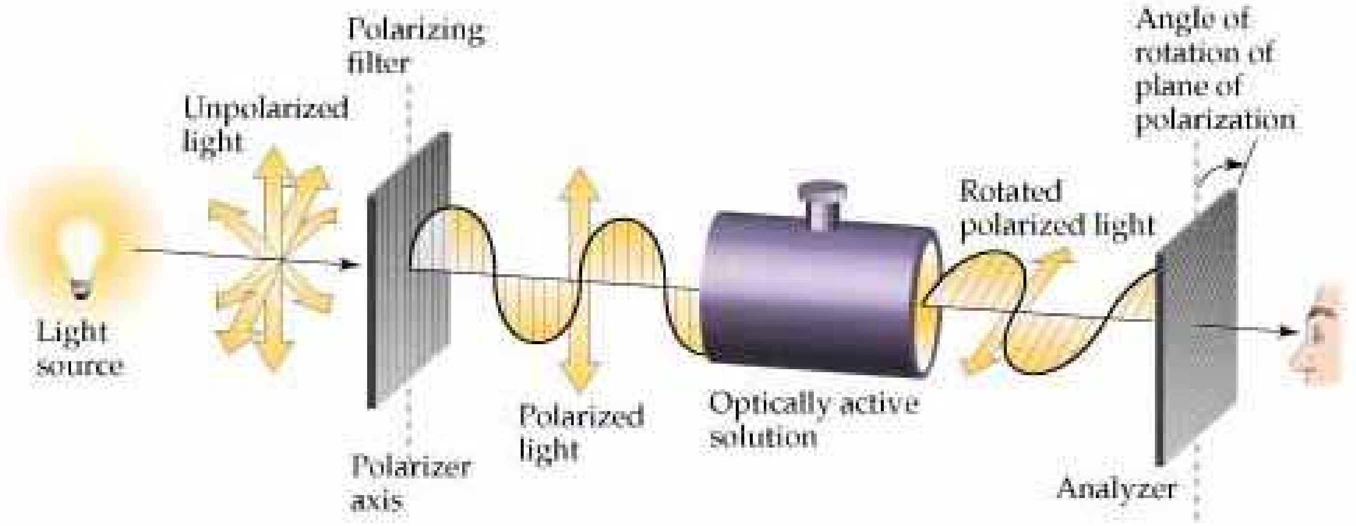


The two refracted rays passing through the Iceland Spar crystal are polarized with perpendicular orientations.



Wave properties of light

Optically active substances (in a crystal form or in a solution) are able to rotate the plane of polarised light. Many organic substances of great biological importance are optically active. It is possible, for example, to measure the rotation angle of polarised light which depends on the concentration of the substance through which the polarised light passed. The concentration of sugars is often measured in this way. The measurement is done by means of instruments called **polarimeters**.



An introduction to photometry

A relatively frequent task is to measure the quantity of light emitted by a body or incident on an illuminated surface. Therefore we will briefly mention some of the most important photometric quantities used in the SI system.

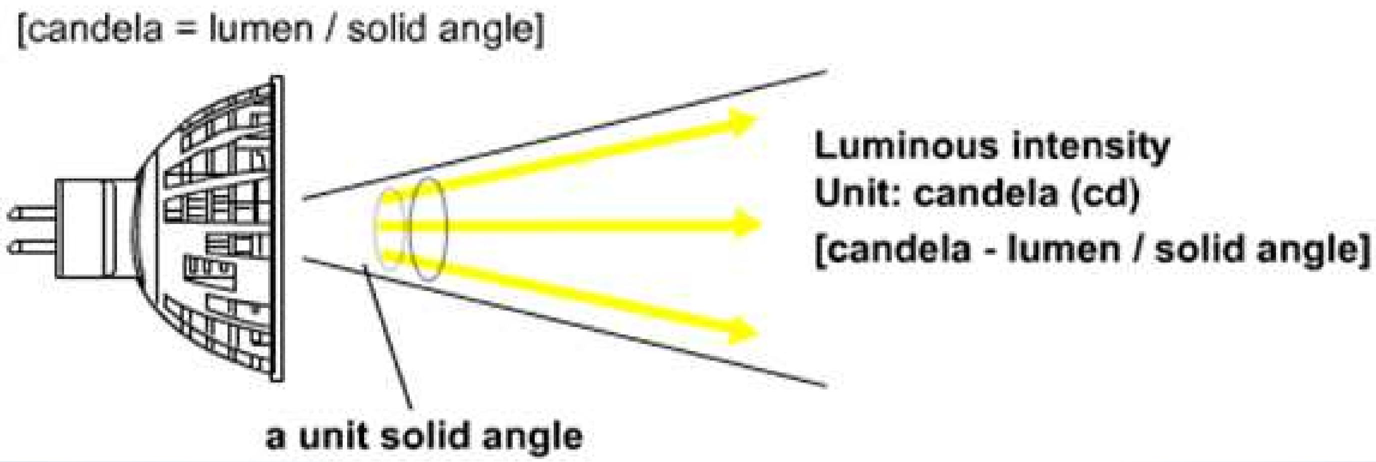
Note: We always assume that the source of light radiates equally in all directions.

The **luminous intensity** *I* is the measure of light produced by a source of unit area in unit time. Its unit, **candela** [cd] belongs among the fundamental SI-units. The candela can be defined by the following statement:

1 cd is one sixtieth of the luminous intensity of a "black body" source, 1 cm^2 in cross-section area, at the temperature of the platinum melting point (1755 ℃), under normal atmospheric pressure and viewed at right-angles to the area.

A new definition since 1979: *The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 × 1012 Hz and that has a radiant intensity in that direction of 1/683 watt per steradian*

Note: A black body does not reflect light, it can only emit light.



An introduction to photometry

Luminous flux *Φ* is the measure of the amount of light emitted into a defined *solid* angle *W*. Its unit is called **lumen** [lm]:

1 lm is the luminous flux produced by a point source of luminous intensity 1 cd into a solid angle of 1 sr (steradian).

Suppose that a 1-cd point source is at the centre of a hollow sphere with radius r = 1 m (called "unit sphere"). A luminous flux of 1 lm will pass through an area of 1 m^2 on the sphere surface.

$$\Delta\Phi = I\Delta\Omega \quad \Leftrightarrow \quad I = \frac{\Delta\Phi}{\Delta\Omega} \qquad \text{[lm]} \quad \text{[cd]},$$

where $\Delta\Omega$ is the solid angle in steradians [sr].

Simply – Luminous flux is the light outpu of a source measured in all directions (a lamp receives watts and emit lumens). The measure of success of doing this is called efficacy and is measured in lumens per watt(lm/W).

An introduction to photometry

The **illumination** (illuminance) *E* [lm.m^{-2} = lx – lux] expresses the amount of light incident onto a surface.

Definition: *Luminous flux of 1 lm per 1 m^2 produces an illumination of 1 lux.*